WESTERN REGION TECHNICAL ATTACHMENT
NO. 96-15
JULY 16, 1996

DISSEMINATION AND DISPLAY OF DIGITAL SATELLITE DATA IN THE WESTERN REGION

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Transfer of Satellite Data

Satellite data for Western Region is transferred to field sites from an HP file server that is located at NWSFO Salt Lake City (SLC). Data on the file server originate from three main locations and includes data from various sensors/spacecraft. The GOES-9 imager data originate in Monterey at the Naval Research Laboratory. Other satellite (GMS, SSM/I, GOES-9 sounder) data originate at NESDIS in Washington, DC and Madison, WI. In the near future, AWIPS SBN will also be a source of data.

GOES-9 data for the Western Region RAMSDIS sites are ingested by a direct receive system using Global Imaging HIPS software and one of two antennae at the Naval Research Laboratory-Monterey. If one of the antennae fails, a simple switch is in place to switch to the other antenna. The Monterey ingest machine is an HP 715 that is dedicated to GOES-9 ingest. Special software developed by the Space Science and Engineering Center (SSEC) at the University of Wisconsin-Madison transmits the satellite data from the HP ingest machine in Monterey to the WR file server (HP 755) at NWSFO SLC via a 512Kbps dedicated communication line. Data are available to all 24 WR offices over the WR Wide Area Network (WAN), which consists of 24 dedicated 64Kbps (burst to 128Kbps) communication lines. Local RAMSDIS machines at WR field sites access the data from the WR file server using a timed scheduler. The scheduler executes commands that check the WR file server for new image products every 3 minutes. Once a new product is detected on the server, a capture command is executed that will send the data to the local RAMSDIS. The images are sectorized on-the-fly as they are sent from the file server to the local RAMSDIS. The image products are available for viewing on the local RAMSDIS within 10 minutes of image time (the image time is the time that the satellite starts scanning for a particular image). In most scanning scenarios, the entire Western Region's area of interest is scanned by 6 minutes after image time. A summary of timeliness of the ingest is given in Table 1. The timeliness should improve by a minute or two for some of the images when a new ingest schedule is implemented this summer. The backup to the Monterey ingest is GOES-9 direct receive system at SPC in Kansas City. Work is currently underway to make the AWIPS SBN data feed that is located at NWSFO-SLC the backup to the Monterey direct receive system. In this case, the GINI format GOES-9 data will be reformatted and sent to the WR file server for access by field sites.

Table 1. GOES-9 timeliness of ingest summary for WR forecast offices. Load to screen times are calculated as the difference between the time when the image is loaded to the RAMSDIS screen and the image stamp time (time of first scan line).

Image Type	Average Load to Screen Time	Ave. Load to Screen Time (RSO)
1 km VIS	8.6 min	7.3 min
4 km VIS	15.4 min	14.0 min
4 km IR	10.8 min	9.4 min
4 km WV	12.5 min	12.4 min
Fog/stratus	11.2 min	10.9 min
16 km IR	18.6 min	18.6 min
16 km WV	16.8 min	16.7 min

GOES-9 imager DPI (derived product imagery) is available from NESDIS in Washington, DC. The data are transferred to the WR file server over an Internet connection. The WR file server queries the NESDIS server every 5 minutes to check for new DPI data. If new data are available, a data capture command is executed. Once the data are resident on the WR file server, field sites access the GOES-9 imager DPI in a manner similar to the GOES-9 image data (see above). The field sites only query the WR file server every 9 minutes since these data are only available on an hourly basis and is less timely than the image data.

GOES-9 sounder data, which includes DPI and sounder retrievals, are received from NESDIS-SDAB in Madison, WI. The data are automatically FTP'd to the WR file server as soon as it is generated at Madison via an Internet connection between Madison and NWSFO SLC. Once the data are on the WR file server, it is accessed by field sites in the same manner as the GOES-9 imager DPI data (see above).

Display of Digital Satellite Data

Digital satellite data in WR are displayed on both PCs (OS/2 based) and HPs (UNIX based). The PC-based system is called RAMSDIS (RAMMBranch Advanced Meteorological Satellite Demonstration and Interpretation System). RAMSDIS was developed at the Regional and Mesoscale Meteorology (RAMM) Branch of NESDIS in Fort Collins, CO. Modifications to the ingest system and display features have occurred in WR-SSD. A detailed description of RAMSDIS is given by Molenar *et al.* (1995). To summarize, the hardware that RAMSDIS runs on includes: PC with 90MHz Pentium processor, 32MB RAM, 1GB enhanced IDE hard drive, quad-speed CD-ROM. 1.44MB floppy drive, 17" SVGA monitor, 1GB internal tape backup, separate monochrome text monitor. The software is based on McIDAS (Man computer Interactive Data Access System) for IBM OS/2. RAMSDIS adds a suite of ingest programs to the core McIDAS programs to allow for timely ingest of satellite data. A function key driven user interface allows easy access to core McIDAS, RAMMB, and WR programs and applications. The data are displayed in a 480 x 640 pixel mode with 256 (8-bit) gray shades. The system has 198 display frames, this will be upgraded to 250 frames in the summer of 1996.

The HP (UNIX) platform has numerous software options for display of digital satellite data. Currently, all field sites can use NSAT (part of NAWIPS) to display near real-time digital satellite data that are ingested (using scripts) from the RAMSDIS PC. NSAT allows for looping of the digital data, applying pregenerated color table enhancements, and automatic loop updating when a new image is received. In the near future, two additional software packages will be made available to field sites for displaying digital satellite data. These are RAMSDIS-X and GARP. RAMSDIS-X, developed at RAMM Branch, is based on McIDAS-X. It includes a graphical user interface (GUI) instead of the function key system used in the PC version of RAMSDIS. Work on the display size and number of frames available is still underway. On an HP715 with 128MB RAM, it is anticipated that the RAMSDIS-X setup will have 100 frames that are 800 x 1200 in size. RAMSDIS-X will provide all the functionality that was present in RAMSDIS. GARP is being developed at COMET and is basically a GUI for GEMPAK. It will allow the combination of satellite, radar, model, and observational data within a single display package. Currently, the satellite display system allows for looping, applying pre-generated color table enhancements, rolling of the color enhancement table, and rubber-band zooming. GARP also allows display of either McIDAS AREA format image files or GINI format image files. Image files are ingested using scripts that run at specified intervals. As with RAMSDIS-X, GARP needs large amounts of RAM to run efficiently.

Datasets Available via the WR File Server

The digital satellite datasets that are available on the WR file server are summarized in Table 2. Some of these are not yet used at field sites. The datasets that are used at the WR forecast offices are shown in Table 3. Forecast offices will start receiving some of the other datasets on the WR file server (imager and sounder GOES-9 DPI) by the end of this summer. The digital data are displayed primarily using RAMSDIS. This allows each of the image types to be displayed in a loop that is accessible by pressing a function key. Most loops are 16 frames in length, except the hemispheric IR and WV which are 24 frames in length. Examples and a short description of each image type will now be presented. All figures that show sample images are at the end of the text.

The full resolution VIS (1 km reso.) is centered at each WR forecast office (FO) so that most, if not all, of the county warning area (CWA) is within the image. Figure 1 shows an example 1 km VIS from the SLC NWSFO. County boundaries are included to aid in warning operations. The 2 hour running mean VIS image is generated by averaging the

8 most recent 1 km VIS images. The visible running mean images can be used to help identify feature such as convergence zones and areas of persistent cloudiness (or lack thereof). Figure 2 shows an example of the 2 hour running mean image for NWSFO-SLC. The radar projection VIS image is also generated from the 1 km VIS image. The VIS data are remapped into a radar type projection to make comparison of the VIS imagery to radar data easier. An example of a VIS radar projection image is shown in Fig. 3.

The 4 km VIS image is used to cover the broad, synoptic scale. Figure 4 shows an example of a 4km VIS image. It is useful in identifying clouds of all types and snow cover.

Table 2. Digital satellite data products that are available on the WR file server.

Data Type	Source	Reso. (km)	Frequency
Full res VIS	GOES-9	1.0	15 min (and RSO)
Reduced res VIS	GOES-9	4.0	15 min
Full res IR	GOES-9	4.0	15 min (and RSO)
Full res shortwave IR	GOES-9	4.0	15 min (and RSO)
Full res water vapor IR	GOES-9	4.0	15 min
Fog/reflectivity product	GOES-9	4.0	15 min (and RSO)
Hemispheric scale IR	GOES-9	16.0	60 min
Hemispheric scale WV	GOES-9	16.0	60 min
Sounder TPW	GOES-9	10.0	60 min
Sounder LI	GOES-9	10.0	60 min
Imager TPW	GOES-9	4.0	60 min
Imager LI	GOES-9	4.0	60 min
Imager skin temp	GOES-9	4.0	60 min
Western Pacific IR	GMS	16.0	60 min
Surface wind speed	SSM/I	~25	120 min
Total precip water	SSM/I	~25	120 min
Rain rate	SSM/I	~25	120 min

Table 3. Digital satellite data products that are available at WR forecast offices.

Data type	Source	Reso. (km)	Frequency
Full res VIS	GOES-9	1.0	15 min (and RSO)
2 hr running mean VIS	GOES-9	1.0	15 min (and RSO)
Radar proj VIS	GOES-9	1.0	15 min (and RSO)
Reduced res VIS	GOES-9	4.0	30 min
Full res IR	GOES-9	4.0	30 min (15 min and RSO, if desired)

2 hr running mean IR	GOES-9	4.0	30 min (15 min and RSO, if desired)
Radar proj IR	GOES-9	1.0	30 min (15 min and RSO, if desired)
Full res water vapor IR	GOES-9	4.0	30 min
Fog/reflectivity product	GOES-9	4.0	15 min (and RSO)
Hemispheric scale IR	GOES-9	16.0	60 min
Hemispheric scale WV	GOES-9	16.0	60 min
Western Pacific IR	GMS	16.0	60 min
Surface wind speed	SSM/I	~25	120 min
Total precip water	SSM/I	~25	120 min
Rain rate	SSM/I	~25	120 min

The full resolution IR (4 km reso.) covers the same area as the 4 km VIS, this allows for easy comparison of the two image types. An example of a 4 km IR image is shown in Fig. 5. The 2 hour running mean IR image is generated by averaging the four most recent 4 km IR images. This loop of images is very useful in flash flood situations when either a storm is stationary or numerous storms move over the same area. An example of this type image is seen in Fig. 6. The radar projection IR image is also generated from the 4 km IR image. The IR data are remapped into a radar type projection to make comparison of the IR imagery to radar data easier. An example of an IR radar projection image is shown in Fig. 7.

The 4 km WV (6.7μm) image covers the same region as the other 4 km images (again for easy multispectral comparisons). This imagery is very useful in identifying shortwaves in the upper-level flow. Figure 8 shows a sample of the 4 km WV imagery.

The 4 km fog/stratus-reflectivity product covers the same region as the other 4 km image types. This product is a combination of the fog/stratus product and the reflectivity product. It is generated by using the 4 km VIS data as a discriminator. Where VIS counts are 30 or below (i.e., night), the fog product is inserted. Where VIS counts are above 30 (i.e., daylight), the reflectivity product is inserted. The fog/stratus product is generated as follows:

> Use the following function to arrive at a brightness count for the "fog" product image:
>
> $$\text{brightness count} = \{10x([T \text{ of ch.}4] - [T \text{ of ch.}2])\}+150$$
>
> This allows the normally rather small (<5°C) differences in temperature between the two channels to be stretched and be centered near the middle of the 1-byte (256 counts) range. Water clouds then show up as light gray (brightness counts over 150), while cirrus appear much darker due to ch 2 temperatures being warmer than

ch 4 temperatures (negative difference). NOTE: No attempt is made to mask out other cloud types since it is helpful to leave in the negative differences so that cirrus that may be passing over a lower cloud deck can be more easily identified.

The reflectivity product is generated using a program developed at CIRA/RAMMB that uses the 11μm (window IR) data to subtract out the emissive component of the 3.9μm data. This leaves a product image that is mostly composed of the reflection of solar radiation and has a small component due to the emissivity difference between the 11μm and 3.9μm channels. This product can help detect fires and distinguish between water and ice clouds. An example of the fog/stratus-reflectivity product is shown in Fig. 9.

The 16 km IR image is generated from the full resolution IR data by remapping it into a polar stereographic projection. These data are useful in tracking hemispheric scale flow patterns at both low and high levels. Figure 10 shows an example of a 16 km IR image.

The 16 km WV (6.7μm) image is generated from the full resolution WV data by remapping it into a polar stereographic projection. These images are very useful in tracking the upper-level flow patterns on the hemispheric scale. An example of a 16 km WV image is shown in Fig. 11.

The western Pacific IR image is generated from GMS data that are remapped into a polar stereographic projection. An example GMS image is shown in Fig. 12.

The surface wind speed product is generated from SSM/I data. These datasets are composited into a single image in a Mercator projection at NESDIS. This product is useful to help estimate the strength of systems that may impact the West Coast. Figure 13 shows a sample SSM/I wind speed product image.

The total precipitable water product is generated from SSM/I data. These datasets are composited into a single image in a Mercator projection at NESDIS. This product is useful to help estimate how much moisture is present over the Pacific Ocean where standard sounding (Raobs) are lacking. Figure 14 shows a sample SSM/I total precipitable water product image.

The rain rate product is generated from SSM/I data. These datasets are composited into a single image in a Mercator projection at NESDIS. This product is useful to help estimate how intense rainfall is over the Pacific Ocean where radar observations are lacking. Figure 15 shows a sample SSM/I rainrate product image.

The sounder total precipitable water (TPW) product is generated at the Space Science and Engineering Center (SSEC) at the University of Wisconsin-Madison using a physical retrieval technique (see http://oldthunder.ssec.wisc.edu/goes/real-time/realtime.html for details). This product is useful in determining the amount of moisture present over the Pacific Ocean. Figure 16 shows a sample sounder TPW product image.

The sounder lifted index (LI) product is generated at the Space Science and Engineering Center (SSEC) at the University of Wisconsin-Madison using a physical retrieval technique (see http://oldthunder.ssec.wisc.edu/goes/real-time/realtime.html for details). This product is useful in determining the amount of instability in the atmosphere. Since it is available hourly, it is also used to watch how instability is evolving through the day. Figure 17 shows a sample sounder LI product image.

The imager TPW product is generated using a physical retrieval technique at NESDIS (see http://orbit7i.nesdis.noaa.gov:8080/dpi.html for details). As with the sounder TPW product, this product is useful in determining the amount of moisture present over the Pacific Ocean. The product has better horizontal resolution than the sounder product, but due to poorer vertical resolution in the imager, the accuracy of TPW is probably lower than for the sounder. Figure 18 shows a sample imager TPW product image.

The imager LI product is generated using a physical retrieval technique at NESDIS (see http://orbit7i.nesdis.noaa.gov:8080/dpi.html for details). As with the sounder LI product, this product is useful in determining the amount of instability present in the atmosphere. The product has better horizontal resolution than the sounder product, but due to poorer vertical resolution in the imager, the accuracy of LI is probably lower than for the sounder. Figure 19 shows a sample imager LI product image.

The imager skin temperature (ST) product is generated using a physical retrieval technique at NESDIS (see http://orbit7i.nesdis.noaa.gov:8080/dpi.html for details). This product is useful in determining the amount of diurnal heating that is taking place at the surface. Figure 20 shows a sample imager ST product image.

The imager and sounder DPI will become available to WR FOs by the end of this summer. Actual GOES-9 sounder retrievals of moisture and temperature will be experimented with in WR-SSD this summer.

Digital Satellite Applications

Numerous applications involving the digital satellite data can be performed using RAMSDIS. These include the following:

1) Obtaining minimum/maximum/average temperature within the cursor from IR images. This is very useful in identifying cloud top temperatures (i.e., severe storm monitoring).

2) Contouring IR temperatures within the cursor. This can be helpful in assessing cloud top temperature or sea surface temperature structure.

3) Relative looping. Very useful in diagnosing severe thunderstorm local environments. Also useful in analyzing large-scale storm systems.

4) Image averaging. Extremely useful in identifying areas that may be susceptible to flash flooding. Image averaging is done automatically on the 4 km IR images and the results are put in a separate loop for viewing. Image averaging can also be used to develop a local cloud climatology.

5) Velocity measurement. Very useful in identifying when a particular feature (front, thunderstorm) will reach a particular point. Also useful in verifying jet level winds.

6) Manipulation of color enhancement table. The color enhancement table can be modified in the following ways:

a) VIS imagery can be enhanced (especially in morning and evening) by stretching the observed brightness counts over the entire display range (256 counts).
b) Enhancements can be "rolled" to highlight areas of interest. The mouse is used to simply move the defined enhancement up or down the brightness count range.
c) Enhancements can be stretched interactively using the mouse by anchoring one end of the enhancement and moving the other end to a different brightness count level.
d) IR imagery can be interactively enhanced between user defined temperature ranges.

7) Omission of bad frames. Frames that contain bad data can be interactively omitted from image loops. A frame is re-included when a new (good) image is ingested to that frame.

8) Overlay of other meteorological data. Surface, ship/buoy, and upper-air (Raob) data can be plotted over the satellite imagery.

9) City locations. Cities and towns can be located using the FIND command. This is extremely useful when receiving spotter reports. The locations in the FIND database come from a database generated at NSSFC. The FIND database can be customized locally to include spotter locations and any other location of interest to the forecasters (i.e., mountain tops, river junctions, etc.).

The experience to date in WR shows that the most widely used applications include: finding city/town locations, min/max/ave temperatures within cursor, image averaging, color table manipulation, and velocity measurement.

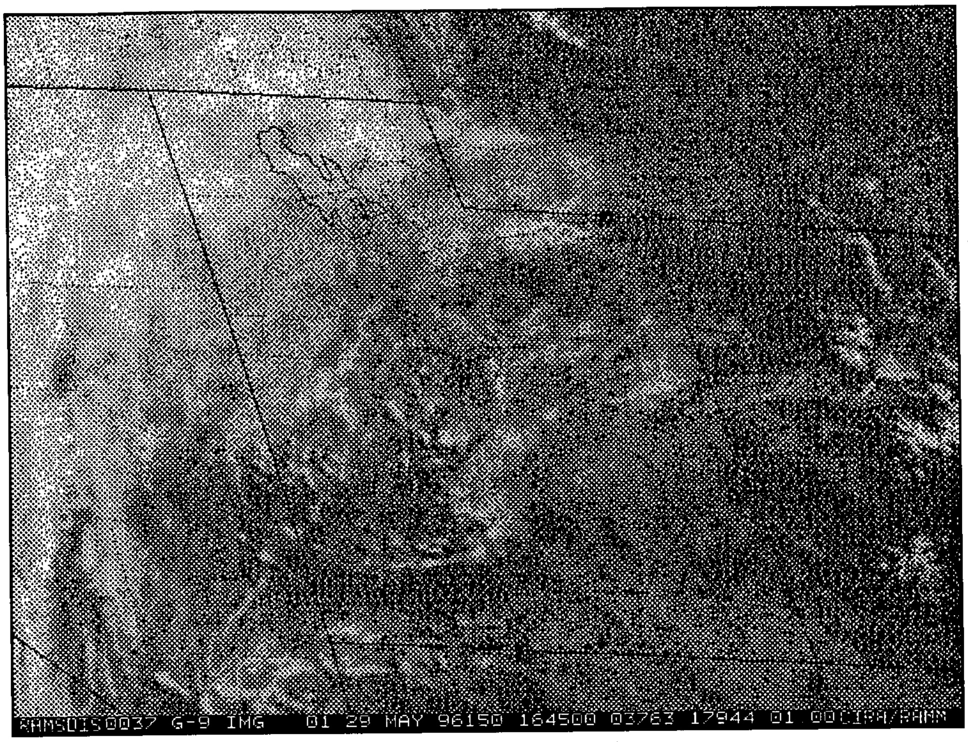

Figure 1. 1 km VIS for WSFO SLC.

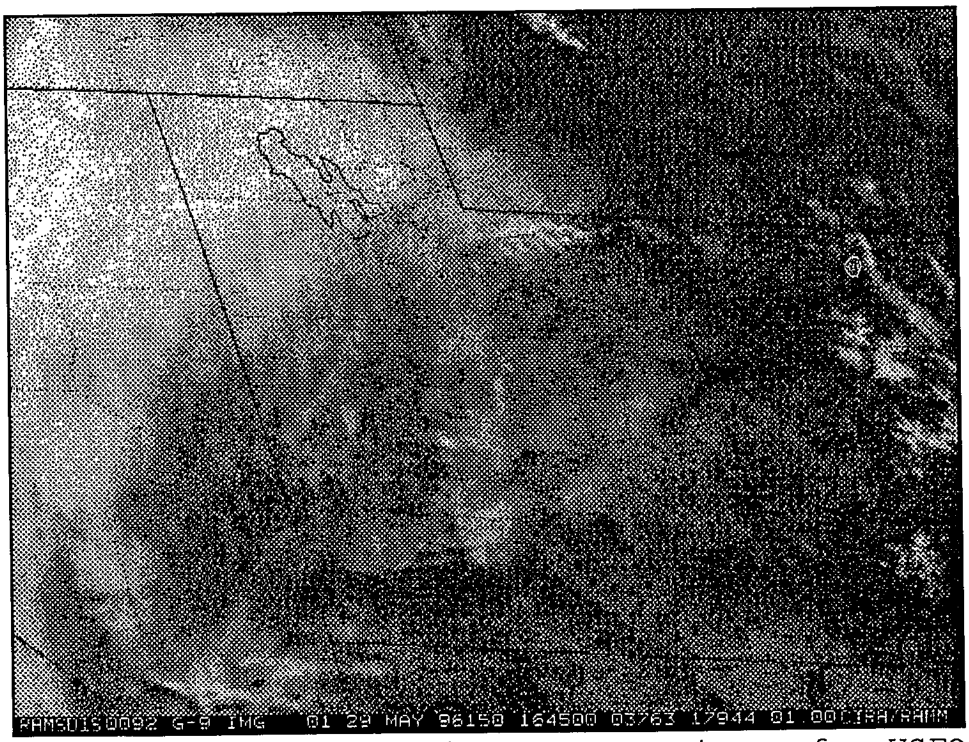

Figure 2. 2 hour running mean VIS image for WSFO SLC.

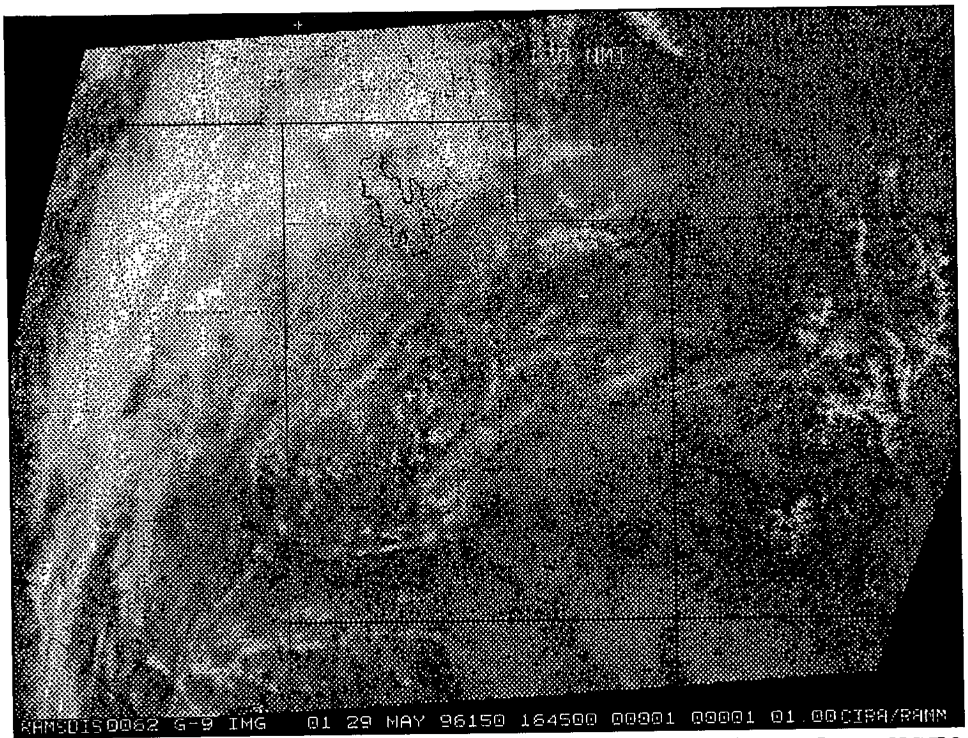

Figure 3. 1 km VIS in radar projection for WSFO SLC.

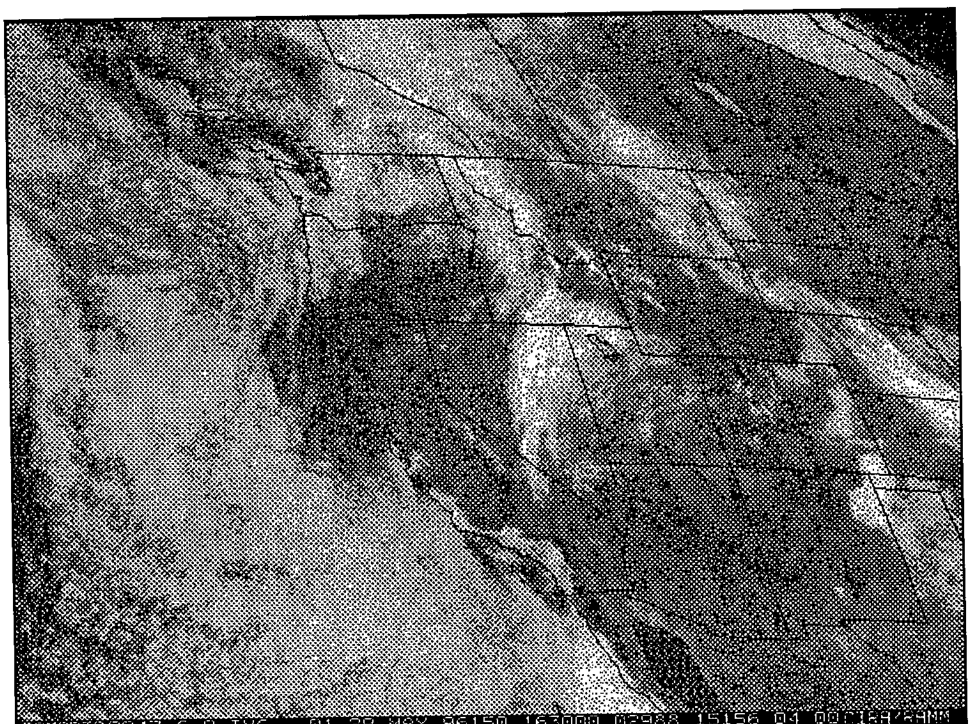

Figure 4. 4 km VIS image for WSFO SLC.

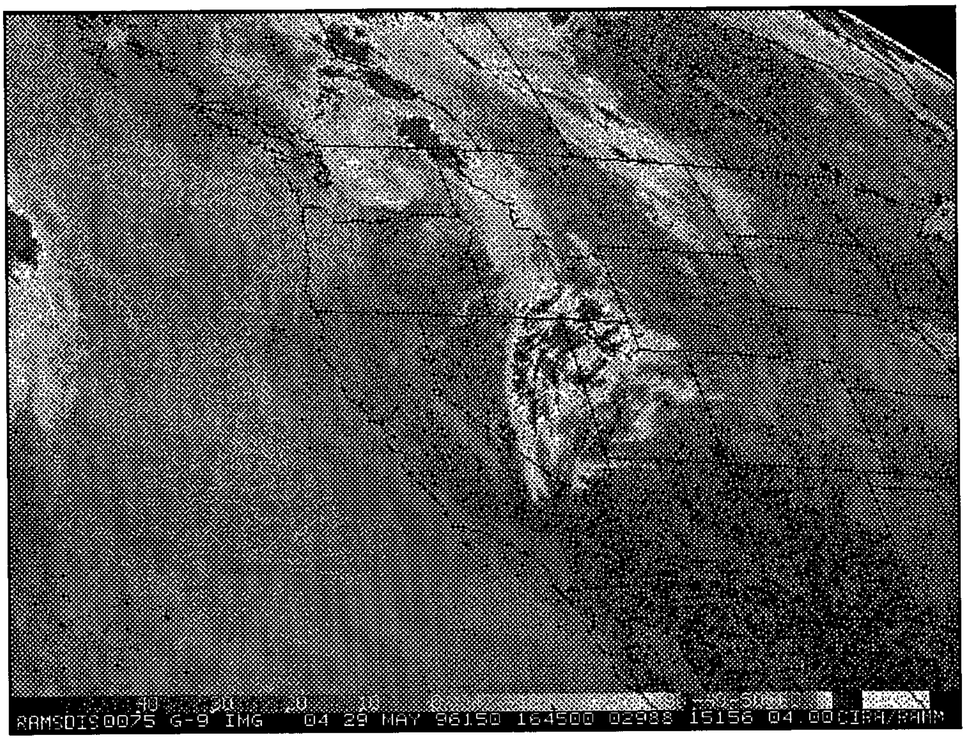

Figure 5. 4 km IR for WSFO SLC.

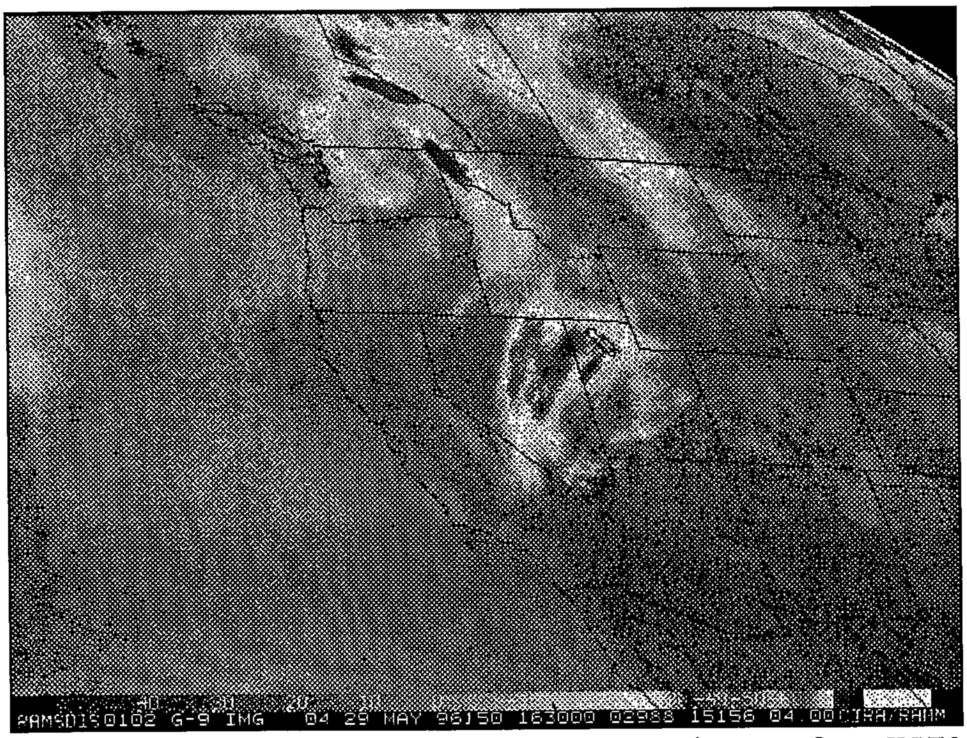

Figure 6. 2 hour running mean IR image for WSFO SLC.

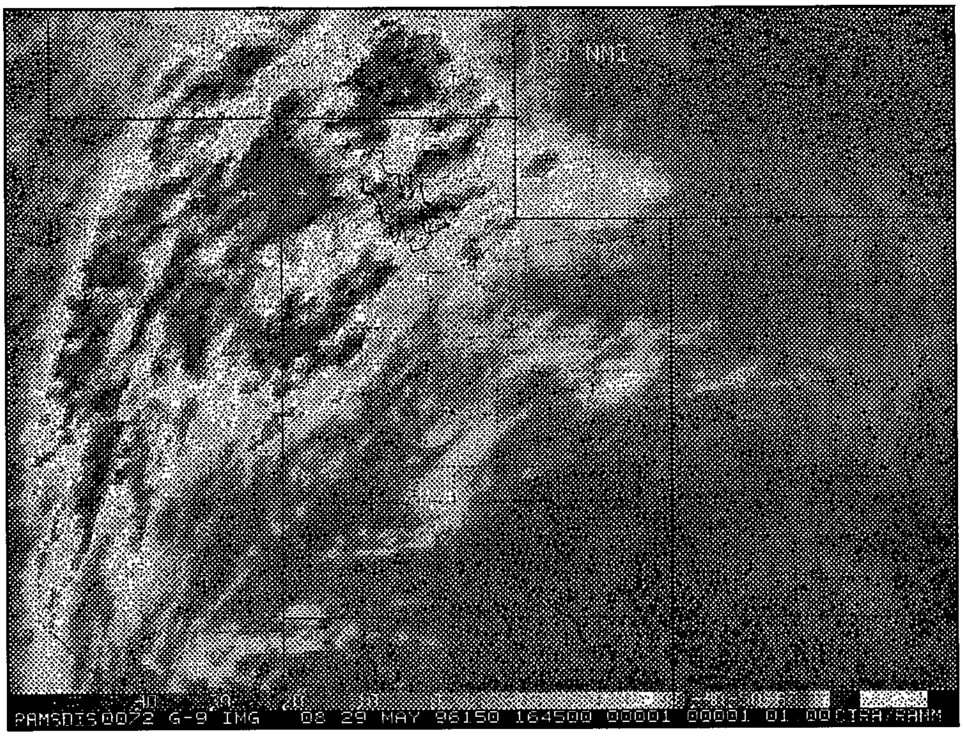

Figure 7. 1 km radar projection IR for WSFO SLC.

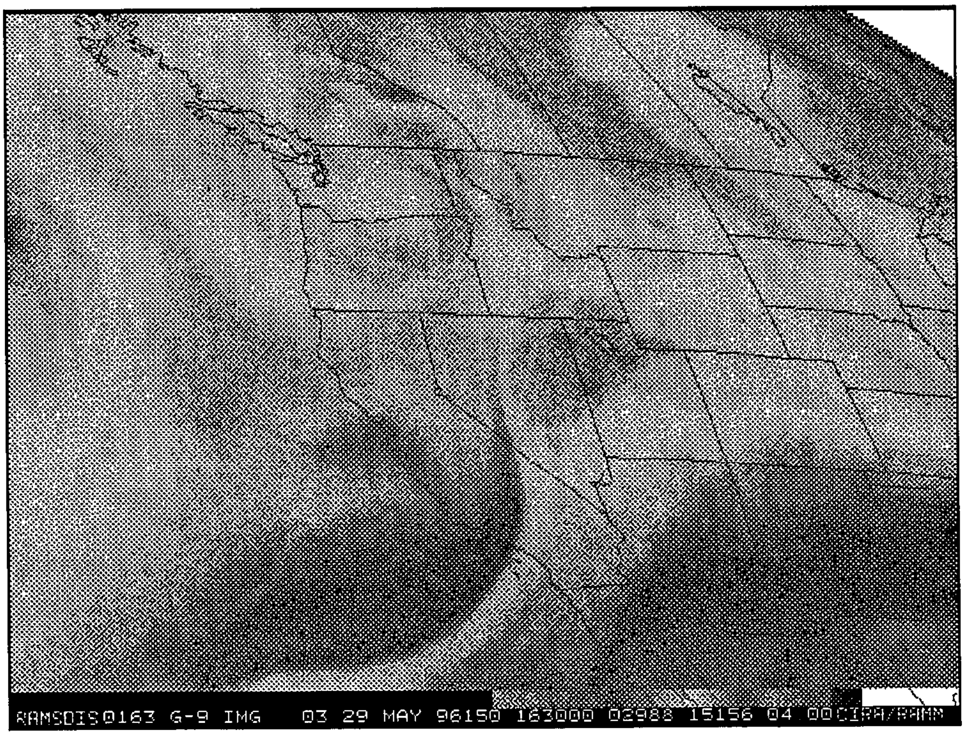

Figure 8. 4 km WV for WSFO SLC.

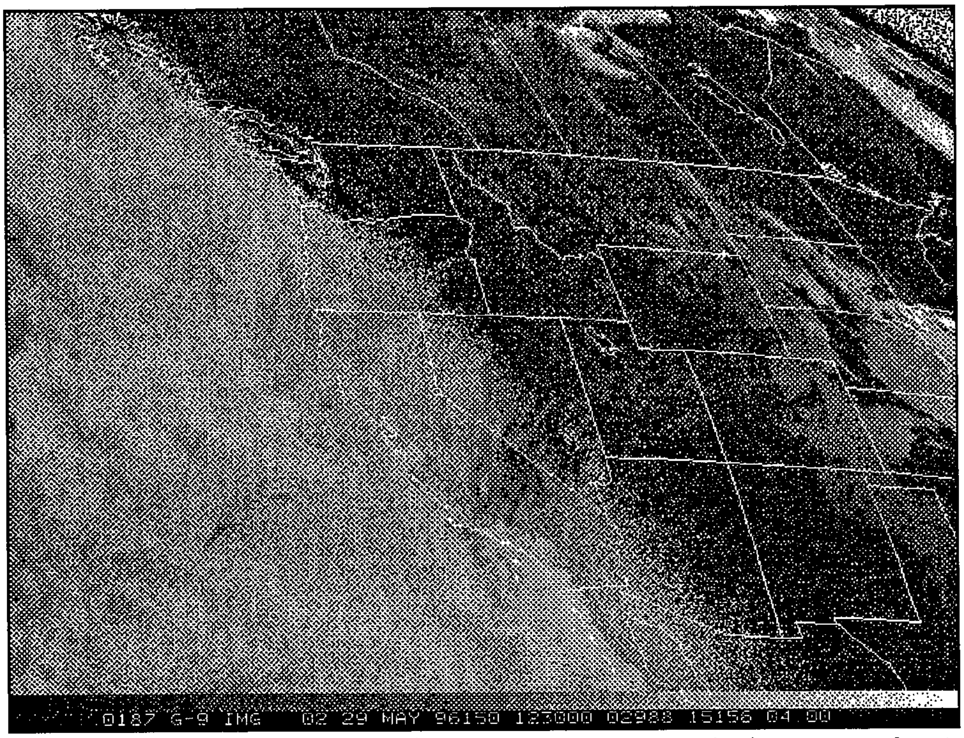

Figure 9. 4 km fog/stratus-reflectivity product for WSFO SLC.

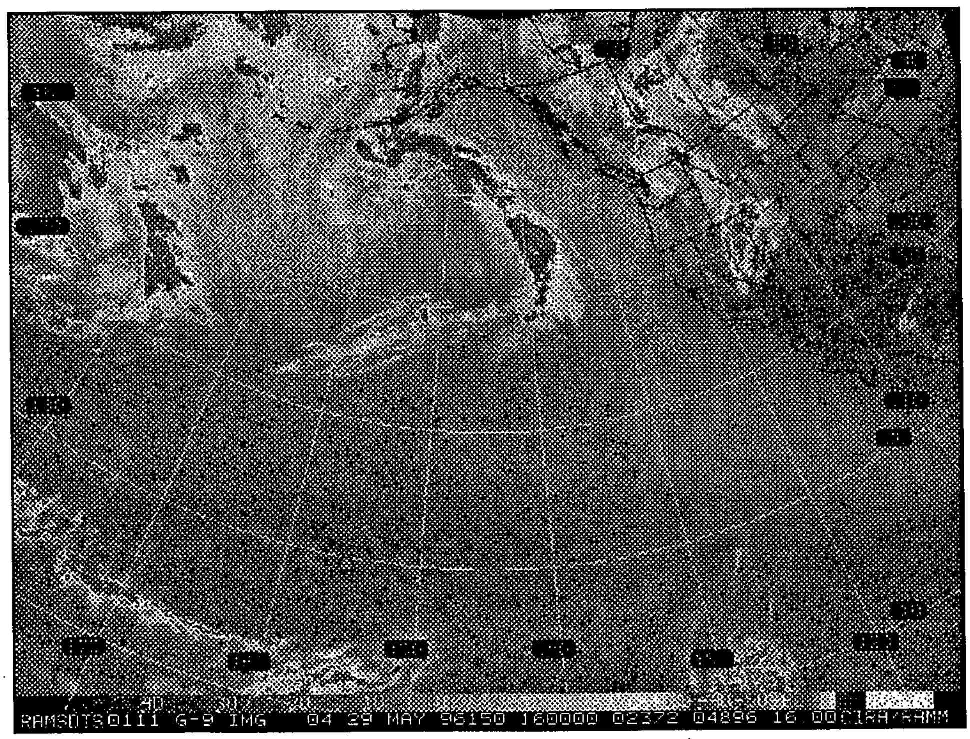

Figure 10. 16 km polar stereographic IR.

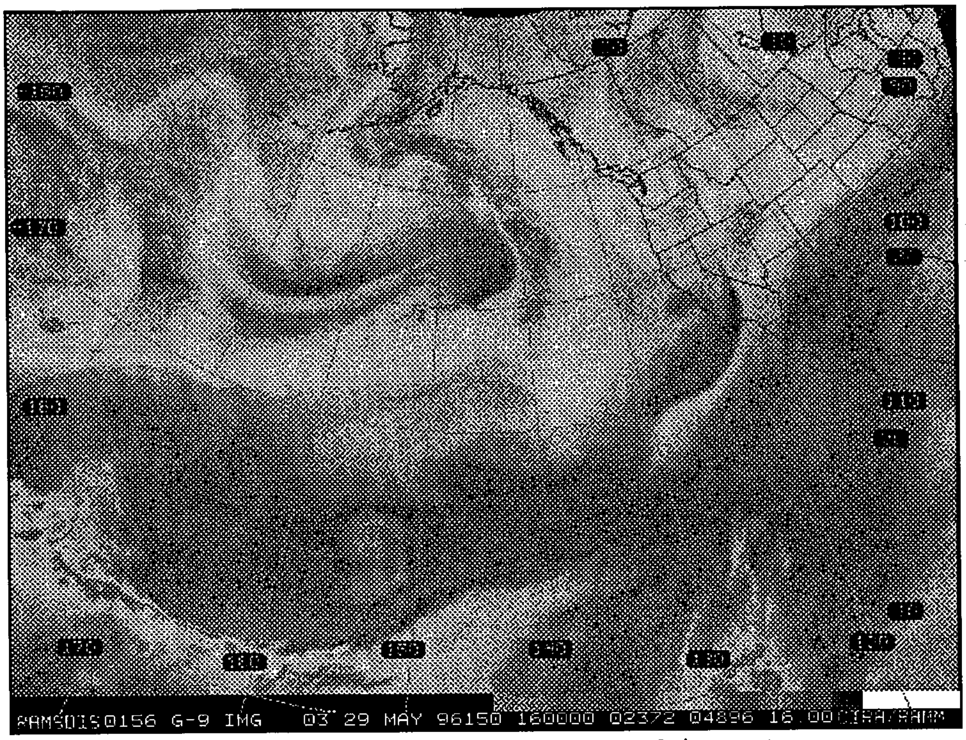

Figure 11. 16 km polar stereographic WV.

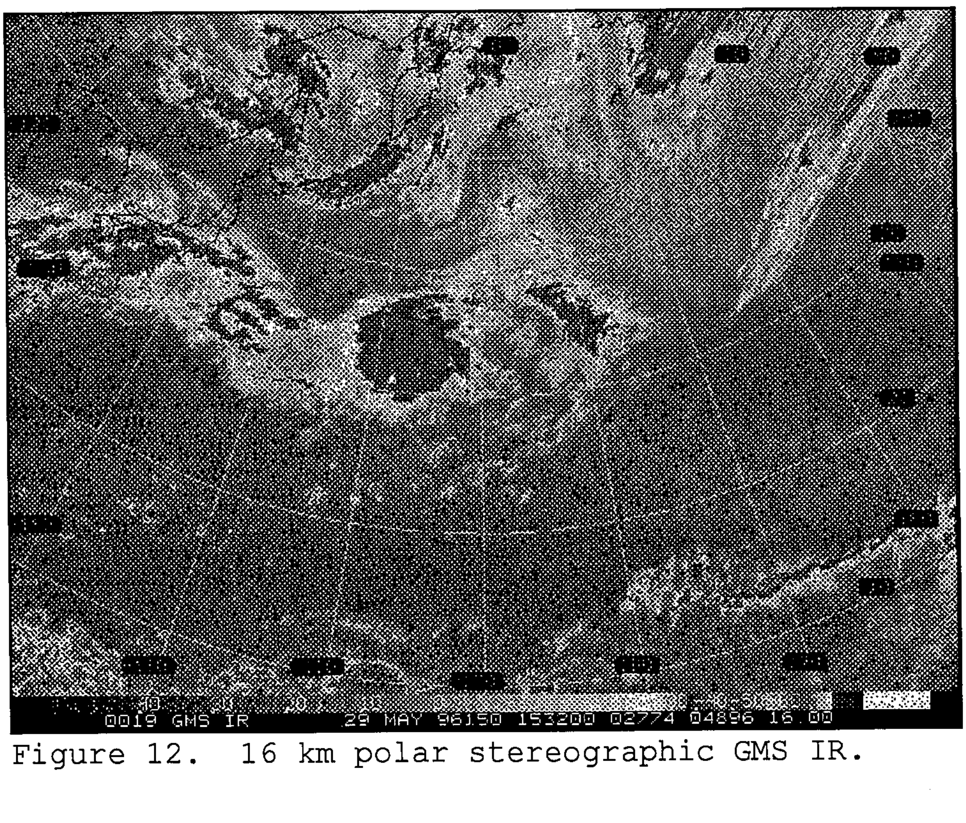

Figure 12. 16 km polar stereographic GMS IR.

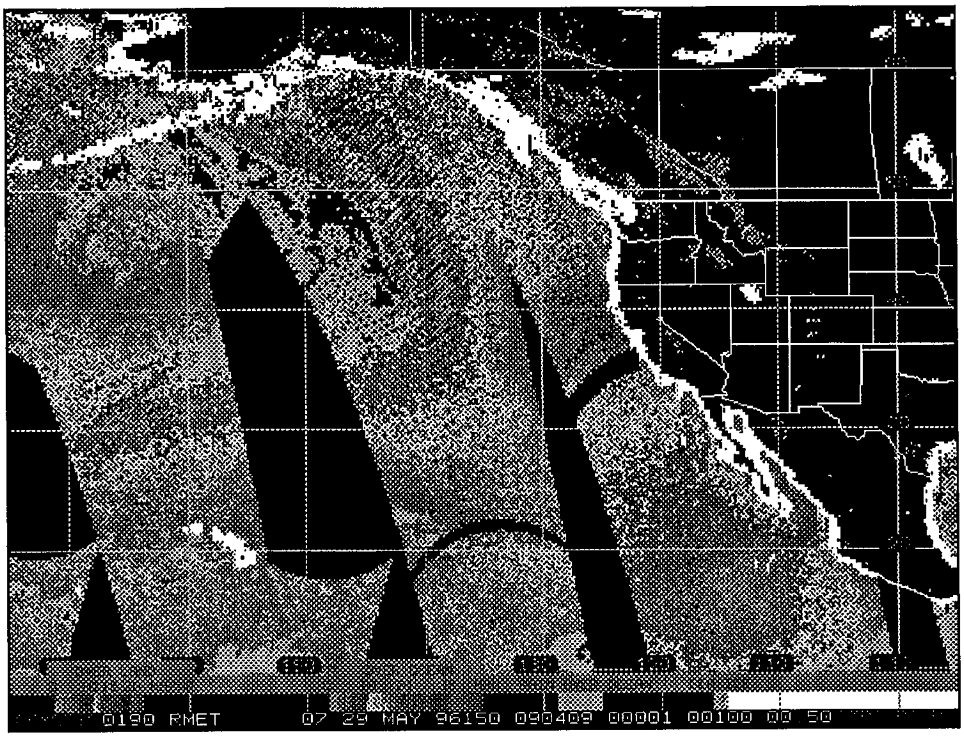

Figure 13. SSM/I wind speed product.

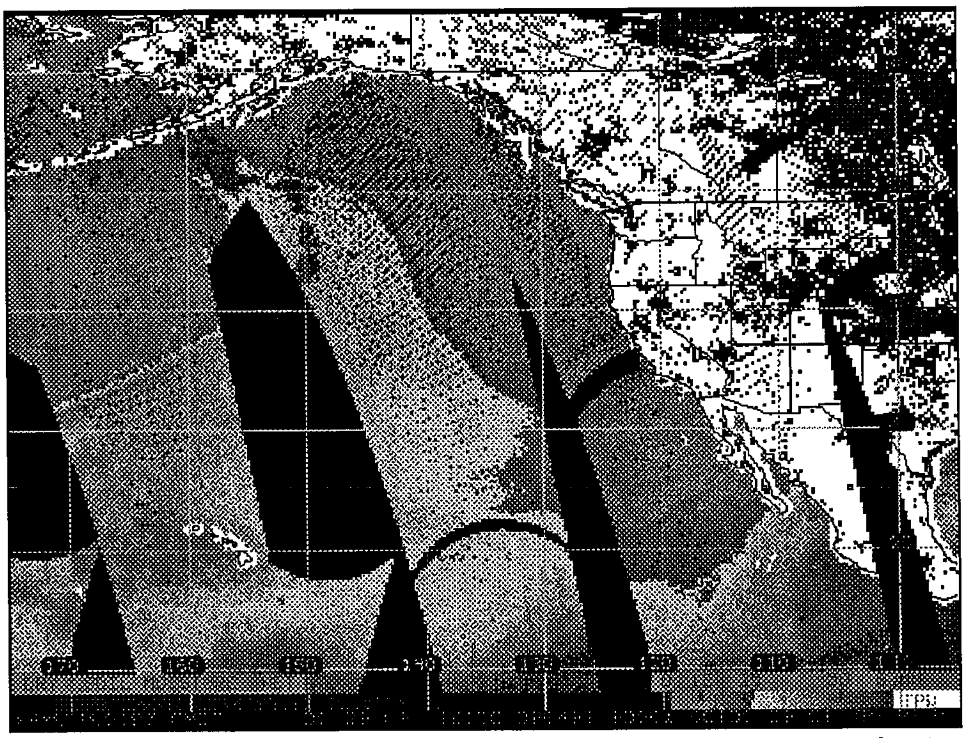
Figure 14. SSM/I total precipitable water product.

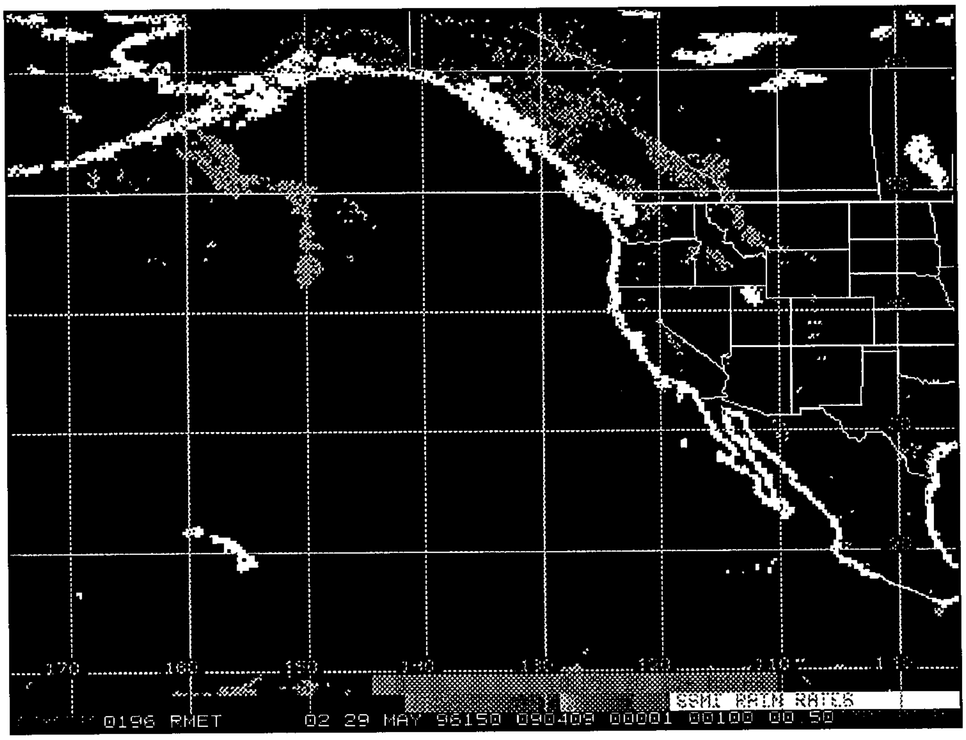

Figure 15. SSM/I rain rate product.

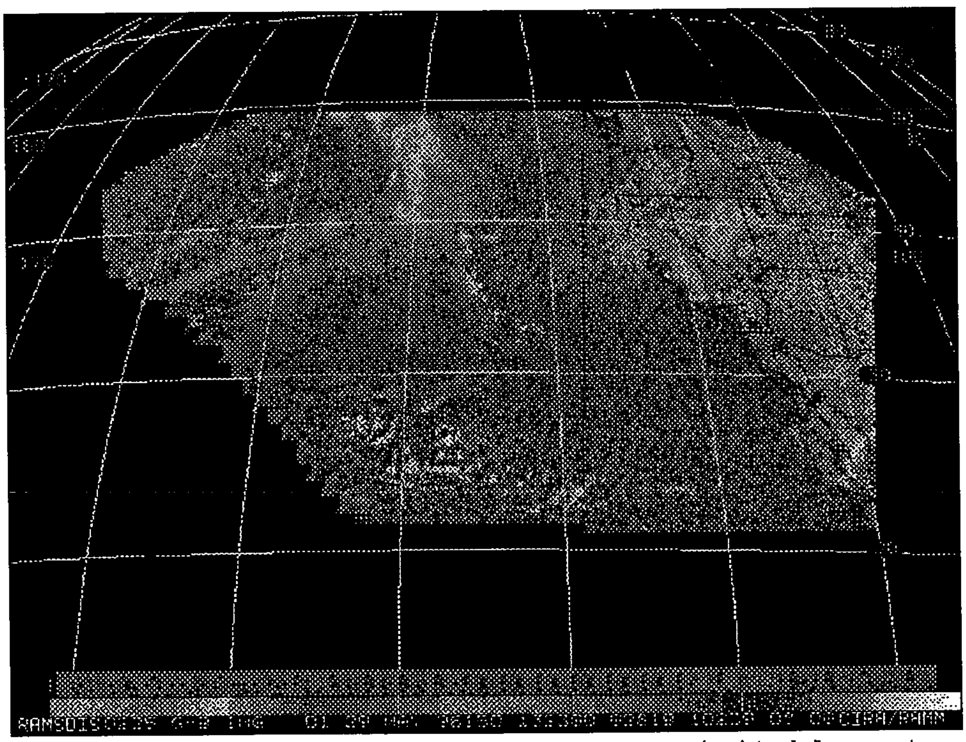

Figure 16. GOES-9 sounder total precipitable water product.

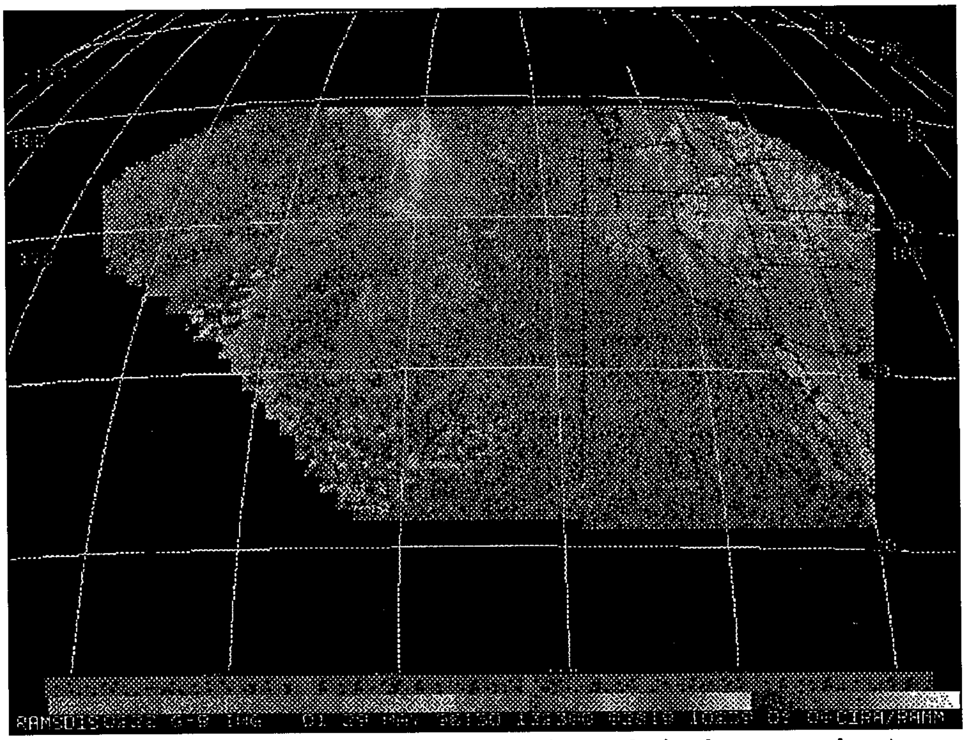

Figure 17. GOES-9 sounder lifted index product.

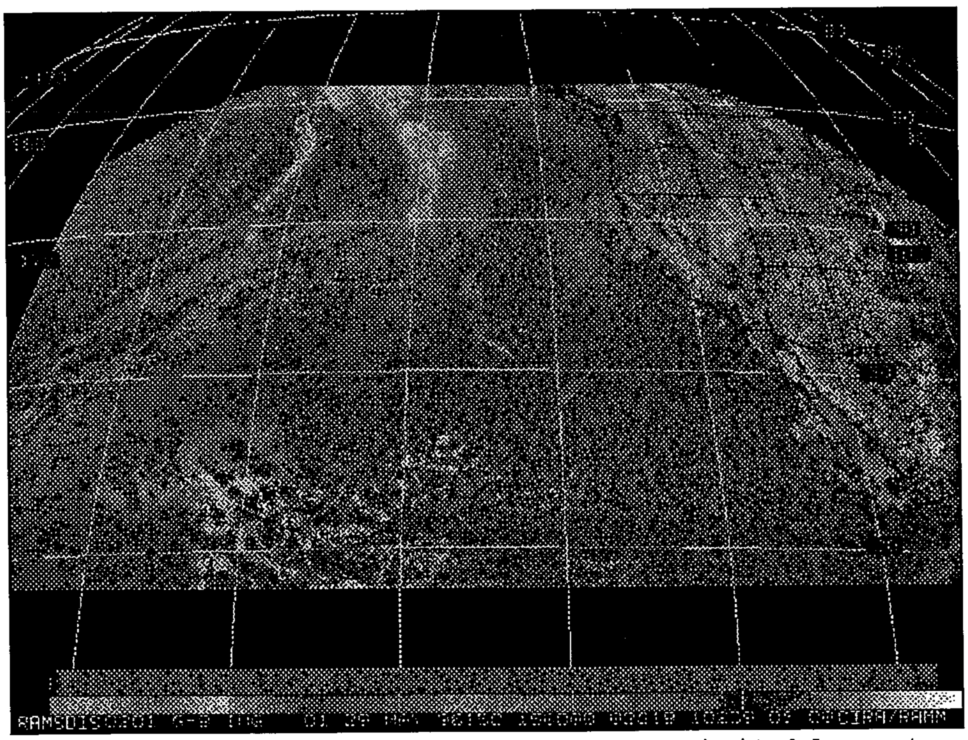

Figure 18. GOES-9 imager total precipitable water product.

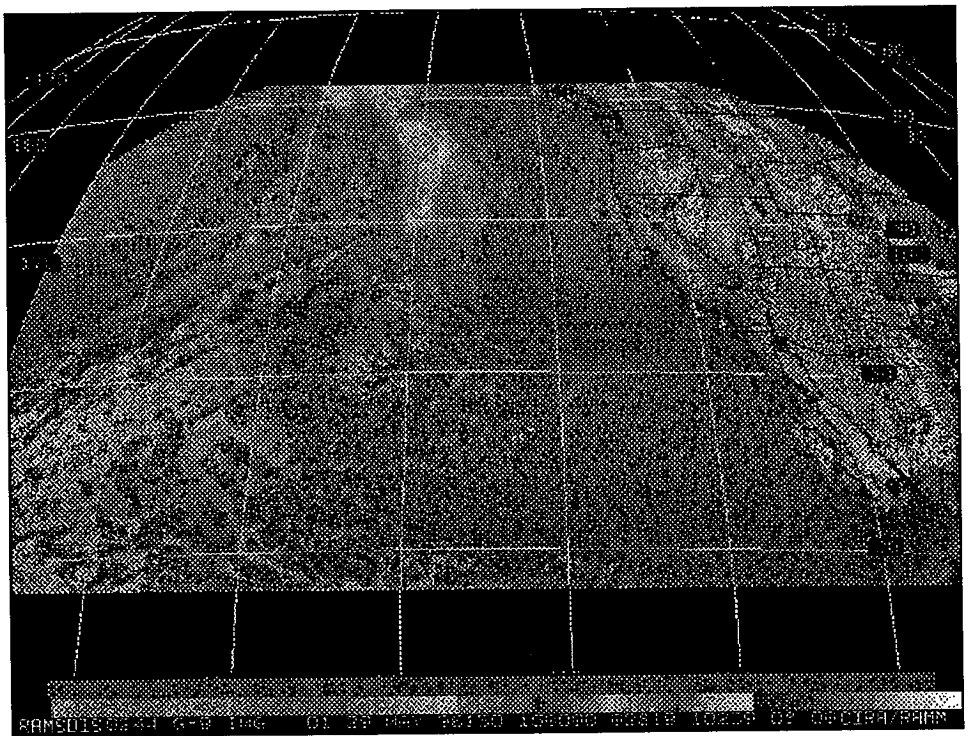

Figure 19. GOES-9 imager lifted index product.

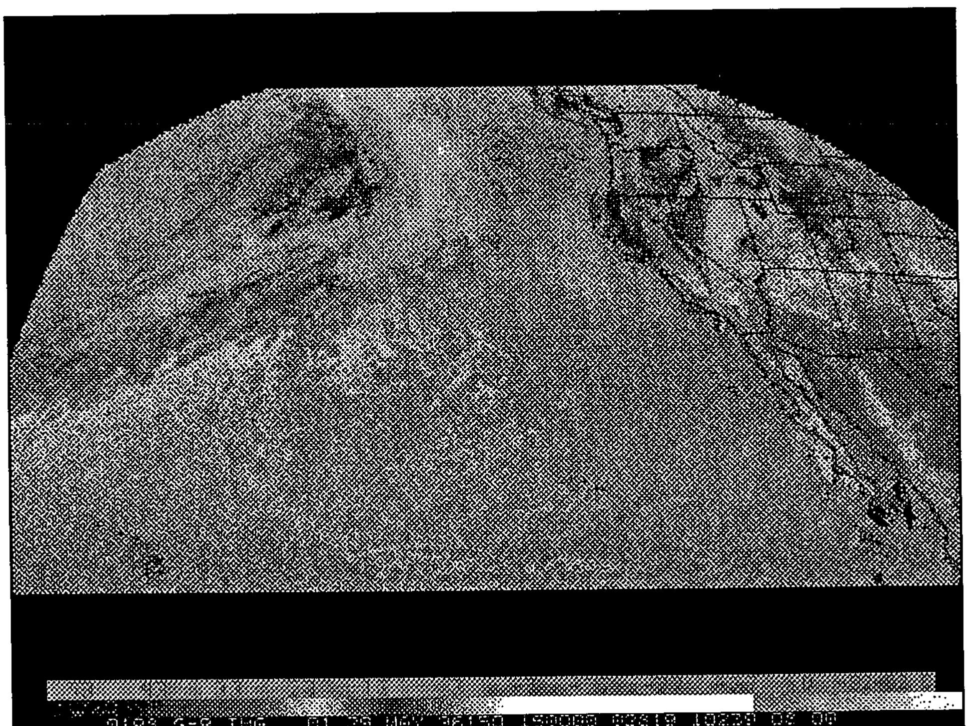

Figure 20. GOES-9 imager skin temperature product.