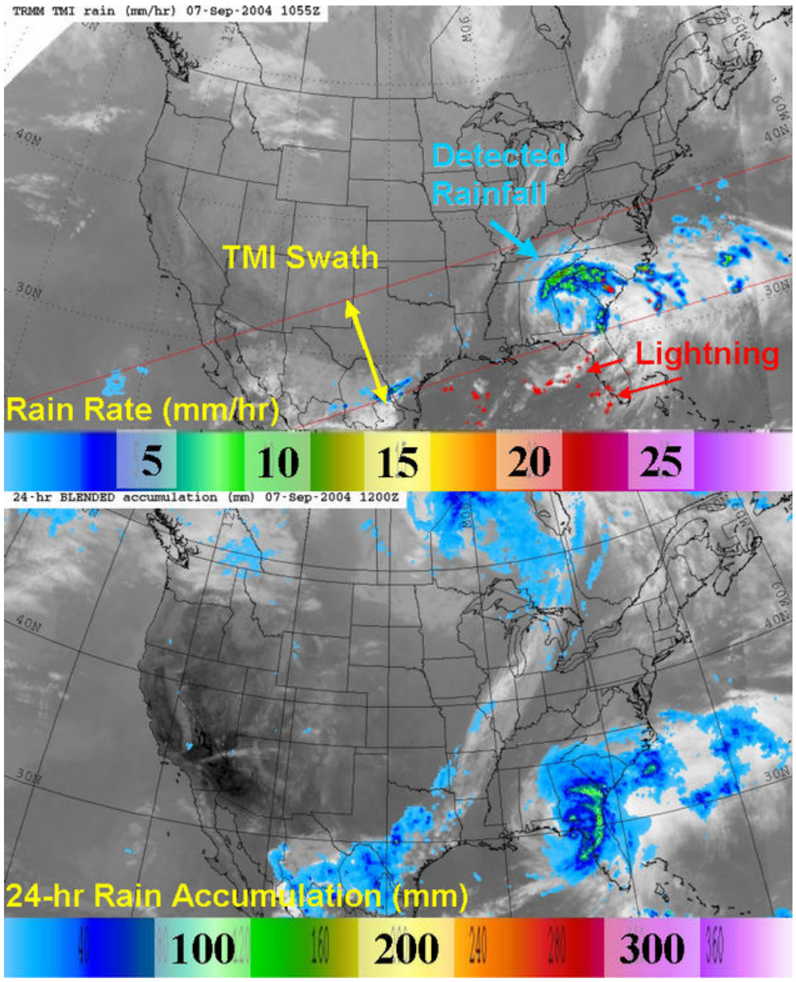
NexSat

Satellite Product Tutorials:

Detecting Rainfall



Above: The NRL blended-sensor precipitation technique estimates both instantaneous rainfall rates and time-integrated accumulations. Satellite techniques are of particular value over poorly monitored ocean areas and mountainous terrain. The technique estimates rainfall using every new update of infrared data from a variety of geostationary satellites, including GOES (over the United States and South America, and the Western Pacific), Meteosat (over Europe, Africa, and the Middle East). Thus, it updates the entire planet between 60 N/S every three hours. It is statistically tuned to agree with more accurate passive microwave sensor-derived rain rates from the Low Earth Orbiting TRMM TMI, DMSP SSM/I, and NOAA AMSU-B satellite instruments. This feature promotes accuracy in both space (global coverage) and time (updated every 3-hours) across a variety of regional rainfall regimes. While not as accurate or reliable as rain gauge data or surface radar measurements, the technique nevertheless represents a quantum leap forward in accuracy over the world's oceans where reasonable and timely estimates are sorely lacking.

Why We're Interested…

Satellite rainfall estimation is not a new technique, but without the addition of passive microwave tuning (discussed below), it is extremely limited. Traditionally, geostationary rainfall estimation is based on the assumption that that rain rate is inversely proportional to cloud top temperatures. That is, the lower the cloud top temperature the stronger the vertical development associated with that cloud; the stronger the updrafts, the greater condensation and collision/coalescence of cloud droplets to form rain, and in turn, the heavier the inferred rain rates at the surface. Thus, a given cloud top temperature is matched to a particular precipitation rate in a fixed lookup table. This "empirical" technique gives qualitatively reasonable rain rates, but due to the indirect nature of the method used, the estimates tend to be accurate only in limited circumstances or geographical areas (the problem is inherently ill-posed: a certain cloud top temperature can correspond to a great diversity of surface rain rates…we need more than the one piece of information provided by infrared measurements). Thus, traditional geostationary rainfall estimation fails to give estimates that can be used reliable across all areas of the world, all seasons of the year, and over variety of different weather regimes (for example, tropical vs. mid-latitude rainfall).

How This Product is Created…

Unlike traditional geostationary rainfall estimation techniques which have been limited to infrared-only approaches, passive microwave estimation based on DMSP SSM/I and TRMM TMI is much more direct and accurate. This is because passive microwave-derived rain rates are based on channels that sense the actual precipitation component within clouds and do not rely on cloud top temperature. However, the problem with passive microwave rates is that they are extremely sparse in space and time. It is therefore unlikely that a user needing a current estimate of rain over a particular region could obtain a timely passive microwave-derived rain rate.

The solution proposed here is to *tune* the abundant (albeit less accurate) geostationary IR passes using the sparse but accurate passive microwave rain rates. This tuning is done by co-locating in space and time the intermittent microwave data sets with the more frequent geostationary data sets within 15-degree latitude/longitude boxes. Using these matched data within each box, an algorithm periodically derives a new lookup table between infrared brightness temperature and rain rate based on the co-located satellite measurements. An important aspect of this procedure is the derivation of a zero-rain rate temperature. At temperatures greater than this threshold, no precipitation is estimated. At lower temperatures, rainfall estimates are made that are inversely proportional to temperature as explained above. Different relationships and zero-rain rate temperatures are derived for each box. Thus, rainfall estimates will be based on relationships that vary over time and from place to place, presumably optimizing accuracy overall by accounting implicitly for different rainfall regimes.

There are a number of relatively minor adjustments applied to this technique to improve the estimates. Cloud tops that are observed to be warming (measured over an hour's time using infrared imagery) are assumed to be decaying. Rain rates are adjusted downward accordingly. Also, there are a number of multi-spectral tests applied over GOES data to test for thin cirrus. If thin cirrus is detected, no rain rates are derived. One difficulty of the technique is that rainfall is sometimes estimated poorly in regions with high mountains. Thus, a procedure checks for land (orographic) effects using the corresponding 850 mb NOGAPS data and a terrain map, and adjusts the totals accordingly (enhancing rainfall on the windward side and diminishing estimates on the leeward side).

How to Interpret…

The satellite rainfall products are presented in two modes: as an hourly "rate", or as an accumulation over a number of hours. The former is more useful to numerical modelers; the latter appeals to hydrologists and disaster management.

ADVANTAGES:

1. The blended technique combines the broad coverage and frequent refresh of the geostationary satellites with the sparse but accurate passive microwave rain rates. The result multiplies the effectiveness of the two data sources into a single product that is useful worldwide, outside of polar regions. The best results are obtained in the 40 N/S latitude range, due to enhanced satellite coverage from TRMM in this region.

2. The technique is regionally tuned, meaning that estimates will be more valid within local rainfall regimes than a single lookup table based on a composite of all rainfall regimes.

3. The output is given both in terms instantaneous rain rate and accumulations over different time scales. The instantaneous rates are useful over oceans because precipitation in the atmosphere can interfere with line-of-sight measurements and communications. The accumulations over land give information about soil moisture and areas at risk of flooding.

4. The potential impact of storms headed for land (tropical cyclones and frontal systems) can be inferred by using this product.

5. Preliminary results suggest that assimilation of this product into numerical models can greatly improve forecasts.

6. The technique should have longevity since many more passive microwave instruments are planned for space. In addition, new multi-spectral satellites will allow improvements worldwide that are now just in effect for GOES.

LIMITS:

1. The technique relies on the assumption that colder cloud top temperatures in the infrared are always associated with higher precipitation rates. This is not always the case. Sometimes relatively warm clouds can be associated with heavy precipitation, and colder clouds in the same scene can be associated with no precipitation.

2. Areas of cold, but thin, cirrus can be misidentified as precipitation on geostationary infrared images. Often this effect appears on the edges of actual precipitation cells as a "fringe" effect. Thus, precipitation may be correctly identified by the technique, but the precipitating area is too large.

3. The technique is most effective for tropical convection. Precipitation estimates may suffer in mid- latitude frontal systems consisting of stratiform clouds, especially over land.

4. The technique should be used with caution over mid-latitude land areas in the colder seasons of the year, especially in particularly cold areas. Regions of surface snowfall may give unreliable results.

5. When relatively few passive microwave instruments are orbiting, or when there is a dropout of microwave data, the resulting match-ups with the infrared can be based on data which are "old" relative to the current time, resulting in degraded estimates.

Looking Toward the NPOESS Era…

The Conical-Scanning Microwave Imager/Sounder (CMIS), to fly aboard the National Polar-orbiting Operational Environmental Satellite System (NPOESS) will provide additional high spatial resolution microwave data supporting this technique. Improved cloud characterization based on Visible/Infrared Imager/Spectrometer (VIIRS) (also aboard NPOESS) will mitigate some facets of the ill-posed temperature/rainfall correlation problem facing the current technique.

Did You Know…?

Of all the water in the earth/atmosphere system, 97.5% is salt water. Of the remaining 2.5% that is fresh (potable) water, about two-thirds is locked up as glaciers and permanent snow cover and the other third is ground water (aquifers). Less than 0.3% of the fresh water component (or, less than 0.000075% of the total water) is renewable water from lakes and rivers. It makes you think twice about watering your lawn!

Want to Learn More?

Visit the TRMM homepage
Learn about plans for the Global Precipitation Mission (GPM)
CloudSat, a NASA research satellite, will assist in light precipitation estimation (where current passive microwave techniques have difficulty)

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