Passive Microwave Radiometers & Climate Monitoring: A Study

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***Abstract*- A brief overview of the role of passive microwave radiometer in climate monitoring is given in this paper. Passive microwave radiometers have been an important part of the emerging field of climate applications of satellite data. Even though the researchers in passive microwave remote sensing are less as compared to visible and infrared remote sensing, the characteristics of microwave radiometers lend themselves more readily to climate applications. I will review some of the important advances this area has seen in the last thirty years, and what the future holds. Some of the applications reviewed are TRMM, applications to land surface parameter retrieval and the effects of weather systems on sea-ice concentration.**

***Index Terms*- EOS, MIMR, TRMM, passive microwaves.**

I. INTRODUCTION

RADIOMETER is a general term for any instrument that quantitatively measures the EM radiation in some interval of the EM spectrum. When the radiation is light from the narrow spectral band including the visible, the term *photometer*s can be substituted. The term *spectroradiometer* tends to imply that the dispersed radiation is in bands rather then discrete wavelengths. Most air/space sensors are spectroradiometers.

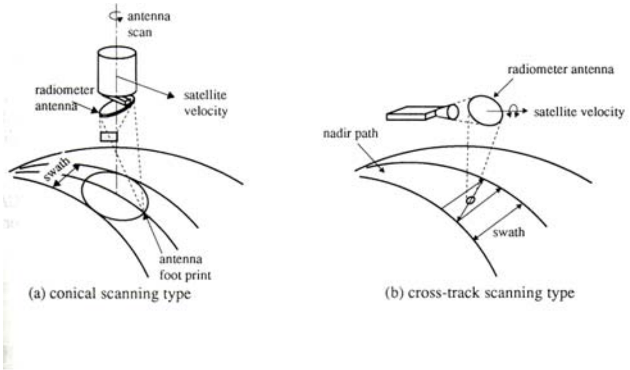
The complete classification of sensors is shown in the appendix. The Multi-frequency Imaging Microwave Radiometer (MIMR), which is planned for NASA EOS platform will be a very significant contribution in the field of land/vegetation monitoring on a global scale. It provides much improved data due to its relatively large number of frequencies and good spatial resolution.

The first launch of a passive microwave radiometer for measurement of natural Earth emissions was accomplished by the U.S.S.R. on a Cosmos satellite in September, 1968. On the U.S. side, these events were followed by a series of window-frequency and sounding frequency radiometers on the NASA Nimbus satellite series, starting with the Nimbus-5 Electrically Scanning Microwave Radiometer (ESMR-5) in 1972. The utility of microwave window frequency has been demonstrated in ESMR-5, to measure the warm thermal emission of rain cells against the low microwave emissivity ocean background.

Two major events in the eventual use of microwave radiometers for climate monitoring were the first launches of the Microwave Sounding Unit in late 1978, and of the Special Sensor Microwave Imager (SSM/I) in mid-1987. There are a series of temperature sounders on some satellites, also flying since 1979, called the Special Sensor Microwave Temperature (SSM/T) instruments.

II. BACKGROUND

A part of the microwave is also radiated by thermal radiation from the object on the earth. Microwave radiometers or passive type microwave sensors are used to measure the thermal radiation of the ground surface and/or atmospheric condition. Brightness temperature measured by a microwave radiometer is the resultant energy of thermal radiation from the ground surface and the atmospheric media. Multi-channel radiometers with multi-polarization are used to avoid the influences of unnecessary factors to measure the specific physical parameter.



(a) conical scanning type

(b) cross-track scanning type

Fig. 1. Microwave Scanning Radiometers

Figure 1 shows two typical microwave scanning radiometers: the conical scanning type and the cross track scanning type. The former is used for the microwave channel, which is influenced by the ground surface, while the latter is used for the channel, which can be neglected, by the influence of the ground surface. The cross track mode normally uses a rotating or oscillating mirror to sweep the scene along a line traversing the ground that is very long but also very narrow. This is sometimes referred to as the whiskbroom mode from the vision of sweeping a table side to side by a small handheld broom.

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III. APPICATIONS

TRMM:

The Tropical Rain Measuring Mission (TRMM) has been providing unique tropical measurement since late 1997, even though it was designed as a three-year mission. It deserves special mention for several reasons. TRMM Microwave Unit (TMI) is one of the major units carried by the TRMM satellite. It also carries a modified SSM/I design, which includes the first externally calibrated channels below 11 GHz. This plays an important role in sea surface temperature (SST) retrievals through clouds that could provide a basis for climate monitoring of cloudy SSTs from future microwave radiometers. There has been a recent decision to boost the TRMM satellite to a significantly higher orbit, from its nominal 350 km altitude. The basic reason behind this is to reduce the atmospheric drag sufficiently that TRMM could conceivably provide a 10-year dataset before satellite reentry.

TRMMs first flight of precipitation radar (PR) is providing a unique validation opportunity of the passive microwave based precipitation datasets, and will pave the way for future high-altitude orbiting radar as part of the NASA Global Precipitation Mission (GPM). The TRMM Microwave Imager (TMI) is used to retrieve nonraining geophysical parameters. Because of the continuous radiometer improvements with respect to the number of channels, their spatial resolution, and their absolute calibration, algorithm development, has naturally focused only upon the latest sensors. Most of the current passive microwave algorithms contain empirically adjusted parameters of procedures that depend on specific channels or channel combinations to optimize the retrieval. In addition, the GPM concept uses a constellation of satellites carrying passive microwave radiometers in order to achieve three hourly rainfall samplings.

The algorithm described by Dong-Bin Shin is designed to create three-dimensional geophysical parameter fields that are consistent with the TMI when no rain is present, and with both the TMI and the TRMM precipitation radar observations where the PR detects rainfall [1].

Arctic Sea Ice Research:

The effects of weather systems on sea-ice concentration retrievals using passive microwaves are investigated because significant errors in estimating short-time variations and climatological concentration trends occur due to clouds and water vapor. Satellite sea-ice observations of climatic interest include sea-ice extent, concentration, and temperature. Analysis of a ninth year sea-ice extent time series based on multi-channel radiometer measurements showed a decrease in the Artic ice cover.

The components of the NASA EOS program and some sensor systems plays an important role to study Artic sea-ice and its role in the Earth's climate system. The Artic sea-ice is monitored using TRMM Microwave Imager (TMI), the results of which are shown in the figure 2. The (a) part represents minimum sea-ice concentration for 1979, while (b) part shows sea-ice for 2003. Reduction rate of about 9% per decade is observed [2].

Fig. 2. Monitoring of Arctic perennial Sea-Ice using TMI.

The polar sea-ice plays an important role in the global climate systems even though it covers only 7 % of the ocean surface. It influences the Earth's surface albedo. Its effectiveness in restricting interchanges of heat, mass and momentum between ocean and atmosphere is also considerable. The ability to monitor polar sea-ice on a global scale has been realized only since the advent of satellite observations.

The two most important sea ice parameters that are derived currently from passive microwave satellite observations for monitoring the sea ice cover and for studying oceanic processes are the position of the ice edge and the ice concentration.

MIMR:

The resolution of Multi-frequency Imaging Microwave Radiometer (MIMR) is well adapted to global scale models. It will provide a unique tool for global scale and is thus necessary to stress the usefulness of such a sensor for land surface applications. It provides complete coverage of the globe with similar resolution. The Scanning Multi-channel Microwave Radiometers (SMMR) has been proven to be useful tool for vegetation and moisture studies, even though it has poor spectral and radiometric characteristics [3].

This section deals with only surface parameters, excluding the atmosphere even though it may have a significant influence on the signal. The spatial resolution is better in case of MIMR, which provides a significant improvement in the utilization of the passive microwave data because of the smaller spatial scale of the surface features. We can classify the land applications of MIMR in 2 parts; large-scale vegetation monitoring with polarization index techniques and soil moisture monitoring using lower frequencies at 6.8 GHz and 10.65 GHz [4]. The microwave emission from bare soil at the MIMR incidence angle will be polarized with vertical polarization having a higher brightness than the horizontal.

Thus, the most promising land applications of the MIMR for land surface parameters are: soil moisture, vegetation biomass, surface temperature, and surface roughness.

We very well know that the lower the frequency, the better the penetration through vegetation and soil. It is important to have the knowledge of soil moisture, especially in GCMs whose resolutions are on the same scale as that of MIMR. Many investigations have been performed on the retrieval of soil moisture in different parts of the world and with varying frequencies. The results may not be valid globally but they are valid locally. In the microwave part of the spectrum, vegetation acts mainly as an absorbing layer with some scattering. It has been proven that the higher the frequency, the more absorption by the vegetation layers for a given moisture content. Vegetation biomass plays an important role in the interactions at the surface/atmosphere interface.

The main problem for using passive microwaves, is to be able to isolate the part of the signal emanating from the soil and the vegetation. Surface roughness needs to be known so as to be able to analyze with good accuracy MIMR data. Several concepts for roughness retrieval exist but need to be tested and validated.

IV. THE MICROWAVE RADIOMETER "ADVANTAGE" FOR CLIMATE APPLICATIONS

The low data rate is the most important practical aspect of all of these microwave radiometers that lend themselves well to climate monitoring. Generally these instruments measure frequencies much lower than visible and infrared radiometers. Thus, antennas of any practical size yield better spatial resolution, depending on channel frequency. Which implies that fewer numbers of measurements are required to cover the entire Earth.

A second advantage is the lack of cloud effects in the microwave temperature sounders. The microwave sounder channels in the oxygen absorption region are insensitive to cirrus clouds, and are only slightly sensitive to cloud water contamination.

V. CLIMATE PRODUCTS IN THE FUTURE

The recent studies shows that there are more microwave radiometers in operational use now than ever before, and the situation will improve even further in the future. In few years, new satellite systems will include the research missions involving the Advanced Microwave Scanning Radiometer (AMSR), a Japanese-built instrument to be flown on the NASA Aqua satellite and on the Japanese ADEOS-II satellite.

Farther in the future, probably after 2010, the National Polar Orbiting Environmental Satellite System (NPOESS) will carry a line of Conically-scanning Microwave Imager Sounders (CMIS), with 2 m antennas and frequencies ranging from 6 GHz to around 200 GHz, as well as a through-nadir scanning microwave temperature sounder.

NASA Earth Observing System PM-1 platform will have a Multi-channel Passive Microwave Radiometer (MPMR) with a broader range of wavelengths and a major improvement in spatial resolution. The MPMR, MIMR, and AMSR all provide an increased capability of observing sea-ice through improved spatial resolution. NASA currently exploring what is clearly the most exciting new development for sea-ice remote sensing in many years: synthetic aperture radiometry technology described by Le Vine et al. (1994) [5].

These upcoming sensors will realize the potential promised by the earliest space-borne passive microwave instruments.

VI. CONCLUSIONS

In this paper, we demonstrated that the information from TRMM precipitation radar could be used in conjunction with cloud-resolving models to construct a parametric framework for passive microwave retrieval algorithms of rain from any sensor.

Thus, from this study, we can depict that Passive Microwave Radiometers play a very important role in climate monitoring.

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