SS2, 특강) 지구환경 연구를 위한 MODIS 위성자료의 활용 가능성

Potential Use of MODIS Satellite Data for Studying the Earth Environment

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1. Introduction

The Earth, along with its major components — land, atmosphere, and oceans, is at the core of the global environmental system. Changes in any component of the Earth thus strongly affect the global and regional environment. With the advent of the new century, many important decisions on agricultural, industrial, societal and political problems will depend upon the Earth's environment. Monitoring the Earth is thus important to capture any sign from the Earth which might be related to the environmental change. Furthermore, more and better data need to be collected and accumulated to understand how current environmental change trends may impact climate and other environmental systems years or decades in the future.

In 1991, NASA established the Earth Observing System (EOS) program to provide in-depth scientific understanding about the functioning of the Earth as an environmental system. Through this program, data are being collected at least for 15 years to base a comprehensive examination of the Earth's environmental/climate system. NASA already has launched four EOS spacecrafts (Landsat 7, QuikScat, ACRIMSAT, and Terra) and plans to launch 15 more EOS satellites through 2003.

Terra, the EOS flagship launched in December 1999, is conducting a comprehensive health examination of the Earth, flying 705 *km* above the earth's surface. The mission of Terra is designed to measure 16 factors that play major roles in determining climate — aerosols, air temperature, clouds, fires, glaciers, land surfaces, land use, natural disasters, ocean productivity, ocean temperature, pollution, radiation, sea ice, snow cover, vegetation, and water vapor. More details on Terra can be found in NASA (2001a).

Among the five sensors onboard the Terra satellite, MODIS (MODerate-resolution Imaging Spectroradiometer) is the only sensor to see the entire surface of the Earth every one to two days (see King and Herring (2000) for the details of all sensors). In this study, characteristics of the MODIS data are investigated for potential use in the study of global and regional environment of the Earth.

2. General specifications of MODIS

MODIS sees the entire globe with four sets of detectors that are sensitive to visible light and to radiation in the near, shortwave, midwave and thermal portion of the infrared spectrum. The sensor measures the Earth's surface at a viewing swath of 2330 *km* (across track) by 10 *km* (along track at nadir) with acquiring data at three spatial resolutions (at nadir) — 0.25 *km*, 0.5 *km* and 1 *km*. This wide spatial coverage enables MODIS to determine the impact of clouds on the Earth's energy budget.

Among 36 discrete spectral bands (between 0.405 and 14.385 μm) in MODIS, bands 1 and 2 are used for detecting land/cloud boundaries, bands for 3-7 are for land/cloud properties, bands for 8-16

are for ocean color/phytoplankton/biogeochemistry, bands for 17-19 and 27-29 are for atmospheric water vapor, bands for 20-23 and 31-32 are for surface/cloud temperature, bands 24 and 25 are for atmospheric temperature, band 26 is for cirrus clouds, band 30 is for ozone, and bands for 33-36 are for cloud top altitude.

The sensor has an unprecedented channel (band 26), centered at 1.375 μm, for detection of cirrus clouds that are believed to contribute to global warming. MODIS monitors how smoke plumes and other aerosols absorb and reflect energy through interactions with clouds. It can also monitors natural disasters such as volcanic eruptions, floods, severe storms, droughts and wildfires. In addition, the sensor is ideal for monitoring large-scale changes in the biosphere by quantifying the photosynthetic activity of plants as well as for sophisticated looking at the marine biosphere by measuring the fluorescent glow of chlorophyll in the ocean. More information on the MODIS specifications are referred to NASA (2001b).

3. MODIS standard data product

MODIS data are transferred to ground stations via the Tracking and Data Relay Satellite System (TDRSS). The data are then sent to the EOS Data and Operations System (EDOS) at the Goddard Space Flight Center (GSFC). After Level 0 processing at EDOS, the GSFC Earth Sciences Distributed Active Archive Center (GES DAAC) produces the Level 1A, Level 1B, geolocation and cloud mask products. Higher-level products are produced by the MODIS Adaptive Processing System (MODAPS), and then are parceled out among three DAACs for distribution. For higher-level products, Level 2 "granule" represents 5 minutes of Terra viewing with 1354 pixels across the granule, and 2030 pixels down the granule (pixels have 1 km resolution) whereas Level 3 is for global products.

There exist 44 standard MODIS data products available to scientists for the study on global change. These products are being used by scientists from a variety of disciplines, including oceanography, biology, hydrology, and atmospheric and environmental sciences. Most users will obtain data products by ordering them through an ordering system from the GES DAAC. Here, data products from MODIS for three major components of the Earth environmental systems are discussed in detail. Discussions on theoretical basis for algorithms in retrieving data are omitted here while documents are available from NASA (2001b).

MODIS-Land: Satellite measurements of various land surface features provide important inputs to parameterize or validate ecosystem process models. These products are divided into three categories: surface radiation measurements, ecosystem process variables and land cover characteristics. More specifically they include surface reflectance; land surface temperature and emissivity; land cover type/change; gridded vegetation indices (corrected for atmospheric effects, soil, polarization, and directional effects); thermal anomalies and fire and biomass burning; leaf area index/fraction of photosynthetically active radiation (LAI/FPAR); net photosynthesis and primary productivity; bidirectional reflectance distribution function (BRDF) and albedo; and vegetation cover conversion. The MODIS land data also covers the cryosphere including snow and sea-ice cover and reflectance.

MODIS-Ocean: The oceans play a vital role in global climate mostly moderating climate due to their immense capacity to store heat and carbon. Meanwhile, the oceans also may be affected and altered by changes in climate. The three categories of MODIS ocean products are ocean color (36 parameters), sea surface temperature (4 parameters), and ocean primary production (8 parameters). Ocean color parameters include normalized water-leaving radiance; pigment concentration; chlorophyll

fluorescence; chlorophyll-a pigment concentration; photosynthetically available radiation (PAR); suspended-solids concentration; organic matter concentration; coccolith concentration; ocean water attenuation coefficient; phycoerythrin concentration; total absorption coefficient; ocean aerosol properties; and clear water epsilon. Sea surface temperature (SST) parameters include daytime/nighttime SST from thermal and mid IR bands. Ocean primary production parameters include ocean carbon and nitrogen productions, annual chlorophyll-a pigment concentration, photosynthetically available radiation, mixed-layer depth, etc. These products will be used to investigate ocean circulation, ocean biology, and ocean chemistry, including the ocean carbon cycle.

MODIS-Atmosphere: Changes in atmospheric trace gases, cloud cover, cloud type, solar radiation, and tropospheric aerosols affect the Earth's climate by modifying the radiative forcing. These properties, which are vital to develop conceptual and predictive global climate models, are monitored through MODIS. There are five Level 2 MODIS atmosphere products: aerosol, water vapor, cloud, atmospheric profile, and cloud mask. Based on these data, Level 3 (global gridded) products are generated for daily, 8-day, and monthly time period with grid resolution of 1 by 1 degree.

The *aerosol* product include aerosol type, aerosol optical thickness, particle size distribution, aerosol mass concentration, optical properties, and radiative forcing. The *water vapor* product monitors precipitable water by assessing columnar water vapor amounts. The *cloud* product combines infrared and visible techniques to determine both physical and radiative cloud properties including cloud particle phase, effective cloud particle radius, cloud optical thickness, cloud shadow effects, cloud top temperature, cloud top height, effective emissivity, cloud phase (ice vs. water, opaque vs. non-opaque), and cloud fraction under both daytime and nighttime conditions. The *atmospheric profile* product consists of several parameters: atmospheric temperature and moisture, atmospheric stability, and total ozone burden. Finally, the *cloud mask* product employs a series of visible and infrared threshold and consistency tests to specify confidence that an unobstructed view of the Earth's surface is observed. The cloud mask also provides additional information about the presence of cirrus clouds, ice/snow, and sunglint contamination.

4. Conclusion

The MODIS products covers almost all parameters in land, ocean and atmosphere which are major components of the Earth environmental systems. Parameters in each component are strongly linked and affect each other, which exert combined effect on climate and environmental change in the Earth. Thus monitoring the Earth and collecting data for a long period using a spaced-based instrument such as MODIS will be essential in capturing the vital signs related the Earth's health and predicting the climate and environmental change in the future. As evidenced, data collected from MODIS can be integrated into a more wholistic study of the Earth environment that includes several vitally important themes: radiation, clouds, water vapor, precipitation and atmospheric circulation; ocean circulation, productivity and exchange with the atmosphere; tropospheric chemistry and greenhouse gases; land ecosystems and hydrology; snow, ice and glacier extent; ozone and stratospheric chemistry; and volcanoes and climate effects of aerosol.

References

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