New Directions in the Pan American Climate Studies Sounding Network for Latin America

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Summary

The Pan American Climate Studies (PACS) Sounding Network (SONET) evolved in response to the perceived lack of in-situ atmospheric measurements over the inter-American region to adequately support climate research studies. The relatively recent availability of the global NCEP reanalyses products had stimulated a large number of studies of climate and climate variability and it was becoming apparent that ground truth measurements were going to be needed to validate these studies. To depend on the individual efforts of each country in the region to enhance their own sounding networks was not viewed as a proactive solution to the lack of sounding data, and in 1997 the OGP supported an initial effort to establish a temporary network to monitor the windfield in central and part of northern South America. This has, over the succeeding 6 years, become what is now called the PACS-SONET.

At the present time the SONET involves pilot balloon observations at some 21 sites in 8 countries in Latin America. Seven sites are operated in Mexico, six in Bolivia, followed by two sites each in Paraguay, Venezuela and Peru, and one each in Ecuador, Colombia and Nicaragua. About 500 observations per month continue to be made. Each site has a specific contribution to the overall scientific objectives of the project, which have in the past several years focused on supporting aspects of the two monsoon experiments, SALLJEX (January 2003) and NAME (summer 2004) supported by OGP. Observations are made daily, near 1200 UTC, except in Mexico, where twice-daily observations are made, and in Piura, Peru where frequent morning cloudiness forces routine afternoon soundings.

Key aspects of the SONET data set that are potential subjects for near-term research are discussed. These topics include the suitability of the SONET data to describe interannual variations of 1) the cross-equatorial flow along the Peruvian coast, 2) the warm season trade wind flow across Central America that is associated with the mid-summer dry season, 3) the gap flow intensity across the Isthmus of Tehuantepec, and 4) the intensity of the monsoonal flow up the gulf of California during the warm season. Each of these is discussed as an example of subjects that are now becoming feasible to study with multi-year records from the PACS-SONET.

Finally, a summary of the directions in which the project intends to advance completes this report.

1. Brief history of the PACS-SONET

The original PACS-SONET configuration consisted of 12 pilot balloon sites (**Fig. 1.1**). The stations were established during April and May of 1997 in Mexico, Nicaragua, Costa Rica, Panama, Colombia, Ecuador and Peru, together with a combined pilot balloon and radiosonde station on Cocos Island in the eastern Pacific Ocean. These observations, made twice-daily, were to describe the conditions associated with wet and dry spells over Central America (Peña and Douglas 2002) and to help evaluate the quality of the NCEP reanalyses windfields over the region - analyses that were (and continue to be) a mainstay of tropical climate research activities. The intended duration of the observations was 6 months, ideally extending through October, and close to the end of the rainy season in much of Central America.

Fig. 1.1. PACS-SONET initial configuration.

Due to the strong El Niño of 1997-98, the observational plan was modified to extend the period of observations at many stations through the mid-year 1998 and to establish additional pilot balloon stations in Ecuador and Peru to better sample conditions in the region of anticipated heavy rainfall. This allowed an unprecedented data set to be obtained to describe the wind field along the Ecuadorian and northern Peruvian coasts, associated with the warm event in the eastern Pacific. In addition, more than 100 raingauges were established throughout northwestern Peru and in western Ecuador to improve the description of daily rainfall over the region.

Pilot balloon observations were also made at Santa Cruz, Bolivia, as part of the special El Niño campaign. Although these observations were only made for 3 months, they showed a strong and variable low-level jet at Santa Cruz, which had not been well described from previous observations. These observations indirectly stimulated further observations from a more extensive network in Bolivia during 1999.

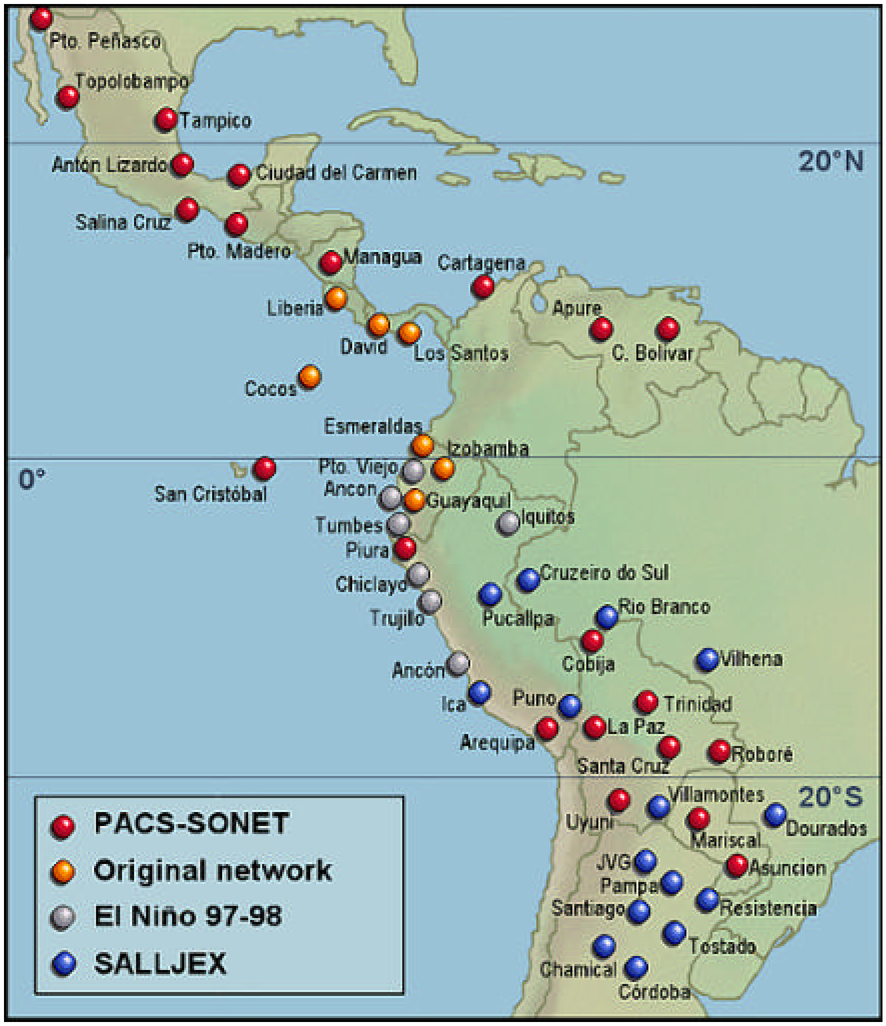

Fig. 1.2 PACS-SONET extensions due to El Niño 1997-98 (white dots), SALLJEX pilot balloon stations (blue dots) and current PACS-SONET sites (red dots).

In late 1999 support was obtained for extension of the PACS-SONET for a 3-year period. In addition to an extension in time of the program, an expansion of the network took place. In terms of geographical extension, new pilot balloon sites were established in Paraguay (2) and Bolivia (6). The primary objective of these additional observations was to describe the variability of the low-level flow east of the Andes and the circulation over the Bolivian altiplano. In Mexico, three additional sites were established in March 2000 to bring to 6 the number operating (one more was added in April 2002). The stations in northwestern Mexico were designed to improve the description of the low-level flow along the Gulf of California. In March 2001 one station was established in Venezuela at San Fernando de Apure, a location in the very flat llanos north of the Orinoco River. In March 2002, a second Venezuelan station was established in Ciudad Bolivar, a city of the eastern llanos on the Orinoco river basin. **Figure 1.2** shows the current PACS-SONET configuration and other stations that have been operational with financial or logistic support from the project.

In addition to more observing sites, a major effort was made to make the network a real-time data collection and distribution activity. This required efforts to upgrade communications at many sites, and the development of procedures to ensure the flow of data not only to research institutions, but also to all interested operational forecasting institutions. The latter is accomplished mainly through the development of the project's web page, in which the observations are made available in near real time, in the form of both raw data and plotted maps at select levels (See **http://www.nssl.noaa.gov/projects/pacs/realtlist.shtml.)**

More recently, the PACS-SONET stations in Bolivia and Paraguay served as the ramp-up network for the upper-air component of the South American Low Level Jet Experiment (SALLJEX), which extended from November 2002 through February 2003 and included intensive pilot balloon observations (**http://www.nssl.noaa.gov/projects/pacs/web/html/salljex.html.)**

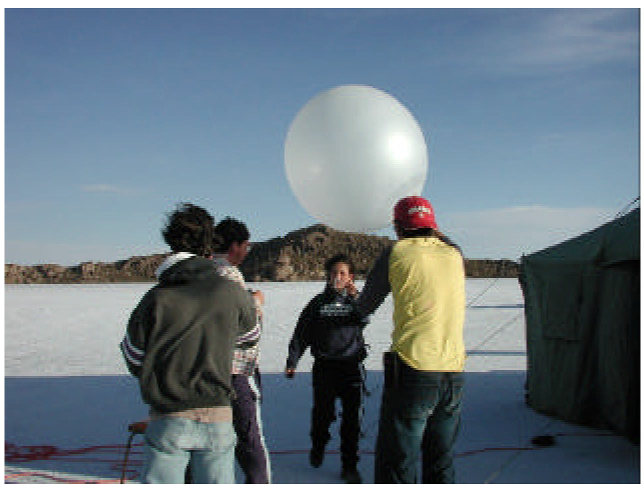

Fig. 1.3. Pictures from two special observing campaigns conducted in Bolivia during SALLJEX around Lake Titicaca (up) and in the Salar de Uyuni (bottom).

In 2003 PACS-SONET was extended for a second 3-year period, subject to a reevaluation of the activity and more consensus seeking on the part of the project.

2. Scientific Rationale for Each Observing Site

While all SONET observing sites contribute to filling gaps in the upper-air sounding network in Latin America, each observing site has one or more specific reasons to justify its operation. In this section we summarize these objectives. Reference to the several networks map in Fig. 2.1 would be useful.

Mexico

Puerto Peñasco. This site is optimally suited, at the northern end of the Gulf of California, to monitor the variability of the Gulf of California low-level jet. This shallow jet is associated with moisture transport into the southwestern deserts of the US and variations of the flow ("surges") are a feature of interest in the 2004 North American Monsoon Experiment (NAME).

Topolobampo. This site, halfway between the radiosonde sites of Guaymas and Mazatlan on the east side of the Gulf of California, is designed to measure the up-Gulf seasonal variation of the wind at low-levels associated with the monsoonal circulation. Also, by operating two sites along the Gulf of California the intensity and latitudinal extent of gulf surges can be more accurately estimated. Both Puerto Peñasco and Topolobampo make twice-daily measurements, unlike Guaymas, so the data also provide better estimates of the mean flow, averaged over the diurnal cycle.

Tampico. This site is located halfway between the radiosonde sites of Brownsville, Texas and Veracruz, Mexico, a large gap in the sounding network on the east coast of Mexico. The original motive of the site's selection was to describe the variability of the recurving trade-wind flow that undergoes strong seasonal variations. Unexpectedly high cloudiness has somewhat hampered the effectiveness of the site.

Anton Lizardo. This site was established only recently (2003), and it is primarily to serve as training for the cadets so that they can supervise the rest of the network operations. The observations provide a check on the radiosonde-winds from a nearby (~20 km away) radiosonde site of the Mexican National Weather Service.

Cd. del Carmen. This site, moved from the nearby Naval facility at Frontera in 2000, provides winds that describe the intensity of the trade-wind flow across the southern part of the Yucatan peninsula. The observations have revealed a strong diurnal variation, with an early morning low-level jet. The observations will primarily help to identify tropical wave passage across this part of southern Mexico during the summer months, and provide additional estimates of variations (intraseasonal and interannual) of the trade wind flow.

Salina Cruz. The strong and variable flow across the gap in the topography at the Isthmus of Tehuantepec is described by measurements at Salina Cruz. Under normal conditions (northerly winds) the skies are relatively cloud free and this site provides profiles to high altitudes (provided the winds are not too strong). Variations in the gap flow, due to tropical wave passages in summer or cold frontal passages in winter can be readily identified at this site.

Puerto Madero. This site was established to monitor tropical wave activity and tropical cyclogenesis in the Gulf of Tehuantepec. The wind regime is vastly different, due to the blockage of the trade wind flow by a 2-3 km high mountain range, which is located about 40 km to the east of the site, across a flat coastal plain.

Figure 2.1 Current radiosonde network (blue circles), current (black dots) and proposed (stars) PACS-SONET sites.

Nicaragua

Managua. The Managua observations, of high quality and generally high altitudinal extent (due to the lack of frequent low cloudiness), were intended to monitor the travel wind variability (on all time scales beyond daily) across Central America. The low terrain over Nicaragua is ideal to avoid the very local effects of high terrain common to other countries in Central America, and the latitude of Nicaragua is near the latitude where the trades are strongest.

Colombia

Cartagena. This site was one of the original 12 sites established in 1997. The justification for the site remains the same - to improve the description of the low pressure that is anchored to the topography in this part of South America and which forms part of the intertropical convergence zone. With the highly intermittent nature of the radiosonde sites in Rio Hacha (Colombia) and Balboa (Panama), the Cartagena site becomes even more important, as it is the only sounding site between Curacao and San Jose, Costa Rica, a distance of 1500 km.

Isla Malpelo (proposed). The observations proposed for Malpelo would improve specification of the cross-equatorial flow closer to the coast of Central America than provided by the site in the Galapagos. In addition, as it is a very small island there will be almost no diurnal cycle and little topographic on the airflow, so the observations should be ideal for describing synoptic and seasonal variations here. The site would also fill an important gap in the sounding network, as it would be on the equatorial side of the mean ITCZ position. Rainfall observations are also proposed for this site, since it lies in the region of greatest discrepancy between satellite estimation techniques for precipitation near the ITCZ.

Banco Serranilla (proposed). This site would provide undisturbed trade wind measurements just north of the core of the maximum winds. The main value of this site is that it is flat and small, so it should be free of island-induced diurnal or topographic effects. The site is located almost equidistant between the radiosonde sites of Kingston (Jamaica), San Andres (Colombia) and Grand Cayman.

Venezuela

San Fernando de Apure. This site continues to be important to describe the low-level flow over the wide, flat llanos of Venezuela. The morning observations show a strong, but shallow low-level jet during the dry season. The original intent of establishing the site was to monitor not only the annual cycle of the trade winds across northern South America, but to describe tropical wave propagation during the warm season as well.

Ciudad Bolivar. This site was established after San Fernando, and provides redundancy in the observations, especially during the rainy season, when cloudiness at both sites can frequently prevent high soundings.

Isla de Aves (proposed). We are proposing to establish a site at Isla de Aves, located 220 km west-southwest of Guadeloupe Island in the Lesser Antilles. This site, flat and extremely small, will be ideal for wind profiles in the trade wind flow for comparison with the radiosonde observations at various locations in the Lesser Antilles. The Venezuelan Navy and Environment Ministry has staff permanently on the island to assure sovereignty and monitor bird and turtle nesting.

Ecuador

San Cristobal, Galapagos Islands. This site was originally established to monitor the cross-equatorial flow, especially for variations associated with the ENSO cycle.

Peru

Piura. This site, about 60 km inland from the coast, on a flat coastal plain, is useful for monitoring variations of the flow near the coast associated with ENSO variations. It has become more useful with time, as the site has the most complete record for interannual variability studies. The site is almost 7 degrees north of the only coastal radiosonde site, Lima. A radiosonde site has been established at Piura as part of ENSO monitoring activities, but this site is not operating every day and the observations are not routinely transmitted.

Arequipa. This site was established in November 2002 as part of SALLJEX. Because of its drier and more cloud-free climate, this site routinely provides wind profiles to higher altitudes than does La Paz. The observations should be useful for monitoring flow over the northern altiplano and the subtle variability of the Bolivian high. Peruvian motivation for the site's operation also is due to the desire to monitor winds for the prediction of ash or fumes from nearby Volcano Misti (Arequipa is Peru's second largest city).

Pucallpa (proposed). The Pucallpa site proved very useful during the SALLJEX, and provided a surprising number of relatively high soundings. This site is feasible to maintain, as good logistical support exists, and the observations provide data well upstream of the Bolivian site at Cobija for monitoring LLJ variability.

Iquitos (proposed). This site currently makes radiosonde observations every other day, and pilot balloon observations are proposed for the site to provide more frequent wind profiles. This site will extend monitoring of low-level flow east of the Andes from Paraguay to nearly the Equator. The observations should be useful for describing the equatorward extent of cold surges during the cool season and the longer-period variations associated with the seasonal cycle. The observations at Iquitos will compliment those at Leticia (Colombia) located some 400 km to the east. The latter observations have been erratic.

Puerto Maldonado (proposed). This site is currently an ENSO-monitoring radiosonde site and pilot balloon observations are proposed to increase the frequency of the wind observations. The site is partially redundant with Cobija, but the future status of Cobija is not known with certainty, and the Puerto Maldonado observations will insure observations between Pucallpa (~8°S) and Trinidad, Bolivia (~15°S). Fundamentally, the site will contribute to monitoring the variability of the East Andean low-level jet.

Bolivia

La Paz. This site, and the site at Uyuni provide altiplano-level measurements for more precisely describing the flow over the Bolivian and Peruvian altiplano. The position of the Bolivian high typically is found between these two sites and subtle shifts in the position can be quantified more accurately through the use of these station's data. There is typically a considerable N-S gradient in the zonal wind during the winter between these two sites.

Uyuni. See comments above. The Uyuni site is more cloud-free than La Paz, thus helping to provide measurements over the altiplano more often that would be possible from only one site.

Cobija. This site was intended to measure wind conditions somewhat upstream (~11°S) from the region of maximum winds (~18°S) associated with the LLJ.

Trinidad. This site, located in a very flat region more than 100 km form the Andes, provides less-cloud contaminated soundings near the core of the LLJ over eastern Bolivia.

Robore. This site describes the LLJ flow at considerable distance from the Andes, providing information on the horizontal extent of the LLJ flow. It is also useful for describing the zonal extent of the flow during cold surges, which typically is more closely confined to the topography.

Santa Cruz. This site, at Viru-Viru International Airport, is near the region of strongest winds associated with LLJ east of the Andes. However, it is a relatively cloudy site.

Paraguay

Mariscal Estigarribia. This site is located very close to the mean position of the low level jet over the Chaco, and as such it frequently reports the strongest winds of the low-level jet SONET sites. The primary objective of this site is to provide estimates of the wind speed and vertical structure of the jet near its core. This site is much less cloudy than Santa Cruz, Bolivia and offers better possibilities of frequent soundings to high altitudes.

Asuncion. This site provides measurements near the exit region of the East Andean low-level jet.

Chile

San Felix Island (proposed). We are proposing this island (26°S, 80°W), about 1000 km west of the coast of Chile, as a future SONET site because of its unique position to describe the flow over the stratocumulus region of this area. Currently there are no soundings made from this island, though VEPIC enhancements are being considered. Wind soundings from the island would allow estimates of the divergence to be made (monthly mean at least), using sites on the coast of Chile and southern Peru. These observations, if successful, could be eventually developed into inexpensive radiosonde observations, or powersonde observations.

3. Current status of the network

Despite the budget-related issues that affected the network during the last fiscal year, most of the stations managed to operate almost regularly and most interruptions were ultimately related to problems particular to each country, as explained in the following paragraphs.

3.1 Summary of station operation and performance by country.

Mexico

There are 7 stations currently operating in Mexico. The most recent addition is the site operating from the Naval Academy in Anton Lizardo, Veracruz. The Mexican Navy (Secretaria de Marina Armada de Mexico, SEMAR) requested the station to be established primarily for educational purposes (all officers in the Mexican Navy are trained there), but observations are also made there routinely and the data is transmitted in real time from the site. At least 5 of the Mexican stations rely on PACS-SONET to cover communications and other expenses; due to the lack of funds to repair a computer, one station (Salina Cruz) has not been able to process and transmit data in real time in the last two months. Other stations had problems with intermittent gas supply caused by delays in transfer of funds for gas purchase from SEMAR to the Naval bases that operate the sites. Most of the gas problems were rapidly solved after a letter was sent to SEMAR explaining the relevance of the observations for NAME, especially those made in northwestern Mexico.

The observations in Mexico are made twice daily, contrasting with most PACS-SONET sites. The reason for this is that the Naval personnel at these sites are dedicated to this activity and it was suggested by the Mexican Navy senior staff that these individuals be more fully utilized. The Navy covers the cost of personnel and hydrogen gas for all sites, SONET covers the balloons and costs associated with data communications (PC's at each site, internet connectivity and some phone line costs). Although the twice-daily observations are an additional cost, the afternoon observations provide information on the diurnal cycle that is missing from most other SONET sites.

Nicaragua

Nicaragua had been operating one station in the airport of Managua since 1997. This site was reliable, and has generated a very good data set, especially during the period 2000-2002. However, Managua is not currently operating because SONET has not been able to transfer funds to INETER, the institution in charge of making the observations. This institution is very strict in regards to payment, and will not make any observations if money is not available from the project to pay for the observers. The forecasters at the airport recognize the value of the observations for the forecast, but this interest has not been able to change the attitudes of senior INETER personnel. This lack of interest on the part of the institution responsible for geophysical observations in Nicaragua is not new, and is motivation for a planned trip to Central America early next year. This travel will seek additional sources of support for observations in the region and provide lectures to broader the awareness of the SONET (and related activities) in the Central American region.

Venezuela

Venezuela has been operating two pilot balloon stations, at San Fernando de Apure and in Ciudad Bolivar. These sites are operated by the Venezuelan Air Force Weather Service, which is the main weather forecasting institution in the country. Both sites are in the flat llanos region along the Orinoco River drainage. San Fernando is reliable and provides good quality data. On the other hand, unreliable gas supply and communication problems at Ciudad Bolivar are causes of this station's poorer performance. Several motivated individuals from Venezuela participated in the PACS-SONET short course in Panama in 2001 and good communication between the project and the country has existed ever since. The person in charge of the stations attended the PACS-SONET coordination meeting in Paraguay. The willingness and collaboration is highlighted by the relatively inexpensive operations in this country, with labor being provided at no cost to the project and transport of balloons effected through Venezuelan Air Force flights from Miami to Venezuela. Hydrogen gas for balloon inflation is also inexpensive in the country.

In addition to the high level of interest shown by the Venezuelan Air Force in the SONET activities, faculty members at the Universidad de Los Andes in Merida, Venezuela have shown interest in SONET activities. Future activities may involve a joint field program and associated follow-on research related to the mesoscale meteorology around Lake Maracaibo. PACS-SONET might contribute expertise in the design of the activity and procedures for analyzing the data.

One possible complication related to the Venezuelan SONET activities is that Venezuela is currently undergoing a major modernization activity that eventually will include the establishment of a number of radiosonde stations. One site will be at Cd. Bolivar, which may obviate the need for the pilot balloon observations there. As these sites will be sustained by an international loan, the long-term sustainability of this network is not assured, complicating decisions about the potential long-term data to be obtained from the sites. We are following this activity, as it may suggest revisions to at least one (Cd. Bolivar) of the Venezuelan station's operations.

Colombia

The Colombian Navy has been operating one station in Cartagena since 1997. However, this station has had a poor performance in the last two years, with an average of only 5 observations per month. The apparent reason for this is not only the lack of personnel at this research facility (CIOH), but also the perceived value of the SONET observations, that keeps them from assigning more people to this activity. We are planning travel to Colombia in early 2004, where we expect to meet with senior-level Navy officials, and to provide a short course related to the meteorology and climate of the region, and the project's objectives. Details of possible observations (Malpelo and Serranilla) on the islands administered by Colombia and staffed by Colombian Navy personnel will also be conducted.

During the past few months, contacts have been initiated with IDEAM, the Colombian institution in charge of Environmental affairs (and the official weather and climate service). As part of planned travel to Colombia we intend to visit the IDEAM office in Bogota with the objective on ensuring collaboration with the establishment of observations (including raingauge) on the islands mentioned above. The IDEAM has asked for help during this past year in maintaining its upper-air network (under budgetary pressure at the moment) and we will provide ideas on what might be feasible (short course possibility).

Ecuador

San Cristobal, in the Galapagos Islands, is the only site in operation in Ecuador. The site at ESPOL in Guayaquil was stopped in May 2002 due to the low number of observations caused by frequent cloudiness at the site (not a problem with the observers or institution). The San Cristobal site performed well during a 5-month period in 2003, but very few observations have been received in the last two months. We have been informed that the reason is lack of personnel in Quito to process and transmit the observations.

Because of the difficulty in maintaining a reliable data stream from the Galapagos site, despite the availability of observers, gas, and communications, we plan a visit to Quito to discuss the feasibility of maintaining this site. It is currently the most expensive site to operate, and if we do not receive strong assurances that it will operate effectively, we are likely to see other institutions on the islands to make the observations. Since our perception is that Ecuador, like Nicaragua, has a weak meteorological infrastructure and lack of appreciation for meteorological and climate information, we are anticipating giving a short course in Quito early in 2004, as part of travel to northwestern South America.

Peru

Two different institutions currently operate pilot balloon stations in Peru. The longest times series, and indeed the best SONET time series of any stations, is from the site at the University of Piura. This site, established in 1997, continues to operate at a high level of efficiency. It is one of the few sites that makes afternoon observations - a fact required by the relatively high frequency of morning low clouds along the coastal plain of northern Peru. **Some analyses of these observations are shown in Section 5.**

The National Meteorological Service in Peru (Servicio Nacional de Meteorologia e Hidrologia, SENAMHI) operated four stations during the SALLJEX at Pucallpa, Ica, Arequipa and Puno. These sites were established in November 2002, and were reliable during SALLJEX. The site at Arequipa became part of the PACS-SONET in July 2003, and has operated very reliably since. SENAMHI has agreed to operate pilot balloon stations also at Pucallpa, Iquitos, and Puerto Maldonado. The latter two sites are currently special El Niño radiosonde sites that make soundings every other day. Arrangements are being made to make pilot balloon observations at these sites; the exact protocol (number of observations per week etc.) has yet to be worked out. The Pucallpa and Iquitos sites are potentially valuable as they describe the currently poorly-monitored conditions upstream of the low-level jet axis over eastern Bolivia.

SENAMHI has also expressed interest in obtaining information on the costs and detailed specifications of recoverable radiosonde systems that were partially demonstrated during the recent workshop in Paraguay. This information is being forwarded to them.

Paraguay

The pilot balloon site at Asuncion has a good record of observations, spanning a 4-year period. The second Paraguayan site, Mariscal Estigarribia is at a location far (500 km) northwest Asuncion with poorly motivated individuals and little supervision. The two sites in Paraguay performed well during SALLJEX, when the Mariscal Estigarribia site was staffed by additional personnel. M. Estigarribia stopped making observations shortly after SALLJEX ended, and has just resumed operations (October 1st) with motivated and more capable observers. Efforts to modernize the meteorological infrastructure and emergency management capabilities in Paraguay have led to the acquisition of a radiosonde system that has been installed in Mariscal Estigarribia. However, shortly after its installation the hydrogen generator failed and, for this reason, radiosondes have not been launched since the equipment was put in place more than one year ago. Now, with closer supervision by DINAC senior staff, we expect the Paraguayan PACS-SONET observations to continue without significant problems for the foreseeable future.

Bolivia
Gas availability and gas costs continue to be the main issues in Bolivia. The gas company (Praxair) in Bolivia has been unable to satisfy the demand of gas despite of the high prices they charge for it. Gas is imported from Brazil and the supply and transport has not been reliable. Also, gas is delivered only at two stations (La Paz and Santa Cruz) and AASANA has to arrange for transportation to the other 4 relatively remote sites. Bad road conditions in Bolivia complicate transportation and recycling of the gas cylinders. The station at Robore has not been making observations for the last 2 months because they ran out of gas. AASANA has been unable to send them gas because of new regulations that prohibit transportation of gas by train. Civil unrest also complicates transport throughout the country; strikes and road blockages are currently common.

We will attempt to have lower-cost gas (either hydrogen or helium) imported from Peru during the coming year. Currently we are using gas purchased as part of SALLJEX activities but which was not delivered until after the experiment ended.

On the positive side, the AASANA observers and other personnel remain committed to the activity and continue interested in spite of some of the difficulties.

3.2 Performance statistics over the past year.

The overall performance of the network appears to be stable in terms of the number of observations per month (Figure 3.1). However, the average number of observations per month is below 500 for the months following SALLJEX; this average is somewhat lower than that in the previous 3 years. On the other hand, the average is higher than expected given the problems with the transfers of funds.

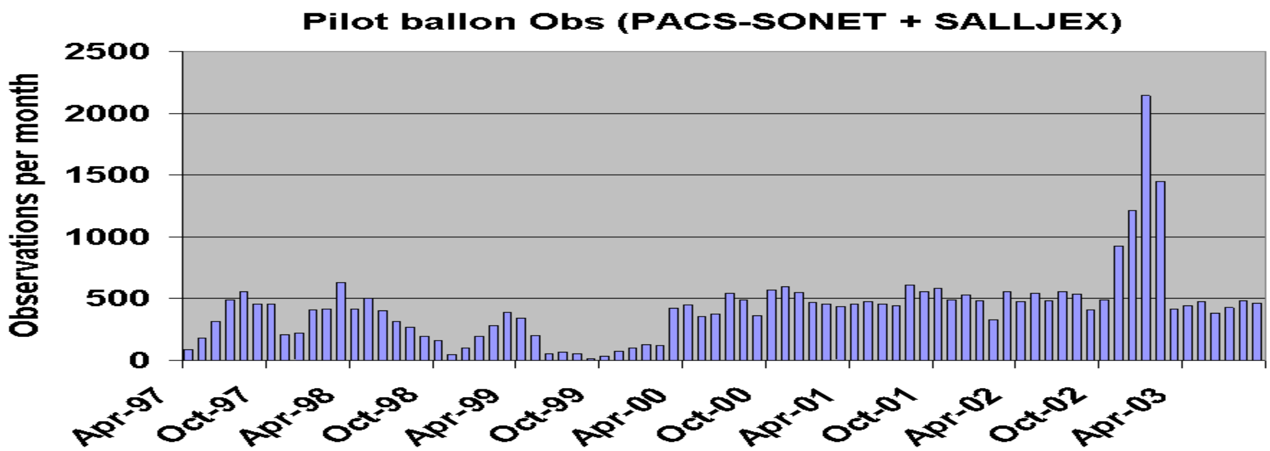

Figure 3.1. Pilot balloon soundings per month (PACS-SONET and SALLJEX combined) from April 1997 to September 2003.

To date, PACS-SONET has generated more than 30,000 observations - more than 5,000 per year in the period 2000-2003 (Fig. 4.2). This calendar year a total of 8,000 soundings are expected, including ~2,000 soundings made at Argentine and Brazilian stations that operated only during SALLJEX months.

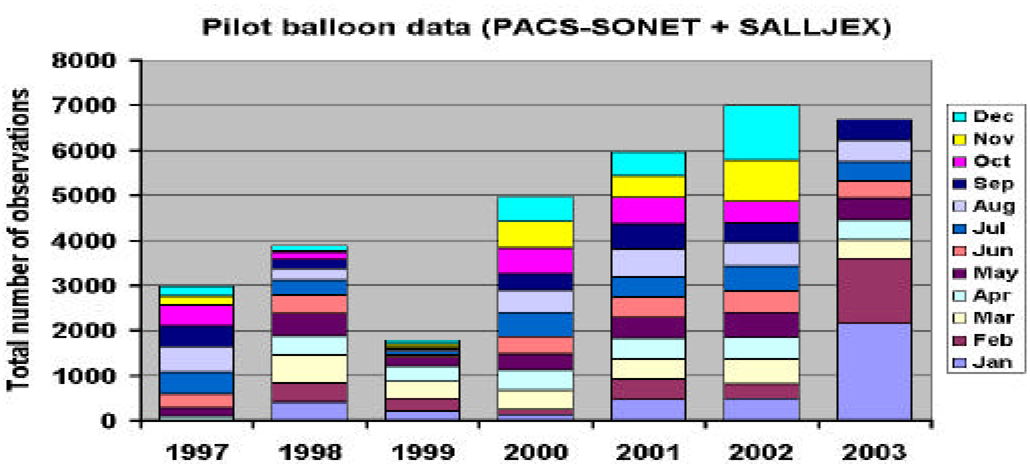

Figure 3.2. Pilot balloon observations per year (PACS-SONET and SALLJEX combined) in the period 1997-2003. For year 2003, only 9 months are shown (Jan-Sep).

3.3 Concerns related to the network

Hardware

The theodolites in use are old Warren Knight units, which were obtained from the US National Weather Service warehouse in Kansas City over the past 6 years. This source of theodolites has now been exhausted, and the remnants of the theodolites all reside at NSSL and in the countries where they are in use. Data loss has occurred because of faulty theodolites, and the inability to repair them rapidly in the field. Our SONET web site now has detailed information on the use of the theodolites, but still lack some information of maintenance, though individuals in each institution have been trained in basic maintenance procedures.

At some point in the not distant future replacement theodolites will be needed, especially since many were used during SALLJEX and are expected to be used during NAME. To some degree it may be possible to use theodolites that exist in Peru and Venezuela; those in Peru are of the same type (Warren-Knight) as used in SONET, while those of Venezuela are a different type, but still usable.

Sustainability, gas supplies

The major topic of the recent SONET workshop in Paraguayan was the sustainability of the network and means to reduce the costs of operations. One means was to use hydrogen gas in some of the countries where helium is currently being used. The importation of less expensive helium or hydrogen into Bolivia in particular could save thousands of dollars per year.

4. Educational activities and annual meetings

PACS-SONET has had, as part of its activities, educational activities throughout its existence. During the first two years 8 visitors participated in 1-3 month visits to NSSL, and carried out applied research activities with the recently started SONET data. Prior to the SALLJEX activities, 6 visitors from South America participated in similar visits to NSSL during the summer of 2002.

In addition to these activities, SONET has supported, or helped support a series of multi-week workshops in Bolivia, Panama, and shorter series of lectures in Mexico, Peru, and most recently Paraguay.

During the recent SONET workshop in Paraguay the concept of SONET-supported educational activities was discussed at length. The principal concern was not that these activities were not a good activity, but rather that the cost involved consumed a significant percentage of the available SONET funds that might otherwise be used for observations. A major workshop or course, involving international participants, has typically incurred an expense of approximately $25K. This is about 20% of the funds available for observations. Much discussion centered on what was the best way to invest the available funds in educational activities. The options discussed included 1) multi-month visits to NSSL, short (several week) courses, sponsoring students at selected educational institutions, funding SONET research activities in certain countries, and having NSSL personnel provide short courses in selected countries (just for members of the particular country). Some of these activities are not feasible, while others will require careful evaluation.

The participants in the SONET workshop prepared a document, which summarizes the discussions that took place during the meetings and presents the participants' views and suggestions about different aspects of the project. Much emphasis was put in the network's design and in the planning of future educational activities. Although many of the changes proposed may not be feasible or may lack sound scientific justification, those highlight the level of motivation of the PACS-SONET coordinators. Their input is much appreciated and we will continue to encourage this kind of participation. The document will be made available in the project's web page through the following URL:

http://www.nssl.noaa.gov/projects/pacs/laquinta/

5. Some aspects of the PACS-SONET data that suggest avenues of further research

In this section we present some aspects of the PACS-SONET data that have shown promise for further work. These analyses are preliminary, mostly because some of these data are not yet quality-controlled. However, the results are unlikely to change in a qualitative sense. These results are presented to suggest areas of further work.

5.1 Observations along the northern coast of Peru. Piura interannual variations

The best SONET data set to describe interannual variability and the mean annual cycle at a particular locality is to be found with the observations from Piura, Peru. This site, at 5.5°S and about 60 km inland from the coast in northern Peru, has nearly 6 complete years of afternoon soundings.

The mean annual cycle for the afternoon Piura meridional winds (**Fig. 5.1**) show a northward flow near the surface of between 3 and 7 m/s, with weakest winds during the February/March time frame when the SST are highest in the eastern Pacific off the coast of northern Peru and the ITCZ is farthest south. The southerly flow increases from March to May, and then again from July to November, when it reaches a peak of about 7 m/s at about 300m above the surface. This southerly flow is very shallow, with near zero meridional flow at the 1.5km level throughout the year. The zonal wind is relatively weak compared with the meridional wind, though it is stronger and deeper during the warm season (time of highest SST's), around February-March.

By subtracting the annual mean values at each level, we can display the monthly evolution of the anomalies of the meridional winds at Piura (**Fig. 5.2**). The zonal wind anomalies are interesting in that they are relatively deep - the period October through April is characterized by westerly wind anomalies of about 1 m/s, while the period from May through September shows easterly wind anomalies. The layer between 1500 and

2000 m shows an inverse relationship with the layer beneath it. It is possible that when the onshore flow (positive zonal) is stronger in February-March the return flow above the afternoon sea-breeze is also stronger (negative zonal wind anomaly). Likewise, when the sea-breeze circulation is weaker than the annual mean (in June-July), the return flow of the sea-breeze, centered at 1.5 km altitude, is anomalous in the opposite sense.

A third perspective of the seasonal variation in the flow at Piura can be seen from **Fig. 5.3**. Here we have averaged the months of February and March and then June and July, to show the vertical wind profiles when the anomalies from the annual mean are largest (refer to **Fig. 5.2**). Most dramatic from **Fig. 5.3** is the large difference in the zonal wind profiles. The onshore flow is approximately twice as deep and twice as strong during February-March as during June-July. This implies that the afternoon onshore mass flux during the warm months is roughly 4 times as large as the cool season transport.

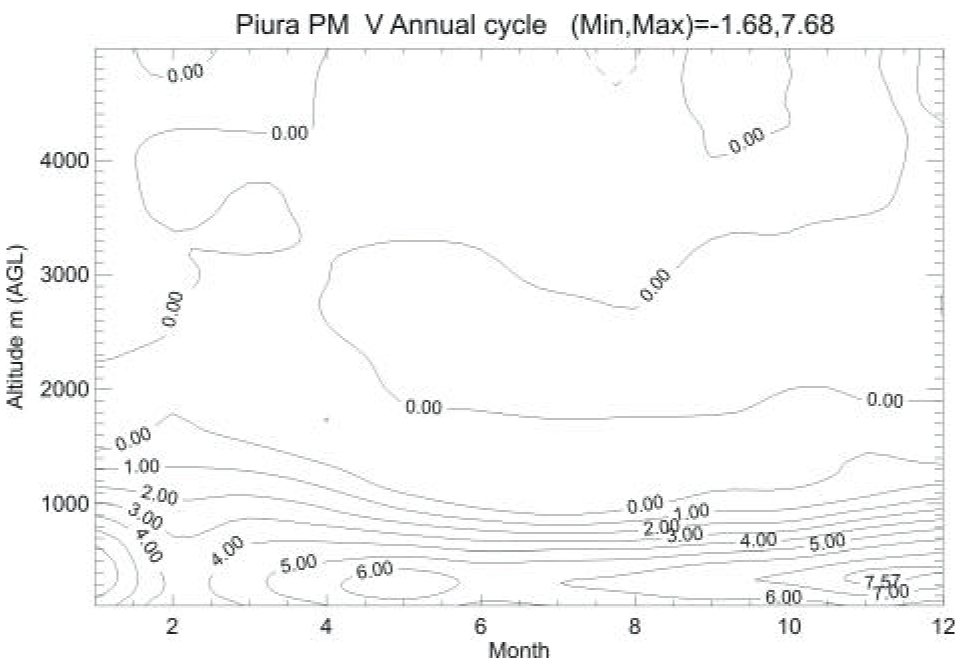

Figure 5.1. The mean annual cycle for the afternoon Piura meridional winds.

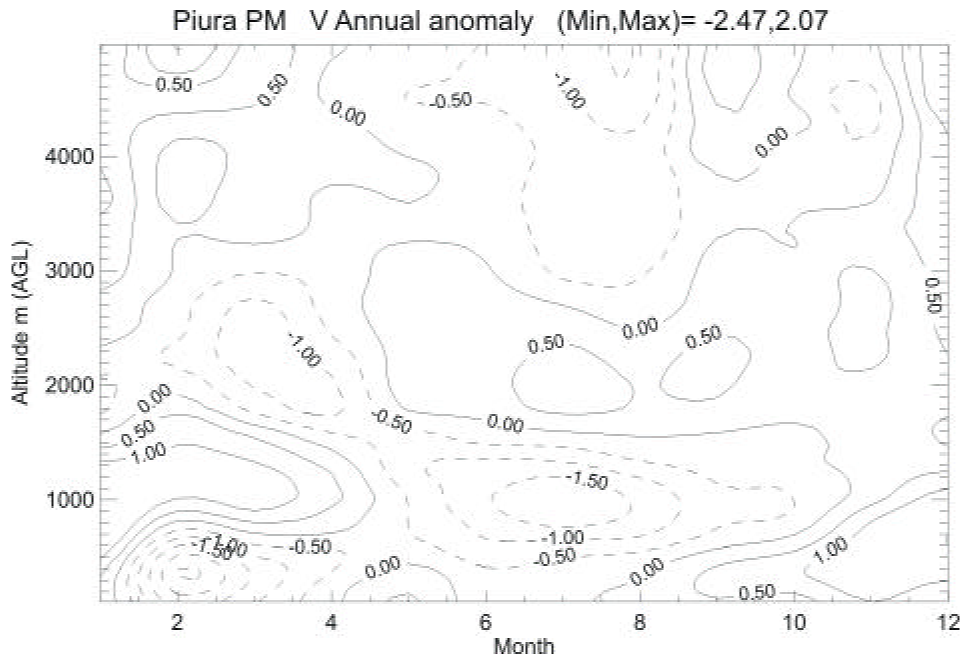

Figure 5.2. Monthly evolution of the anomalies of the afternoon meridional winds at Piura.

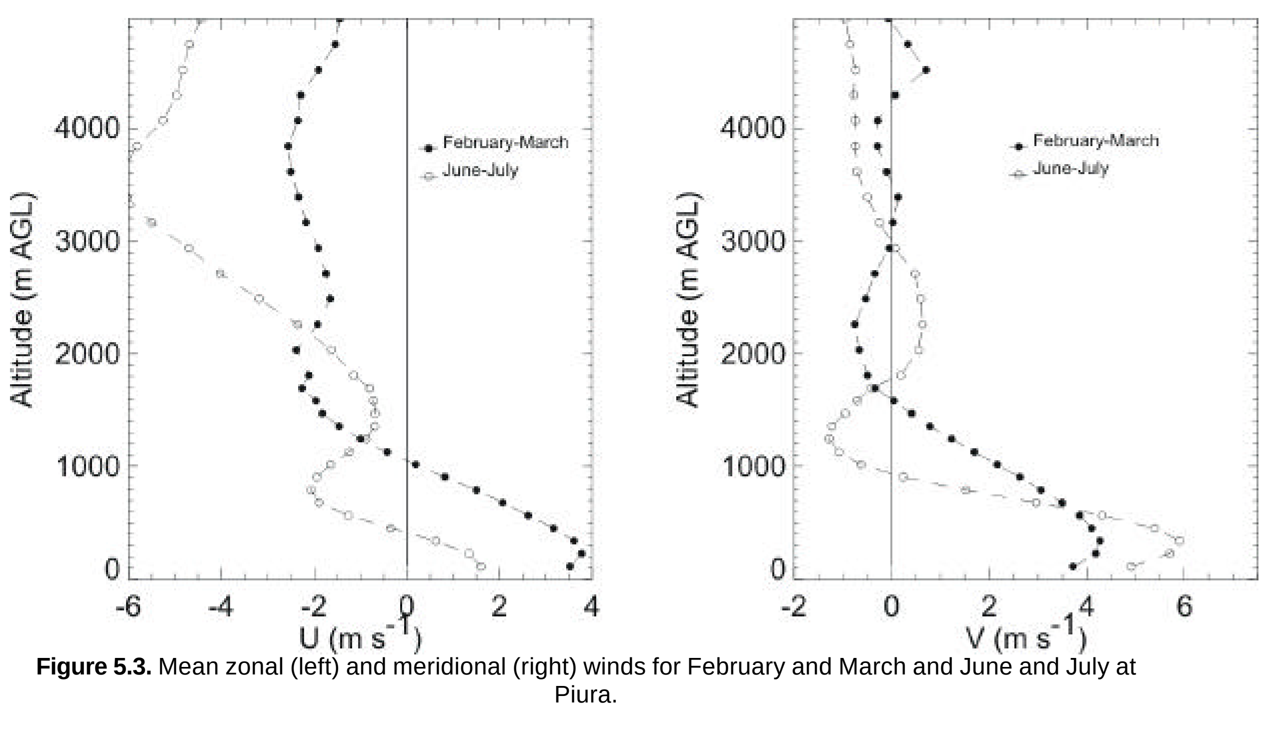

Figure 5.3. Mean zonal (left) and meridional (right) winds for February and March and June and July at Piura.

The difference in meridional wind profiles is apparent from **Fig. 5.3**, with shallower (~1000m) and stronger (~ 6m/s max) northward flow during the cool months and deeper (~1500m) and weaker (~4 m/s max) flow during the months of highest SST.

A summary of the vertical profiles of the zonal and meridional winds at Piura during each of the years, averaged over months when the profiles appeared similar, is shown in **Fig. 5.4**. The essence of this complex figure is that the interannual variations are quite small, compared with the mean profiles (not plotted, but evident by "eyeballing" the mean value of the individual profiles. The largest variability appears during the warm season and the least difference in the profiles appears to be during the June to August period, though may vary with the level considered.

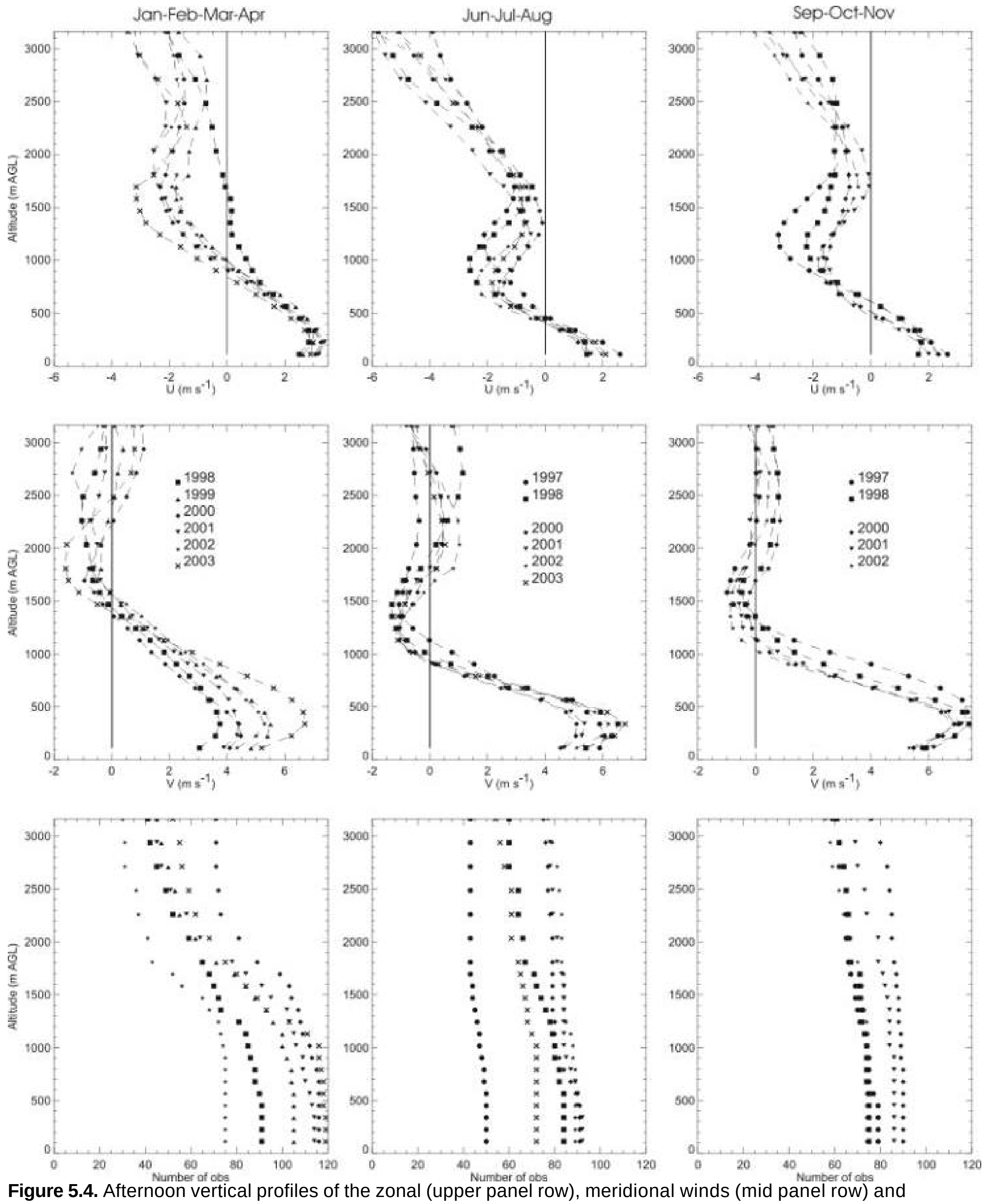

Figure 5.4. Afternoon vertical profiles of the zonal (upper panel row), meridional winds (mid panel row) and number of observation taken into account (lower panel row) at Piura during each of the years. Averaged over the months of January to April, June to August and September to November on the left, center and right panel columns, respectively.

5.2 Low-level jet crossing the Yucatan peninsula

The observations at Frontera, and more recently at Ciudad del Carmen (~100 km east of Frontera on the flat coastal plain), on the southern part of the Yucatan peninsula, have shown a strong, diurnally oscillating low-level jet. This jet is most common during the spring months, under pre-frontal synoptic conditions but is also clearly present in monthly mean profiles. The strongest easterly flow occurs during July, similar to Managua farther south, with the zonal wind anomaly extending throughout the lower-middle troposphere (**Fig. 5.5**). As with Managua, the NCEP reanalyses at 850 mb (**Fig. 5.6**) underestimate the strength of the flow; the observations suggest a zonal wind near 7.5 m/s while the analysis indicates about 5.5 m/s.

The July mean u and v profiles (**Fig. 5.7**) show that the diurnal variation is considerably larger than the interannual variability, and also show that the diurnal variations are large only below about 1700 m. Above this level, despite there being fewer observations, the difference in the mean morning and mean afternoon profiles is quite small - at least up to 3 km.

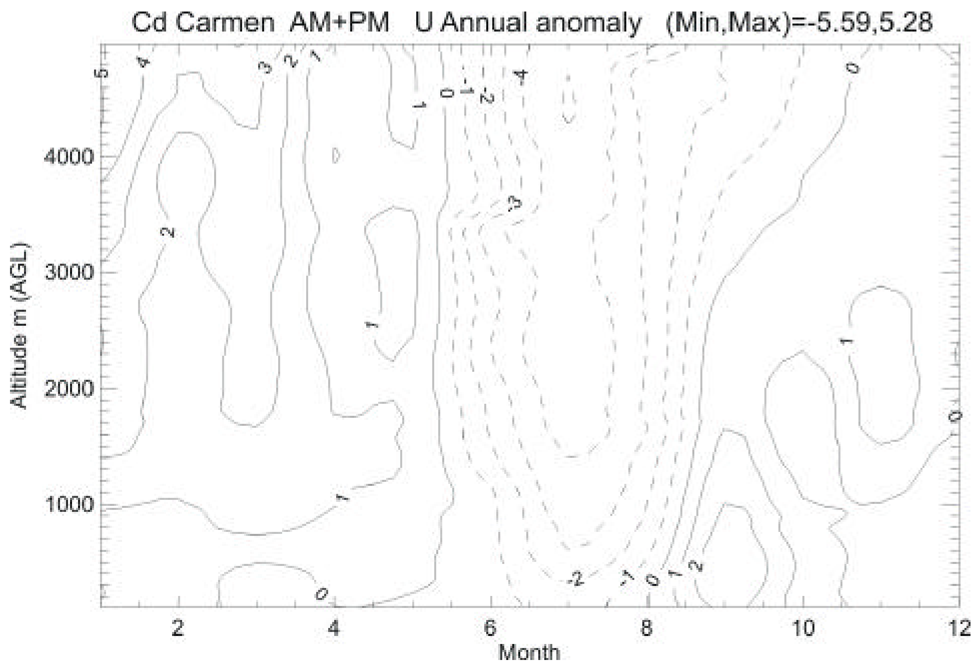

Figure 5.5. Annual anomalies for the morning (AM) and afternoon (PM) zonal winds at Ciudad del Carmen.

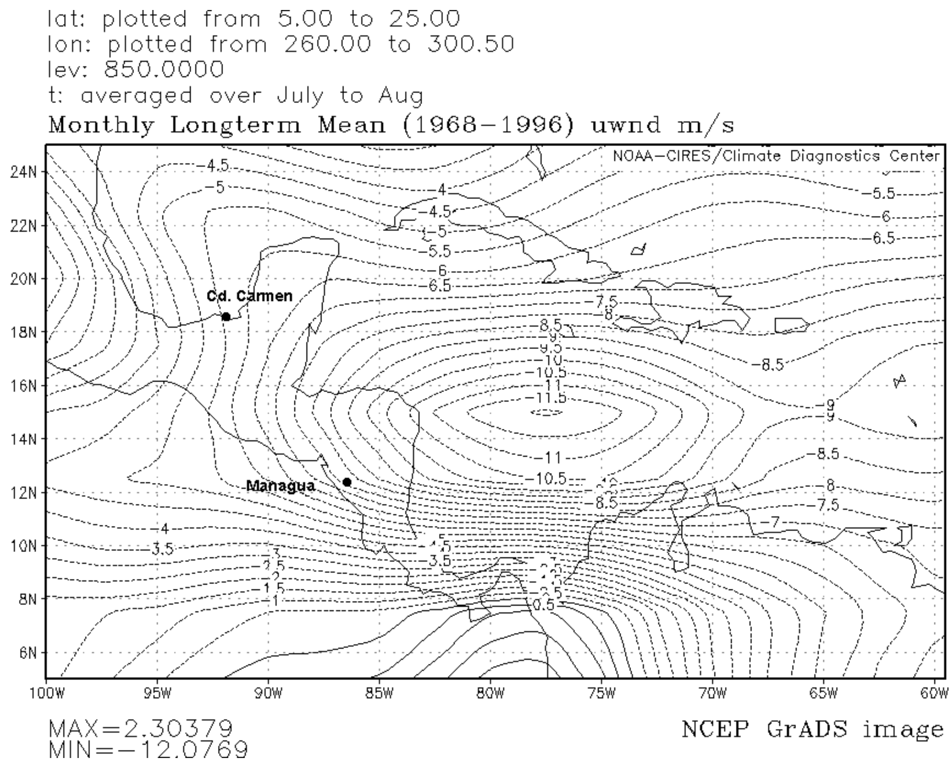

Figure 5.6. Zonal winds contours averaged from July to August at 850mb. Taken from NCEP/NCAR Reanalysis web page http://www.cdc.noaa.gov/cdc/reanalysis/reanalysis.shtml

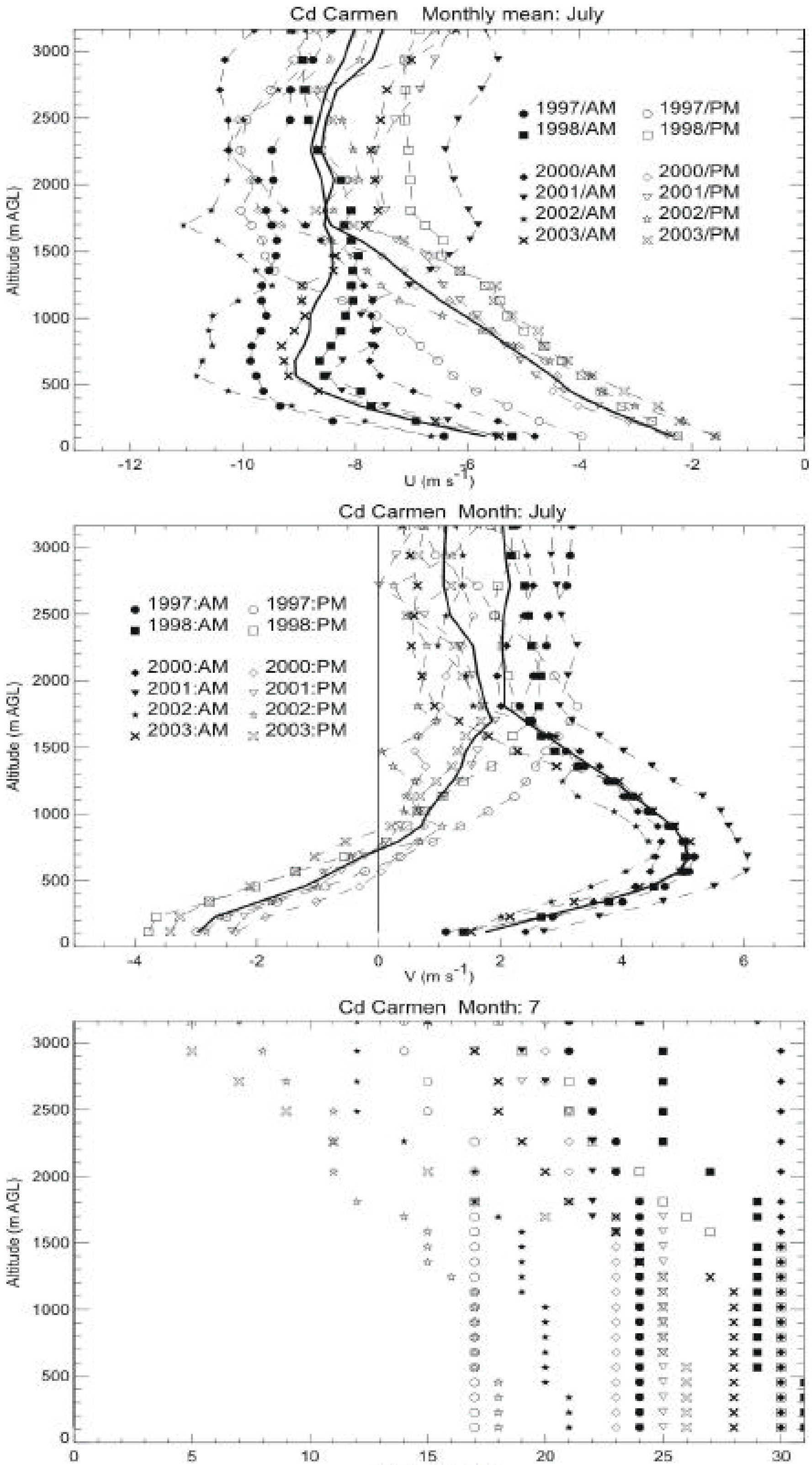

Figure 5.7. AM and PM vertical profiles of the zonal (upper panel), meridional winds (mid panel) and number of observation taken into account (lower panel) at Ciudad del Carmen during each of the years. Averaged over the month of July.

5.3 Gap flows at Salina Cruz

The cross-gap flow at the Isthmus of Tehuantepec is a well-known feature, and is now being routinely documented by scatterometer observations. However, the only direct measurements of the vertical structure of the flow come the PACS-SONET observations at Salina Cruz, started in 1997 there to monitor gap flow and its variations associated with tropical wave passages in the summer and cold frontal surges during the winter.

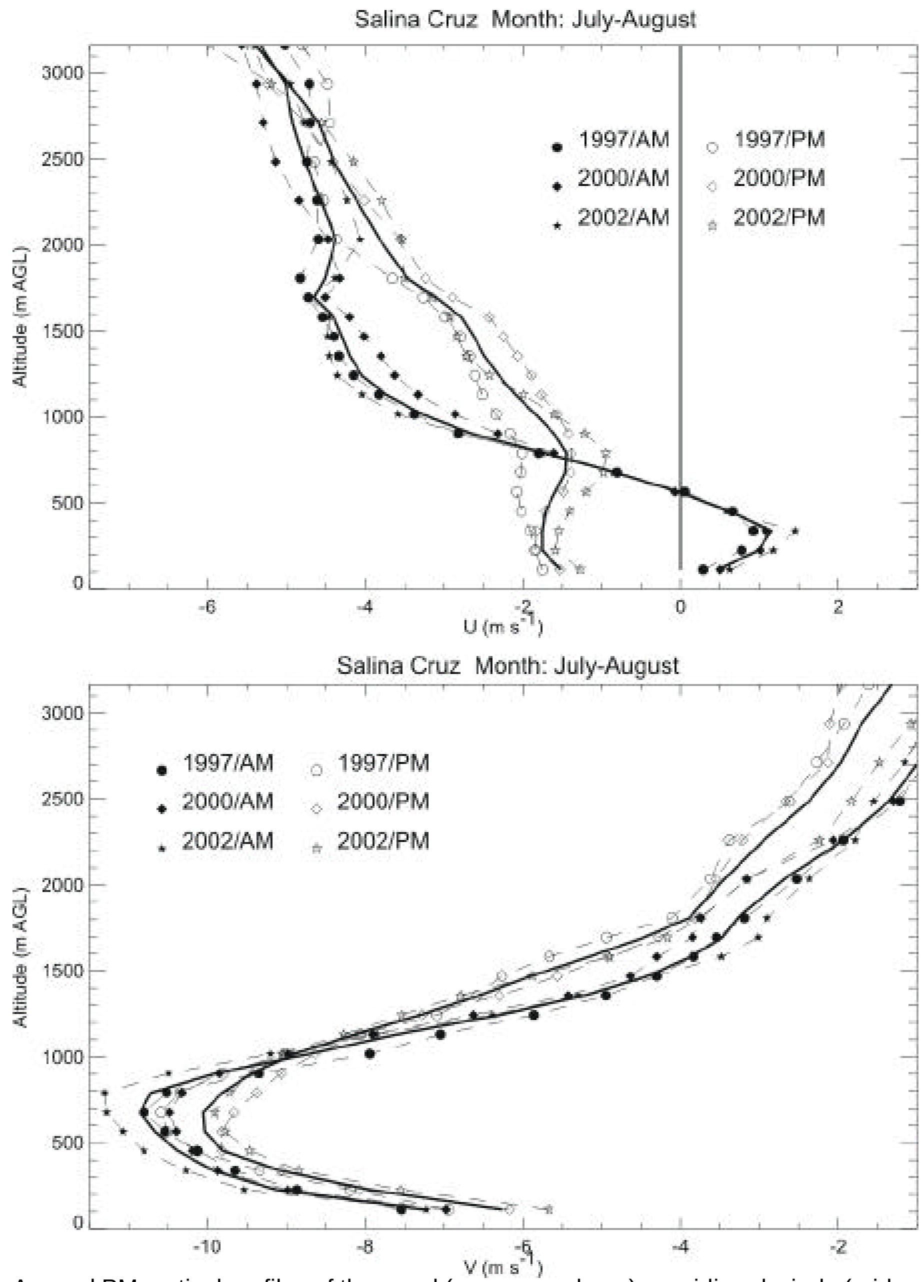

Figure 5.8. Am and PM vertical profiles of the zonal (upper panel row), meridional winds (mid panel row) at Salina Cruz during each of the years. Averaged over the months of July to August.

Figure 5.8 shows the profiles of the morning and afternoon wind components, averaged over the months of July and August, for three years of particularly complete data. **Figure 5.8** also showing the mean (AM + PM) of these years. The most significant aspect of these figures is that the interannual variability of the monthly mean flow is quite small - compared with the mean profiles. The diurnal variability of the meridional wind profiles is detectable - about 1.5 m/s difference near the wind maximum at 700 m asl, but is small compared with the meridional wind (~10 m/s). The range of the diurnal variation of the zonal wind is larger, about 3 m/s. There is a clear vertical reversal of this diurnal variation (also evident in meridional wind), associated with the sea-land breeze. In general, the implication of these observations is that the interannual variability is small compared with the amplitude of the diurnal cycle. This implies that care must be taken in order to compare the observations to larger-scale analyses that do not resolve the diurnal cycle well.

5.4 Topolobambo. Inflow into the lower Gulf of California

This site, near the lower end of the Gulf of California, has the most complete record of the two PACS-SONET sites along the Gulf. **Figure 5.9** shows the annual cycle of the u and v components. The main feature is that, below 1 km altitude, the meridional wind undergoes a prominent annual oscillation between northerly winds from October to April and southerly winds present during the period June through September. Strongest northerly winds occur from December to February, while the strongest southerly winds are found during June and July. Variations in the zonal wind component are much smaller near the surface, but increase with height and are larger than meridional variations by 3 km asl. **Figure 5.10a** shows the difference in the mean zonal flow for different years, and highlights the fact that the diurnal cycle is far larger than the interannual variability of this component of the wind. However, there is a larger interannual variability of the meridional wind (Fig. 10b). The mean of the morning and afternoon soundings, again averaged over the period June-September, is shown in **Fig. 5.10c-d**. In all years there is up-Gulf flow, though the depth and intensity can vary. The northward flow vanishes at about 1500 m, in the mean.

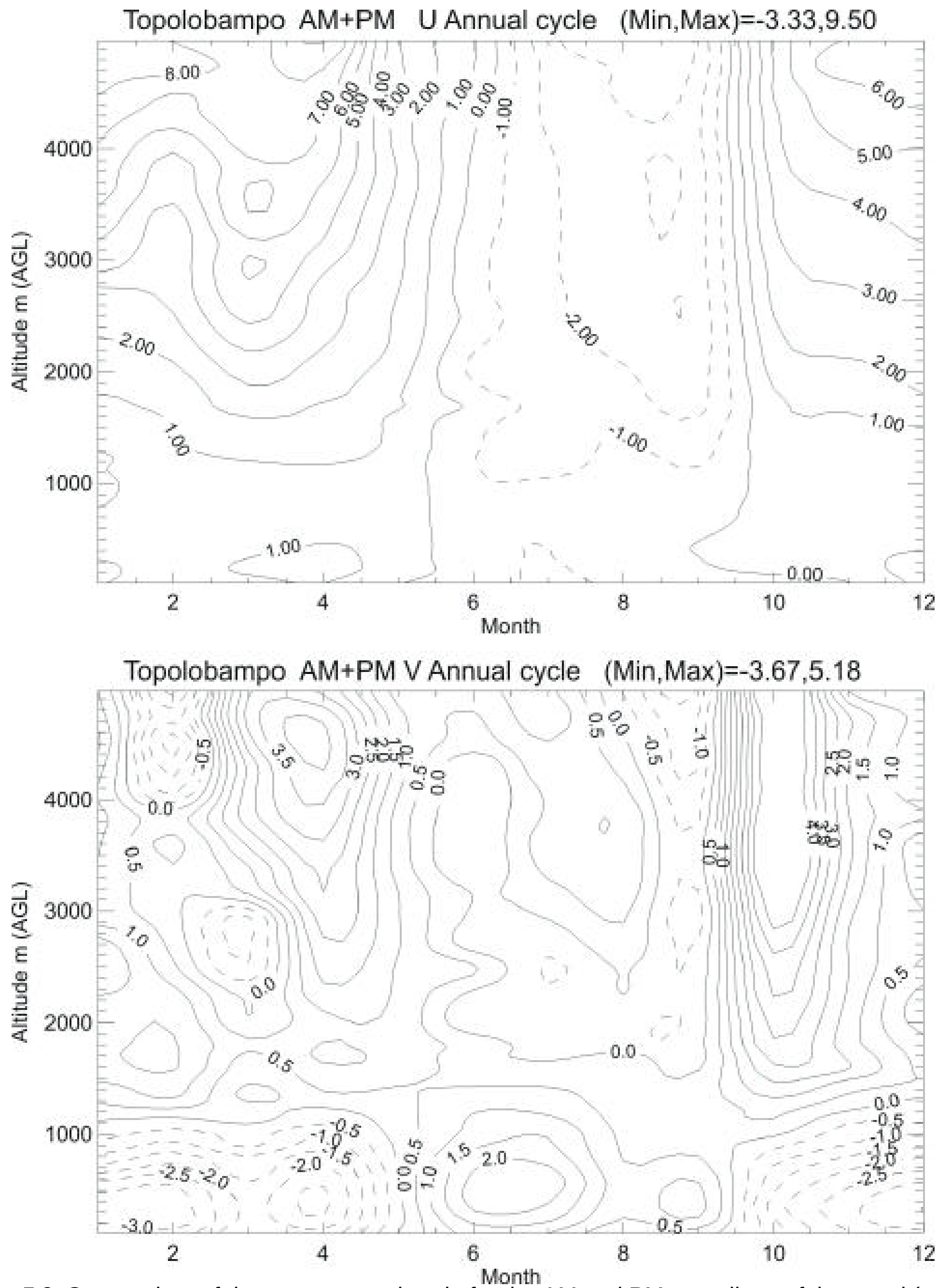

Figure 5.9. Composites of the mean annual cycle for the AM and PM soundings of the zonal (up) and meridional (bottom) winds at Topolobambo.

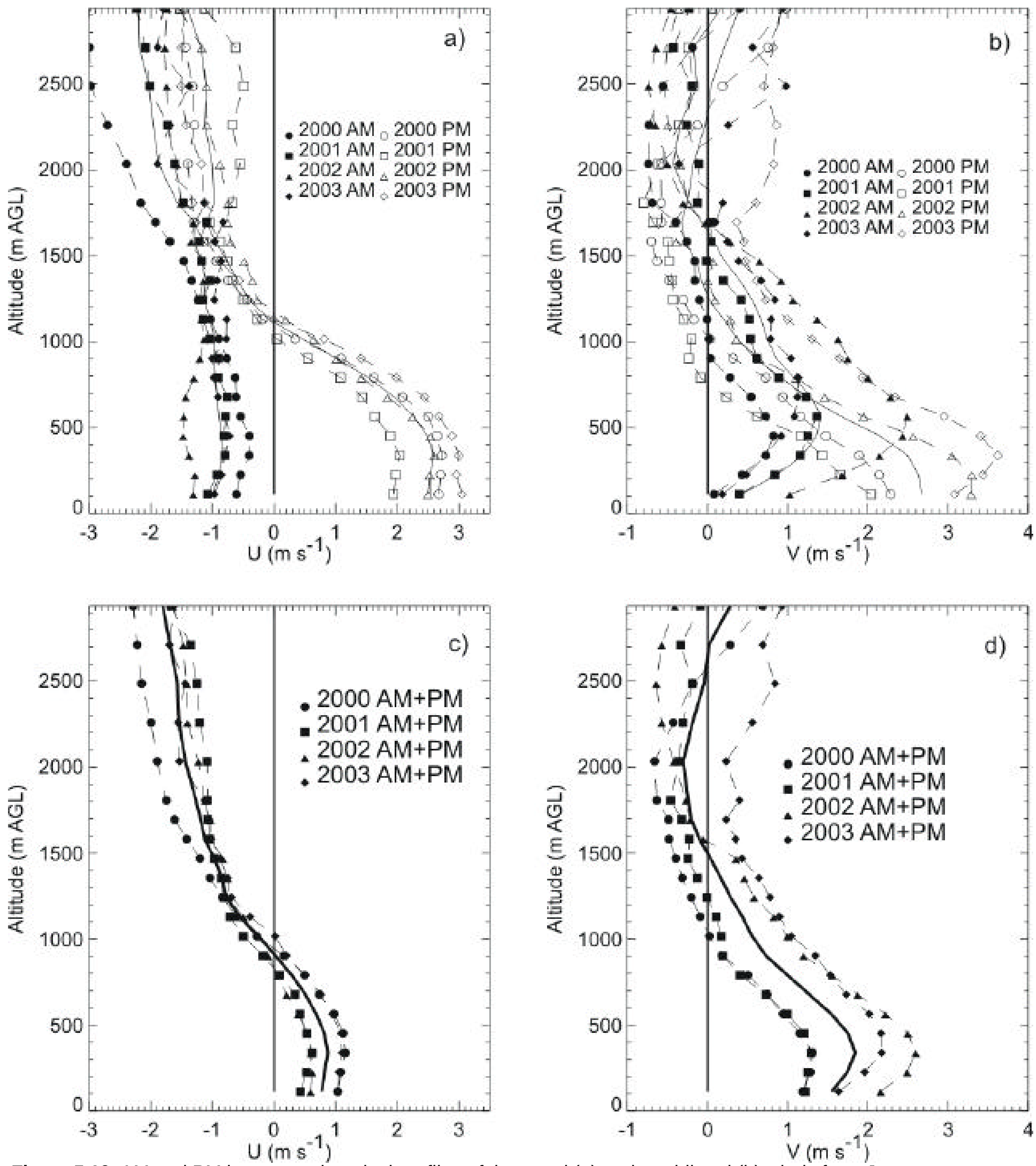

Figure 5.10. AM and PM interannual vertical profiles of the zonal (a) and meridional (b) winds from June to September during each of the years at Topolobambo and average for the AM and PM vertical profiles for the zonal (c) and meridional (d) winds.

The importance of these simple observations from Topolobampo is apparent when one examines the results of studies such as those involving Eta-model diagnostics (e.g. Berbery 2001) that show flow down the Gulf at this location. Over this region, the eta analyses are clearly *wrong*.

5.5 Flow at the northern end of the Gulf of California. Puerto Peñasco

The observations at Puerto Peñasco were intended to monitor the strength of the flow over the northern Gulf of California, and as such, the intensity of the summer north American monsoon circulation. This site has reported stronger low-level winds than any other sounding site in the region, and displays a clear wind direction shift of the monthly mean winds between winter and summer (not shown). As with most sites, the diurnal variation is larger than the interannual variation (**Fig. 5.11a-b**), especially in the zonal wind component below 1000m. However, the interannual variability is significant, especially above 1 km asl. The near-constant difference between the morning and afternoon mean meridional wind profiles (above the surface layer - where it is very small) is curious, since it cannot be ascribed to fewer observations with height.

It should be noted that the Puerto Peñasco (and other site's) soundings have not been fully quality-controlled and it is expected that the results will be smoother when this is completed. This site is one of two of the 7 Mexican sites that are not located at Oceanographic offices of the Mexican Navy and unfortunately this has led to problems with supervision of the observers and quality control of the observations.

The most significant result from the Puerto Peñasco observations is the fact that every year, when observations are averaged over morning and afternoon and over the months of June-August, shows a clear up-Gulf flow throughout the lower few km (**Fig. 5.11c-d**). The meridional wind, nearly equal to the total wind since the zonal component is quite small, shows a maximum of about 4.5 m/s near 300 m asl. The interannual variability is smallest near the surface and increases with height.

Comparison with the results for Topolobampo shows that the meridional (and total wind) is about twice as strong in Puerto Peñasco than at Topolobampo. This agrees with earlier findings based on SWAMP-1990 and EMVER-1993 experiment data of much more limited duration.

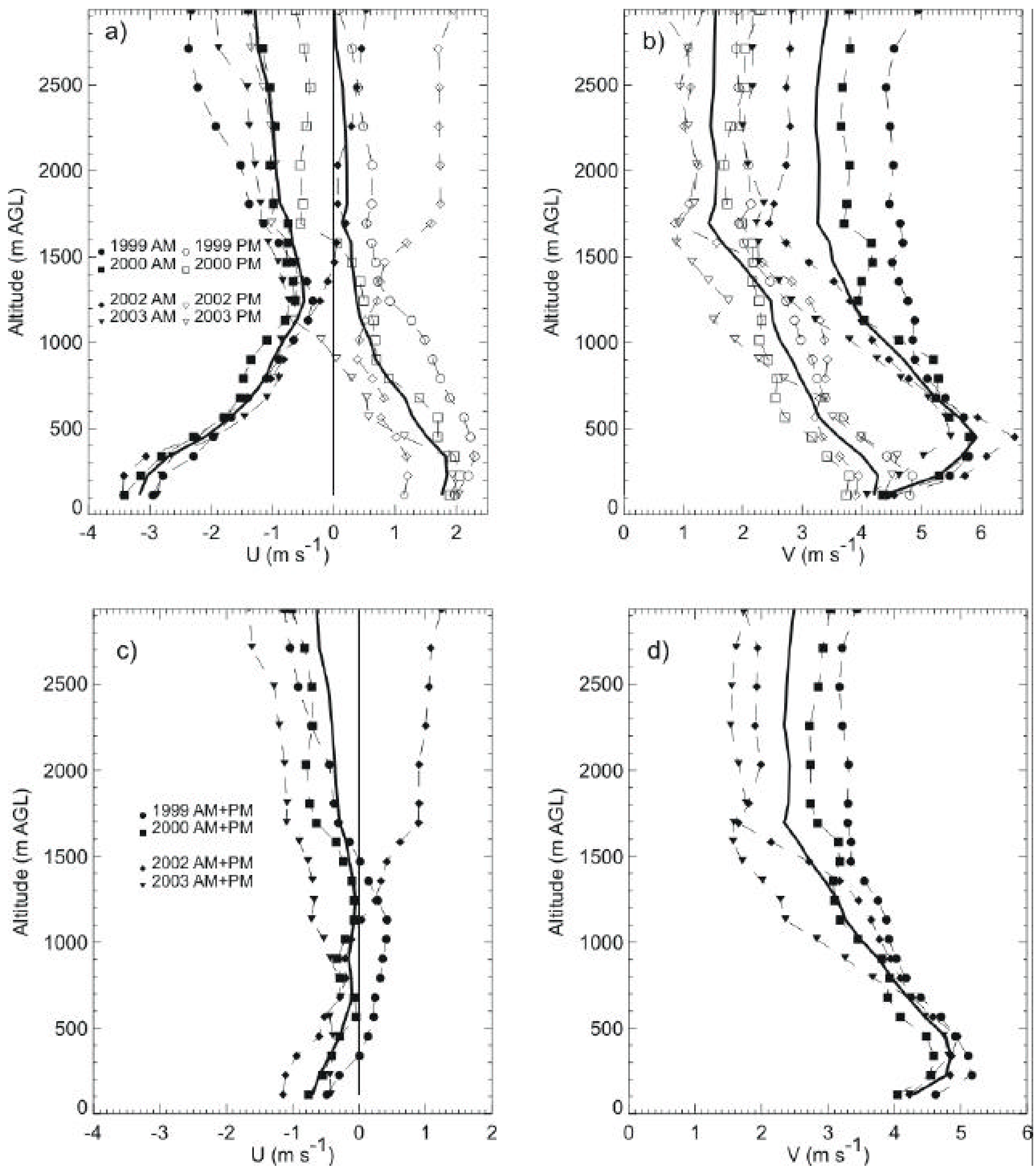

Figure 5.11. The same as figure 6.10 but at Puerto Peñasco.

5.6 Gap flow through Central America at Managua

Observations at Managua, with the exception of the current year, have been generally reliable and of high quality. These are sufficient to describe the annual cycle; the zonal wind section is shown in **Fig. 5.12**. The monthly mean zonal wind shows two peaks during the year. The first, which occurs in July-August, is of about 15 m/s. This peak abruptly weakens to near 6-7 m/s during September and thereafter starts to increase, reaching about 18 m/s in February. Both peaks in zonal wind occur near 1.5 m ASL. However, the anomaly cross section of the zonal wind (**Fig. 5.13)** shows that the amplitude of the anomaly is vertically extensive, with the maximum anomaly near 3 km in July-August, but extending to above 6 km with nearly the same amplitude.

The monthly mean zonal winds at Managua are considerably larger than those based on the NCEP reanalyses (**Fig. 5.14**), which indicate for July-August mean winds, a broad maximum in the easterly flow between the 850 and 700mb levels, with speeds over Nicaragua of between 7.5 - 8 m/s (at 850 mb). Curiously, the NCEP reanalyses show the winter maximum in the easterly flow to be slightly weaker than the summer maximum.

The comparison of the pilot balloon-based mean zonal wind at Managua with the radiosonde station observations at San Andres island is of interest. The island is about 500 km east of Managua, along the axis of maximum winds in the trades over the Caribbean Sea. While there is good agreement between the zonal winds at 5-6 km from both Managua (see **Fig. 5.12**) and San Andres (**Fig. 5.15**), the difference between 1-2 km is quite large - about 5 m/s for the July mean zonal wind (~ 9 m/s for San Andres and ~15 m/s for Managua). The difference is even larger during the January - March winter peak in zonal winds, where Managua shows a broad maximum of winds above 14 m/s with a peak of 18 m/s, while San Andres shows values of 7-8 m/s respectively. The vertical shear above the Managua jet is much larger than at San Andres, though the San Andres data did not always include the full-resolution radiosonde data and may thus be smoother than the actual soundings.

The stronger winds found at Managua can be explained (*away?*) as a gap-induced effect, but this is hardly a narrow gap, and the strong winds found at Managua are quite high (~1.5 km) rather than closer to the surface. The NCEP reanalyses do not have the spatial resolution to show this gap wind structure (see **Fig. 5.6.)**.

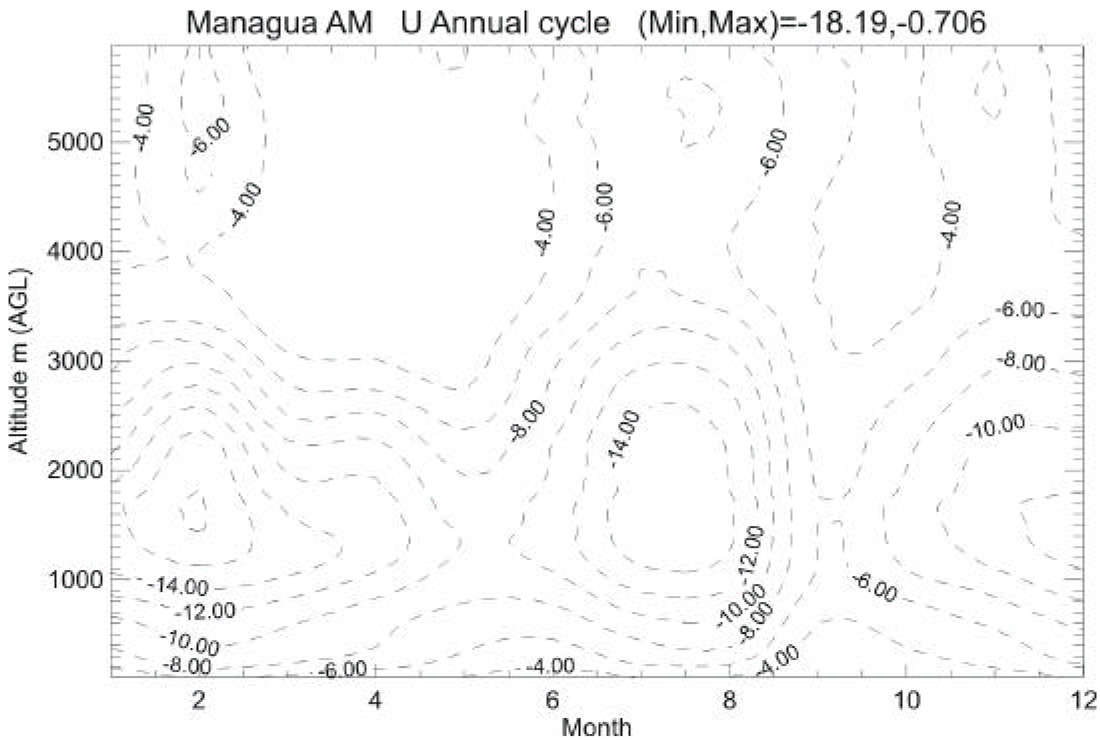

Figure 5.12. The mean annual cycle for the morning Managua zonal winds.

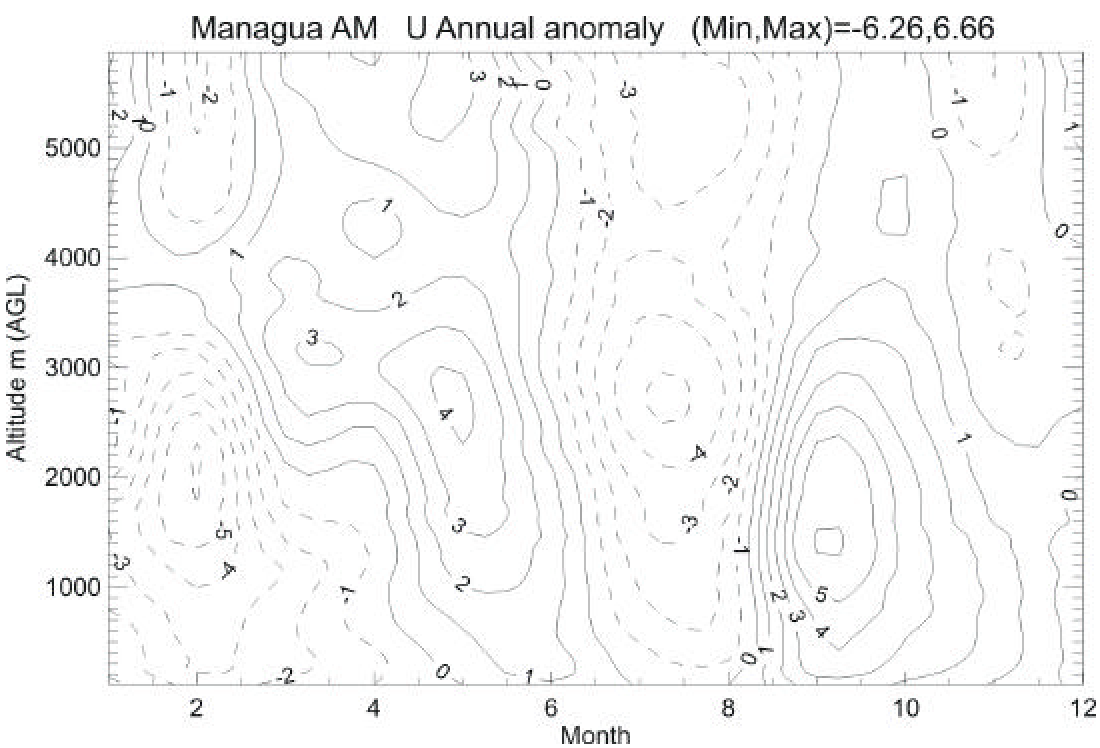

Figure 5.13. Morning monthly evolution of the anomalies of the zonal winds at Managua.

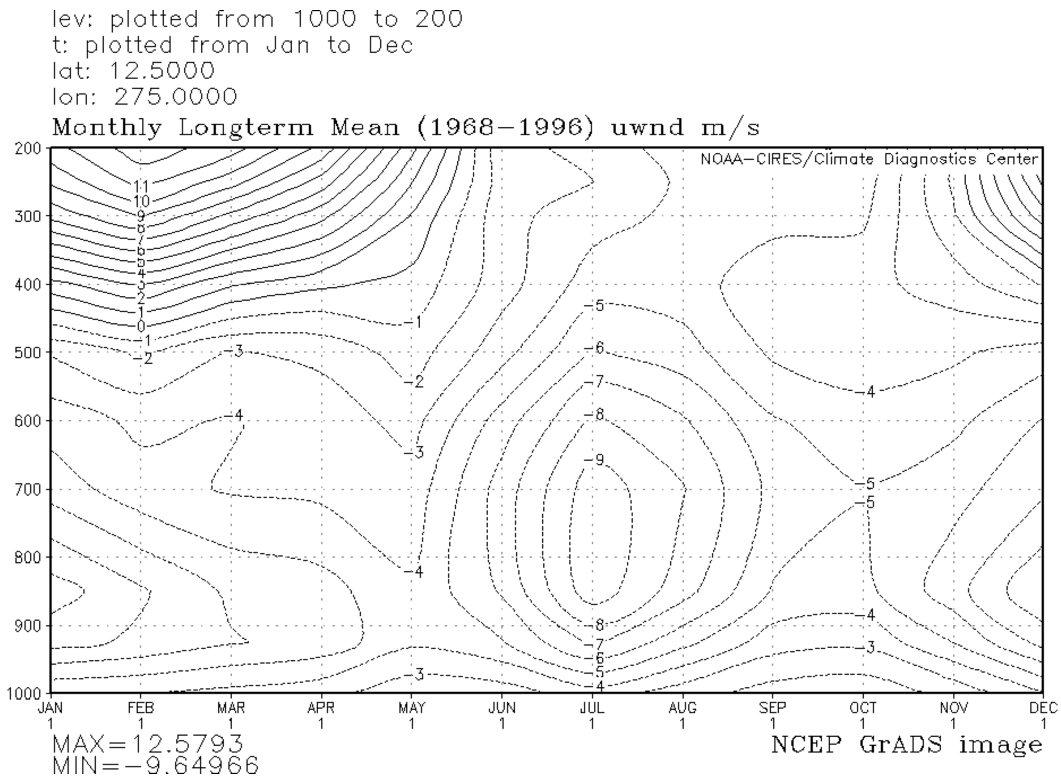

Figure 5.14. Annual cycle for the zonal winds at Managua (closest grid point) using NCEP/NCAR Reanalysis data http://www.cdc.noaa.gov/cdc/reanalysis/reanalysis.shtml

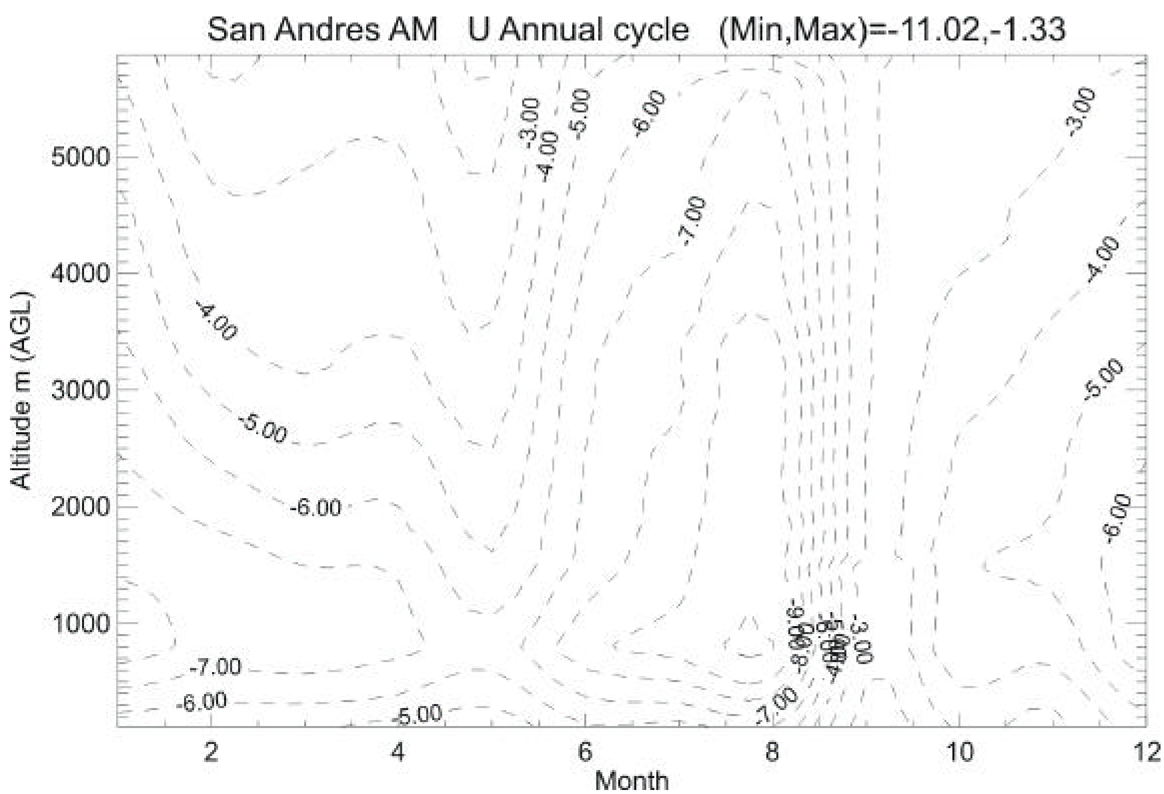

Figure 5.15. The mean annual cycle for the morning San Andres zonal winds. The average was performed using the same year available for Managua. San Andres wind soundings were obtained from the Forecast Systems Laboratory (FSL) web page http://raob.fsl.noaa.gov/ .

5.7 San Fernando de Apure and the trade wind flow across the Venezuelan Llanos

The annual cycle at San Fernando de Apure, in the Venezuelan llanos (a very flat region) shows a dry season low-level jet with maximum zonal winds of 15 m/s in February the jet is quite low - about 600 m agl (**Fig. 5.16**). The anomaly plot of the zonal wind annual cycle (**Fig. 5.17**) shows a relatively symmetric pattern, with a 5 m/s positive anomaly in August and a 5 m/s negative anomaly in February.

A comparison with the NCEP reanalyses (**Fig. 5.18**) shows that the low-level strong winds are not captured in the NCEP analyses. However, some similarities are present, including the June-July maximum in easterly winds near 4 km (~600mb) and the secondary east wind maximum in winter at low levels.

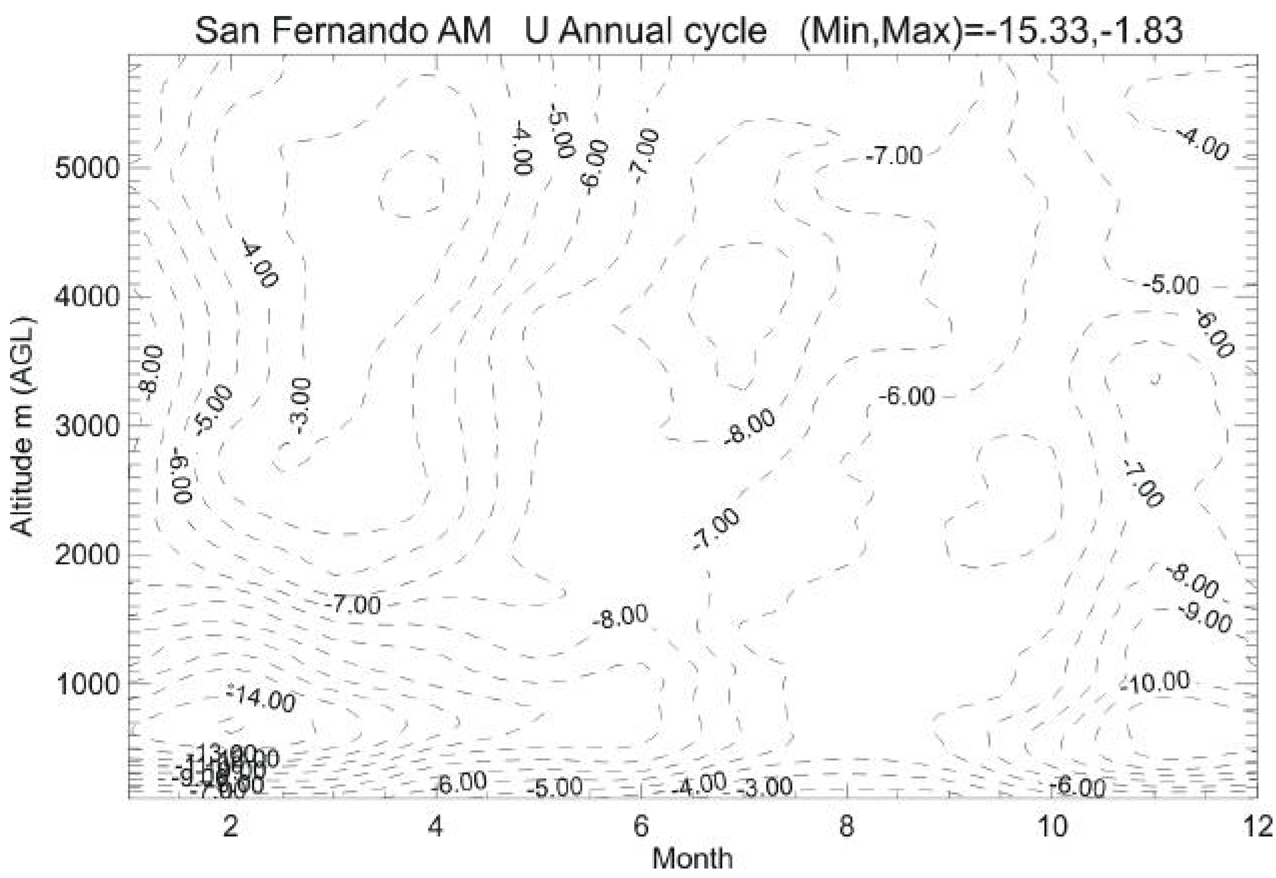

Figure 5.16. The same as figure 6.12 but at San Fernando, Venezuela.

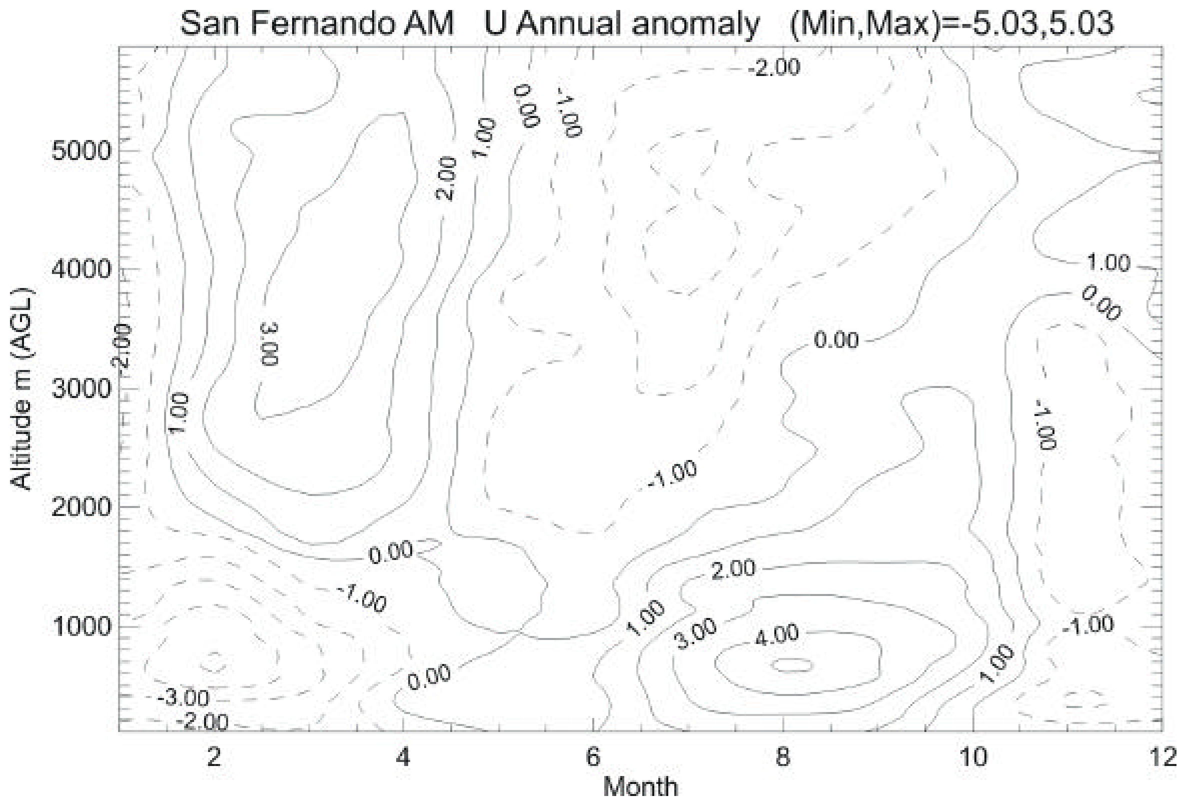

Figure 5.17. The same as figure 6.13 but at San Fernando, Venezuela.

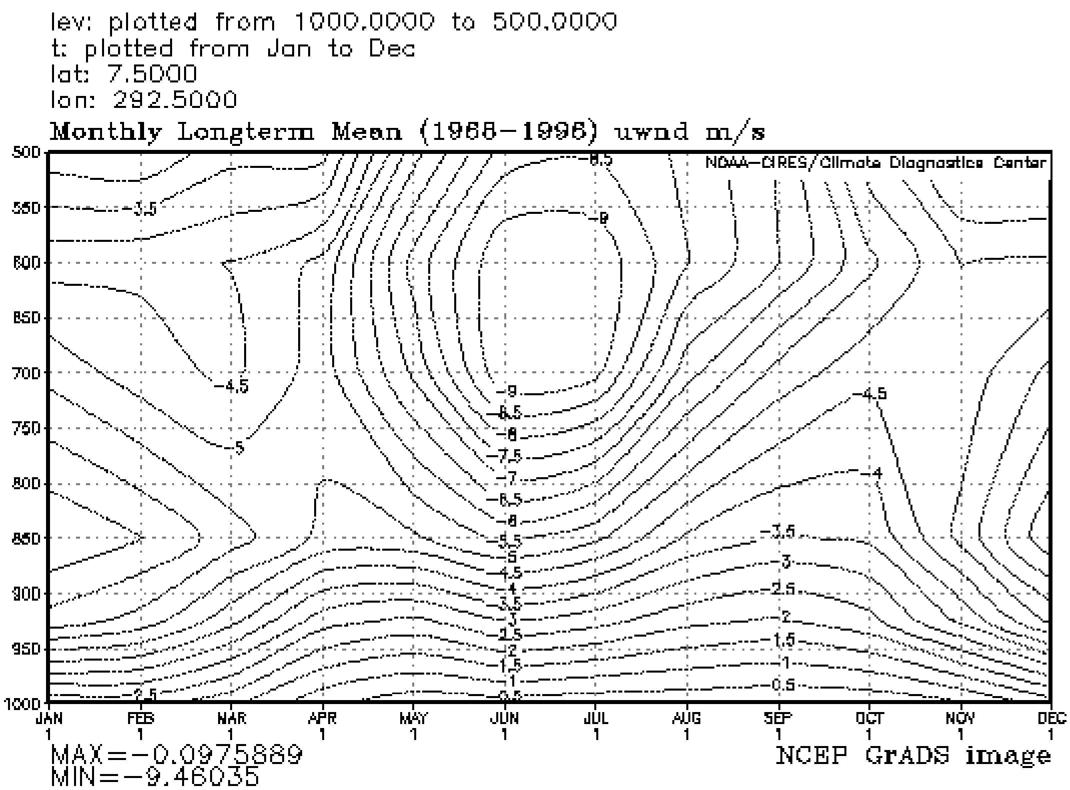

Figure 5.18. The same as figure 6.14 but at San Fernando, Venezuela.

6. Year 2004 activities

6.1 Quality-control of the historical PACS-SONET data

Much of the pilot balloon data from the SONET has not been fully quality controlled. The observations are often sent from the stations in near-real time without a careful screening of the data for errors. This is despite the fact that the procedure to calculate the winds actually requires passing through the quality-control stage where the data is graphically displayed. (One can shorten the "processing time" by hitting the return key instead of actually correcting erroneous data. There is not time for an individual at NSSL to correct all of the incoming data, and a significant fraction of the data appears in paper format only after months or when the hard copy original reports are sent to NSSL.

Although many of the stations have quite acceptable quality observations and many others have been checked over the years for errors we continue to find problems with different stations in different years. Even a few bad observations per month can affect the computation of a monthly mean wind, and this impacts studies of interannual variability with the data.

To systematically quality control all of the data we have hired several undergraduate students to carry out this task. During the summer of 2003 they processed all of the SALLJEX soundings and begun on the earlier SONET database. This activity will continue through the end of FY 2004, when we will be able to "release" a fully quality-controlled data base covering the period 1997-2003. Although late, these observations eventually will feed into future versions on NCEP reanalyses (and regional reanalyses), so the work must be completed for the observations to have a full impact in these analyses.

6.2 Expansion of the network

Given the difficulty in maintaining the current SONET network of about 20 stations, it might be hard to imagine expanding the current network. However, some sites are being considered for elimination, depending on either establishment of radiosonde sites at these, or nearby localities, or because of continuing difficulties in operating sites that are providing non-critical data. For example, we are likely to establish new sites in Peru where the National Weather Service (SENAMHI) has indicated that personnel and communications exist, as the sites are currently radiosonde sites established as part of a World Bank-sponsored activity. However, there are insufficient funds for daily radiosonde launches and the SENAMHI would like, as a minimum, to provide daily soundings as part of the SONET network. The Paraguayan SONET site at Mariscal Estigarribia and a Venezuelan site at Cd. Bolivar are being equipped to make radiosonde observations. Once reliable observations begin at these sites it may be possible to stop pilot balloon observations at these sites - but only after careful consideration to the sustainability of the radiosonde observations.

Most of the motivation for establishing additional observing sites for SONET is to take advantage of opportunities that have arise for better communications with the institutions that are responsible for sites that would be especially beneficial for climate monitoring. Many factors determine a site's value for long-term monitoring. The feasibility of operating a site over many years (potentially) requires a stable institution and interest in the observations at the local level. But physical factors are also crucial, such as the frequency of low clouds or the proximity to the local effects of topography or land-water interfaces that might induce large diurnal wind oscillations. If the site's observations are perturbed by very local conditions it will be difficult to relate the observations to larger-scale analysis products, such as the NCEP reanalyses, which cannot resolve very local effects. PACS-SONET continues to seek locations that not only satisfy logistical considerations, but also improve the networks spatial coverage and provide "higher quality" observations. A "high quality" observing site would be one that would show little effect of topography and a small diurnal cycle. Usually these are hard to find, as even sites over flat land and far from nearby mountains will show a diurnal cycle in the wind profile due to boundary changes due to daytime heating and nighttime cooling. The best sites are small, flat islands that should have neither significant diurnal cycles or show the effect of local topography. Observations from these sites should be most comparable to larger-scale analysis output.

Four sites have been identified as being potentially of particularly high quality. These are Malpelo and San Felix Islands in the Pacific and Serranilla Bank and Aves Island in the Caribbean Sea (**Fig. 6.1**.) All of these sites are inhabited constantly by military personnel from either Colombia, Chile, or Venezuela. Serranilla is a flat sand island of very small size, and without any island-induced disturbance of the airflow (unlike most Caribbean islands). Malpelo is a large rock (**Fig. 6.2**), with a maximum altitude of about 300 m, but of small horizontal extent (~ 2 km long). Malpelo is situated in a critical data void west of Colombia, and has been the site of previous (but unsuccessful) efforts to maintain surface meteorological stations and tide gauges.

A slightly different justification exists for establishing observations on Aves Island, belonging to Venezuela. This well-staffed facility is ideal, being a flat (less than 2 m high) sand island less than 1 km long and 100m wide (**Fig. 6.3**). It is about 200 km downwind of the largest (~40km wide) and highest (~1500m peak) island in the Lesser Antilles, Guadeloupe (**Fig. 6.1**), which is the site of a radiosonde station with a long historical record. We will seek to make trial observations on Aves Island with the aim of comparing the wind profiles obtained from Aves with other Antillean radiosonde sites that might be affected by both the diurnal cycle and the effect of topography induced by the larger islands.

Finally, we have begun the process of communicating with the Chilean Navy regarding a proposed installation of a pilot balloon site on San Felix Island, which has been passed through the US Embassy in Chile. San Felix is a small, relatively flat island (**Fig. 6.4**) that is ideally suited for measuring conditions in support of possible VEPIC-type activities in the future. Our longer term goals are to actually operate a powersonde system from the island, since the island maintains a large paved runway, and there are no air-traffic concerns.

Initially, we plan to seek approval for trial observations on all of these islands to evaluate the feasibility of more permanent observations being made. Since personnel rotations are frequent on these islands, it may be feasible to only make one month of observations initially, unless training procedures are established adequately for new crews. In any case, surface observations, which will be part of all of these sites, should be easier to maintain for longer durations, and these observations will be valuable (and unique) in themselves.

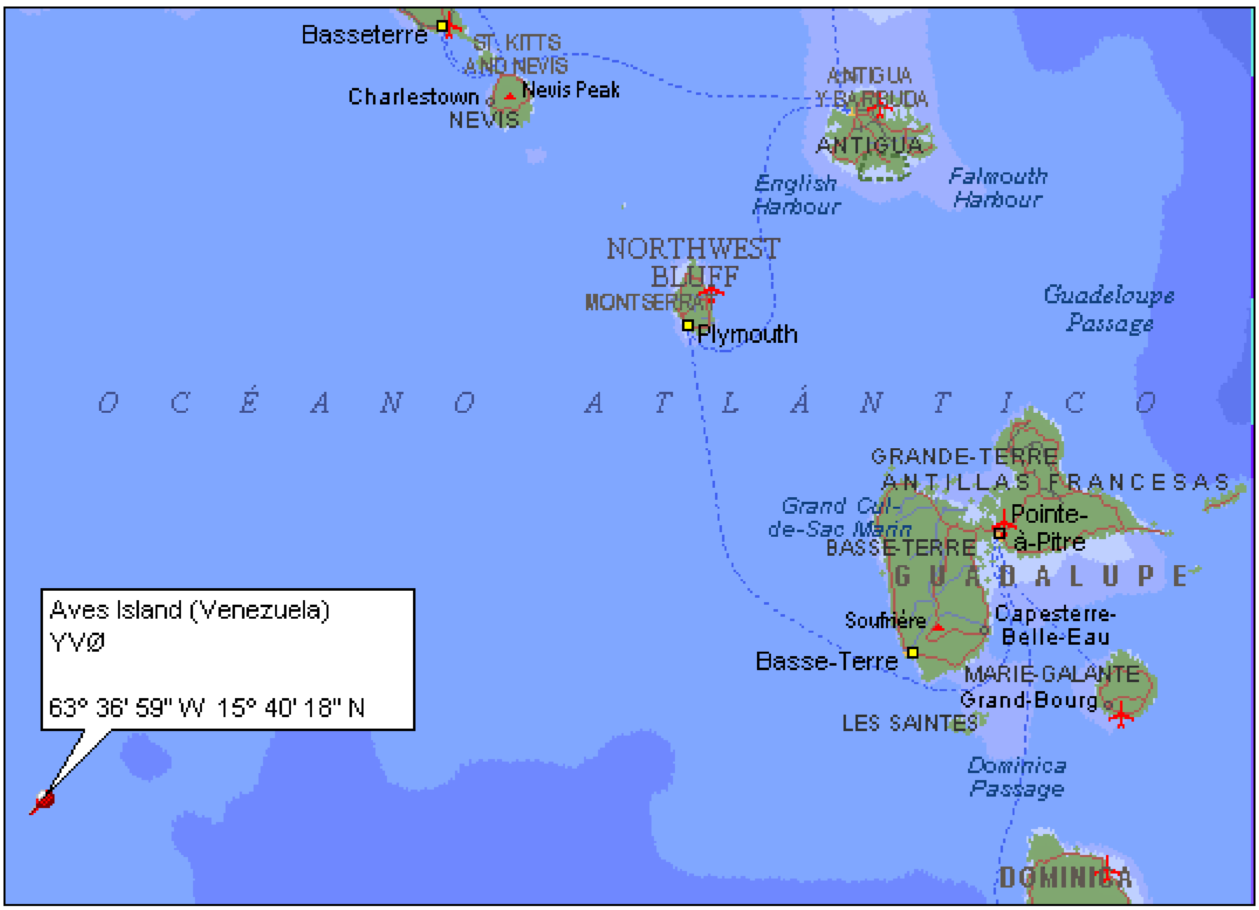

Figure 6.1. Location of Aves Island

Figure 6.2. Malpelo Island, about 300m high. The inhabited part is about one-third of the way up, and in the middle of the island.

Figure 6.3. Approaching Aves Island, the inhabited platform and the island are visible. The island is only about 100m wide.

Figure 6.4. San Felix Island, Chile. An airfield almost 2000 m long bisects the island (not easily visible in this photo).

6.3 Implementation of radiosonde sites as part of PACS-SONET

Implementing a routine, if not daily, radiosonde launch at San Cristobal, Ecuador is a goal of the radiosonde component of SONET. This would be carried out with older RS-80 Vaisala omegasondes that can be very inexpensively obtained. Other possibilities exist, including evaluating the quality of these sensors by interspersing launchings of the omegasondes with launches of newer RS-80 radiosondes. This was suggested by the Peruvian representatives to the Paraguayan workshop.

The challenge in implementing routine radiosonde observation in the Galapagos is in ensuring that the institution that maintains the San Cristobal site in the Galapagos Islands (INAMHI) responsibly undertakes the activity. SONET has had mixed results with this institution in the past and a visit to evaluate their responsibility with a new director will be undertaken early in 2004. A site visit to the island may also be carried out, or this may be done in coordination with NOAA Aeronomy lab personnel who also periodically visit the island.

Another possibility involves the establishment of recoverable radiosonde (either glidersonde or powersonde) technology at one or more site in the region, but this option depends heavily on development work that has not been concluded.

6.4 NAME modifications

During the coming year the planned North American Monsoon Experiment (NAME) may put a strain on the operations of the SONET, both in terms of personnel and equipment. One component proposed for NAME is a network of pilot balloon stations; if this is approved then as many as 18 pilot balloon sites will be temporarily established in Mexico during the summer of 2004. This will strain the available resources - there are currently not 18 theodolites available as part of SONET. In addition, personnel currently overseeing SONET activities will be partly detailed to NAME activities.

6.5 Educational Activities

Despite the expressed interest in the Paraguayan workshop in educational activities and the need for these to continue, it appears infeasible within the current budget to support major courses every year. During the coming year we intend to carry out two special SONET-related trips, to strengthen the SONET activities in these countries and provide information to a much larger audience that can previous courses. The first of these trips will be to Central America, and include multi-day visits to Nicaragua, Costa Rica, El Salvador and Honduras. The latter 3 countries are not currently part of SONET but either were in the past (Costa Rica), have expressed interest (El Salvador), or control valuable sites for SONET observations (Honduras). During our visits we intend to communicate with institutions other than the NMS's; the educational institutions and other ministries that may also have interest in climate-related studies. A common weak link is the lack of communication between research carried out in national universities and the NMS's. We are preparing a 3-day course that will be given in each country to a broad audience.

The second planned trip will be to Venezuela, Colombia, and Ecuador. Although Venezuela has carried out SONET observations reliably, modernization activities now underway will require some modifications to the SONET network. These modifications, plus the possibility of observations from Aves Island, will require travel to Venezuela early in FY2004. This travel will be followed by travel to Colombia to (hopefully) arrange observations on Isla Malpelo and Serranilla Bank with Colombian Navy personnel, and explain our activities to the IDEAM staff in Bogota. The final component of this travel will be to Ecuador, where we have to resolve the problems with the Galapagos pilot balloon site with the Director of INAMHI. Continuing inefficiencies at this site require a re-evaluation of the site, especially if radiosonde observations are to be considered for the island.

While in Quito, we intend to offer our 3-day short course to not only INAMHI staff, but also personnel from local universities and other institutions. In our view INAMHI is perhaps in greatest need of such educational materials.

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