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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
NATIONAL METEOROLOGICAL CENTER

OFFICE NOTE 244

Evaluation of VAS Sounding Data for Two April 1981 Cases: Part 1 of 2

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This is an unreviewed manuscript, primarily intended for informal exchange of information among NMC staff members.

Introduction

This note presents the results of a preliminary evaluation of VAS (VISSR Atmospheric Sounder) data for two cases, 12 GMT 14 April and 12 GMT 15 April 1981, hereafter referred to as Cases A and B, respectively. Section 1 presents discussions of both the synoptic conditions during these cases, and the results of comparing VAS temperature soundings with those from radiosondes. Section 2 discusses the differences between layer thicknesses derived from VAS and those derived from various NMC analysis and forecast systems. Finally, section 3 presents LFM analyses made with and without VAS data.

The soundings for Cases A and B were made in the dwell sounding (DS) mode of the VAS radiometer (Smith, 1981). Table 1 summarizes the characteristics of the VAS radiometer in the DS mode.

TABLE 1. VAS instrument characteristics.

Spectral channel	Central wavelength (μm)	Central wavenumber (cm^{-1})	Weighting function peak (mb)	Absorbing constituent	Inflight single sample noise ($mW\,m^{-2}\,sr^{-1}\,cm$)	Typical spin budget[1]	Typical sounding radiance noise[2] ($mW\,m^{-2}\,sr^{-1}\,cm$)
1	14.71	679.95	40	CO_2	4.125	2	0.583
2	14.45	691.90	70	CO_2	2.525	4	0.253
3	14.23	702.89	150	CO_2	1.763	7	0.133
4	13.99	714.85	450	CO_2	1.488	7	0.112
5	13.31	751.37	950	CO_2	1.131	4	0.113
6	4.52	2214.35	850	CO_2	0.028	7	0.002
7	12.66	789.89	surface	H_2O	1.069	3	0.123
8	11.24	889.52	surface	window	0.119	1	0.024
9	7.25	1379.69	600	H_2O	1.225	9	0.082
10	6.73	1486.33	400	H_2O	0.306	2	0.043
11	4.44	2254.28	500	CO_2	0.026	7	0.002
12	3.94	2538.07	surface	window	0.007	1	0.001

[1] Number of spins sensed by the same detector with filter and mirror positions fixed.
[2] After averaging 25 samples in one sounding area.

After Smith (1981)

The individual soundings are selected by a human operator and processed by the method mentioned in Smith et al. (1981), and Smith (1981), at the Cooperative Institute for Meteorological Satellite Studies (CIMSS), Madison, Wisconsin. All the soundings for Cases A and B were cloud-free. The first guess is the 12-hour forecast from the National Meteorological Center (NMC) limited fine mesh (LFM) model (designated FM12, for fine mesh 12-hour forecast) verifying at VAS observation time. Further, CIMSS uses the 1000 millibar FM12 height field as the reference or "anchoring level" from which to build soundings, and to provide the 1000 mb temperature for all VAS soundings over water (Kit Hayden, CIMSS, personal communication).

1. Synoptic Conditions and Comparison of VAS Soundings with Observations.

During the period 13-15 April 1981 a cyclone system moved eastward across the eastern North Pacific at an average speed of about 15 knots. A large-scale upper-air trough accompanying this system was situated at about 145°W, and a ridge lay near 125°W. Satellite images (figures 1a-1e) clearly show that the cyclone was accompanied by a cold front, and that a considerable amount of dry air had penetrated the center of the storm. Between about 00 GMT 14 April and 12 GMT 15 April (figures 1b-1e) a disturbance moved northward along the front. Analyses of surface ship reports (figures 2 and 3) indicate that this region is the location of a surface pressure trough and wind-shift line. The low pressure center moves rapidly northeastward by 12 GMT 15 April, leaving behind it a low pressure trough (figure 3).

VAS temperature and moisture soundings were compared with coastal radiosondes, and with soundings constructed from LFM forecast fields. Proximate soundings were plotted on skew-T log-P diagrams and visually compared (Appendix 1). In five out of seven instances where a radiosonde profile displays a low-level temperature inversion, the VAS profile contains a strikingly similar feature. Likewise, in all seven comparisons in Appendix 1 the VAS soundings locate the tropopause with fair accuracy. The LFM temperature profiles (not shown), while similar to those of VAS and radiosondes, especially at the tropopause, contain no strong low-level inversions. Thus, while the resemblance of the profiles at the tropopause might be attributed to the influence of the FM12 first guess, this cannot be the case in the 1000-850 mb layer. The explanation for the existence of these features probably rests with the choice of the 1000 mb temperature in the VAS retrieval system. For soundings over the ocean, the FM12 1000 mb temperature is used, while for soundings over land, VAS uses either the Service A data when available, or VAS radiance data (Kit Hayden, personal communication). Thus, those VAS soundings in Appendix A containing inversions very likely fall into the latter category. Please note therefore, that the VAS soundings shown in Appendix 1 are not typical of those comprising the bulk of the data in the cases under consideration.

Appendix 2 contains VAS soundings over the ocean at the location shown in figure A. All the VAS soundings analyzed statistically in Section 2 are of this type. They share the distinction of having their 1000 mb temperature assigned from the LFM FM12 first guess. This fact may be the reason that the Case A soundings shown in Appendix 2 all exhibit marginally stable or unstable lapse rates in their lowest layer, while soundings for Case B all bear stable lowest layers. It is also possible that these features owe their existence to a poor first guess in Case A. All the oceanic profiles shown are smoother, and have less well-defined tropopauses than those shown in Appendix A.

2. Comparison of VAS Thicknesses with NMC Analysis and Forecast Thicknesses.

VAS thicknesses were compared with thicknesses calculated from 1) the LFM analysis (FMANL), 2) the LFM 12-hour forecast (FM12) valid at the time of the VAS observations, 3) the NMC spectral global 12-hour forecast

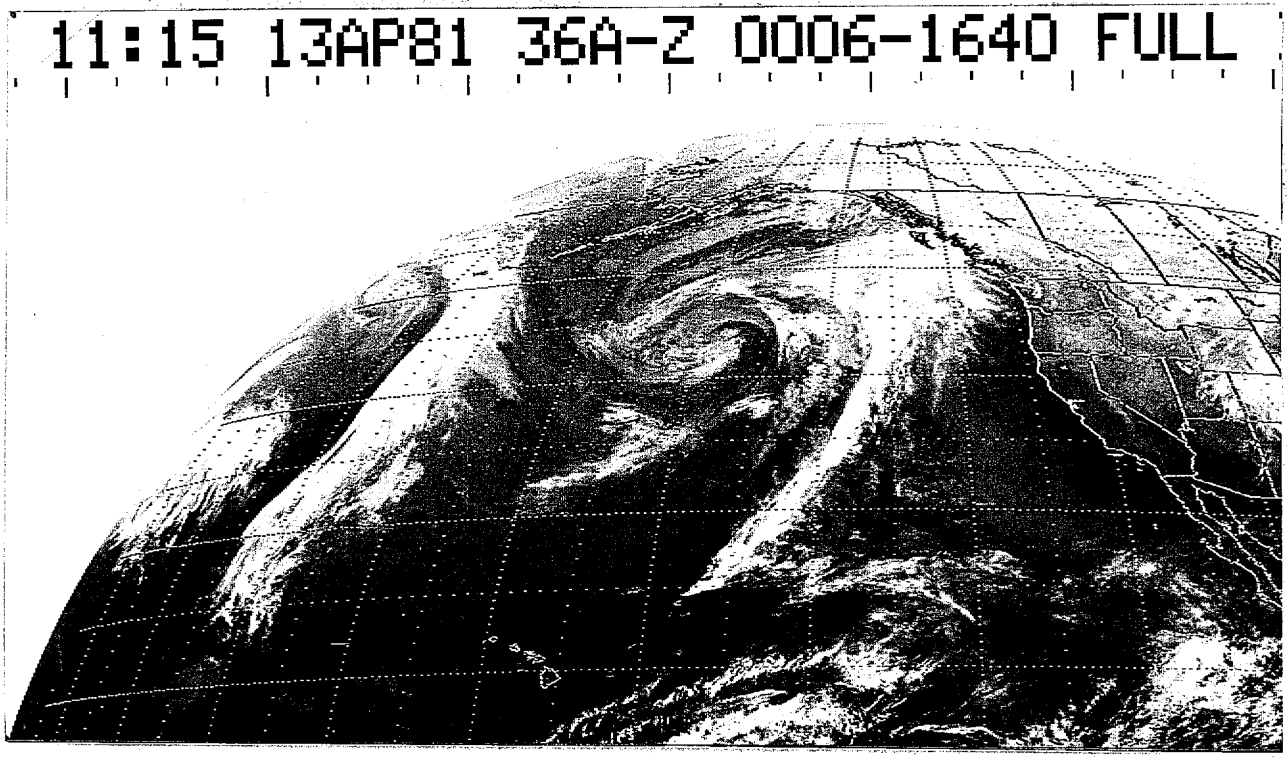


Figure 1a. Full disc infrared satellite image, 1115 GMT 13 April 1981.

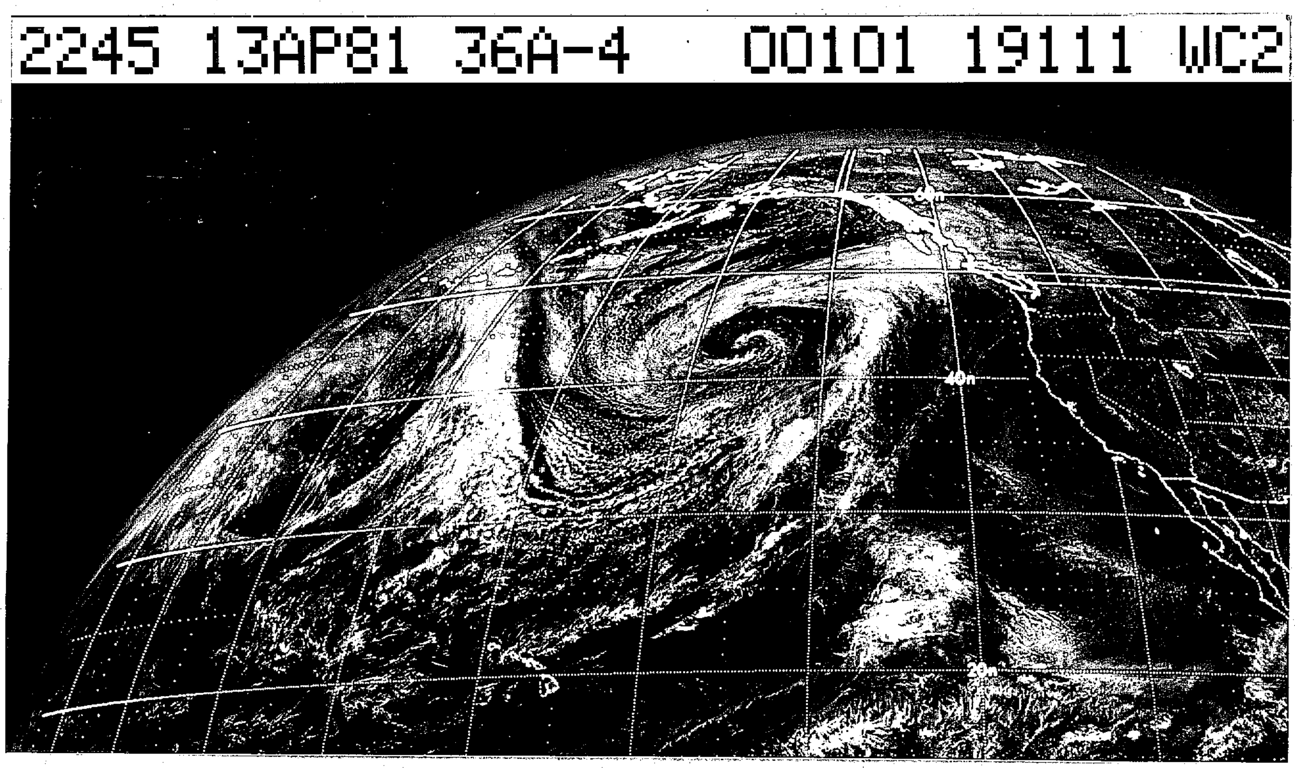


Figure 1b. Visual satellite image, 2245 GMT 13 April 1981.

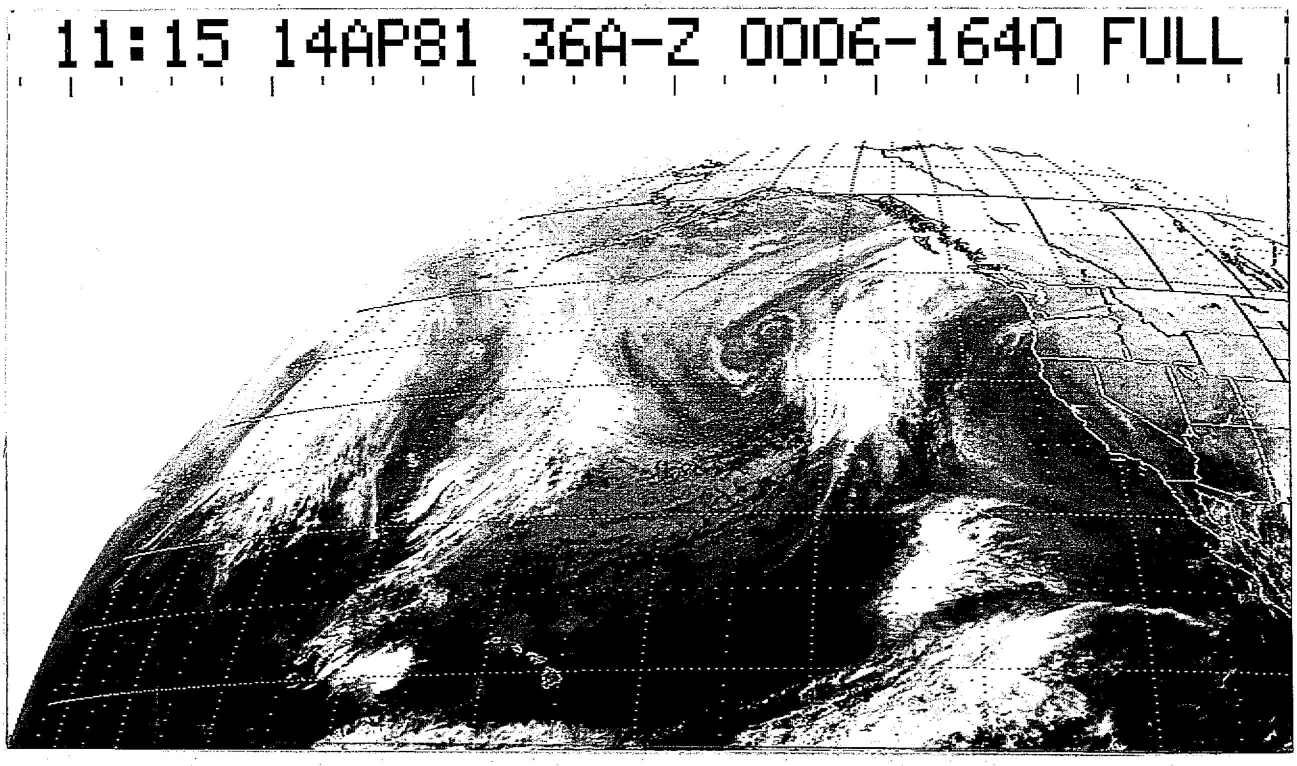


Figure 1c. Full disc infrared satellite image, 1115 GMT 14 April 1981.

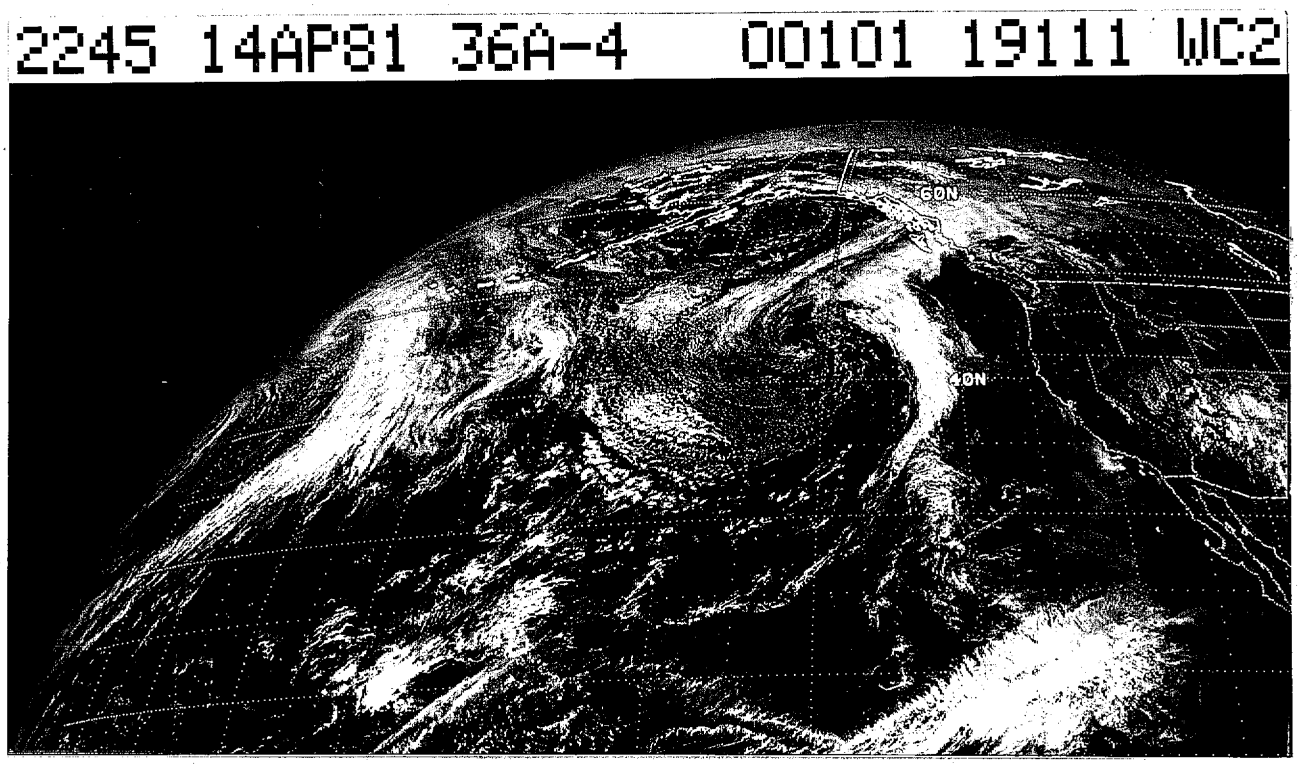


Figure 1d. Visual satellite image, 2245 GMT 14 April 1981.

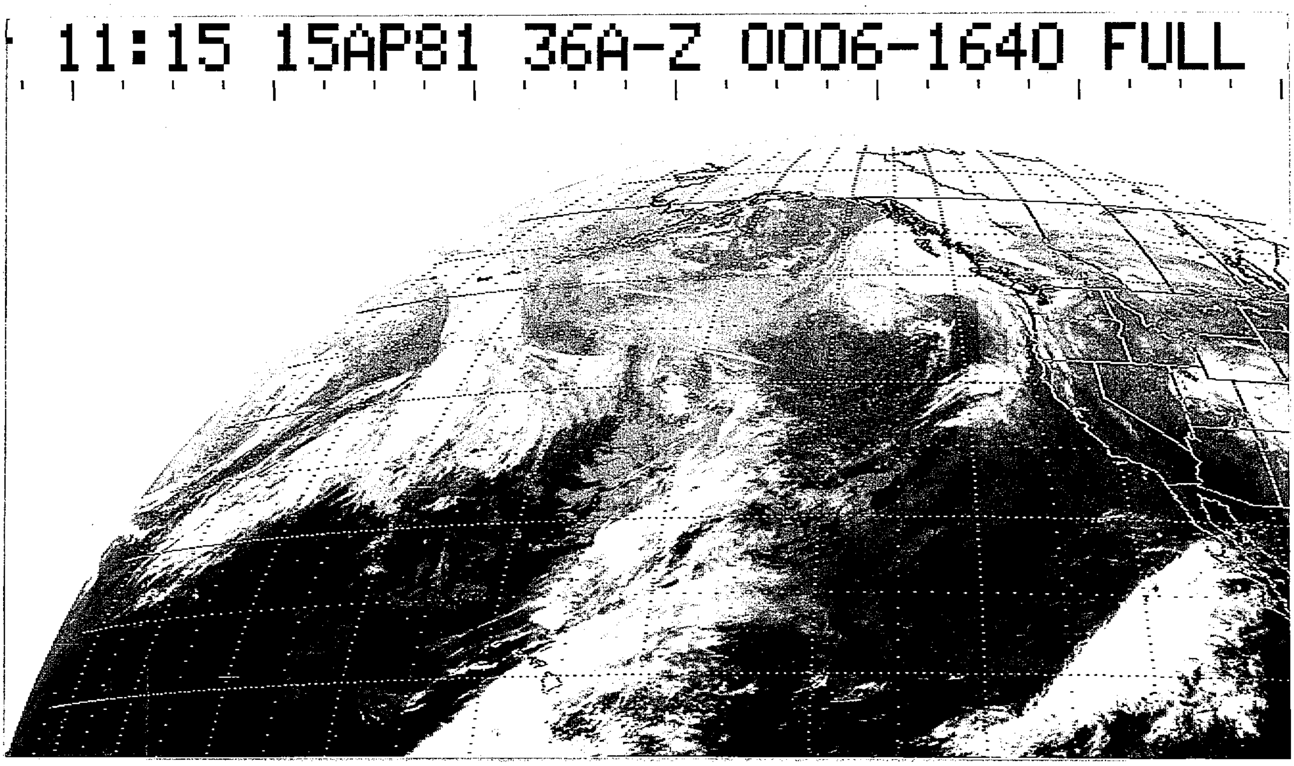


Figure 1e. Full disk infrared satellite image, 1115 GMT 15 April 1981.

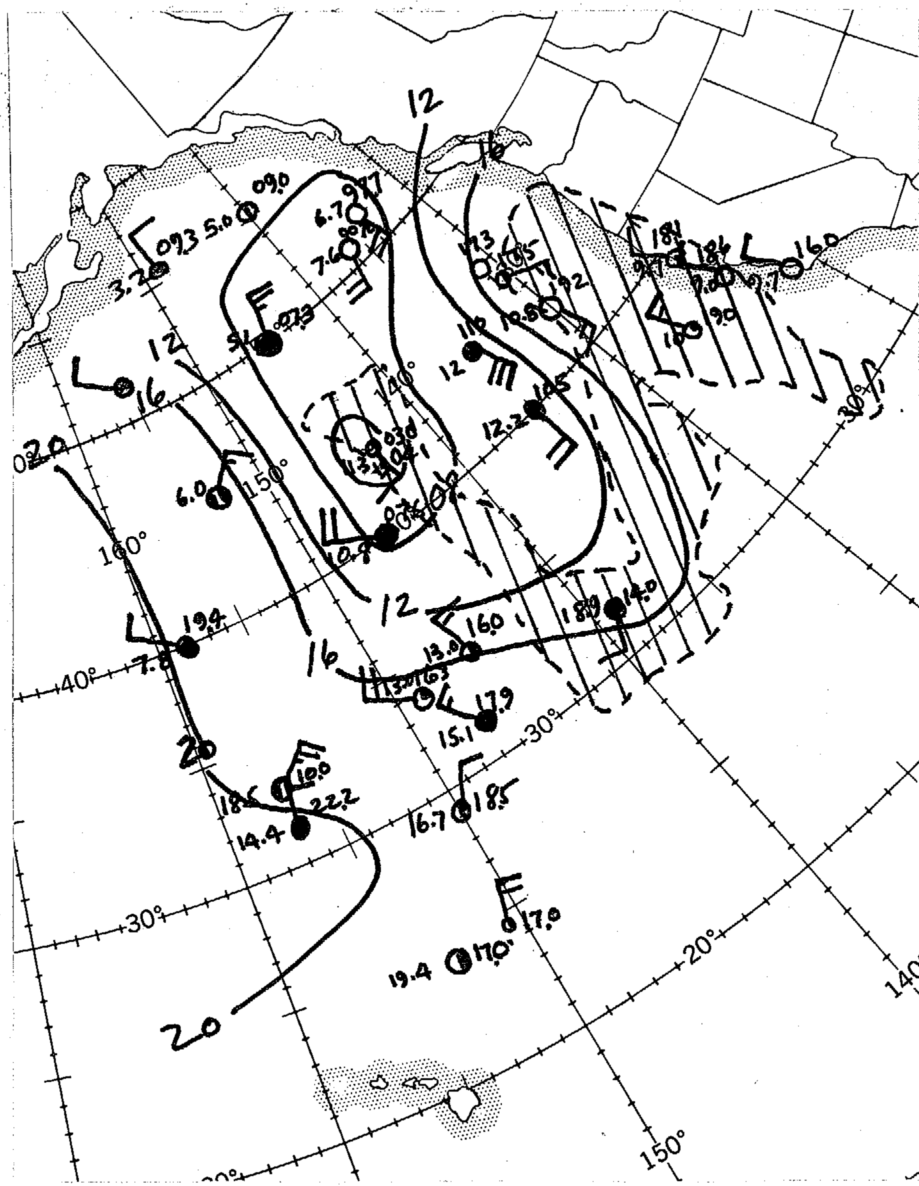


Figure 2. Surface ship observations and a few coastal surface observations with MSL analysis for 12 GMT 14 April 1981 (units are MSL pressure minus 1000 mb). Region containing VAS data is hatched.

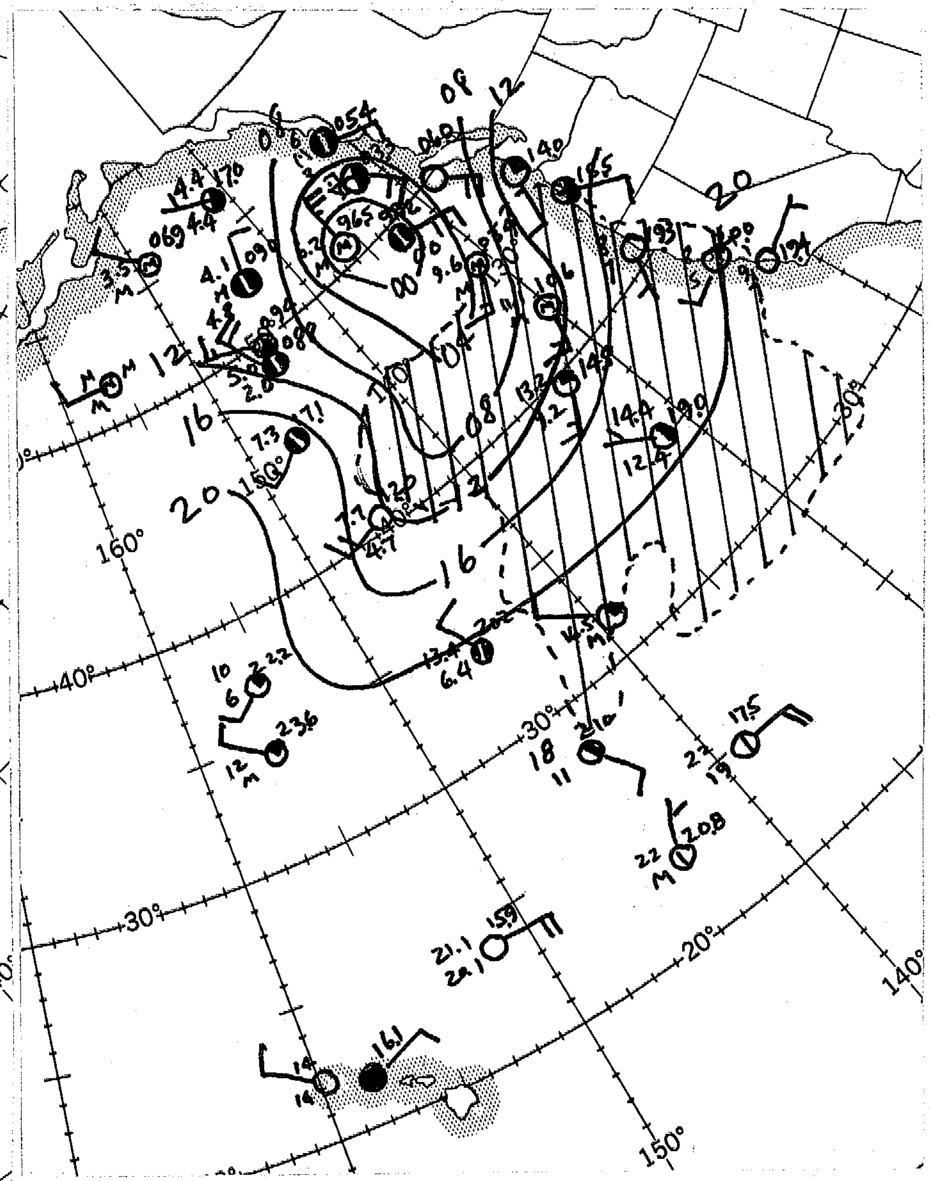


Figure 3. Surface ship observations and a few coastal surface observations with MSL analysis for 12 GMT 15 April 1981 (units same as for figure 2.). Region containing VAS data is hatched.

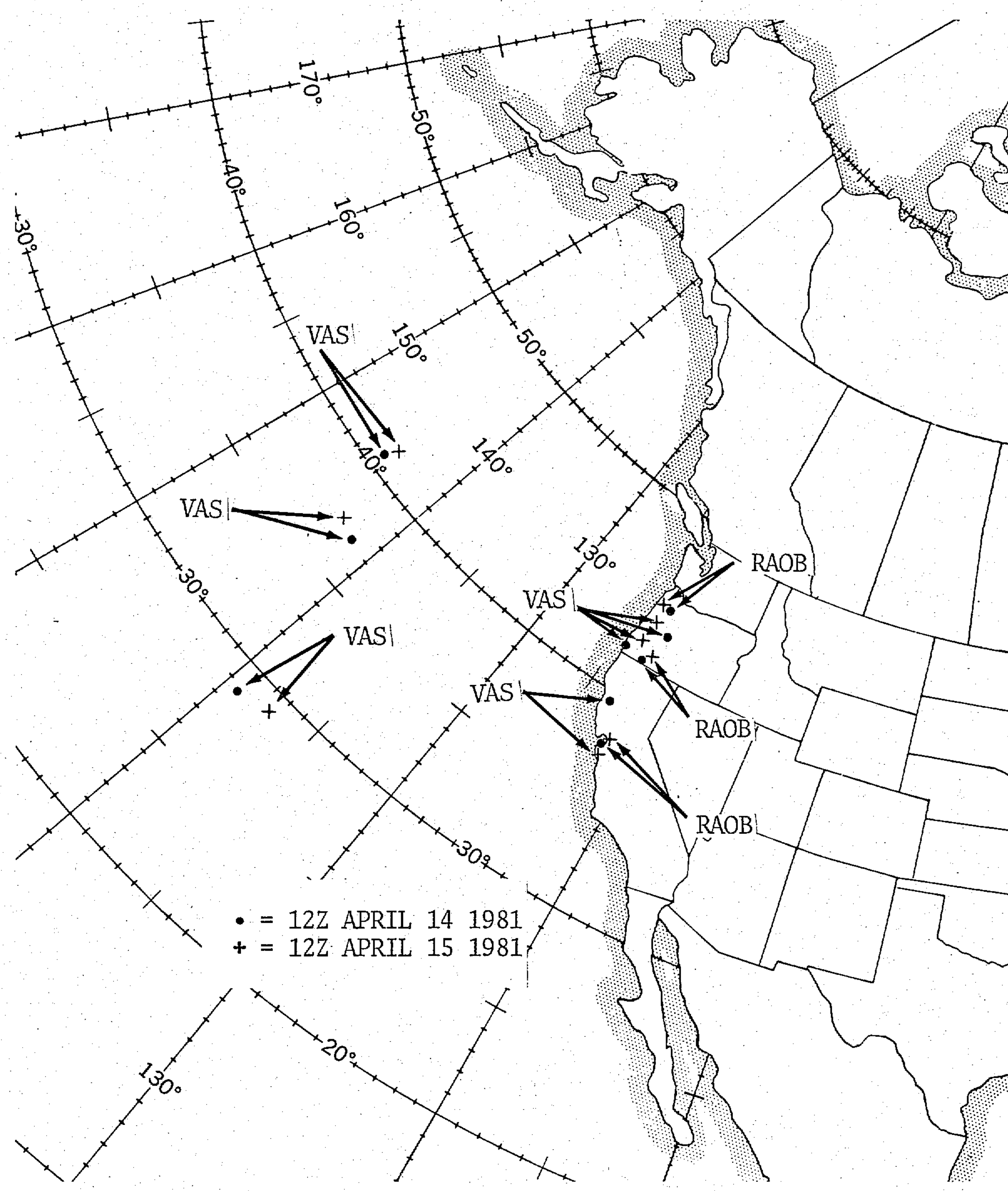


Figure 4. Locations of some selected VAS oceanic and coastal soundings, and coastal radiosondes.

(GF12) made from FINAL cycle, also valid at VAS observation time, and 4) the operational (Hough) analysis. Figure 5 shows VAS observation locations.

The differences between VAS thicknesses and the analysis or forecast thicknesses for various pressure layers were calculated and expressed in terms of thicknesses (in meters) according to

$$TK(Z) = (Z_2 - Z_1)_{vas} - (Z_2 - Z_1)_{nmc} \quad .$$

Mean temperature differences were expressed via the hypsometric equation as

$$TK(\overline{T}) = TK(Z) \cdot R_d \ln(P_1/P_2)$$

where,

$TK(Z)$ = thickness difference, in meters,

$TK(\overline{T})$ = mean temperature difference, in centigrade degrees,

Z_2 = height of upper pressure level P ,

Z_1 = height of lower pressure level P ,

R_d = gas constant for dry air.

Figures 6a and 6b show the 1000-500 millibar thickness and mean thickness-temperature differences for both cases, while Table 2 summarizes the gross statistical characteristics of the differences for this layer, for each case.

Table 2. Thickness and Mean Thickness-Temperature Difference Statistics, 1000-500 millibar Layer (Soundings over land excluded)

	CASE A, 12Z 14 April		CASE B, 12Z 15 April	
COMPARISON	MEAN DIFFERENCE $TK(Z)/TK(\overline{T})$ (m) (deg)	RMS DIFFERENCE $TK(Z)/TK(\overline{T})$ (m) (deg)	MEAN DIFFERENCE $TK(Z)/TK(\overline{T})$ (m) (deg)	RMS DIFFERENCE $TK(Z)/TK(\overline{T})$ (m) (deg)
VAS-FMANL	-72.9/-3.6	77.6/3.8	-45.6/-2.3	51.6/2.5
VAS-FM12	-78.6/-3.9	84.5/4.2	-46.8/-2.4	54.0/2.7
VAS-GF12	-54.5/-2.7	58.3/2.9	-45.6/-2.2	54.3/2.7
VAS-ANL	-53.1/-2.6	60.0/3.0	-47.8/-2.4	53.0/2.6

The VAS-FMANL and VAS-FM12 differences in Table 2 are about forty percent larger for Case A than for Case B, while those for VAS-GF12 and VAS-ANL (Hough) are only about fifteen percent larger. In contrast, the Case B mean and RMS differences for all four comparisons are nearly identical. Thus, the LFM may have been poorly initialized in Case A and, therefore, the impact of VAS data may be larger in that case than for Case B.

Vertical profiles of mean and RMS thickness (figures 7,8) exhibit some notable similarities and differences between the two cases. The

A

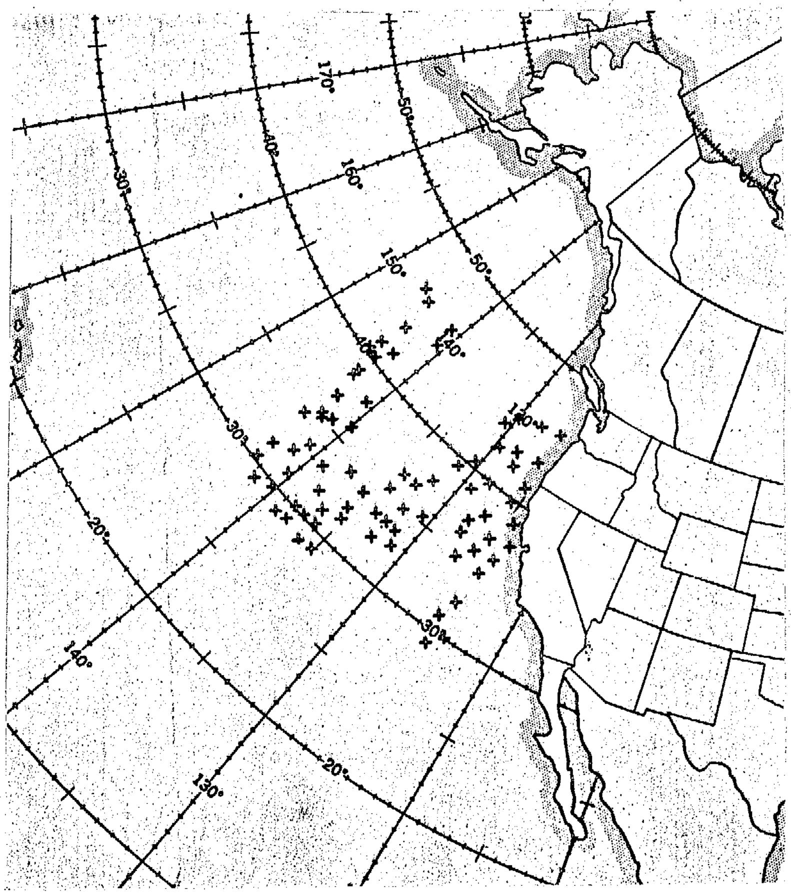


Figure 5a. Location of VAS observations at 12 GMT 14 April 1981.

B

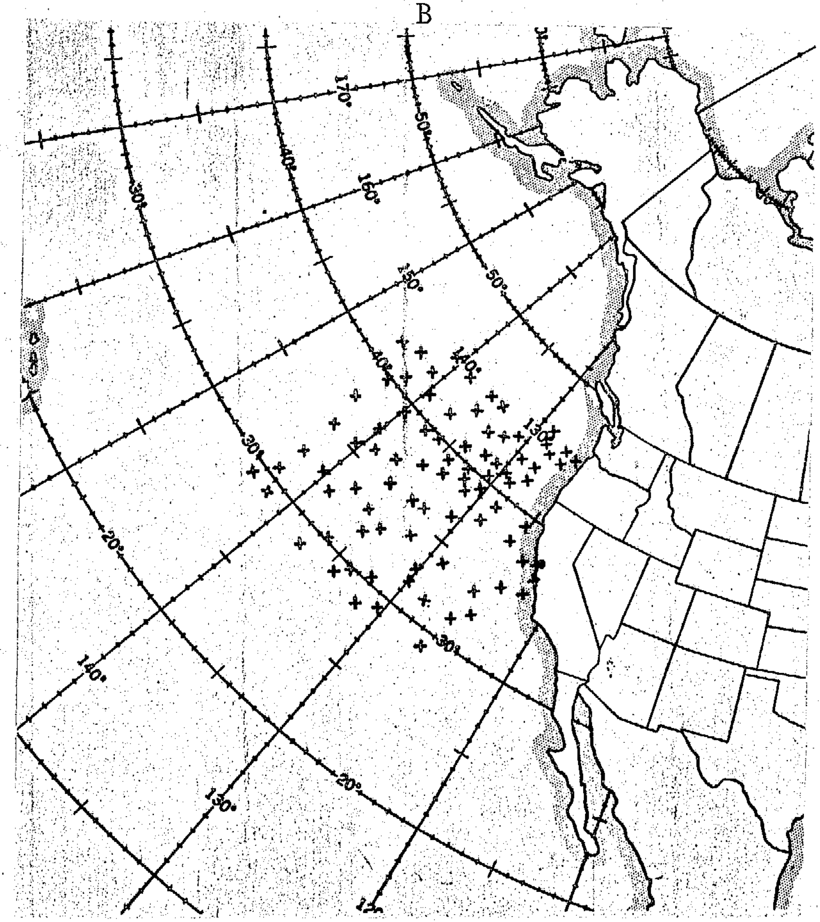


Figure 5b. Location of VAS observations at 12 GMT 15 April 1981.

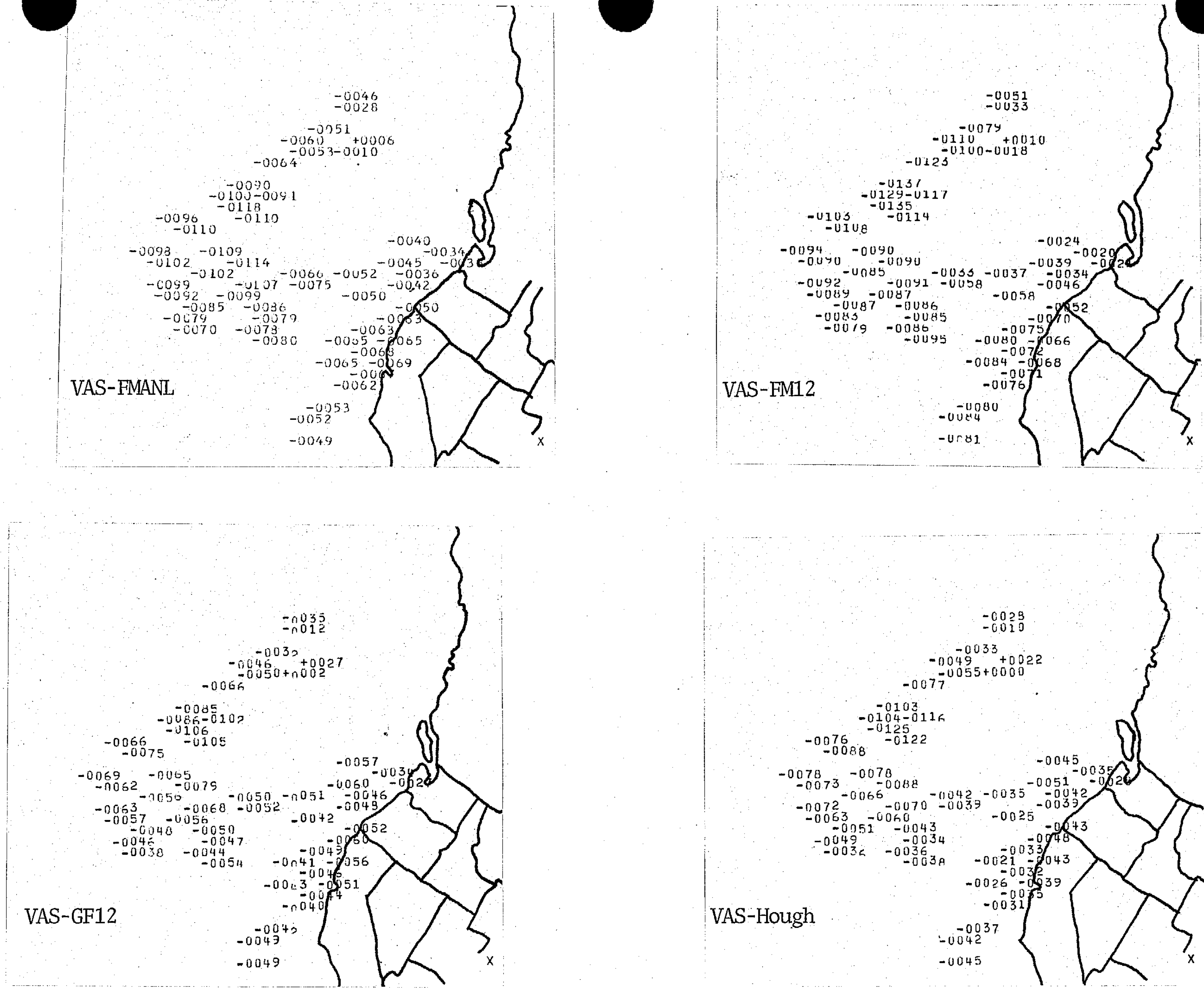


Figure 6a. 1000-500 mb thickness differences (meters), 12 GMT 14 April 1981.

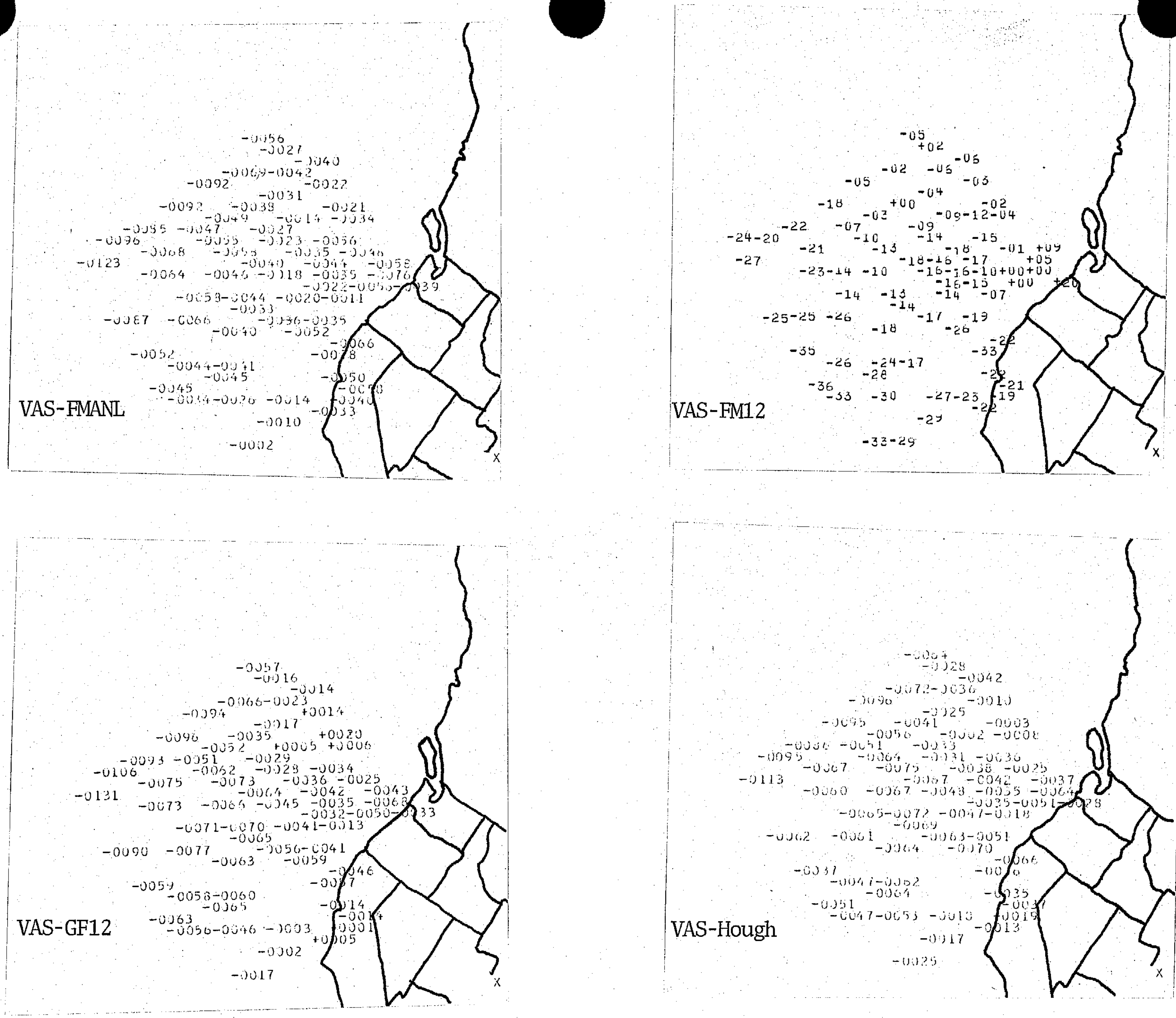


Figure 6b. 1000-500 mb thickness differences (meters), 12 GMT 15 April 1981.

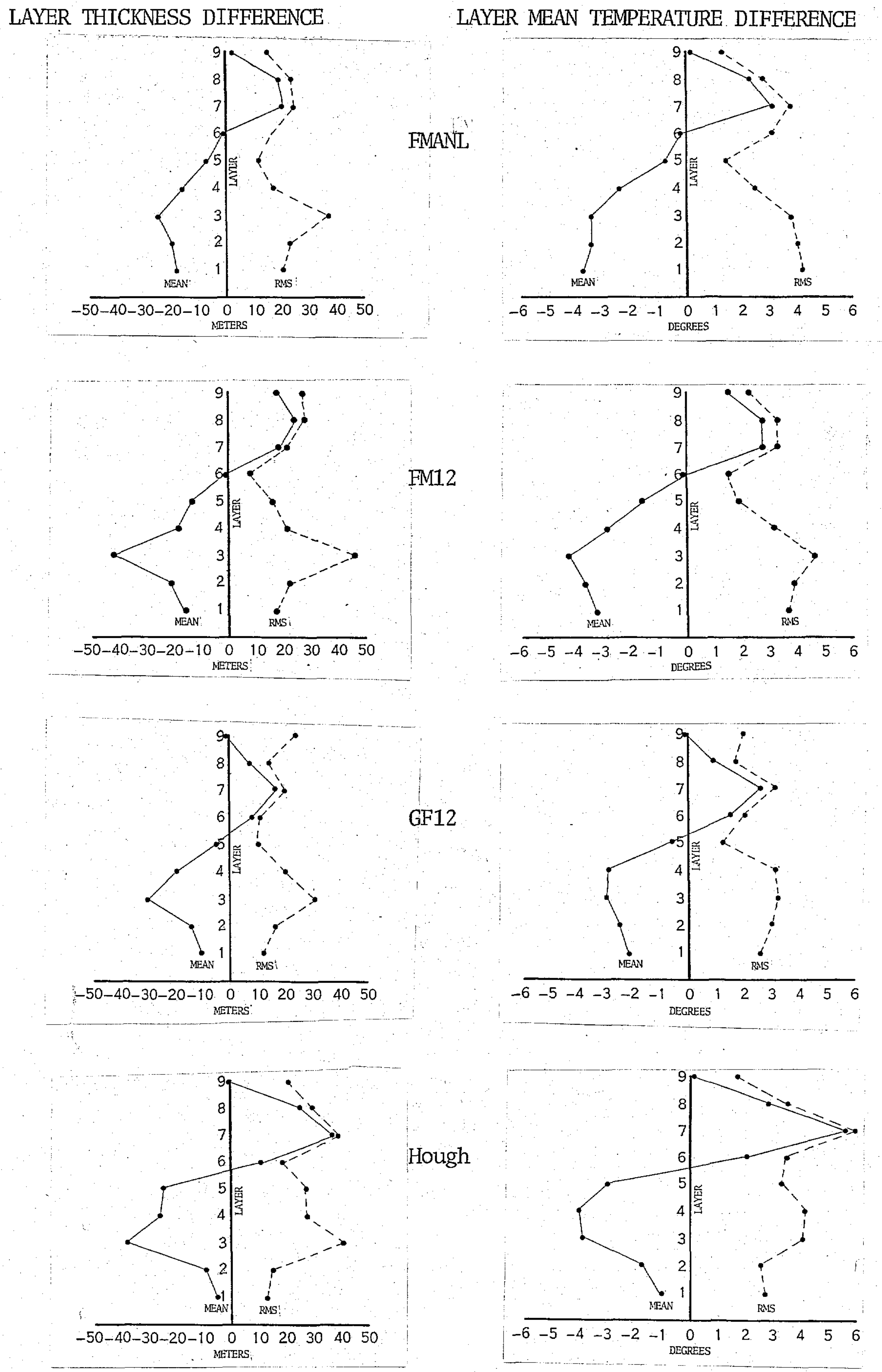


Figure 7. Thickness (meters) and mean temperature differences (degrees), 12 GMT 14 April 1981, for 74 soundings over water.

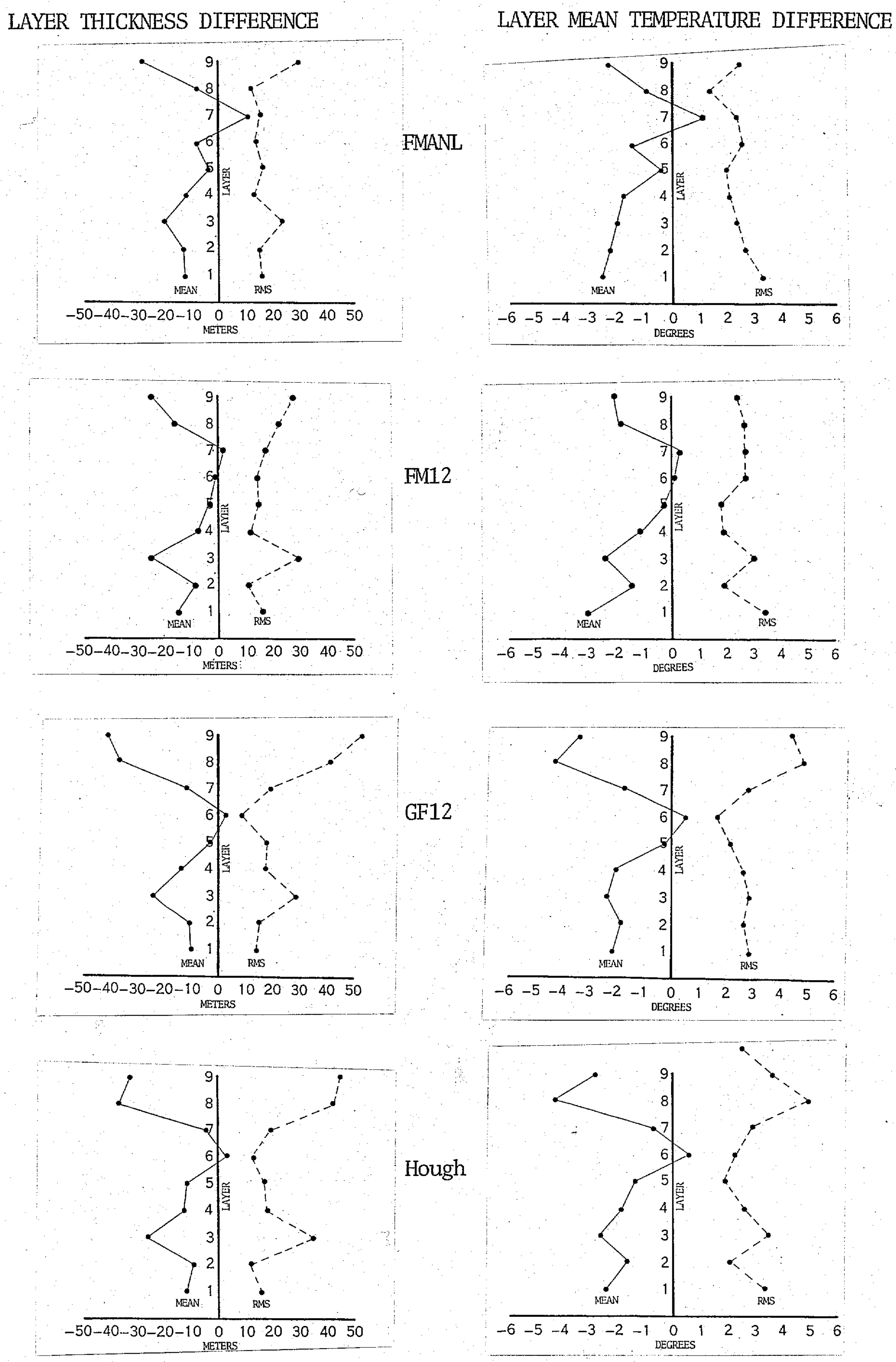


Figure 8. Thickness (meters) and mean temperature differences (degrees), 12 GMT April 1981, for 83 soundings over water.

large 1000-500mb VAS-FMANL and VAS-FM12 differences in Case A, mentioned previously, are largely accounted for by very large (up to 4.5 degrees) cold biases in layers 1-3 (Figure 7). In fact, both cases contain substantial layer 1 differences, indicating that the assignment of VAS 1000 mb temperatures could possibly be improved. Currently, surface temperatures in VAS soundings over water are taken exclusively from the FM12 first-guess. Sea surface temperatures are not used in constructing VAS soundings, nor is any input from VAS sounding data, except for soundings over land (Kit Hayden, personal communication).

Vertical profiles of mean and rms thickness difference and mean temperature difference (figures 7,8) contain some notable similarities and differences between the two cases. Table 3 summarizes these attributes.

3. LFM Analysis with and without VAS data.

In order to obtain a subjective measure of the impact of VAS data upon LFM analyses, LFM analysis reruns were performed using VAS data and compared with the original (no-VAS) analyses (Figure 9). The effects of using VAS data in the Case A LFM analysis (FMANL), made apparent in Figures 9a,b, include

1) deepening of the trough at 42.5° N and 142° W by about 30 meters and extending its influence farther south;

2) the height contours just west of the Oregon and California coasts are turned from a southwest-to-northeast orientation to a more south-to-north orientation.

The effect of the VAS data on the Case B FMANL (Figures 9 c,d) is similar to that observed in the previous case. The short wave-length trough approaching the coast is deepened, the height gradient is rotated more east-west. Subsequent forecasts from these analyses are required to demonstrate the true effect of VAS data upon the LFM analysis/forecast system for these two cases. These forecasts are presented and discussed in Part 2 of this preliminary evaluation (Office note 245).

4. Results and Conclusions.

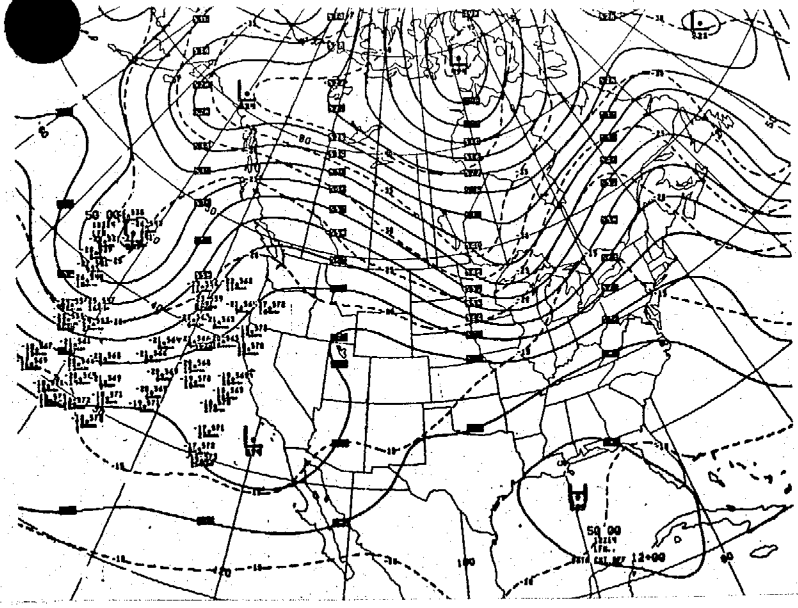
This note has presented a preliminary evaluation of VISSR Atmospheric Sounder (VAS) data for two cases during April 1981.

VAS and radiosonde temperature profiles were first compared subjectively. Similarities between VAS and radiosonde soundings over land (Appendix 1) were attributed to a combination of the probable influence of the first guess at upper levels, and to the use of Service A observations to provide surface temperatures. The VAS data was observed to be cold-biased below about 300 mb. Mean and rms difference statistics of thickness difference and thickness-temperature difference (VAS-minus analysis, or forecast) confirm that the VAS soundings were 2-4 centigrade degrees cooler than radiosondes below 300 mb in both cases. However, only in Case A were VAS soundings also 1-3 degrees too warm above 300 mb.

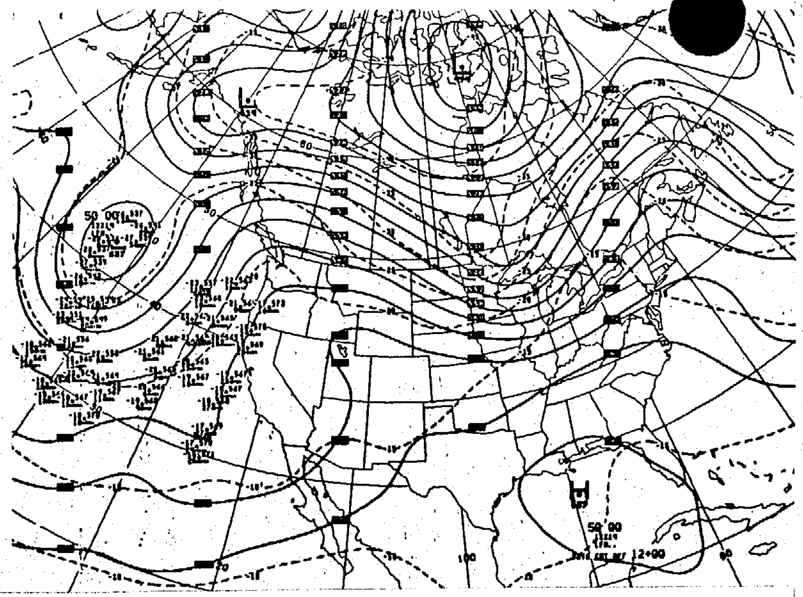
Table 3. Comparison and Contrast of Thickness and Temperature Difference Profiles

similarities	differences
1) profiles for both cases are very similar in both mean difference (negative bias) and in shape below layer 6* (300-250 mb layer),	1) Case A has a pronounced positive mean difference above layer 6,
2) both cases contain relative maxima of mean difference at layer 6 or 7*,	2) Case B has its relative maxima of mean difference at layer 6, lower than in Case A,
3) two-dimensional plots (figure 6) show that largest differences for both cases occur farthest from the California coast and nearest the cold air.	3) Case B has smaller differences than Case A below layer 6, by about 1 centigrade degree and 10 m.

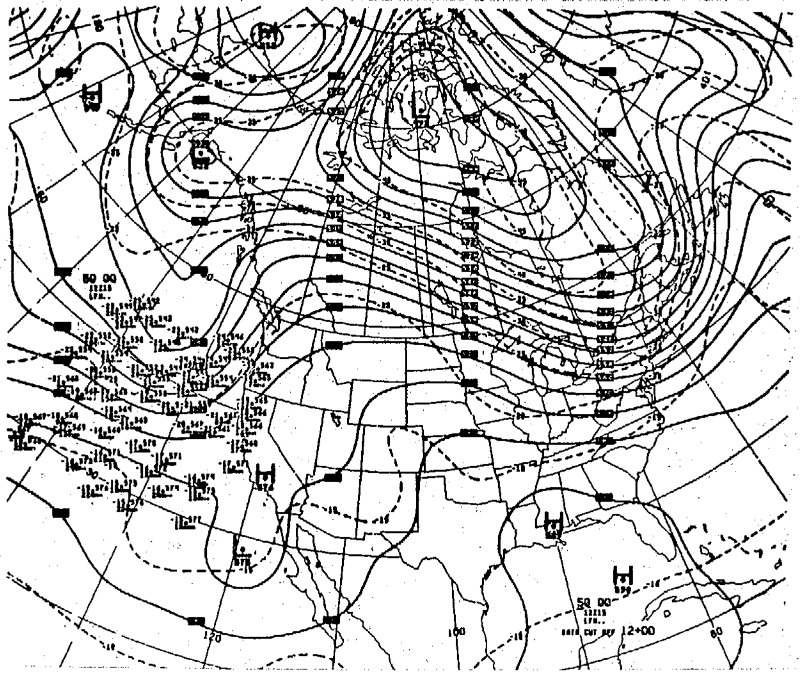
* The layers referred to are defined as follows:
layer 1 = 1000 to 850 mb
layer 2 = 850 to 700 mb
layer 3 = 700 to 500 mb
layer 4 = 500 to 400 mb
layer 5 = 400 to 300 mb
layer 6 = 300 to 250 mb
layer 7 = 250 to 200 mb
layer 8 = 200 to 150 mb
layer 9 = 150 to 100 mb



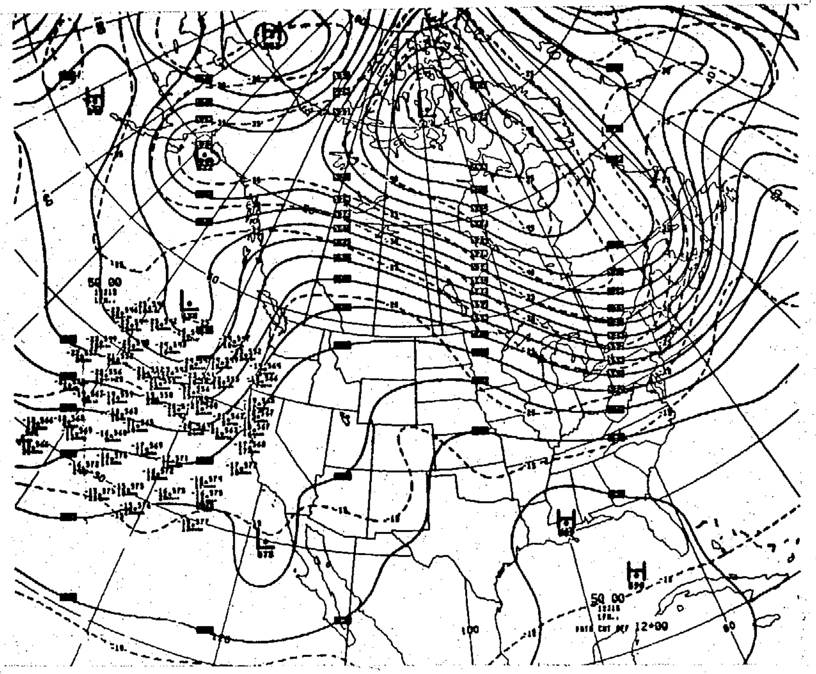
a. Analysis without VAS, 12 GMT 14 April 1981



b. Analysis with VAS, 12 GMT 14 April 1981



c. Analysis without VAS, 12 GMT 15 April 1981



d. Analysis with VAS, 12 GMT 15 April 1981

Figure 9. LFM 500 mb analyses of heights and temperatures, without and with VAS data (VAS data is over-plotted).

The potential for the VAS data to significantly impact the LFM analysis system was demonstrated by comparing LFM analyses made with, and without VAS data. In both Cases A and B, introducing VAS data in the analysis increased the amplitude of the major height field features. Forecasts performed from these analyses are presented in Part 2 of this evaluation (NMC Office Note 245).

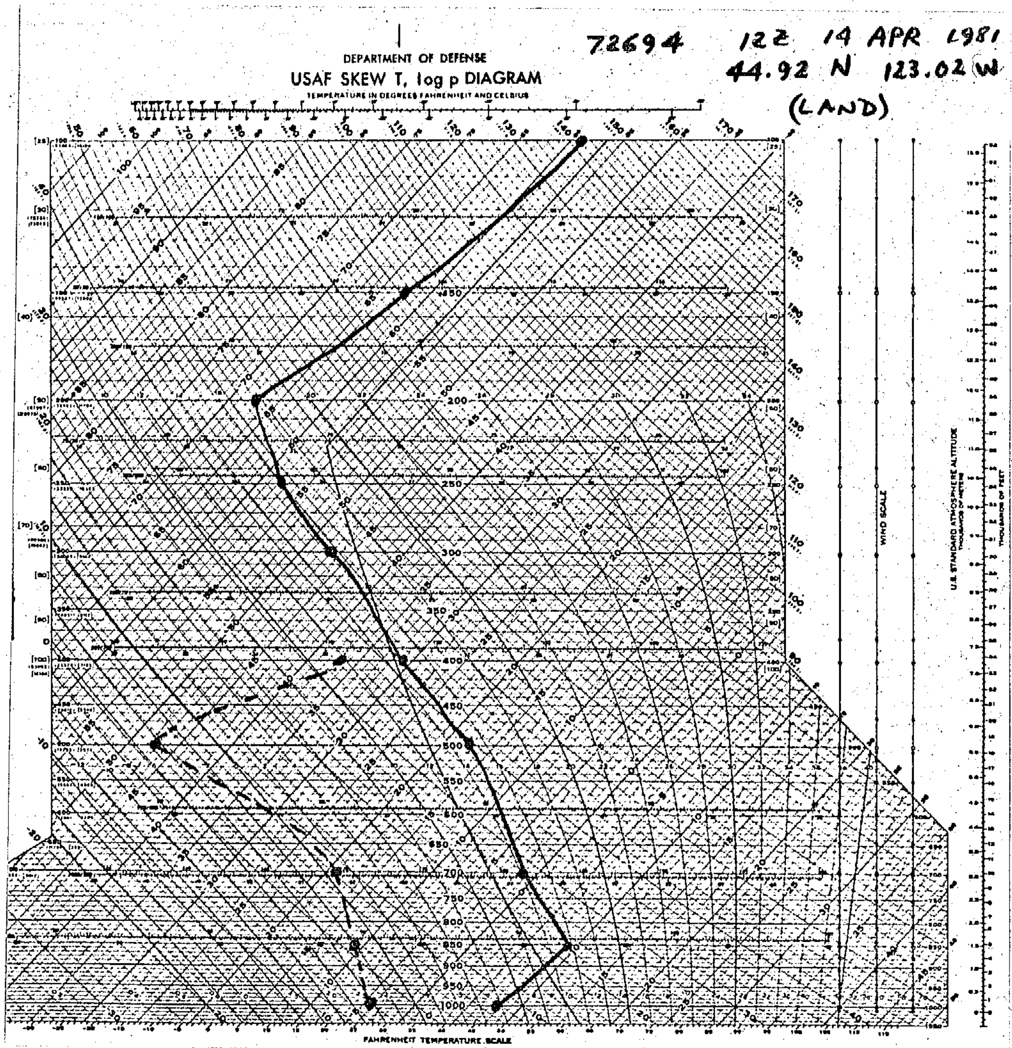
REFERENCES

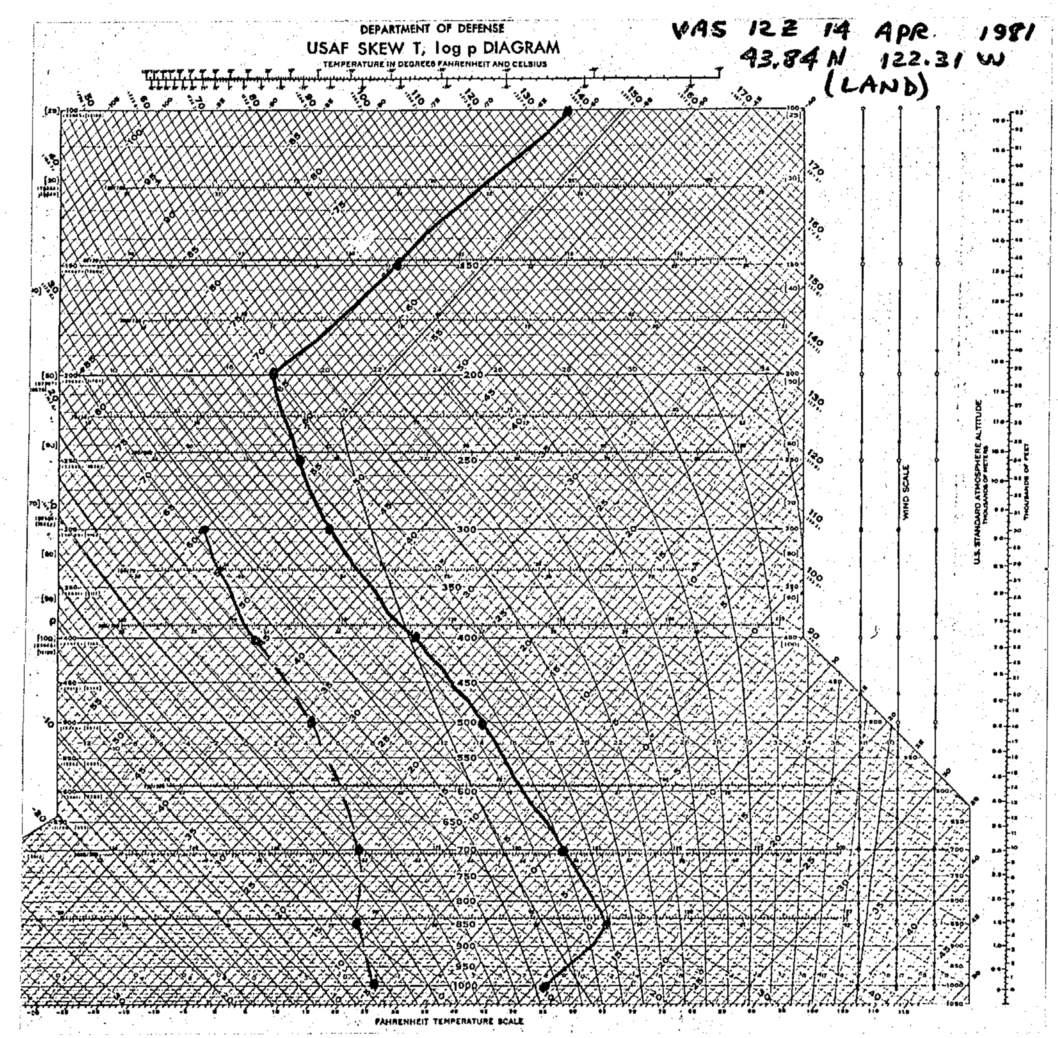
Smith, W.L., 1981: First Sounding Results from VAS-D. Bull. of the Amer. Meteor. Soc., 62, 232-236.

______, 1981: Algorithms Used to Retrieve Surface Skin Temperature and Vertical Temperature and Moisture Profiles from VISSR Atmospheric Sounder (VAS) Radiance Observations, Preprint Volume: Fourth Conference on Atmospheric Radiation, June 16-18, 1981, Toronto, Ont., Canada, Published by the Amer. Meteor. Soc., Boston, Mass.

APPENDIX 1

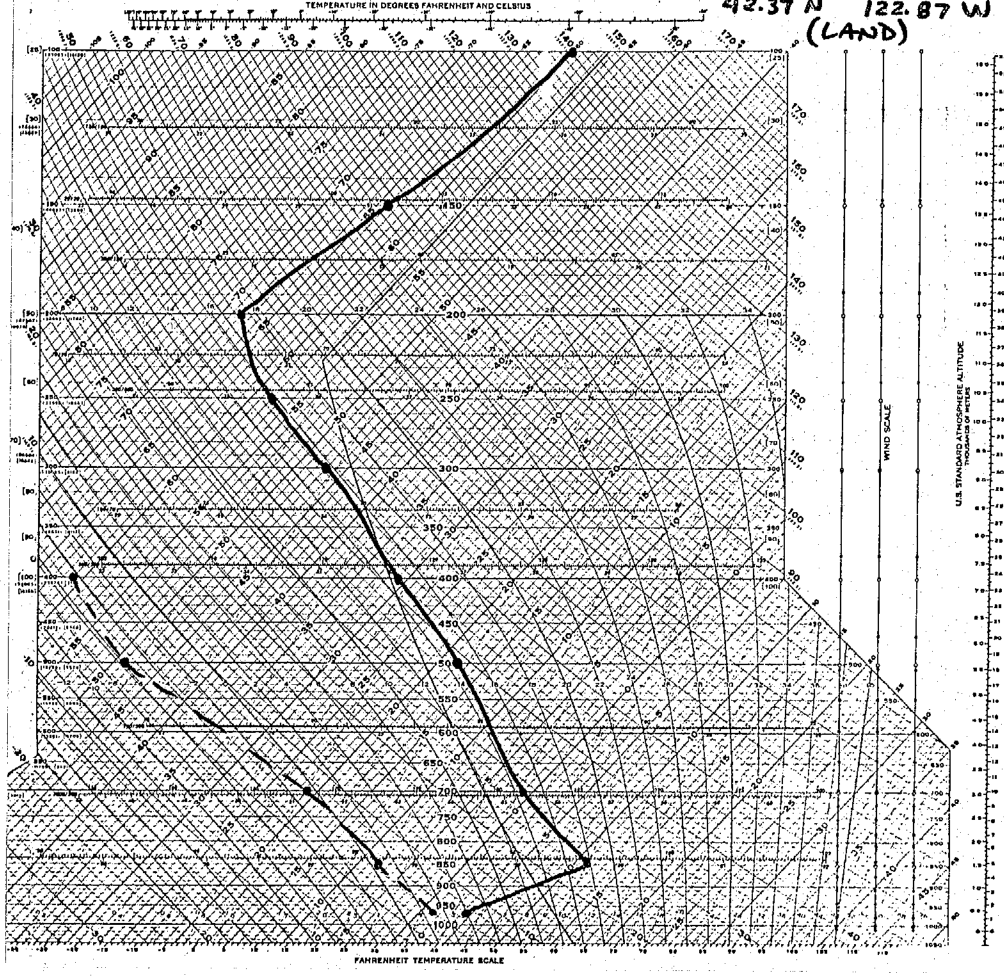
Proximate VAS and Radiosonde Vertical Temperature Profiles


72694 12Z 14 APR 1981
44.92 N 123.02 W
(LAND)
DEPARTMENT OF DEFENSE
USAF SKEW T, log p DIAGRAM
TEMPERATURE IN DEGREES FAHRENHEIT AND CELSIUS
WIND SCALE
U.S. STANDARD ATMOSPHERE ALTITUDE
FAHRENHEIT TEMPERATURE SCALE


VAS 12Z 14 APR 1981
43.84 N 122.31 W
(LAND)
DEPARTMENT OF DEFENSE
USAF SKEW T, log p DIAGRAM
TEMPERATURE IN DEGREES FAHRENHEIT AND CELSIUS
WIND SCALE
U.S. STANDARD ATMOSPHERE ALTITUDE
FAHRENHEIT TEMPERATURE SCALE

DEPARTMENT OF DEFENSE
USAF SKEW T, log p DIAGRAM

72597 12Z 14 APR 1981
42.37 N 122.87 W
(LAND)



DEPARTMENT OF DEFENSE
USAF SKEW T, log p DIAGRAM

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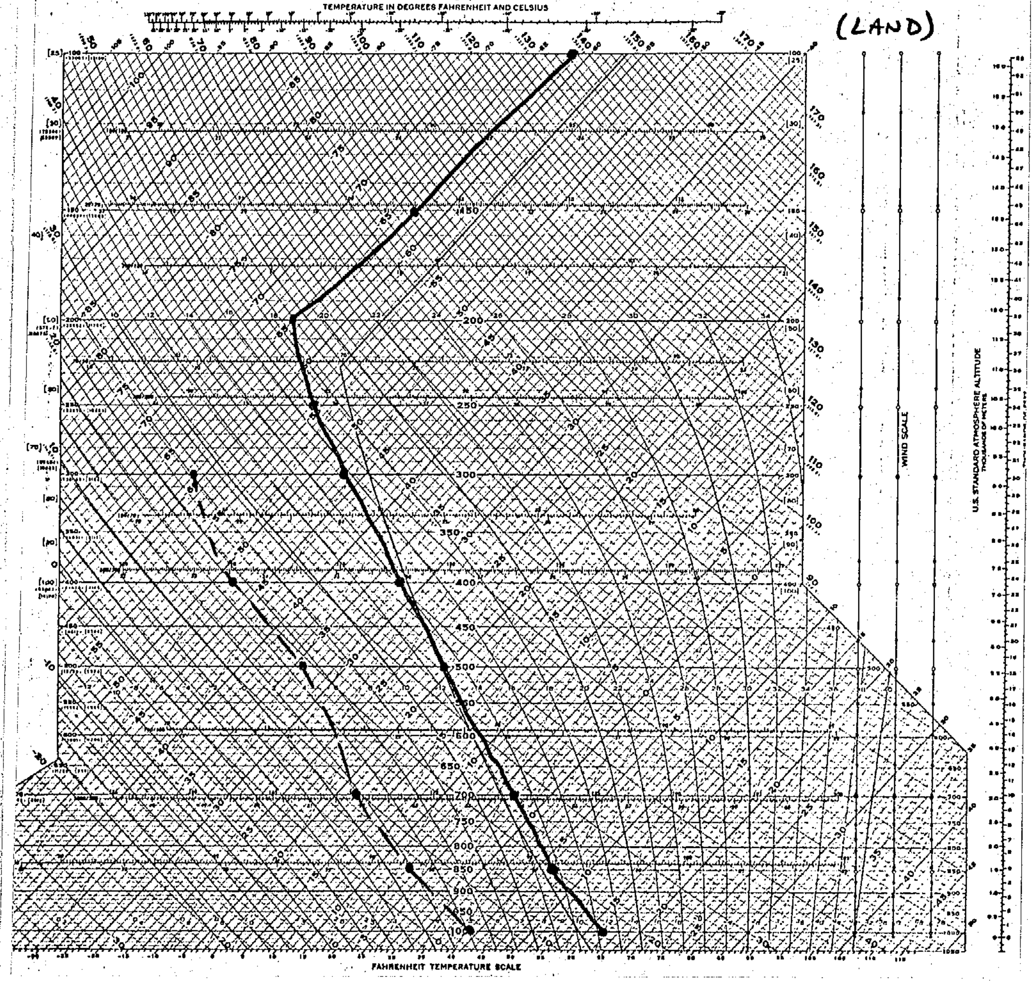
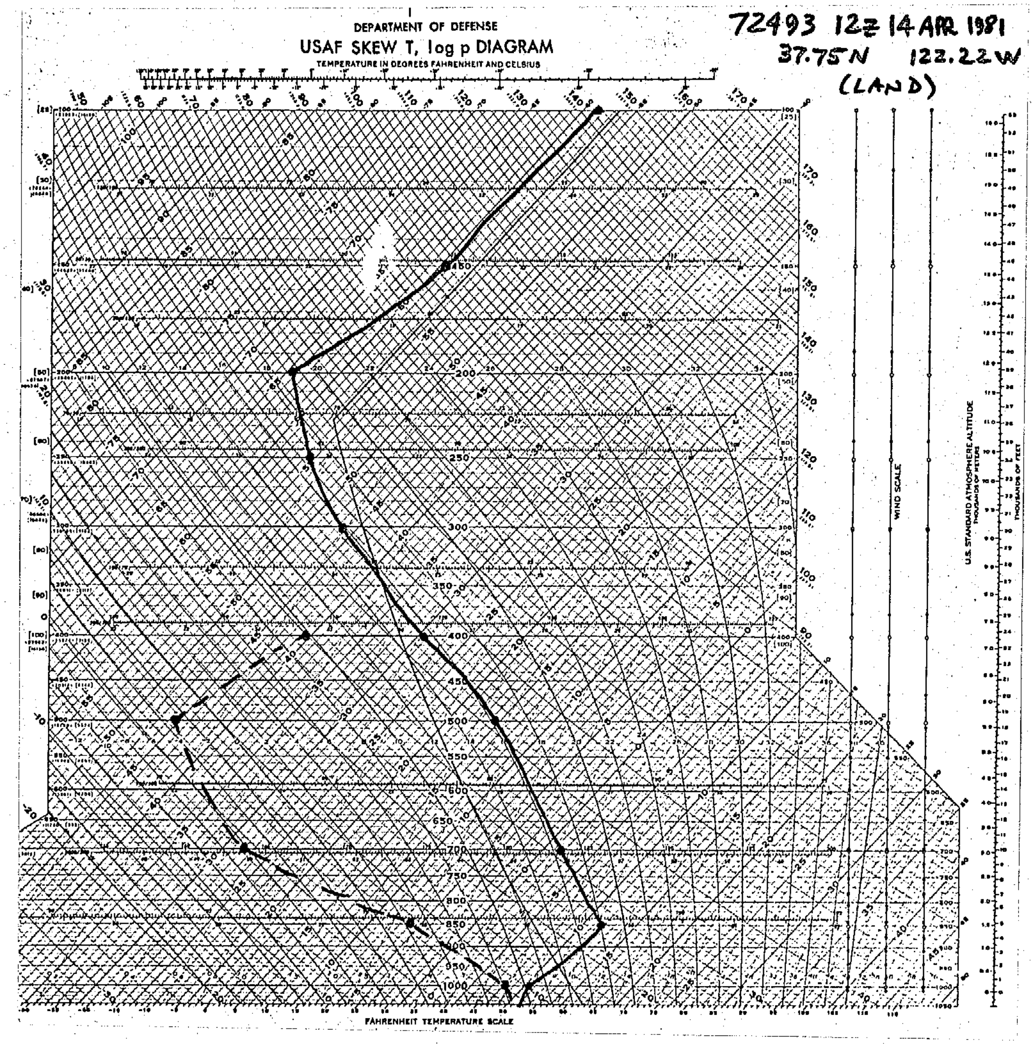
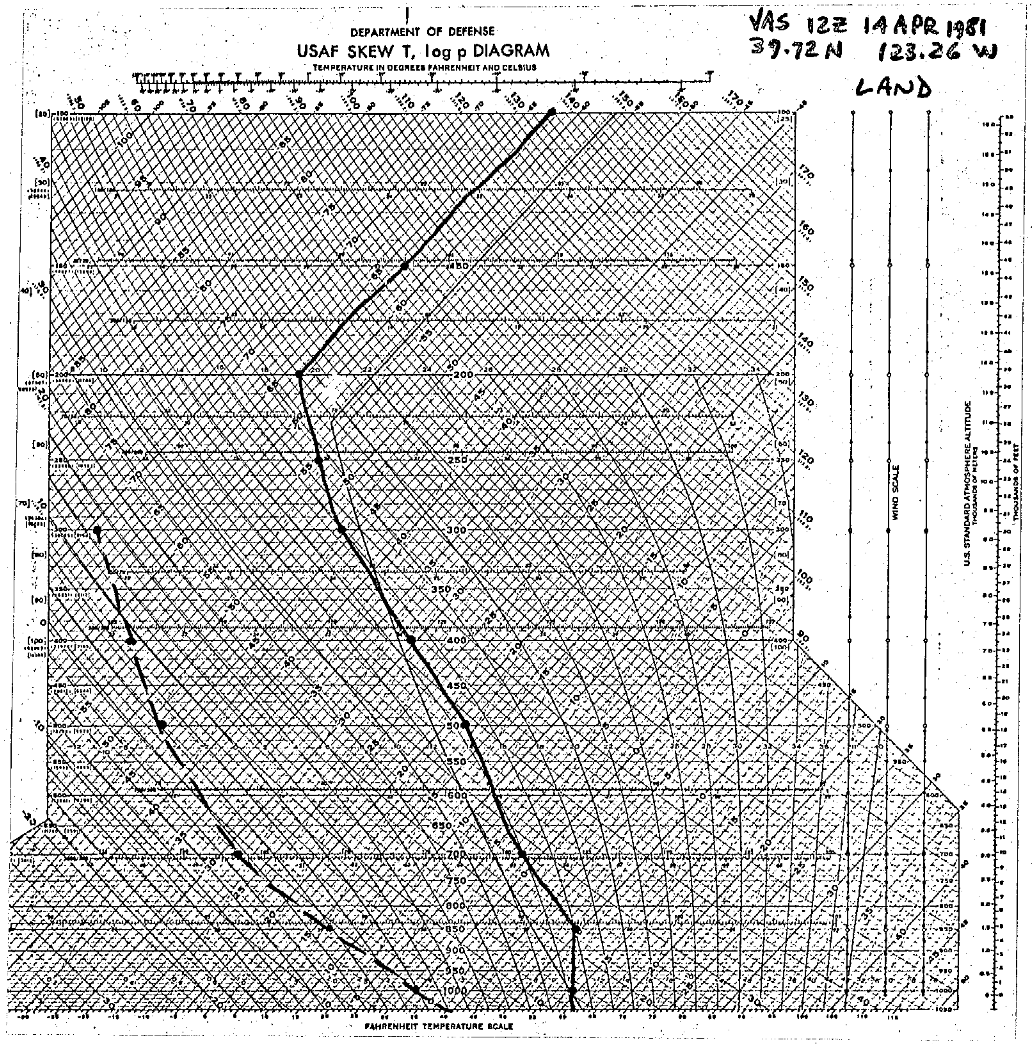
(LAND)




DEPARTMENT OF DEFENSE
USAF SKEW T, log p DIAGRAM
TEMPERATURE IN DEGREES FAHRENHEIT AND CELSIUS
72493 12Z 14 APR 1981
37.75N 122.22W
(LAND)
WIND SCALE
U.S. STANDARD ATMOSPHERE ALTITUDE
FAHRENHEIT TEMPERATURE SCALE


DEPARTMENT OF DEFENSE
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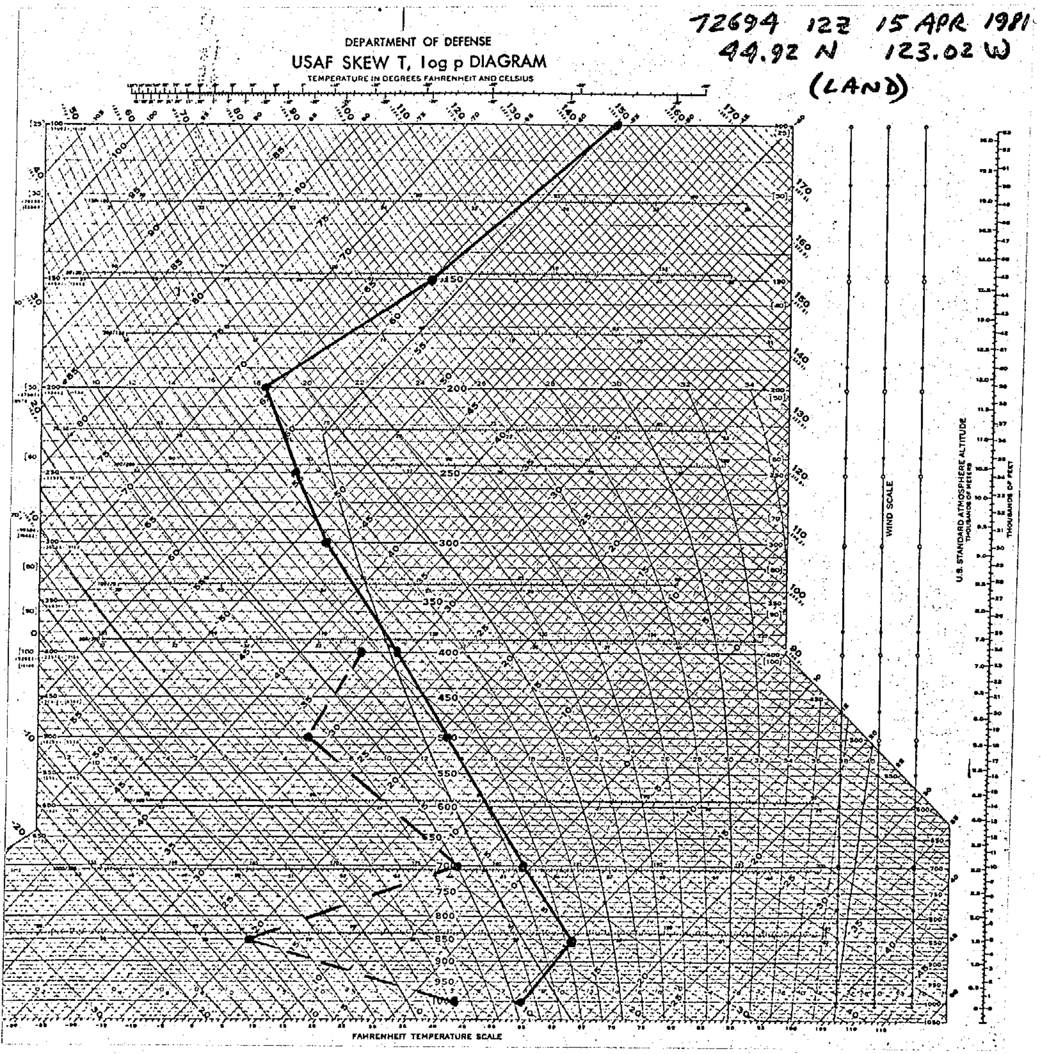
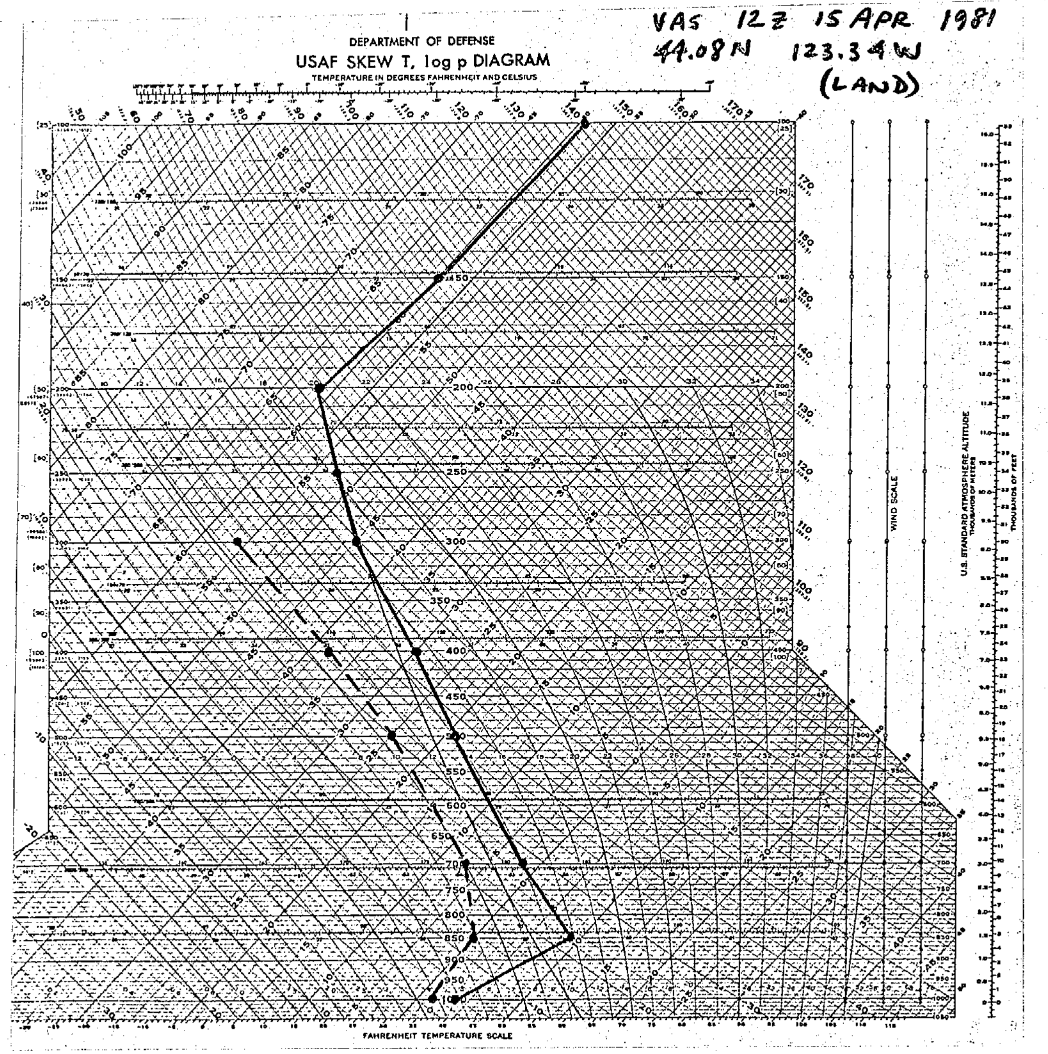
U.S. STANDARD ATMOSPHERE ALTITUDE
FAHRENHEIT TEMPERATURE SCALE


72694 12Z 15 APR 1981
44.92 N 123.02 W
(LAND)
DEPARTMENT OF DEFENSE
USAF SKEW T, log p DIAGRAM
TEMPERATURE IN DEGREES FAHRENHEIT AND CELSIUS
WIND SCALE
U.S. STANDARD ATMOSPHERE ALTITUDE
FAHRENHEIT TEMPERATURE SCALE


VAS 12Z 15 APR 1981
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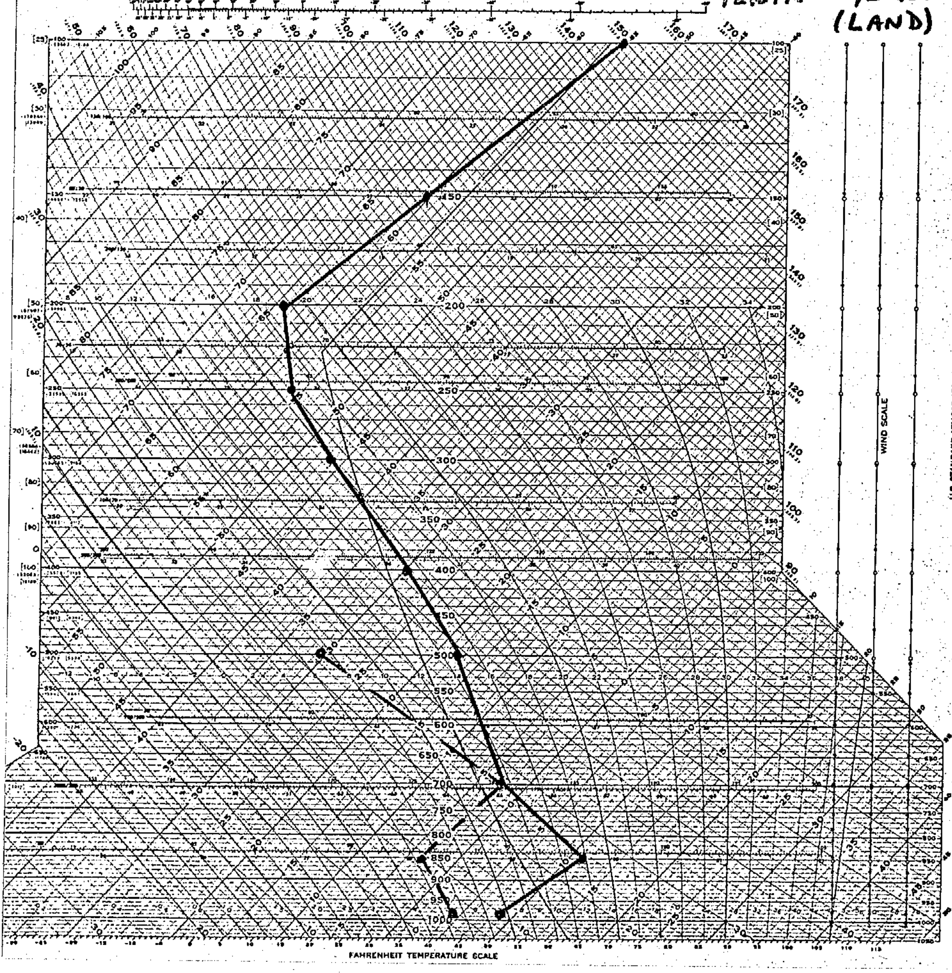
(LAND)
DEPARTMENT OF DEFENSE
USAF SKEW T, log p DIAGRAM
TEMPERATURE IN DEGREES FAHRENHEIT AND CELSIUS
WIND SCALE
U.S. STANDARD ATMOSPHERE ALTITUDE
FAHRENHEIT TEMPERATURE SCALE

72597 12Z 15 APR 1981
42.37N 122.87W
(LAND)

DEPARTMENT OF DEFENSE
USAF SKEW T, log p DIAGRAM
TEMPERATURE IN DEGREES FAHRENHEIT AND CELSIUS



VAS 12Z 15 APR 1981
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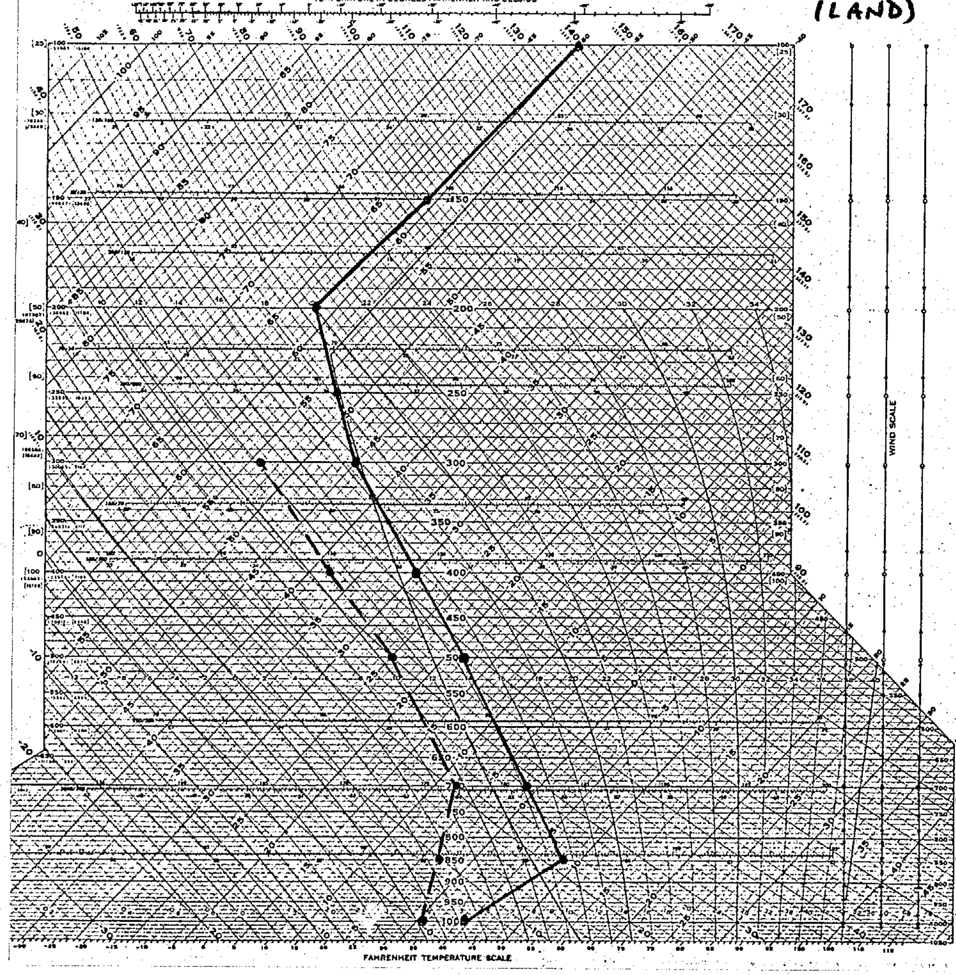
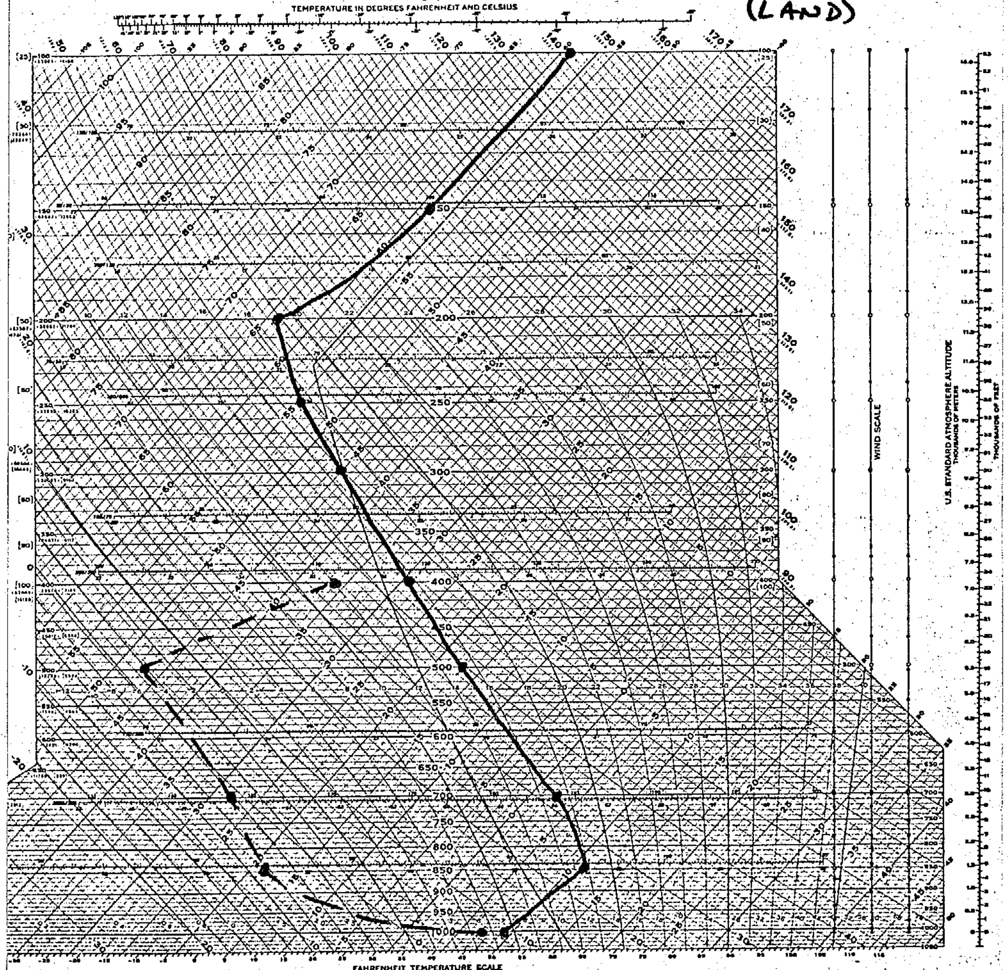
(LAND)

DEPARTMENT OF DEFENSE
USAF SKEW T, log p DIAGRAM
TEMPERATURE IN DEGREES FAHRENHEIT AND CELSIUS



72493 12 Z 15 APR
37.75 N 122.22 W
(LAND)



VAS 12 Z 15 APR 1981
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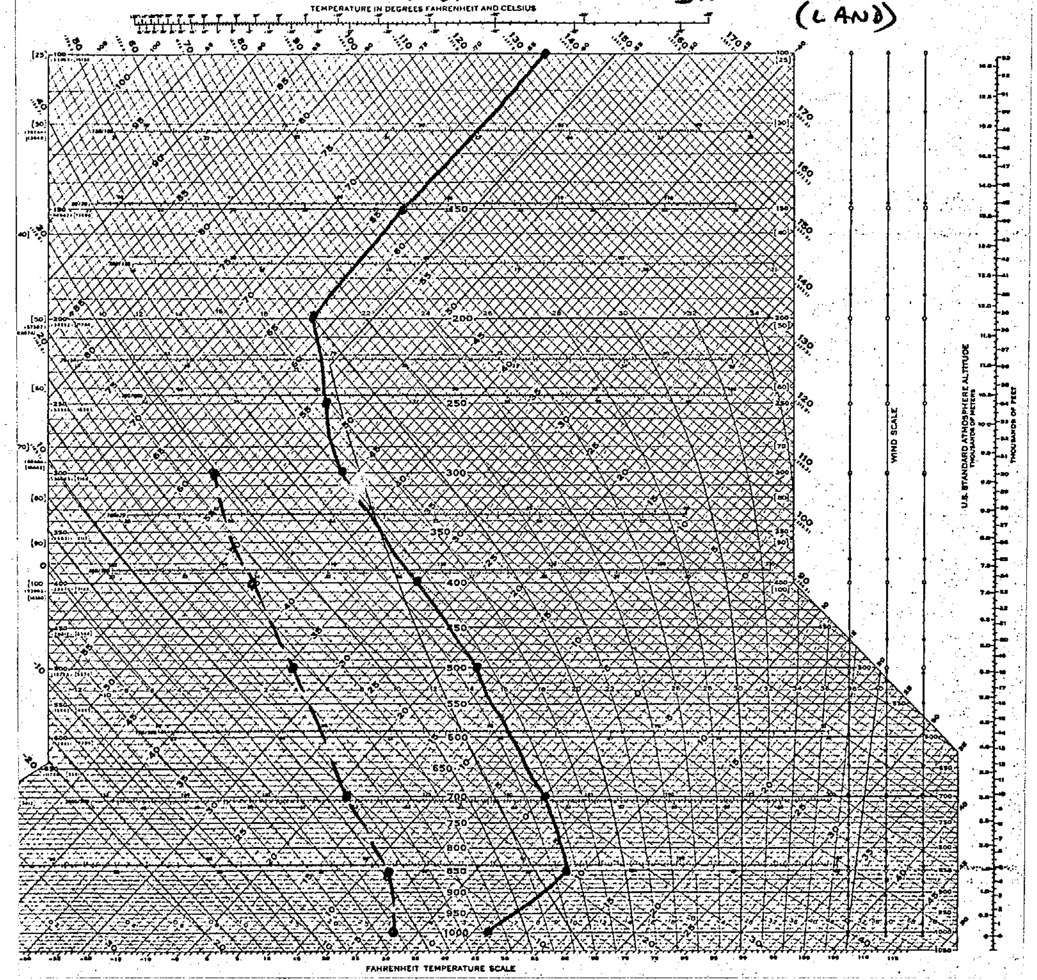
(LAND)

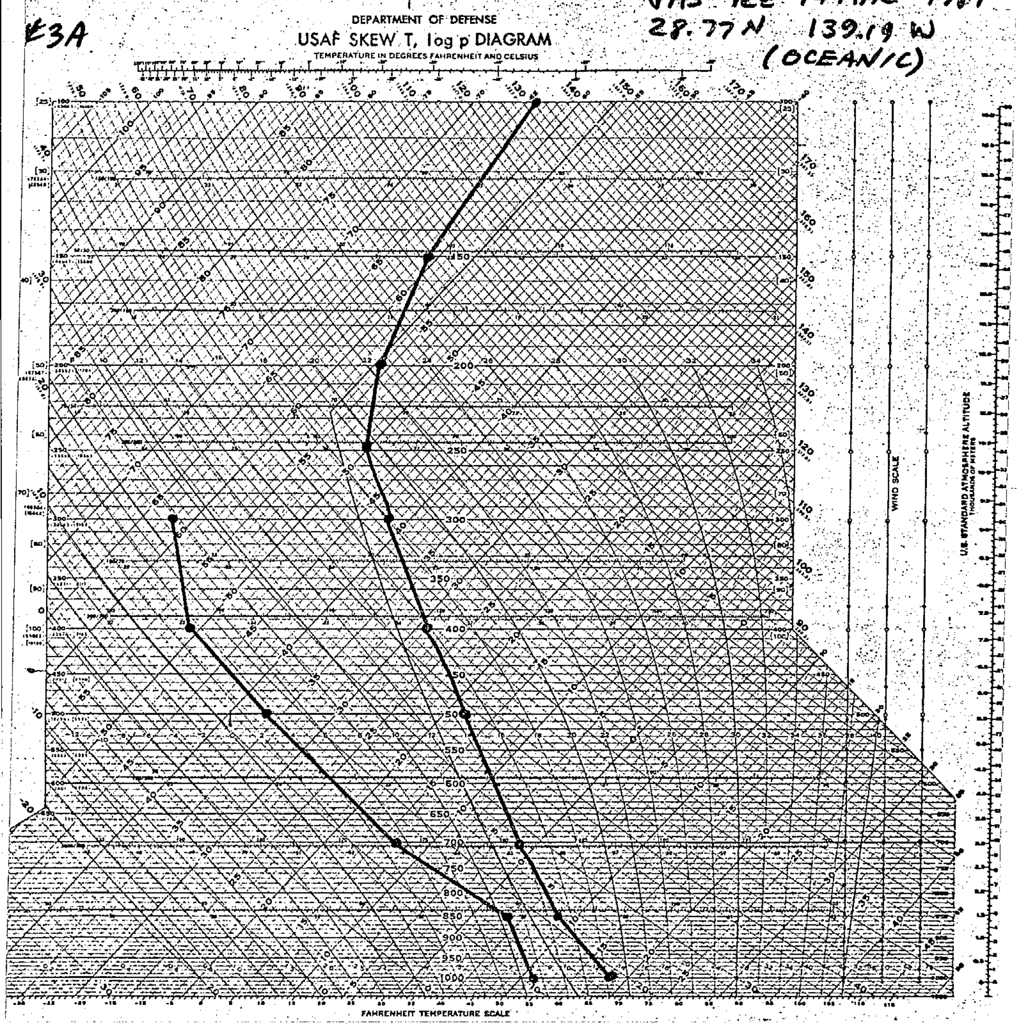


APPENDIX 2

Oceanic VAS Vertical Temperature Profiles

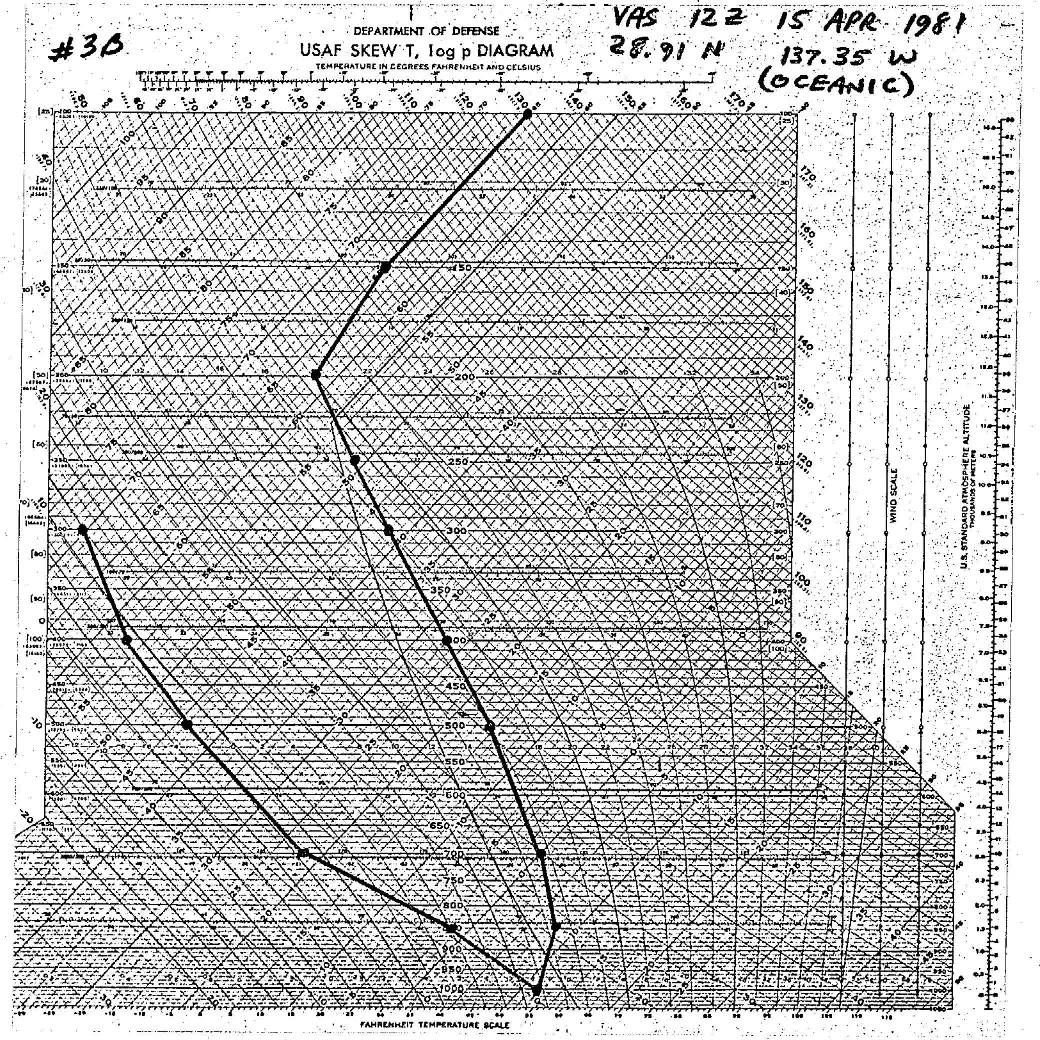
#3A

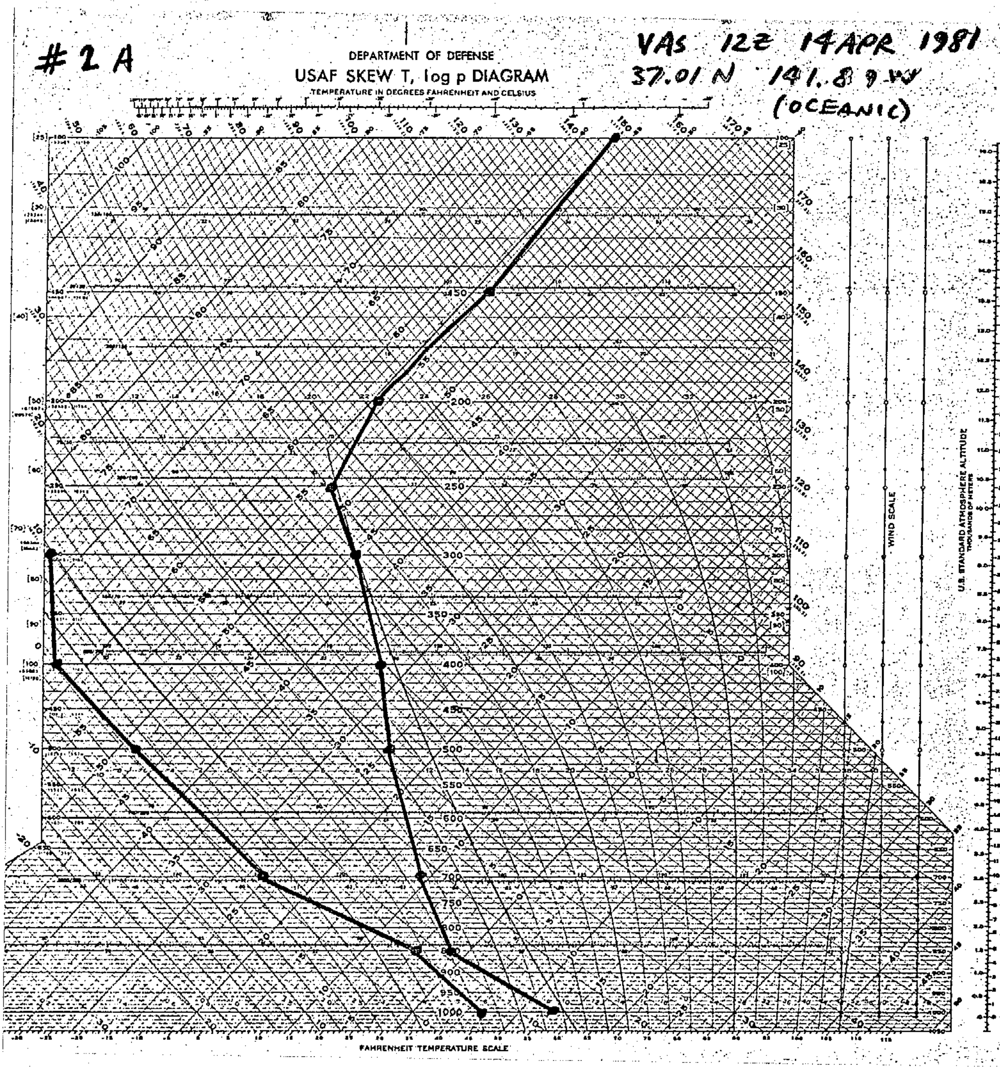
VAS 12Z 14 APR 1981
28.77 N 139.19 W
(OCEANIC)

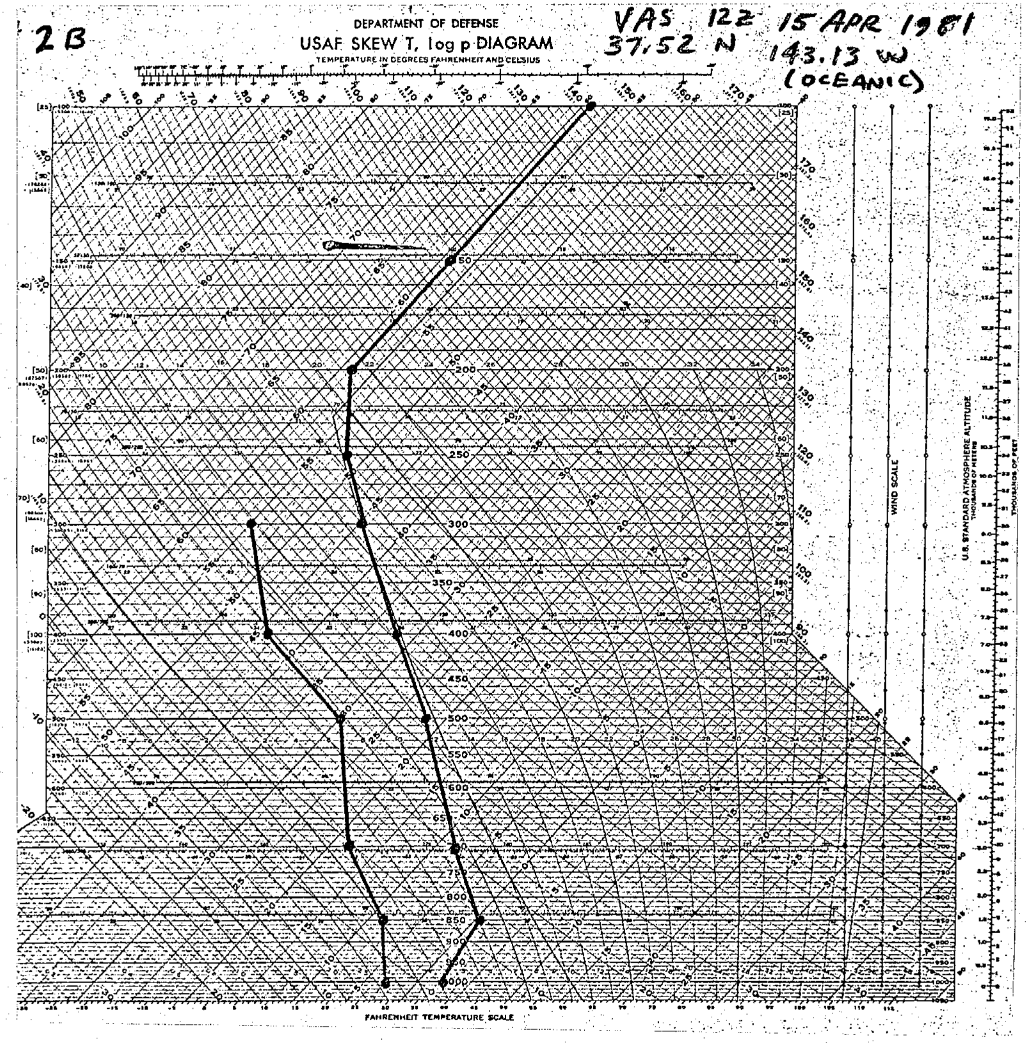


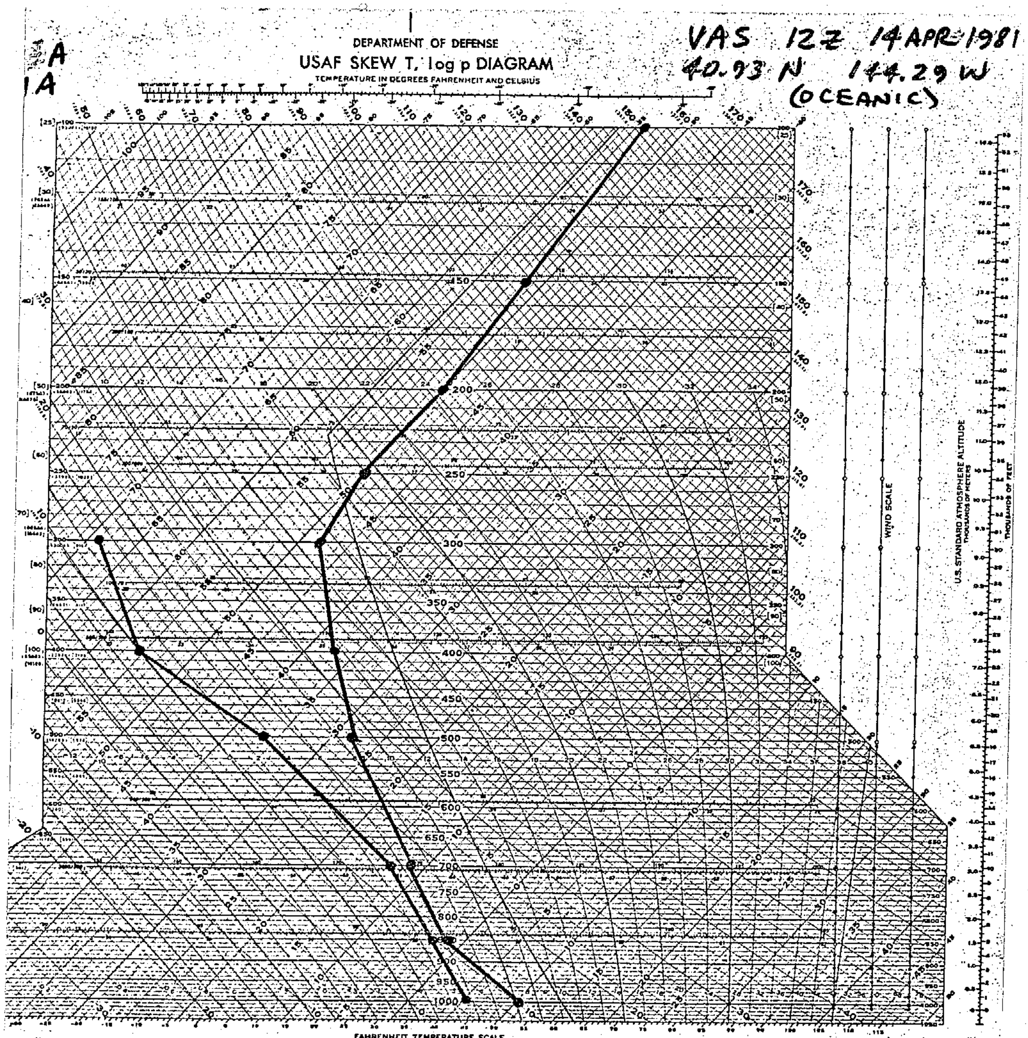
#3B

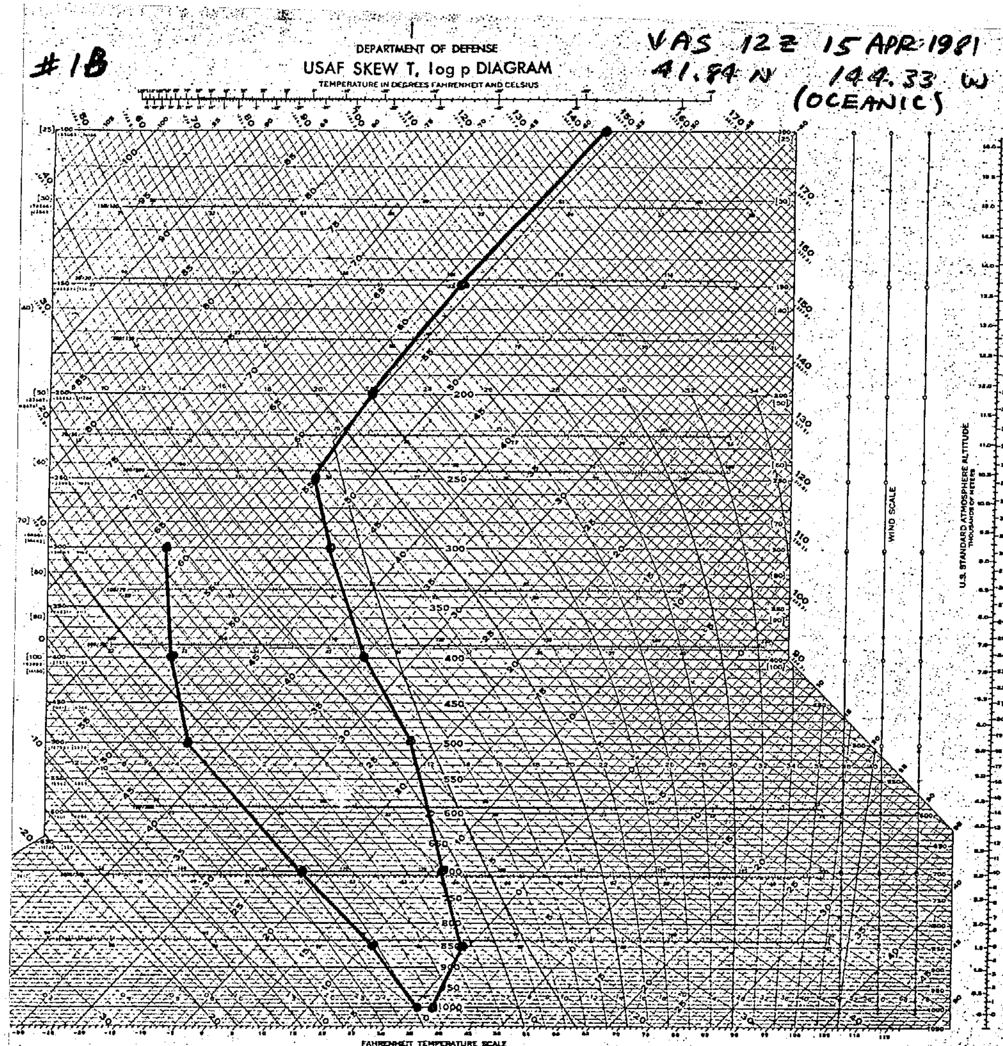
VAS 12Z 15 APR 1981
28.91 N 137.35 W
(OCEANIC)




#2 A
DEPARTMENT OF DEFENSE
USAF SKEW T, log p DIAGRAM
TEMPERATURE IN DEGREES FAHRENHEIT AND CELSIUS
VAS 12Z 14 APR 1981
37.01 N 141.89 W
(OCEANIC)
WIND SCALE
U.S. STANDARD ATMOSPHERE ALTITUDE
FAHRENHEIT TEMPERATURE SCALE


2 B
DEPARTMENT OF DEFENSE
USAF SKEW T, log p DIAGRAM
TEMPERATURE IN DEGREES FAHRENHEIT AND CELSIUS
VAS 12Z 15 APR 1981
37.52 N 143.13 W
(OCEANIC)
WIND SCALE
U.S. STANDARD ATMOSPHERE ALTITUDE
FAHRENHEIT TEMPERATURE SCALE


1A
DEPARTMENT OF DEFENSE
USAF SKEW T, log p DIAGRAM
TEMPERATURE IN DEGREES FAHRENHEIT AND CELSIUS
VAS 12Z 14 APR 1981
40.93 N 144.29 W
(OCEANIC)
WIND SCALE
U.S. STANDARD ATMOSPHERE ALTITUDE
FAHRENHEIT TEMPERATURE SCALE


#1B
DEPARTMENT OF DEFENSE
USAF SKEW T, log p DIAGRAM
TEMPERATURE IN DEGREES FAHRENHEIT AND CELSIUS
VAS 12Z 15 APR 1981
41.84 N 144.33 W
(OCEANIC)
WIND SCALE
U.S. STANDARD ATMOSPHERE ALTITUDE
FAHRENHEIT TEMPERATURE SCALE