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Storm Census [1]

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Published in 1995

New passive microwave method yields first global maps of mesoscale storm systems.

Two meteorologists pioneered a new application of a single passive microwave frequency using DAAC data in 1995. Karen Devlin and Edward Zipser of Texas A&M University used the frequency to identify, survey, and make the first global maps of thunderstorm ensembles known as mesoscale convective systems.

"Our research shows that the 85 GHz frequency is a viable, legitimate, and exciting way of characterizing mesoscale systems," says Edward Zipser. "Nobody has ever done a satellite definition of these systems around the entire globe. It's a real first -- the first time anyone has used 85 GHz the way we did to get a consistent global picture of the occurrence of mesoscale storm systems."

Mesoscale convective systems (MCSs) are organized collections of individual thunderstorms that last for hours and stretch up to hundreds of kilometers. The systems are organized in the sense that their constituent thunderstorms are coherently related to one another, often occurring in neat lines, arcs, and clusters.

"A mesoscale convective system is essentially self-generating. As one thunderstorm dies, it sows the seed for the next one to grow," Zipser says. "Each system itself consists of a whole set of thunderstorms, some of which are growing, some of which are mature, and some of which are dying."

Mature thunderstorms can climb to 15 kilometers above the Earth's surface. Because the freezing level is typically no higher than 5 kilometers, any liquid water drops carried into the upper part of the cloud system by updrafts freeze into ice particles. The ice particles grow by accretion of smaller supercooled water droplets and by deposition of water vapor on the ice. These ice particles, especially the larger ones known as graupel and hail, make the storm systems evident in the Special Sensor Microwave Imager (SSM/I) data that Devlin and Zipser obtained from the Marshall Space Flight Center DAAC.

The SSM/I instrument measures the Earth's microwave radiant energy in brightness temperature units. Because the ice particles in the storm systems scatter the radiant energy, the systems show up in the SSM/I data as areas of lower brightness temperature.

The amount of microwave radiation that the ice particles scatter -- and thus shield from the SSM/I instrument -- depends on three factors. If the size and number of the ice particles, and the depth over which they occur in a thunderstorm are great enough, they produce what scientists call an ice scattering signature.

"The physics of the ice scattering signatures are pretty well understood. More ice results in more scattering," says Karen Devlin. "What we did in our work was take that understanding and apply it to our problem." Knowing that stronger updrafts deliver more and larger ice particles, Devlin and Zipser hypothesized that the 85 GHz ice scattering signature can be used as a proxy for the strength of storm updrafts in MCSs. "We think that the 85 GHz signature is a rather robust measure of the size and number and depth of large ice particles," says Zipser.

Although many researchers have applied the 85 GHz signature in algorithms estimating rainfall, no one has employed it the way that Devlin and Zipser did to identify MCSs and estimate their intensities. The signature allows only estimates because storms are smaller than the resolution of the satellite instrument. "While the signature does tell us something about the strength of the systems," says Zipser, "we still have a lot of work to do in order to further quantify what we mean by strength."

Preliminary results produced using the 85 GHz signature are in substantial agreement with existing knowledge. Scientists know where the storm systems occur according to the seasons, and the signature places the systems in essentially the same places. Moreover, Devlin and Zipser's passive microwave method produces results that are consistent with infrared MCS surveys.

Despite the limitations of the instrument, Devlin and Zipser are confident their new method is viable and have used it to create a census of mesoscale systems for four months in 1993. For the census, they chose January and July to capture the world's seasonally strong storm systems in the southern and northern hemispheres respectively. April and October were selected as transition months.

To select systems from all available SSM/I data, the researchers first formed a working definition of an MCS. By their definition, a system had to have a threshold brightness temperature, cover a minimum area with that temperature, and have a strong enough signal to be considered convective. Devlin and Zipser then used a pattern recognition program to extract from the available data only those systems meeting all three criteria. After classifying the storm systems by intensity and size, the team compiled this information and the system locations in a database.

With the census completed, Zipser and Devlin ran another program to plot the frequency and distribution of the systems around the globe. For each of the four months they studied, Devlin and Zipser produced two maps, one showing the systems by area and another by intensity.

The maps, which are the first to cover the global tropics, show some significant geographic differences in MCS distribution. "The systems were smaller near the equator and fairly weak over the oceans. The most intense systems tended to occur away from the equator," Devlin says.

"An interesting regional finding is that the largest MCSs occurred in the South Pacific and over North America. South America tended to have smaller MCSs than North America," she says. "Over the South Pacific, they tended to be large but very weak."

"We have also learned new things from the maps," Zipser says. "For example, even though South America and Africa are well known to have similar rainfall, the systems over Africa appear to be stronger. Another surprise is that there were quite a few rather strong systems over the Middle Eastern deserts."

"Not only have we developed some confidence in using the 85 GHz ice scattering signature and our methodology, but we also made some interesting findings with it," says Devlin.

The census that Devlin and Zipser have created could be used in a number of ways to make additional findings in the future. Because the census is a computer database, researchers could simply manipulate it to learn more about the 1993 MCSs. Or they could expand it to include all SSM/I data going back to 1987.

Zipser and Devlin will soon add the SSM/I data for 1995, a La Nina year, to the census. They will then look for differences between the 1995 data and the existing data for 1993, an El Nino year. Specifically, they will be looking for interannual changes in the distribution of tropical convection.

"One of the things we don't know about global climate change is how precipitation and storm patterns will change with time," Zipser says.

"What we have in the census is really a prototype of what could become a climatology," he says. "All we would have to do to make it a climatology is collect more data," says Devlin.

Microwave data produced by NASA's Tropical Rainfall Monitoring Mission (TRMM) could be incorporated into a such a climatology. "We feel we're getting knowledge and experience we can use when TRMM data start coming in," says Devlin. "We'll already know what kinds of problems we're going to solve and how best to use the data. What we're doing with 85 GHz data is a good way of developing ideas about how to best use the TRMM data."

Reference(s)

Devlin, K. I., and E. J. Zipser. 1996. Defining mesoscale convective systems by their 85 GHz ice scattering signature. Bulletin of the American Meteorological Society. In press.

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