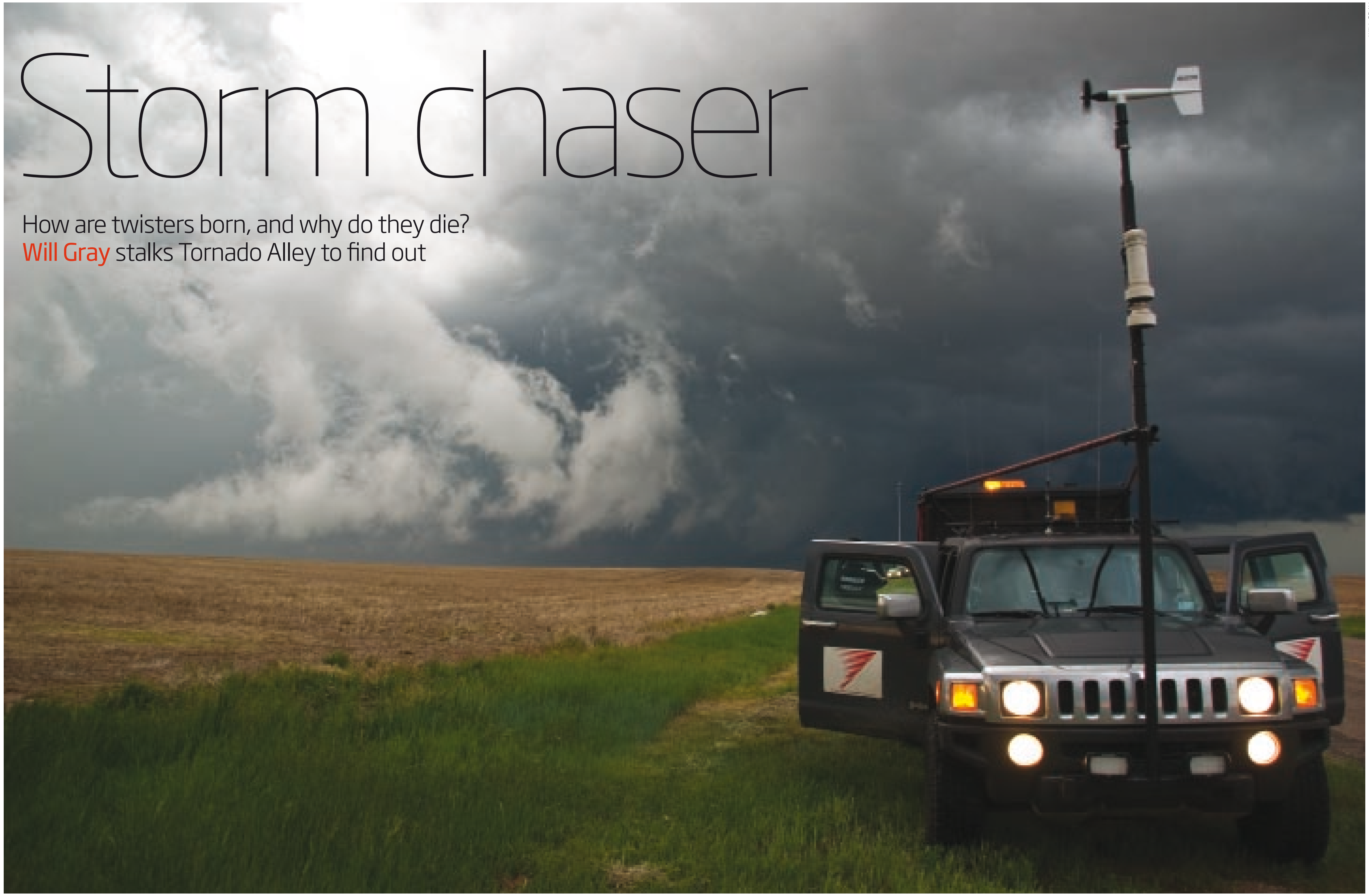
Storm chaser

How are twisters born, and why do they die?
Will Gray stalks Tornado Alley to find out



WILL GRAY

Last Spring VORTEX2 scoured the Midwest, hoping to catch sight of a twister as it formed

5 JUNE 2009. It's mid-afternoon and I am sitting with a group of researchers in a dusty parking lot in north-west Nebraska. There's a growing buzz of excitement as equipment is checked one last time and then we set off. Finally, we are about to catch a glimpse of what we have been hunting for weeks: a tornado.

I have joined the biggest tornado hunt in history. The two-year, $12 million project, called Verification of the Origin of Rotation in Tornadoes Experiment, or VORTEX2, began on 10 May with the aim of recording, for the first time, the entire life cycle of a tornado. A team of more than 100 researchers has assembled an unprecedented variety of instruments which it hopes will force tornadoes to give up their secrets. Until today, though, things had not gone to plan.

Over the last three-and-a-half weeks, this nomadic tribe has travelled almost 10,000 kilometres, through six states of America's Midwest, searching for signs of supercells, the huge thunderstorms that spawn tornadoes.

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They'd had no luck, though. Each time the 40 vehicle convoy reached a promising area, either nothing developed or they arrived just in time to watch the storm fade away.

This is in stark contrast to 2008 – one of the most violent years on record, when 1691 tornadoes killed over 120 people. Tornado reports for 2009 are down 75 per cent, and the team is getting desperate. Morale-boosting pep talks, practice instrument deployments plus the odd hour of relaxing down time have helped keep the researchers ready for their big moment. And now it has arrived.

We get the call to say it's looking good just over the border in Goshen County, Wyoming, and 40 minutes later, we are parked beneath heavy skies, watching a swirling mass of black cloud. Over the radio comes the voice of Karen Kosiba, co-ordinator of the VORTEX2 probe vehicles: "The storm is 12 kilometres away and it's travelling straight for us. We have a high probability of a tornado here. Please get ready to deploy your pods..."

Tornadoes occur around the globe, but where we are sitting is the most active place on the planet. The conditions here are just right to conjure up a perfect storm. In spring, the air column is split into three layers: warm, moist air blown in from the Gulf of Mexico lies close to the ground; hot, dry air from the Mexican desert is next; and on top sits a cooler layer pulled in from the Rocky mountains by the jet stream. When strong winds and high temperatures destabilise this layer cake violent thunderstorms can be triggered.

During the most active months of May and June, people who live in "Tornado Alley" – a region stretching between the Rockies and the Appalachian mountains – are on high alert. In 2009, the tornado season started early with a major outbreak in April, so the prospects for VORTEX2 looked good. Then settled weather descended. With the jet stream pushed north, conditions were too stable to kick-start severe thunderstorms.

From a clear blue sky

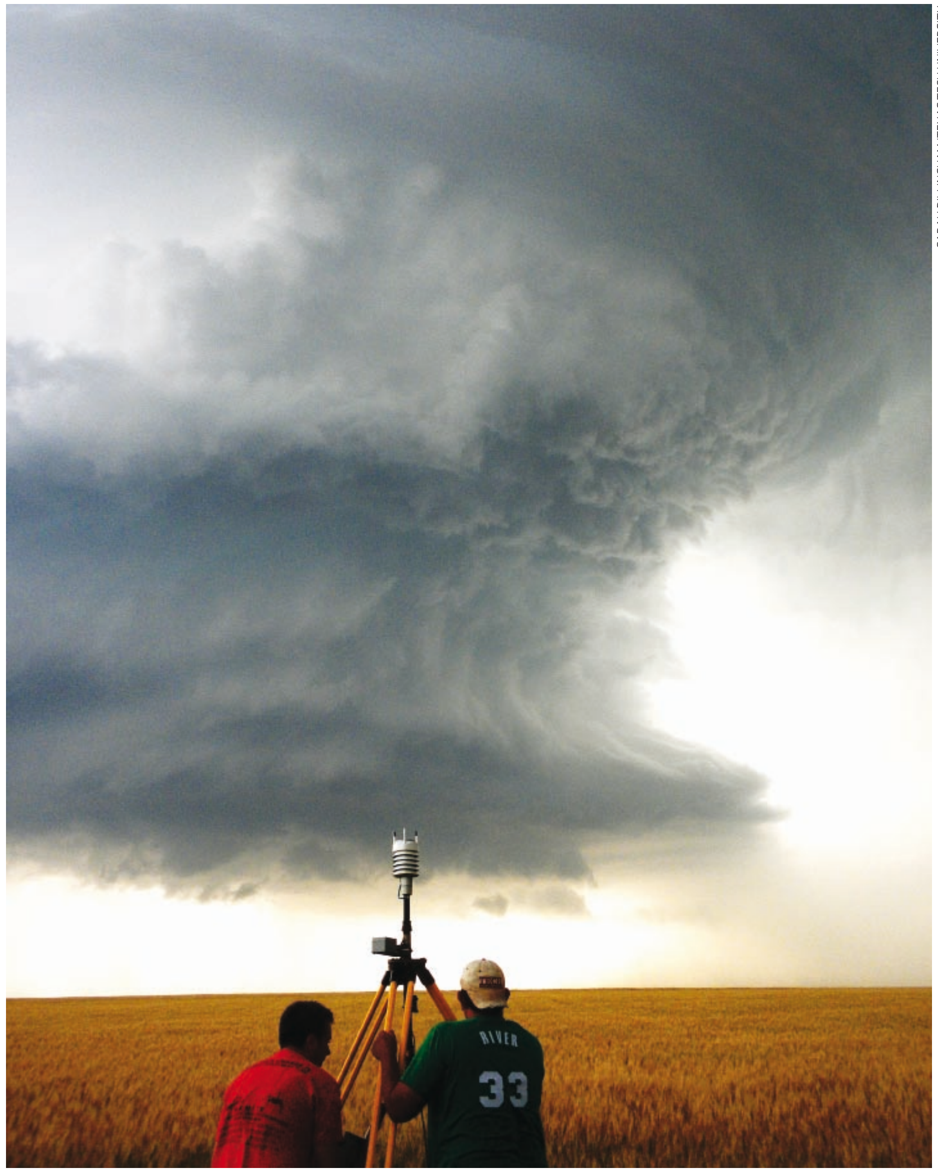
On the morning of 5 June, it looked like more of the same: there were blue skies all round. Yet supercells are so localised that they can seemingly appear from nowhere. A day's prospects are revealed more by subtle indicators – temperature, humidity and the wind profile up through the atmosphere – than by clouds in the sky. These are monitored regularly using radar and weather balloons and so far, we are told, the signs are good.

Researchers have a pretty good understanding of how supercells form. As the moist layer of air closest to the Earth's surface heats up in the morning, it begins to rise. It keeps rising until it is stopped by the layer of hot, dry air around 1 to 2 kilometres up. This collision creates characteristic cumulus clouds with flat tops. By the late afternoon, though, if the air becomes warm enough, it can punch through this cap into the cooler air above. This results in a rapid updraft that is visible as plumes of clouds shooting into the sky.

For tornadoes to form, this rising air needs to be rotating, which is where the region's winds come in. In Tornado Alley, warm surface winds typically blow from the south-east while cooler upper-layer winds come from the west. Where these winds cross, a horizontal tube of spinning air is created. This rotating tube is then drawn up until it is vertical by the rapid updraft of air in the now stormy atmosphere. This rotating air mass is known as a mesocyclone, the defining feature of a supercell and the potential parent of a tornado. Much beyond this, however, remains speculation. Most mesocyclones don't result in tornadoes, and forecasters have a difficult time predicting when they will form.

A big step forward came during VORTEX1, a similar project in 1994 and 1995. Joshua Wurman, now head of the Center for Severe ›

As the thunderstorm approaches, the race is on to deploy networks of weather sensors in its path



SARAH DILLINGHAM/TEXAS TECH UNIVERSITY

Weather Research in Boulder, Colorado, used a Doppler weather radar mounted on a truck to study the insides of a tornado. This revealed the movement of air currents by tracking rain and hail, as well as recording the wind speed and direction, all in high resolution.

Since then, around 140 tornadoes have been studied using these mobile radar systems. But they have their limitations: radar doesn't see clearly close to the ground so there is a dearth of ground-level measurements. What little information there is suggests that winds around tornadoes are more intense at lower levels than first thought, which could play a significant role in keeping tornadoes going. One intriguing measurement made recently by Wurman's team suggests that at ground level tornadoes might not be formed of a symmetrical solid vortex but have a structure similar to a cartwheel, with jets of air rushing inwards towards a central core. Researchers suspect that this could help increase the power of a tornado once it is formed.

None of this explains why only 1 in 5 supercells gives rise to a twister, though, or why some tornadoes are more dangerous than others. Which is why I am sitting here watching a writhing mass of black cloud.

At around 4 pm, beyond the town of La Grange in Wyoming, it finally happens. Descending out of the cloud like a bony finger, a thin funnel stretches, then fades. But the clouds keep swirling and moments later the finger stretches down again until it touches the ground. Our first tornado has arrived.

The armada is perfectly positioned, laid out across 60 square kilometres, with all instruments ready. Video cameras and 10 mobile radars are trained on the storm, weather balloons are released into the clouds, and Sticknet, a network of 24 tripod-mounted sensors, is deployed ready to measure conditions just above ground level. Suddenly it is our turn.

With the tornado grinding towards us at around 30 kilometres per hour, we have 20 minutes to deploy 12 instrument pods, each one containing temperature and humidity sensors, wind speed indicators and a pair of cameras. Laid out at 150-metre intervals in a carefully planned sequence, the pods should gather data as the twister passes over them. "The pod drop is dangerous if you don't do it right," Wurman had warned me in a training session two days earlier. "The pod teams are the closest of any to the tornado so they have to get in, deploy and get out quickly."

Since tornadoes are anything between 200 and 1500 metres wide, the pods must be precisely positioned to score a direct hit. And with the average tornado lasting no more than 10 minutes you only get one shot.

> "All the signs suggest this storm is a monster that will throw out multiple tornadoes"

The deployment complete, we are about a kilometre away from the tornado as the spinning grey funnel tears across the road behind us. For a full minute, the 200-kilometre-per-hour winds create a deafening roar, rocking our vehicle like a toy. Then calm returns as the tornado heads east. We watch as it stretches out into a white tube before disappearing back into the clouds.

Six days later, we are in Missouri, sitting in the path of what looks like the most violent storm of the season. All the signs suggest it is a monster that will throw out multiple tornadoes. Yet for some reason it produces nothing. Clearly our powers of prediction are lacking. But we grab what data we can since this event could still prove valuable.

A few months later, Wurman and his team have had a chance to examine the results. The 5 June event, Wurman tells me, "is by far the best tornado data ever collected – and the results are already looking quite intriguing".

The Doppler radar proved particularly successful. It took a snapshot of the supercell once a minute, and thanks to careful planning and a bit of luck, Wurman now has movies made up of more than 30 detailed frames where normally he would have just a handful.

These videos show a strong downward current of air on the trailing side of the supercell, called the rear flank downdraft (RFD), which many researchers believe is crucial for the creation of a tornado. This downdraft is driven by less-buoyant, cold air sinking to the Earth's surface. Several mechanisms help feed it, including falling hail, rain and snow, which help to drag the air downwards. As it falls, evaporating raindrops and melting hail and snow, processes which take heat from the atmosphere, reduce the air temperature. "Without this downdraft it's very difficult to spin up a tornado," says Wurman. "The challenging thing is that all supercells have an RFD, yet not all produce a tornado."

The temperature of the downdraft may be the deciding factor. The VORTEX2 team had planned to record this using uncrewed aerial vehicles, but unfortunately air traffic control restrictions meant that none could be flown. Instead, they are using the radar measurements to infer temperature inside the tornado. Early results indicate that the downdraft was a little cooler than the air flowing into the tornado, but not so cold as to slow the updraft, says Wurman. Comparing this temperature information with that collected during the storm which failed to produce a tornado could confirm this, he says.

Wind watchers

Another key aspect of the project is to understand the role of ice, hail and rain throughout the life cycle of a tornado. As well as being important for the creation of a downdraft, some researchers believe that the formation of rain and hail plays a crucial role in setting up the tornado's updraft, by releasing latent heat energy which can feed the rising air currents. For this reason, Katja Friedrich from the University of Colorado in Boulder is using the radar measurements to monitor the position and size of these particles in the clouds throughout the tornado's lifetime.

Unfortunately, there's bad news about our pod drop: the tornado made a last-minute turn and passed between our instruments. However, an anemometer, which measures wind speed, on the armoured tornado intercept vehicle (TIV), which was parked directly in the storm's path, provided a slice of readings right through the tornado's eye. In addition, a rapid-scanning Doppler radar that takes measurements every 7 seconds was just 400 metres away, providing unprecedented detail, says Wurman. "You can see individual features spinning around the tornado."

In fact, we seem to have found details that have never been observed before, behaviour that could finally link the downdraft to the formation and ultimate power of a tornado. "This is very preliminary," says Wurman, "but it seems the vertical winds in the RFD are pulsing with variable strength."

A pulsing RFD showed up in computer models in 1997, but this is the first time it has been seen in such detail in real life, says Wurman. "It is possible that the pulses are related to changes in tornado intensification," he says. Such fluctuations may act like a set of bellows, pumping the tornado with new energy. Indeed, the radar measurements reveal that the tornado seemed to intensify a few minutes after the RFD did, and die out when the RFD pulses weakened. Wurman hopes that further analysis of the VORTEX2 data will show why this pulsing occurs.

Another unusual feature of our tornado was the wind patterns at its base. Results from the TIV showed that rather than the cartwheel pattern Wurman had previously found, the air on the edge of the tornado appeared to spiral smoothly inwards at 45 degrees, while near the centre it spins in a circle. This suggests that air was blowing into the tornado, says Wurman, but not reaching its core where there was probably a strong downdraft.

Mapping the wind structure onto video images taken right next to Wurman's radar also threw up some surprises. It seems that the winds outside the funnel are stronger than those at its edges. Understanding this flow should help the researchers calculate how much air is going into the tornado and help explain why some tornadoes do more damage than others.

These findings are just the start. Wurman and colleagues hope to discover even more when the concluding part of VORTEX2 hits the road in May this year. Catching another twister or two may not be sufficient to unravel the complex birth of these beasts, but it will help hone the tornado-forecasting models. And that is critical when every extra second of warning could help save lives. ■

Will Gray is a freelance writer based in London, UK

Anatomy of a super storm