Clouds modify the amount of solar heating and thermal cooling of the Earth system. Since clouds vary greatly over the Earth, researchers must look at all clouds in all places to understand their effect on weather and climate change. Scientists at SSEC use satellite observations to study the global distribution of clouds and how these distributions change with time. Researchers also study the effects of volcanic eruptions, El Niño and jet contrails on cloud cover.

Clouds by the numbers

One group of SSEC scientists analyzed two sources of satellite data to study trends in global cloud cover for the last two decades in the 20th century: data from the International Satellite Cloud Climatology Program (ISCCP) and from the High Resolution Infrared Radiometer Sounders (HIRS). ISCCP has collected the largest global cloud data set using visible and infrared measurements from an international suite of weather satellites; however, the ISCCP reliance on measurements from the visible portion of the energy spectrum limits its ability to detect high, thin ice clouds, or cirrus. Multispectral infrared measurements from NOAA’s polar orbiting HIRS have been used to enhance detection of cirrus both day and night.

Scientists perform analyses on the HIRS data using a method called CO₂ Slicing to determine global cloud cover. The name alludes to how each of the instrument’s sounding channels views a different vertical layer of the atmosphere. Clouds are detected and their heights estimated by the amount that each CO₂ channel is affected by the clouds.

Studies of HIRS cloud data have revealed a number of trends, and in some cases have found surprising results. The globally averaged frequency of cloud detection (excluding the poles where cloud detection is less certain) has stayed relatively constant at 75% over the 20-year study period. In addition, scientists have discovered that clouds can be found most frequently in two locations: (1) the Inter-Tropical Convergence Zone (ITCZ) in the deep tropics where trade winds converge and (2) the middle to high latitude storm belts where low pressure systems and their fronts occur.

The most significant feature gleaned from this data study may be that the globally averaged cloud cover changed very little in spite of dramatic volcanic and El Niño events. During the four El Niño events, winter clouds moved from the Western Pacific to the Central Pacific Ocean, but their global average in the tropics did not change. El Chichon in southeast Mexico and the Philippines’ Pinatubo spewed volcanic ash into the stratosphere that did not dissipate completely until a year or two later, but cloud cover was not affected significantly.
In addition to looking at overall cloud cover, scientists are reviewing trends in high clouds. High thin clouds capture some of the Earth's infrared radiation similar to the effect of CO₂, which means they contribute to global warming in the same manner. High clouds in the upper troposphere (above 6 km above the Earth) are found in roughly one-third of HIRS measurements, indicating a small increasing trend of approximately two percent per decade. [56]

One notable change in high cloud cover occurs during the northern hemisphere's winter season. Increases have occurred in most parts of the world except the tropical South Pacific, Atlantic, and Indian Oceans south of the ITCZ where decreases in high clouds have been found. While jet aircraft have been suspected of increasing cirrus cloud cover due to their contrails, the HIRS data do not reveal such a trend. While increases in high clouds occur in areas of high air traffic, such as central and western North America and Europe, they also occur in areas of rare air traffic, such as the Southern Ocean around Antarctica. Larger weather systems appear to be the major cause for high cloud cover changes during northern hemisphere winters.

While total cloud cover stayed relatively steady over the two decades included in the analysis, the small increase in high clouds is worth monitoring, particularly given their role in trapping the Earth's infrared radiation. Clouds do not appear to be off-setting global warming by increasing their reflection of incoming solar radiation; instead they may be enhancing global warming with a modest increase in high thin ice clouds.

**Different approach to clouds ... different answers?**

Another group of scientists in SSEC is using a different approach, or rather satellite instrument, to tackle some of the same research. The Advanced Very High Resolution Radiometer (AVHRR) is the visible and infrared imager on NOAA's Polar Orbiting Environmental Satellites (POES). The AVHRR has flown on the POES platform since 1979 and is expected to fly until 2012. Traditionally, NOAA has used the AVHRR to generate imagery, sea surface temperature, oceanic aerosols, and a picture of vegetation health. More recently, NOAA has sought to increase the use of AVHRR for quantitative remote sensing. The Clouds from AVHRR-Extended (CLAVR-x) project is an example of NOAA's modernization of AVHRR processing.

Designed as NOAA's newest AVHRR cloud processing system, CLAVR-x has been further developed into a system to reprocess climate data called PATMOS-x for AVHRR Pathfinder Atmospheres-Extended. Because the CLAVR set of algorithms is time and spacecraft independent, it is suitable for decades-long climate studies and has been adapted to reprocess the AVHRR data record. A major CLAVR-x modification was an increase in the number of ancillary data types used in PATMOS-x to improve the ability of its products to be useful in climate studies.

PATMOS-x builds on the original PATMOS program of the 1990s, but with significant improvements. PATMOS-x generates more cloud products, including: cloud mask, cloud type, cloud amounts by layer, cloud optical thickness, particle sizes and cloud-top heights. To increase the diurnal resolution of the climate records, PATMOS-x also uses data from AVHRRs on all the NOAA satellites. By using a common processing path, PATMOS-x developers can generate multiple products on the same grid. While the spatial resolution (0.5 degrees) is coarser than that typically offered by other climatologies that focus on surface products, having cloud, aerosol, surface, and radiometric products together allows for a more thorough diagnosis of any one time-series of data.

The graph above illustrates a current weakness in cloud climatologies—their inability to agree. The time series shows the amount of high clouds in the tropics from several sources, including PATMOS-x. The UW/HIRS climatology uses HIRS data to estimate cloud top pressure and emissivity using the CO₂ slicing method. The International Satellite Cloud Climatology Project (ISCCP) is a cloud climatology based mainly on geostationary imager data supplemented by AVHRR data. The Aqua data comes from the MODIS instrument and is produced using algorithms also developed at SSEC/CIMSS.
Global cloud cover statistics are crucial to the study of Earth’s climate. A technique developed by a CIMSS team tracks cloud cover. The cloud-mask algorithm characterizes cloud cover using observations from the MODerate Resolution Imaging Spectroradiometer (MODIS), an imaging instrument flown on two of polar orbiting research satellites. SSEC has a direct broadcast system that obtains real-time MODIS data and access to global MODIS data, putting the CIMSS team in an opportune position to develop and test the cloud-mask algorithm.

The cloud-mask algorithm ranks each pixel in a satellite image based on the likelihood that the pixel depicts cloudy or clear conditions. The system uses four categories: clear, probably clear, probably cloudy and cloudy. These categories allow scientists to use the cloud information in research where this information is required for the algorithms to operate accurately.

In addition to providing a ranking system, other details, such as the surface type or the presence of snow or ice, are also included in the result. When the cloud-mask team was determining how to package the cloud-mask algorithm they considered that it had to be useful to a variety of researchers, the file size could not be too big, it could not use too much of a computer’s processing power, and it had to be robust. The first two restrictions limited the cloud detection techniques they could consider.

Often it is imperative simply to determine if clouds are present in a satellite’s field of view. Cloud retrieval techniques need to be employed on a data set that is cloudy, while others can only be used on a data set that is clear. It is extremely important for the cloud-mask to be as accurate as possible; otherwise it can cost researchers extra time redoing work, and even result in inaccurate final statistics.

When the SSEC first began developing a cloud-mask detection algorithm in the 1990s, scientists tested the