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WEATHER SATELLITE INTERPRETATION - Introduction to Weather Satellite Imagery

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FOREWORD

This manual was designed to be a basic self-study course for the new GOES user. It can also be beneficial to those who have been using GOES products without the benefit of any formal training.

Content of the manual includes basic operation of the GOES system and detailed explanations of some of the most commonly used GOES photos. The intent was to thoroughly explain the shading on the various types of imagery so the user can accurately determine just what any particular gray shade represents in terms of the earth's surface or the tops of clouds. No attempt is made to explain the synoptic situation in any of the photos. Except for a brief reference to atmospheric stability in connection with cloud types, no meteorology is discussed. The material in this manual can provide a basic understanding of GOES Satellite products which, in turn, can provide a good foundation for subsequent endeavors in meteorological interpretation of satellite imagery.

The text consists of two chapters, a criterion test at the end of each chapter, and a comprehensive photo interpretation examination. Answers to the criterion tests and the comprehensive exam are located in the back of the book. There are also page references for easy location of the subject material covered in each question on the criterion tests and a brief explanation of each correct answer on the comprehensive exam.

Each examination should be completed before referring to the answers. If any questions are missed, the material should be restudied as necessary for understanding.

GOES SATELLITE COURSE

I. INTRODUCTION

Satellite imagery is an excellent source of observed data, and as such, it is a very helpful aid to the pilot briefer. Like other aids, such as surface observations and radar reports, it should never be used alone. A good briefer uses all available information to insure that pilots get the latest and most accurate weather picture possible.

One of the greatest advantages of satellite imagery is that the exact geographical coverage of a cloud system can often be seen. This is not possible with other types of observed data because of the large distances between observation stations.

GOES SATELLITE PHOTO RECOGNITION



FIGURE 1 GOES West and GOES East Coverage.

CHAPTER 1

GOES IMAGERY

This lesson will introduce you to satellite imagery. It will briefly cover the satellite itself and the photo equipment on board, then it will cover in detail the types of imagery available from the satellite.

There are two main types of meteorological satellites: the Polar orbiters and the Equator orbiters. The Polar orbiters are at altitudes of 600 to 800 NM. They circle the earth once every hour in an orbit that carries them over both poles. Imagery from the Polar orbiters is routinely available in Alaska and Hawaii but not in the remaining 48 states.

The GOES satellites are in orbits directly over the Equator. They are approximately 19,000 NM above the earth and make one revolution every 24 hours. Their speed is exactly timed with the rotation of the earth so they stay over the same spot on the earth all the time. The acronym GOES stands for *Geostationary Operational Environmental Satellite*. They may also be referred to as SMS, Synchronous Meteorological Satellite. Five GOES satellites launched by the U.S. and two others launched by Europe and Japan provide global coverage plus backup capability. Two of these cover the U.S.; GOES East, located at 75 W. Long. and GOES West, at 135 W. See figure 1.

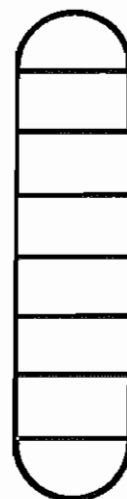
The scanning equipment aboard the Polar orbiter is very similar to that on the GOES satellite. The resultant imagery is also quite similar so photo interpretation is essentially the same for both types. This course will deal primarily with the GOES system.

The satellite contains two types of sensors, visible and infrared (IR). As the satellite spins at 100 rpm, these sensors scan the earth in horizontal lines starting at the North Pole and working down to the South Pole. When the sensors are facing away from the earth toward outer space, their aiming angle is lowered slightly. With each successive spin then, the sensors scan a horizontal line on earth directly below the preceding one. It requires 1,821 lines to make a full disc photo and at 100 rpm that takes 18.2 minutes. A new scan is started every 30 minutes. Approximately 30 minutes after the start of a new scan, a finished photo is available to users. That is *almost* real time information.

The visible sensor has eight identical channels arranged vertically as shown. Each time the scanner makes a horizontal sweep across the earth, eight lines of data are gathered, each line covering a strip $\frac{1}{2}$ mile wide across the earth's surface. As a result, the full disc visible photo is composed of 14,568 lines of data ($8 \times 1,821 = 14,568$) and the resolution can be as sharp as $\frac{1}{2}$ NM, or in other words, anything $\frac{1}{2}$ mile or more across is large enough to be reproduced on the photo. The IR sensor utilizes only one channel so the IR photo contains only 1,821 lines of data, giving it a resolution of 5 NM. Operationally, the visible photos you receive will have $\frac{1}{2}$ NM, 1 NM, or 2 NM resolution, depending on the size of the area portrayed. GOES IR imagery will always have 5 NM resolution regardless of area size.

The raw data from the satellite is transmitted to ground stations in the Washington, D.C. area where it is filtered, computer-processed, and assembled into final form. Then the data is sectorized, photos are produced, and film loops are made.

Sectorizing consists of extracting portions of the data that make up smaller areas or "sectors" of the northern hemisphere. This sectorized data is transmitted to the Satellite Field Service Stations (SFSS's) via telephone lines. The SFSS's then distribute the data to the users also by telephone lines. (See figure 3.)



– 4 –

GOES IMAGERY

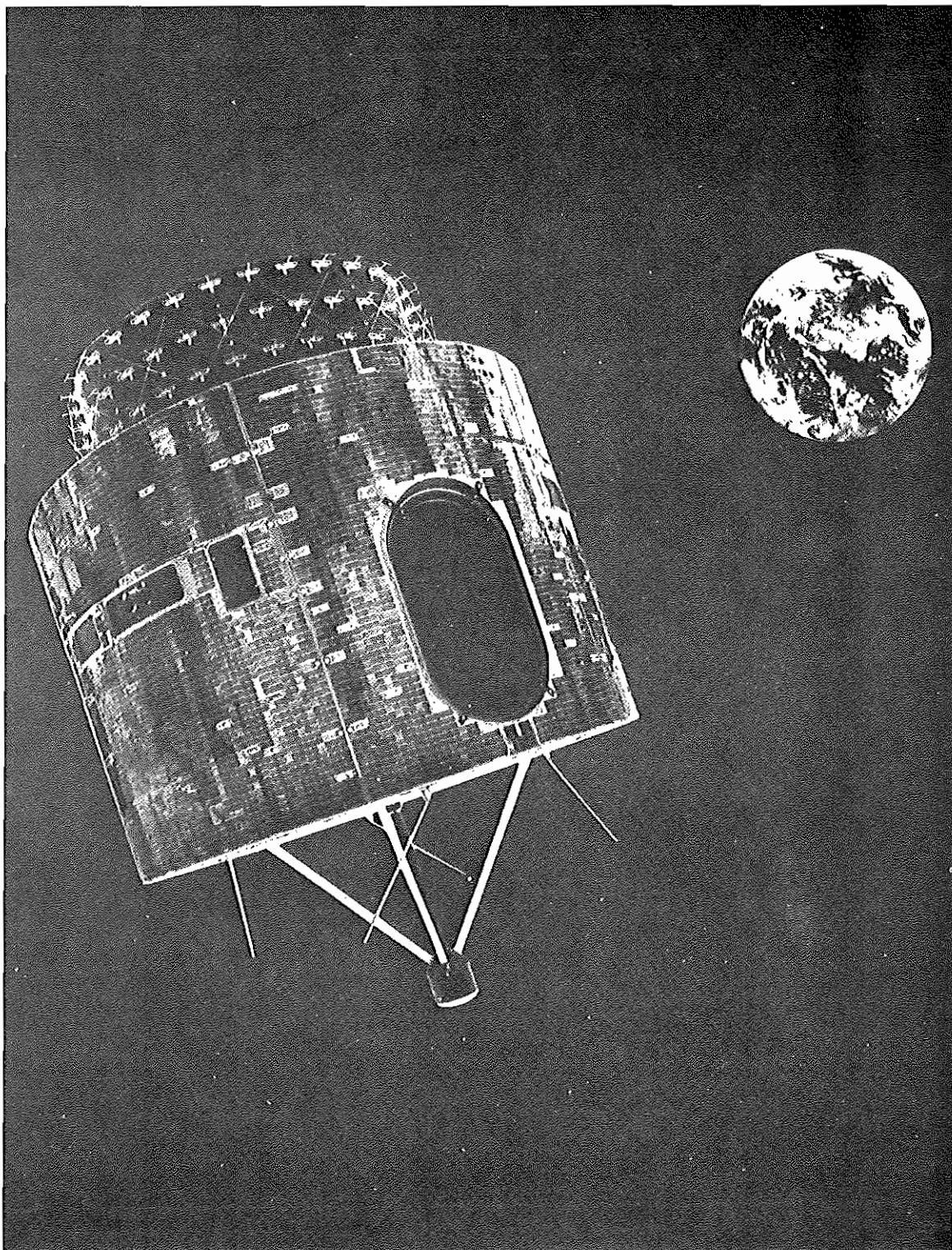
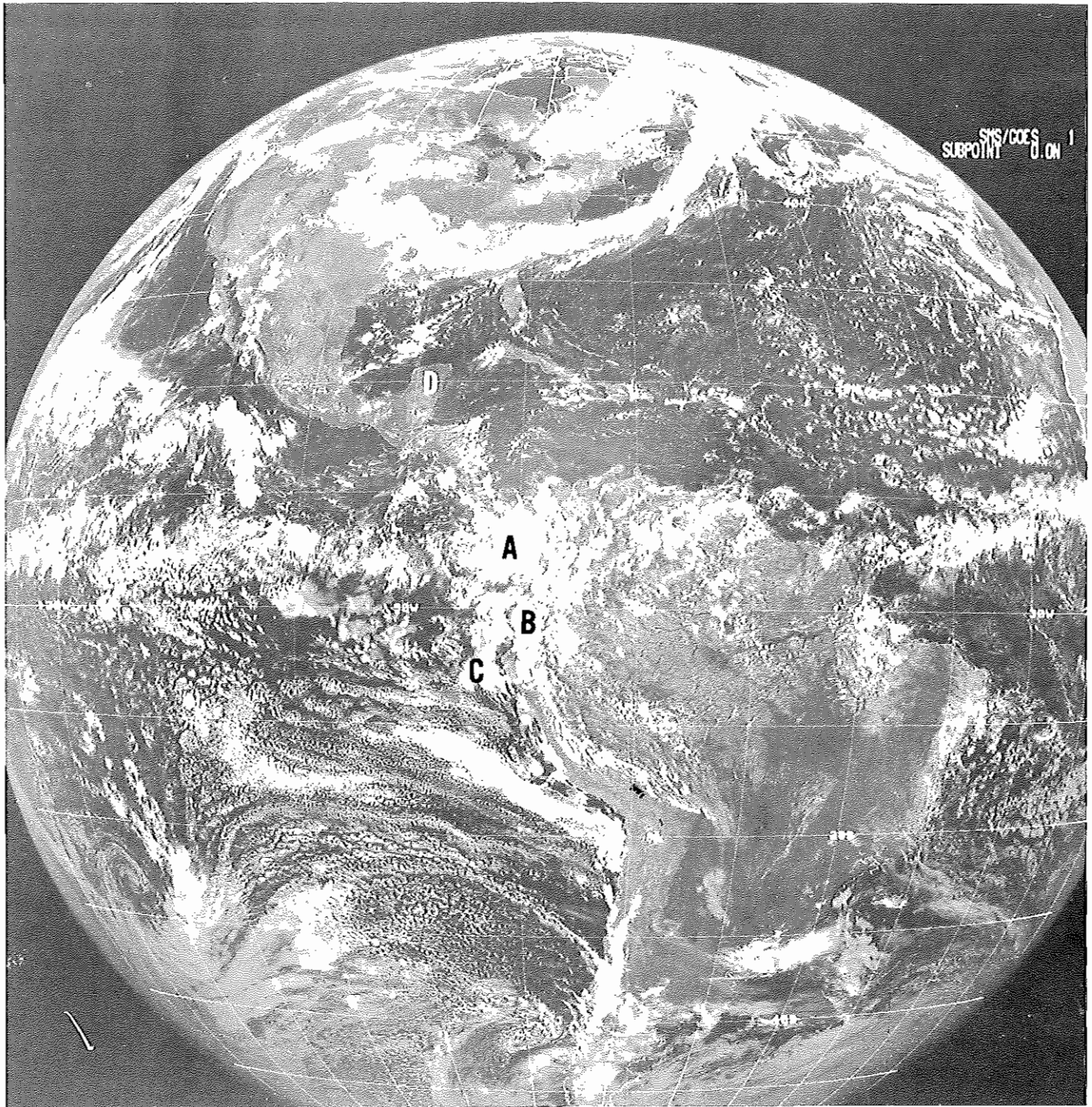


FIGURE 2 GOES/SMS.

GOES SATELLITE PHOTO RECOGNITION

PHOTO NUMBER ONE

1700 26JL77 13A-2 00101 19111 WC1



GOES IMAGERY

VISIBLE IMAGERY

This is a full disc visible photo from GOES East. (See photo No. 1.) The clouds are white, the land masses are gray, and the water areas are very dark, almost black. The visible photo is the result of reflected sunlight. Clouds are excellent reflectors so they appear very white. At night when there is no sunlight, there can be no visible imagery. Notice the black background. Neither the earth's atmosphere nor empty space reflect any sunlight, so any background area on a visible photo will always be black.

The reflectivity table (table 1) shows the percent of sunlight reflected by various surfaces. The best reflector of all is a large cumulonimbus, but all *thick* clouds reflect most of the sunlight that strikes them, so on a visible photo, thick clouds will all appear white. Thin clouds or areas of very small clouds will appear darker because much less sunlight is reflected.

Various types of terrain have intermediate or low reflectivity so land surfaces will appear as some shade of gray. Water surfaces are the poorest reflectors of all so they will appear almost black. Land-water contrast will normally be very good on visible imagery. Water will always be very dark unless it is very shallow, muddy, or frozen.

1. Large thunderstorm	92%	7. Thin stratus	42%
2. Fresh new snow	88%	8. Thin cirrostratus	32%
3. Thick cirrostratus	74%	9. Sand, no foliage	27%
4. Thick stratocumulus	68%	10. Sand and brushwood	17%
5. White Sands NM USA	60%	11. Coniferous forest	12%
6. Snow, 3-7 days old	59%	12. Water surfaces	9%

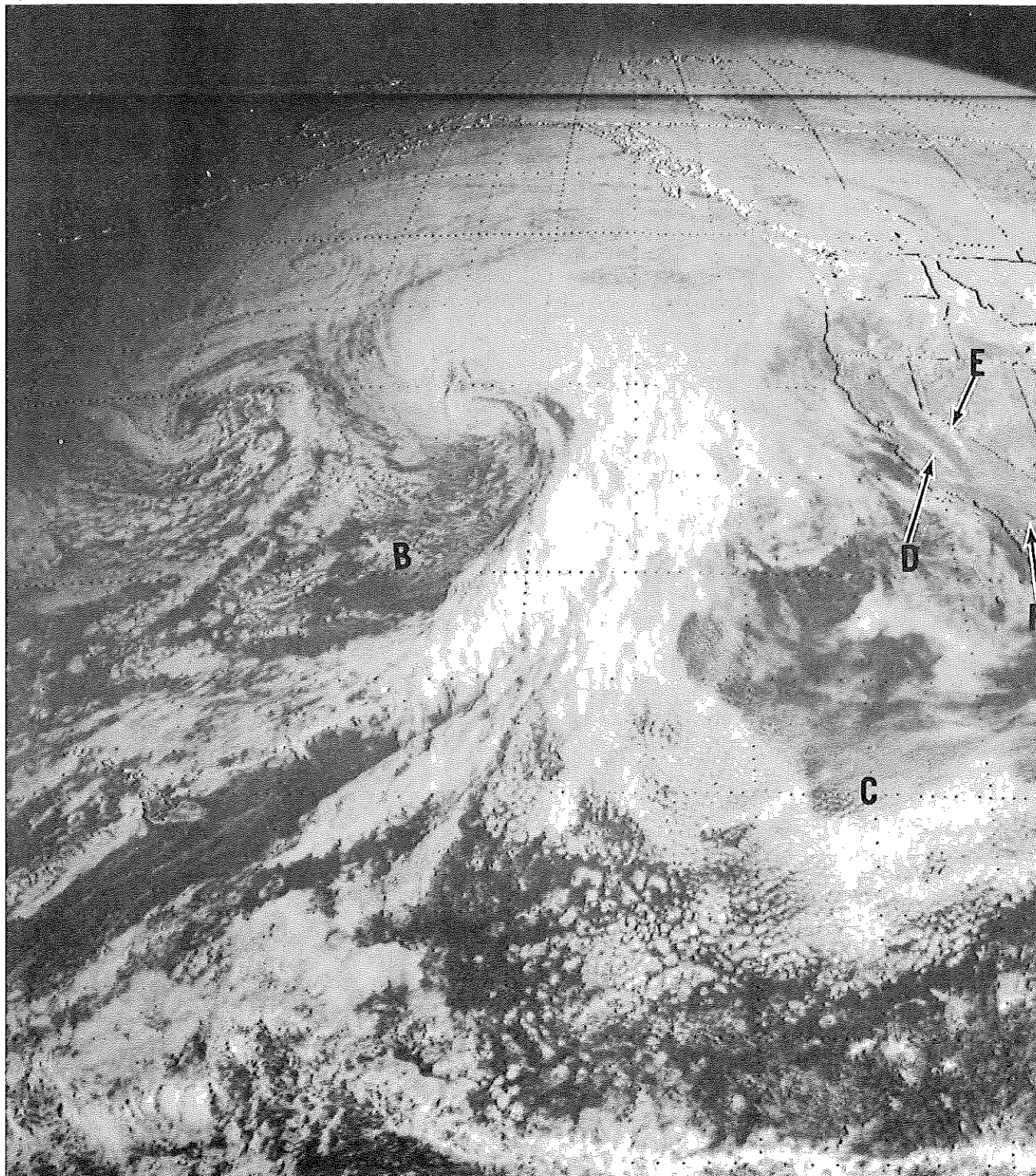
Table I Reflectivity of various surfaces

Visible satellite photos look very much like standard black and white photographs. Actually, they are constructed here on earth, line by line, from digital information gathered by the satellite sensors, but they can be interpreted just as if they were snapped by a regular camera in space. In this respect, visible imagery can be thought of as an old familiar tool being used in a new unfamiliar area.

GOES SATELLITE PHOTO RECOGNITION

PHOTO NUMBER TWO

1815 12FE81 35A-4 00352 19171 UC2



GOES IMAGERY

GOES users seldom need a full disc photo; normally, you will want one of the sectors. This photo (No. 2) from GOES West portrays an area less than half the size of the full-disc photo. The resolution is 2 NM, so some of the small scale feature cannot be seen. Look closely at the clouds over the ocean such as the area west and southwest of Baja, California (C). The clouds are not all uniformly white. Thin clouds or areas of small clouds show up as a gray shade. Again, this is because thin or small clouds just do not reflect as much sunlight as thick clouds.

Note the dark area in the upper left-hand portion of the photo. This is the sunrise-sunset line, commonly known as the *terminator*. That part of the world is still in darkness so it cannot be seen on visible imagery.

The fog and low stratus that is so persistent in the central valley of California in the winter can be seen at (D). The snow-capped Sierra Nevada mountain range (E) forms the eastern boundary of the valley. Large scale features such as these can usually be identified on visible imagery when they are not obscured by higher clouds. Identification of smaller scale features such as the Salton Sea in southern California (F) requires familiarity with the terrain and close inspection of the photo.

GOES PRODUCT LEGEND

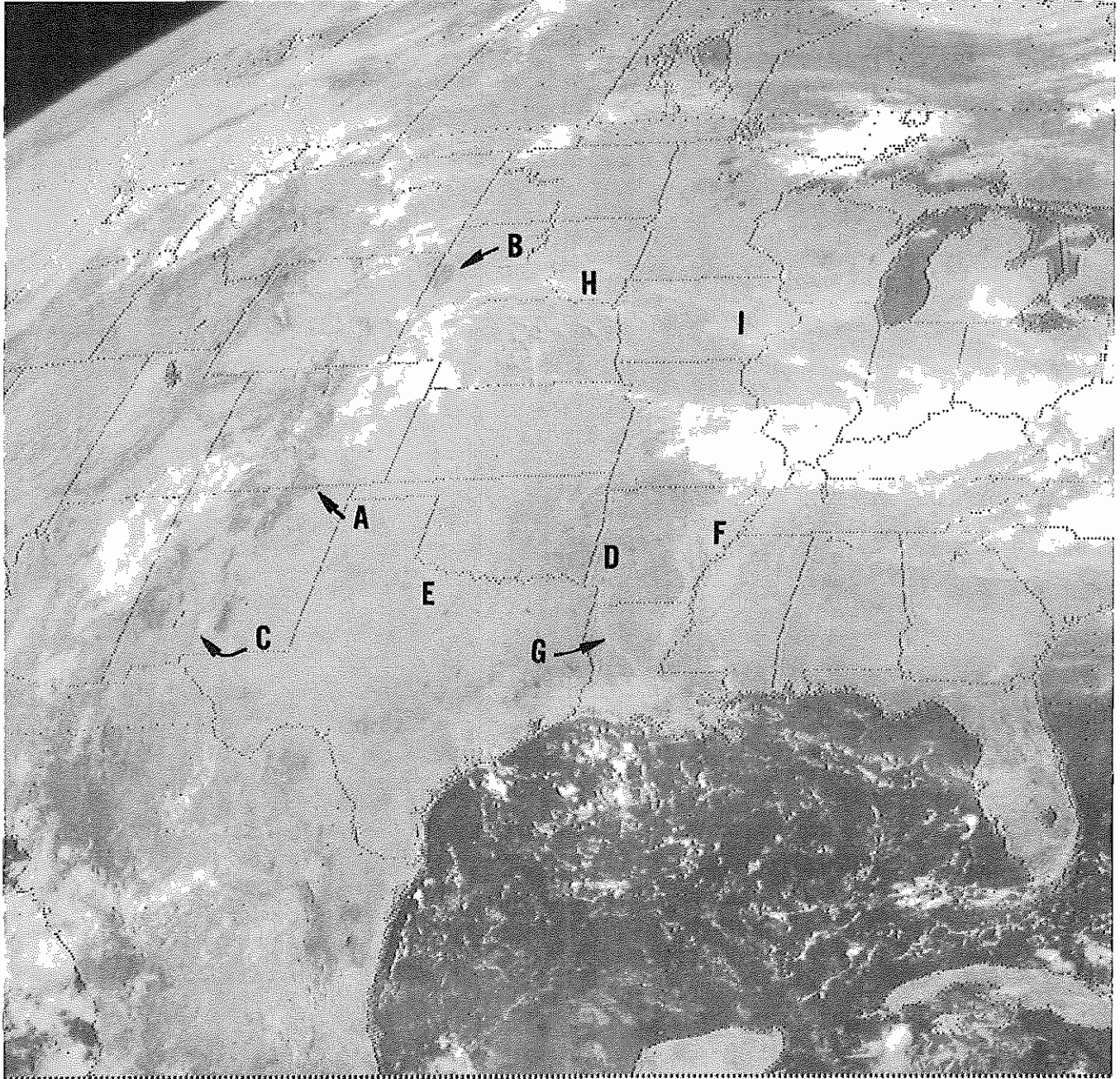
A partial explanation of the GOES product legend is shown below. A complete explanation is available in Satellite Manual FM-5.



FIGURE 4.

GOES SATELLITE PHOTO RECOGNITION
PHOTO NUMBER THREE

1530 10JL80 12A-2 01392 13372 KB8



GOES IMAGERY

Photo 3 is from GOES East and shows a sector about half the size of the previous one. The resolution is 1 NM. Notice the extraordinary detail such as (A) the Continental Divide in Colorado and New Mexico. The heavily wooded mountain ranges show up much darker than the grassy valleys and rangeland nearby. The Black Hills area of South Dakota (B) is a very prominent landmark for the same reason. The White Sand Desert in south-central New Mexico (C) is another feature that can easily be seen, because the reflectivity of the white sand is much greater than that of the nearby darker soil.

The Great Lakes, the Gulf of Mexico, and various smaller lakes such as the Great Salt Lake in Utah show typical land-water contrast. The relatively thick clouds in the Ohio River Valley appear predominately white, whereas the thin, small clouds over central Nebraska and Iowa appear almost the same shade as the terrain.

There are other more subtle differences in shading that show much more detail than one would imagine. Look closely at the general area of eastern Texas, eastern Oklahoma, western Louisiana, and western Arkansas (D). It is a noticeably darker shade than most of the surrounding country. In the summer, this area is predominantly covered with green trees which do not reflect as much sunlight as the open rangeland to the west (E) or the open farmland in the broad, flat Mississippi River flood plain directly to the east (F). The flood plain of the Red River (G) is also easily seen from the northwest corner of Louisiana across the state toward the southeast where it empties into the Mississippi. The river itself is less than a mile across so it is too small to be shown on the photo, but the relatively treeless flood plain may be 10 to 15 miles across, and it shows up as a definite lighter shade than the tree-covered land on either side.

If possible, you should have a cloud-free photo for each season posted near your receiver for comparison purposes. This would be a great help to new people learning to use GOES products.

THIN OR SMALL CLOUDS

The subject of thin clouds or areas of small clouds deserves further clarification. Thin or small clouds, in themselves, are no hazard to aviation. A problem might arise, however, if a briefer were to give a pilot wrong information based on erroneous interpretation of a satellite photo. In that respect, it is important to be able to accurately interpret the shading on a photo, especially when there is some variation from what might be expected.

In an area of small or thin clouds (see fig. 5), part of the reflected sunlight sensed by the satellite is from the tops of the clouds and part is from the land or water surface below. The resultant gray shade on the photo, then, depicts an average of the two reflectivities. It is darker than a thick cloud area and lighter than the normal surface shade.

An exception to this would be if the surface were covered with snow or perhaps a thick layer of low clouds. Then there would be no noticeable error in shading. Under these circumstances, thin or small clouds may not be detectable at all.

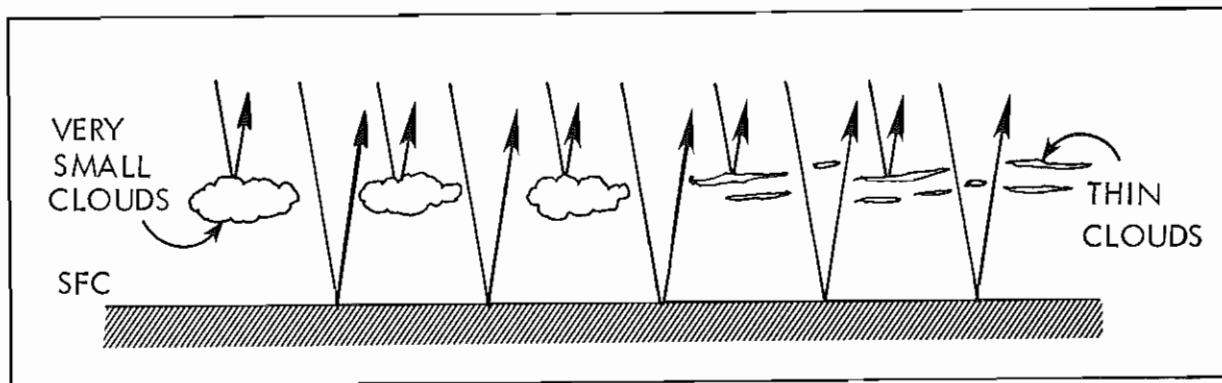


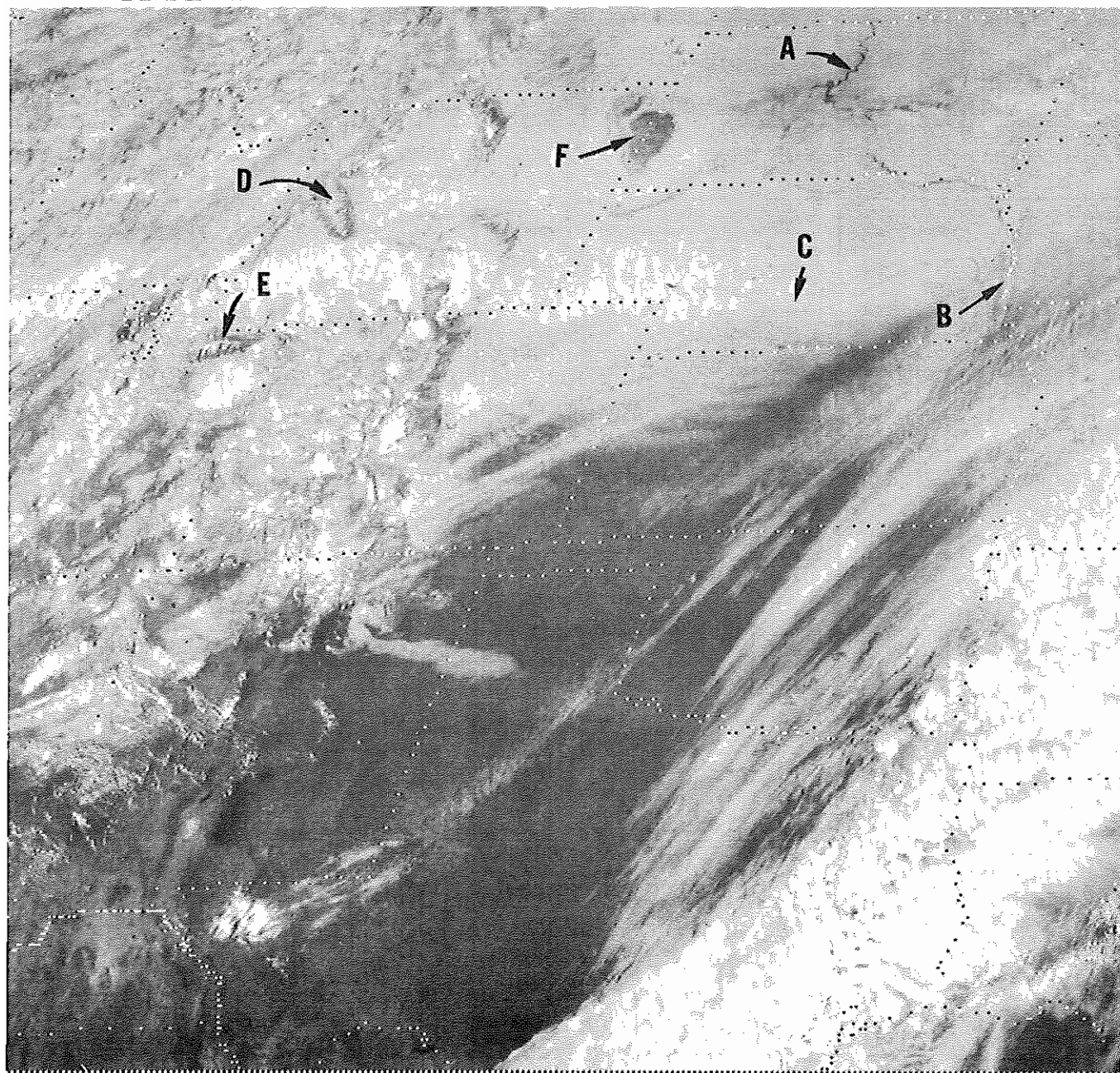
FIGURE 5.

To a small segment of the pilot population, thin clouds or areas of very small clouds are very important. Aerial photography and photogrammetry pilots usually need clear skies for their specialized missions. The low-altitude flights can often operate effectively in spite of thin middle or high cloud cover, but the high-altitude flights normally cannot tolerate clouds at any level regardless of how thin or small they are.

To meet the specialized needs of these pilots, the briefer must not only be able to accurately identify areas of thin and small clouds, but also be able to estimate their relative height. The subject of height determination will be covered later in the discussion of infra-red imagery.

GOES SATELLITE PHOTO RECOGNITION
PHOTO NUMBER FOUR

1902 03DE78 14A-H 02176 11872 KA4



GOES IMAGERY

SNOW COVER

Photo 4 is an example of the smallest sector size that is routinely available to GOES users. It covers an area less than half the size of the area covered in photo 3. The resolution is $\frac{1}{2}$ NM, so much more geographical detail can be seen than on the larger sectors.

Snow cover is often very difficult to identify on satellite imagery. Like clouds, snow reflects most of the sunlight that strikes it (see table I, pg 7), consequently, clouds and snow cover may look exactly alike, especially over relatively flat terrain. The most reliable indicator for differentiating between clouds and snow cover is being able to recognize known terrain features such as unfrozen rivers and large lakes. Clouds normally obscure terrain features, but snow cover does not.

In photo 4, the states of Nebraska, South Dakota, and Wyoming are nearly cloud-free and mostly covered with snow. Note the Missouri river in South Dakota (A). It is clearly visible in central and southeastern South Dakota and can be identified as far south as Omaha, Nebraska (B). The Platte River (C) is identifiable from Omaha westward almost to the Wyoming border. In fact, someone who is very familiar with the topography of Nebraska could identify most of its major rivers and several of its large lakes on this photo. To someone unfamiliar with this area, these dark lines and spots may look like shadows on a low cloud layer or perhaps holes or thin spots in a cloud layer.

Snow in mountainous country is usually easier to identify because it often forms a dendritic (branchy) pattern. Mountain ridges above the tree line are essentially barren, and the snow is visible there, but in the tree-filled valleys, most of the snow is hidden beneath the trees (see fig. 6). Two good examples are shown at D and E on the photo. Mountain areas such as the Black Hills (F) that are completely covered with trees do not exhibit the dendritic pattern but are still easily recognized by the sharp contrast with the nearby open country.

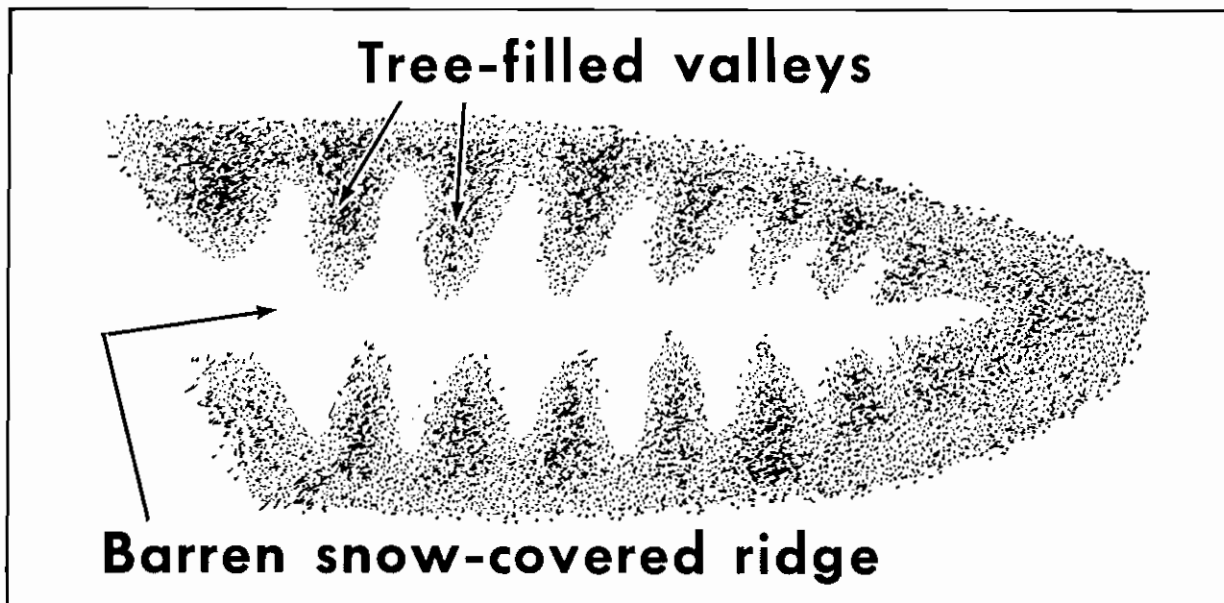


FIGURE 6.

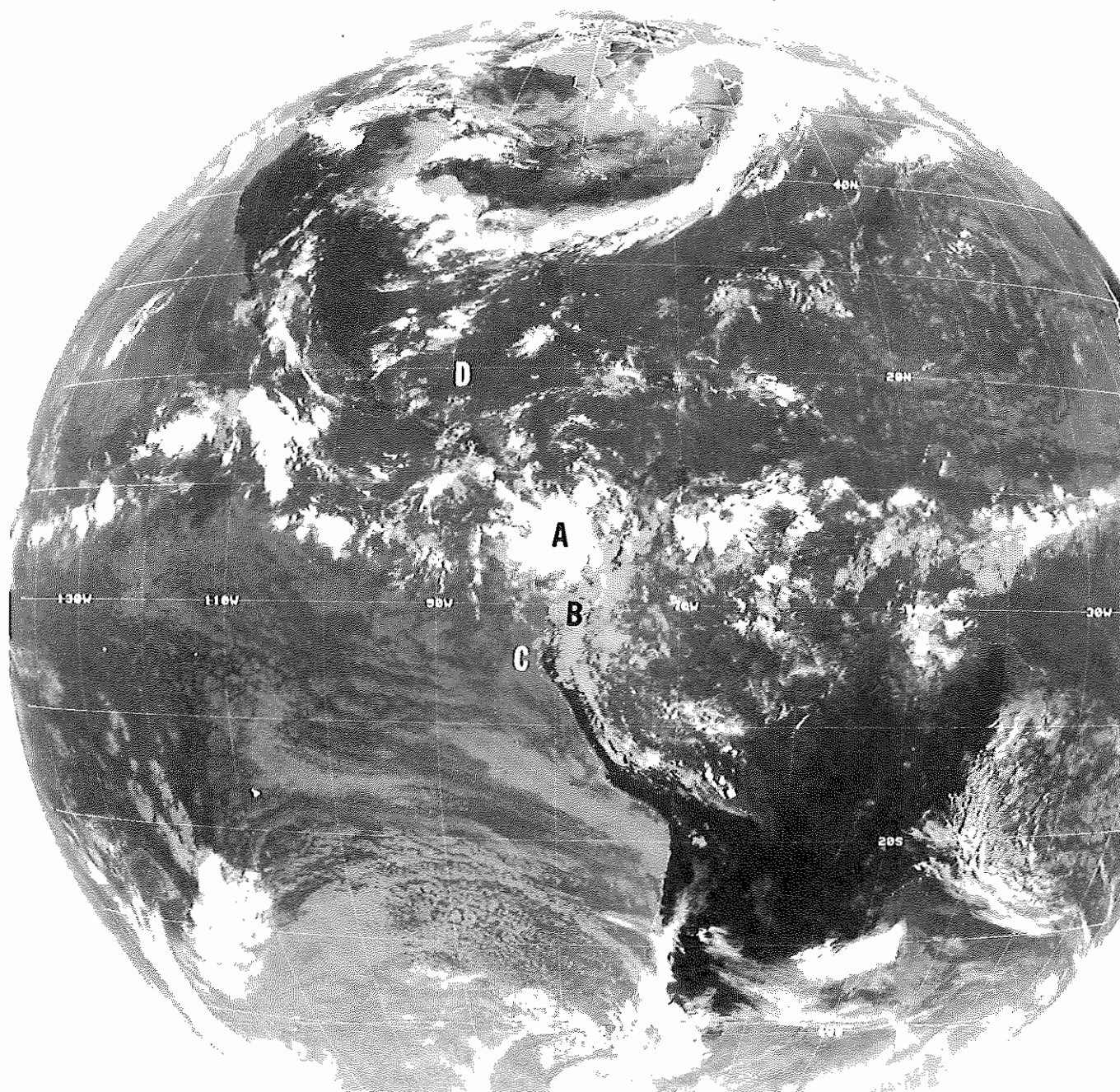
There are several sources of observed data to help you determine snow cover. Surface observations and pilot reports are very helpful, especially when they confirm that the sky is clear. Also, you can compare current photos with earlier photos. Cloud patterns can change noticeably in a few hours, whereas snow cover normally changes very little from day to day.

Finally, if you have access to meteorological facsimile charts, the National Weather Service issues an Observed Snow Cover chart once a day during the winter season.

GOES SATELLITE PHOTO RECOGNITION

PHOTO NUMBER FIVE

↑ 17:00 26JL77 13A-Z 0006-1640 FULL DISC IR



GOES IMAGERY

INFRA-RED IMAGERY

This is a full disc IR photo. It is from GOES East and was taken at the same time as photo #1. IR imagery is just a picture showing different temperatures as black, white, or some shade of gray.

Everything with a temperature above absolute zero radiates electromagnetic energy. The wavelength of this radiation varies with the temperature. The IR sensor on the satellite simply measures the wavelength of the energy radiated from the surface of the earth and the tops of clouds. This temperature/wavelength information is transmitted to the receiving station in Washington, D.C., where it is converted by computer processing into shades of gray. In this way, any temperature can be shown as black, white, or some gray shade. High clouds are very cold so they will appear white; for example, the clouds near (A). Mid-level clouds are somewhat warmer so they will be a light gray shade (B). Low clouds are warmer still, so they will be a darker shade of gray (C). Often, low clouds are the same temperature as the surrounding terrain and cannot be distinguished at all. In that case, you need a visible photo or surface observations to detect them. The low clouds at C are easily seen on photo 1 but are not easily seen on photo 5.

Land-water contrast is also dependent on temperature contrast. In this photo the coast of California is easily seen because the land is warmer, so it is noticeably darker. At night, however, the land cools rapidly and may become cooler than the water. Then it would appear as a lighter shade. If the water and the land are approximately the same temperature, such as around the Yucatan Peninsula in Central America (D), they will also be the same shade of gray, and there will be no land-water contrast.

The graph in Fig. 7 shows exactly how the unenhanced IR photo is shaded. It is simply a straight-line relationship between temperature and gray shades. Temperature is shown on the bottom along the horizontal axis, and shades between black and white are on the vertical axis. The temperature range covered is from a plus 134°F (56.8°C), which might be found in the Sahara Desert in summer, to a minus 165°F (−109°C) which might be found at the tops of very high clouds (about 60,000 ft.). The graph shows that 134°F (56.8°C) would be black, a minus 165°F (−109°C) would be white, and every temperature in between would be some specific shade of gray.

The computer is capable of producing and recognizing 255 distinct shades between black and white. The human eye, however, can only distinguish from 15 to 40 shades, depending on conditions; so the unenhanced IR photo is not used much operationally. A technique called Enhancement is used to highlight areas of interest.

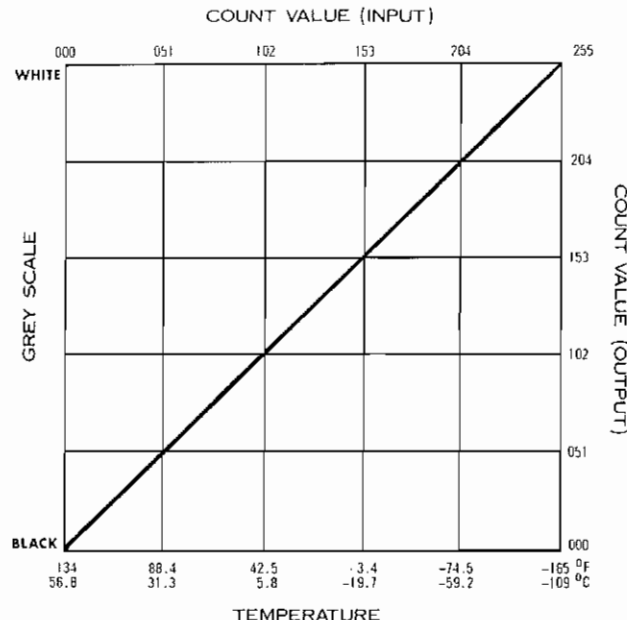


FIGURE 7.

GOES SATELLITE PHOTO RECOGNITION

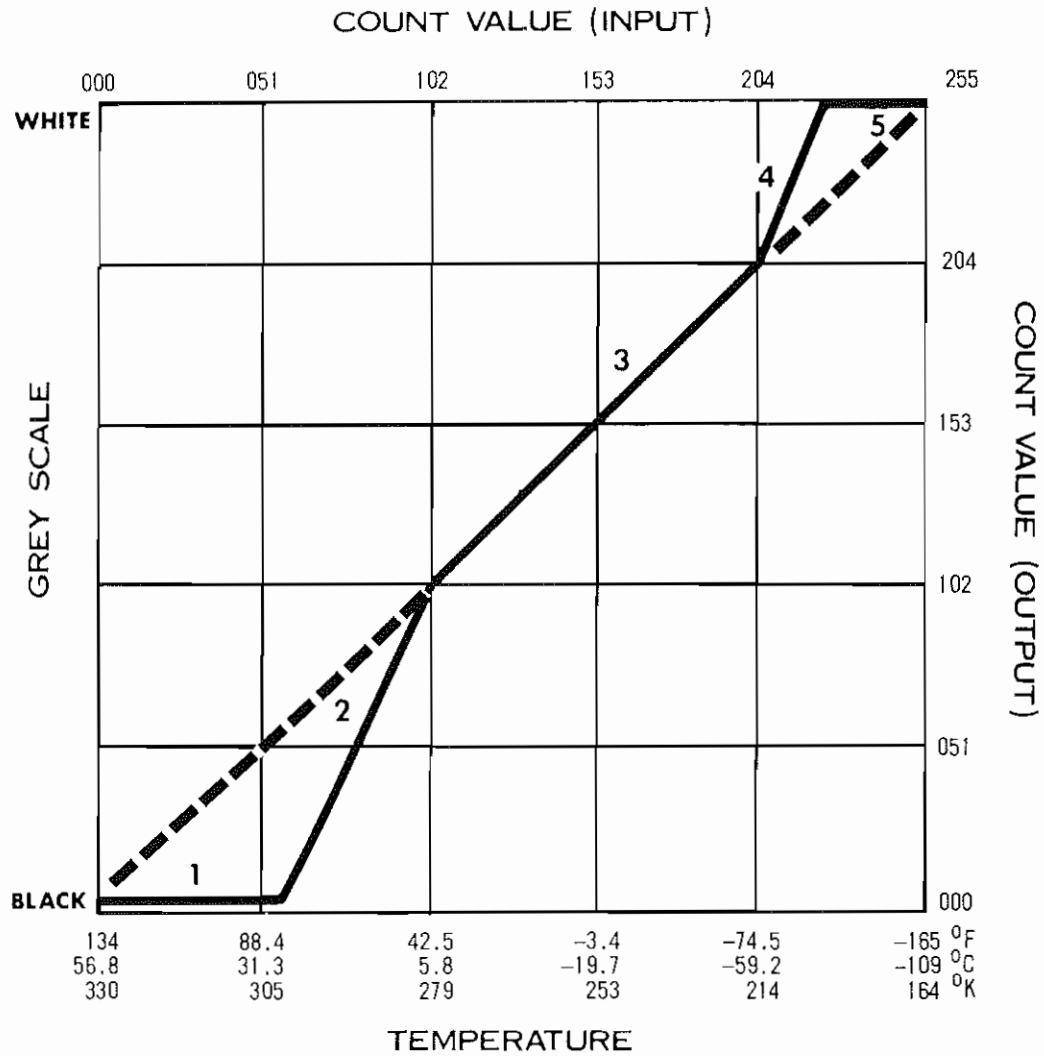


FIGURE 8.

GOES IMAGERY

ENHANCEMENT

On the unenhanced IR photo, each degree of temperature was represented by a slightly different shade of gray. In the enhancement process, any shade of gray may be assigned to any temperature when more contrast is needed to highlight a certain temperature range.

The ZA curve (see figure 8, solid line) is a slight modification of the unenhanced curve (dashed line). The very warm temperatures in segment 1 (56.8°C to 29.3°C) are all shown as black. Since there are no clouds in that temperature range, there is no need for a difference in shading.

Segment 2 (28.8°C to 6.8°C) contains the temperatures of most low clouds and sea surfaces. In this way, the darker shades of gray are used over a smaller temperature range so that small differences on temperature can be more easily detected.

A similar process is done at the other end of the temperature scale except that it affects a much smaller range of temperatures. All temperatures of minus 75.2°C or colder are shown as pure white (segment 5). Here, too, since there are so few clouds in this temperature range, there is no need for a difference in shading. The very light gray shades out to white are used in the temperature range of the very high cirrus clouds (segment 4, -56.2°C to -75.2°C).

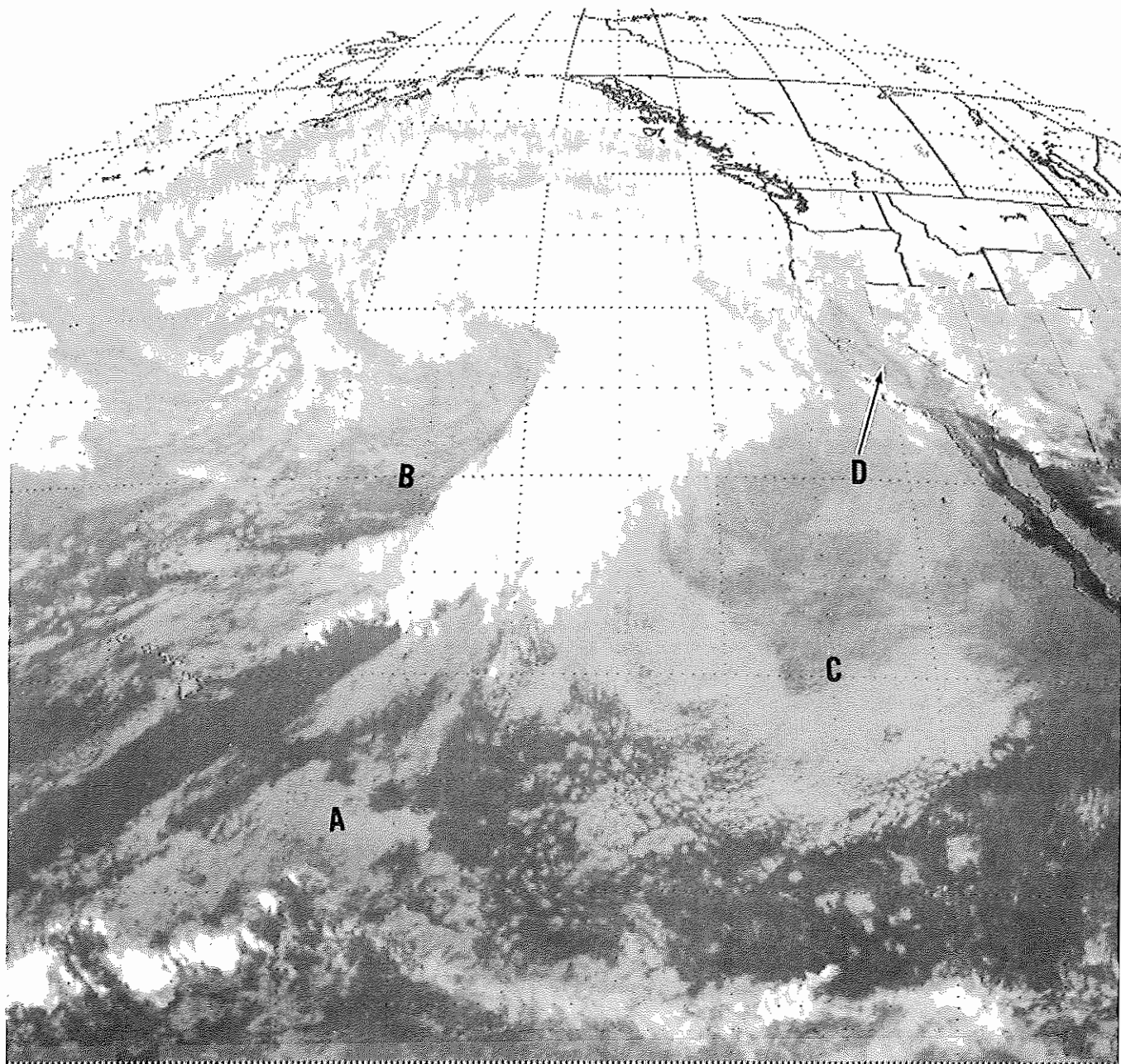
Between these two extremes in segment 3 (6.3°C to -55.2°C), no enhancement is used. Clouds in that temperature range will be shaded the same as on the unenhanced IR photo. The ZA curve can be thought of as a somewhat improved version of the unenhanced curve, and the ZA infrared photos are generally used in place of the unenhanced infrared photos. The end result of the ZA curve is that the temperature range we are observing has been narrowed somewhat by effectively eliminating the very warm and the very cold temperatures.

Interpretation of the ZA photo is essentially the same as the unenhanced IR photo because *in the temperature range of interest*, each degree of temperature has its own separate shade of gray which is not used for any other temperature.

GOES SATELLITE PHOTO RECOGNITION

PHOTO NUMBER SIX

1745 12FE81 35E-42A 00361 19171 UC2



GOES IMAGERY

THE ZA PHOTO

This is an example of an IR photo using the ZA enhancement curve. Operationally, the ZA curve is used quite often, especially at night. This photo is approximately the same time as photo #2. Note the excellent land-water contrast along the coasts of Mexico. Note also, there is good contrast between the sea surface and the lower clouds in warm southern Pacific (A) but poor contrast in the cold northern Pacific (B). The low clouds in that area are almost the same temperature as the sea surface.

The fog and low stratus in the central valley of California (D) can be seen on this photo as well as photo 2. The temperature at the top of the stratus layer is about the same as the temperature of the higher terrain surrounding the valley; however, the sun has heated the valley floor around the edges of the fog and the warm surface temperatures appear as a dark outline around the fog area. At night the warm surface will cool rapidly so that by early morning the entire area will probably appear as one light shade of gray. Temperature contrasts at the surface and between the surface and low clouds are usually at a minimum just when they are needed most, in the early morning before visible imagery is available.

GRAY SCALE WITH TEMPERATURE VALUES

Every enhanced IR photo has a gray scale directly below the product legend. It is a visual explanation of the enhancement curve used (see Fig. 9 and photo 6). The vertical lines are 10-degree increments of temperature in degrees Celsius. This temperature scale is shaded the same way the photo is shaded so you can tell at a glance what temperature or range of temperatures is depicted by any shade on the photo. Notice that to the right of -30°C the vertical lines are only half as far apart. They still represent 10 degrees of temperature change, however.

Notice, also, that in the legend, just to the right of the enhancement curve identifier, there is a 5-digit group beginning with zero. The vertical line representing 0°C will always be just below the first zero of that group.

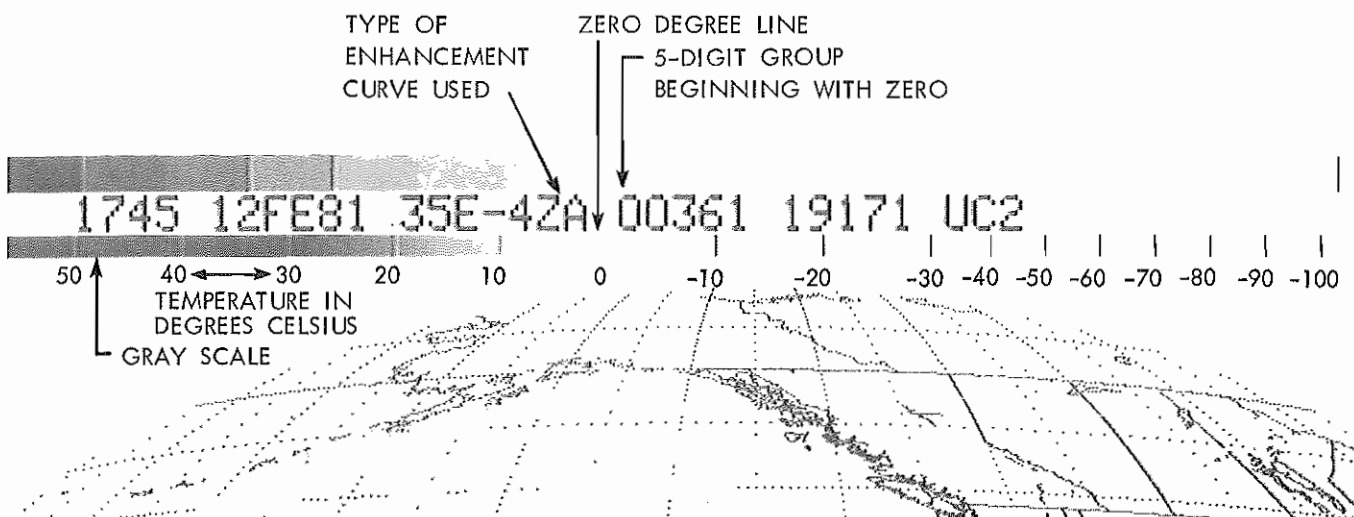


FIGURE 9.

GOES IMAGERY

THIN OR SMALL CLOUDS ON IR IMAGERY

Thin or small clouds create errors in shading on IR photos as well as visible. Assume an area is exactly half-covered with small clouds (see Fig. 10). The tops of the clouds are at 10,000 ft., and the temperature at the tops of the clouds is 0°C . The temperature of the surface at sea level is 20°C . Half of the radiation coming from that area would be from the tops of the clouds and half from the earth's surface. The satellite would sense an average temperature of 10°C , and the resultant gray shade on the photo would correspond to 10°C .

Again, thin or small clouds are not a hazard to aviation but GOES users must be aware of the shading errors they produce.

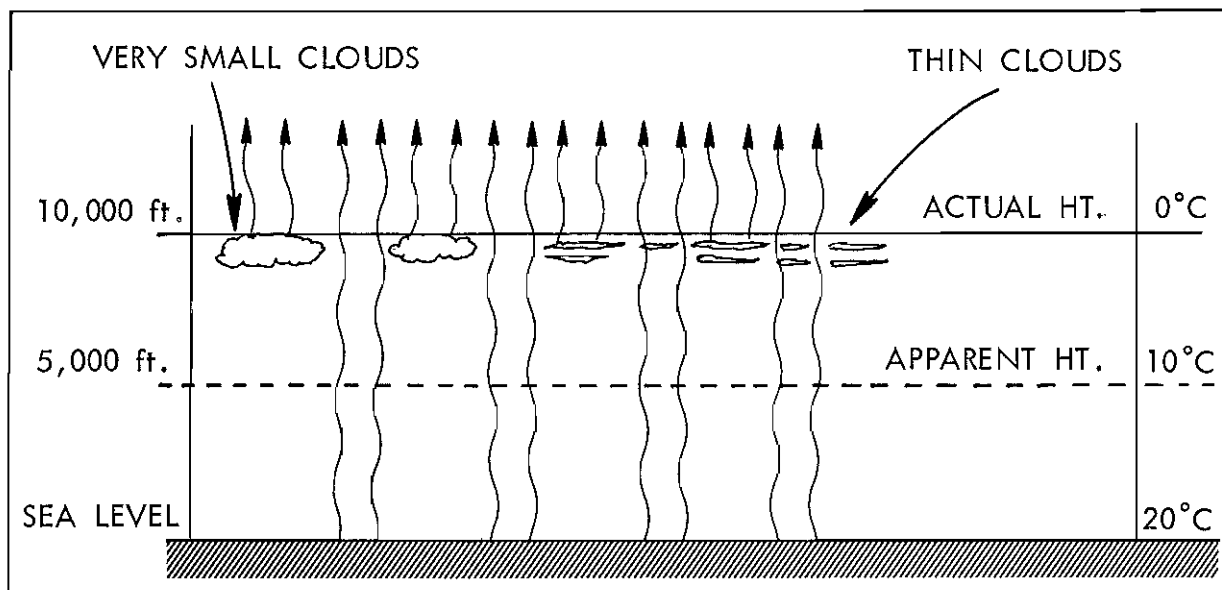
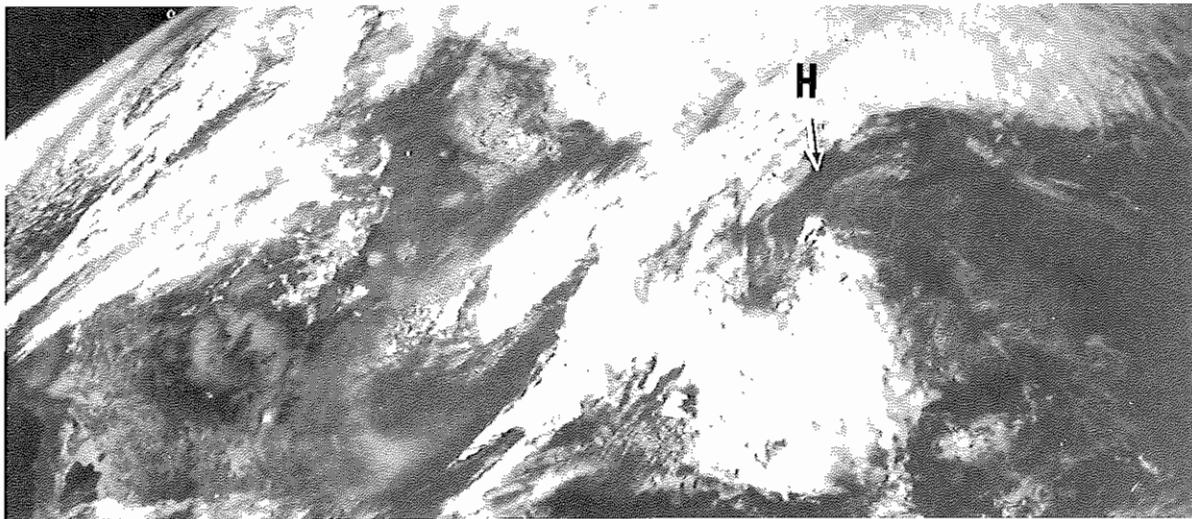


FIGURE 10.

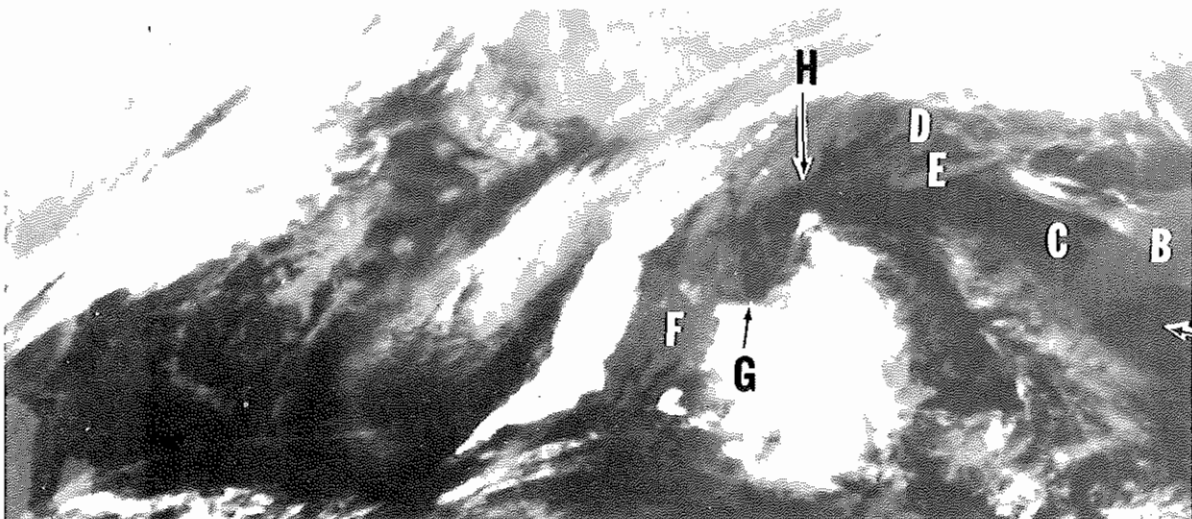
GOES SATELLITE PHOTO RECOGNITION

PHOTO NUMBER SEVEN

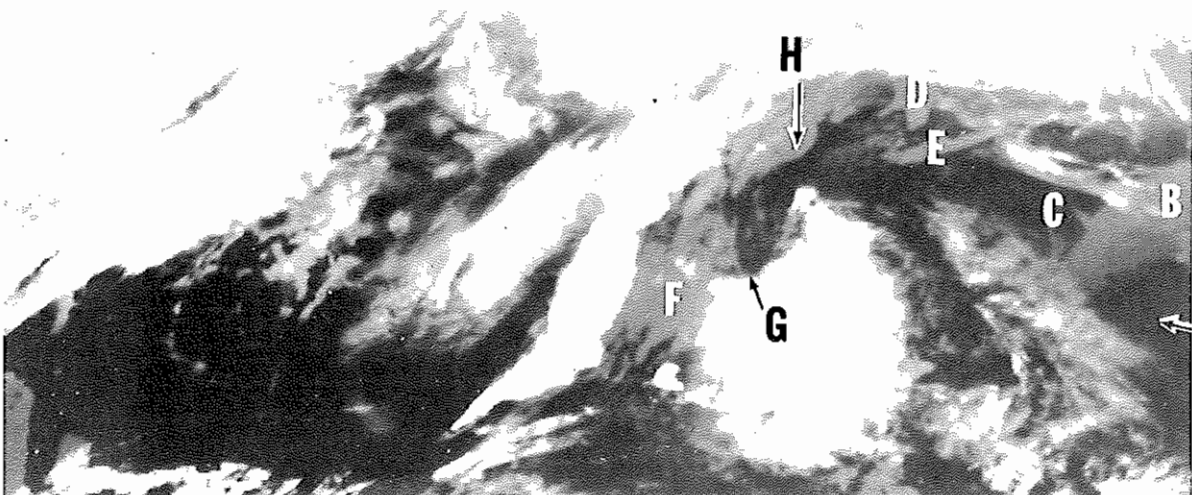
ENHANCED IR COMPARISON 2130Z 26 Mar. 76



VIS



UNENHANCED



ZA

A

GOES IMAGERY

INTERIM SUMMARY

Photo 7 is a comparison of the three types of photos we have discussed so far. On the visible photo, the clouds are essentially all white. Only areas of thin clouds or small clouds appear as a somewhat darker shade. Terrain varies from medium gray to dark gray, depending on type of soil and foliage. Water areas are almost black.

On the unenhanced IR photo, each degree of temperature is shown by some shade of gray between black and white. Very cold temperatures are shown as white and very warm as black. A rough comparison of cloud height can be made from the different shades. Keep in mind that cloud families are classified according to the height of their bases, but the satellite sees only tops. Therefore, we can only compare relative heights of cloud tops.

The ZA curve photo is very similar to the unenhanced photo. The major difference is more contrast in the warmer temperatures of the land surfaces, water surfaces, and low clouds on the ZA photo. Note the more pronounced difference in the shading between the warm waters of the Gulf Stream (A), the cold waters of the Labrador Current (B), and the East Coast of the U.S. in the Delaware Bay and Chesapeake Bay area (C). The cool waters of Lake Huron (D) and Lake Erie (E) are other examples of better land-water contrast. Also note the increased contrast between the low clouds at (F) and the nearby cloud-free area (G).

The visible photo shows that Lake Michigan (H) is partially covered by clouds. Both of the infrared photos show that the water temperature and the cloud top temperature in that area are about the same. Because these temperatures are the same, neither infrared photo can show how much of the lake is covered by clouds and how much is not. Without the visible photo, the location of the edge of the clouds over the water cannot be seen.

During daylight hours, when both visible and infrared imagery are produced, the maximum amount of satellite information is available. The location of the clouds can be determined from the visible photo and their relative heights (high, middle, or low) can be estimated from the infrared photo. During the hours of darkness, when only infrared imagery is produced, high level and middle level clouds are usually readily apparent, but the warmer low clouds may not be distinguishable.

GOES SATELLITE PHOTO RECOGNITION

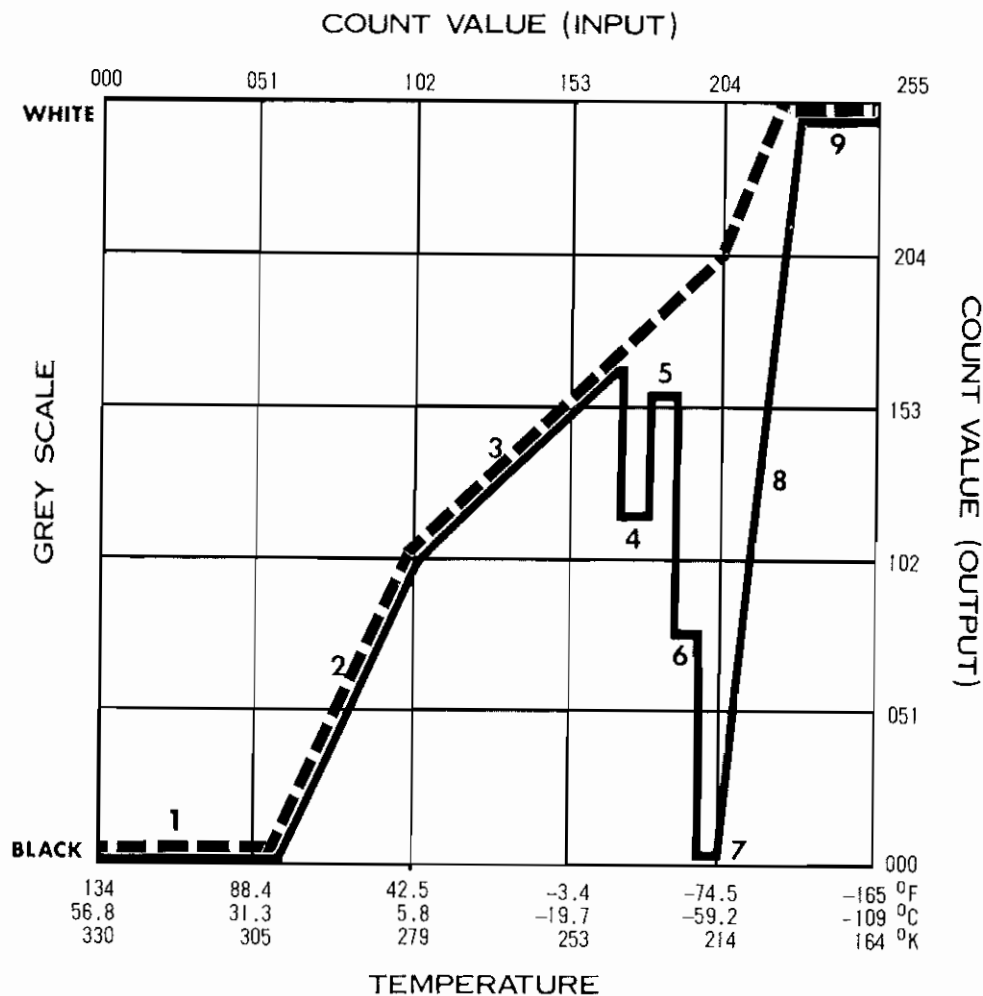


FIGURE 11.

THE MB CURVE

The enhancement curve that is used most is the MB curve. The solid line in Fig. 11 is a graph of temperature versus shading of this curve. The dashed line represents the ZA curve. Note that the warm part of the MB curve is the same as the ZA curve (segments 1, 2, and part of 3). The MB curve is meant to show overshooting tops of thunderstorms so the real enhancement starts at the cirrus cloud temperature level (-32.2°C). See Fig. 12.

GOES IMAGERY

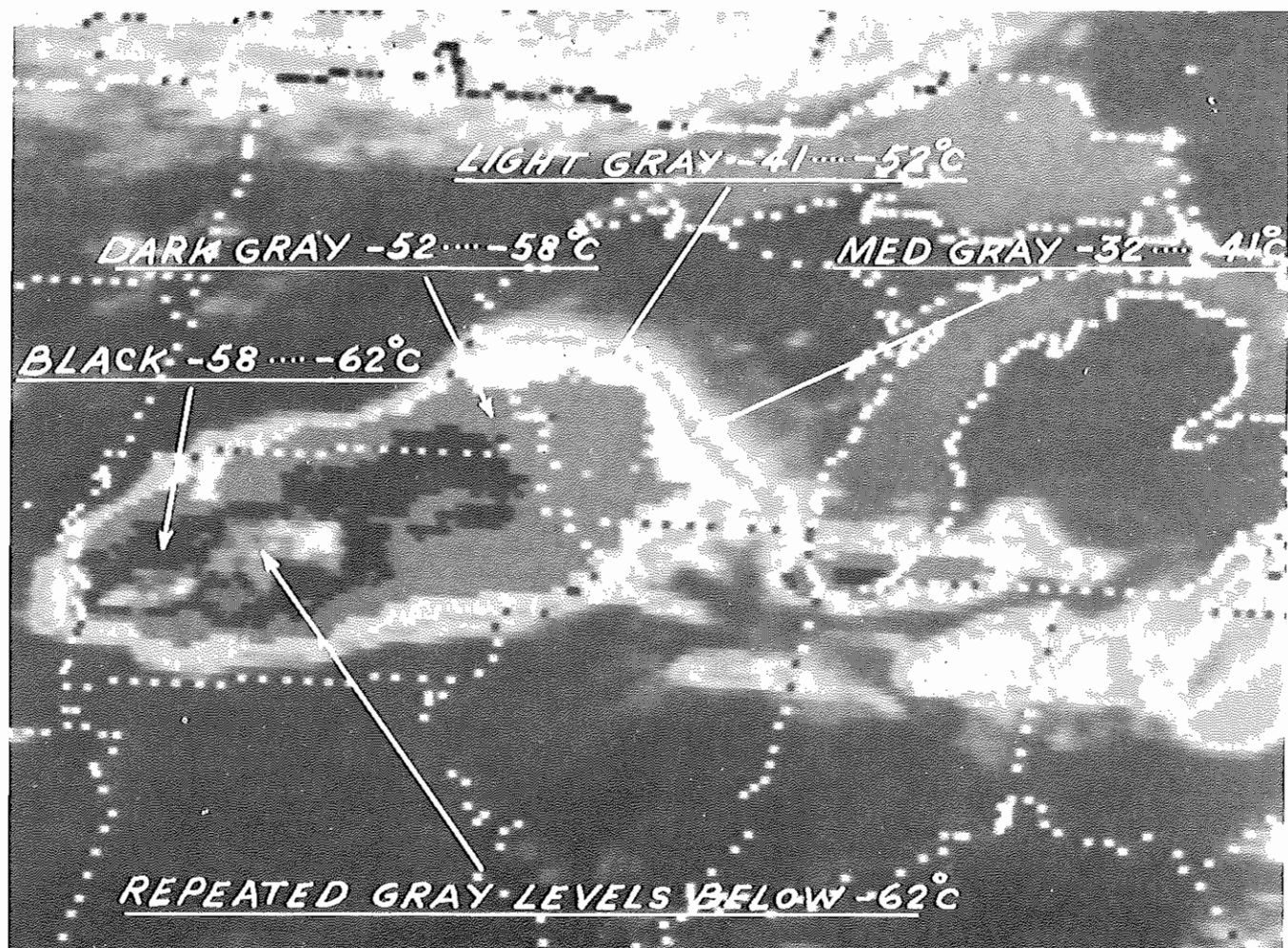


FIGURE 12.

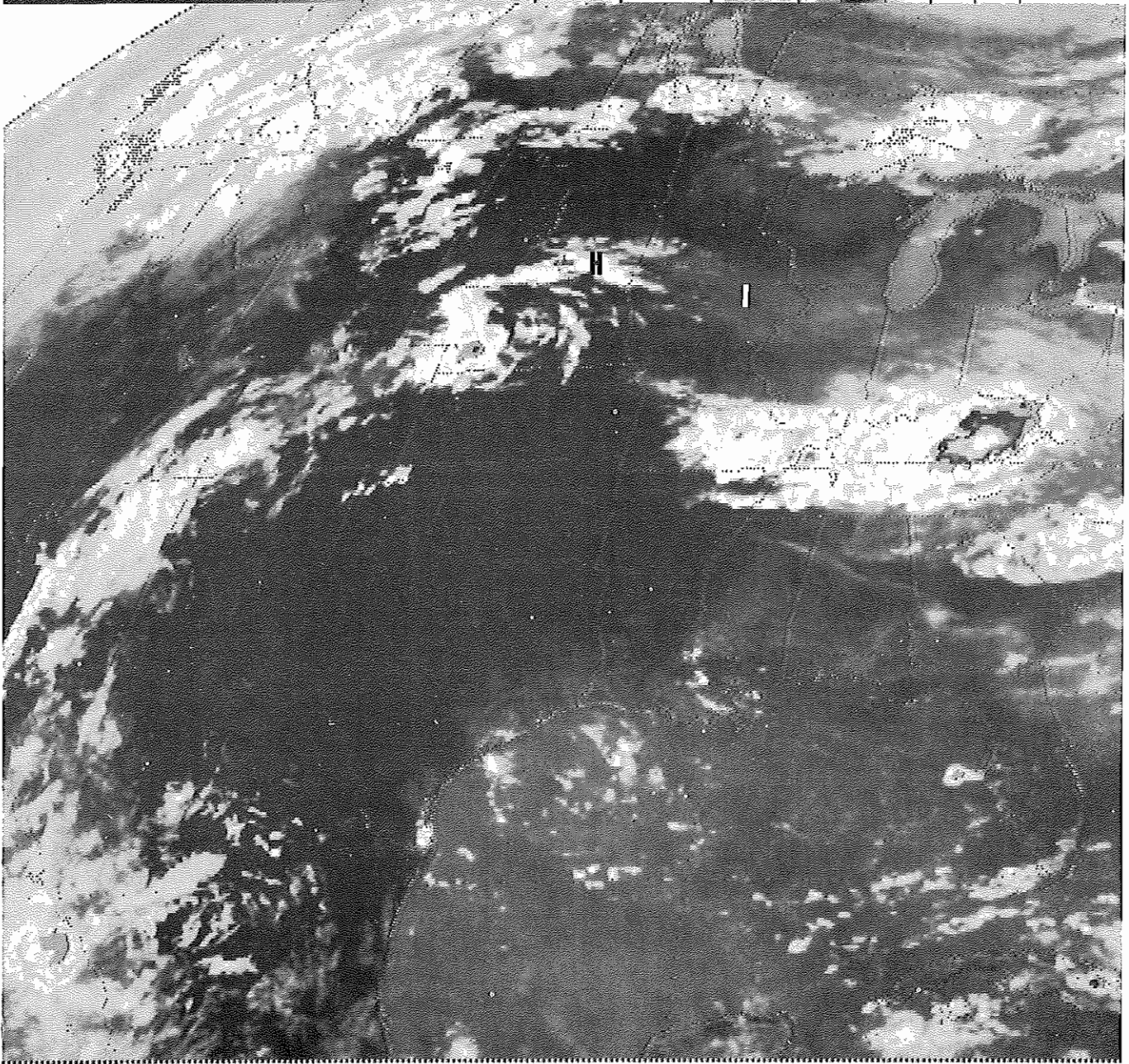
Figure 12 is a magnified, detailed illustration of segments 4 through 9 of the MB curve. Temperatures are rounded off to whole numbers for convenience. The process of using contrasting gray shades for progressively colder temperature ranges forms a contour pattern. (Refer to Fig. 11 as well as Fig. 12 as you proceed.) Segment 4 (-32 to -41°C) forms the first contour. It is shaded medium gray to make it stand out plainly. Segment 5 (-41 to -52°C) is shaded light gray, segment 6 (-52 to -58°C) is dark gray, and segment 7 (-58 to -62°C) is black. In this way, the areas of intense up-drafts are clearly defined because the clouds formed in these up-drafts are higher and, therefore, colder than the surrounding cirrus clouds.

Segments 8 and 9 utilize all the shades from black to white and indicate cloudtop temperatures colder than minus 62°C .

GOES SATELLITE PHOTO RECOGNITION

PHOTO NUMBER EIGHT

1700 10JL80 12E-2MB 01421 13352 KB8



GOES IMAGERY

THE MB PHOTO

This is an MB photo at midday in July. Most of the Central U.S. is shaded black. This is quite common in the summer. Refer to the gray scale on the photo and to Fig. 11. The very warm temperatures, 56.8°C to 28.2°C (134°F to 83°F) are all black. In other seasons, especially winter, surface temperatures do not get that high, so the only black areas would be the enhancement in the very cold (−59.2°C to −62.2°C) thunderstorm tops. Also, surface temperatures usually cool to below 83°F at night even in summer, so an early morning IR photo will be predominately gray and may appear quite different from the daytime photos.

This photo shows a larger cluster of thunderstorms covering most of eastern Kentucky. The contour pattern indicates an unusually large area of very high tops with temperatures colder than minus 62°C (see Fig. 12). The high tops are a good indicator that these thunderstorms are severe. Now look at these same clouds on photo 3. The visible photo gives no indication that severe weather is occurring in that area.

Refer to photo 3 and look at the thin clouds in Nebraska and South Dakota (H) extending eastward through Iowa (I) to the Lake Michigan area. Then look at those same clouds on photo 8. Notice the marked difference in shading on photo 8 from H to I. The thin clouds near H are high clouds, and their cold temperatures make them easier to see than the lower, warmer thin clouds to the east (I). Both areas are subject to the shading errors that thin clouds produce, but thin high clouds can usually be recognized on an IR photo; whereas, thin low clouds are often undetectable without a visible photo for comparison.

For each of the first three visible photos (1, 2, and 3) there is a corresponding size in infrared imagery (5, 6, and 8). Both enhanced and unenhanced infrared imagery are available in these three sizes. (The resolution of GOES infrared imagery is 5 NM. regardless of sector size.)

For the smallest sector size, such as photo 4, however, there is no equivalent infrared size normally available. To compare this size visible photo with infrared imagery, one must use a larger sector size infrared photo such as the size of photo 8. When comparing two photos of different sector size, keep in mind the difference in size of the area portrayed.

SNOW COVER ON IR

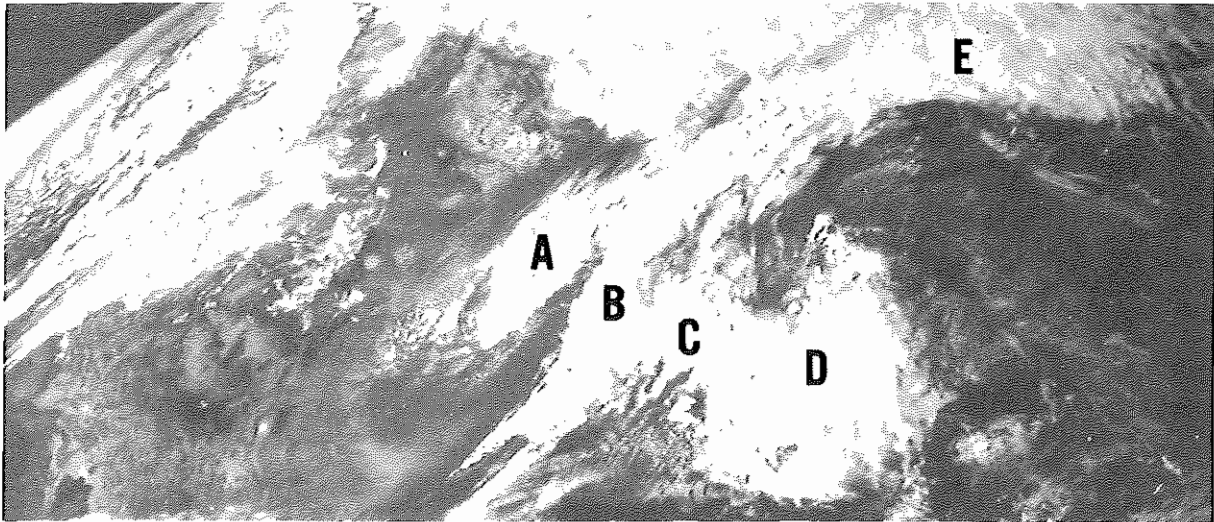
In identification of snow cover, the unenhanced infrared and the two most common infrared enhancement curves (ZA and MB) are usually no help at all. Normally, there is not enough temperature contrast between the snow cover and the adjacent surface to appear as contrasting shades of gray. On days when the sky is clear, barren terrain that is not covered by snow *can* become significantly warmer than nearby snow-covered terrain, at least for a few hours in the afternoon. Under these conditions, the boundaries of snow cover can be identified on infrared imagery. However, under these ideal conditions, snow cover can be seen in detail on visible imagery.

There are enhancement curves developed specifically to show snow cover and snow melt information, but they are used mostly for hydrology rather than pilot briefing and are seldom requested by aviation users.

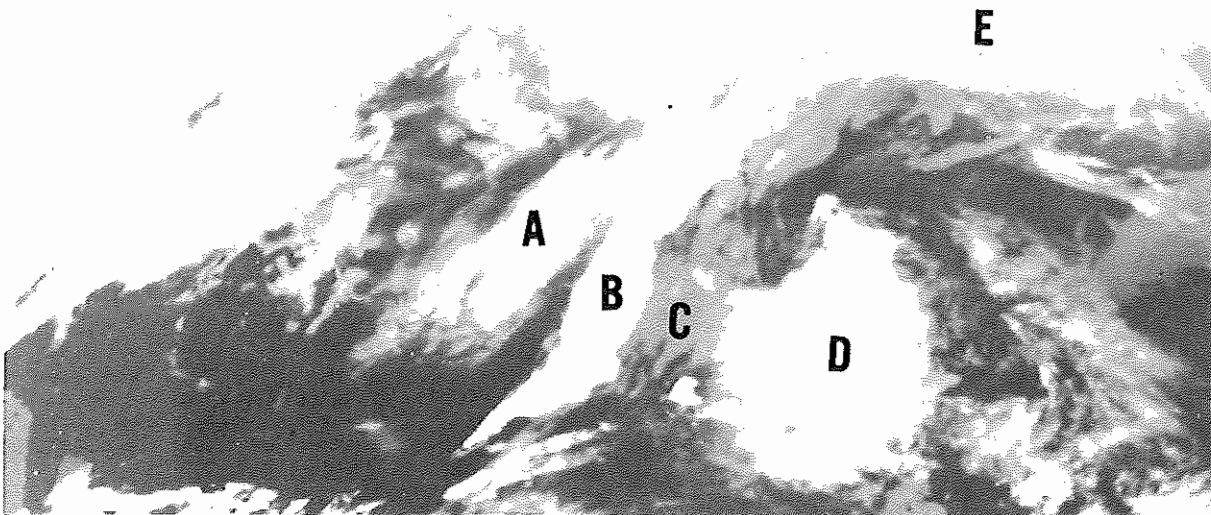
GOES SATELLITE PHOTO RECOGNITION

PHOTO NUMBER NINE

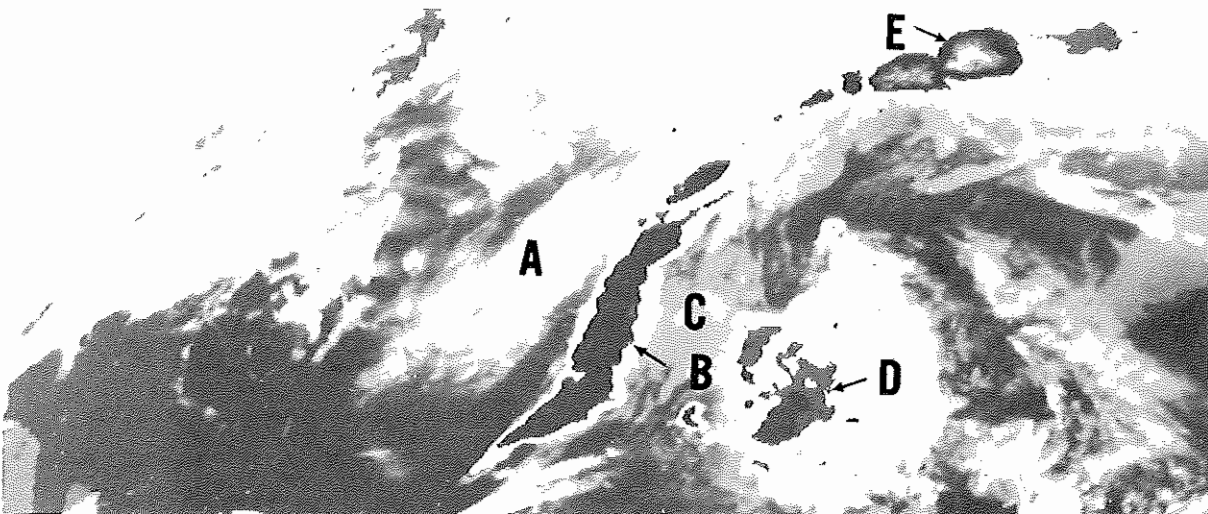
ENHANCED IR COMPARISON 2130Z 26 Mar. 76



VIS



ZA



MB

GOES IMAGERY

SUMMARY

Photo 9 is a comparison of the three types of photos you will see most often in day-to-day use.

On the visible photo, all thick clouds will be essentially the same shade, almost white. Thin or small clouds will appear darker than thick clouds because they do not reflect as much sunlight. Differences in shading do not provide any information about cloud height, only cloud thickness. Thick clouds may look very much alike regardless of their altitude. (Refer to A, B, C, & D on the visible and ZA photos.)

The ZA curve photo is very similar to the unenhanced IR photo except that the very warm temperatures are all black and the very cold temperatures are all white. In between, from 28.8°C to -75.2°C (83°F to -103°F) each degree of temperature has its own shade of gray which is not used for any other temperature.

The MB curve is similar to the ZA curve in the warm temperature range, from very warm surface temperatures up through the mid-level cloud temperature range. In the cold high cloud temperature range, contrasting gray shades are used to highlight the high, cold overshooting tops of thunderstorms (B, D, & E).

Note on the ZA photo, there is a large area of clouds in the vicinity of D that is shaded white. This indicates that the tops of all these clouds are high level but it does not give any indication that some of the tops are higher than others. The MB photo shows that only a small portion of this area contains overshooting tops of thunderstorms. The majority of the area consists of a thick cirrus layer which is located at a somewhat lower altitude. Also, it is evident that the coldest (and therefore probably the highest) clouds on the photo are located at E.

Look closely at other areas on the visible photo and note how each area appears on the ZA and the MB photos. Keep in mind that all infrared photos are nothing more than representations of temperatures. Surface temperatures can vary greatly from day to night so the shading on infrared photos can also vary considerably in a 24-hour period.

The ZA and the MB are commonly used enhancement curves, but there are many others. Over a hundred have been evaluated by NESS and about a dozen are available to you at any one time from your Satellite Field Service Station (SFSS). It is beyond the scope of this text to illustrate a large variety. If you see a photo utilizing a curve that is new to you, study the shading strip very carefully to see exactly what temperature range or ranges have been enhanced. This will give you a good idea of what features are being highlighted and will help you interpret the shading. If you want to discuss a certain enhancement curve or have a question about photo interpretation, call your SFSS. They are on duty 24 hours a day, and providing guidance to users of GOES products is an important part of their job.

CRITERION TEST

CHAPTER I

1. The visible photo is a result of
 - a. reflected sunlight
 - b. terrestrial radiation
 - c. absorbed solar radiation

2. The brightest feature on visible imagery is
 - a. fresh, new snow
 - b. a frozen lake surface
 - c. a large thunderstorm

3. On visible imagery, water will appear darker than land unless the water is
 - a. muddy
 - b. frozen
 - c. either muddy or frozen

4. Infrared imagery is the result of
 - a. reflected sunlight
 - b. terrestrial radiation
 - c. reflected solar radiation

5. On unenhanced infrared imagery, water will appear darker than land if the water is
 - a. muddy
 - b. warmer
 - c. colder

6. Thin clouds will appear darker than thick clouds on
 - a. visible imagery
 - b. unenhanced infrared imagery
 - c. both visible and unenhanced infrared imagery

7. Enhancement is used in infrared imagery to
 - a. increase the resolution
 - b. highlight areas of interest
 - c. amplify surface reflectivity

GOES SATELLITE PHOTO RECOGNITION

8. The smallest resolution on GOES infrared imagery is
 - a. $\frac{1}{2}$ NM.
 - b. $\frac{1}{2}$ KM.
 - c. 5 NM.
9. What would be the darkest feature on infrared imagery that has been enhanced using the ZA curve?
 - a. a hot land surface
 - b. an ocean surface
 - c. the overshooting top of a thunderstorm
10. On a visible photo, the darkest feature would be
 - a. a hot land surface
 - b. an ocean surface
 - c. the overshooting top of a thunderstorm
11. What would be the darkest feature on infrared imagery enhanced using the MB curve?
 - a. a hot land surface
 - b. the overshooting top of a thunderstorm
 - c. both a and b
12. Which surface would appear darker on visible imagery?
 - a. a thick forest
 - b. open rangeland
 - c. a desert
13. The ZA curve and the MB curve are
 - a. completely different
 - b. alike in the cold temperature range
 - c. alike in the warm temperature range
14. Snow cover is difficult to identify by the use of visible imagery alone because it looks very much like
 - a. cloud cover
 - b. barren terrain
 - c. tree-covered terrain
15. What type of satellite imagery is most useful as an aid in identification of snow cover?
 - a. Enhanced infrared
 - b. Unenhanced infrared
 - c. Visible
16. Select the most accurate statement concerning snow cover and cloud cover on visible imagery.
 - a. Snow cover obscures prominent terrain features but cloud cover does not.
 - b. Cloud cover obscures prominent terrain features but snow cover does not.
 - c. Both cloud and snow cover obscure prominent terrain features.

CHAPTER II

CLOUD TYPES ON SATELLITE IMAGERY

Clouds are formed when air is cooled to its dew-point. The most common way that nature cools air is by lifting it. As air rises, it cools and clouds are formed. Most of the clouds you see on satellite imagery are the result of one or more of nature's lifting mechanisms.

Another way that air can be cooled is by contact with a cold surface. When this happens, the cloud forms on the ground and we call it fog. On satellite imagery, fog is just another low cloud.

Basically, there are only two types of clouds: cumuliform and stratiform. Either type may form at any level: high, middle, or low.

Cumuliform clouds are rounded, billowy, and puffy because they are formed in unstable air. Stratiform clouds are flat and sheetlike because they are formed in stable air. As such, clouds are excellent indicators of atmospheric stability.

Aviation hazards associated with stable conditions are quite different from those associated with unstable conditions. *In general*, unstable conditions are associated with thunderstorms, showery precipitation, gusty winds, low level wind shear, convective turbulence, clear icing, good visibility, and an absence of low ceilings. Stable conditions are *usually* associated with low ceilings, poor visibility, steady precipitation, rime icing, calm or steady wind, and no convective turbulence but possible mountain wave turbulence in mountainous areas.

The ability to recognize cloud types on satellite imagery can give a briefer a good idea of the stability of the atmosphere in a certain area and the type of hazards to look for.

In unstable air, uneven heating causes convective currents. Pockets or parcels of warm air rise and create updrafts. The rising air cools and clouds are formed in the updrafts. Between the updrafts, the air is sinking so no clouds exist. (See Fig. 1.)

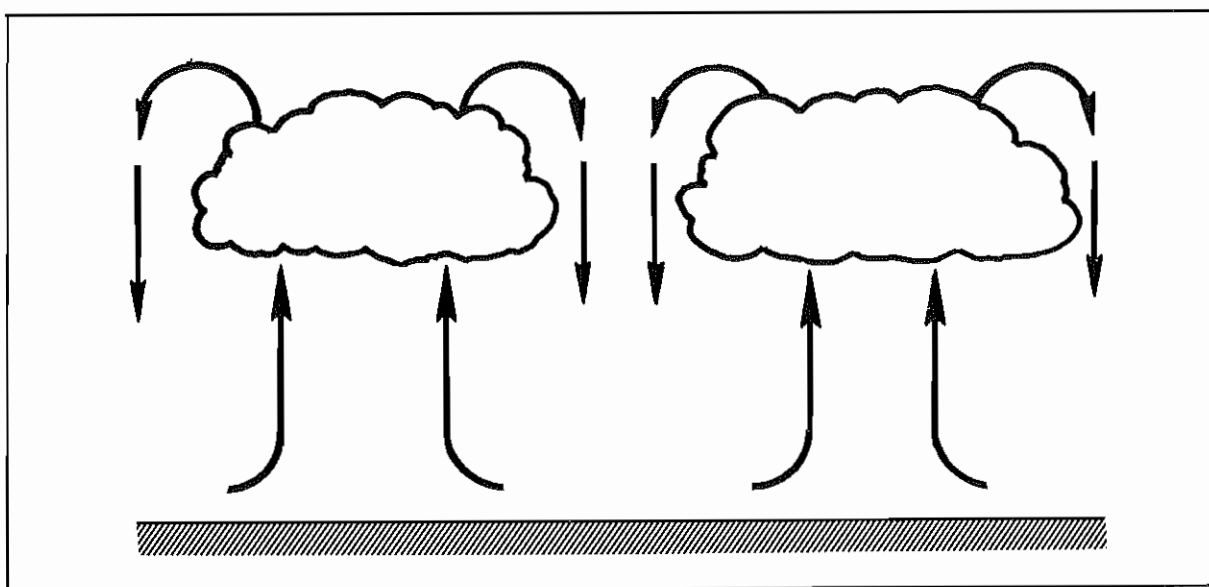
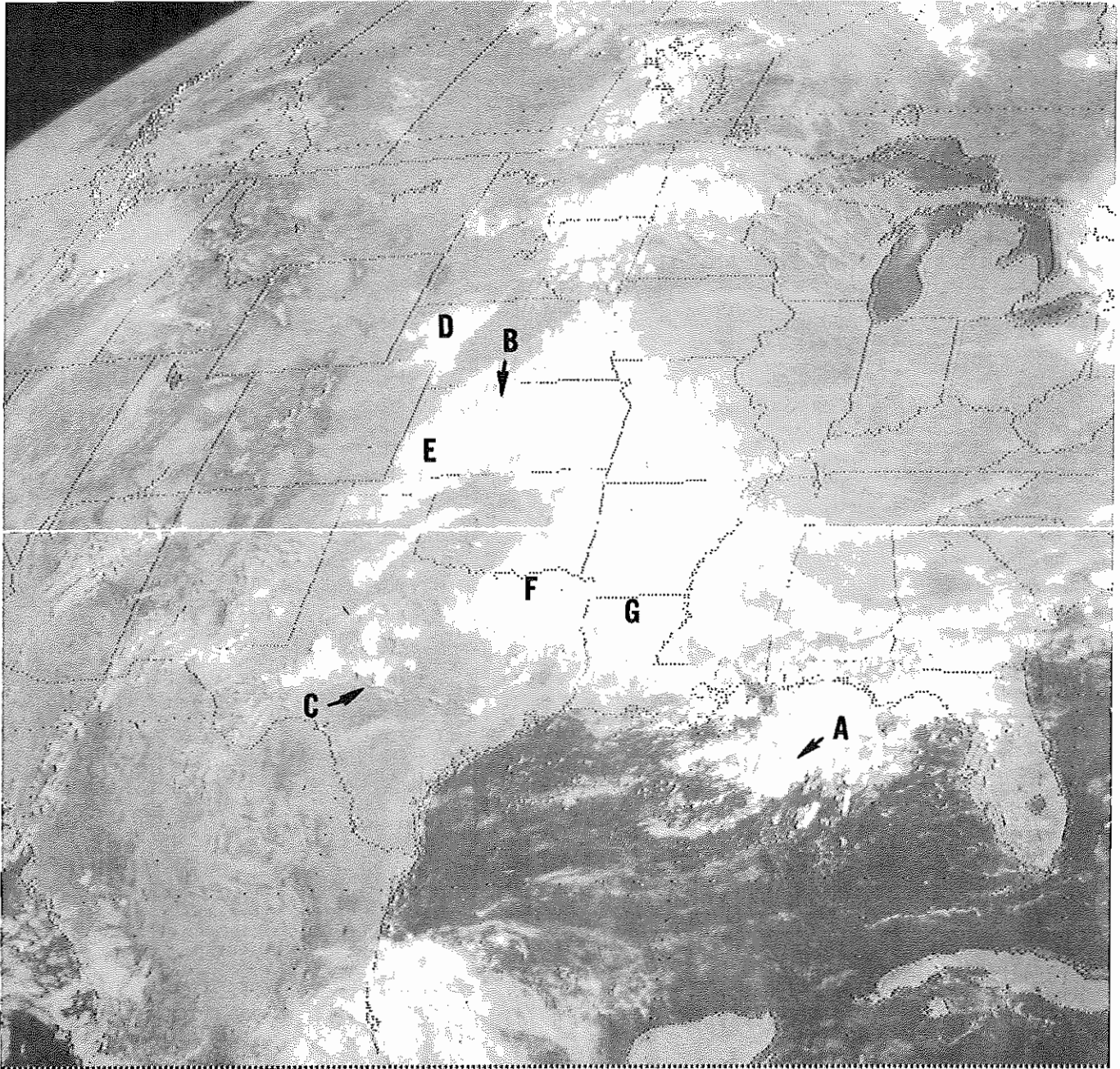


FIGURE 1.

GOES SATELLITE PHOTO RECOGNITION

PHOTO NUMBER TEN

1430 20JN80 12A-2 01363 13251 KB8



CLOUD TYPES ON SATELLITE IMAGERY

) Often in unstable air, the tops of some cumulus clouds are higher than others. Early in the morning and late in the evening when the sun angle is low, the higher tops cast shadows on the lower ones. (See Fig. 2.)

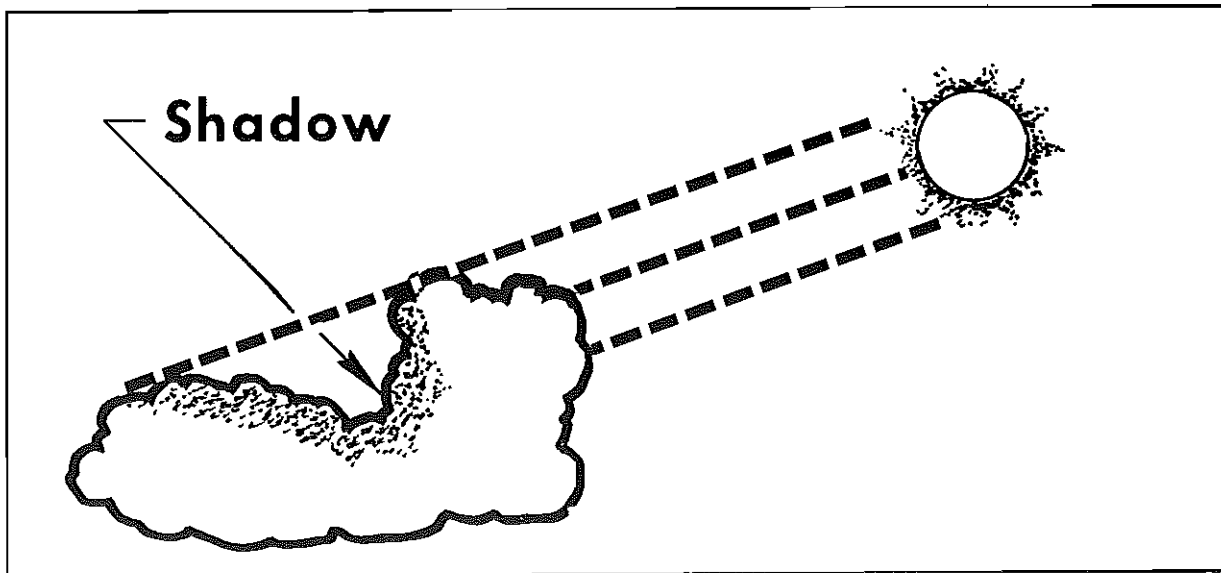


FIGURE 2.

) These shadows can be seen on visible imagery and the resulting pattern is called texture.

Examples of texture can be seen at A and B, photo 10. Shadows can also be cast on the earth's surface, producing a similar effect (C).

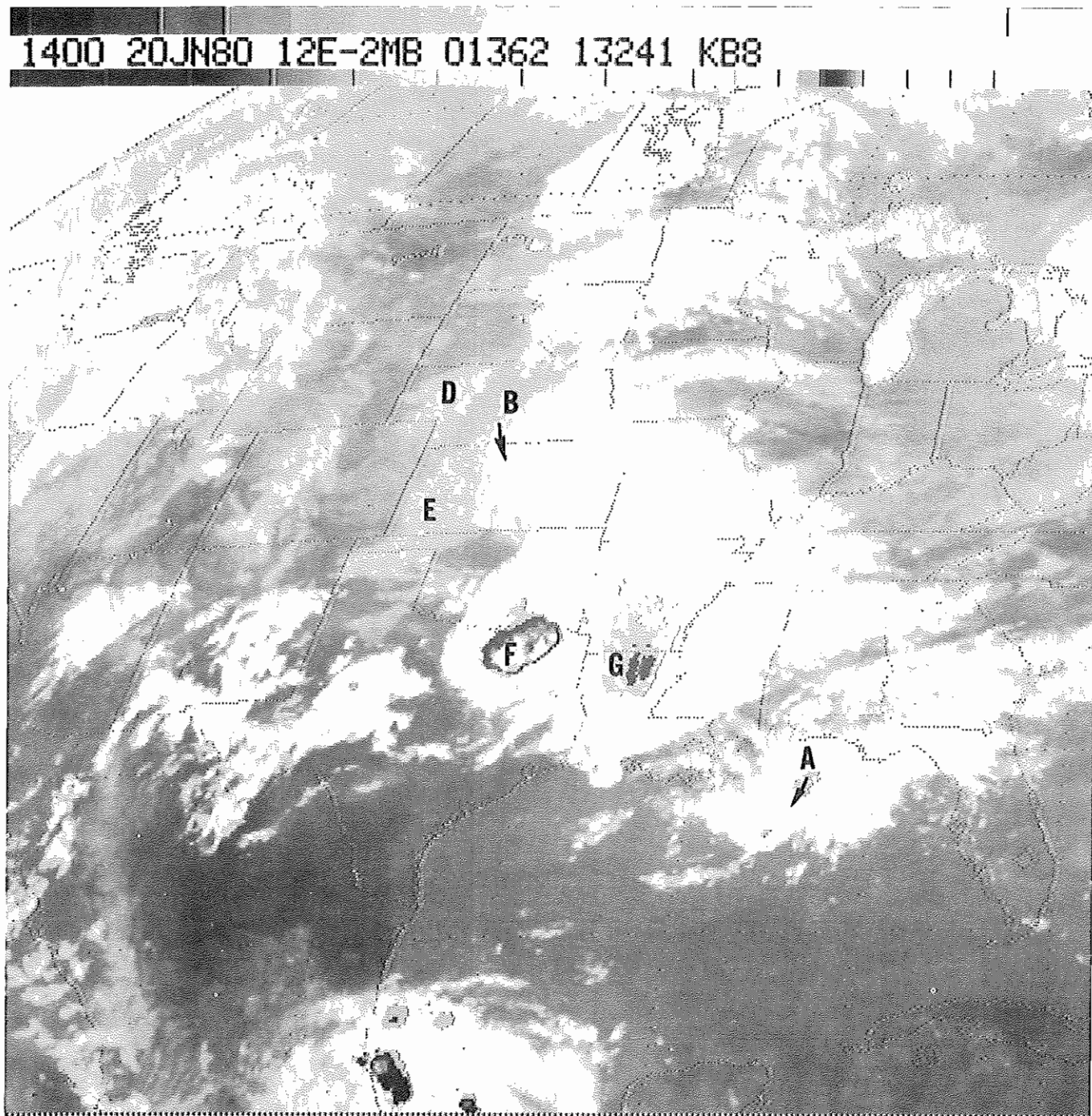
At midday when the sun is directly overhead, no shadows are cast, and there will be no texture. Even when there are no shadows, cumuliform clouds may still be recognizable by their lumpy appearance, for example, the clouds around A. Sometimes, however, cumuliform clouds may look very much like stratiform clouds on a visible photo. Refer to photos 10 and 11 and note that on photo 10 the cirrus anvils of the thunderstorms at F and G look very much like the areas of fog and low stratus at D and E. In cases like this, you need an infrared photo or other aids such as surface observations and PIREPS to accurately determine cloud types.

Stratiform clouds normally do not have texture because of their flat tops; however, when there is more than one layer of clouds, the higher layer may cast shadows on the lower layer and produce the same effect. (See B, photos 10 and 11.)

Shadows do not appear on IR imagery so there is no texture, but sometimes there will be contours on the MB curve IR photo where the shadows appear on the visible photo (see A and B, photo 11). The contours show the edges of the higher clouds very clearly compared to the shade of the lower clouds.

GOES SATELLITE PHOTO RECOGNITION

PHOTO NUMBER ELEVEN



CRITERION TEST

CHAPTER II

1. Most clouds are formed in air that is cooled by
 - a. contact with a cold surface
 - b. mixing with colder air
 - c. being lifted
2. How many basic cloud types are there and what are they called?
 - a. (2) cumuliform and stratiform
 - b. (3) high, middle, and low
 - c. (2) thick and thin
3. Stratiform clouds are characteristically
 - a. rounded and lumpy
 - b. flat and sheetlike
 - c. thin and wispy
4. Stratiform clouds are formed in
 - a. descending air
 - b. unstable air
 - c. stable air
5. Cumulus clouds are formed in
 - a. descending air
 - b. unstable air
 - c. stable air
6. Unstable conditions are usually associated with
 - a. steady wind
 - b. low ceilings and poor visibility
 - c. convective turbulence
7. Stable conditions are usually associated with
 - a. steady precipitation
 - b. showery precipitation
 - c. thunderstorms
8. Texture on satellite imagery is the result of
 - a. warm areas that show up darker
 - b. shadows on clouds from higher tops or layers
 - c. openings between clouds that show darker terrain below
9. Texture can be seen on
 - a. visible, unenhanced infrared, and enhanced infrared imagery
 - b. visible and unenhanced infrared imagery only
 - c. visible imagery only
10. Texture is best seen at
 - a. sunrise
 - b. midday
 - c. midnight

GOES SATELLITE PHOTO RECOGNITION

COMPREHENSIVE EXAM

NOTE: REFER TO PHOTOS 12 AND 13 TO ANSWER QUESTIONS 1 THROUGH 8. BE SURE TO USE **BOTH** PHOTOS FOR EACH QUESTION.

1. On photo 12, there are dark spots at A and B. Why are these spots darker than the surrounding area?
 - a. They are warmer and, therefore, show up darker.
 - b. Water surfaces reflect less sunlight than terrain surfaces.
 - c. Heavily wooded areas reflect less sunlight than open rangeland.
2. On photo 12 there is a dark spot at C. Why is this spot darker than the surrounding area?
 - a. It is warmer and, therefore, shows up darker.
 - b. Water surfaces reflect less sunlight than terrain surfaces.
 - c. Heavily wooded areas reflect less sunlight than open rangeland.
3. On photo 13, southeastern Oklahoma and most of the other southern states are a lighter shade than northwestern Oklahoma, Kansas, and Nebraska. What is the reason for the difference in shading?
 - a. The lighter area is mostly covered by thin clouds.
 - b. The darker area is heavily wooded and reflects less sunlight.
 - c. Both areas are mostly clear; the shading represents surface temperatures.
4. The clouds at D are most likely
 - a. mid-level clouds
 - b. high, thin clouds
 - c. low, thin clouds
5. The clouds at E are most likely
 - a. mid-level clouds
 - b. low, thin clouds
 - c. high, thick clouds
6. On photo 13, A and B show up as lighter-shaded spots. This is because they are
 - a. areas of tree-covered higher, cooler terrain.
 - b. large bodies of cool water
 - c. covered by low clouds
7. What type of clouds are found around E?
 - a. Stratiform
 - b. Cumuliform
 - c. Cannot be determined

GOES SATELLITE PHOTO RECOGNITION

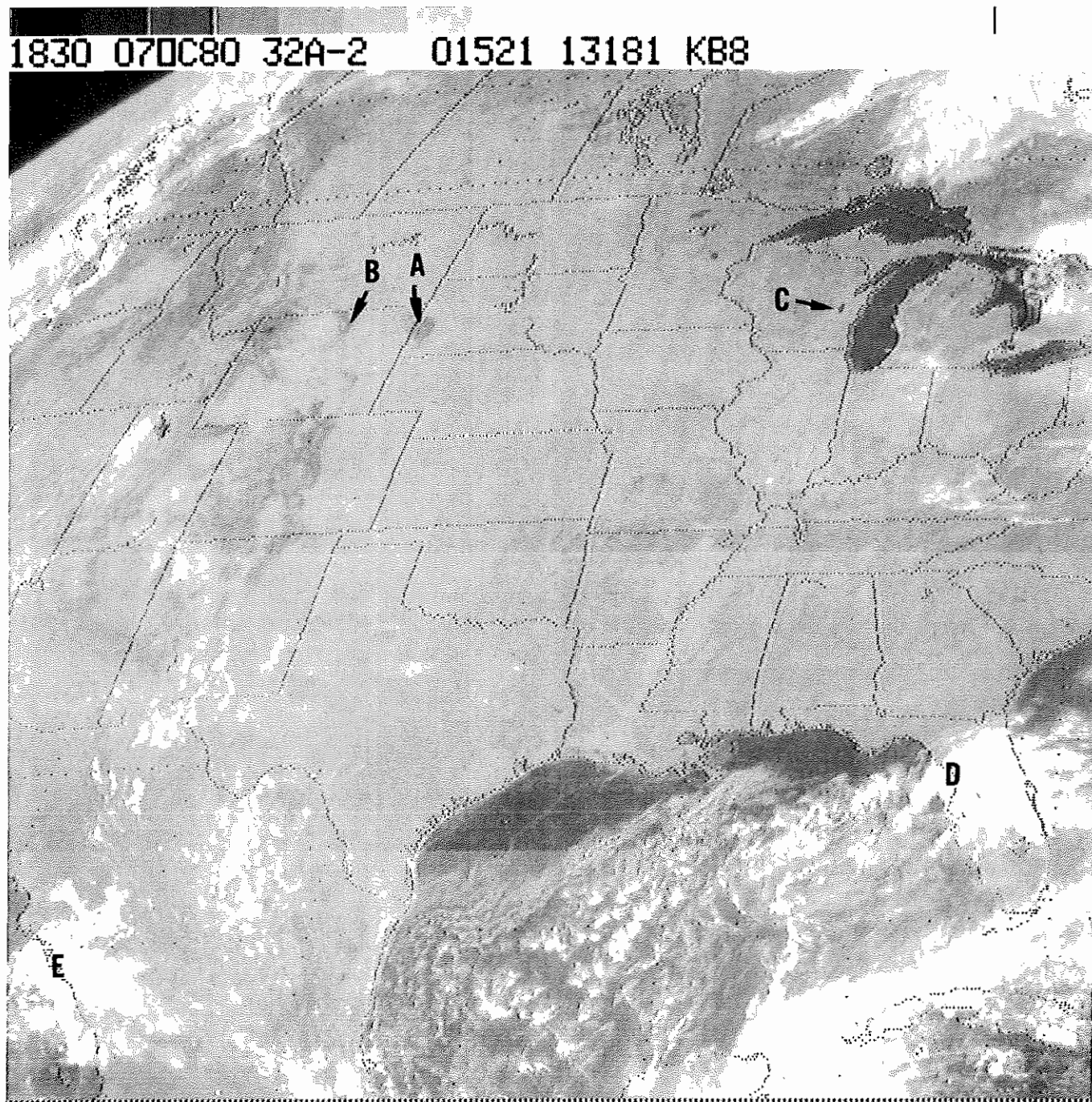
8. What aviation hazard would pilots and briefers more likely be concerned with at an airport in the vicinity of E?
- a. Widespread low ceilings and steady rain.
 - b. surface visibility restricted due to fog.
 - c. low-level wind shear from thunderstorm gust fronts.

NOTE: REFER TO PHOTOS 14 and 15 TO ANSWER QUESTIONS 9 THROUGH 15.

9. What type of cloud is located at A?
- a. Stratiform
 - b. Cumuliform
 - c. Cannot be determined
10. To what family does this cloud belong?
- a. High
 - b. Middle
 - c. Low
11. What aviation hazard would pilots and briefers more likely be concerned with in this area?
- a. Convective turbulence
 - b. Low ceiling and restricted surface visibility
 - c. Gusty surface wind
12. On photo 15, the area around B is a definite shade lighter than around C and D. Why?
- a. The area around B is covered by low clouds.
 - b. The sea surface at B reflects more sunlight so it appears lighter.
 - c. The sea surface temperature at B is cooler than at C and D.
13. The dark spots at E are
- a. islands protruding through low clouds.
 - b. the sea surface seen through holes in the clouds.
 - c. shadows on low clouds from higher clouds.
14. On photo 14, the dark line at F is a
- a. large river.
 - b. heavily wooded mountain ridge.
 - c. shadow from the high cloud just to the west.
15. Select the most likely statement concerning the clouds at G and H. The clouds at G are
- a. low; at H, mid-level
 - b. high; at H, low
 - c. mid-level; at H, mid-level

GOES SATELLITE PHOTO RECOGNITION

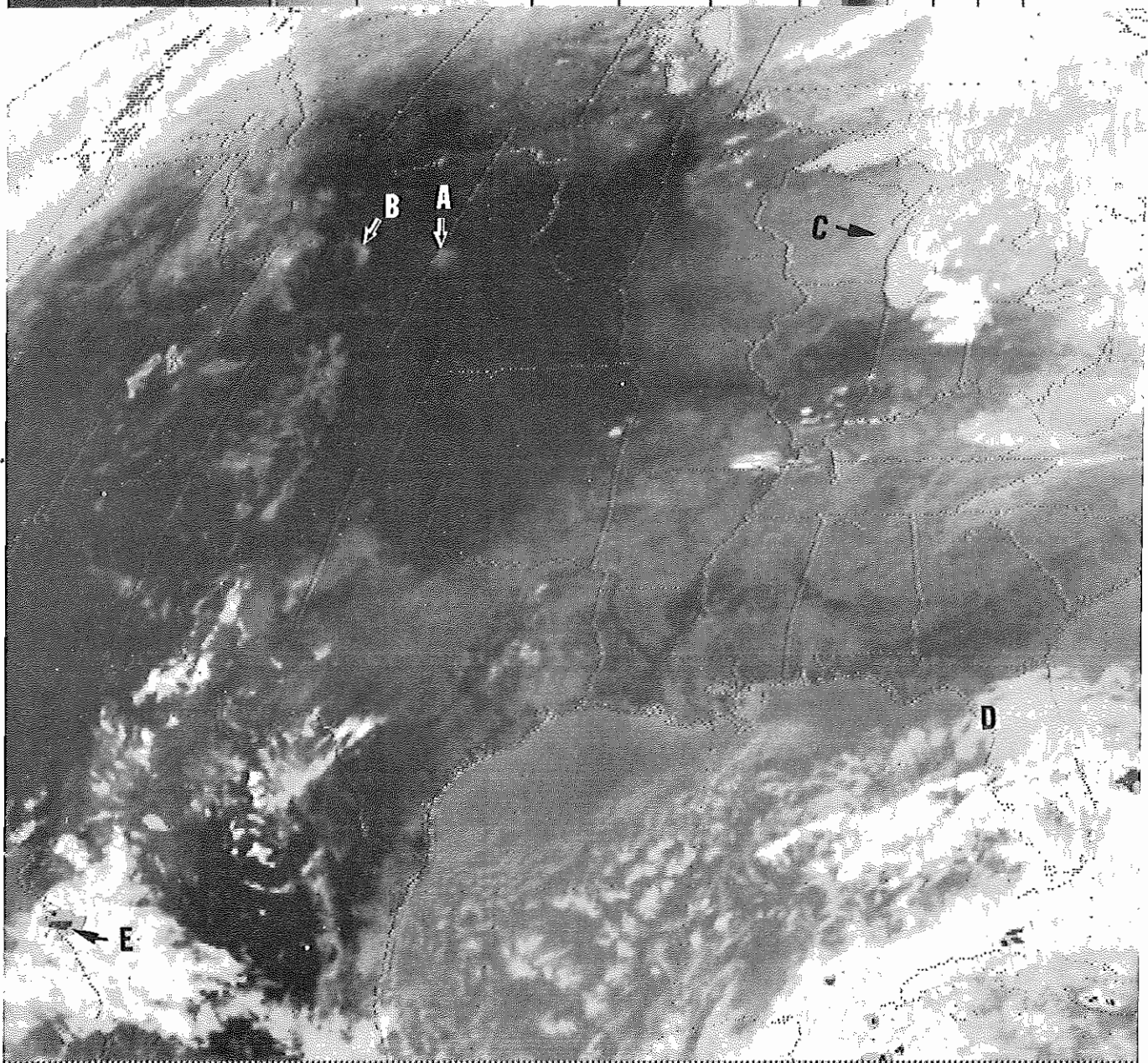
PHOTO NUMBER TWELVE



GOES SATELLITE PHOTO RECOGNITION

PHOTO NUMBER THIRTEEN

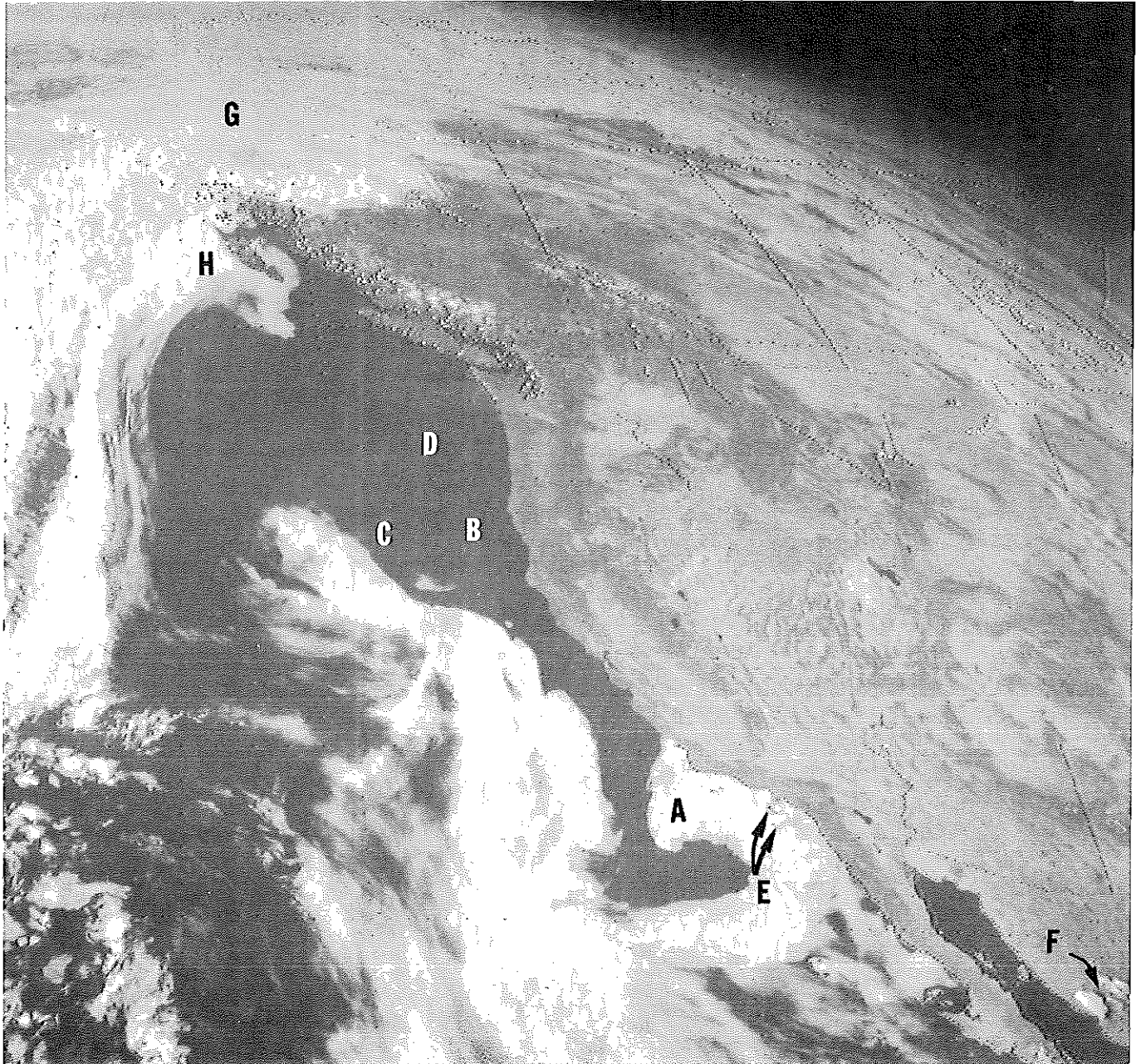
1800 070C80 32E-2MB 01524 13202 KB8



GOES SATELLITE PHOTO RECOGNITION

PHOTO NUMBER FOURTEEN

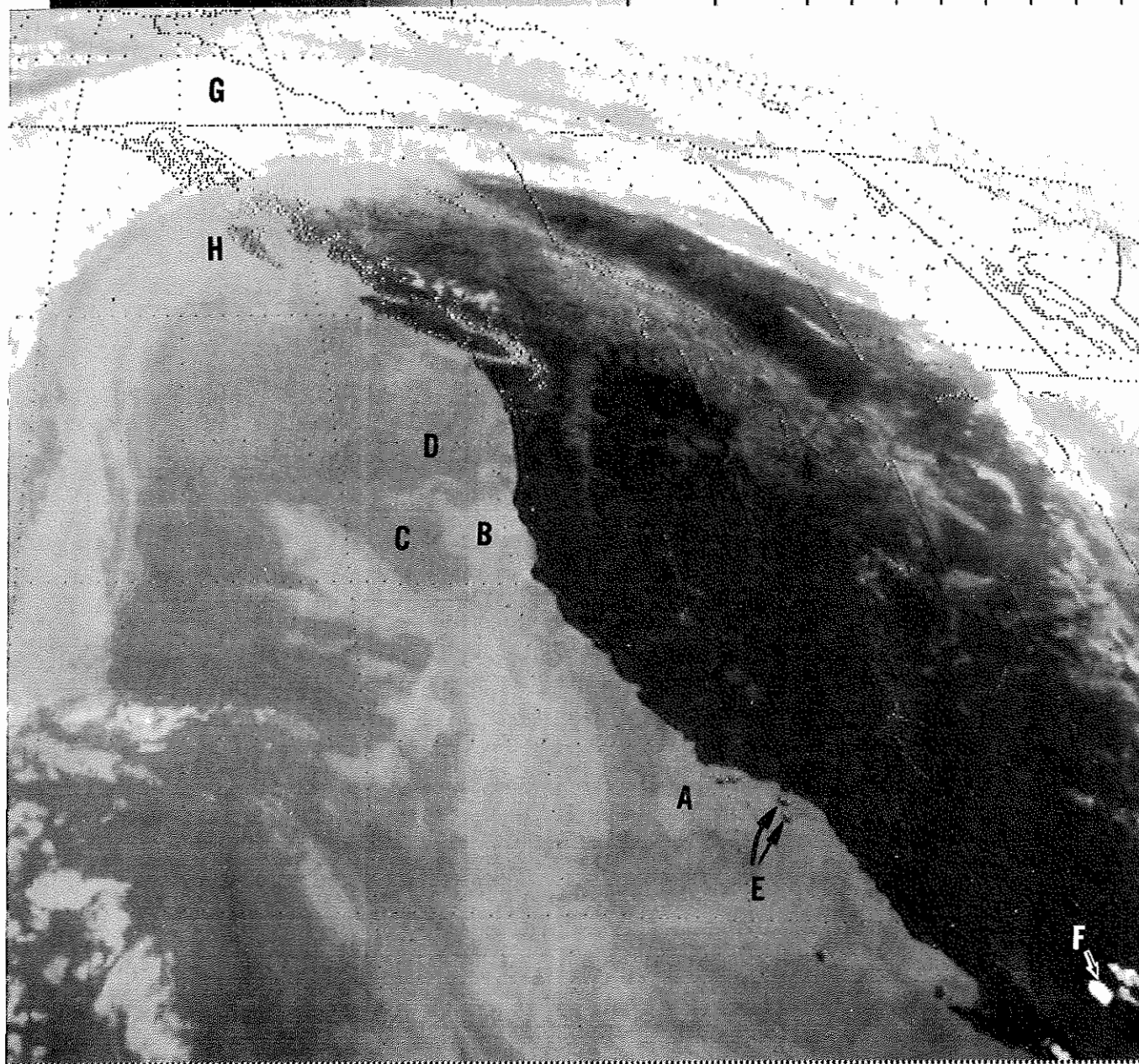
2315 020C80 15A-2 00614 22141 SB6



GOES SATELLITE PHOTO RECOGNITION

PHOTO NUMBER FIFTEEN

2245 020C80 15E-22A 00614 22141 SB6



GOES SATELLITE PHOTO RECOGNITION

CRITERION TEST 1

Answer	Page Reference
1. a	7
2. c	7
3. c	7
4. b	17
5. b	16-17
6. c	9-13
7. b	17-19
8. c	7
9. a	18-21
10. b	7
11. c	26-29
12. a	7
13. c	18 and 26
14. a	15
15. c	15 and 29
16. b	15

CRITERION TEST 2

Answer	Page Reference
1. c	35
2. a	35
3. b	35
4. c	35
5. b	35
6. c	35
7. a	35
8. b	37
9. c	37
10. a	37

COMPREHENSIVE EXAM

Answer	
1. c	Heavily forested Black Hills of SD and Bighorn Mountains of WY.
2. b	Lake Winnebago, WI.
3. c	Visible photo shows no clouds, IR shows temperature difference.
4. a	Medium gray shade. High clouds, even thin, would be whiter, low thin clouds would be much darker.
5. c	MB contouring indicates very cold (high) tops.
6. a	Higher elevation plus tree cover keeps mountainous areas cooler.
7. b	MB photo shows overshooting top of a thunderstorm.
8. c	Low-level wind shear results from downrush of air in a thunderstorm.
9. a	Stratiform clouds appear flat and sheetlike, no texture.
10. c	Dark shading on IR indicates quite warm, therefore low.
11. b	Stable conditions often cause low ceilings and poor visibility.
12. c	Visible photo shows no clouds, IR shows significant temperature difference.
13. a	IR photo shows the spots much darker (warmer) than the open sea surface.
14. c	IR photo confirms high cloud to the west, afternoon sun casts a shadow to the east.
15. b	IR photo shows white shade at G, dark shade at H.

