THE LIGHTNING IMAGING SENSOR

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ABSTRACT: The Lightning Imaging Sensor (LIS) is a NASA Earth Observing System (EOS) instrument on the Tropical Rainfall Measuring Mission (TRMM) platform designed to acquire and investigate the distribution and variability of total lightning (i.e., cloud-to-ground and intracloud) between ±35° in latitude. Since lightning is one of the responses of the atmosphere to thermodynamic and dynamic forcing, the LIS data is being used to detect deep convection without land-ocean bias, estimate the precipitation mass in the mixed phased region of thunderclouds, and differentiate storms with strong updrafts from those with weak vertical motion.

INTRODUCTION

Lightning measurements provided by the Lightning Imaging Sensor (LIS) on the Tropical Rainfall Measuring Mission (TRMM) offer an unique opportunity to develop combined data algorithms to investigate the electrical, microphysical, and kinematic properties of tropical thunderstorms. It is hypothesized that the type and frequency of lightning are intimately related to the microphysical (e.g., ice mass, liquid water content) and kinematic properties (e.g., updraft speed) of thunderstorm systems and to the environment (e.g., available buoyant energy). Recent evidence suggests that lightning activity can provide empirical estimates or bound the range of values for some geophysical properties such as the convective rain flux and rain rate, the vertical structure and distribution of storm mass, (convective) latent heating rates, the number and distribution of thunderstorms.

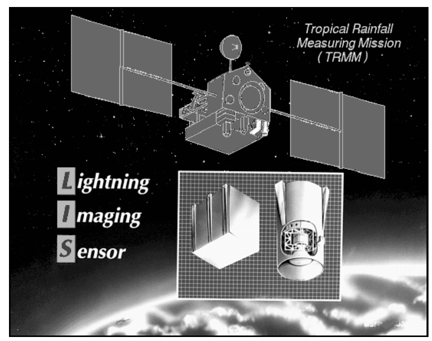

Figure 1. The Lightning Imaging Sensor integrated aboard the TRMM satellite.

INSTRUMENT DESCRIPTION

The Lightning Imaging Sensor (LIS) is a scientific instrument that is integrated aboard the Tropical Rainfall Measuring Mission (TRMM) Satellite, as depicted in Fig. 1. On November 28, 1997, the LIS was launched into a low Earth orbit, and now circles the Earth at an altitude of 350 km. The inclination of this orbit is 35 degrees, thus allowing LIS to observe lightning activity in the tropical regions of the globe, as shown in Fig. 2.

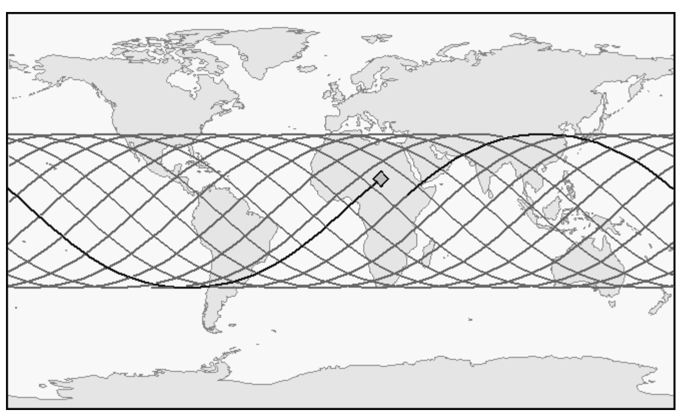
Figure 2. The LIS field-of-view and the orbital track of the TRMM satellite during a 24 hour period.

The LIS sensor contains an optical staring imager which is used to identify lightning activity by detecting momentary changes in the brightness of the clouds as they are illuminated by lightning discharges [Christian et al., 1992]. Due to the sensitivity and dynamic range of the sensor, it can detect lightning even in the presence of bright, sunlit clouds. The LIS instrument detects “total” lightning, since cloud-to-ground, intracloud, and cloud-to-cloud discharges all produce optical pulses that are visible from space. Data recorded by this instrument includes the time of the lightning event, its radiant energy, and its location.

The primary component of the staring imager is the 128×128 charged coupled device (CCD) array which has a sampling rate slightly greater than 500 frames per second. The wide angle lens, combined with the 350 km altitude of the TRMM spacecraft, permit the sensor to view a 600 km × 600 km area of the Earth with a spatial resolution of between 3 and 6 km (3 at nadir, 6 at limb). Since the LIS travels around the Earth with a velocity greater than 7 km/s, the instrument can monitor individual storms and storm systems for lightning activity for almost 90 seconds as it passes overhead.

DISCUSSION

The LIS instrument is one of five instruments on the TRMM platform. The other instruments include the TRMM microwave radiometer (TMI), the Visible and Infrared Scanner (VIRS), the Precipitation Radar (PR), and the Cloud and Earth Radiant Energy System (CERES) [Kummerow, 1998]. Each instrument provides a unique set of data that can be used to learn more about atmospheric circulation, weather, and climate. An example of data from four of these instruments is shown in Fig. 3. In this example, the TRMM spacecraft made an overpass over a weather system that spanned across parts of Texas and Louisiana on January 22, 1998. Data from VIRS instrument shows information on the cloud cover and cloud-top height, while the 85 GHz TMI data shows where cloud ice is most prevalent. Although the PR has a much smaller swath width, its data is extremely useful in quantifying the amount and location of precipitation. Also shown in Fig. 3 is the lightning data from the LIS instrument, which is coincident with the areas of producing the highest rainfall rates. By comparing the LIS data with data from the other instruments on TRMM, it is possible examine relationships between lightning activity and several important climatological parameters, including rainfall, latent heat release, and convection.

Data from the LIS is also being used to build a global lightning and thunderstorm climatology. As demonstrated in Fig. 4, the distribution of lightning activity in the tropics shows an affinity to land as well as some latitudinal variations according to the seasons. The solar flux and associated warming is believed be the dominant influence on this seasonal variation, and the relatively low frequency of lightning activity over the oceans can been attributed to weaker updrafts in oceanic storms. Since lightning activity is thought to be a sensitive indicator of climate change (even subtle temperature variations), the seasonal lightning climatologies found in Fig. 4, along with climatologies compiled in the future, will be used to test this theory.

SUMMARY

The Lightning Imaging Sensor on TRMM has demonstrated that lightning activity can easily be detected from space. Simple comparisons of the LIS data with coincident TMI, PR, and VIRS data suggests that the detection of even a single discharge is significant and provides important information about storms, including estimates of the rate of precipitation, storm height, and the presence of ice. Further research should continue examine the role of lightning in the distribution of convective precipitation as well as the release and transport of latent heat.

REFERENCES

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Kummerow, C., W. Barnes, T. Kozu, J. Shiue, and J. Simpson, The Tropical Rainfall Measuring Mission (TRMM) Sensor Package. J. Atmos. Ocean Tech., Vol. 15, No. 3, 1998, pp. 809-817.

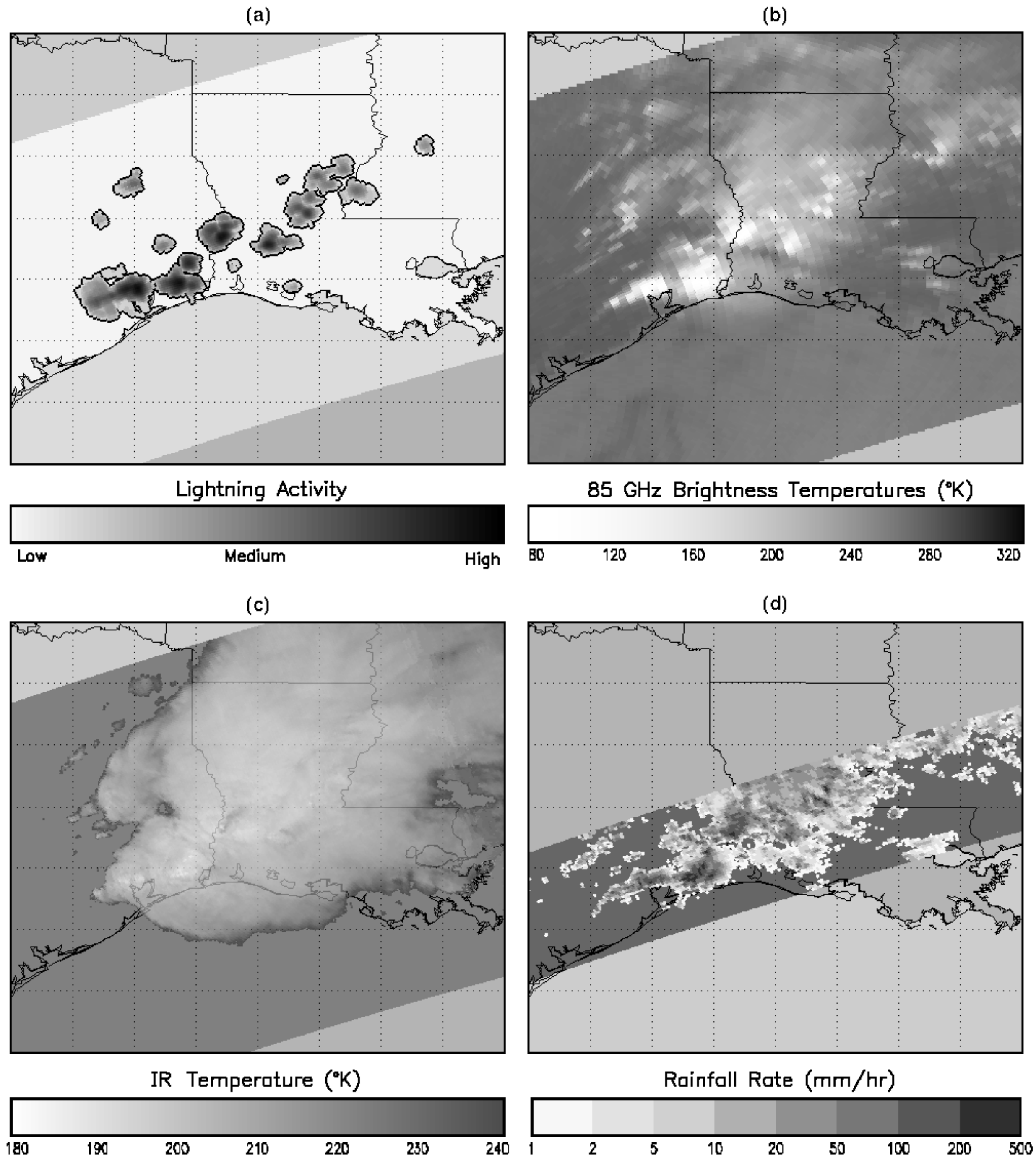

Figure 3. An example of (a) LIS, (b) TMI, (c) VIRS, and (d) PR data for storms in East Texas and Louisiana on January 22, 1998 at 0412 UTC.

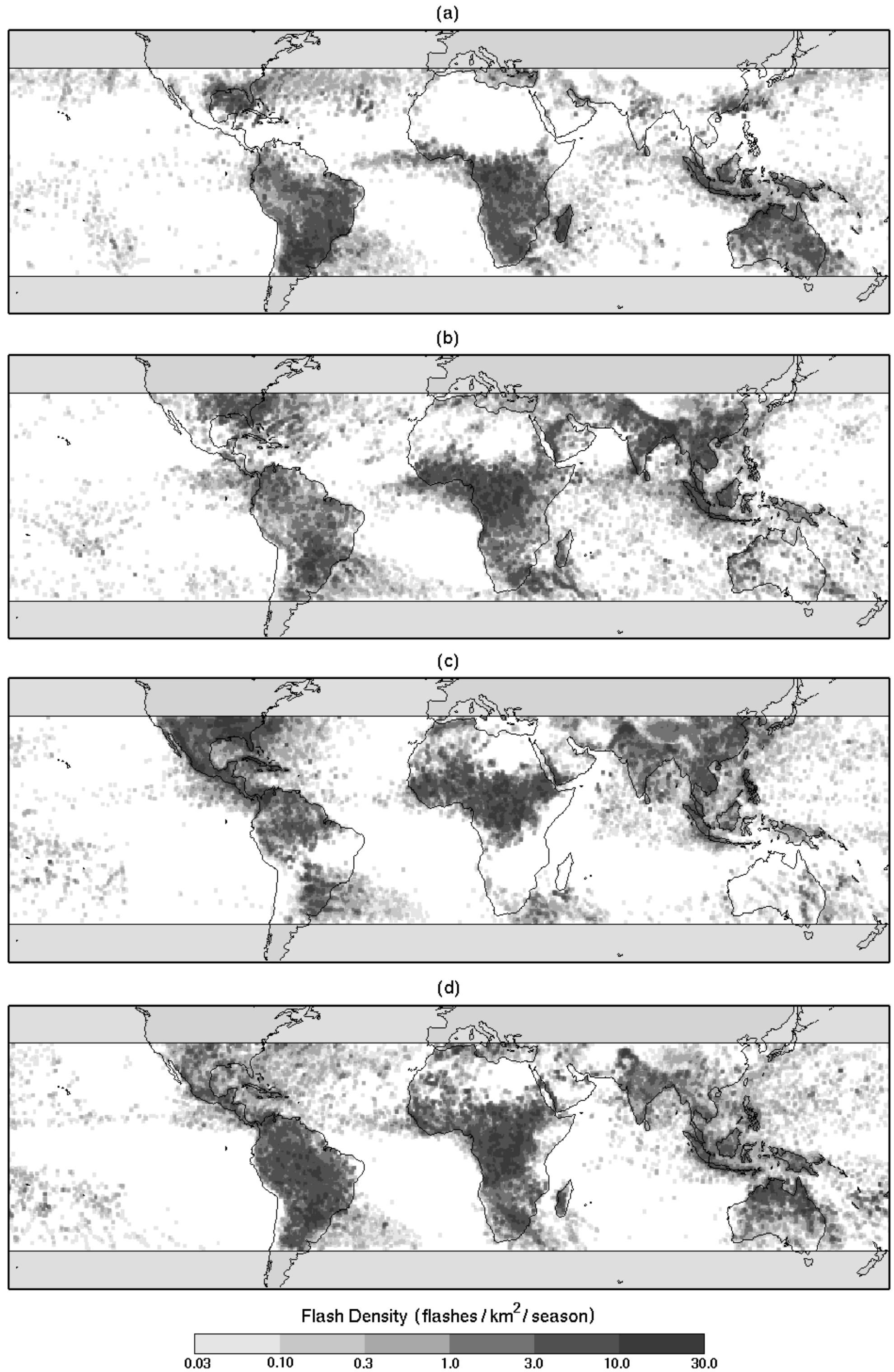

Figure 4. The 1998 seasonal distribution of lightning flashes as observed by LIS for (a) December, January, and February, (b) March, April, May, (c) June, July, and August, and (d) September, October, and November.