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MONITORING GULF OF CALIFORNIA MOISTURE SURGES WITH GOES-9 DATA AND THE WSR-88D AT YUMA, ARIZONA

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This paper was originally presented at the AMS 16th Conference on Weather Analysis and Forecasting. The actual presentation, which contains additional examples and color images exclusively from the GOES-9 Sounder, is available on-line at: http://www.wrh.noaa.gov/tucson/research/sounder/slide1.html

Introduction

It has been a popularly held belief that moisture originating from the Gulf of Mexico is the primary moisture source for summer thunderstorms over the low deserts of Arizona (Jurwitz 1953; Bryson and Lowry 1955; Sellers and Hill 1964). It was hypothesized that moisture from the Gulf of Mexico was advected into Arizona via easterly flow (Bryson and Lowery 1955) and provided the fuel for summer thunderstorms over all of Arizona. While this argument has merit for the higher mountainous regions of northern and eastern Arizona, recent evidence strongly suggests that the moisture source for summer thunderstorms over the low deserts is the Gulf of California (e.g., Brenner 1974; Douglas 1995; Hales 1972, 1974; Stensrud et al. 1995)

A growing body of evidence continues to show that the main source of low-level moisture over the low desert of Arizona is from the Gulf of California. McCollum et al. 1995, illustrated a case where such a low-level surge of moisture from over southwest Arizona and the Gulf of California resulted in a dramatic increase in convective instability. The resulting nocturnal Mesoscale Convective System produced flash flooding in both the Phoenix and Tucson metropolitan areas. From the perspective of many Arizona forecasters, Gulf Surges are directly or indirectly responsible for the majority of significant convective events in the low desert of Arizona such as that documented in McCollum et al. 1995.

This document provides observational evidence that low-level moisture originating from the Gulf of California can be observed with GOES-9 derived moisture products and subsequently used to improve forecasts over southern Arizona. The first example shows how the GOES-9 Imager and the Vertical Wind Profile (VWP) from the Weather Surveillance Radar 1988 Doppler (WSR-88D) radar at Yuma, Arizona can be used to identify and track a Gulf Surge of low-level moisture into southern Arizona. The second example uses the GOES-9 Sounder to show a narrow plume of moisture advected into the lower deserts of Arizona in response to a synoptically driven southerly flow originating over the Gulf of California.

The Gulf of California Moisture Surge of August 26, 1996 Observed with the GOES-9 Imager and the WSR-88D

<u>The WSR-88D at Yuma, Arizona</u>

The VWP from the WSR-88D at Yuma, Arizona is a useful tool for identifying when a Gulf of California surge has begun to move into the lower Colorado Basin and the low desert of southwest Arizona. Figures 1a and b show the VWP from August 26, 1996 between 0144 and 0312 UTC, the period of time prior to when the moisture surge moved across Yuma. From 0144 until 0202 UTC, west to southwest flow at 10 kt was present. A temporary wind shift to the south at 10 kt occurred between 0207 and 0242 UTC but this was not the onset of the Gulf of California moisture surge because the wind shifted back to the southwest at 10 kt between 0242 and 0312 UTC. This shifting behavior in the pre-surge wind field is common and was noted by Brenner (1974) in the pre-surge surface observations at Yuma in his 1974 study. No firm explanation was given for the mechanism behind these pre-surge wind shifts.

Figure 1b shows the onset of the gulf surge between 0312 and 0440 UTC on August 26, 1996. The surface to 1,000 ft flow shifted to south at 10 kt at 0318 UTC and proceeded to deepen and strengthen with time. By 0405 UTC, the surface to 3,000 foot flow was from the south-southeast at about 25 kt which continued the remainder of the night at Yuma.

Several other cases similar to this have been identified on the Yuma WSR-88D VWP during the 1996, 1997, and 1998 monsoons. Clearly, the WSR-88D VWP was very useful to the forecasters by providing information that a surge was occurring, as well as an estimate of the depth and strength of the surge.

<u>The GOES-9 Imager</u>

One of the most significant new products since GOES-9 (and recently GOES-10) became operational has been the precipitable water (PW) derived image. The estimate of PW is computed using the difference in water vapor sensitivity between the 10.7 and 12.0 micron infrared channels. These channels were available on the previous generation of GOES, but the capability to estimate PW has only become reliable with new technology aboard GOES-9. This new technology includes: 1) GOES-9 continuously peers at the earth (the old GOES spun on an axis); 2) there are separate imaging and sounding units with improved sensors; and 3) the computer processing has been improved allowing for better image navigation and registration. These new features eliminate much of the noise that haunted similar derived images from the previous generation of GOES satellites.

A videotape loop of all the PW images from the GOES-9 imager for the summer of 1996 covering the southwest United States, much of Mexico and adjacent water bodies was provided to the authors by Frances C. Parmenter-Holt, Chief of the Atmospheric Research and Applications Division of the National Environmental Satellite, Data, and Information Services (NESDIS). This videotape was closely examined. Using a transparent overlay on the television screen, the various positions of the 35 and 40 mm PW contours were noted for the three-day period of August 25, 26, and 27.

Figures 2a and b show the position of the 35 and 40 mm PW contours on consecutive days from August 25 at 1200 UTC to August 27 at 1200 UTC. From Fig. 2b on August 25 at 1200 UTC, it can be seen that the 40 mm PW contour was located well south of Arizona but by 1200 UTC on August 26, the 40 mm contour had moved northward into the southwest desert of Arizona (not quite reaching Tucson). By August 27, the moisture surge had moved into the medium to high desert regions of Arizona with a dramatic increase in PW over all the southwest desert areas of Arizona. This timing agrees quite nicely to the passage of the surge through Yuma (see Fig. 1) at 0318 UTC on August 26, 1996, as indicated by the VWP.

Combining the two technologies, it is easy see that a low-level wind shift from the south (Fig. 1b and c) was accompanied by a dramatic increase in PW across southwest Arizona (Fig. 2b). The Yuma VWP enables the forecaster to analyze the depth, strength (in terms of wind speed) and longevity of the moisture surge. The PW derived image from the GOES-9 imager allows an analysis of the horizontal moisture field and to some degree the ability to estimate the vertical moisture profile (based on estimates using nearby soundings, surface data and assumptions about the basic structure of Gulf of California moisture surges). These technologies offer the potential for a dramatic improvement in the analysis of the precursor convective environment during the monsoon in Arizona.

Moisture Plume on July 9, 1997 Observed with the GOES-9 Sounder

The GOES-9 Sounder PW product is derived using 18 channels providing far superior vertical resolution compared to the Imager. Operationally, the authors have found that the Sounder product is of a higher quality and more accurate than the Imager product, but have yet to quantitatively compare the two. Figure 3 shows the PW from the GOES-9 Sounder July 9, 1997 at 1423 UTC. A narrow plume of relatively high PW is shown extending from the east shore of the Gulf of California into the low deserts of south-central Arizona. PW values within this tongue of high moisture are greater than 15 mm over south-central Arizona and over 20 mm near the border of Arizona extending to the Gulf of California. Values over the remainder of southern Arizona are on the order of 10 mm or less. The moisture transport was forced by an unseasonably deep trough along the west coast of California, and was not considered a true Gulf Surge. Nevertheless, the GOES-9 Sounder provided high resolution, accurate data allowing the forecaster to track the advection of this moisture plume into south-central Arizona. Forecasts, originally not calling for convection, were updated prior to thunderstorms which developed along the east side of the moisture plume during the afternoon hours.

Summary

New remotely sensed data are revolutionizing the ability of the forecaster to monitor and predict moisture advection and convective outbreaks over Arizona. The Gulf Surge described in this document as well as the early July moisture plume were both recognized in real-time by forecasters at the National Weather Service Office in Tucson through the use of the WSR-88D VWP at Yuma, Arizona and PW estimates from the GOES-9. Timely updates were then made to the forecasts prior to the development of convective activity. Remotely sensed data such as those briefly described are making significant contributions to operational forecasting.

Acknowledgments

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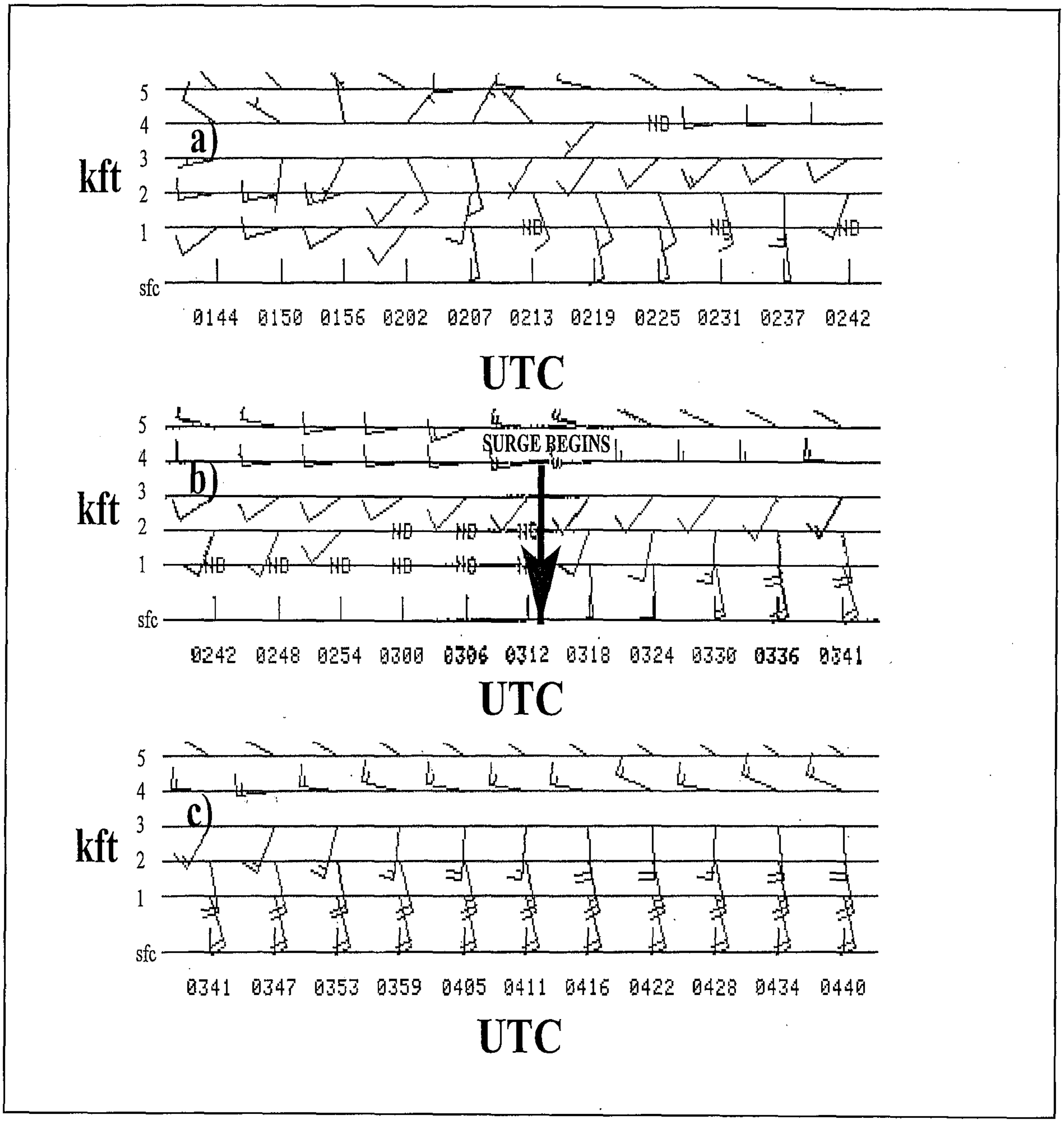

Figure 1. The VAD Wind Profile (VWP) from the WSR-88D at Yuma, Arizona from August 26, 1996 for: a) 0144 through 0242 UTC, b) 0242 through 0341 UTC, and c) 0341 through 0440 UTC. Vertical axis is elevation above sea level in kft. Horizontal axis is UTC time. Wind speed 5 knots per half wind-barb.

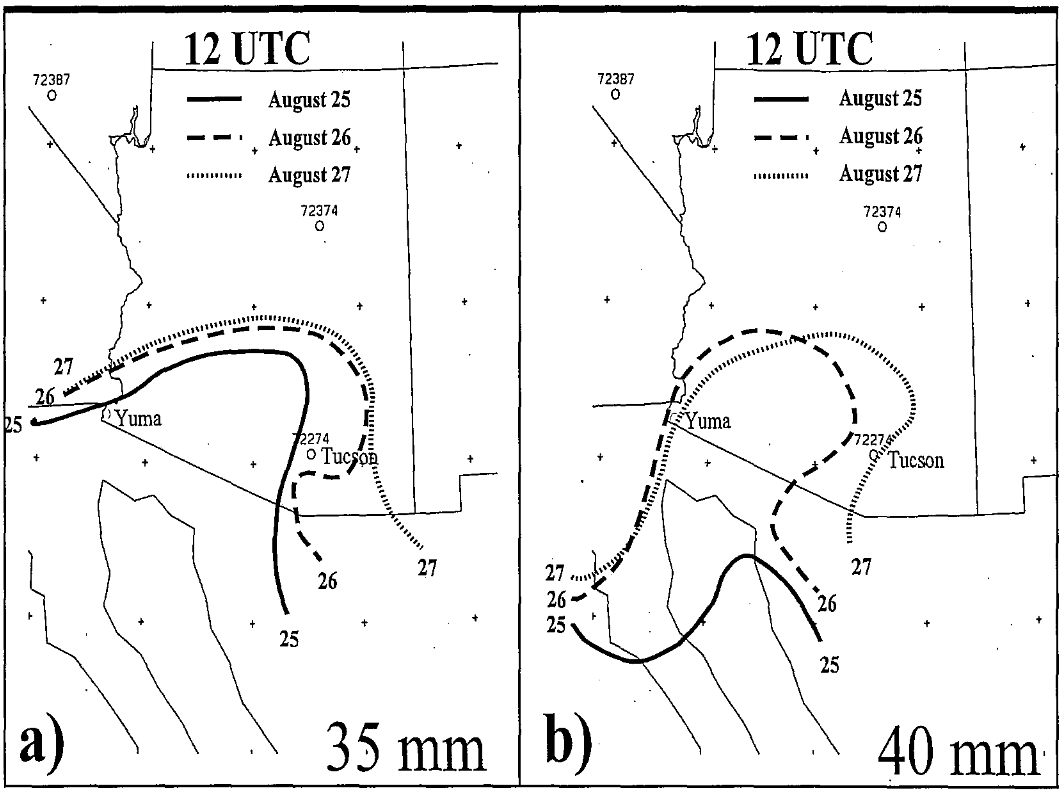

Figure 2. a) The 35 mm PW contour for August 25, 26, and 27, 1996 from the GOES-9 Imager at about 12 UTC. b) Same as in a) except the 40 mm contour is shown.

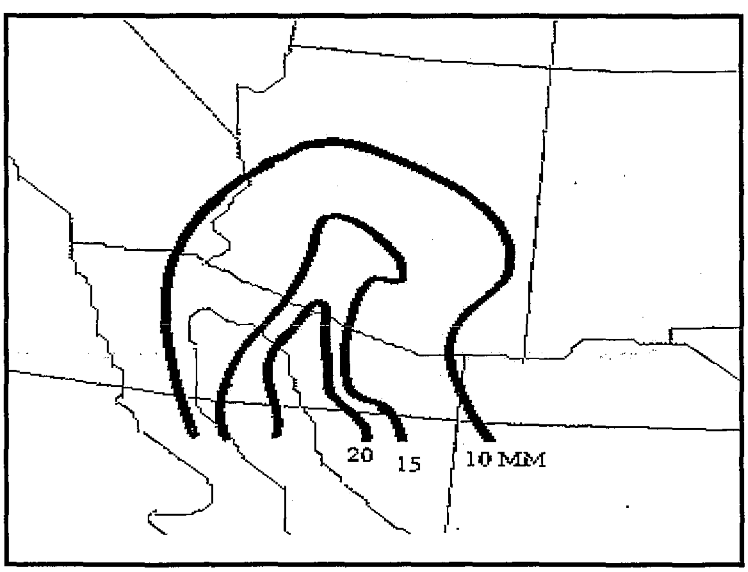

Figure 3. The PW from the GOES-9 Sounder on July 9, 1997 at 1423 UTC showing narrow plume of moisture into south central Arizona. Units are in mm.