An Examination of a Stratus Surge Along the Central California Coast Using the Weather Event Simulator (WES)

Wilfred Pi and Warren Blier
WFO Monterey (San Francisco Bay Area), CA
June 30, 2003

Introduction

A classic stratus surge event occurred along the central California coast starting on the evening of 27 August 2002. From an extensive area of stratus initially off the southern California coast, significant northward advection occurred overnight and by 0900 UTC (2:00 am PDT) 28 August the leading edge of the clouds had nearly reached Monterey Bay. Stratus surge events like this one are a regular warm season weather phenomenon along the California coast, with their arrival typically resulting in the termination of a period of much warmer than normal daytime temperatures throughout the Monterey CWA. They also result in re-establishment of the marine layer and onset of southerly winds across our coastal waters (which then gradually shift towards being more onshore).

Overview of WES Exercise

The purpose of this WES exercise was to remind the forecasters to the characteristic evolution of a typical summer season stratus surge event, including its speed of propagation northward along the coast, along with the types and magnitudes of the changes in the sensible weather conditions that can occur as a result. The WES exercise was literally run for just the 30-min period 1:00-1:30 am PDT 28 August, but the focus was on using the information up to and through this period to prepare selected morning (4:00 am) short-term (first period) forecasts. Here's the scenario the forecasters were told to consider:

I*t is now 1:00 am Wednesday August 28, 2002 and you are working the A shift at the public desk. The key question you're focusing on as you write your ZFP is what the first period weather conditions will be -- and how much change (if any) is needed from the forecasts you've inherited. To simplify this a bit, for the sake of this exercise we're just going to focus on 4 of our spot forecast locations (Santa Rosa, SFO Airport, Santa Cruz, and Monterey) -- and the forecast for Wednesday (today) for the zone groups they're in. With this simplification, here are the forecasts you've inherited from the afternoon of Tuesday August 27 (and then the actual zone forecasts issued by WFO Monterey that afternoon were provided).*

They were then given the following assignment:

(1) Decide how much change, if any, is needed from the above forecasts you've inherited and then (a) write your Period 1 Zone Forecasts corresponding for the 3 zone forecasts groups given above, and (b) provide your Period 1 High Temperature forecasts for the 4 spots noted above.

(2) Provide your forecast reasoning, just as you would in an AFD -- but again just focusing on the Period 1 portion of the forecast.

(3) Make specific spot forecasts of the sky cover (CLR, FEW, SCT, BKN, OVC), temperature (F), dew point (F), wind direction (nearest 10 degs) and wind speed (knots) for the STS, SFO, and MRY ASOS locations for 23Z Wednesday.

Some high temperatures that occurred on the afternoon of August 27 (the day before the stratus surge occurred) included: 77 oF at San Francisco compared to a normal of 70 oF; 85 oF at downtown Oakland (vs.74 oF); and 96 oF at Santa Rosa (vs. 82 oF). The stratus surge affecting central California brings a big change in the weather: daytime temperatures become cooler, winds deviate from the climatologically persistent summer sea-breeze pattern, and terrain becomes a factor affecting sky cover near the coast.

Synoptic Overview

We begin with a series of satellite images, overlaid on the concurrent surface observations, showing the northward propagation of the surge-related stratus during the 12-h period 0600 to1800 UTC 28 August. An IR "fog product" (11 - 3.9 microns) satellite image at the 0600 UTC (Figure 1) shows a narrow tongue of stratus having rounded Pt Conception and extending along the coast northward to about the southern border of the Monterey CWA. Farther north along the coast, including the entire San Francisco and Monterey Bay Regions, skies remain completely clear. Note that the time of this satellite image is just a couple of hours prior to the data cut-off time for the WES exercise. The superimposed HPC surface analysis shows a characteristic summer season sea level pressure pattern of lower pressure over the warm Central Valley of northern and central California, and higher pressure offshore. This synoptic-scale analysis only hints, however, at a key mesoscale feature associated with the northward propagation of the surge and associated stratus: the development of a south-to-north pressure gradient along the coast. The plotted surface reports show a pressure gradient of 2.7 mb between Santa Maria (KSMX, 1009.9 mb) and San Francisco (KSFO, 1007.2 mb). In the subsequent 6 hours, significant northward propagation of the surge-associated stratus occurs. By 1200 UTC 28 August (Figure 2), the stratus has extended northward along the coast to Monterey Bay, and is even beginning to move into the northern Salinas Valley. Further increase in the south-to-north pressure gradient along the coast has occurred, with the pressure at Santa Maria now 3.6 mb higher than at San Francisco. Reversal of the nearshore wind direction to southerly, from the usual (and just previously) prevailing northwesterlies, is also evident in association with the surge from the buoy reports south of Monterey Bay. Finally, a 1-km resolution visible image from 1800 UTC (Figure 3) shows the surge having propagated northward well past the San Francisco and the Golden Gate, extending almost to Pt Arena. Winds at all of the buoys off the central California coast have become south-southeasterly with gusts exceeding 15 knots.

The GFS (AVN) 500 mb analysis for 0600 UTC (Figure 4) shows an upper-level low centered over the northern Great Basin, with a weak short-wave trough embedded in the trailing north-northwesterly flow in the region of the central California coast. The corresponding analyses of geopotential height and wind at 850 mb (Figure 5) show a low centered over southern Nevada with a ridge of high pressure extending eastward into the Pacific Northwest and the northern Great Basin. The net result is offshore flow over northern and north-central California, and associated subsidence warming and drying of those coastal regions; this is a common precursor to a coastal surge event. The surge itself thus propagates down the surface pressure gradient established between these lower pressures to the north and the coastal area of higher pressure resulting from the already well-established marine layer over the waters off southern California. The leading part of the stratus is associated with a wedge of cooler air and acts to ramp up the marine layer. Lower-tropospheric wind and temperature data from the Fort Ord profiler (Figure 6), located about 10 km northeast of Monterey, show only a very shallow marine layer during the evening of August 27, but then rapid deepening overnight in association with the passage of the coastal surge (note that as the profiler site is located a few km east of the easternmost extension of Monterey Bay, it does not directly experience the low-level wind structure of the surge itself – which is primarily confined to the oceanic coastal waters). The resulting higher surface pressures along the central California coast sets up a stronger onshore flow the next day when daytime heating lowers surface pressures over land.

Eta Model Performance

Overall, the Eta model run initialized at 0600 UTC 28 August performed relatively well in forecasting this stratus surge event. Examination of the high-resolution boundary-layer relative humidity output (not shown) indicated that the model correctly forecast the stratus to reach the northern Sonoma County coast by 1800 UTC. Likewise, relatively good agreement was found between the model predicted boundary-layer winds and observations. Figure 7 shows 18-h model output winds (valid 0000 UTC 29 August) and selected surface observations for 2300 UTC 28 August (the latest time surface observations were available for this WES case). Decent agreement is found for both the offshore low-level southerly winds (buoy reports not shown) and wind speeds and directions over land (aside from the effects of local small-scale topographic influences). Surface temperature output from the Eta model (not shown) was examined as potential guidance in forecasting changes in high temperatures in association with this surge event. It turns out, however, that while it forecasted cooler temperatures, it failed to catch the true magnitude of the cooldown, particularly for places that cooled off more than 10 oF.

Discussion

The surge-associated increase in marine layer depth and onshore flow brought significant cooling through most of the Monterey WFO County Warning Area. The maximum temperature cooled 8 oF from the previous day at San Francisco, 15 oF at Oakland, and 20 oF at both San Rafael in Marin County and Santa Rosa in Sonoma County. Interestingly, Monterey cooled only 1 oF from the previous day and was very close to average high for 28 August on both days. This is because Monterey reporting site is exposed to the ocean to its northwest, but much more protected from marine influence from the south or southwest by the intervening orography. On the day preceding this surge, 27 August, a light northwesterly onshore flow acted to maintain seasonal temperatures at Monterey itself, while all other locations in the Monterey CWA (aside from those additional coastal stretches with a northwest exposure) experienced significant warming. Then the next day, following the passage of the coastal surge, the mountains to the south and west of Monterey shielded that area from the primary cooling effects of the more southerly onshore flow and thus Monterey ended up with an almost identical afternoon temperature. This demonstrates one of the forecasting challenges associated with these surge events: while most places experience significant associated reduction of afternoon temperatures, there are exceptions. On the other hand, southward-facing coastal locations like Santa Cruz, well-protected from the northwesterly onshore flow that typically precedes passage of one of these coastal surges, become especially exposed to the southerly marine winds and stratus following the surge – and thus tend to experience an especially dramatic reduction in afternoon temperatures and increase in low-cloud cover.

Figure 1

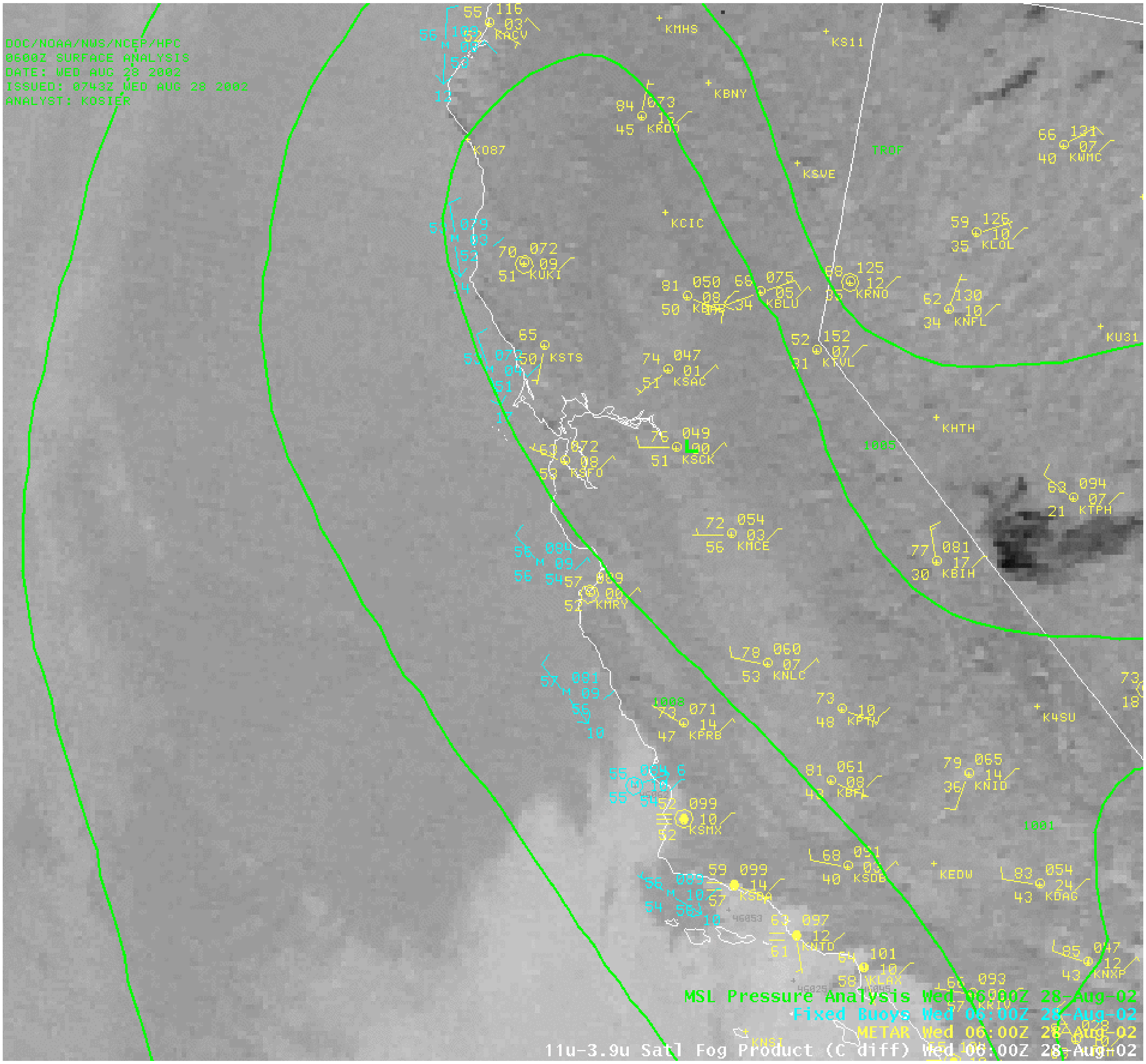

DOC/NOAA/NWS/NCEP/HPC
0600Z SURFACE ANALYSIS
DATE: WED AUG 28 2002
ISSUED: 0743Z WED AUG 28 2002
ANALYST: KOSIER
KACV
KMHS
KS11
KBNY
KRDD
KO87
KSVE
TROF
KWMC
KCIC
KLOL
KUKI
KBLU
KRNO
KNFL
KSTS
KSAC
KTVL
KU31
KHTH
KSCK
KSFO
1005
KTPH
KMCE
KBIH
KMRY
KNLC
KPRB
KFTW
K4SU
KBFL
KNID
KSMX
1001
KSDB
KEDW
KDAG
KSBA
KNTD
KLAX
KNXP
MSL Pressure Analysis Wed 06:00Z 28-Aug-02
Fixed Buoys Wed 06:00Z 28-Aug-02
METAR Wed 06:00Z 28-Aug-02
11u-3.9u Sat'l Fog Product (C diff) Wed 06:00Z 28-Aug-02

Figure 2

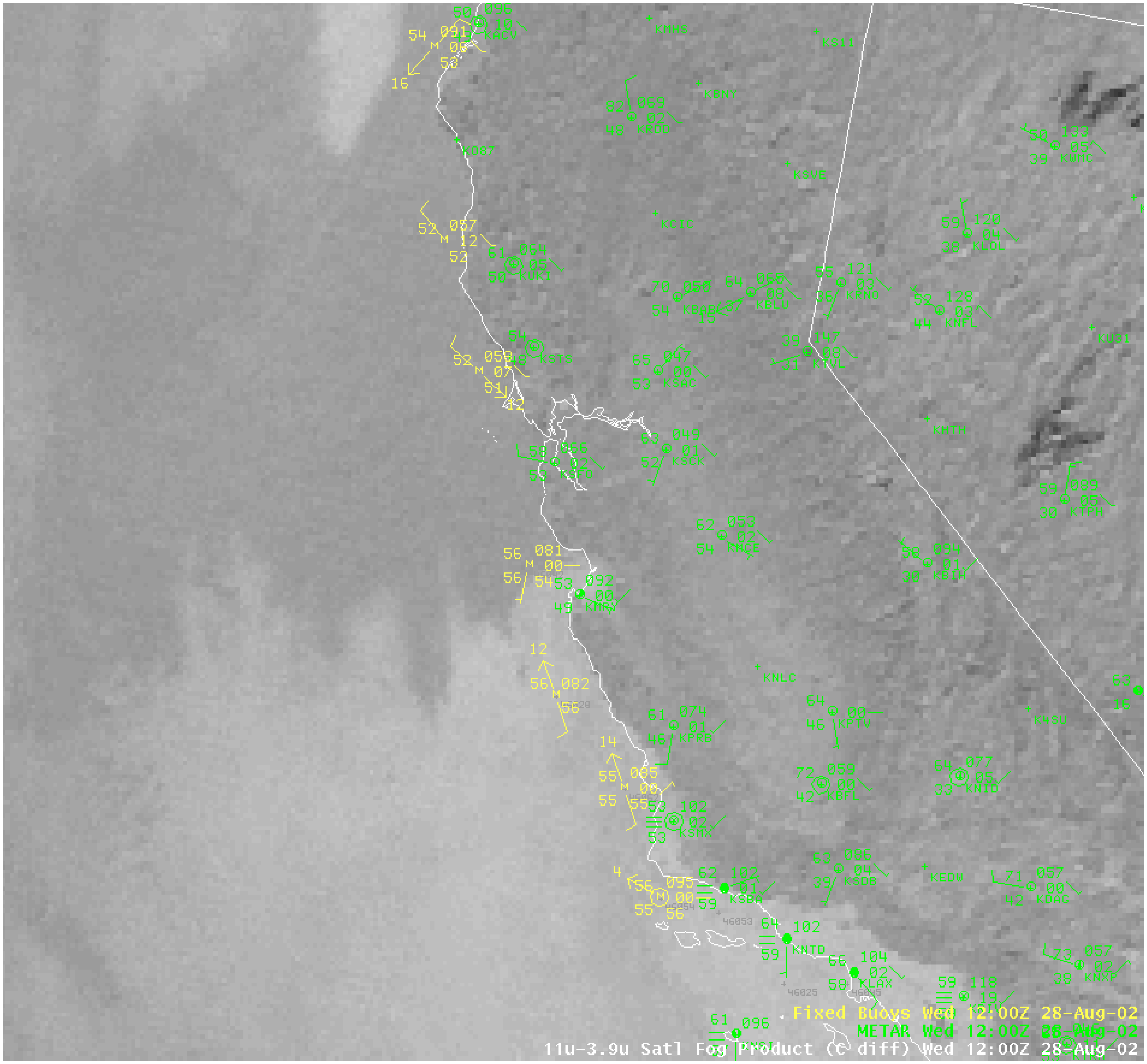

Fixed Buoys Wed 12:00Z 28-Aug-02
METAR Wed 12:00Z 28-Aug-02
11u-3.9u Satl Fog Product (C diff) Wed 12:00Z 28-Aug-02

Figure 3

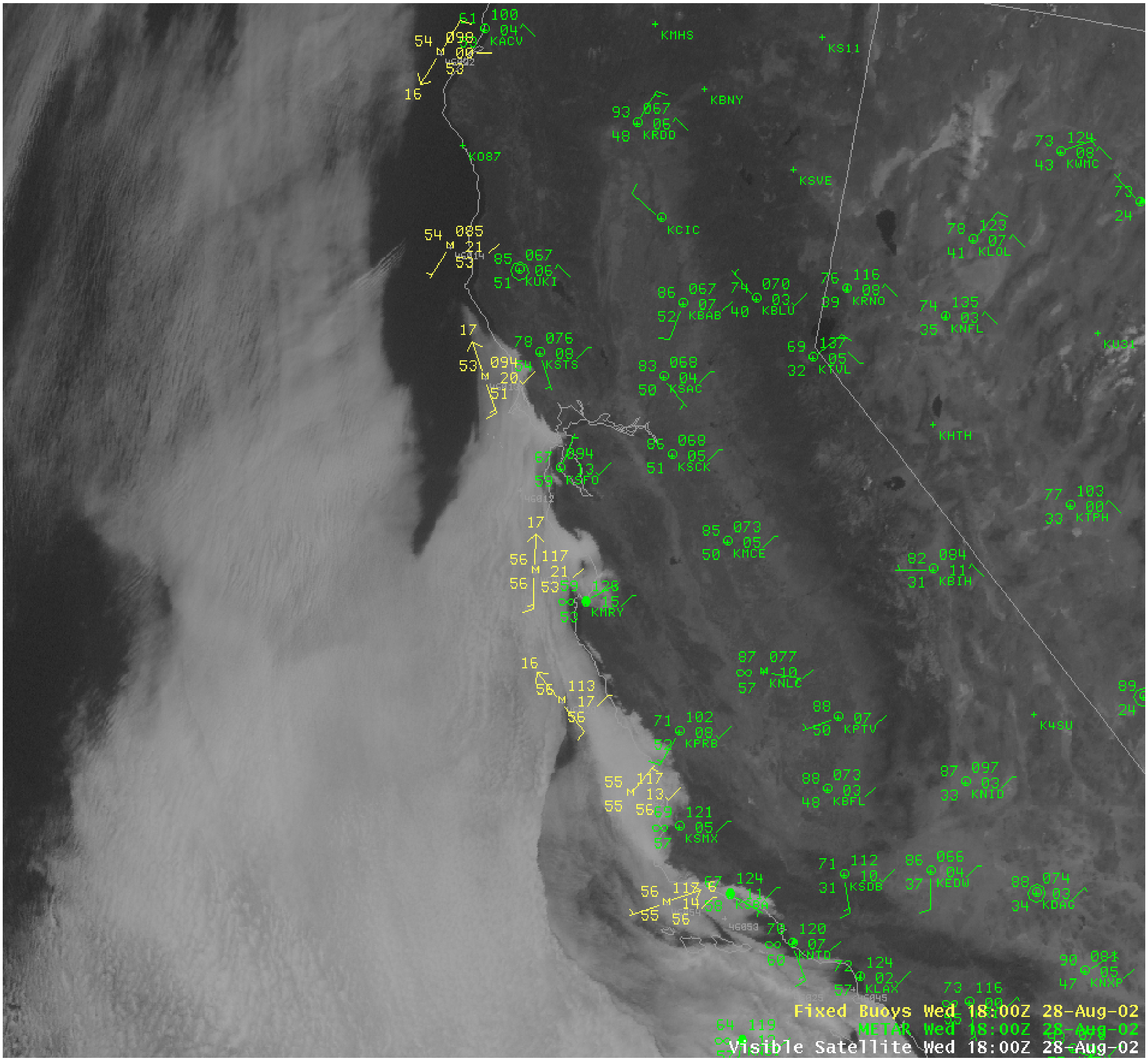
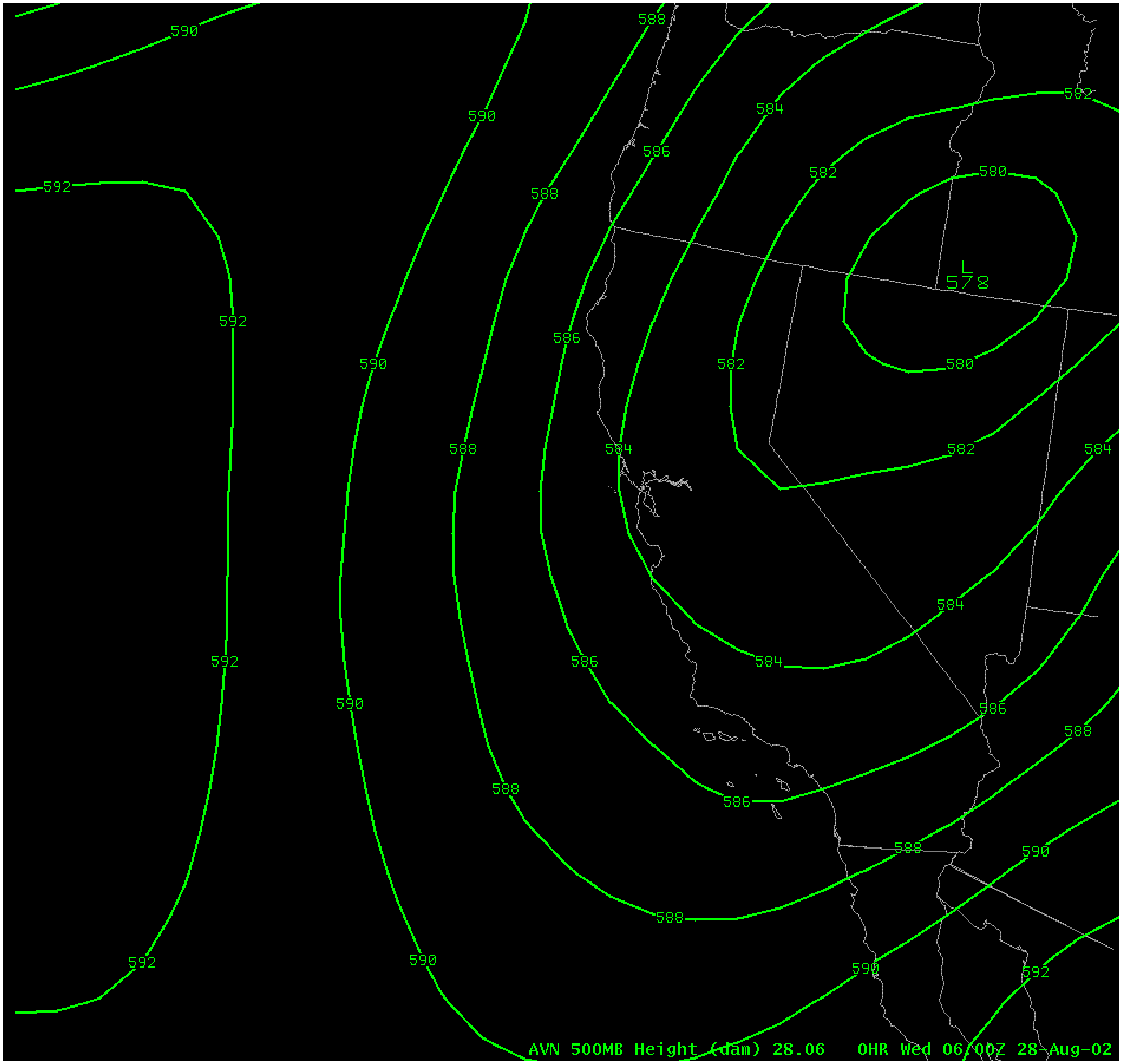

Fixed Buoys Wed 18:00Z 28-Aug-02
METAR Wed 18:00Z 28-Aug-02
Visible Satellite Wed 18:00Z 28-Aug-02

Figure 4



590
588
584
582
592
586
580
L
578
AVN 500MB Height (dam) 28.06 OHR Wed 06:00Z 28-Aug-02

Figure 5

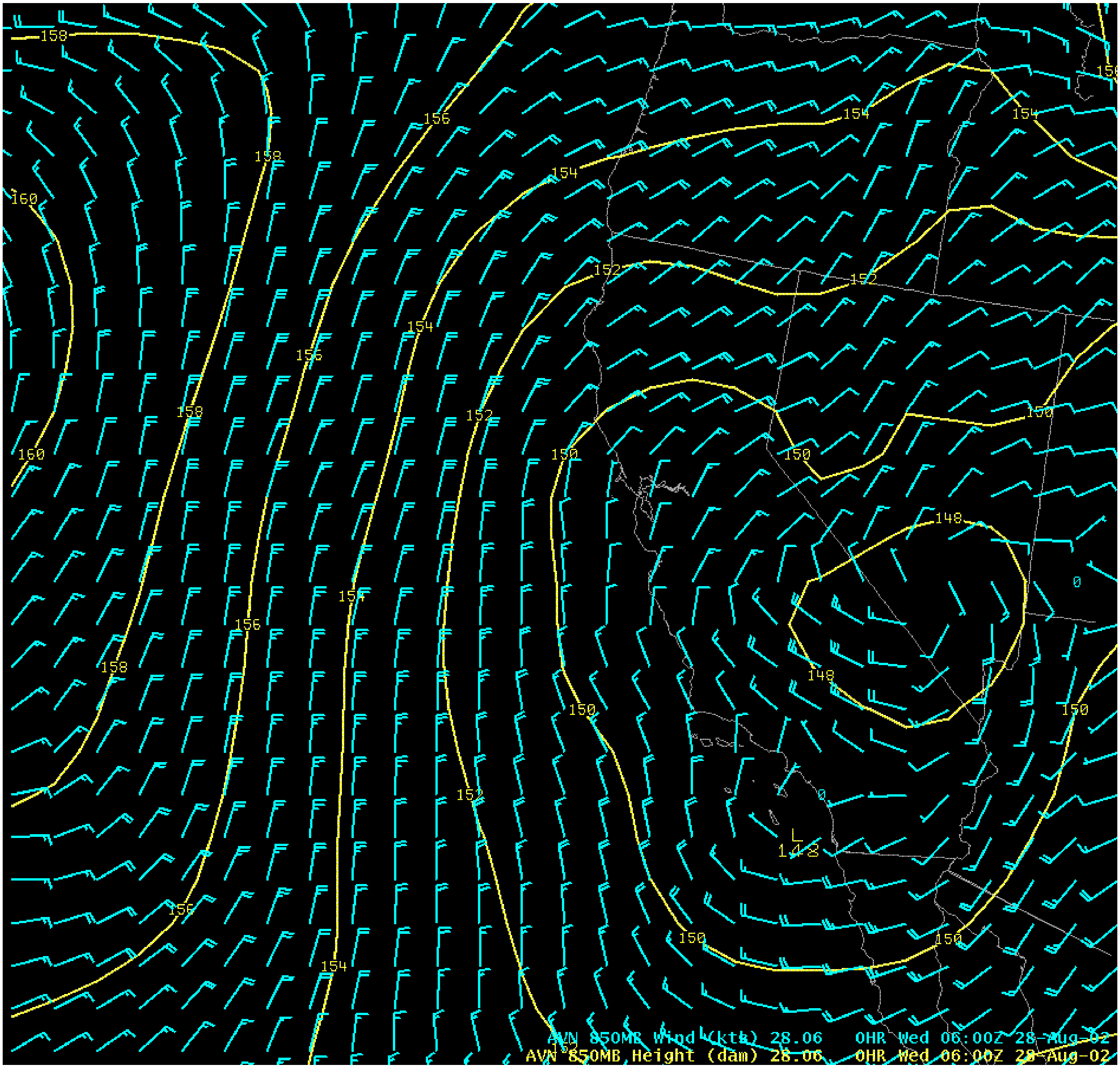

AVN 850MB Wind (kts) 28.06 0HR Wed 06:00Z 28-Aug-02
AVN 850MB Height (dam) 28.06 0HR Wed 06:00Z 28-Aug-02

Figure 6

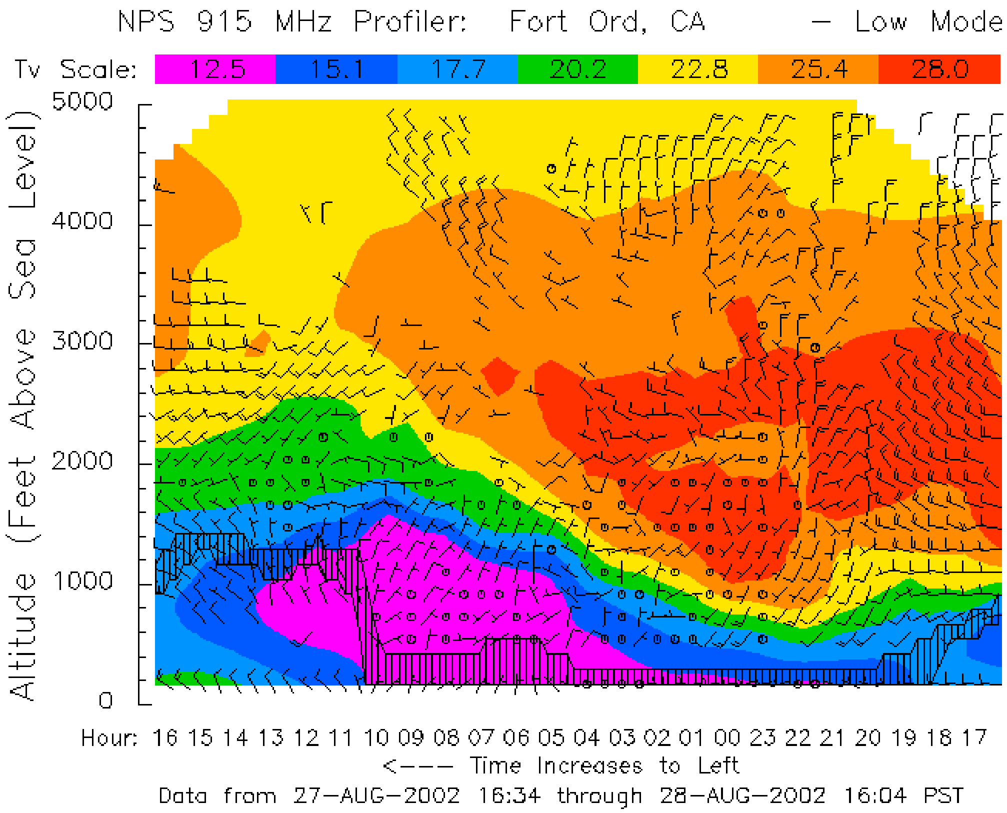
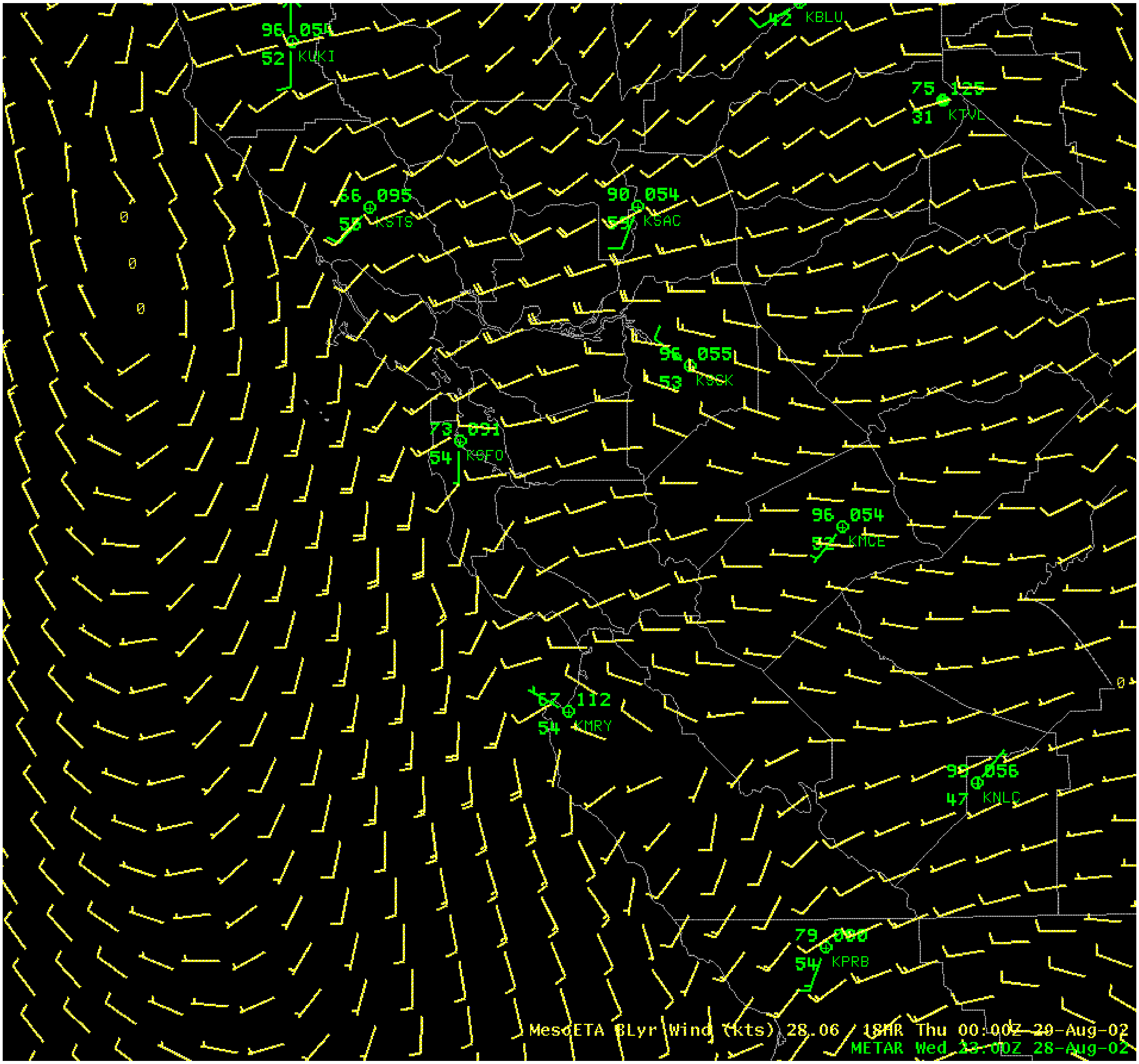

NPS 915 MHz Profiler: Fort Ord, CA — Low Mode
Tv Scale: 12.5 15.1 17.7 20.2 22.8 25.4 28.0
Altitude (Feet Above Sea Level)
5000
4000
3000
2000
1000
0
Hour: 16 15 14 13 12 11 10 09 08 07 06 05 04 03 02 01 00 23 22 21 20 19 18 17
<--- Time Increases to Left
Data from 27-AUG-2002 16:34 through 28-AUG-2002 16:04 PST

Figure 7


96 054
52 KUKI
42 KBLU
75 125
31 KTVL
66 095
58 KSTS
90 054
59 KSAC
96 055
53 KSCK
73 091
54 KSFO
96 054
52 KMCE
67 112
54 KMRY
99 056
47 KNLC
79 000
54 KPRB
MesoETA BLyr Wind (kts) 28.06 / 18HR Thu 00:00Z 29-Aug-02
METAR Wed 23:00Z 28-Aug-02