genes contain multiple copies of the target DNA sequence. The proteins must bind to at least two of these to produce their effects and binding to the first site facilitates binding to the second.

Robert Tjian and his colleagues at the University of California at Berkeley have identified a protein that binds to one of the regulatory regions of the SV 40 genome and is needed for transcription of the associated viral genes (*6*). Several cellular genes also respond to the protein, which is called Sp1. Indirect evidence suggests that the mode of contact of Sp1 and its target sequence on DNA may resemble the interaction between the prokaryotic factors and their target sequences.

There are major differences, however. Sp1 appears to contact only one DNA strand, not two, and the sequence recognized by the protein is not symmetrical. The lack of symmetry raises an interesting paradox, Tjian notes. Binding of Sp1 activates transcription no matter what the orientation of the target DNA segment and it is difficult to imagine how an asymmetric sequence might work in both directions. The results imply that Sp1 might itself be symmetrical.

Control of SV 40 gene expression involves more than one type of regulatory sequence. Sp1 acts on the promoter, which is needed for accurate initiation of transcription. Other proteins that bind to the SV 40 enhancer are being identified. Direct participation of these proteins in transcription has yet to be conclusively demonstrated, but if some or all are involved then gene control in eukaryotes would be significantly more complicated than in prokaryotes.

Even more intriguing are indications that the peptide encoded by the "homeo box," a DNA segment that has been linked to a number of developmentally important genes of the fruit fly and is also found in mammalian genomes, has an amino acid sequence that may have the capacity to fold into the two-helix motif. Fruit-fly proteins that bear the homeo-box sequence have been implicated in gene control during development. A DNA binding site would be consistent with this hypothesis.

In view of the complex life cycles of higher organisms, it would not be especially surprising if eukaryotic gene control is more complex than that in prokaryotes, as the SV 40 work implies. Bacteria after all do not have the developmental problems of the eukaryotes, which must turn specific genes on or off in particular cell types as they grow from single cells to multicellular organisms. That problem has long intrigued investigators, who are now finding new clues in the proteins that interact with DNA.

—**Jean L. Marx**

References and Notes

1. J. E. Anderson, M. Ptashne, S. C. Harrison, *Nature (London)* **316**, 596 (1985).
2. C. A. Frederick *et al.*, *ibid.* **309**, 327 (1984).
3. R. P. Wharton and M. Ptashne, *ibid.* **316**, 601 (1985).
4. J. Miller, A. D. McLachlin, A. Klug, *EMBO J.* **4**, 1609 (1985).
5. C. S. Parker and J. Topol, *Cell* **37**, 273 (1985).
6. D. Gidoni, W. S. Dynan, R. Tjian, *Nature (London)* **312**, 409 (1984).

Tracking a Stormy Beast in the Night

Weather satellites have revealed thunderstorms organized into unexpectedly large nighttime rainstorms over the central United States

The thunderstorms were ordinary enough to begin with, if rather severe. They broke out during midafternoon of 23 June in a line from south-central Iowa across southeastern Nebraska and into northeastern Kansas. For several hours the storms, especially those over Lincoln, Nebraska, unleashed tornadoes, wind gusts to over 130 kilometers per hour, hail as big as baseballs, and up to 10 centimeters of rain.

That kind of weather is not unusual on a summer afternoon in the central United States, but these storms did not stop with a bit of brief, locally severe weather. By 9 p.m. that evening, they had somehow created a single, roughly circular rainstorm 200,000 square kilometers in area. Outlasting smaller storms from that afternoon, it persisted until dawn, when only a lingering swirl of clouds remained. But then, again unlike an everyday thunderstorm, its remnants lingered into the next afternoon, when the heat of the day rejuvenated it so that once again it unleashed severe weather, this time over southern Illinois and western Kentucky.

Until a few years ago, meteorologists would have likely attributed this weather to a number of big but scattered thunderstorms. Now the perspective gained through weather satellites has shown that by somehow organizing the circulation of the atmosphere around them, some thunderstorms can transform themselves into larger, longer-lived rain systems, perhaps through processes found in tropical storms. This newly recognized organization of thunderstorms is called a mesoscale convective complex, or MCC. However the transformation occurs, the size and longevity of MCC's offer meteorologists a better chance to forecast the sometimes disastrous, sometimes life-giving, rains of the summertime central United States.

What sets an MCC apart from other kinds of summer thunderstorms, at least from the point of view of those getting rained on, is how long the rain continues. The rain from storms along a rapidly moving front is heavy but brief as the front passes by quickly. It is the front's motion, in fact, that plows warmer, moist air upward ahead of it to produce rain. Once started upward, the air expands and thus cools, condensing some of the moisture. That condensation leads to rain as well as still more vertical motion through the heat it releases—warmer air is lighter, more buoyant. Similar vertical motion or convection can also pop up here and there on a warm, humid summer afternoon due simply to random atmospheric disturbances. In any case, the rainfall of the resulting scattered storms is also limited to a small area and is usually brief.

The rain from MCC's, on the other hand, can be heavy at times, cover a large area, and go on for hours. These storms get their start as typical convective systems during warm summer afternoons east of the Rockies. But then, unlike systems in the West or East, they grow into a different sort of storm. A single system of convection may expand or a group of scattered storms may merge.

The new storm will have one, two, or even three lines of towering convective cells embedded in it that can produce all the damaging weather for which severe thunderstorms are renowned. Ray McAnelly of Colorado State University has found that 12 MCC's in his study typically had areas producing more than 5 centimeters of rain per hour. The MCC that hit Johnstown, Pennsylvania, on the night of 19 July 1977 dumped more than 25 centimeters of rain that created a flash flood, killing 77 persons.

What sets MCC's apart from other convective systems is the thick blanket of midlevel, more shallowly convecting clouds that engulf the lines of deep convection. These clouds broaden the storm and the distribution of its rainfall to cover at least 100,000 square kilometers, an area equal to half of Kansas, and at times more than 300,000 square kilometers. During an MCC's typical lifetime of 12 hours, it will drop an average of 1 to 2 centimeters of rain over as much as 1 million square kilometers, according to McAnelly. Michael Fritsch of Pennsylvannia State University sees MCC's as "this nation's most prolific rain-producing phenomenon," exceeding the less frequent hurricane.

In spite of being such hefty rain producers MCC's have kept a low profile. Until Robert Maddox of the National Oceanic and Atmospheric Administration's Environmental Research Laboratories (ERL) in Boulder defined them in 1980 (*1*), no one had taken much notice of them. Their typical diameter of 400 kilometers lets them slip through the network of balloon-borne weather instruments. Without either a broad satellite view or densely spaced observation, forecasters tended to attribute this stormy weather to scattered thunderstorms and areas of cloudiness. Unlike the 1000-kilometer storms of the weather map's familiar low pressure systems, incipient MCC's do not appear in even the most detailed computer models used by forecasters, accounting in part for the models' poor forecasting of summertime precipitation (*2*). The best that forecasters can do is note forecasted conditions that favor but do not guarantee MCC development.

Maddox first took note of MCC's in satellite images, particularly infrared images from geostationary satellites. These revealed more or less circular shields of cloud more than 8 kilometers above the ground with some convective clouds poking up more than 12 kilometers, or near the top of the weather-containing troposphere. This was the moisture being spewed from the top of the storm's convective systems.

According to a recent compilation of satellite observations of 140 MCC's, which was produced by Diana Bartels, Jane Skradski, and Raymond Menard of ERL (*3*), such storms have typically first appeared in April, when they move eastward across the Gulf Coast states. By late June about three MCC's per week were seen in the central United States, from northern Texas and Louisiana to North Dakota and Minnesota. The seed storms of most MCC's first appear during the afternoon, grow to the 100,000-square-kilometer minimum size requirement during the early evening, peak in size around midnight, and shrink below the minimum size by shortly after dawn, before they drift much farther eastward than Illinois.

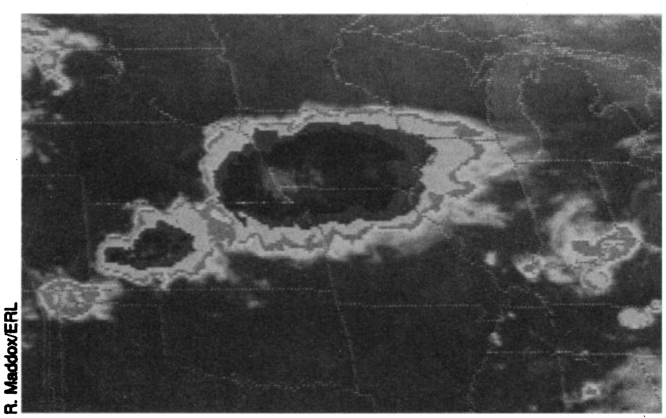
Of course, MCC's are not the only mesoscale convective systems evident in satellite images. The ERL group found two or three smaller, shorter-lived clusters of convective clouds for every MCC and an equal number of lines of convective activity. Thus, MCC's stand at one extreme of a continuum of convective systems. After all, Maddox originally defined MCC's in part to identify systems big enough and long-lived enough for convenient study. Still, the MCC portion of the spectrum does loom large. Fritsch and Maddox have estimated that MCC's provide 40 to 60 percent of summer rainfall to some areas.

MCC's may distinguish themselves in another way—they may tend to act like tropical storms. It was long known that both kinds of storms have a core of relatively warm air, but recently researchers have found that MCC's, like tropical storms and hurricanes, can start the atmosphere swirling about them to form a pinwheel of clouds. Fritsch has found such vortices in images of day-old, decaying MCC's whose shield of obstructing high clouds has dispersed. As the day warms, the low pressure at the center of such a vortex can draw in more moist air and help rejuvenate the convection that presumably first formed it. Fritsch has seen a similar low appear in a high-resolution computer model simulating the Johnstown flood MCC. The real Johnstown storm went out to sea and apparently became a tropical storm.

Researchers got inside such a vortex for the first time this June when they flew an instrumented plane through the MCC that hit Lincoln as the storm weakened after midnight. The flight was part of the Preliminary Regional Experiment for STORM-Central, a 2-month effort intended in part to test equipment and procedures in preparation for a major study of mesoscale weather later in this decade. "A lot of what we're seeing over land is remarkably similar to tropical storms," says Maddox, except that there is no warm ocean beneath. It is the warmth and moisture picked up from the ocean by air being drawn into the low of a tropical storm that fuels its growth and eventual emergence as a hurricane.

The tropical storm inclinations of MCC's may be a clue to the mystery of how ordinary thunderstorms transform themselves into MCC's in the first place. The problem is how does vertical motion over a few small areas lead to widespread cloudiness and precipitation. Fritsch has tentatively suggested that the heating from a number of small convective systems may be able to warm a significant portion of the storm's interior, creating a low pressure center that eventually leads to the broad, midlevel cloud cover and rain that distinguishes an MCC. The heating and low pressure at these lower levels might then create a lingering vortex as converging air begins to spin about the low in order to conserve its angular momentum. It is such mechanisms that must be tested in models and against observations if forecasters are to do more than warn of conditions that favor MCC formation.

—RICHARD A. KERR



R. Maddox/ERL

An MCC in Infrared

This infrared satellite image reveals the high, cold clouds of a 200,000-square-kilometer mesoscale convective complex over parts of Iowa, Nebraska, and Kansas at 8 p.m. on 23 June. The localized convection that carried moisture to more than 12 kilometers also apparently created broad underlying rain clouds.

References

1. R. A. Maddox, *Bull. Am. Meteorol. Soc.* **61**, 1374 (1980).
2. R. A. Kerr, *Science* **228**, 40 (1985).
3. D. L. Bartels, J. M. Skradski, R. D. Menard, *Mesoscale Convective Systems: A Satellite-Data-Based Climatology* (NOAA Technical Memorandum ERL ESG-8, National Oceanic and Atmospheric Administration, Environmental Research Laboratories, Boulder, Colo., 1984).