NEW SATELLITE SUPPORT FOR THE SOARING WEATHER FORECASTER AND PILOT

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INTRODUCTION

Considerable work has been done in the application of satellite cloud pictures to soaring. Clouds indicating the presence of mountain waves have received particular attention (1,2,3,4). A wide variety of convective cloud patterns are, of course, also revealed. Now, with the Improved TIROS Operational Satellites (ITOS) and the upcoming new geostationary satellites, there is reason to expect significant advancements in the use of satellite data in forecasts for soaring. Sensors aboard these new spacecraft are providing more "looks" per day in an increasing variety of spectral channels. Better spatial resolution and better response range are providing improved views of cloud structures that affect soaring weather. Simultaneous views in visible and infrared channels are providing 3-dimensional insight into these structures. And finally, such sensors on new geostationary satellites will provide almost continuous information on short-term cloud changes. Using recent samples of cloud photographs, we would like to review the operational environmental satellite situation and discuss potential application improvements in support of both wave and thermal soaring.

Polar Orbiter Image Data Applications

The current ITOS satellite, NOAA-2, is in a quasi-polar orbit; equator crossings occur at 8:50 AM (southbound) and 8:50 PM (northbound) local sun time. Unlike earlier ESSA satellites, NOAA-2 has no vidicon cameras. Rather, the primary imaging sensor contains visual and infrared (IR) detectors that receive energy by means of a motor-driven scanning mirror sweeping the earth scene at right angles to the flight path 48 times per minute. Spatial resolution for this Scanning Radiometer (SR) is two miles in the IR channel and about one mile in the visual channel. Large scale computer facilities are used to process this global SR image data. This seven day per week, round the clock operation produces a variety of outputs (5). The basic resolution of this imagery is reflected in figures 1 and 2. Here the raw data have been adjusted to an approximate equal area display and the response range has been "tuned" to the range of the display device.

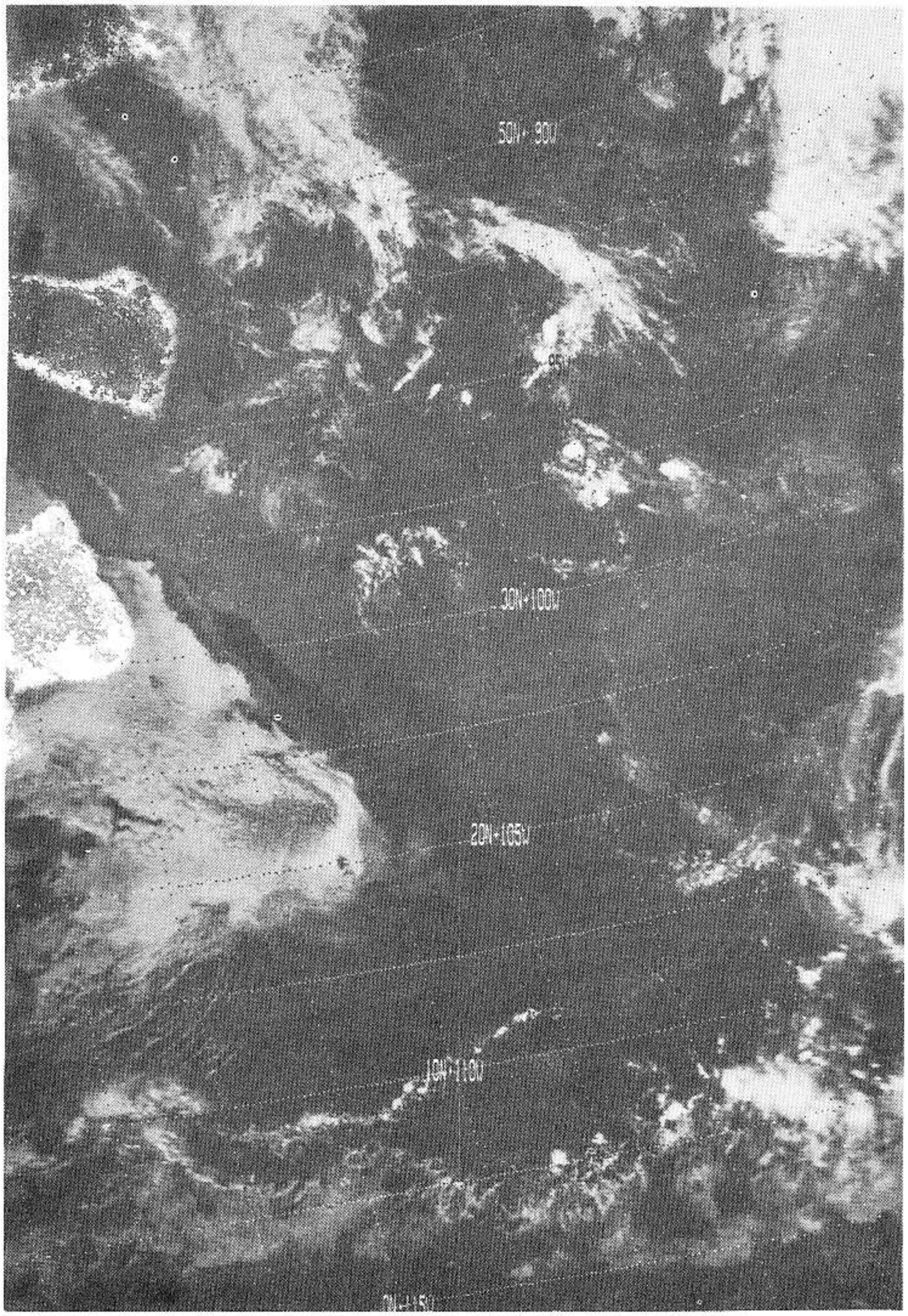

FIGURE 1. Visual channel image from the NOAA-2 Scanning Radiometer (SR) near 9AM local time on May 21, 1973. Earth locater lines and labels are implanted in the image as the digital samples are geometrically altered to an approximate equal area projection.

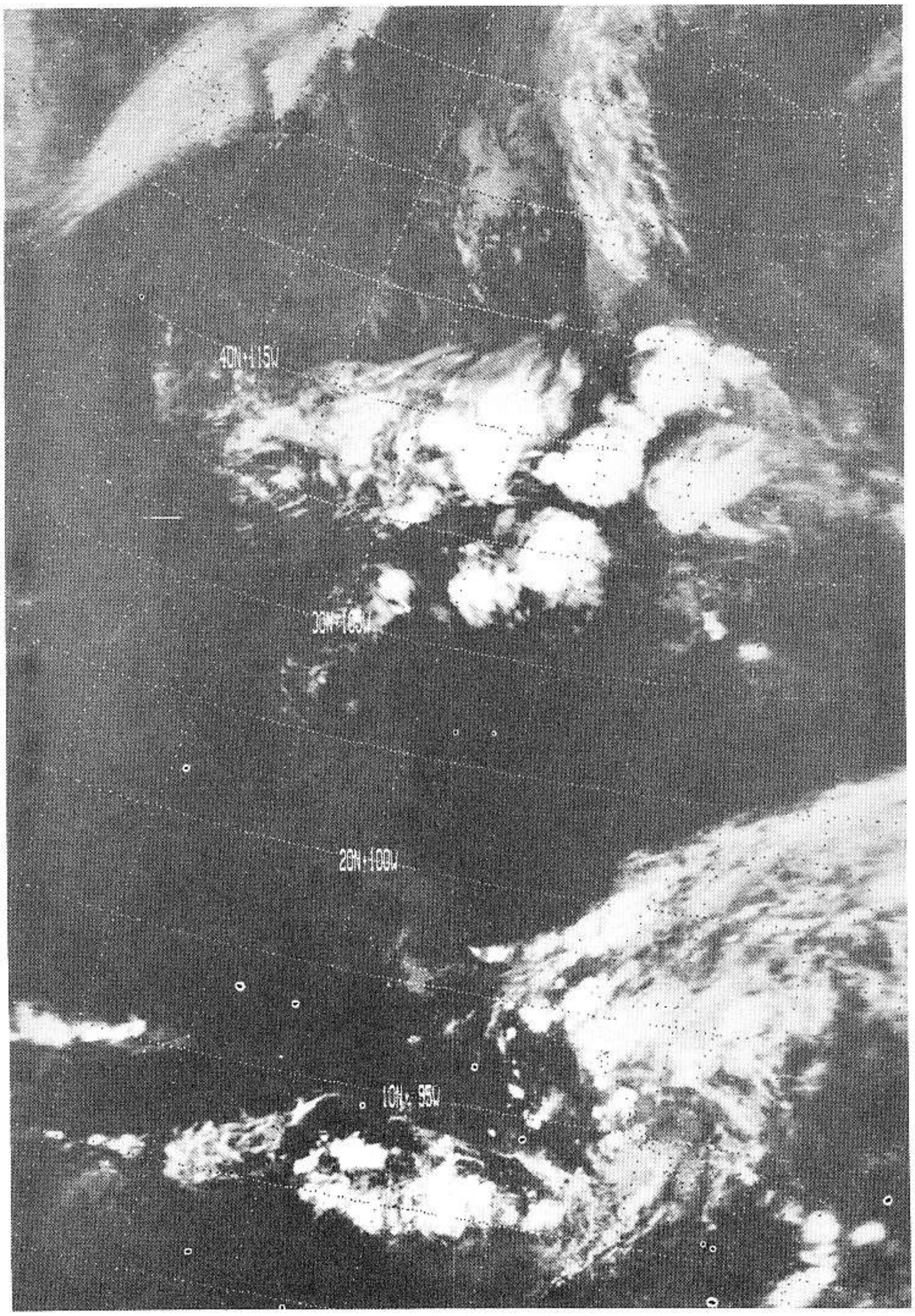

FIGURE 2. Infrared view obtained from the NOAA-2 SR near 9PM local time on May 22, 1973.

A similar Very High Resolution Radiometer (VHRR) scanning at 400 rpm provides IR and visual image data at half mile resolution. VHRR and SR data are available by direct readout to anyone having suitable receiving and image recording equipment (6) while global SR data are also available for central processing. In either case, one may obtain three views per day -- coincident IR and visual images near 9:00 AM and IR image near 9:00 PM. The question arises -- how can three looks per day with better sensors improve the forecast of soaring conditions?

First, the morning-evening orbit provides substantial tactical advantage. Wave clouds were easily detected in earlier 3:00 PM vidicon photographs as shown, for example, in the picture of the Appalachians obtained from ESSA-9 on February 21, 1970 (figure 3). In this remarkable example (3), wave conditions were extensive and persistent. On this weekend, soaring pilots were out in force and significant wave flights were made over Cumberland and Frederick, Maryland, and at Warrenton and Lexington, Virginia. On Saturday flights reached 15,000 feet and on Sunday some reached 17,000 feet. In general, however, wave conditions are less well developed so midafternoon cloud pictures are not always good indicators of wave soaring conditions the following morning. Now, with IR images, one may detect wave patterns both morning and evening (figure 4). With such information available, planning may be done in the evening, and the soaring pilot can then prepare for a tow into the wave at sunrise.

In a 1968 study of many satellite cloud pictures, Lindsay (4) measured wavelengths in lee wave patterns, and the downwind extent of such patterns. The study also indicated mountainous regions that favored wave cloud formation and indicated the areas of relatively more frequent occurrence over the Appalachians. With half mile resolution data, such as that shown in figure 4, future studies of wave clouds can be carried out with greater ease and precision. Trends in wave cloud development in these favored regions may be observed more easily by means of both morning and evening satellite imagery. Twelve hourly changes in weather patterns have long been employed as forecast tools, so it appears likely that knowledge of trends in wave cloud developments over similar periods will also prove useful. In sum, the morning-evening orbit seems to offer two advantages: the convenience of preparing for early morning operations with more recent information and the advantage of shorter term trend information from the morning-evening IR imagery.

In addition to indicating trends in wave cloud developments, IR image data offer the fascinating possibility that they can be used to indicate thermal convective soaring conditions. Using the coincident IR and visual images eases some of the burden of precise feature identification and earth location. However, the extraction of information on local surface heating contrasts represents the real payoff in support of thermal soaring. The higher resolution VHRR IR data appears to offer particular promise for this purpose. In this connection, one must take full advantage of the instrument's response range.

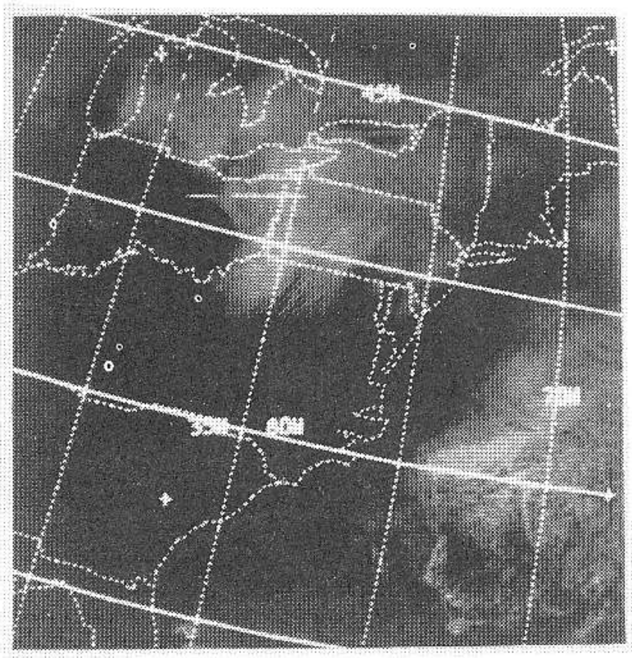

FIGURE 3. Appalachian wave clouds as seen by the ESSA-9 vidicon camera near 3PM on February 21, 1970.

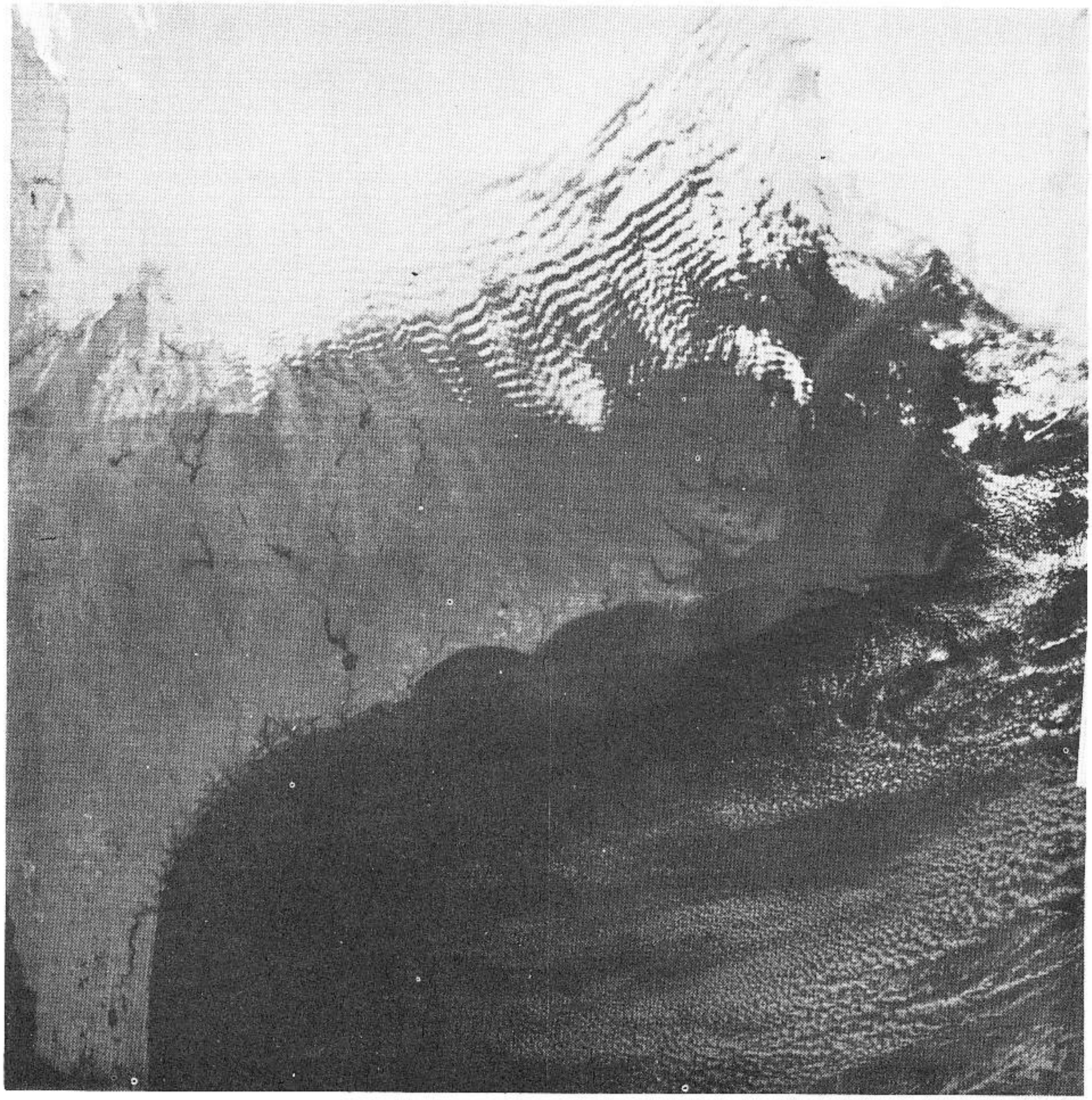

FIGURE 4. Infrared view of Appalachian wave clouds obtained from the NOAA-2 Very High Resolution Radiometer (VHRR) near 9PM on March 12, 1973

The response range of the VHRR scanner extends considerably beyond the practical display range of a good photo recorder. This can readily be demonstrated by further treatment of an image sector with reduced scene response. For example, the March 28, 1973 visual channel view of the southwest shown in figure 5 was prepared with reduced scene response. The scene enclosed in the rectangle of figure 5 contains a substantial Texas-New Mexico sector that is essentially cloud free. Figure 6 was produced by spreading the full black-white display range of the photo recorder over the reduced response for this sector. Natural land features are more easily identified.

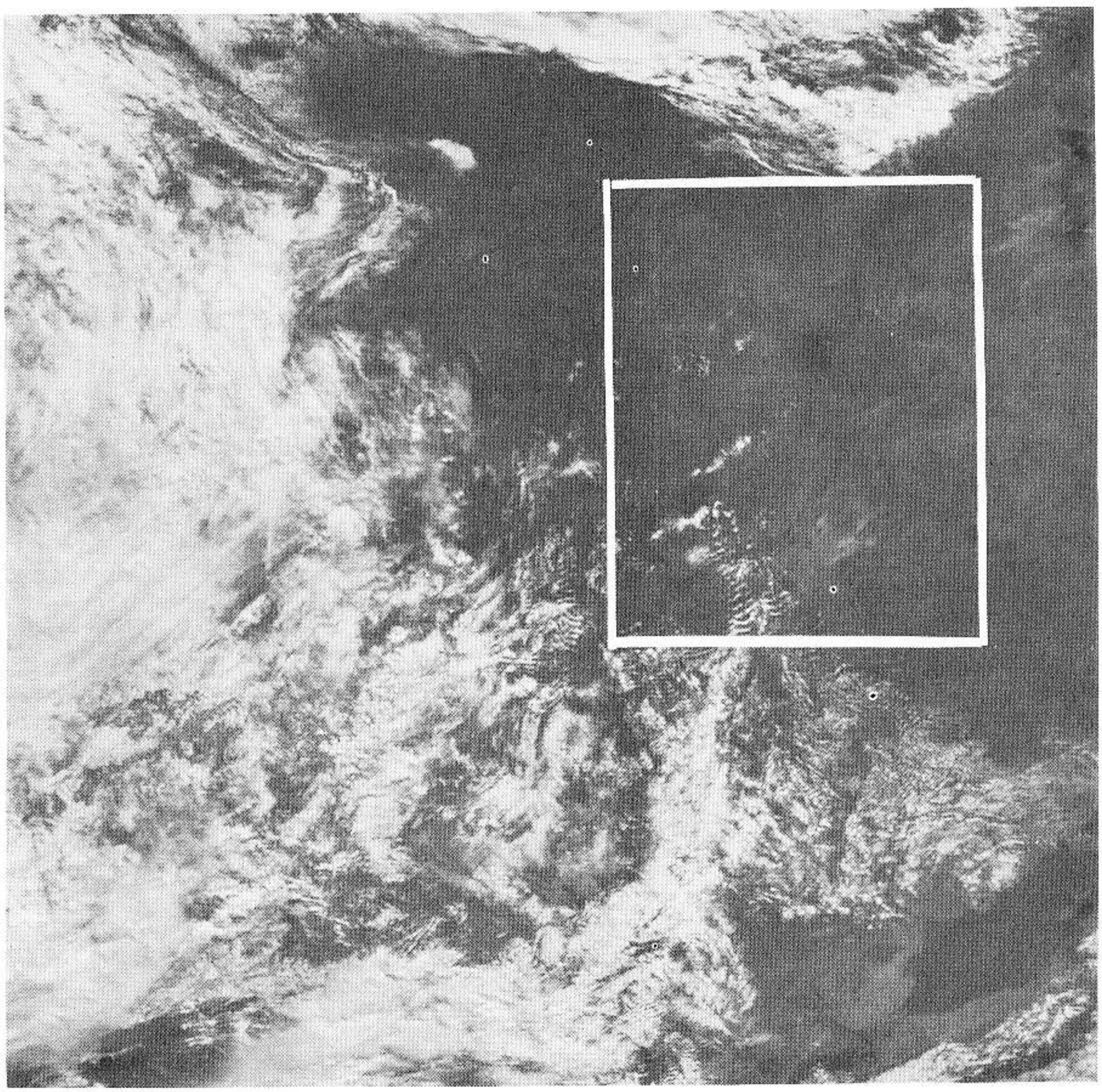

FIGURE 5. This half mile resolution visual channel image of the south-western portion of the United States was obtained from the NOAA-2 Very High Resolution Radiometer (VHRR) near 8:40AM local time on March 28, 1973. The region covered extends from Salt Lake to the California Gulf in the west and from Mid-Kansas to the lower Rio Grande along the eastern edge.

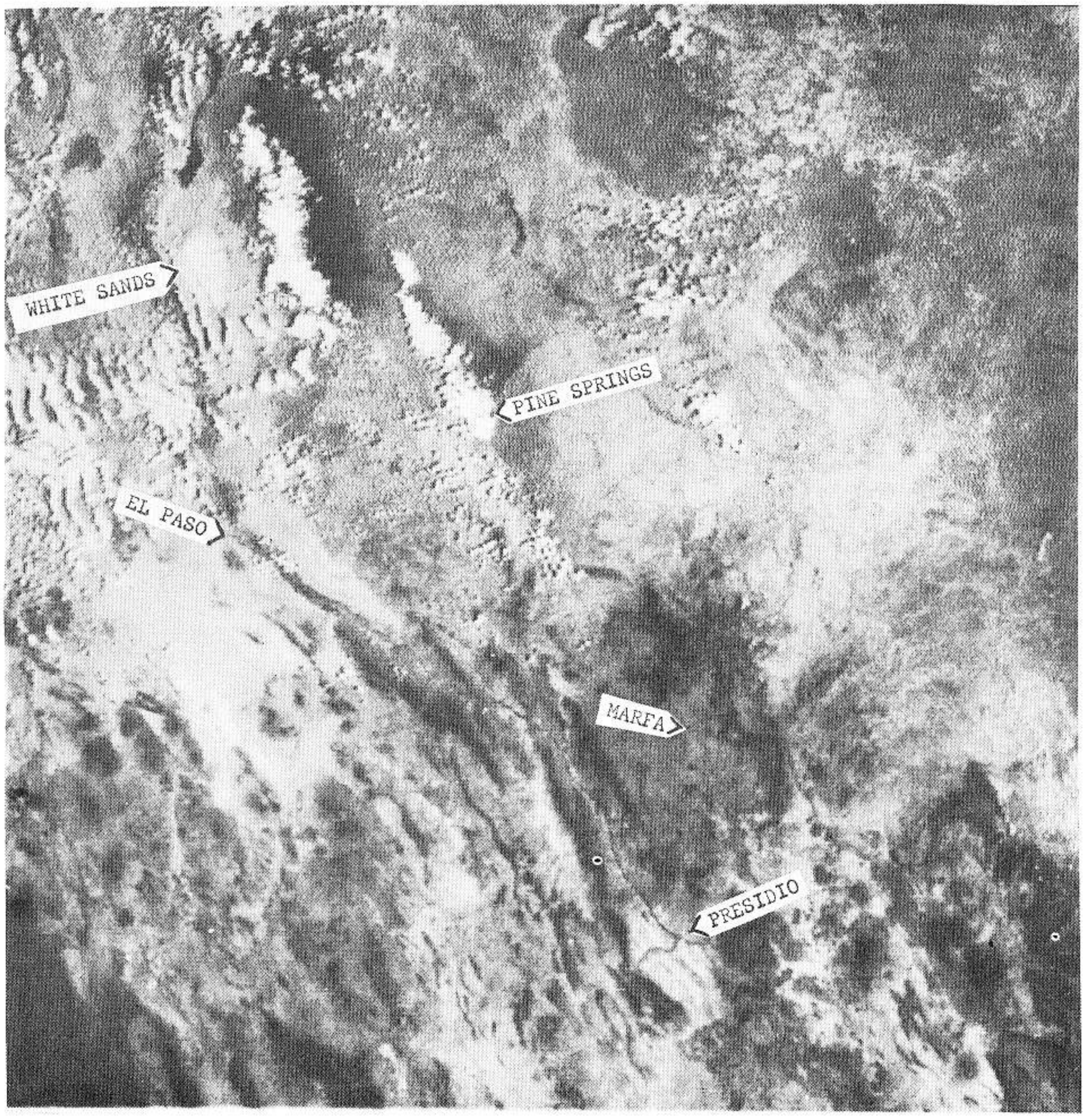

FIGURE 6. West Texas--New Mexico enhanced version of inset area from Fig. 5.

Once the visual channel image has been used first to select a cloud-free situation and then, through enhancement, to locate the area of interest through "landmark navigation", the coincident infrared image scene can be used to locate clues to possible soaring conditions. Figure 7 is the companion IR image to figure 6. Here an enhancement similar to that used to produce figure 6, was done to emphasize variations in the thermal pattern. In terms of relative radiative temperatures, bright features represent cool terrain (and clouds) and dark features warm terrain. In terms of relative radiative temperatures, without referring to the day's weather situation, one can immediately see routes likely to be favorable

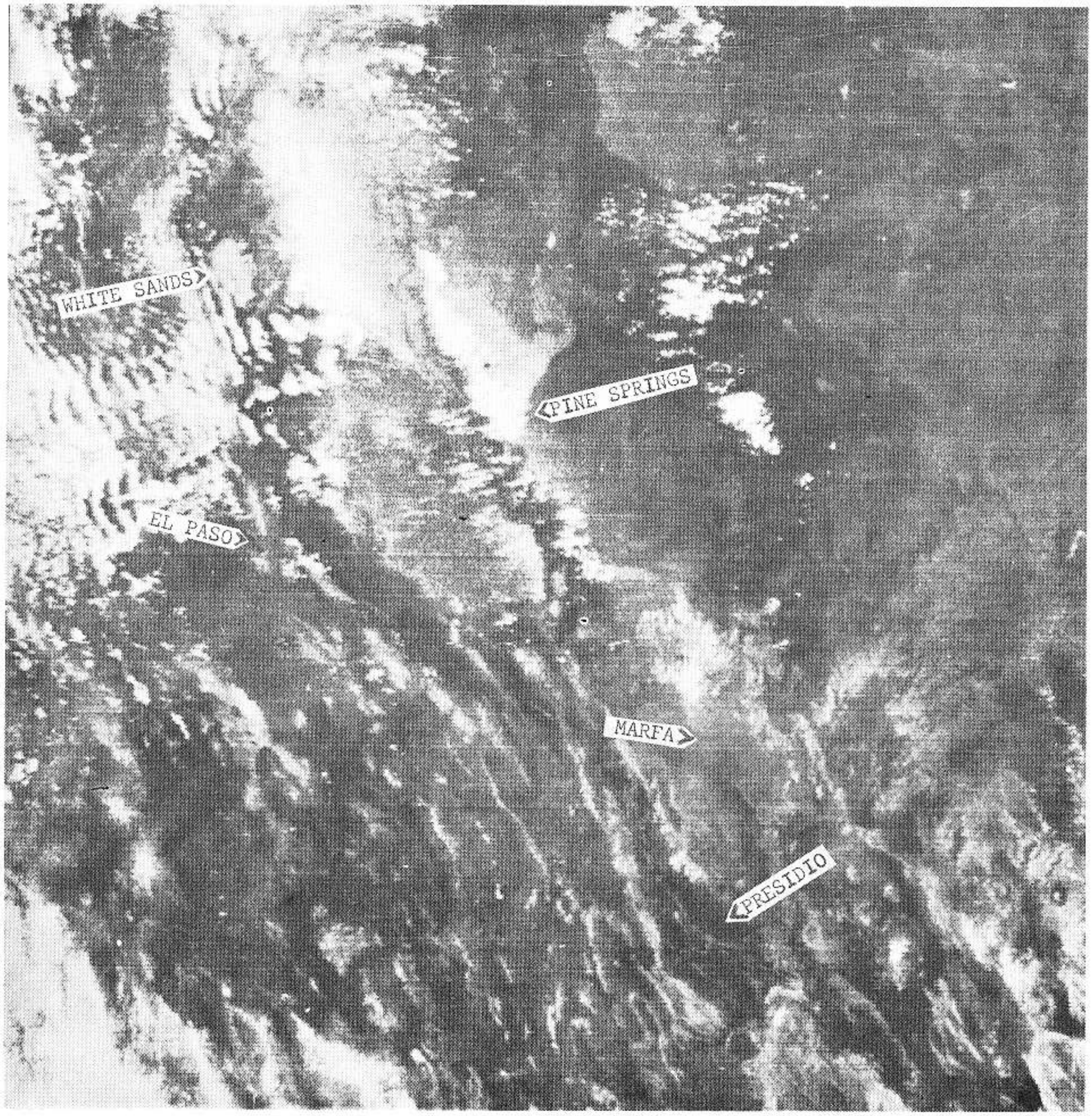

FIGURE 7. Enhanced Infrared VHRR companion to Fig. 6.

for cross country flights. For example, on the flight route from Presidio to White Sands, the IR image shows "warm streets" that imply convective support. And to the southeast of Presidio there appear to be several possible routes with convective support for local "out-and-return flights.

Although one might expect many similarities over the same cloud-free area on another day, there may well be differences reflecting subtle changes in wind or thermal stability, or relating to past rainfall. Figures 8 and 9 are the visual and IR views of approximately the same area shown in figures 6 and 7, but for April 12, 1973.

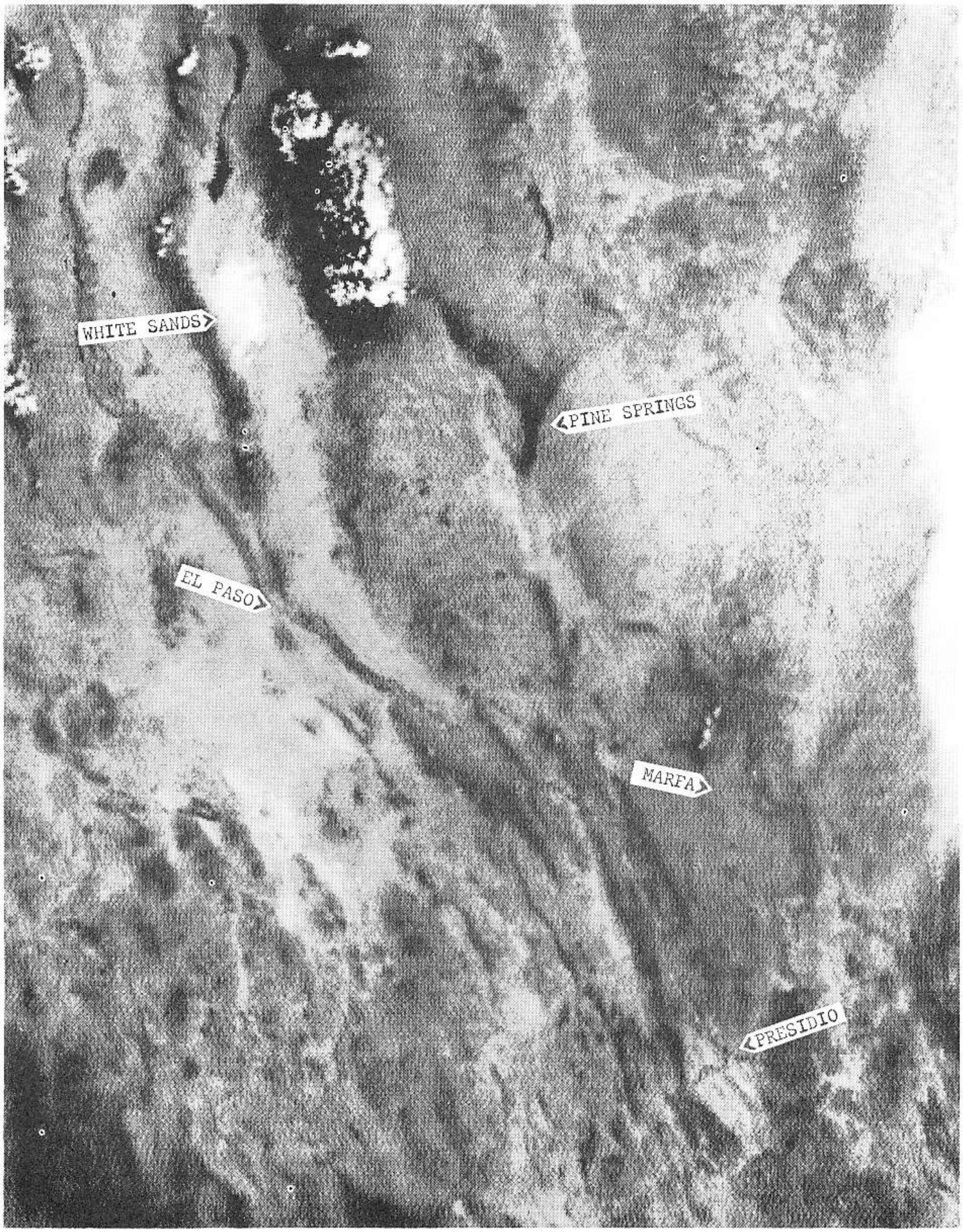

FIGURE 8. Enhanced visual channel VHRR image obtained on April 12, 1973 in approximately the same area as shown in Figs. 6 and 7.

FIGURE 9. Enhanced Infrared VHRR companion to Fig. 8.

In figure 8 we see far less cloud cover than in figure 6; here a different wind flow regime is indicated by the shift in cloudiness over the Sacramento Mountains east of White Sands. In comparing figures 7 and 9 one sees many similar features such as the warm streets between Presidio and White Sands and the relatively cooler features such as the salt flats southwest of El Paso. One noteworthy difference is the apparent shift in the relatively warmer surface from the Presidio area in figure 7 to an area south of Pine Springs in figure 9. Close study of such difference probably will reveal the influence of past cloud cover or the effect of showers. In general, this new information on thermal patterns in cloud-free regions provides an entirely new area for investigation.

Vertical Thermal Structure

In addition to the IR instruments that provide improved image data, NOAA-2 also carries a new indirect sounding instrument that provides routine observations of the atmosphere's thermal structure (7). The multi-channel radiance measurements made by this Vertical Temperature Profile Radiometer (VTPR) show promise of replacing radiosonde stations, particularly in remote areas where ground based stations are costly. Since these indirect soundings are inherently less detailed for the lower layers of the atmosphere, their utility in forecasts for soaring has yet to be evaluated. With proper developmental effort, it appears likely that VTPR data could be useful, particularly in areas with sparse radiosonde networks.

The Ongoing Polar Orbiter Program

The ITOS satellite series will continue in operation with periodic launches to replace old spacecraft and to assure continuous operational capability. The next spacecraft will be launched before the end of 1973. Although displaced somewhat from NOAA-2, its orbit will retain the 9:00 AM - 9:00 PM equator crossings. There is a possibility that some follow-on ITOS spacecraft will be launched in 3:00 AM - 3:00 PM orbits. Should this occur, there might then be opportunity for viewing convective cloud patterns and dry thermal patterns at the time of maximum afternoon heating. Such information would augment current information and would provide the source for a "climatology" of soaring conditions including those over sparsely settled regions.

Planning is currently under way for a late 1970's follow-on spacecraft with improved sensors and an all-digital information relay system for more reliable and stable performance. Present projections include an advanced VHRR scanner with more spectral channels and combining the attributes of the present SR and VHRR sensors. Of particular interest will be a water vapor channel which will provide information on patterns of moist and dry tongues. In cloud-free areas, such imagery may provide further clues to convection; this in turn will be useful for locating where subsequent cloud formation may take place.

Data From Geostationary Satellites

Since late 1966, NASA's Advanced Technology Satellites (ATS) have provided pictures of the full earth disk at about two-mile resolution. Pictures such as that shown in figure 10 can be obtained at half-hour intervals as the visual channel telescope sweeps the earth. Using clouds as tracers, these repeated views are providing the means for obtaining wind estimates (8,9). Time-lapse movie loops also are routinely constructed from these pictures; from these valuable information on diurnal changes and three-dimensional flow mechanisms can be obtained (10).

A new series of Geostationary Operational Environmental Satellites (GOES) will be launched; the first is planned for early in 1974. NASA's Synchronous Meteorological Satellite (SMS-A) will be the first in this series. Again the trend is for more viewing channels. Visual data will be provided at half-mile resolution and IR data will be provided at about 5-mile resolution. These spacecraft will provide essentially continuous IR viewing of fixed earth regions. In cloud-free areas the IR data will permit tracing the surface temperature through its diurnal cycle. And, through successive pictures reflecting the dynamic scene, it should be possible to detect any intrusion of convection-damping cirrus clouds.

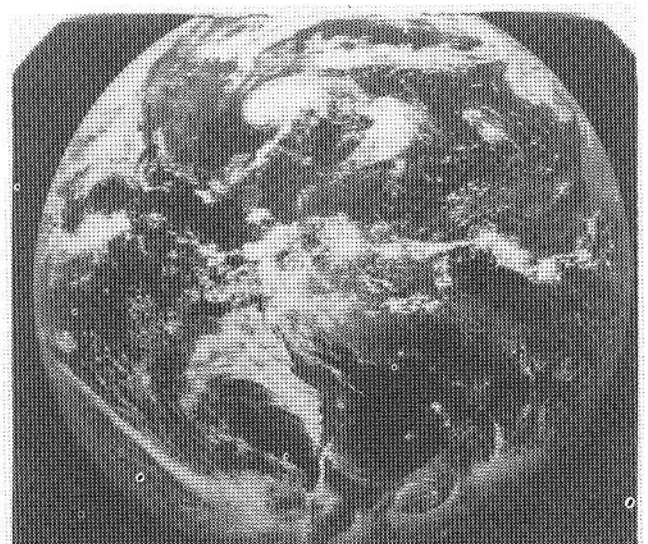

FIGURE 10. Near noon view of the Western Hemisphere obtained from NASA's Advanced Technology Satellite ATS-3 on June 19, 1972.

Plans for the GOES system call for a two-spacecraft U. S. operation by late 1974, with most of the Western Hemisphere under almost constant surveillance. It now appears likely that, in the late seventies, other nations will contribute additional geostationary spacecraft to complete coverage at all longitudes.

Although wideband ground facilites probably will continue to be high cost items, substantial image information will be rebroadcast for receipt by relatively inexpensive Automatic Picture Transmission (APT) ground facilities. Periodic APT Information Notes are available for those interested in direct readout facilities (11). Such field APT stations offer a potential source for new day and night image data in support of forecasts for soaring.

CONCLUSIONS

Weather satellites have progressed well beyond the experimental stage, and with the improvements in sensors, the diversity of applications into oceanography, hydrology and other areas is steadily widening. With the establishment of several field service stations, the impact of satellite data will continue to increase.

In the private sector, an increasing variety of image products will be available through direct readout of polar orbiter data, through connection of quality photo recorders to ground communications systems, and through acquisition of image data relayed via geostationary satellites. Apart from direct imagery, a substantial improvement to computer facilities is under way; these facilities will contribute toward the generation of more timely derived-image products for tactical, near-real-time application.

The intent of the foregoing is to indicate potential. The availability of satellite data for direct use at soaring events is recognized as a resource requirement. With the current trend toward automated mass production of National Weather Service forecasts for items such as maximum temperatures for cities, perhaps some form of specialized forecast of soaring conditions might be considered. Alternatively, we may be presenting a challenge to the private sector. A digitally oriented modern APT facility might provide the basis for a variety of specialized services. Wave clouds and evidence of convective activity are of interest to a wide variety of aviation and other activities. Support for soaring activities, therefore, might be linked to a more generalized support for the broad spectrum of private flying. The information is coming, and there appears to be a real challenge in providing a means for its exploitation for soaring.

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