NAME Tier 1: Radar – Profiling – Sounding Network

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Scientific rationale

The principal rationale for a dense network of soundings, profilers and radars in Tier 1, together with rain gauges, is to describe and understand the diurnal cycle of precipitation and the structure of precipitation in the core region of the NAMS and to better understand regimes associated with intra-seasonal variability, including the influences of surges, jets, surface fluxes and topographic blocking.

Objectives (to which radars, soundings, profilers, surface flux obs will contribute)

- Observe and describe statistically the daily evolution of “ordinary” convective rainfall over the high Sierra Madre Occidental, the western and eastern slopes, the Gulf of California coastal plain, and the southern Gulf region.

- Clarify the relationship of convection on east and west slopes of the Sierra Madre Occidental and water vapor transport from the Gulf of Mexico and the Gulf of California.

- Observe and describe statistically the location and amplitude of “organized” mesoscale rainfall systems within the diurnal cycle.

- Observe and diagnose the principal mechanisms that force or maintain mesoscale rainfall systems so that the effects of these may be adequately represented in models (e.g. convectively-generated cold pools, sea and land breeze fronts, microphysics, other diurnally-varying and/or topographically-influenced aspects).

- Assist in the identification of local properties and processes associated with variability in the precipitation (e.g. anomalous surface latent or sensible heat fluxes, quasi-permanent convergence zones)

- Observe the development and propagation of southerly surges and associated low-level jets in the Gulf of California in the broader regional context of tropical easterly waves and mid-latitude westerly trough passages.

- Clarify the relationship of southerly surges/jets to the forcing, organization and northward propagation of convectively-generated precipitation.

Instrumentation and Practical design constraints

The plan is to maximize use of observing systems currently operated by the SMN and to augment these with research systems currently maintained by U.S. agencies. There are five SMN sounding sites in Tier 1 – Obregon, Mazatlan, Torreon, Chihuahua, and La Paz. There are four 5 cm Doppler radars in Tier 1 – Obregon, Gusave, Cabo San Lucas, and Palmito. The sounding sites are presumed to be fully functional, so experimental design constraints mainly concern the frequency and scheduling of soundings and the provision of expendables as may be required. All of the radars are operational, however, none currently meet standards for systematic recording of calibrated 3-D data suitable for research.

Several types of sites are planned:

UHF wind profilers (with Radio-Acoustic Sounding System (RASS) capabilities)
Virtual Integrated Sounding Systems, VISS (co-located SMN sounding + UHF profiler)
NCAR Integrated Sounding Systems, ISS, (UHF profiler + RASS + rawinsonde)
SMN 5 cm Doppler radars (4)
10cm Doppler-polarimetric radar (NASA N-POL)
The Ron Brown shipboard platform (VISS, 5 cm Doppler radar, surface fluxes, etc.)
Additional NOAA/ETL shipboard flux system (on a TBD Mexican research vessel)

UHF wind profilers provide continuous low-to-mid tropospheric wind profiles from approximately 150 m AGL through 2-6 km MSL, depending upon atmospheric conditions and instrument performance specifications (expected altitude performance in the NAME region is currently being investigated by W. Neff, ETL). RASS capabilities, in conjunction with all profilers, provide continual virtual temperature (air density) soundings in the lowest 1 – 2 km. A network of these systems describes the general wind field and some of its first order derivative properties; the depth of the planetary boundary layer and its thermal stratification; and the passage of breeze fronts, surges, cold pools, other convergence lines; and limited information about the position of rainfall systems in relation to the above. *A robust network of profilers is essential to Tier 1 diagnostic studies including core monsoon budget calculations and the initialization and validation of limited-area models.*

Integrated Sounding Systems (and **VISSs**) combine the capability of continuous wind profiles in the low-to-mid troposphere with full-tropospheric thermodynamic and wind soundings. These also include standard surface meteorological observations. The data provide critical information on environmental convective available potential energy (CAPE) and vertical shear of the horizontal wind, which together are the principal modulators of sustained mesoscale rainfall systems. These data also are central to estimation of latent heating/cooling profiles and the redistribution of momentum as a direct consequence of convective overturning. Co-location of sounding and profiling systems enhances the interpretation of both individual observing systems.

SMN 5cm Doppler Radars provide broad area characterization of rainfall patterns, their evolution throughout the diurnal cycle, and identification of organized mesoscale rainfall systems. Properly calibrated, these radars can provide estimates of rainfall amounts over portions of the coverage area, the uncertainty of which is dependent upon radar-range and the quality of the electromagnetic horizon. Operated in Doppler mode, it may be possible to detect the kinematic properties of breeze fronts, surges, and jets both in the absence of and in relation to areas of precipitation when such clear-air phenomena are located close to a radar. Together with rain gauges, the SMN 5cm radars will be an important tool for statistically describing the relative distribution of precipitation as a function of time in the diurnal cycle and regional scale flow regime.

NASA 10 cm Doppler-polarimetric radar (N-POL) will provide quantitative statistics on precipitation amount and distribution, condensate mass and distribution, and hydrometeor categorization as a function of the diurnal cycle within 100-150 km range of the radar. NPOL precipitation measurements also can be used to "tune" the surrounding Z-R estimates of the SMN and Ron Brown radars. Doppler measurements will detect breeze front positions, surges and other convergent lines under both clear and cloudy air conditions generally within and sometimes beyond 50 km range. Such measurements will likely prove critical to understanding and describing the complete diurnal cycle…especially nocturnal phases of precipitation system regeneration where solar heating is not a forcing mechanism. This knowledge is essential for improved model representations of precipitation variability over the diurnal cycle.

The Ron Brown platform offers a somewhat mobile and critically unique location for surface fluxes, soundings, profiling, 5 cm Doppler radar coverage at the mouth of the Gulf of California, while immersed in land breezes, surges, and the associated low-level jet. Initially incorporated as an augmentation to the ground-based network, the Brown has become central to operations in the more focused New Tier 1 configuration.

Additional Flux System to quantify interfacial fluxes in the GoC northward from the Ron Brown position.

The New Tier 1 Proposal

A map of the Tier 1 region and the proposed locations of instrumentation is shown in Figure 1. As in previous proposals, the Mexican observational infrastructure is utilized to the maximum extent feasible, including four, 5 cm Doppler radars and five rawinsonde stations.

As in previous proposals, a fully instrumented Ron Brown is nominally stationed near the mouth of the Gulf of California (GoC) to directly observe the interaction among various processes in the lower GoC region. The Brown is an integral part of the radar - sounding - profiling - surface flux - budget network, strategically located to increase the value of all observing systems.

Tier 1 ground-based research radars have been reduced in number from two to a critical minimum of one, based on priorities, funding expectations, and reduced needs for radar coverage given the more compact geographical region represented by New Tier 1. Several other observing systems (including the Ron Brown Doppler radar) are now clustered near the mouth of the GoC and in the southern Gulf region more generally.

Concentration of observations in the southern Gulf region is based on the climatology of rainfall, the apparent geographical origin of surge events, and diurnal tendency in this region for rainfall to propagate westward, down the SMO slopes, onto the coastal plain and into the GoC itself. More specifically, the scientific rationale for focusing on this region is solidly rooted in the findings of previous observational and modeling studies (dating from the early 1970's to the 2000's) reported in the literature and summarized below:

1. It is important to note that *any* climatology of southwestern Monsoon rainfall represents a sum over many episodic mesoscale rainfall events occurring over a given warm season. This embedded intra-seasonal variability, or alternatively "bursts" and "breaks" in the monsoon, has been previously associated with favorable synoptic conditions convolved with the presence or absence of Gulf surge events. Gaining an increased understanding and better simulation of this "intra-seasonal variability" is listed as a *primary objective* in the NAME Science and Implementation Plan.

2. The thermodynamic and kinematic forcing for Gulf surges and GoC Low Level Jet (GCLLJ) phenomena may well originate with convection over the SMO and/or convergence and convection located in or southward of the GoC mouth.

3. Synoptic forcing for monsoon bursts likely involves the phasing/passage of tropical easterly waves, depressions or tropical cyclones over central and southern Mexico, which generally increase in intensity south of 25°N.

4. Though rainfall climatologies indicate less rainfall over the GoC than the adjacent SMO, it is known that periodic MCS activity in the southern Gulf of California is associated with convection originally located over the SMO (e.g. see Figure 2). This coupling may result in the driving of a major monsoon burst (and associated GCLLJ) in the southwestern U.S.

5. A set of continuous, high resolution and reliable deep tropospheric precipitation, wind and thermodynamic measurements utilizing radar, profiler and sounding observations over the southern one half of the SMO and GoC are critical (cf., Summary of NAME modeling session from VAMOS meeting in San Jose) to the proper initialization and validation of both regional and cloud resolving numerical models. The co-location of RAOBs and profilers will minimize uncertainties in the significance of data from each individual observing system and increase the quantitative applications of both. Observations over the GoC channel, including SST and interfacial fluxes, are also critically important.

The above statement are supported by a series of papers (list not inclusive) by Hales (1972), Brenner et al. (1974; MWR), Douglas et al. (1995; J. Climate), Stensrud et al (1997; MWR), Adams and Comrie (review paper, BAMS, 1997); Fuller and Stensrud (2000; MWR), Berg et al. (2000; GRL); Anderson et al. (2001; Precipitation Prediction, Extreme Events and

Mitigation Workshop, AMS Annual Meeting, 2001) and the NAME Science and Implementation Plan (2001; Higgins et al.).

To accomplish NAME Tier-1 scientific objectives, an increased emphasis has been placed on ship, buoy, and/or island-based observations recognizing the need to have a continuous time series over the GoC to detect and quantify surge events and the related jets; to diagnose the specific role of breezes in forcing and/or maintaining organized rainfall episodes; and to sample interfacial fluxes in quiescent and disturbed conditions. Owing to the low predictability of disturbances and their rapid evolution, high temporal resolution in a long time series of the PBL over and near the GoC is required. Vertically pointing UHF wind profilers and ISS are proposed at various locations in the Tier 1 region (with emphasis in the lower GoC) to examine the spatial and temporal variability of surge phenomena across the GoC and to quantify the effects of terrain induced channeling on surge evolution.

Continuity of precipitation and surge events is maintained northward to the US border through the strategic location of a sounding-profiling system in the northern GoC region and the use of satellite imagery to bridge the gap between the core of Tier 1 and various observational assets in the U.S.

Budget studies in the presence of deep convection will be facilitated in the (roughly) hexagonal region surrounding the southern Gulf and the adjacent SMO mountains, including a nested region surrounding the southern GoC. In these regions, full tropospheric soundings at a minumum frequency of six per day are required with co-located UHF wind profiler and RASS virtual temperature measurements. The high frequency of soundings is essential to fully resolve the diurnal cycle. It will be possible to conduct episodic operations in IOPs, thereby reducing soundings to less than six per day for up to half of the period. This will be based on forecasts for strong suppression, though we acknowledge there is little if any skill in predicting convection. Of order 10 convectively active periods need to be captured at full resolution over the six to eight week time series to statistically characterize the intensity and evolution of convection in the Tier 1 region.

Action Plan

0. A preliminary survey was completed at each of four SMN 5 cm Doppler radars with the assistance of staff from the Commission Nacional Del Agua. These radars are located at Obregon, Gusave, Los Cabos, and Palmito. The radar at Obregon is of a more modern design and has somewhat greater potential for research application, including a polarimetric capability that is not used operationally. All of the radars are at sites with blockage from mountains and/or buildings and some have extensive ground clutter.

It was determined that the SMN radars are operational and have the potential to provide useful data for NAME provided they are: 1) equipped and trained to be regularly calibrated; 2) equipped to record native resolution reflectivity and Doppler velocity; 3) scanned in a manner to provide three-dimensional structure. To achieve a useful research status will require purchase of calibration test equipment; establishment of calibration procedures; and training to implement these procedures. Installation of digital data recording devices and related software on reliable and easily transferable media is essential. Furthermore, it is necessary to negotiate with the SMN modification of operating parameters to serve both the standard operational functions as well as research data acquisition.

0. The Ron Brown reservation, with all applicable instrumentation, has been requested by Chris Fairall, Chief Scientist and several co-investigators from CSU, UCSB, and UNAM. The request is for a 45 day minimum, 55 days desired, June to September 2004.

1. Specify hardware and software improvements to the SMA radars, refine estimates of these costs, and identify providers of any existing hardware, qualified services and funds for implementation (by late 2002). It is recommended that the Atmospheric Technology Division of NCAR assume these responsibilities subject to identification of funding.

2. Conduct a detailed site survey and logistical preparation for deployment of UHF profilers, ISSs, and the NASA N-POL radar following decisions on the combined Tier 1 network design. Such surveys are usually conducted by owner-operators of equipment at NOAA/ETL/AL, NASA, NCAR/ATD, and UCAR/JOSS (by late 2002).

3. Perform SMA radar modifications and training (spring 2003).

4. Install and conduct limited operation of 3 UHF profilers (June-July 2003) and routine operations of modified SMA radars (June- Sept 2003).

5. Evaluation of UHF and SMA radar data, (Fall-winter, 2003-4)

6. Installation of ISSs, UHF profilers for VISS sites, and 10 cm radars (spring 2004)

7. Conduct a six-to-eight week operation (July-August) of ISSs and VISS sites (sounding frequency @ six per day during IOPs, twice per day otherwise, average 4/day)

8. Conduct a six-to-eight week 24/7 operation (July - August) with NASA N-POL radar for previously-stated objectives that are unique to this system and fully coordinated with ISS/VISS IOPs.

9. Conduct QC and archival of sounding, profiling and radar data continually throughout and immediately following operational periods (UCAR/JOSS, NASA, NCAR/ATD, NOAA/AL/ETL, as appropriate).

Data dissemination plan

Summary GIF image products from radars, profilers, soundings in near real time. Real-time communication of radar images (metadata) is needed as a means to monitor and evaluate operations and to assist in the deployment of research aircraft operations and event-dependent soundings. Standard Archive data access from UCAR/JOSS, NCAR/ATD and NASA/GSFC, as appropriate.

Addendum Concerning Pibals, RPVs,

We are aware of alternative proposals that emphasize pibals and remotely piloted aircraft. We do not include several types of observations in the core Tier 1 sounding-profiling suite, including pibals and RPVs, because we consider these of lesser value and impact to key NAME objectives associated with Tier 1. This is not to say such observations are without value and perhaps of high value in relation to unrelated objectives.

Pibals are of limited utility compared to other devices employed in our plan and, specifically, are of very little utility for the direct calculation of budgets in presence of deep convection. Diagnostic budget calculations in the presence of convection require wind *and* thermodynamic soundings that are *fully* tropospheric in depth and *reliable* in cloudy sky conditions. Pibals satisfy none of these requirements. Furthermore, pibals cannot provide adequate information for location and kinematic properties of breezes and surges, their relationship to convection over the localized zones in which they appear at any given time. For this aspect of the diagnosis we require essentially continuous timeseries at representative locations (radars and profilers). Finally, given the other observing systems proposed, we see little improvement in further characterization of the diurnal cycle that could result from acquisition of pibal data in Tier 1.

We recognize the potential utility of radiosonde-type data from small, remotely-piloted (or autonomous) aircraft, provided such data could be obtained with high reliability at low cost and with quality assurance. We note that the so-called "Aerosonde" RPV is a slightly larger vehicle of this general type that has been tested and subsequently operated in similar environments, beginning with the MCTEX Experiment in 1995. Carbone et al. (2000) were the first PIs to use Aerosonde PBL data in publishable research based on that experiment. The Aerosonde is a well-capitalized effort led by highly talented and dedicated individuals and could be considered for a role in NAME Tier 1-2. However, despite sizeable engineering efforts over nearly one decade, the Aerosonde, so far, has proved more costly to operate than anticipated and has an uncertain reliability record. Therefore, even a relatively mature Aerosonde might fall short of that which is required in field campaigns of relatively short duration in air space otherwise controlled for commercial and general aviation purposes.

Based on our understanding of the status of the as yet informally-proposed RPVs in NAME, cost, performance, reliability and quality assurance standards are highly unlikely to be met in our opinion. Therefore, we have not considered the use of RPV platforms associated with Tier 1 objectives and we recommend that these not have the status of a "standard observation" in NAME.

We do encourage proposals for a manned, heavy-lift aircraft presence during a portion of the 2004 observing period, since the observations from a NOAA P-3 or other aircraft would be reliable, highly cost effective, and present some unique opportunities with respect to sampling rainfall and PBL circulations associated with surge events, among several other tractable objectives. We believe that Dr. Brad Smull of NOAA is both experienced in the

NAME region and well-qualified to integrate an airborne sampling plan into Tier 1 objectives.

We are uncertain about the utility of land-atmosphere surface flux measurements, mainly because of representativeness issues in highly varied and complex terrain. We seek to further evaluate the utility of such observations toward NAME Tier 1 objectives with experts in this field of observation and the modeling community.

References

Adams, D. K., and A. C. Comrie, 1997: The North American monsoon. *Bull. Amer. Meteorol. Soc*., **78**, 2197-2213.

Anderson, D. M., W. K. Berg, and J. J. Bates, 2001: Satellite observations of Pacific moisture surges associated with the North American monsoon. *Preprints, Precipitation Prediction: Extreme events and mitigation*, American Meteorological Society, 14-19 January, 2001, Albuquerque, New Mexico.

Berg, W. K., D. M. Anderson, and J. J. Bates, 2000: Satellite observations of a Pacific moisture surge associated with flooding in Las Vegas. *Geophys. Res. Lett*., **27**, 2553-2556.

Brenner, I. S, 1974: A surge of maritime tropical air- Gulf of California to the southwestern United States. *Mon. Wea. Rev*., **102**, 375-389.

Carbone, R. E. , J. W. Wilson, T. D. Keenan, J. M. Hacker, 2000: Tropical Island Convection in the Absence of Significant Topography. Part I: Lifecycle of Diurnally Forced Convection, *Mon. Wea. Rev*., **128**, 3459-3480.

Douglas, M. W., R. A. Maddox, K. Howard, and S. Reyes, 1993: The Mexican monsoon. *J. Climate*, **6**, 1665-1677.

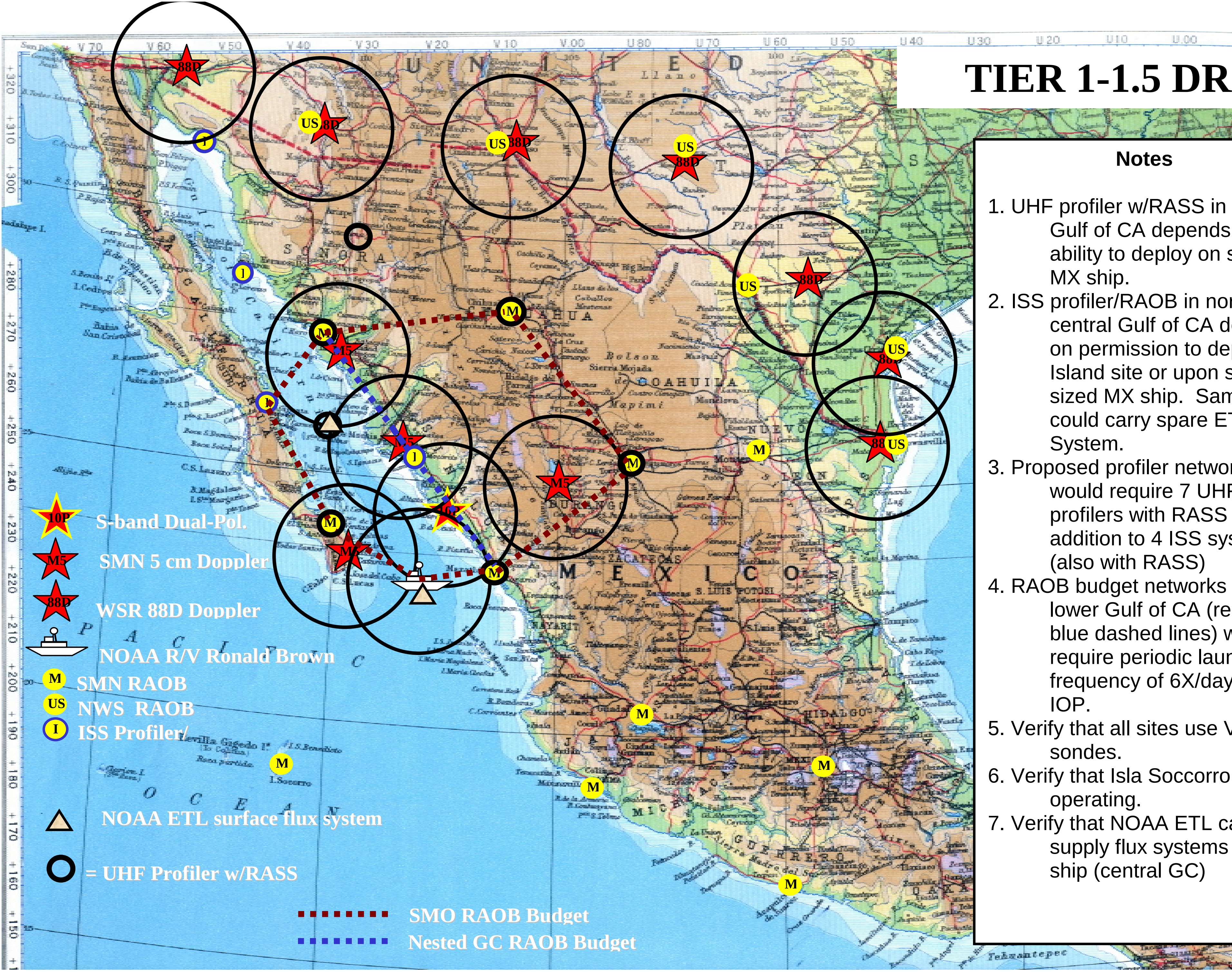
Fuller, R. D., and D. J. Stensrud, 2000: The relationship between tropical easterly waves and surges over the Gulf of California during the North American monsoon. *Mon. Wea. Rev*., **128**, 2983-2989.

Hales, J. E., Jr., 1972: Surges of maritime tropical air northward over the Gulf of California. *Mon. Wea. Rev*., **100**, 298-306.

Higgins, W., and coauthors, 2002: North American Monsoon Experiment (NAME): Science and implementation plan. Located on the internet at http://www.cpc.ncep.noaa.gov/products/precip/monsoon/NAME.html

Stensrud, D. J., R. L. Gall, and M. K. Nordquist, 1997: Surges over the Gulf of California during the Mexican monsoon. *Mon. Wea. Rev*., **125**, 417-437.

TIER 1-1.5 DRAFT



Notes

1. UHF profiler w/RASS in lower Gulf of CA depends on ability to deploy on suitable MX ship.
2. ISS profiler/RAOB in north central Gulf of CA depends on permission to deploy on Island site or upon suitably sized MX ship. Same ship could carry spare ETL Flux System.
3. Proposed profiler network would require 7 UHF profilers with RASS in addition to 4 ISS systems (also with RASS)
4. RAOB budget networks in lower Gulf of CA (red and blue dashed lines) will require periodic launch frequency of 6X/day during IOP.
5. Verify that all sites use Vaisala sondes.
6. Verify that Isla Soccorro will be operating.
7. Verify that NOAA ETL can supply flux systems to MX ship (central GC)

Figure 1. NAME Tier 1 instrumenation sites and surrounding Tier 2 operational infrastructure.

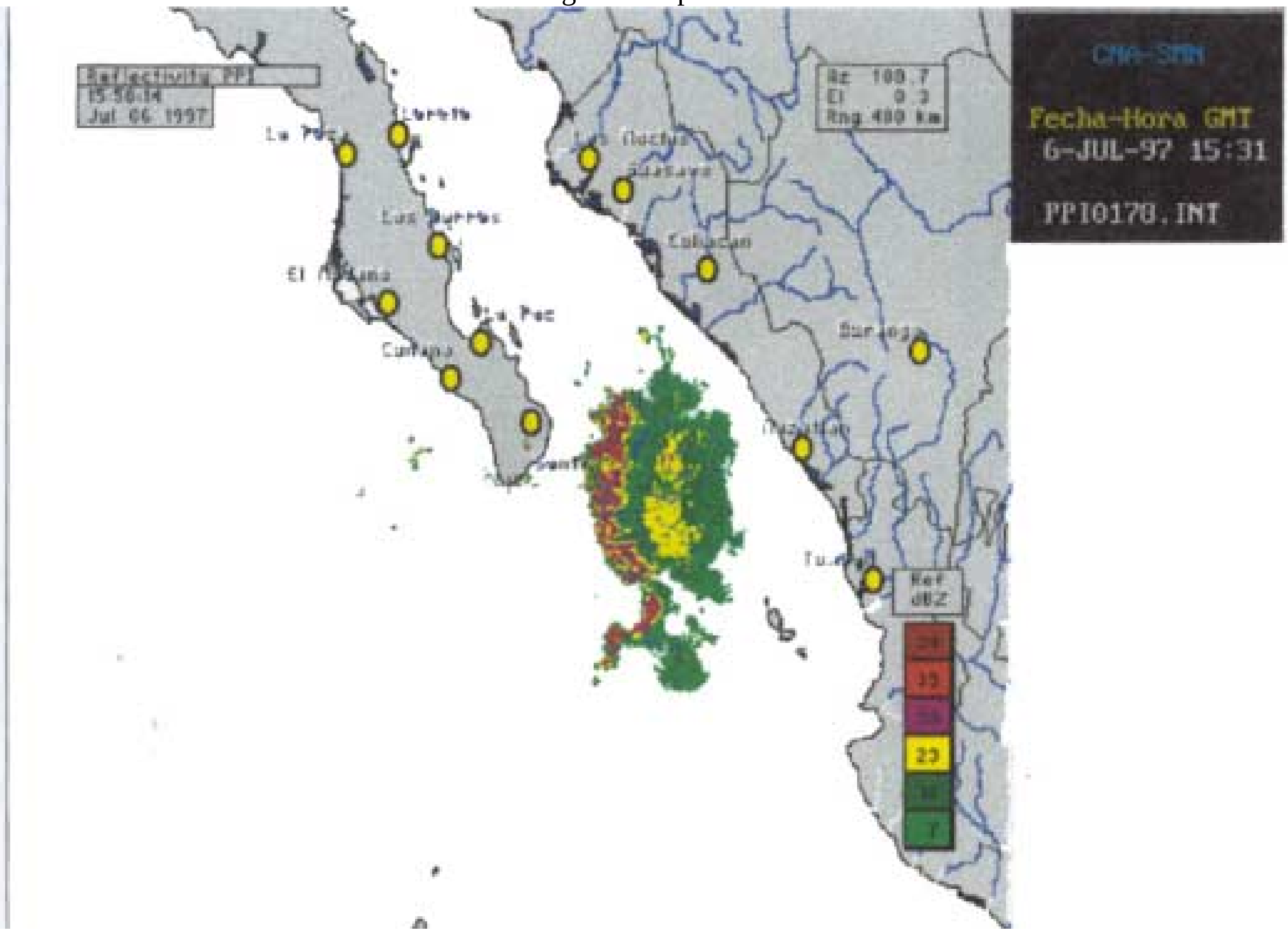


Figure 2. MCS traveling westward from the SMO across GoC (Cabo radar image)