NOAA Technical Memorandum NWS WR-195

RADID INTERPRETATION GUIDELINES

Salt Lake City, Utah
March 1986

U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Weather Service

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AFOS	Automation of Field Operations and Services
ALERT	Automated Local Evaluation in Real Time
AP	Anomalous Propagation
ARAP	AFOS Radar Processor
ARTCC	Air Route Traffic Control Center
AZRAN	Azimuth and Range (coordinate system)
cm	Centimeter
CP	Circular Polarization
CWSU	Center Weather Service Unit
db	Decibel
DVIP	Digital Video Integrator Processor
FAA	Federal Aviation Administration
FSS	Flight Service Station
FT	Terminal Forecast
IR	Infrared
LEWP	Line Echo Wave Pattern
MTI	Moving Target Indicator
NAFAX	National Facsimile (circuit)
NEXRAD	Next Generation Weather Radar
n mi	Nautical Mile
NWS	National Weather Service
NWSTC	National Weather Service Training Center
RADID	Radar Display Device
RAFAX	Radar Facsimile (circuit)
RHI	Range-Height Indicator
ROBEPS	Radar Operating Below Performance Standards
RRWDS	Radar Remote Weather Display System
SDC	State Distribution Circuit (AFOS)
STC	Sensitivity Time Control
VIL	Vertically Integrated Liquid
VIP-n	Video Integrator Processor-Coded Value for Reflectivity, Where n=1,6
WBRR	Weather Bureau Radar Remoting
WSFO	Weather Service Forecast Office
WSO	Weather Service Office
WSR	Weather Surveillance Radar

LIST OF FIGURES

RADID INTERPRETATION GUIDELINES

I. Introduction

Color weather radar remoting systems have greatly increased the availability of near real-time radar data to NWS forecasters, FSS specialists, military personnel, and private sector users such as airlines and television stations. Several benefits accrue to those whose mission effectiveness is increased by use of radar data. However, these devices have many inherent limitations and several deficiencies related to their operational reliability. The purpose of this Technical Memorandum is to provide interpretative guidelines for users of radar remoting systems, primarily focusing on:

The benefits and inherent limitations of this approach to weather radar data communication and display.

Radar interpretation, particularly unique problems in the Western United States.

This set of guidelines applies principally to RADID (Radar Display Device) displays but will also be useful for RRWDS (Radar Remote Weather Display System) and commercial color radar remote users.

RRWDS consists of two primary components - a digitizer on a radar for generating VIP-level data and a display system which includes a separate processor. RADID is a display device only. RADID can access data from RRWDS and commercial digitizers. RRWDS displays can only access data from RRWDS digitizers.

Radar interpretation using devices such as RADID is not simply a matter of turning on the equipment and obtaining automatic answers to forecast and warning problems. The RADID user should have a good understanding of the capabilities and limitations of radar. It is also vitally important to use other sources of information, such as local data networks, spotters, radar summary charts, radar narrative summaries, and calling network radar offices in order to fully exploit RADID's potential.

II. Strengths and Weaknesses of RADID Compared With Other Methods of Radar Data Communication

National radar summary charts on AFOS and NAFAX; Weather Bureau Radar Remoting (WBRR) systems; AZRAN and digital code observations; narratives; ARAP (AFOS Radar Processor); and RAFAX all were devised to serve a purpose in weather radar data communications and interpretation.

A. Radar Display/Communications Methods.

Figure 1 is a depiction of a RADID display at two different times. Note the major deficiencies discussed above: No interpretation or annotation is included with the display. The resolution

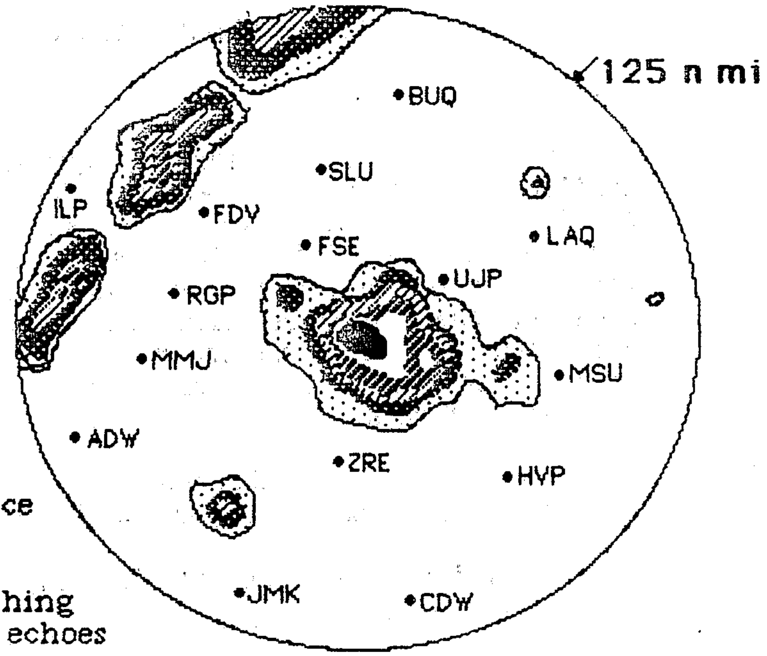
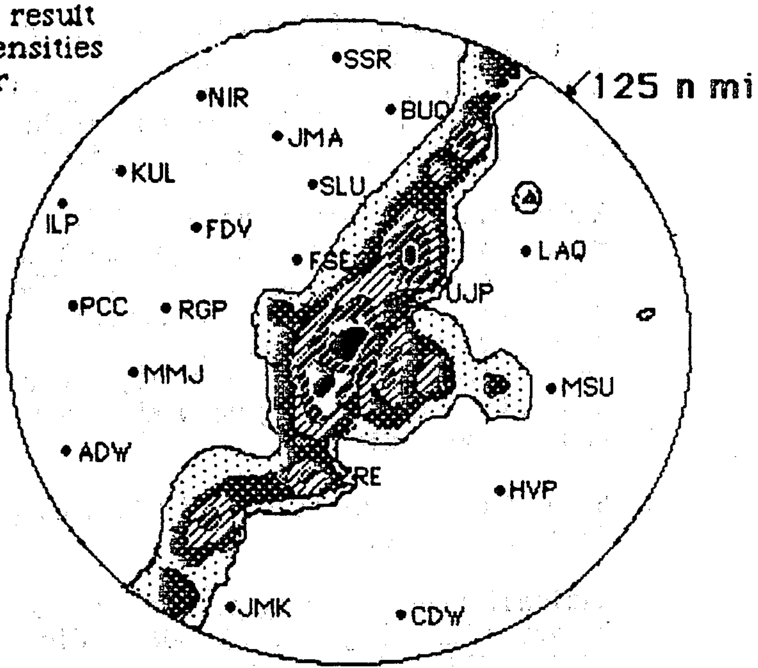


Fig. 1. Depiction of RADID sequence showing:

- Line of thunderstorms approaching radar from NW. VIP-1 to VIP-6 echoes surrounding radar are clutter.

- Apparent intensification of echoes between upper and lower depictions. This could be actual intensification, or result of range factors diminishing intensities when line was further from radar.

- Difficulty of interpreting RADID image when line is over heavy ground clutter near radar. Both intensities and precipitation extent are very confused in clutter area.



VIP	1	2	3	4	5	6
	░	▓	▨	▨	□	■

and timeliness are, however, excellent. Also, with looping capability, the time of arrival of the thunderstorms at any downstream point may be estimated.

Figure 2 is a copy of a RAFAX chart for 2/3/86 0135Z. Note that interpretation and annotation of the intensities, tops, movements, precipitation type, intensity trend, and radar status are included. The resolution is also quite good, but receipt of only one chart an hour and the length of time it takes to receive charts after the observation is taken are disadvantages, particularly during convective weather.

Figure 3 is a copy of the AFOS/NAFAX radar chart at the same time as Figure 2. Note the very coarse resolution. However, annotation of features is included. Timeliness is even more of a problem than with RAFAX.

Another source of radar data that is gaining rapid acceptance in the Western Region is the AFOS Radar Processor (ARAP) Program. This system works in conjunction with AFOS and a second minicomputer to generate detailed radar products. Just the fact that the data are displayed on AFOS, rather than at another work station, makes this a very useful program. The grid is much finer than the one used for preparation of AFOS/NAFAX radar charts, and data are available as frequently as every two minutes. ARAP data are much more timely than RAFAX or NAFAX charts. Figure 4 is an example of an ARAP product.

Many of the ARAP products are similar to those prepared manually at network radar offices, e.g., tops, intensities, and movements. However, many of the ARAP products are unique, e.g., Vertically Integrated Liquid (VIL), precipitation accumulation maps, alarm/alert warning products. The data are not interpreted prior to dissemination on AFOS. Therefore, as with RADID, misinterpretation by inexperienced radar users is a concern. Also, ARAP data are only available from some Western Region WSR-74C radars. Limitations exist on transmitting data outside the AFOS SDC. Ground clutter is suppressed to some extent by ARAP, but may result in substantial loss of weather data over heavy clutter areas. Another deficiency, similar to RADID data, is that many severe weather signatures are not discernible on ARAP products.

WBRR systems are no longer operated by the NWS. Facsimile charts of radar overlays produced at a radar office were printed by the WBRR via a dedicated line arrangement. WBRRs have been supplanted by RADIDs. Though not as timely as RADID, they did have the advantage of displaying interpreted, annotated data.

AZRAN coded observations require plotting to be readily usable. Digital code observations are manually produced for automatic preparation of the radar summary charts which are disseminated on AFOS and NAFAX.

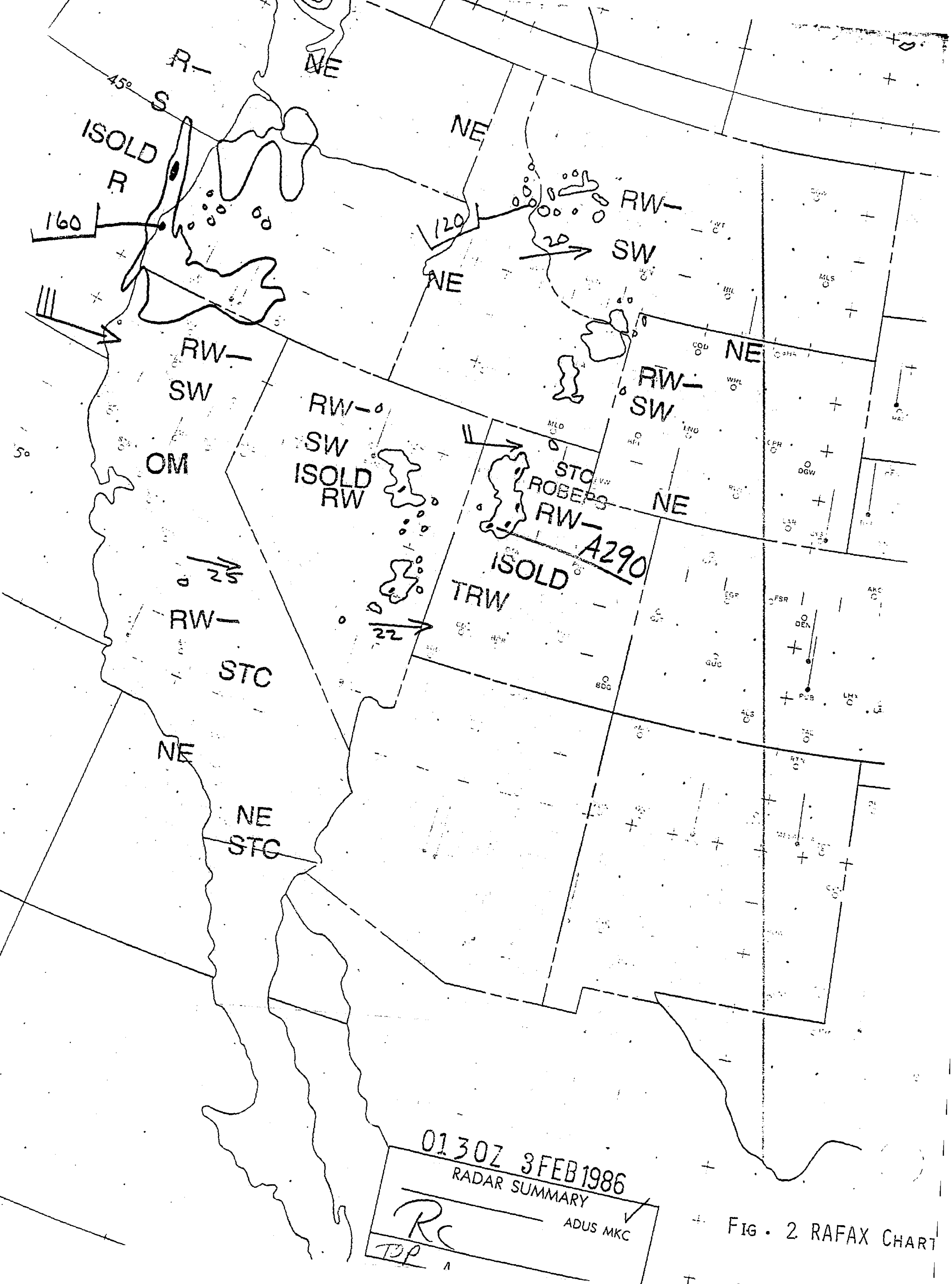


Fig. 2 RAFAX Chart

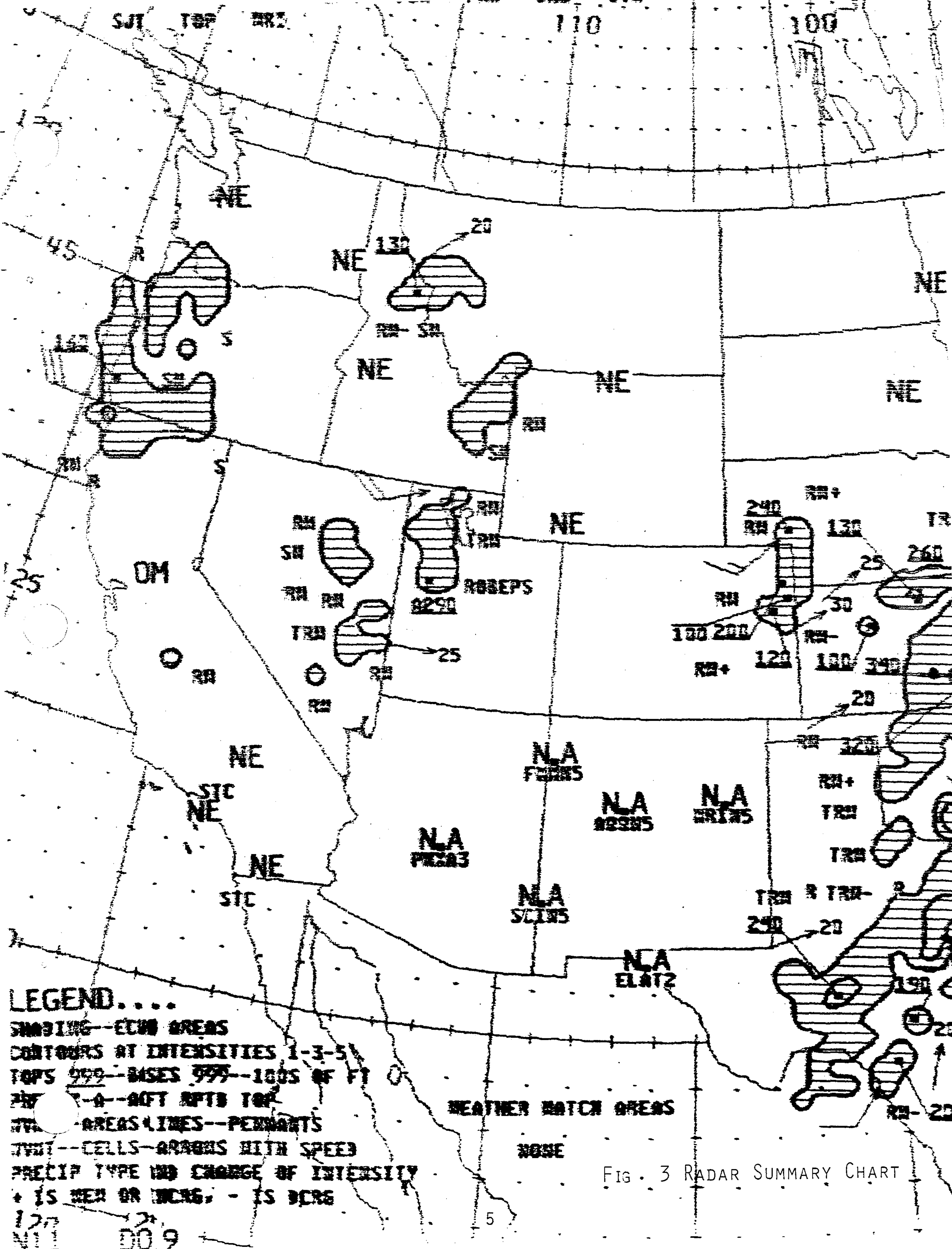


Fig. 3 Radar Summary Chart

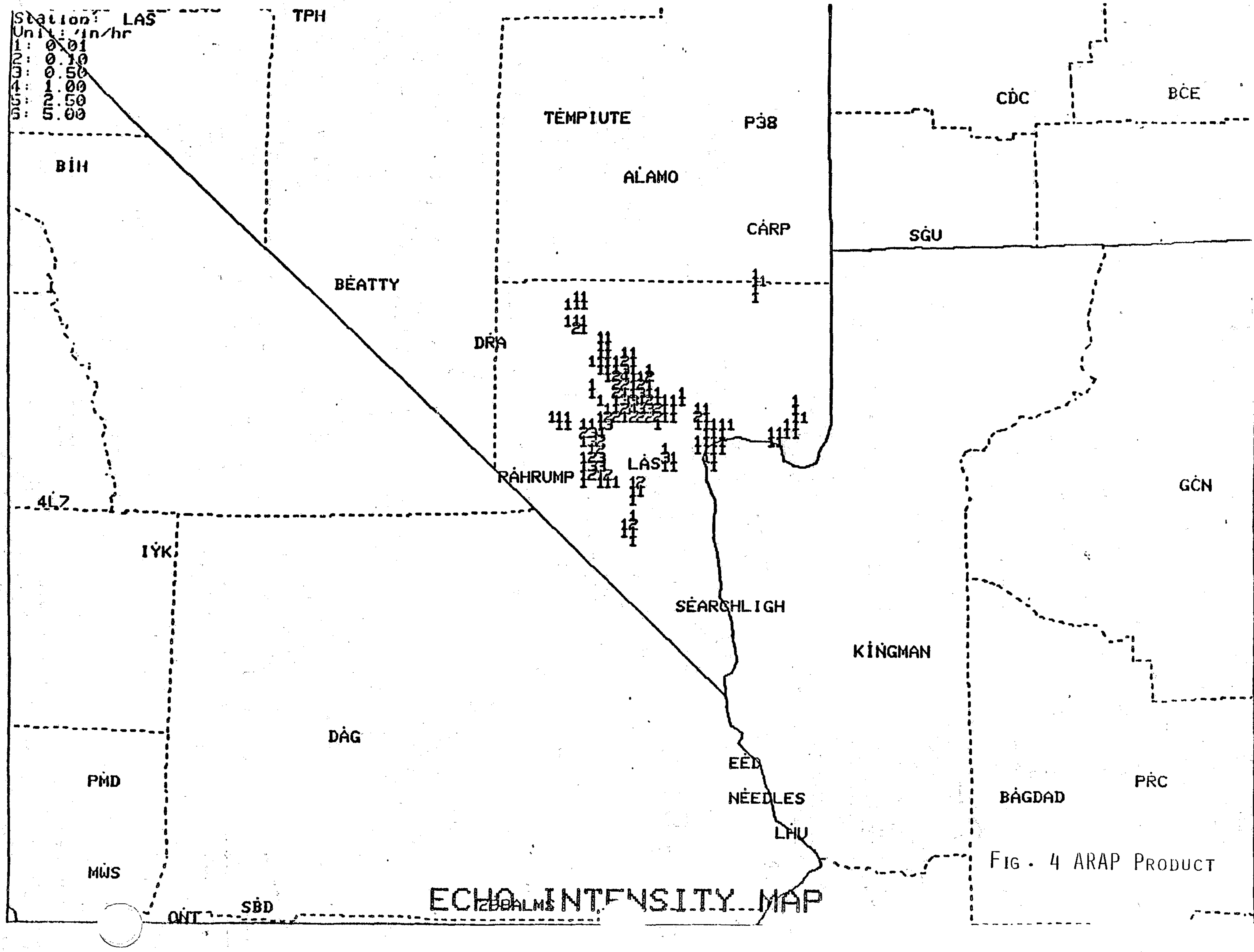


Fig. 4 ARAP Product

B. Strengths of RADID:

Timeliness. The data most recently accessed are only a few minutes old.

Detail. Data resolution is higher than with other systems.

Transmission and receipt of data are highly automated.

Motion or animation.

Animation loops are automatically produced when a dedicated line to the radar of interest is available. Unfortunately, most of the RADIDs used in the Western Region are not served by radar dedicated lines. To make meaningful loops, it is necessary to either dial in for an extended period of time (costly and ties up radar access for others if only a single port is available) or make frequent dials (labor intensive).

It has been demonstrated in Western Region that animated loops are very useful for discriminating between weather echoes and ground clutter.

C. Weaknesses of RADID:

Only non-annotated VIP level data are available; an experienced radar observer has not interpreted the data. Movements may be determined only if the animation capability is utilized. Animation is not automatic unless dedicated lines are used. Intensity trends may only be inferred from watching loops or calling up data frequently. Echo top data are not included. In many cases, severe weather signatures are not discernible on the remoting system. Thus, the only means of fully evaluating many important weather features is by augmenting RADID with other sources and calling the radar observer.

Ground and other clutter are particularly severe problems in the Western Region. By experience and manipulating several controls, an observer at an NWS radar can effectively differentiate between clutter and weather. To a limited extent, NWS observers at ARTCCs perform this function, prior to dissemination of RAFAX charts and digital coded data. However, color radar remoting systems display clutter in a way that it is not distinguishable from weather, unless looping capability is available. Also, Moving Target Indicator mode can help with this problem on FAA radars, but leads to other interpretation difficulties; these will be discussed in detail in Section IV.

III. How to Optimize Use of RADID

Radar and radar remoting systems are most effective as forecast and warning tools during warm season convective outbreaks. Many of the inherent limitations of radar are amplified when observing precipitation from cool season synoptic scale weather systems, such as fronts and upper lows. These limitations and others will be discussed in Section IV. Despite the limitations, radar remoting systems can provide valuable data even during the cool season, particularly if these limitations are well understood.

A. RADID as a Mesoscale Tool.

RADID should be considered a tool like other systems used for assessing and predicting the weather. In certain situations it is very useful, particularly for identification of severe local storms. It can efficiently provide information that other tools cannot.

For example, the extent, movement, intensity and intensity trend of a line of thunderstorms approaching a city can quickly be determined by glancing for a few seconds at a RADID operating in the looping mode. This can help to readily determine which spotters should be called to obtain ground truth to aid the NWS office in issuing a warning, or verifying a warning. Airports likely to be affected can be advised and terminal forecasts amended. The RADID may be used to provide a framework for mentally synthesizing all that is known about the line of thunderstorms from satellite imagery, lightning data, pilot reports, surface observations, ALERT data, spotter networks, and other radar products such as narrative summaries.

B. The Importance of Interpreted Radar Data and Ground Truth.

By calling the NWS observer at a NWS radar site or ARTCC, additional details, such as severe weather signatures or tops can be determined, or requests to change an FAA radar's operating mode can be made.

NWS OFFICES SHOULD NOT HESITATE TO CALL THE RADAR OBSERVER TO ASSIST IN INTERPRETING THE RADID DISPLAY. IN GENERAL, A WARNING SHOULD NOT BE ISSUED WITHOUT FIRST CALLING THE RADAR OBSERVER TO VERIFY YOUR INTERPRETATION OF THE RADID DATA. GROUND TRUTH FROM SPOTTERS OR OTHER SOURCES SHOULD ALSO BE OBTAINED, IF POSSIBLE.

IT IS ALSO VERY HELPFUL TO PASS ON GROUND TRUTH REPORTS TO THE RADAR OBSERVER.

C. An Example of Effective Use of RADID.

A recent example of excellent use of RADID as a mesoscale tool occurred during the evening of February 2, 1986. RADID indicated an intensifying band of thunderstorms moving toward the Salt Lake Valley from the west. See Figures 2 and 3 which show the RAFAX and AFOS/NAFAX depictions of these echoes, respectively, at 0130Z. Prior to this time, the Salt Lake City WSFO RADID was used effectively to identify the cells as possible thunderstorms and to assess their movement and intensity trend. The WSFO notified the CWSU of their concerns and received pilot reports that the band contained thunderstorms in deep convection. One report indicated lightning near Wendover, another that a 29,000-foot top was in the area. Confirmation of what the RADID was indicating was also obtained by discussing the situation with the ARTCC radar unit and monitoring the RAFAX charts.

Additionally, by tracking the thunderstorms with RADID, the forecasters accessed appropriate remote automatic weather stations and contacted spotters in the storm's vicinity. These reports provided vital ground truth of strong, gusty winds and brief but heavy precipitation. In this case, satellite imagery was not particularly useful. The IR data were too coarse and not timely enough to thoroughly assess the thunderstorm development.

Based on this highly efficient use of RADID as a framework for mesoscale analysis and integration of numerous data sources, the forecasters were able to:

Amend the Salt City International Airport FT with a precise projection of the time of arrival of the thunderstorms.

Update the local public forecast and provide Nowcasts on NOAA Weather Radio.

Promptly issue a Severe Thunderstorm Warning for downstream counties after noting the formation and rapid intensification to VIP-4 of a cell over the Great Salt Lake. Prior to issuing the warning a nearby spotter was called and reported wind gusts of 64 mph.

IV. Limitations and Cautions

As with any tool used to analyze and forecast the weather, RADID's effectiveness is largely dependent upon the user's knowledge of the tool's capabilities and limitations. The following information focuses on radar's limitations, particularly its use when remoted, and special considerations which apply in the Western Region. The February 2, 1986 case described above is an excellent example of proper use of radar and RADID. In order to more fully understand radar, the reader is encouraged to review materials in the NWS Radar Self Study Course, the references included with this Technical Memorandum, and, if he/she hasn't already done so, attend a NWSTC Radar Meteorology course.

A. All Radars

Range Limitations Due to Distance from the Radar and Beam Configuration. The signal strength returned from a meteorological target is inversely proportional to the square of the range to the target. Thus, an echo 200 n mi from the radar will return energy only 1/16th as strong as an equally reflective echo at 50 n mi.

In practice, STC (Sensitivity Time Control) circuitry is used to remove the displayed echo intensities' dependence on range. This is known as range normalization because all echoes displayed on the radar or RADID within a specified range will appear as they would at that range. This also decreases the extent of ground clutter and weak weather echoes near the radar. On NWS radars, intensities of echoes within 125 n mi are normalized to 125 n mi.

Radar beam filling. The inverse square law assumes that the reflecting target fills the radar beam. A radar beam diverges with range. Energy returned from a distant echo which does not extend high enough into the atmosphere to fill the beam, or is narrow in the horizontal, is assumed to be from an echo which fills the beam. The signal strength returned is an average of all echo intensities in the sample volume. Thus, averaging precludes accurate intensity measurements of distant, high intensity VIP targets which are not extensive in the horizontal or vertical. Intensities are underestimated, sometimes significantly. In many cases, distant targets will not return enough energy to be detected.

Additional limitations during cool season precipitation. Cool season precipitation is also subject to underestimation of intensity, or non-detection, because snow and other frozen precipitation above the melting level are less reflective than rain. Additionally, in the liquid phase, cool season droplet sizes are usually smaller than those of convective season showers and thunderstorms. Reflectivity is proportional to the sum of the sixth power of the drop size diameters in the radar sample volume. Thus, during the cool season, three factors - lower tops, frozen precipitation, and small drop sizes - combine to greatly reduce the radar's ability to accurately measure VIP levels and detect precipitation. Further, at ranges beyond the radar horizon, the beam is gaining altitude with range. Eventually, the only part of the cloud penetrated by the radar beam will be the upper level portions which are less reflective.

An illustration of poor intensity measurement capability is shown in Figure 5. This sketch is an approximate composite of all echo intensities detected during several winter seasons on the Sacramento WSR-57 radar. The bulls-eye shape of the echo intensity contours is due to underestimation of intensity with range. The bulls-eye is not symmetrical because of terrain effects on the beam's geometry, resulting in, for example, better echo detection and intensity measurement up and down the valley than to the east or west.

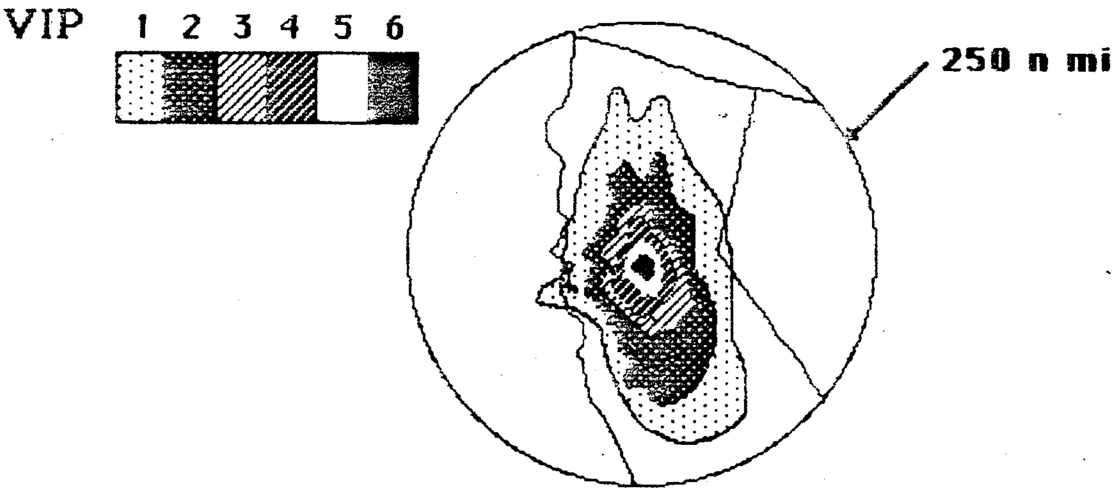


Fig. 5. Composite of several winter season echoes for Sacramento WSR-57 radar. Note the bulls-eye shape of the VIP contours. Distortions in the bulls-eye are caused by terrain blocking:

- The Sierra Nevada and Coast Ranges;
- Gaps in the Coast Range near San Francisco.
- Sutter Buttes, NNW of Sacramento.

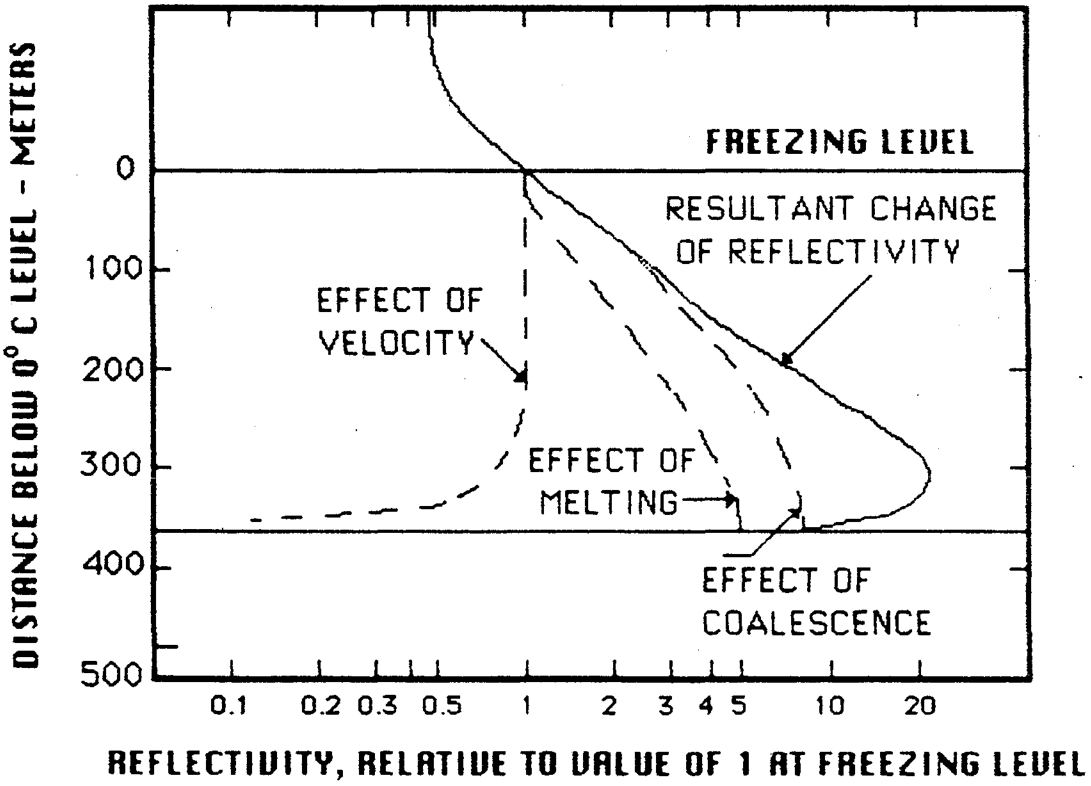


Fig. 6. Schematic drawing showing the effects of particle coalescence, melting, and changes in the terminal velocity on radar reflectivity through the bright band.

Echo top distortion. Another important consideration is the effect of low reflectivity in the upper portions of echoes on echo top measurements. This deficiency is most pronounced in the cool season. Detection of higher altitude echoes is less likely, leading to underestimation of storm tops, at times by several thousand feet.

An opposite effect can occur due to the beam's power cross section. Energy outside of the beam's half-power points (defined as the volume of space outside of the beam) can be detected by the radar, particularly if it is intense and close to the radar. This detection occurs either due to energy outside the half-power points, but in the main lobe, or energy returned from side lobes. This causes overestimation of echo tops, sometimes with a false echo "spike" reaching to the top of the RHI display. In severe convective situations, such a "spike" may be caused by highly reflective large hail.

The Bright Band is a phenomenom which has both a positive and negative effect on radar interpretation. It occurs near the beam's intersection with the freezing level. It is also known as the "melting level". The bright band provides a reliable approximation of freezing level height. The presence of a bright band has been shown to be a good indicator of aircraft icing, with the most severe icing at the height of the bright band.

Three meteorological processes result in a band of higher reflectivity on the Range Height Indicator (RHI) scope, just below the freezing level. Melting of the frozen hydrometers increases reflectivity as the phase change from ice to liquid occurs. Secondly, as the snow melts, it often coalesces into larger, highly reflective aggregates of water and ice. Thirdly, the increase in terminal velocity as snow changes to raindrops near the bottom of the bright band results in a sharp reduction in reflectivity. Once the phase change is complete, falling raindrops result in fewer hydrometers per unit volume.

The melting level phenomenon is only observed during relatively stable, stratiform precipitation. Turbulent mixing in convective clouds prevents formation of bright bands.

The melting level or bright band effect can have a deleterious affect on radar measurements of rainfall intensity. At a distance from the radar, dependent upon the height of the freezing level and the antenna elevation angle, overestimation of rainfall rate will occur within a ring of enhanced reflectivity. This overestimation may be observed on RADID scopes as an area of higher VIP levels around the radar. It usually amounts to 6 to 10 db.

Figure 6 depicts the melting level phenomenon by showing the relative effects of each meteorological process, and the resultant effect.

Refraction. Consider a radar located near the earth's surface which is radiating at an elevation angle near zero. If there were no atmosphere, the beam would be tangent to the surface and rise higher and higher above the earth with range due to the earth's curvature. If the atmosphere were such that the refractive index gradient with height decreased at a certain rapid rate, the beam would follow the earth's surface exactly. Finally, consider a refractive index gradient with height that is representative of the real atmosphere. in this case, the beam lies somewhere between the situations described above. This is what most often occurs in the atmosphere. The beam propagates in such a manner that it curves, but not rapidly enough to follow the earth's surface. The result is diminishing capability of the radar to detect and measure intensities as range increases.

Anomalous Propagation (AP) occurs to a noticeable degree when the moisture and temperature distribution in the low levels of the atmosphere is significantly different than the standard atmosphere.

Pronounced AP occurs in marine inversions, i.e., a mixed moist layer beneath a dry layer in which temperature increases with height. In this situation, super-refraction occurs (increased bending of the beam due to a more rapid than normal rate of refractive index decrease with height). This results in the radar detecting targets at more distant ranges than normal. In the more extreme inversion conditions, a duct forms near the earth's surface. This causes increased detection of ground targets or precipitation, sometimes at great distances. The usually undetected ground targets are called "AP". Super-refraction, even ducting, can occur when thunderstorm downdrafts bring cool, moist air to the earth's surface. The resulting AP targets are easily confused with precipitation on a RADID because they appear where ground targets normally are not observed.

A less common form of anomalous propagation, called sub-refraction, occurs when the rate of refractive index decrease with height is much lower than normal. An example would be when an elevated, moist, cool air mass moves over a dry desert region. This may cause significantly less bending of the radar beam and a decrease in the radar's precipitation detection capability, particularly at distant ranges.

Terrain blocking. This was mentioned above in the discussion regarding range limitations. The resulting highly detrimental impact on precipitation detection and intensity measurements is one of the problems depicted in Figure 5. Mountains may severely block significant echo features and the higher intensity precipitation in the lower portions of a storm. Buildings which are near the radar have a similar affect, and may cause false "back echoes" due to reflection of radar energy off of the buildings.

Ground clutter is a serious problem over much of the Western Region. It frequently masks precipitation because high intensity clutter echoes may be quite extensive. In some cases the clutter extends to distant ranges. The problem arises because the clutter frequently has a higher reflectivity than the precipitation. Figures 7 and 8 are sketches taken from photos of the Missoula WSR-57 and Spokane ARTCC radar ground clutter patterns.

Users of data from the Spokane radar are helped by the Moving Target Indicator (MTI) circuitry used with FAA radars. Thus, the presentation seen on RADID usually has most of the clutter removed. The Missoula radar has no real clutter suppression circuitry. A form of STC is used in conjunction with NWS DVIP circuits. However, this performs no signal processing and precipitation will be suppressed along with the clutter.

Clutter from other sources, such as the ocean and buildings, is also a serious concern for many radars. Sea clutter results from reflection off of ocean waves; in general, the rougher the sea the stronger the sea clutter. Buildings in major metropolitan areas cause significant amounts of clutter.

If suitable land is available, a radar may be sited in a "bowl" in order to cut off extraneous main and side lobe energy. The result is a radar with very little ground clutter to interfere with precipitation observations. This is called a natural clutter screen. A man-made clutter screen may also be constructed but is seldom done because it adds substantially to the cost of the radar system.

Clutter may be reduced or eliminated by: natural or man-made clutter screens; electronic circuitry, usually based on the Doppler principle, to filter out stationary targets; or tilting up the antenna to reduce returns from clutter causing features. Clutter screens are either difficult to find or expensive to construct. Electronic signal processing circuitry for clutter reduction is used on FAA radars (similar capability will be a component of NEXRAD, but strong clutter areas will still be observed, unless special algorithms are available). STC circuitry, as discussed above, is also used, in part, to reduce near-in clutter.

Upward tilting of the antenna offers the best solution for present NWS radars. This may also be done in conjunction with a reduction of receiver sensitivity to find the most intense weather echoes. However, this diminishes the radar's capability for detection and intensity measurements of distant echoes. It works best for warm season, convective storms because the echoes are strong and extend to great heights. Therefore, strong, high altitude echoes may still be detected and their intensities measured accurately, both over the heavy clutter areas and at extended ranges.

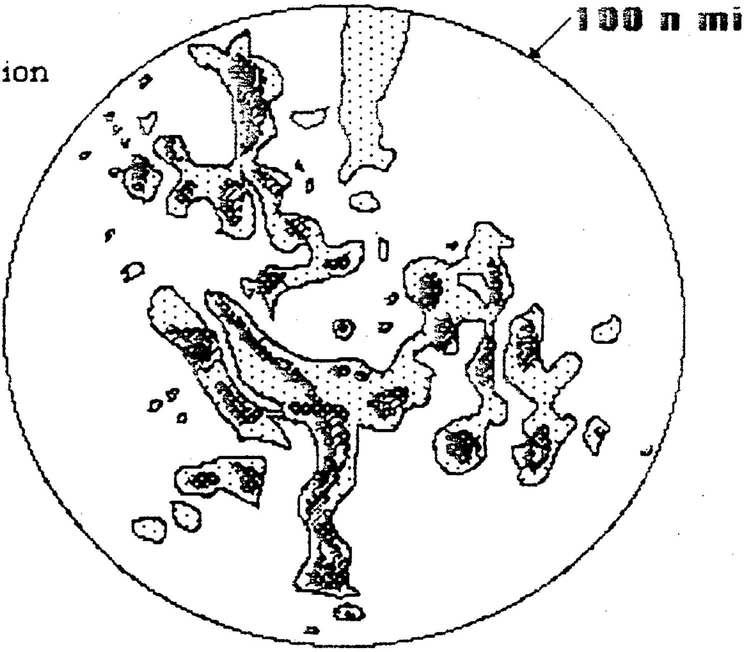


Fig. 7. Approximate depiction of Missoula WSR-57 radar ground clutter. STC on, no weather echoes present.

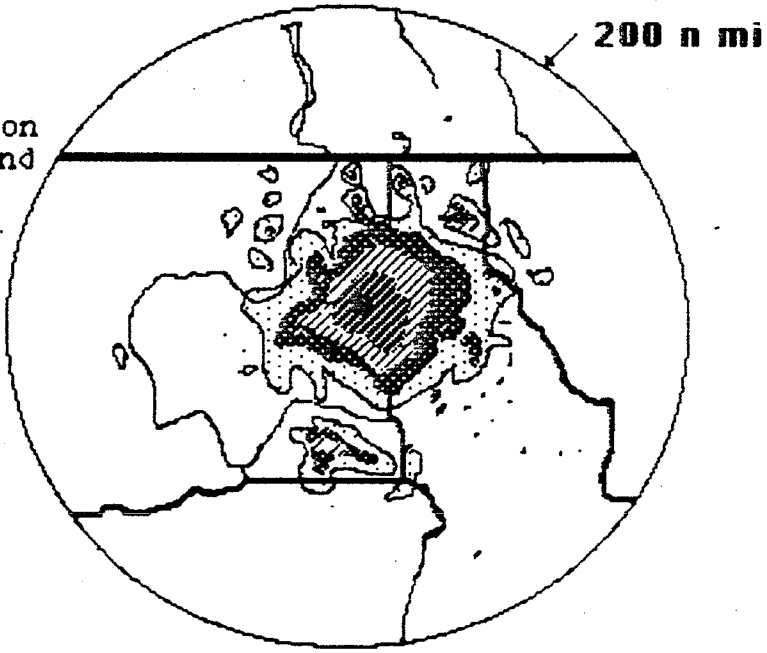
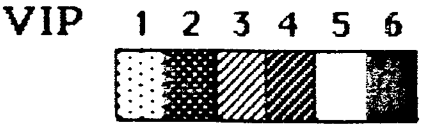


Fig. 8. Approximate depiction of Spokane FAA radar ground clutter. STC and MTI off. No weather echoes present.



Precipitation Attenuation. The shorter a radar's wavelength, the more it is subject to two-way precipitation attenuation, or loss of echo detection capability. The beam's penetration of precipitation containing small hydrometers results in minimal attenuation for the wavelengths commonly used for storm detection. However, the shorter, 3 and 5 cm, wavelengths, used for weather radars, are significantly attenuated by large hydrometers, particularly heavy rain and large hail. A wet radome may also contribute to the severity of the attenuation for these wavelengths. Wavelengths of 10 cm or more suffer only minimal loss due to attenuation by large hydrometers. Figure 9 illustrates an instance of severe attenuation of a C-band (5 cm) radar, e.g., a WSR-74C. However, Figure 10, showing the same storm as observed by an S-band (10 cm) radar, e.g., a WSR-57, is able to detect two of the most dangerous echoes present.

There have been many instances of 3 and 5 cm radars so seriously attenuated by intervening rainfall that killer thunderstorms, flash floods, and tornadoes at more distant ranges were not detected. Figure 11 is an illustration of this extreme, but real problem.

Precision for Severe Weather Applications. NWS radars generally have the precision required for resolution and correct placement of small severe weather signature echoes. Features often associated with severe convective weather, such as hook echoes, Line Echo Wave Patterns (LEWP), V-shaped notches, and echo-free vaults are frequently resolved on these radars, particularly at close range.

FAA radars have more difficulty with detection of these echoes because of inherent design limitations. Additionally, RADID displays frequently will not have sufficient resolution and other capabilities, such as RHI display, for detection of these signatures.

Dial-in Problems. As already mentioned, dial-in of radar data is not the best arrangement because manually making loops is time consuming. Additionally, contention for single-line access arrangements and connection problems are most likely to occur during severe weather.

B. FAA Radars

Beam Configuration. FAA radars are designed for detection of aircraft from near the surface to high altitudes. Therefore, their antenna design optimizes such detection by having a large beam width in the vertical and small in the horizontal. Typical beam widths for FAA radars are 1.2° horizontal and 3.75° in the vertical.

Fig. 9. RADID display of C-band radar demonstrating:

- Severe precipitation attenuation, particularly cell WNW of CXS and obscuration of a hook echo WNW of IEX.
- The VIP-5 cell just NW of the radar and the extensive VIP-2 echo NE of the radar are the causes.
- Extensive ground clutter returns around radar, between AZE and RDE and between IEX and OJE could not be distinguished from weather echoes on a RADID.

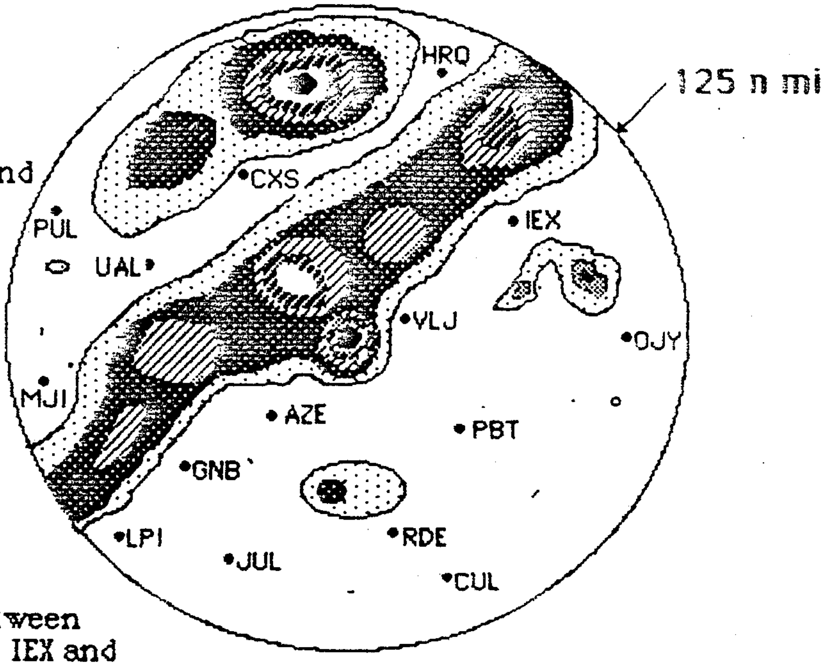
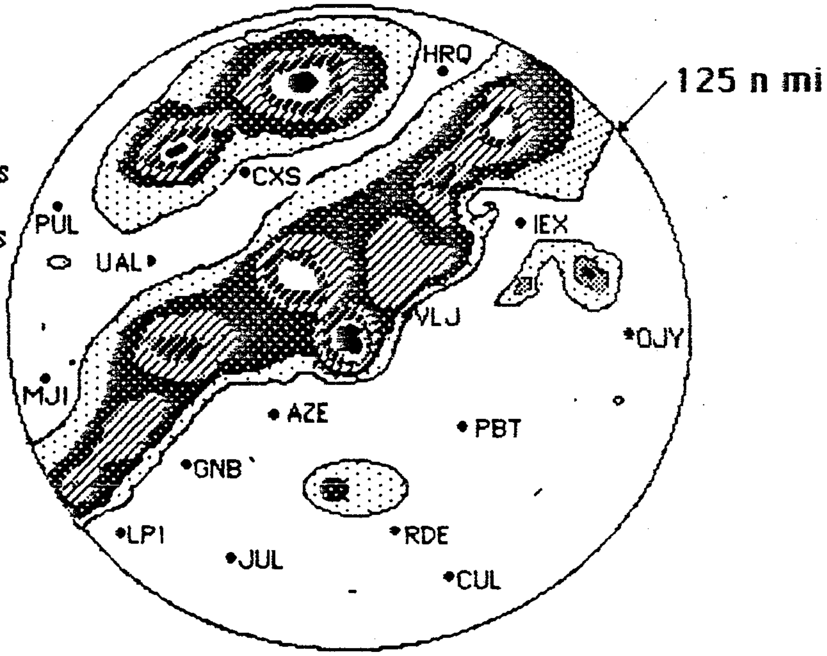
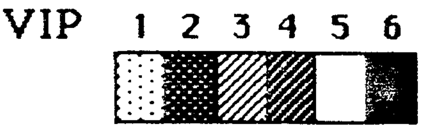


Fig 10. Same as above, but S-band radar. Note differences in intensity and coverage, particularly cell WNW of CXS is really a VIP-6; and hook echo WNW of IEX. C-band radar has not detected two of the most dangerous echoes.





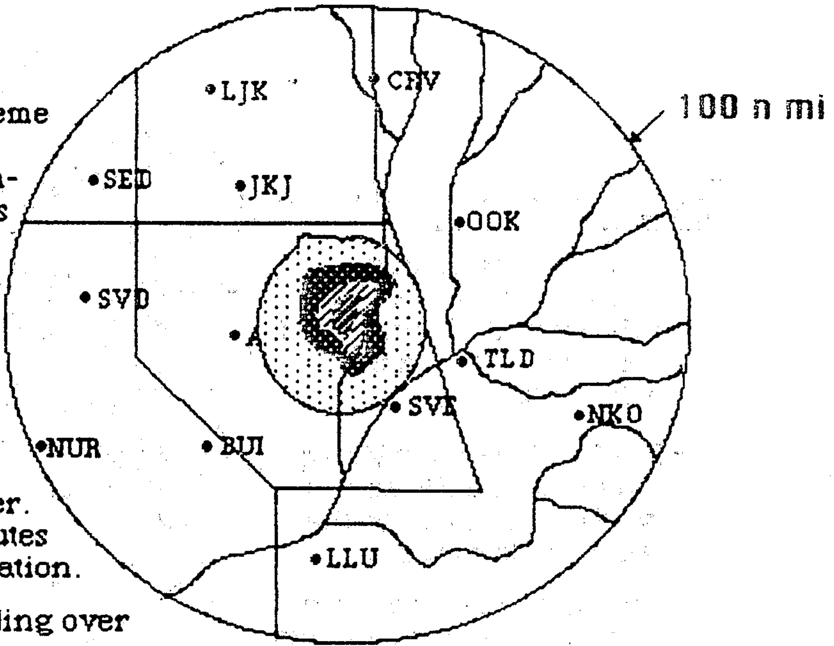
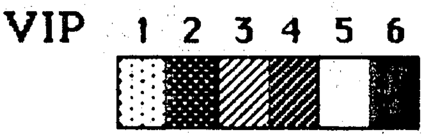


Fig. 11. Depiction of extreme example of attenuation during an epiosde of extensive, heavy thunderstorms with hail. There is heavy precipitation over much of the area within 100 n mi of the radar. However, attenuation of the C-band radar energy by precipitation has severely restricted the radar's ability to detect the weather. A wet radome also contributes significantly to the attenuation.

The threat of flash flooding over the river basin would not be discernible if radar alone were relied upon to assess the situation.

A similar case occured in Cheyenne, Wyoming during the summer of 1985.



When utilizing FAA radars for weather detection, it is seldom that even moderately distant echoes fill the radar beam. Thus, adifferent assumption must be made when comparing the relative intensities of echoes at different ranges. Instead of varying as the inverse square of the range (meteorological target filling the beam) or inverse fourth power of the range (point target), an inverse third power relationship is closer to reality. In general, weather echoes will not be detected as readily at distant ranges with FAA radars when compared to NWS radars. Use of RRWDS also has an effect because less of the weaker portions of VIP-1 echoes will be displayed than on either FAA broadband or NWS radars. However, FAA radars operate at higher transmitting powers which helps to increase their detection capability.

<u>STC</u>. The STC curves in use for FAA radars are primarily for suppression of ground clutter and close-in precipitation. These curves amplify difficulties in using FAA radar for precipitation measurements because they have no relation to radar meteorology. On FAA radars, any of several STC curves may be in use to deal with clutter. Additionally, the range cubed STC compensation is used to normalize VIP levels in the RRWDS digitizer. These two STC curves, one for eliminating clutter and one for range normalizing meteorological targets, are chained such that strong echo suppression occurs before the radar data enters the digitizer. The digitizer attempts to reconstruct the reduced or eliminated weather echoes. In many instances, weather echoes have been "destroyed" and can't be recovered by the RRWDS circuitry. This leads to situations, especially over heavy ground clutter, where weather echoes are not observable, or barely detected, on RADID. Figure 12 provides an illustration of this severe limitation. Such cases have been noted on RADIDs in Western Region. When you suspect that this is occurring, the best things to do are to contact the WSO(ARTCC) responsible for observations from the radar and/or check other available radar and ground truth sources.

Two methods are used to <u>measure reflectivity</u> with FAA radars. The first of these is not quantitative and is based on the brightness of the echoes on a broadband PPI display. The second was developed in conjunction with the RRWDS project and attempts to utilize radar meteorology theory in conjunction with ground clutter suppression STC curves. As discussed above regarding FAA radar STC curves, and below in connection with other inherent limitations, there are many problems associated with such quantitative intensity measurements using FAA radars.

The extent of precipitation, as well as intensities generated by RRWDS digitizers on FAA radars, may also be different than observed on NWS radars or on FAA broadband displays. WSO(ARTCC) Salt Lake City and Auburn made extensive comparisons during the 1985 convective season of intensities and coverages on RRWDS displays compared with the conventional broadband data they use. Results are shown in Figures 13 through 16. (The arrows on the

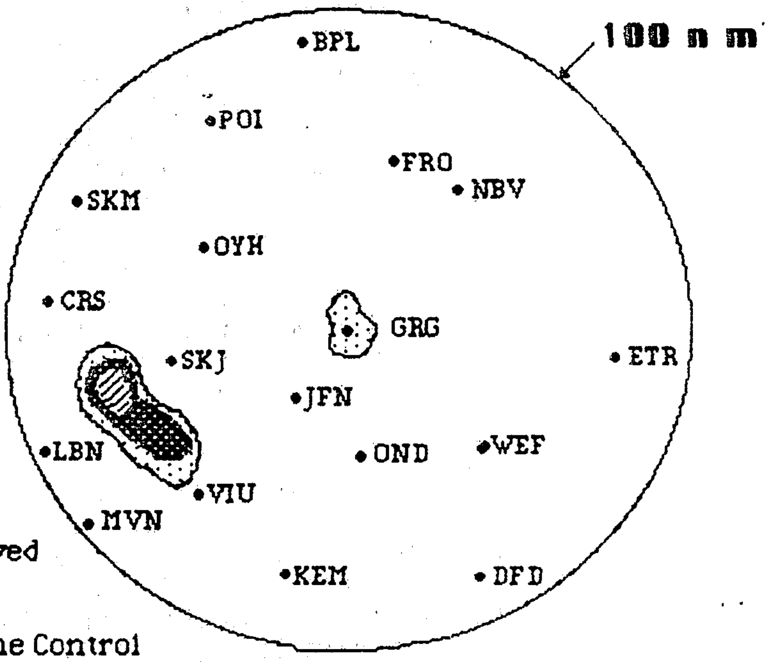
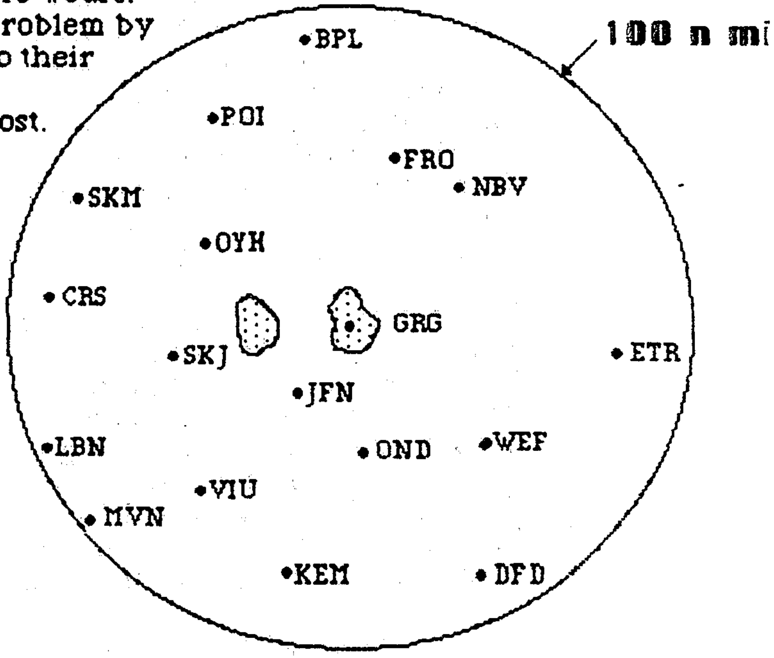


Figure 12. Illustration of two problems unique to many RRWDS-equipped FAA radars. The thunderstorm in the southwest quadrant of the RADID display in the top diagram moves to a position just west of the radar in the lower diagram. The cell is actually a VIP-6 severe thunderstorm.

a. Inadequate receiver dynamic range of the FAA radar allows only three levels of intensity to be displayed in the top picture.

b. The "non-weather" Sensitivity Time Control (STC) in use is not intended to provide range compensation. Rather, its purpose is to eliminate extensive, strong ground clutter. As the thunderstorm approaches the radar, the STC reduces the echo strength much more than a range compensation, or "weather", STC would. The RRWDS attempts to correct this problem by reconstructing the intensity levels to their values before the STC was applied. However, too much signal has been lost.

The overall result is severe underestimation of the thunderstorm's strength, at both times, and the implication that the storm has diminished considerably while moving toward the radar.



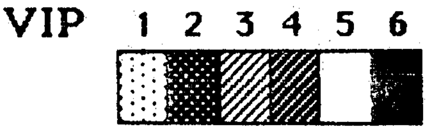


FIG. 13

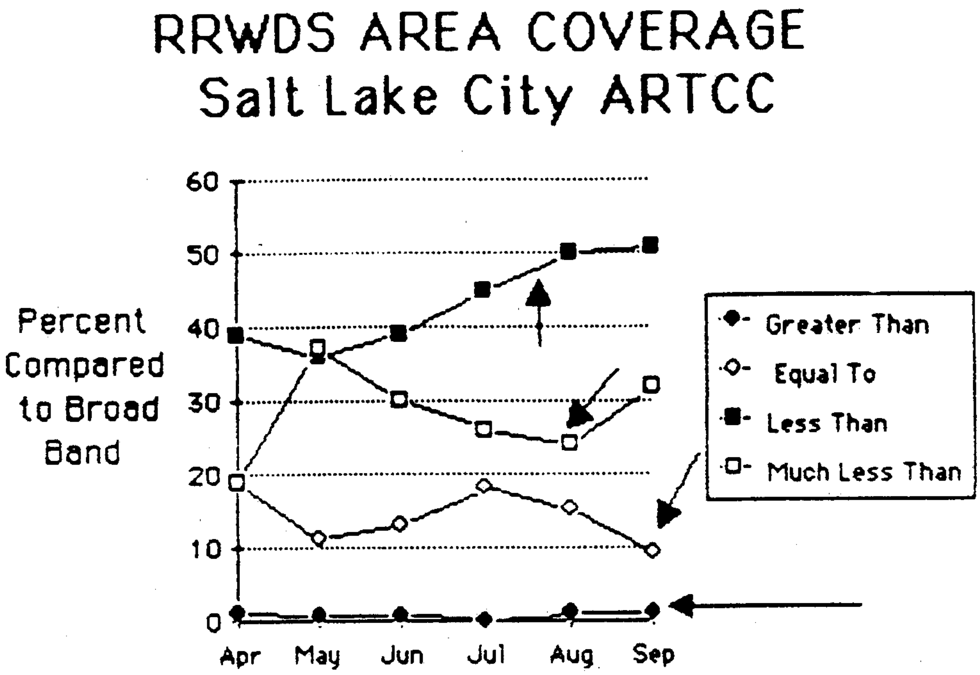

RRWDS AREA COVERAGE
Salt Lake City ARTCC
Percent Compared to Broad Band
60
50
40
30
20
10
0
Apr
May
Jun
Jul
Aug
Sep
Greater Than
Equal To
Less Than
Much Less Than

FIG. 14

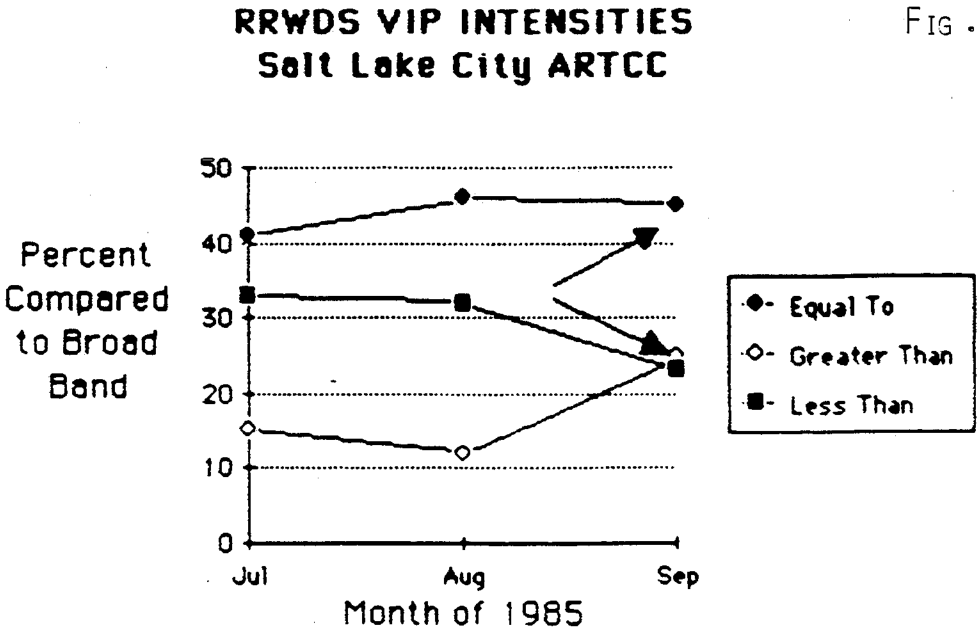

RRWDS VIP INTENSITIES
Salt Lake City ARTCC
Percent Compared to Broad Band
50
40
30
20
10
0
Jul
Aug
Sep
Month of 1985
Equal To
Greater Than
Less Than

FIG. 15

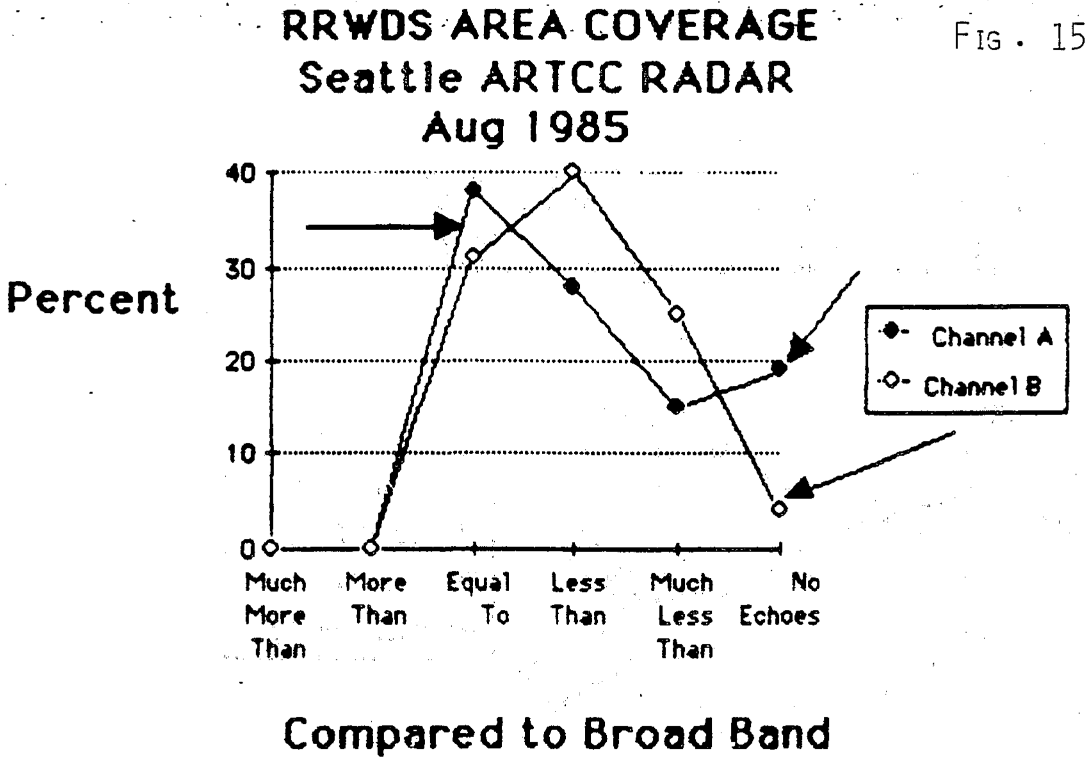
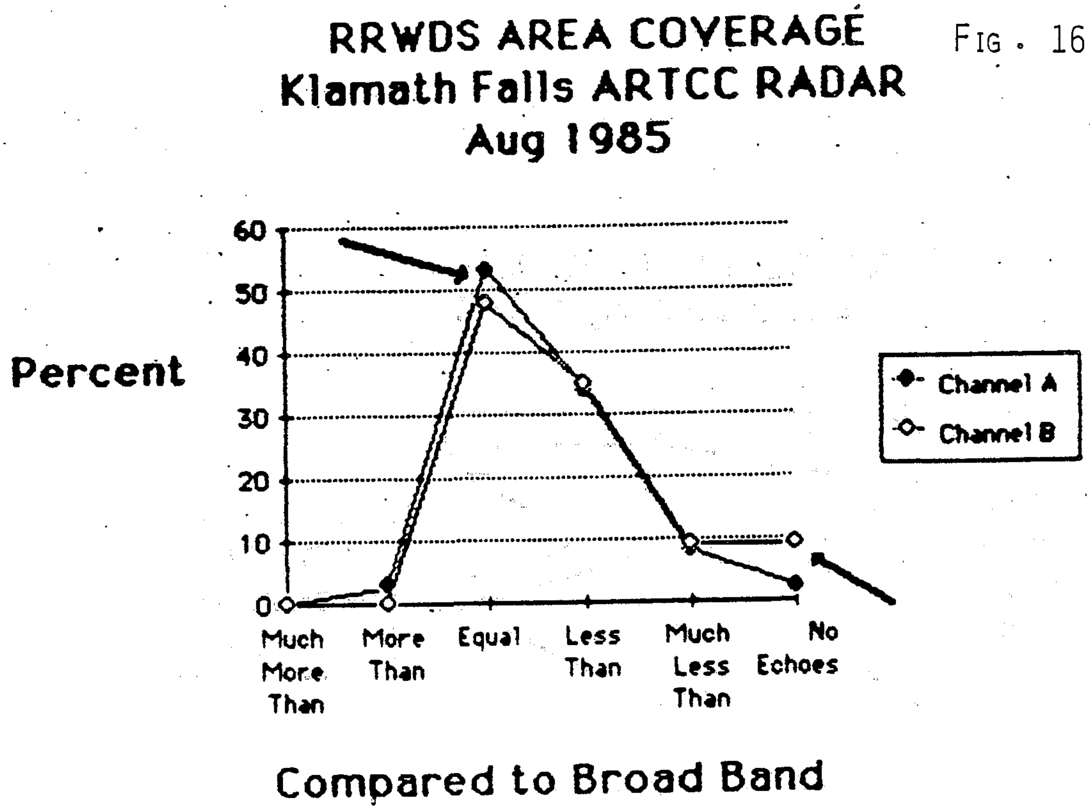

RRWDS AREA COVERAGE
Seattle ARTCC RADAR
Aug 1985
Percent
40
30
20
10
0
Channel A
Channel B
Much More Than
More Than
Equal To
Less Than
Much Less Than
No Echoes
Compared to Broad Band

FIG. 16


RRWDS AREA COVERAGE
Klamath Falls ARTCC RADAR
Aug 1985
Percent
60
50
40
30
20
10
0
Channel A
Channel B
Much More Than
More Than
Equal
Less Than
Much Less Than
No Echoes
Compared to Broad Band

graphs, originally done for a briefing, point out features such as trends with time and other pertinent features of the data.) Most of the time, the comparisons indicated poorer areal coverage was provided by RRWDS. Intensities on the radars monitored by Salt Lake City were usually less when observed with RRWDS than with broadband. The data for the Klamath Falls radar coverages were very close using both systems. However, coverage is much less important than intensity for severe weather applications. Channel A and Channel B on the Seattle and Klamath Falls radars refers to the two separate data channels which can be used by the FAA with these radars. The channel comparison was done because the FAA changes, without notice, the data channel. Frequently, when this occurs, major differences in echo coverage and intensity are noted.

Mountain-Top Radar Sites. Most FAA radars used by the NWS for weather detection in the Western Region are sited on high mountain peaks. The radars are on peaks to optimize detection of aircraft at distant ranges. However, while this advantage also applies to weather detection at distant ranges, it becomes a disadvantage by greatly increasing the amount of ground clutter. It also causes overshooting of many of the low-level phenomena the forecaster is concerned with.

Other Inherent Limitations. As discussed above, FAA radars are designed to optimize aircraft detection at the expense of weather detection.

Among the devices deployed with FAA radars to eliminate weather is Circular Polarization (CP). When CP is in use, round-shaped targets tend to be rejected, while permitting detection of horizontally oriented targets such as aircraft. This amounts to a known average decrease in the intensities of weather targets. The use of CP depends on the amount of weather and how much it is interfering with aircraft detection. As the CP is switched on and off, it gives the radar observer an opportunity to roughly estimate a few levels of intensity because the use of CP is equivalent to elimination of all VIP-1 echoes. CP can be a problem, especially during winter, because the extent of echoes detected will be reduced. When CP is in use, the RRWDS digitizer attempts to compensate by increasing the intensities of all displayable echoes by an amount equal to the known average decrease caused by CP.

Moving Target Indicator (MTI). FAA radar MTI is another device which works both to the advantage and disadvantage of the RADID user. MTI is intended to minimize those weather echoes that are relatively slow moving, and ground clutter. Partial or total elimination of ground clutter is a distinct advantage when trying to use a radar with considerable clutter, e.g., the Spokane FAA radar (see Figure 8). RRWDS circuitry will retain much of the precipitation normally lost when MTI is in use.

However, when MTI is chained together with other signal suppression devices, such as CP and clutter suppression STC, much of the precipitation data are often lost. This reduces the effective range for precipitation detection and may cause intensities to be underestimated.

Sub-Clutter Visibility is a problem when using FAA radars in MTI mode. Over areas of strongest ground clutter, for example a large mountain range, precipitation echoes must be about 26 db stronger than the clutter in order to be detected. This can result in sudden disappearance of weak echoes, or sharply reduced intensities for stronger echoes, as they move over the worst clutter areas.

Inadequate Receiver Dynamic Range on most FAA radars severely limits their capability to measure intensities. This is a problem when MTI is in use, which is most of the time for FAA radars in the Western Region due to extensive ground clutter. The result is that these radars can only display two or three intensity levels at once. Therefore, a VIP-4, 5, or 6 echo will only be displayed on RADID as VIP-2 or VIP-3. Figure 12 includes an illustration of this deficiency. The FAA has let a contract for new, wider dynamic range receivers for these radars. The new receivers will be installed within a year or two.

There are many RRWDS system defects, in both design and operation. In addition to the many problems discussed above in using RRWDS as a meteorological tool, many defects related to maintenance and operation of the system plague users trying to gather radar intelligence from FAA radars.

Calibration of RRWDS is a particularly acute problem which has not been solved as of this writing. The use of RRWDS implies that accurate, quantitative VIP level data are attainable with FAA radars. However, the RRWDS calibration procedures used by the FAA are inadequate at this time. Before great reliance can be placed on RRWDS for quantitative intensity measurements, the calibrations must be more reliable. Hopefully, the FAA will soon be able to resolve the many problems we're experiencing with RRWDS calibrations and other critical maintenance procedures.

V. Summary

RADID has proven to be an effective operational mesoscale analysis and forecasting tool. The system requires a fair amount of radar interpretation skill in order to optimize its use. Considerable knowledge of NWS and FAA radar capabilities and limitations, as well as good understanding of radar's unique performance characteristics in the West, are needed to fully exploit this valuable tool and avoid misinterpretations of the data.

Additionally, NWS radar and ARTCC radar observers should be contacted in order to clarify many of the images seen on RADID. These observers have many devices available to them for interpretation that are not available at RADID sites. They also have developed excellent interpretation skills for each of the radars they monitor. However, WSOs and WSFOs equipped with RADID have access to local observation networks and spotters. This ground truth is extremely valuable when interpreting radar data, particularly in the West where many factors associated with FAA radars affect its use for meteorological purposes.

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