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1. INTRODUCTION

The North American Monsoon Experiment (NAME) was held over southwestern North America and northwestern Mexico during the summer of 2004. The overall long-term goal of the activity was to improve the forecasts of rainfall over the region by achieving a better understanding the components of the North American Monsoon System (NAMS) and their interactions. As part of the field campaign, a special network of observations was designed to evaluate diurnal and seasonal changes in the sea-land breeze circulation, boundary laver depth and evolution, vegetation cover change, sea surface temperature and rainfall that occur in the central part of the Gulf of California throughout the warm season. The aim of this particular network was to explain the factors involved in the migration of the rainfall from the slopes of the Sierra Madre Mountains towards the coast as the monsoon progresses. This talk will provide an overview of the observational program, including the special sounding and surface measurements that were made. A preliminary assessment of the data set and some implications will also be presented. Further information http://www.nssl.noaa.gov/projects/ can be found at: pacs/web/html/NAME/ENGLISH/index.html

One of the foci of the NAME was to improve the understanding of the precipitation around the Gulf of California. Previous observations in this region have shown that during the onset of the monsoon the maximum rainfall occurs close to the western slopes of the Sierra Madre Occidental Mountains. As the season progresses, the rainfall maximum moves towards the west reaching the coast and the Gulf of California in late August. Figure 1 shows the seasonal distribution of precipitation for two sets of four stations, one located near the zone of maximum rainfall (inland at low elevations) in southern Sonora (near 27°N) and the other located near the coast in the same region. Note that inland the maximum rainfall occurs in July and in the coast occurs in August.



Figure 1. Monthly precipitation collected by two sets of four stations, one located inland from the coast of southern Sonora (black) and the other one located near the coast (gray).



Figure 2. Monthly mean maximum temperatures for an inland site (solid line with circles), for a coastal site (dashed line with circles) and monthly mean Gulf of California SST (dashed line with triangles). Notice that the SST is closer to the maximum mean land temperatures after July.

The westward migration of the rainfall maximum may be due to seasonal changes in the land-sea temperature contrast as well as seasonal changes in the thermodynamic structure of the lower atmosphere induced by the monsoon itself. Figure 2 shows the seasonal evolution of the land-sea temperature contrast by displaying the evolution of the monthly sea surface temperature (dashed line with triangles), the monthly

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maximum temperature at the coast (dashed line with circles) and the monthly maximum temperature inland (solid line with circles). During the pre-monsoon months (May and June) the difference between the maximum temperature at the coast and at the interior territories is the largest (~4°C). The difference between the Gulf of California's SST and the maximum temperature at the coast is also large (~9°C). As the rains develop, the surface temperature gradient between the coast and the interior decreases disappearing in the month of August. Furthermore, the Gulf of California reaches its maximum temperatures late in the summer, therefore reducing the sea-land temperature contrast to a minimum (~4°C) in the months of August and September.



3.b. Early Monsoon - Mid July



3.c. Late Monsoon - Late August



Figure 3. Scheme showing the seasonal evolution of the North American Monsoon (NAME) and the interactions between surface temperature, vegetation cover, sea-land breeze circulation, boundary layer depth and rainfall.

These changes in the surface temperature gradient may modulate the intensity and distribution of the sealand breeze circulation. During the pre-monsoon, the breezes are expected to be the strongest and to penetrate the furthest inland associated to the strongest sea-land temperature contrasts (Figure 3.a). As the season progresses the surface temperature gradients weaken due to a rise on the sea surface temperature and a decrease on the maximum temperature at the interior associated to a change in the surface radiative balance. This change is caused by an increase in the soil moisture and vegetation cover due to the monsoon rainfall. The response of the breezes (Figure 3.b) is to weaken allowing the region of low-level convergence to migrate towards the west. By the late monsoon (Figure 3.c), the diurnal breezes weaken even more in response to a very weak surface temperature gradient allowing the rains to form over the coast and even over the Gulf of California.

We further hypothesize that a rapid increase in foliage after the start of the rains, together with surface wetness, has a feedback on the atmospheric radiation balance in the surface layer, which in turn affects the maximum temperature of the inland terrain. This reduces the land-ocean temperature contrast during the afternoon hours and reduces the sea breeze forcing of afternoon convective storms.

2. SPECIAL OBSERVATION NETWORK

The station network utilized for this study consisted on a flux tower, a network of 300 simple raingauges, 8 pilot balloon stations and an Operations Center located in Tesopaco, Sonora. The latter included frequent radiosonde and tetheredsonde observations, cloud and vegetation photography and surface observations carried out during four Intensive Observation Periods (IOPs). The network started the operations between late May and early June and ceased the operations in September 30 2004. Figure 4 shows the distribution of the stations of the special observation network. The setup began on May 19th with the pilot balloon site of Empalme and finalized on July 10th with the flux tower located at La Estrella, Rosario, Sonora.

Extensive Operation Period (EOP)

The extensive observation period (EOP), which was held between late May and September 30 2004, is shown in table 1. Some components such as the flux tower and the raingauge network remained collecting data after the EOP came to an end. They are expected to operate at least until the rainy season of the next year (2006).

A more detailed description of the stations and networks installed for the EOP follows.

1. Flux Tower

A flux tower was setup for micrometeorological studies near La Estrella and Tesopaco in Southern Sonora. The main objective of the tower is to evaluate the energy and moisture fluxes, before, during and after the appearance of the foliage in the dry forest of southern Sonora. The tower has 18 m. on the vertical and is surrounded by forest.

	Flux Tower	Raingauge Network	Pillot balloon network	Tesopaco Radiosonde, tetheredsonde, pilot balloon
May-06				
May-13				
May-20		Installation	Installation	Installation
May-27				Regular Operation
Jun-03				IOP 1
Jun-10		Regular	Regular	Degular Operation
Jun-17		Operation	Operation	
Jun-24				IOP 2
Jul-01				Degular Operation
Jul-08	Installation			Regular Operation
Jul-15	Regular			
Jul-22	Operation			IOP 3
Jul-29				Regular Operation
Aug-05				1054
Sep-30				10P4
	Operations continued for 1 more vear	Operations continued for 1 more year	Cease of observations	Cease of observations

Table 1. Schedule of the extensive observation period (EOP).

2. Sounding Network

Seven (7) pilot balloon stations were temporarily setup near the central region of the Gulf of California to build a network of 8 upper air sites, including the PACS-SONET (http://www.nssl.noaa.gov/projects/pacs) station at Topolobampo. Even though the installation campaign started in late May, the entire special sounding network started to operate in late June and finished in September 30 2004. The purpose of this network was to better describe the circulation characteristics associated with the diurnal cycle, describe the characteristics and seasonal evolution of the sea-land breeze that occurs on the east side of the gulf, and finally to complement the observations of the Special Sounding Network installed in western and northern Mexico for the NAME. The observations were made twice a day, everyday. The morning observation was made at 14 UTC and in the afternoon at 23 UTC.

At Empalme, a Mexican Meteorological Weather Service radiosonde station, the observations were carried out in addition to the routinary radiosonde observations. In Topolobampo, the Oceanographic Station of the Navy Secretariat continued making observations twice a day, as in the last four years. The Huatabampo site was installed in the Instituto Tecnologico de Hutabampo (ITHUA) and the observations were carried out twice a day with the exceptions of the IOPs. During these periods the observations were collected more frequently to complement the observations collected at Tesopaco. The inland locations were Tesopaco and Choix. Both sites have a relatively low altitude and are thought to be useful to describe the intensity of afternoon breezes that propagate towards mountains. Both locations are surrounded by dry forest that quickly develops leaves after the first intense monsoon rain events.

Two additional pilot balloon sites were located in Loreto and Santa Rosalia, in Baja California. The purpose of these sites was to complement the estimations of convergence and divergence to diagnose the characteristics of the vertical motions over the Gulf of California.

3. Raingauge Network

The simple raingauge network was installed to describe the space and time evolution of rainfall by recording daily precipitation. The installation campaign started in late May, before the beginning of rains. About 250 raingauges were distributed among 9 municipalities in southern Sonora and northern Sinaloa. Some raingauges were distributed in parts of Baja California also, near Loreto and Santa Rosalia. Due to time constrains, the raingauges were separated into groups and distributed along the municipalities. A short presentation and training course was provided. In addition, each raingauge included a form designed to collect the data until October 31 2004.

Intensive Observations Periods (IOP)

Four intensive observation periods were carried out during the NAME. Two sites modified the schedule of observations increasing the frequency of pilot balloons: Tesopaco and Huatabampo. In Tesopaco the IOP also included frequent radiosonde and tethersonde soundings with a focus on describing the diurnal and seasonal evolution of the boundary layer. The evolution of the storms near the Sierra Madre Occidental was captured through cloud photography. Furthermore, 17 points along the forest were chosen to monitor the evolution of the foliage by photography as well.

The IOPs started on June 3rd and ended by September 30th organized in 4 different periods: IOP 1 from 3 June to 11 June; IOP 2 from 29 June to 3 July; IOP3 from 14 July to 27 July; and the IOP4 from 5 August to 30 September. The most intensive observations were carried out during the 3 first IOPs.

1. Radiosonde and tetheredsonde observations

The intensive observations include one or two radiosondes per day, continued tetheredsonde soundings from 13 UTC to 20 UTC and hourly pilot balloon observations from 13 to 01 UTC. The radiosondes reached about 200 or 250 mb; the tetheredsonde soundings reached about 850 mb in the first two IOPs and about 700-750 during the last ones; the pilot balloons reached about 940 to 200 mb depending on the cloudiness, wind and position of the



collection of long soundings in most of the cases.



Figure 4. Special Observations Network.

2. Additional observations at Tesopaco

Hourly cloud pictures were taken from 13 UTC to 20 UTC; the vegetation pictures were taken along 17 different points between La Estrella and Tesopaco every 4 days before the rains and every 2 days after they started; the surface observations at Tesopaco were collected every 30 minutes from 13 UTC to 20 UTC.

CURRENT STATUS OF THE STUDY

A large part of the data set is still being collected and compiled to further organize it and expose it to quality control routines. All the information gathered during the IOPs is being organized. The pilot balloon dataset is being organized and processed as well. The data that may take the longest to collect and process is daily rainfall data since the number of raingauges is large and the quality control procedures required for such data set may be complex.

Even though most of the data is currently unavailable in a clean and organized fashion, some preliminary

analyses suggest that some of the hypotheses posed may be on the right track. Some of the atmospheric soundings collected at Tesopaco (Figures 5, 6 and 7) suggest that the boundary layer becomes shallower as the rainy season progresses. During IOP #1 held during the pre monsoon the boundary layer depth at 22 UTC (4 pm local time) oscillated between 800 and 710 mb (figure 5). By mid July, during the early stages of the monsoon, the boundary layer depth oscillated between 850 and 770 mb, about 50 to 60 mb shallower than the depth observed before the monsoon (figure 6). During the late stages of the monsoon (early September) the boundary layer depth oscillated between 890 and 830 mb, about 40 to 60 mb shallower than the one observed during the early stages of the monsoon (figure 7).

Figures 5, 6 and 7 also reflect the seasonal variation of the temperature near the surface. During the pre monsoon the temperatures near the surface oscillated between 35 and 40°C. During the early monsoon they oscillated between 29 and 34°C and between 30 and 36°C during the late monsoon.



Figure 5. Temperature and dewpoint soundings collected in Tesopaco at 22 UTC during selected days of the IOP #1.



Figure 6. Temperature and dewpoint soundings collected in Tesopaco at 22 UTC during selected days of the IOP #3.



Figure 7. Temperature and dewpoint soundings collected in Tesopaco at 22 UTC during selected days of the IOP #4.