RETRIEVAL OF AGROMETEOROLOGICAL PARAMETERS FROM SATELLITES

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Abstract: In this article the techniques of the retrieval of agro-meteorological parameters like cloudiness, rainfall, soil moisture, solar radiation, surface temperature, and shelter temperature/humidity using different approaches are discussed. A discussion is presented on the state-of-the-art sensors, and how they can be helpful in providing some additional parameters and also, the conventional parameters (as mentioned above) with better accuracy.

INTRODUCTION

Satellites offer a unique source of information for many agricultural applications. Among their attributes are: (1) regular, repetitive observation patterns; (2) large scale synoptic view of the earth surface from space; and (3) availability of a permanent information archive for establishing baseline data. In the following sections a brief outline of the weather parameters of agro-meteorological importance is provided, and a discussion about the usefulness of satellite observations in the retrieval of these parameters is given.

PARAMETERS OF AGRO-METEOROLOGICAL INTEREST

Although a large number of atmospheric parameters can affect the agricultural production in short and long time scale, we will confine the current discussion to a few parameters. Also, we will see how the satellite observations can play a role in determination of these parameters. The parameters discussed in the following subsections are:

Satellite Remote Sensing and GIS Applications in Agricultural Meteorology
pp. 195-211

- Clouds
- Rainfall
- Soil Moisture
- Solar Radiation
- Surface Temperature
- Temperature and Humidity Profiles.

Meteorological satellites play an important role in retrieval of the above parameters at large spatial scales. The following subsections provide the discussion on this aspect.

Clouds

Interpretation of Cloud in Visible/Infrared Imageries

The cloud configuration seen in satellite imagery represents a visible manifestation of all types of atmospheric processes. The complete interpretation of cloud structure must make use of both satellite imagery and other available observational data. One should remember that the satellite sensors view only tops of clouds while in surface observations their bases are seen. Basically following six characteristic features of satellite pictures are helpful in extracting information for weather forecasting:

i) Brightness - The brightness depends strongly upon the albedo of the underlying surface in visible pictures. Highly reflecting surfaces like cumulonimbus (Cb) tops and snow appear pure white whereas the sea looks black. Other clouds and land appear in varying degrees of gray. In IR images warm land surfaces appear very dark while cold ones are white (e.g. Cb tops, thick cirrus, snow etc.). Lower level clouds and thin cirrus appear gray.

ii) Pattern - Cloud elements are seen to be organised into identifiable patterns like lines, bands, waves etc.

iii) Structure - In a VIS image, shadows of taller clouds fall on lower surfaces. Shadows and highlights thus give an idea of the cloud structure. In IR imagery this information is provided by the cloud top temperature (CTT) more directly.

iv) Texture - The cloud surfaces when viewed by the satellite vary in degree of apparent smoothness. Some clouds appear smooth while some may look ragged.

v) Shape - Clouds assume a variety of shapes - rounded, straight, serrated, scalloped, diffused or curved.

vi) Size - The size of a pattern or the size of individual elements in a pattern are useful indicators of the scale of weather systems.

While interpreting satellite pictures continuity in time has to be maintained. The pictures should not be viewed in isolation but must be interpreted with reference to past weather and earlier imageries. It is necessary to keep in mind the time of the day, season and local peculiarities while interpreting satellite imageries. In VIS pictures illumination depends on the position of the sun which will vary the brightness of clouds. Similarly in different seasons (e.g. summer and winter) the image disc of the northern and southern hemisphere will have different brightness. Local features like mountains and valleys introduce their own effects. In IR imagery elevated land like Tibetan Plateau will be cold at night and would appear very bright whereas tropical oceans would maintain about the same gray shade throughout the diurnal cycle.

Interpretation of Visible Imageries

Clouds have higher albedo than land (apart from snow cover) and appear white or light grey in a VIS imagery. Their brightness depends on their physical properties. Clouds with high albedo have large depth, high cloud water (ice) content, small cloud-droplet size whereas clouds with low albedo have shallow depth, low cloud water (ice) content, large average cloud-droplet size. The water content and depth of the cloud are the most important. Typical Albedo values are given in Table 1.

Table 1. Albedo values of different surfaces and clouds

Earth surface	(%)	Clouds	(%)
Oceans, Lakes	8	Shallow broken clouds Cu, Ci, Cs, Cc	30 35
Land Surfaces	14-18	St	40
Sand, Desert	27	Thick clouds (Cs)	74
Ice and Snow		Ac, As, Sc	68
Sea ice	35	Cu	75
Old snow	59	Ns	85
Fresh snow	80	Cb	90

VIS imagery is useful for distinguishing between sea, land and clouds (Figure 1). Seas and lakes have low albedo and hence appear dark. Land appears brighter than sea but darker than clouds. Albedo of land varies with the type of surface. Deserts appear very bright in contrast to the darkness of forests and vegetated areas. When the sun shines obliquely onto clouds the shadow thrown by an upper cloud layer onto a lower layer reveals the vertical structure of the cloud in VIS imagery.

The texture of the cloud in VIS imagery can help in its identification, (for example) its cellular pattern can distinguish stratocumulus clouds (Sc) from stratus (St). No VIS imagery can be obtained at night. To distinguish clouds from snow covered ground a knowledge of the surface topography is essential. Thin clouds have low albedo and do not show up very brightly in VIS imagery so that the cloud cover over dark surfaces may be underestimated. In the same manner thin cloud over a high albedo desert surface may look misleadingly bright and thick. Mesoscale cumulus (Cu) clouds which are smaller than the resolution of the satellite will be depicted in rather lighter grey shades in VIS imagery quite unlike the normal view of convective clouds.

Interpretation of IR Imagery

IR imagery indicates the temperature of the radiating surfaces. In black and white image warm areas are shown in dark tones and cold areas in light tones. Clouds will generally appear whiter than the earth surface because of their lower temperature. In this respect IR and VIS images have some similarity.

Because cloud top temperature decreases with height IR images show good contrast between clouds at different levels. This is not possible in VIS imagery.

Coast lines show up clearly in IR images whenever there is strong contrast between land and sea surface temperatures. During the day the land may appear darker (warmer) than the sea but at night may appear lighter (cooler). At times when land and sea temperatures are almost same, it becomes impossible to detect coastlines in IR imagery. The most marked contrast between land and sea is normally found in Summer and Winter and is least in Spring and Autumn. Thin Ci which is often transparent in the VIS can show up clearly in IR especially when it lies over much warmer surface.

IR imagery is inferior to VIS in providing information about cloud texture as it is based upon emitted and not scattered radiation. Low clouds and fog can rarely be observed in IR at night because they have almost the same temperature as the underlying surface. But during day, such clouds are easily detected in.

Interpretation of WV Imagery

Water vapor imagery is derived from radiation at wavelengths around 6-7 μm. Though this is not an atmospheric window, it is part of the spectrum where water vapor is the dominant absorbing gas. It has a strong absorption band centered on 6.7 μm. In regions of strong absorption, most of the radiation reaching the satellite originates high in the atmosphere. The stronger the absorption, the higher is the originating level of the emission that ultimately reaches the satellite. As the Relative Humidity (RH) decreases the main contribution of the radiance received by the satellite comes from lower in the troposphere.

WV imagery is usually displayed with the emitted radiation converted to temperature like IR imagery. Regions of high upper tropospheric humidity appear cold (bright) and regions of low humidity appear warm (dark) i.e. when the upper troposphere is dry, the radiation reaching the satellite originates from farther down in the atmosphere where it is warmer and appears darker on the image. In a normally moist atmosphere most of the WV radiation received by the satellite originates in the 300-600 hPa layer. But when the air is dry some radiation may come from layers as low as 800 hPa. Due to the general poleward decrease of water vapor content, the height of the contributing layer gets lower and lower towards the poles.

Since clouds do emit radiation in this wave band, high clouds may be seen in this type of imagery. Thick high clouds as Cb anvils stand out prominently in both WV and IR imageries. Broad-scale flow patterns are particularly striking in WV imagery. This is because WV acts as passive tracer of atmospheric motions. WV imagery is therefore useful for displaying the mid tropospheric flow (for example), upper tropospheric cyclones are defined clearly by moist spirals or comma-shaped patterns. Subsidence areas appear dark. Jet streams are delineated by sharp gradients in moisture with dry air on the poleward side. Even when a WV image indicates a very dry upper troposphere, there may well be moist air near the surface. Moist air or cloud in the lower half of the troposphere is not depicted well in WV imagery.

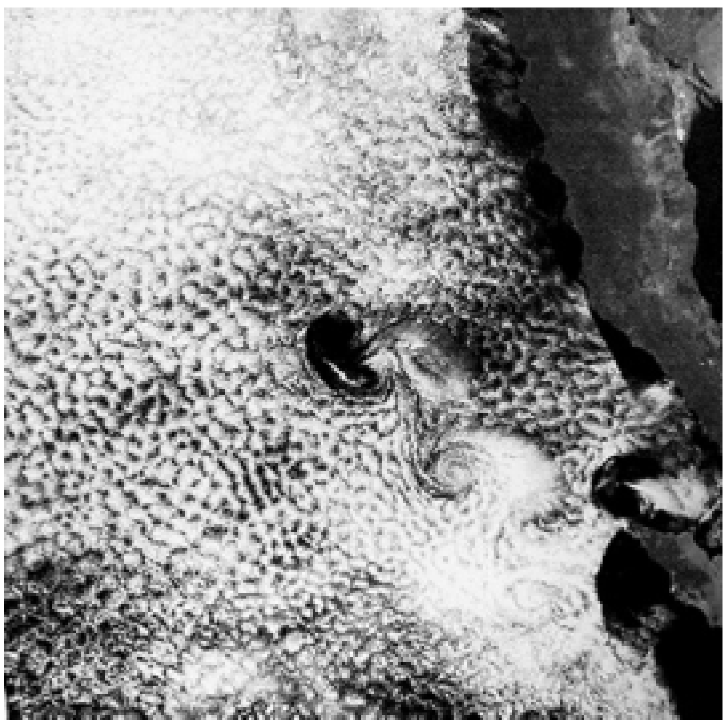

Figure 1: Karman cloud vortices in Pacific Ocean as they are seen in visible images

Rainfall

Rainfall is not only an important parameter for agro-meteorology, it is also a vital component of earth's hydrological cycle. Oceans receive heat from the sun, and the evaporation takes place. When the same evaporation travels vertically, it gets condensed to form clouds and eventually precipitation. During this process, enormous amount of energy is released which is called the latent heat of condensation. This is one of the major sources of energy that drives the circulation in tropical atmosphere. Hence, the knowledge of rainfall and its distribution at current time is also important for its future prediction.

There are several techniques to derive rainfall from satellite observations. The earliest developed methods that are useful even today are based on the visible/infrared observations from satellites. Techniques based on visible sensors rely on the identification of cloud types. Each cloud type is assumed to have different rain intensity, and then the rain is derived based upon the extent of each cloud type. In infrared-based methods, the most common approach is to find cold clouds (say, colder than 250^{o}K) within an overcast area. The raining potential of the clouds is proportional to the fractional area covered by cold clouds, and thus the rainfall derived. More complex techniques use both visible and infrared observations to create a bi-spectral histogram of the cloud images. Bi-spectral histogram method is a simple technique in which the clouds can be classified based on the combination of cloud signatures in visible and infrared frequencies. Then the rainfall is derived by estimating the extent of each type of cloud and multiplying it by the a-priori rain potential of respective classes. However, all the rain-retrieval techniques based on visible/IR observations are basically "inferential" in nature, because these sensors can sense the clouds (that too, the top surfaces of the clouds) but not the actual rain, that occurs at several layers below the clouds. Visible/IR techniques make a "guess" about the rainfall based on the cloud features. Due to this shortcoming, the estimates of rainfall based on visible/IR technique are not very accurate on instantaneous time scale. However, long time averages (e.g. daily, weekly, and monthly) of rainfall are better and usable for practical purposes.

On the other hand, rainfall estimation techniques based on microwave frequencies (0.1 cm to 100 cm wave length) are more direct in nature. Due to their large wavelengths, these frequencies can easily penetrate clouds. However, these frequencies interact effectively with rainfall. Let us consider the case of passive microwave methods. In these techniques, the microwave instrument onboard satellite does not have any source of microwave illumination. It has just a receiver that can gather the microwave emission coming from earth, ocean or atmosphere. Due to small emissivity in microwave region, ocean surface emits small amount of microwave radiation. When the rainfall occurs over a layer in the atmosphere, two different processes take place.

The atmospheric rain layer itself emits microwave radiation and thus the radiation received at satellite is greater than the radiation received in no-rain situation. This process is predominant at lower frequencies (e.g. 19 GHz, or about 1.5 cm wavelength). On the other hand, the rain drops, ice and snow particles, scatter the microwave radiation (particularly at higher frequencies, e.g. 85 GHz, or about 0.3 cm wavelength) that is coming up from the ground. In this case the radiation received at satellite will be smaller than that in no-rain situation. In both the cases, the change in the microwave radiation (measured in terms of brightness temperature) can be related to the intensity of rainfall. Various algorithms have been developed in the past that use either low frequency or high frequency, or a combination of both. It is to be noted that for emission based algorithms (using lower frequencies of microwave e.g. 19 GHz), it is important that the emission from the background should be uniform and also as little as possible, so that the emission from rainfall can be detected clearly. So emission based algorithms are effective only over the ocean surfaces, while the scattering based algorithms using higher frequencies of microwave, can be used over the ocean as well as over the land. Special Sensor Microwave Imager (SSM/I), and TRMM Microwave Imager (TMI) are good examples of passive microwave sensors that are quite effective in the determination of global rainfall (Figure 2).

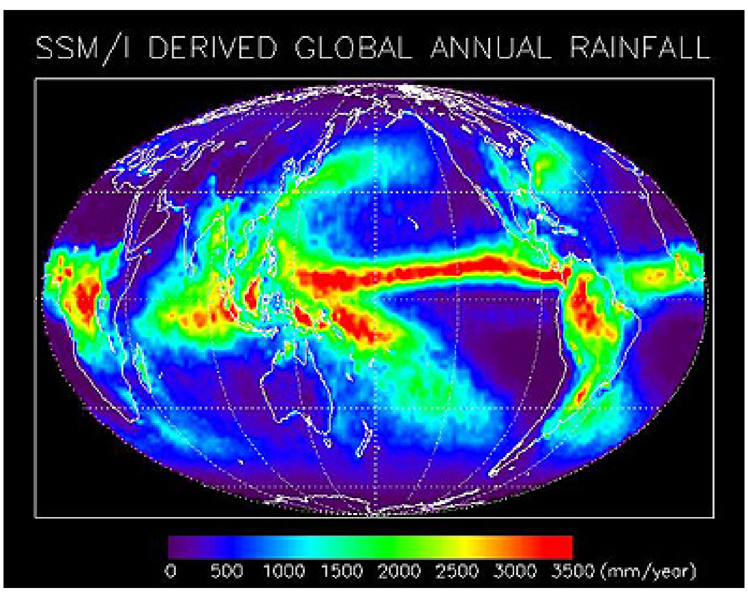

Figure 2: Global annual rainfall observed by Special Sensor Microwave/Imager (SSM/I) (Picture courtesy : rst.gsfc.nasa.gov)

Soil Moisture

Recent advances in remote sensing have shown that soil moisture can be measured by a variety of techniques. However, only microwave technology has demonstrated a quantitative ability to measure soil moisture under a variety of topographic and vegetation cover conditions so that it could be extended to routine measurements from a satellite system. Both active and passive microwave techniques have been applied by researchers for the estimation of soil moisture. Two material properties provide clues about composition and surface state by the manner in which these attributes interact with the microwave radiation. One property is the dielectric constant (its symbol is the small Greek letter, *k*), which is the ratio of the capacitance of a material to that of a vacuum. It is a dimensionless number that is set at 1.00. This electrical property describes a material's capability (capacity) to hold a charge, which also measures its ability to polarize when subjected to an electric field. Microwave radiation penetrates deeper into materials with low dielectric constants and reflect more efficiently from those with high constants. Values for *k* range from 3 to 16 for most dry rocks and soils, and up to 80 for water with impurities. Moist soils have values typically between 30 and 60. Thus, variation in emitted microwave radiances (in case of passive microwave observations e.g. by radiometers) or reflected-pulse intensities (in case of active microwave observations e.g. by radar) may indicate differences in soil moisture, other factors being constant. Dry soil has a high emittance; water surfaces have low emittance in microwave region. If one adds water to the soil, the emittance falls and becomes polarized. With the knowledge of "normal" emittance at a particular location (which depends upon soil type and vegetation), microwave observations can be used to detect changes in emittance and therefore of soil moisture. Since the soil moisture is changed by precipitation, these emittance changes between two satellite passes can serve as a proxy of precipitation, known as Antecedent Precipitation Index (API).

The second material property is roughness that can be used to define the ***soil texture***. Materials differ from one another in their natural or cultivated state of surface roughness. Roughness, in this sense, refers to minute irregularities that relate either to textures of the surfaces or of objects on them (such as, closely-spaced vegetation that may have a variety of shapes). Examples include the textural character of pitted materials, granular soils, gravel, grass blades, and other covering objects whose surfaces have dimensional variability on the order of millimeters to centimeters. The height of an irregularity, together with radar wavelength and grazing angle at the point of contact, determines the behavior of a surface as smooth (specular reflector), intermediate, or rough (diffuse reflector). A surface with an irregularity height averaging 0.5 cm will reflect Ka band (l= 0.85 cm), X band (l= 3 cm), and L band (l= 25 cm) radar waves as if it were a smooth, intermediate, and rough surface, respectively. Other average heights produce different responses, from combinations of “all smooth” to “all rough” for the several bands used. This situation means radar, broadcasting three bands simultaneously in a quasi-multi-spectral mode, can produce color composites, if we assign a color to each band. Patterns of relative intensities for images made from different bands may serve as diagnostic tonal signatures for diverse materials whose surfaces show contrasted roughness.

Solar Radiation

Incoming solar radiation is the primary source of energy for plant photosynthesis. Solar radiation also plays a key role in evapotranspiration. Visible observations from satellites provide an excellent source of information about the amount of solar radiation reaching the plant canopy. A measurement of solar energy reflected to space from earth-atmosphere system immediately specifies the maximum amount of solar energy that can be absorbed at the surface. Incoming solar radiation can be known by adjusting the amount absorbed. Hence, for the computation of downwelling solar radiation, the albedo of the surface must be known. This is especially important over the regions of high reflectivity such as snow and desert. Tarpley (1979) used a statistical regression technique to obtain surface fluxes over the land from Visible channel observations from geostationary satellites. In this model, cloud amount is estimated for a given location from satellite visible data. Three separate regression equations are then used to estimate solar radiation for three categories of clouds. This method provides an accuracy of 10% for clear sky, 30% for partly cloudy and 50% for overcast conditions. Other algorithms like those by Moser and Raschke (1984), and Pinker and Ewing (1985) used physical approaches, and treated the interaction of incoming and reflected solar radiation with the atmosphere and land surfaces in physical manner. The transmittance of solar radiation in these approaches is solved by the use of radiative transfer equations that take into account the concentration profile of different atmospheric components. These physical schemes also take into account the cloudiness and atmospheric water vapor. These methods provide relatively higher accuracy. However, statistical techniques have remained the choice for operational use. These methods require coincident satellite and ground (pyranometer) observations to develop the coefficients in the regression equations. These methods produce daily total insolation, based on hourly estimates made from geostationary satellite data between 0800 and 1600 LST, with interpolation used toward both sunrise and sunset and for any other missing hourly values.

Surface Temperature

Air temperature is significantly related to crop development and conditions. Operational crop and soil moisture models require daily minimum and maximum shelter temperature and dew point temperature. Canopy (or skin) temperature may be more directly related to growth and evapotranspiration than the shelter temperature. The difference between the two is a measure of crop stress. The ability to observe canopy temperature directly is an advantage of satellite observations. However, it is to be noted that the satellite derived “skin temperature” and “crop canopy temperature” are equivalent only when a satellite field of view (FOV) is filled with vegetation. If FOV constitutes a mixture of bare soil, water bodies, etc. the relation between the two becomes complex. Satellite observations in the thermal IR window (10-12 μm) are used to obtain estimates of canopy or skin temperature. Price (1984) found that surface temperatures over vegetated land can be estimated with an accuracy of 2-3^{o} C using AVHRR split window technique. The errors can largely be attributed to imperfect knowledge about atmospheric water vapor content and wavelength dependent surface emissivity. Clouds pose a serious problem in the estimation of surface temperature by infrared techniques.

Satellite surface temperature estimates have been used to delineate areas of freezing for frost warning and for monitoring freezing events that can affect food production. In U.S., the infrared observations from geostationary satellite GOES are used for freeze forecasting by following the diurnal progression of the freeze line. Accurate freeze forecasts permit farmers to protect crops only when there is a significant freeze threat.

Shelter Temperature

Shelter temperature, its minimum/maximum values along with canopy temperature are important factors of consideration for assessment of crop development and crop stress. Shelter temperature is more directly related to the air temperature than the surface temperature. Observations from atmospheric sounders like TOVS (TIROS-N Operational Vertical Sounder) are used in methods for estimating shelter temperature. A simple linear regression approach is generally used to derive shelter temperature from satellite soundings. (A brief description of sounding principles is given in next section). Collocated and coincident sets of satellite soundings and shelter temperature observations are used to develop regression coefficients (Davis and Tarpley, 1983). This method provides the shelter temperature with an accuracy of about 2° C. In winter time, a temperature inversion generally persists over the cold ground. This results in a bias of 1-2° C (satellite estimates being warmer) in the nighttime estimates of shelter temperature during winter.

Temperature and Humidity Profiles (Sounding)

Temperature and moisture structures of earth's atmosphere are some of the most significant factors that influence the weather and climate patterns on the local as well as on global scale. The vertical structure of temperature and humidity is retrieved by satellite "sounders" that operate in infrared and microwave frequencies. Sounders use the principle of gaseous absorption for the retrieval of temperature and humidity profiles. For the retrieval of temperature, absorption spectra of some uniformly mixed gas such as CO_2, or, O_2 is used (Fig. 3). These gases absorb earth's upwelling radiation. However, at some wavelengths (say, l_1) their efficiency of absorption is very strong, while at some neighboring wavelengths (say, l_2), it is very weak. Now, any radiation of wavelength l_1 coming from lower layers of atmosphere has very little chance of reaching up to satellite, because it is getting strongly absorbed by the given gas. So, at this wavelength, most of the radiation will be coming from the upper layers of the atmosphere. Similarly, the radiation emitted from the ground at wavelength l_2 will reach the satellite without much interruption, because the atmospheric gases absorb this radiation very weakly. It means that the radiation at wavelength l_2 contains information about the atmospheric layers near the surface. Similarly, radiation at other wavelengths lying between l_1 and l_2 is sensitive to different atmospheric layers in vertical.

Since the radiance from these layers is highly sensitive to the temperature of these layers, the temperature information can be retrieved if we know the radiances reaching the satellite at different wavelengths. A sounder is designed to measure the upwelling radiances at different wavelengths, which are used for retrieving the temperature information. However the actual mathematical procedure of retrieval is quite complex.

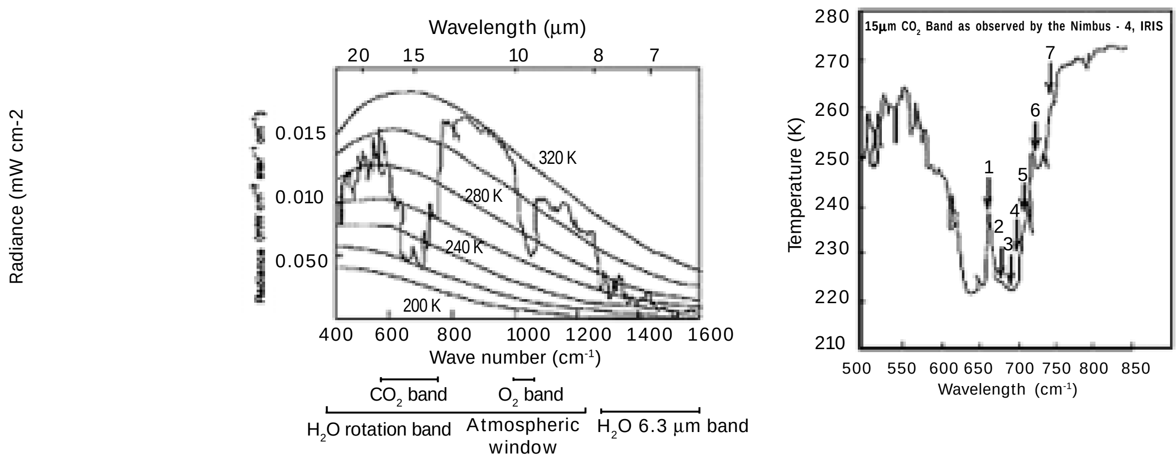

Figure 3: (a) Curve showing the absorption of infrared radiation by different gases in the atmosphere. (b) Numbers shown in this curve (1,2,3,4…7) denote the central wavelengths of CO_2 absorption band used for sounding of atmospheric temperature profiles

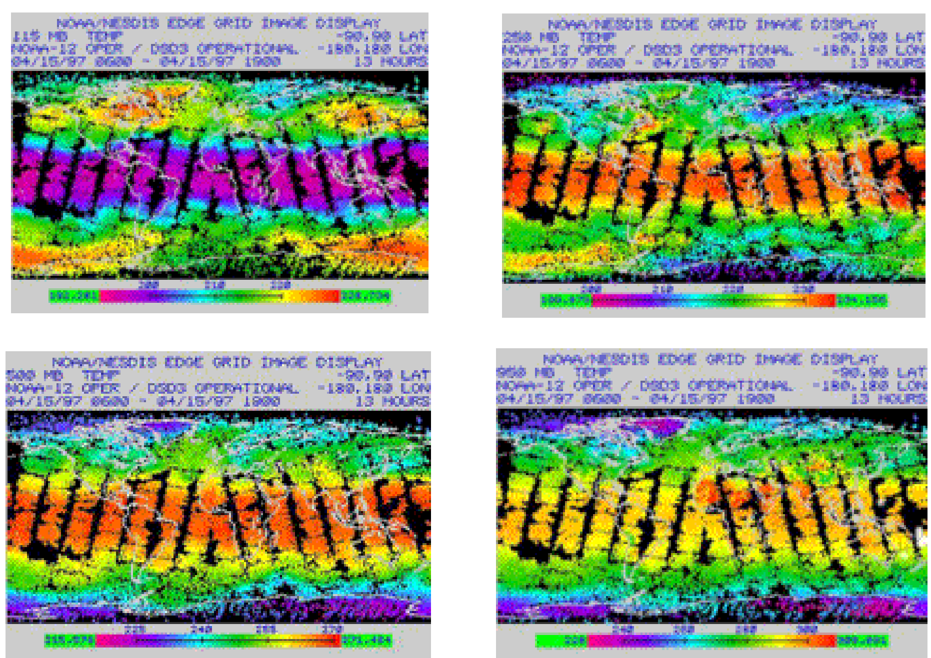

Figure 4: Distribution of global temperature at four vertical levels by TOVS (Picture courtesy : rst.gsfc.nasa.gov)

The principle of the sounding of humidity profiles is similar to that of temperature. However, water vapor is not a uniformly mixed gas, and also it changes phase (i.e. ice, water, snow, or vapor) very frequently within the atmosphere. Satellite water vapor sounders use the water vapor absorption frequencies (~ 6 lm in IR sounder, and ~ 183 GHz in microwave sounders). However, the upwelling radiation at these wavelengths/frequencies not only depends upon the water vapor amount in different atmospheric layers, but also on the temperature of those layers. In this case a-priori information about the temperature structure of the atmosphere is crucial for the retrieval of humidity profiles.

An example of infrared sounders is TIROS Operational Vertical Sounder (TOVS), onboard NOAA series of satellites. This instrument is designed to profile temperature and water vapor. The TOVS is actually a three instrument complex: the High Resolution IR Sounder (HIRS-2), with 20 channels; the Stratospheric Sounding Unit (SSU), with three channels near 15 µm, and the Microwave Sounding Unit (MSU), a passive scanning microwave spectrometer with four channels in the 5.5 µm interval. Advance Microwave Sounding Units (AMSU-A, and AMSU-B onboard recent series of NOAA) are the examples of microwave sounders that are designed to sense temperature and humidity profiles respectively.

OBSERVATIONS OF THE EARTH'S SURFACE

The brightness of the earth's surface in VIS imageries depends on the time of the day, season of the year, the geographical location etc. It is easy to distinguish dry land from a water surface and to identify shorelines, rivers, lakes, islands etc. Dry land, depending on the type of relief, assumes various grey shades in VIS imageries.

The tone of the underlying surface in IR imageries depends on temperature and so its appearance is affected on the latitudinal, diurnal and seasonal variations. During day light hours and in summer dry land surfaces appear darker than the water surface but at night it has a lighter tone than a water surface. IR imageries reveal only large irregularities of relief of vegetation pattern which are associated with marked temperature gradients whereas VIS pictures can reveal even small terrain variations.

Deserts and Vegetated Areas

Dense vegetated areas appear relatively dark in VIS imageries. Mountains with thick forests can be easily identified when sparsely vegetated plains surround it. Deserts with very sparse vegetation combined with red and yellow soils and rocks make the earth's surface highly reflective. These areas appear brightest in satellite pictures.

Surface temperature differences between deserts and vegetated regions are often modified diurnally by water vapor absorption in moist low levels of the atmosphere. Hence the radiation emitted from the surface reaches the satellite undiminished only when the atmosphere is dry. When it is moist the radiation from the high cold levels only reach and hence the IR imagery is not much influenced by the surface characteristics.

Snow

Knowledge of surface geography together with an appreciation of the climatological variation of snow cover through the seasons is a basic prerequisite for the analysis of satellite imagery in respect of snow.

The tone of snow on VIS imagery varies from bright white to light grey depending on the nature of the relief, vegetation, the age of snow and the illumination. In areas of relatively flat terrain without trees snow surfaces appear uniformly white in tone. In areas covered by extensive forests a snow-covered surface appears patchy, brighter patches correspond to areas where there are no trees and dark patches to forest areas.

In IR imagery, snow covered terrain often appears whiter than its surroundings. At night the snow surface cools more rapidly than its surroundings and during the day it warms gradually. Light snow on the tops of high mountain ranges is less detectable in IR than in VIS data as the temperature difference between cold land and snow is small while the difference in albedo between snow and land is large.

ATMOSPHERIC POLLUTANTS

Dust and Haze

Dust is characterized by a dull, hazy and filmy appearance similar to thin cirrostratus. Dust can extend to adjacent water bodies and sometimes obscure the coastline. The edges of dust areas are ill defined.

Blowing dust and sand can be observed in satellite imageries when the reflectivity of the suspended particles differs greatly from the reflectivity of the underlying surface.

Haze particles scatter quite effectively at the blue end of the visible wavelength (channel 1) and hence areas of haze show up better in images of this channel.

Particles of dust or sand carried by the wind form a cloud that causes land marks to appear blurred or to disappear in VIS images. To be detected in IR imagery a dust cloud must be very deep. There are two reasons for the same. Firstly the dust must be composed of large enough particles (over 15 m) to obscure radiation emitted from the ground at least partially. Secondly it must be deep enough to have low temperature otherwise it will not be able to distinguish it from the surface.

Forest Fires

The usefulness of weather satellites are not limited to meteorological observations alone. Their camera systems, sensors and their global coverage enable them to perform a variety of non-meteorological tasks as well. These are detection of forest fires, the tracking of locust clouds, observing volcanoes etc. The sensors of weather satellite enable detection of forest fires characterized by a dull, hazy appearance as in the case of dust. Detection becomes difficult in VIS imagery if the smoke is not prominent. Under such condition it might be possible to spot the fire in IR imagery by sensing the thermal radiation given off. But the detection depends on the intensity of forest fire, its extent, the resolution of the satellite, presence or absence of clouds etc. If a thick cloud system covers the area of forest fire or if clouds have been generated by hot air rising above the forest fire zone it may not be possible to detect forest fires efficiently.

CONCLUSIONS

Various agrometeorological parameters such as clouds, rainfall, soil moisture, solar radiation, land surface temperature, temperature and humidity profiles etc. can be effectively retrieved by using optical, thermal-IR and microwave sensors data onboard various meteorological and earth resources satellites. This information is vital for management of agro-resources and environment.

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