How on-farm weather stations deliver greater accuracy

Comparisons of actual vs. estimated data

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Recently, we used spatial interpolation to analyze the accuracy of estimated weather observations used in many precision agriculture applications against the known observations gathered from on-farm local weather stations.

This study showed that the estimated observations are much less accurate and may lead to poor operational decisions. This is a significant finding, as many precision agriculture applications, such as crop growth stage, nitrogen use, and crop yield—often used to time and target fertilizer and chemical applications—depend heavily on weather data.

Using our network of more than 5,000 weather stations located on farms throughout rural North America, we can show that weather data gathered on-farm greatly improves accuracy throughout the growing season.

- Precipitation is **20 percent** more accurate.
- Growing Degree Days (GDD) are **4 percent** more accurate.

Based on these findings, we can show that:

- There are significant differences between measured rainfall and temperatures on farms and estimates made without measurements.
- The average error in precipitation amounts is more than 3 inches (75mm) or 20 percent of the normal amount in the growing season—which translates into a similar 20 percent impact on yield.
- Precision agriculture applications that use estimated weather data to feed crop growth models that estimate plant stage, nitrogen use, or yield should expect errors of 20-25 percent—just based on the weather.
- There is no substitute for an actual on-farm weather station; when paired with precision agriculture applications, better decisions will be made.

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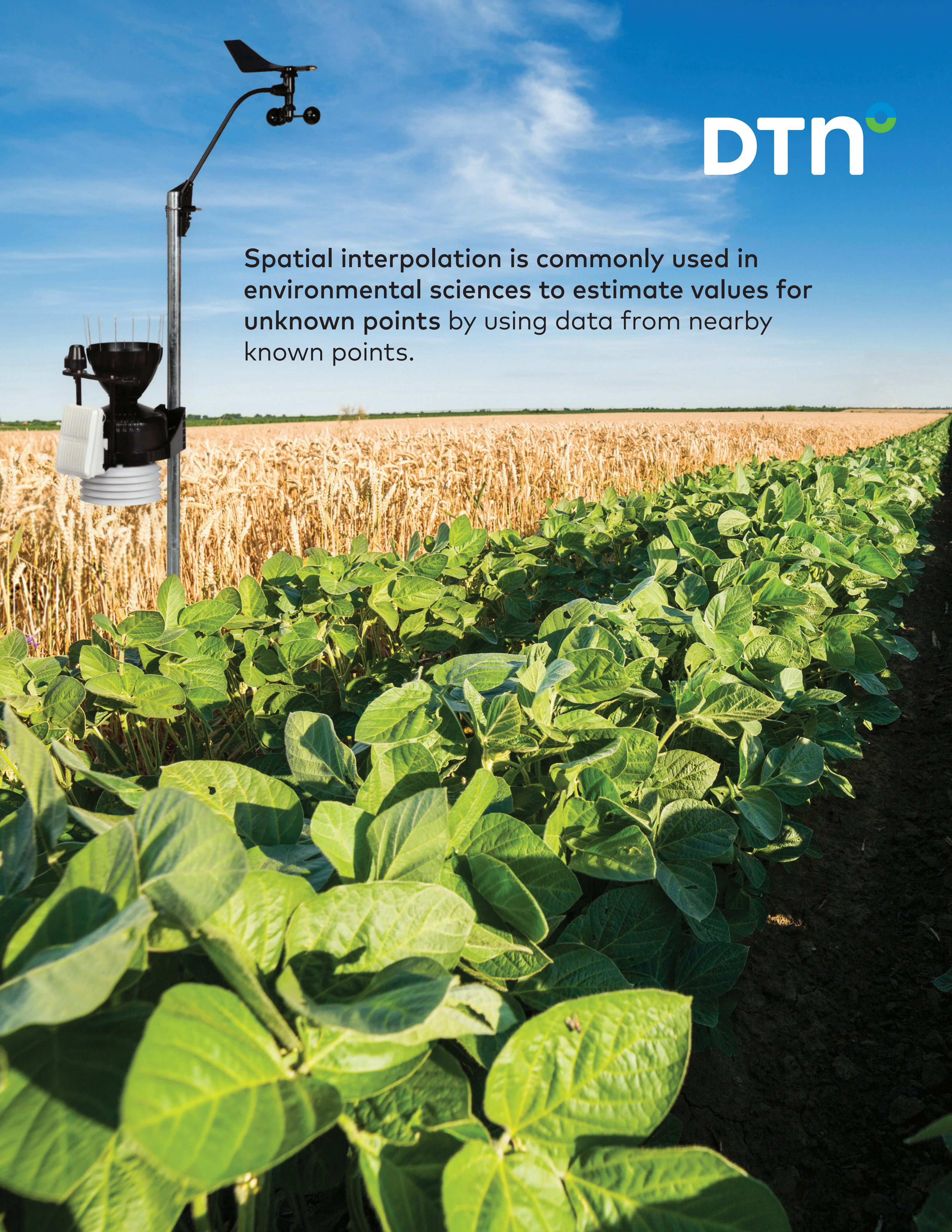
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Spatial interpolation is commonly used in environmental sciences to estimate values for **unknown points** by using data from nearby known points.

The DTN Ag Weather Station Network

In 2013, we started deploying our weather station network. Today, we operate a global network of more than 5,000 weather stations, the vast majority of which are located on North American farms.

We install and maintain the stations and manage data collection. Each station reports observations every 15 minutes. We then perform rigorous quality and consistency checks to ensure the data's integrity. Producers can easily access their weather station's data using our mobile apps or websites, which provide decision support tools powered by the data.

Producers find many applications for their data:

- They enhance their planting, irrigation, spraying, fertilization, crop disease management, insect outbreak predictions, and yield estimate decisions with precise, field-level weather and soil measurements.
- They use their stations' radar and satellite imagery to calibrate other remote sensors, supporting crop health monitoring.
- They enjoy greater productivity and sustainability with best-in-class weather forecasts and alerts for their farms, powered by their own on-farm data.

Standard weather station measurements...

- Precipitation
- Air temperature
- Dew point temperature
- Wind speed & direction
- Barometric pressure

Optional parameters...

- Soil temperature & moisture (at one or more depths)
- Solar radiation

Accurate weather observations are critical:

- Precise, continuous weather observations for each farm or field are vital as conditions like rainfall and wind can vary greatly over short distances.
- Soil and solar conditions impact plant growth and crop stages, so farmers must know what is happening above and below their plants.
- Alerts for both current and forecast weather provide advanced warning to conditions that impact operational decisions and expenses.
- Decision support tools for activities, such as spraying and field work, help improve planning and scheduling, reducing costly application errors.
- Crop-specific pest and disease models enhance understanding of the impact of local weather and pests on yield.

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Weather data accuracy comparison—methodology

In precision agriculture, the most crucial weather parameters are precipitation and temperature. In particular, precipitation can vary greatly over short distances—less than one mile or two kilometers.

Most official weather observations are taken by national meteorological services, such as the National Weather Service and Environment Canada in North America. The majority of those observations are taken at airports, which are primarily located near cities and urban areas. Virtually none of the official stations are located on farms, so users who do not have access to the DTN weather station network must rely on these observations and then estimate what precipitation and temperature might be for their specific farm or field.

Most applications use one of three methods to estimate precipitation and temperature values:

1. Use the nearest official weather station as a proxy for a local observation.
2. Use a distance-weighted interpolation of official stations.
3. Use radar or weather models in lieu of actual observations.

For precipitation, many applications use radar-estimated rainfall, also known as quantitative precipitation estimates. This produces spatially-consistent rainfall patterns and is generally considered to be the most accurate method of estimating rainfall amounts. For this study, we compared rainfall amounts and temperatures for each weather station to the estimated values typically used by most agricultural applications.

The comparison used these assumptions:

- Only the growing season months of May, June, July, and August of 2018 were included.
- Precipitation (rainfall amount) and temperature (GDDs for corn) were compared at 1,689 DTN weather station locations throughout the United States and Canada. The areas covered are described in the tables and maps that follow.

DTN weather forecasts have proven to be at least 20 percent more accurate than publicly-available forecasts.

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The results

The results of the comparison varied by weather parameter.

Precipitation

Precipitation comparisons were made by subtracting the actual measured amount of daily precipitation at each DTN weather station from the estimated amount, using radar-estimated rainfall as previously described.

Precipitation (in)					
Month	Average |error|	Median	90th Percentile	Normal	% Normal
May	0.84	0.63	1.71	4.19	20.0%
June	1.02	0.74	2.16	4.4	23.2%
July	0.77	0.55	1.73	4.31	17.9%
August	0.76	0.57	1.66	4.4	17.3%
Total for May-August	***3.05***	***2.53***	***6.01***	***17.3***	***19.6%***

Table 1 Precipitation comparison of actual to estimated (predicted) amount for all stations.

The spatial distribution of differences between actual and estimated (or predicted) precipitation show that the differences were widespread—and almost uniformly negative. Estimated precipitation was larger than what was actually measured.

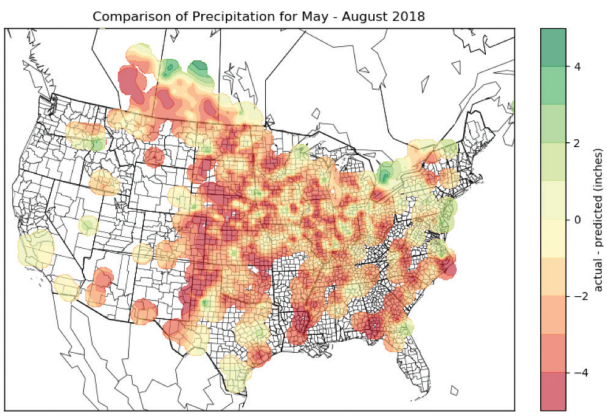


Figure 1 Spatial distribution of differences between actual and estimated precipitation amounts.

When compared to the climatological normals (based on 1981-2010 decadal normals), the error size was very significant. On average across all locations, there was nearly a 20 percent difference in precipitation amounts for the entire growing season.

GDDs

For the temperature study, we converted the daily maximum and minimum temperatures into GDDs for each location. We used the common value for corn—50 degrees F (10 degrees C)—as a base. We then subtracted the actual weather station-measured GDD values from the estimated GDD values, using distance-weighted interpolation.

Growing Degree Days (deg F)					
Measurement	Average |error|	Median	90th Percentile	Normal	% Normal
May	15.1	11.8	33.8	341	4.4%
June	16.1	12.9	34.8	555	2.9%
July	20.6	16.8	43.8	976	2.1%
August	20.1	16.1	43	324	6.2%
Total for May-August	***66.2***	***53.3***	***144***	***2196***	***3.9%***

Table 2 GDD comparison of actual to estimated (predicted) amounts for all stations.

The spatial distribution of differences between actual and estimated (predicted) GDDs show that the differences were smaller, and slightly negative (the estimated GDD was larger than the actual measurement).

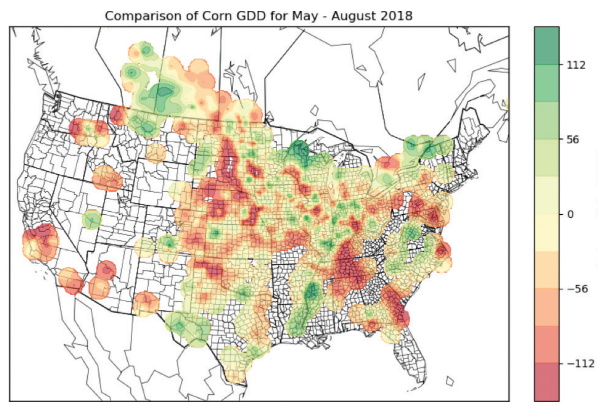
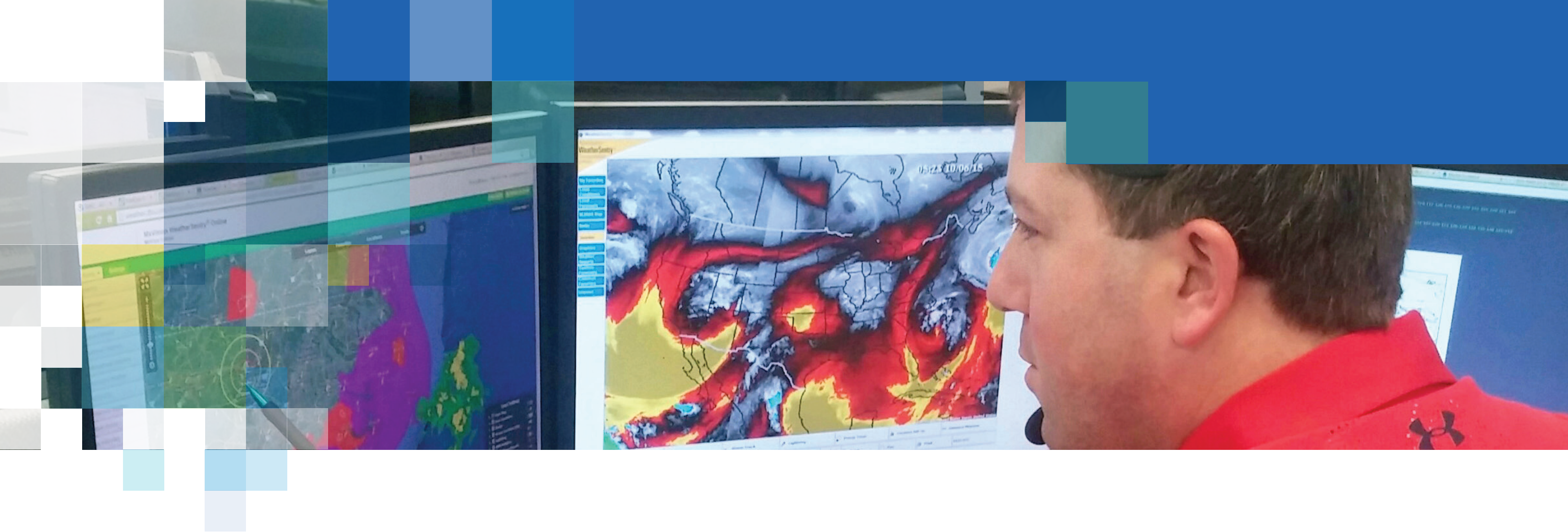


Figure 2 Spatial distribution of differences between actual and estimated accumulated GDD amounts.

When compared to the climatological normals (again, based on the 1981-2010 decadal normals) the error size is more modest. Across the entire growing season, there is an average 4 percent difference in GDD totals.



Key takeaways

- There are significant differences between measured rainfall and temperatures on farms and estimates made without measurements.
- The average error in precipitation amounts is more than 3 inches (75mm) or 20 percent of the normal amount in the growing season—which translates into a similar 20 percent impact on yield.
- Precision agriculture applications that use estimated weather data to feed crop growth models that estimate plant stage, nitrogen use, or yield should expect errors of 20-25 percent—just based on the weather.
- There is no substitute for an actual on-farm weather station; when paired with precision agriculture applications, better decisions will be made.

About the authors

James Block, chief meteorological officer & Chad Aeschliman, vice president of Analytics

James Block is DTN's chief meteorological officer, responsible for all of the weather content within DTN. He holds both bachelor's and master's degrees in meteorology from the University of Wisconsin-Madison. Block has more than 37 years of commercial meteorology experience, and is an American Meteorological Society CCM. He was elected as a fellow of the society in 2010.

Chad Aeschliman has a passion for using data and technology to solve big problems that seemed unsolvable. He received a PhD in Electrical and Computer Engineering from Purdue University studying machine learning and computer vision. Since then he has been active in a variety of areas from radar systems for vehicles to new decision support tools for agriculture. Chad is currently vice president of Analytics at DTN, where he continues his mission to use data to solve problems.

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