Technical Newsletter

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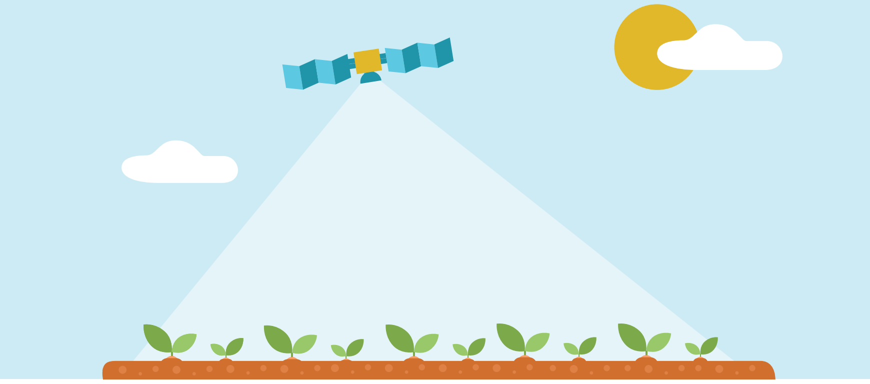


GUIDE TO AGRICULTURE INSURANCE
PART I
Overview of new satellite offering and use

Introduction

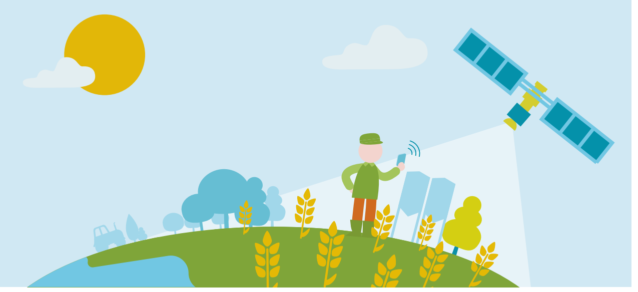
Initially used to cover hail threats, Agriculture insurance is more than 100 years old. Today, innovative tools and new techniques based on satellites technology are available to improve, develop and expand this domain. The aim of this Technical Newsletter, published over two volumes, is to provide an understanding of the different types of satellites that can be used for agriculture insurance, and how they can be used. In the second volume we will focus on satellite imagery technology and assess the key factors to be taken into account in the agricultural and insurance decision-making process.

As we all know, several factors are putting significant pressure on the food production chain:

- the anticipated growth of the world's population, requiring investment to manage future food production;
- the threat of climate change and the increased frequency of extreme weather events, requiring new ways in which to protect agricultural assets; and
- social instability/unrest

"AGRICULTURE (RE)INSURANCE HAS A MAJOR ROLE TO PLAY."

Among the tools supporting the agriculture industry, satellites have been used for decades, but their use has only recently become easy and affordable, not just for research purposes but also to achieve better performance and support the decision-making process.



Agriculture was one of the first users of satellites

Farmers have been using satellite images to manage their fields, and GPS technology to guide their tractors, for more than 15 years. Although the potential use of satellites for agricultural insurance was identified very early on, the development of insurance products based on satellite technology, and the incorporation of this technology into the insurance process, have proved far more difficult than expected.

It has to be said that we have seen plenty of projects, ideas and launches over the last 10 years, and that the number of successes has been limited, creating frustrations, disappointments and sometimes suspicion with regard to satellite-based products. But farmers, corporates and the whole (re)insurance world are all looking for the best possible solution in this regard.

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What should be done today?

Sticking to traditional methods, and leaving satellite tools to research, is not an option.

There is no doubt that satellite technology can be extremely powerful, providing our industry with better information, new solutions and new products and giving us access to new markets. But, like any tool, it has to be used in a sound way.

In many cases, the issues that have arisen when this technology is put into use have not been due to the technology itself, but to the way in which it has been implemented. It takes time, investment and energy to implement new technology in such a way that it results in a long-term, sustainable insurance scheme. And all too often, insufficient analysis and overly rapid implementation lead to failure, particularly in Agriculture.

In this context, the insurance industry is currently facing a great challenge: how to choose the appropriate technology, and how to implement it in the best possible way to achieve its targets and serve its clients, thereby bringing stability to Agriculture production and expanding a profitable and sustainable portfolio.

Figure 1: Nile delta, Egypt satellite view

Source: Satellite Image UK-DMC2 - Airbus Defence & Space

Overview of the satellite family

When they refer to satellites, people are very often referring to a very wide range of tools and technologies.

This is not necessarily clear for everybody, and can lead to confusion when deciding to launch a project.

Satellites can be classified into several groups:

- **Telecoms satellites used for information transmission** (TV, telephone etc.)
- **Weather satellites used for measuring weather parameters** (temperature, moisture, wind speed, etc.)
- **GPS satellites used for geolocation**
- **Scientific Satellites dedicated to very specific missions**
- **Earth observation satellites.** These are usually referred to under the general term "satellite imagery". They actually cover a whole range of sensors with different resolutions, revisit times and characteristics.

All of these satellites have in common a relatively low altitude (around 800 km compared to 36,000 km for geostationary satellites) and therefore also have a high ground speed (e.g. one orbit in 106 min for a SPOT satellite), plus the fact that they retrieve information from the earth's surface ("pictures").

Earth observation satellites can then be split into two main groups:

> Radar satellites, mainly SAR (Synthetic Aperture Radar)

To create a SAR image, successive pulses of radio waves are transmitted to "illuminate" a target scene, and the echo of each pulse is received and recorded. The pulses are transmitted and the echoes received using a single beam-forming antenna, with wavelengths ranging from one meter to several millimeters. As the sar device on board the aircraft or spacecraft moves, the antenna location relative to the target changes with time. Signal processing of the successive recorded radar echoes allows the recordings from these multiple antenna positions to be combined – this process forms the 'synthetic antenna aperture', and allows the creation of higher resolution images than would otherwise be possible with a given physical antenna.[1]

One key point about SAR satellites is that clouds don't disturb the signal and a picture can be obtained whatever the weather. This feature is specifically advantageous for crops growing in tropical or monsoon climates, like rice or tea. While widely used for mapping and elevation measurements, SAR satellites are not widely used for agricultural purposes at the present time, mainly because of their image-taking capacity and the limited plant information that can be extracted from these images.

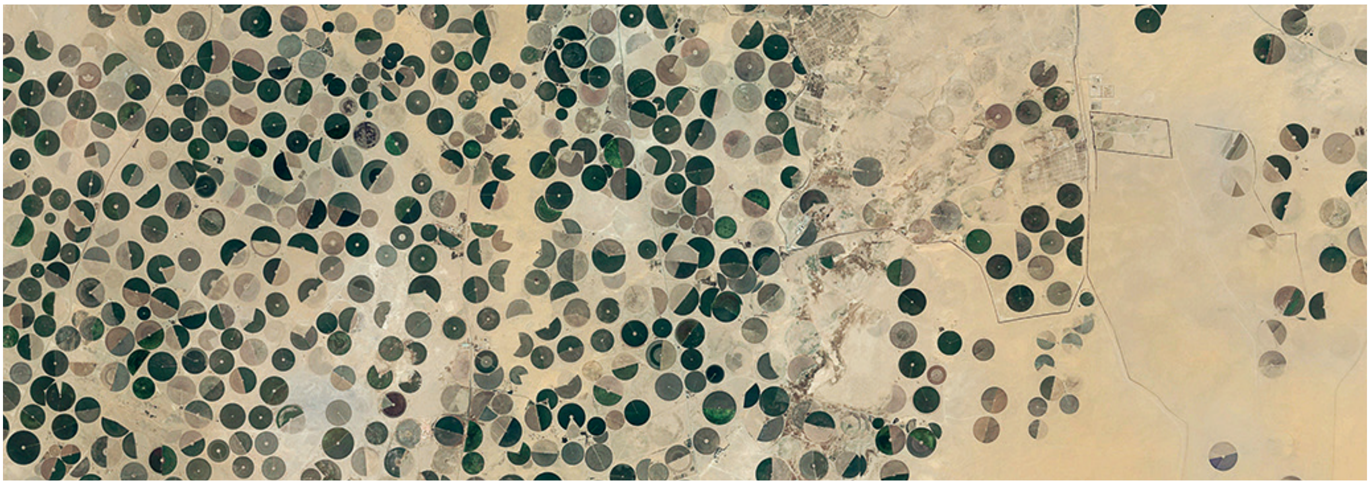
> Optical satellites

In an optical satellite, the sensor is passive (not emitting). It captures the light from the sun, which is reflected and disturbed by the observed layers (atmosphere, clouds, crops, soil, etc.). The way the original light is disturbed provides information about the observed object. Of course, the raw image is rarely used as such. The data collected, consisting of "quantity of light per color" (wavelength), can be processed and transformed into many indicators, indices or agronomic values, which are usable in the different agricultural and insurance decision-making processes. This process is widely used today in many industries.

"THESE KINDS OF IMAGES FORM THE BASIS FOR PRECISION AGRICULTURAL SERVICES, WHICH HELP FARMERS TO OPTIMIZE THEIR CROPPING PRACTICES ACCORDING TO THE BEHAVIOR OF THE PLANTS INVOLVED (FERTILIZATION, IRRIGATION, QUALITY MANAGEMENT, AND SO ON)."

In the case of agricultural index insurance, two satellite groups are of particular interest: optical earth observation satellites and weather satellites. Both can provide data usable for the development of insurance indices. Let's take an in-depth look at these two groups.

Figure 2: Saudi Arabia - Asir region - Satellite view



Source: ©CNES 2005 - Distribution Astrium Services/Spot Image

[1] Introduction to Airborne RADAR, G.W. Stimson, Chapter 1 (13 pp)

How is optical satellite imagery used?

As mentioned earlier, **optical satellite imagery is probably the most commonly used satellite data in agriculture** (besides weather forecasts). It is used in a number of areas, including fertilization, irrigation, quality management and of course insurance. **For agricultural insurance, this type of imagery can be used in two main ways:**

> Index insurance:

In this case the raw image is processed to generate an index strongly related to production. This index is then used as a base for the design of the insurance product. Satellite pictures capture the behavior of vegetation very well. This is why the correlation between index and production is better when the biomass (vegetation) is the main objective (grass, fuel biomass, etc.).

In cases where the main target is fruit or grain, the biomass becomes a second-level indicator. For example, we need a good biomass to have a good corn yield, but a good biomass will not necessarily ensure a good yield (e.g. if there is a problem with pollination). For these reasons, satellite images should only be used as the sole sources of data for indices on crops like pasture.

> Loss assessment optimization:

In many cases, a historical insurance scheme exists already. This scheme is generally known to and widely accepted by the different stakeholders involved, such as the insurance companies, the brokers/agents, the loss assessment companies and the farmers. For the farmer, used to conducting field visits with a loss adjuster, changing to index insurance can be very difficult.

But it should be borne in mind that traditional loss assessment is not an exact science, and that loss estimation can vary quite a lot depending on the individual loss adjuster involved. In this case, satellites can also be of great help.

By taking high resolution pictures of the affected field and processing the images correctly, the fields can be classified into different groups with the same "behavior", but can also be mapped according to the development of vegetation inside the field. Armed with a clear view of the fields within the affected area, the loss adjuster can take samples at the optimal location and correctly weight the different results.

This kind of tool, which does not change the system in place, can dramatically increase the accuracy of a loss assessment, and therefore the performance of the insurance product.

Did you know?

Satellite tools can be used in two main ways:

a) to improve the traditional loss adjustment process

b) as the basis for an index insurance product.

Let's take a look at some examples of these two main uses:

> **Satellite imagery to improve the traditional** loss assessment process, i.e. involving a visit to the fields, relies mainly on two factors: the experience of the loss adjuster and the quality of the field analysis process (number of samples, location of samples, measured parameters etc.).

Of course, it is crucial to understand the spatial variability of the field, and this is very often difficult to achieve. For a 50 or 100 hectare cornfield in full vegetative stage, assessing the exact area affected by a weather event can be extremely challenging. In such cases, detailed infield maps using processed, high resolution images can dramatically improve the accuracy of the loss adjustment. By optimizing the number and location of samples, guiding the inspection of the loss adjuster or weighting the different samples according to the size of their respective zones, we can achieve a far better estimation of the field status. Different pictures taken at different times of the year can also help to understand the behavior of the crop, and in some cases to detect cases of mismanagement or other accidents during the crop cycle.

> **Using satellite imagery to generate an insurance index.** In the specific context of agricultural index insurance, the number one key for success is the design of the index itself. This is crucial to develop a sustainable product with a reasonable basis risk.

The basis risk (the difference between the actual incurred loss and the index calculated loss) is in many cases the reason behind the failure of an index insurance program. If the basis risk is too high, the consequence could be that the farmer is not compensated for a loss. Very quickly, this type of issue leads to a loss of credibility for the agricultural insurer, for the whole concept of index insurance, and potentially also for satellite technology. A common way to limit this basis risk is to aggregate the insured units into a larger entity, grouping farmers together where the index will be more correlated to production.

Basically, the index of a well-designed and sustainable insurance program should:

- assess production variation compared to a normal situation;
- be reliable, robust and repeatable;
- have a spatial resolution adapted to the country's agriculture;
- cover a large territory;
- be scientifically approved and validated;
- be understood and trusted by the insurance production chain.

When insuring agricultural production that is directly linked to biomass production (as opposed to fruit or grain), **satellite images can be used to generate a production index, which can be used as the basis for an insurance product.** This technology is very well suited to pasture insurance schemes, for example. In France, the insurance company Pacifica has successfully established this kind of product in partnership with Airbus Defence and Space, and other versions also exist in Spain and Mexico.

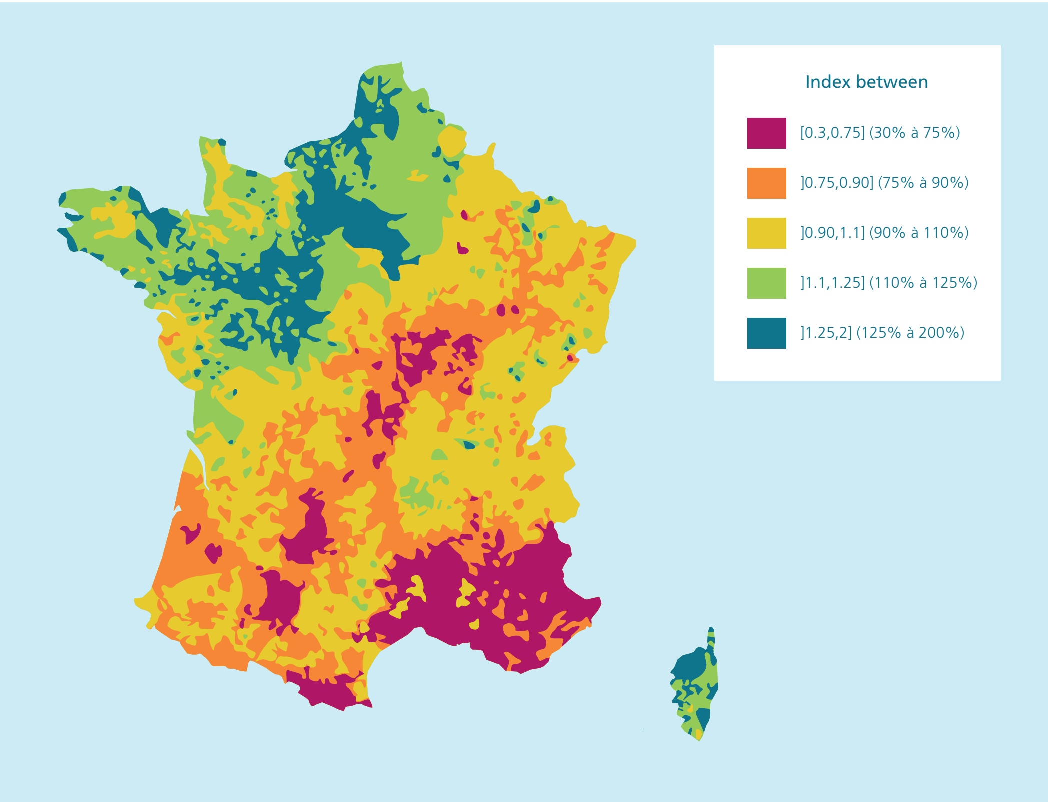
In these cases, pictures (generally medium resolution – 300m x 300m pixels) are collected and undergo a selection and cleaning process. A procedure is then applied to extract the vegetation parameter that is best correlated to actual production.

In specific cases, for example when the crops are mixed in a region, a specific processing procedure should be added. The image shows the presence of different vegetation in a single pixel (pasture, wheat, corn, forest, etc.). The information retrieved by the satellite is therefore a composite of the vegetation behavior for all the crops in the pixel. Looking at time series and aggregating several pixels together, a "de-mixing" process is applied. This process separates the contribution of each individual crop to an average measure, thereby allowing us to extract the one we want to observe and insure.

Following this processing procedure, the final result is a pasture vegetation value for each pixel.

This is the point from which the insurance work can start. Firstly, this process is applied to historical images. Through this we can build a historical database, used for actuarial analysis, pricing and trigger definition. Then the same process is used in real time to monitor actual production and to compare it to historical production.

Figure 3: Pasture Production Index season 2012



Source: IPF map 2012 (IPF -Forage production index per township)
Photo credit: © Airbus DS

WORKS AND POINT OF VIEW FROM OUR PARTNERS

Satellites are key in meteorological and crop yield forecasting

View of Joseph A. PIETROWICZ,

Ph. D. Senior Research Scientist,
Chief Meteorologist/Climatologist at ZedX, Inc.

Dr. Pietrowicz has over 20 years of experience in the television broadcast industry as an on-air meteorologist. Since December 2004, he has been employedby ZedX, Inc. as a Senior Research Scientist.

The science of meteorology is more than the study of the atmosphere; it must also include any systems that are in any way connected to the atmosphere. Modern meteorological models include exchanges of energy and mass, i.e. water vapor, ozone, greenhouse gases, chemical pollutants, into and out of the atmosphere. These processes include exchanges between the biosphere, the hydrosphere, the lithosphere, the cryosphere and the atmosphere.

All scientific models need initial conditions, or observations, to start the computations. When numerical weather prediction started in the 1950's, direct measurements from the surface and upper air balloons were used. As the technology of the numerical weather models became more complex, the need for global initial data became apparent, especially in data-poor areas. Remote sensing is the natural choice.

Early techniques were able to extract atmospheric temperature profiles from satellite data and incorporate it into the global analysis. Since those early days the technology of satellites has increased in quality, through greater spatial and temporal resolution. Today's satellite data includes measurements such as sea surface temperatures, high resolution winds, wave swells and wave heights. Over land, satellites are providing information about land use and land cover. Additionally, the chemical composition of the atmosphere, which has significant impacts on weather, climate models, and human health, is captured by satellites. These include stratospheric and surface ozone, water vapor, carbon dioxide, methane, carbon monoxide from fires, aerosols and SO_2, dust storms and volcanic eruptions, and surface air quality.

These values are used in combination with instrumented observations. Understanding of the radiation balance, and its changes, is critical to weather and climate models. Satellites provide this data on a routine basis. Knowledge of precipitation has many uses. Techniques continue to be developed to provide precipitation estimates on a global scale.

One technique uses polar orbiting and geostationary satellites to generate these values in 30-minute time steps. The combination of station observations and satellite data is critical in monitoring the global state of the atmosphere. Meteorological analysis and weather models generate fields which are represented on a three-dimensional grid. The increasing power of computers allows for finer horizontal and vertical resolution, which gives a better representation. The grid system for weather variables is important, because we have data where no stations exist. Additionally, the gridded data represents the average weather conditions for the area of the grid cell.

ZedX uses the gridded weather fields as input to its agronomic models, i.e. crop yield, phenology, disease and pest models, and historic weather analysis. The fields are represented for the area of the grid cell. ZedX agronomic models can be configured to run on a single grid point or on multiple years. The data produced from ZedX's models can be used to construct databases.

These databases can be used in a variety of ways, such as assessing risk and the return period of extreme events, and monitoring a crop within a season. The use of satellite data is critical in modern atmospheric science in order to better serve society by increasing the quality of weather and climate outlooks and environmental science. This has been a brief overview of uses of low earth orbiting and geostationary satellites in weather. Research continues to improve the quality of the satellites, information extraction methods and the use of this information in meteorology.

For a further understanding of satellites, please consult the University Center of Atmospheric Research (UCAR) COMET educational module "Satellite Monitoring of Atmospheric Composition" at: https://www.meted.ucar.edu/EUMETSAT/atmos_comp/index.htm

How are weather satellites used?

THE HISTORY OF WEATHER SATELLITES

When insuring agricultural production, the vast majority of the main perils are weather-driven. Of course, traditional loss adjustment methods with field visits directly assess losses in the field, but they require a heavy infrastructure. Index insurance does not need field visits, it is based on an index that can proxy production. The quality and the correlation between loss and index will set the level of basis risk. In the case of a weather index, the quality of the initial weather data is crucial to ensure a good product (see "basis risk").

Weather stations constitute the first obvious source of weather data. Ground-based, and measuring parameters, on a very frequent basis, weather stations should be best source for weather-based insurance. But some limitations must be mentioned, the first one being the number and location of the stations. Stations are often located far from agricultural fields, or in locations that are not representative of the fields (e.g. airports and other built-up areas). This is a key issue, as the distance between the insured field and the weather station can introduce a severe bias in the index.

The second limitation is the quality of the data. In order to produce accurate data, a weather station has to be maintained and regularly controlled and calibrated. While this is the case for international standard-level weather stations, it is often not true of many other stations. This implies a considerable amount of data cleaning and quality control.

In some cases, local regulations can limit the use of weather stations.

For decades now, weather scientists have been using satellites to retrieve weather data. Thanks to the different sensors onboard, they can measure weather parameters at any point on the globe and at different altitudes in the atmosphere. Whether they are polar-orbiting or geostationary, weather satellites give permanent access to the required information.

But weather satellites also have certain limitations, such as not being able to provide accurate measurements for very local events like precipitation, or having special resolutions that are sometimes too crude to be used in mountainous areas (too much altitude variation within a single grid cell).

Although not the panacea for all insurance index products, they constitute a great tool that is often under-used in the insurance industry. There are various examples of products based on weather indices, such as those created by the African Risk Capacity agency, and by the Weather-Based Crop Insurance Scheme in India.

"COMBINING THE STRENGTHS OF WEATHER STATIONS AND SATELLITES CAN ALSO BE A VERY POWERFUL TOOL."

FROM POINT TO GRID…

In the terminology of weather stations, weather data is treated as a number of points, each station representing a point and each point having a geographical location on the globe. In order to estimate the specific temperature at a specific point between two weather stations, interpolation must be performed. Of course, many different methods of interpolation can be used. But the greater the distance between stations, the higher the uncertainty around the interpolated value.

Unlike the "points" system used by weather stations, satellite data is handled as a "grid", due to the nature of the measuring instrument itself. The atmosphere is divided into individual cells at horizontal level and vertical level, and each cell is then given a value for a specific parameter.

Atmospheric models are managed in the same way, hence the possibility of merging data between stations and satellites.

Weather scientists have developed datasets, mixing all available data sources - radiosondes, satellites, ground stations, aircrafts, ship reports – and using data assimilation schemes and atmospheric models. The combination of observations and model output through data assimilation is used in numerical weather prediction and in reanalysis. Unlike numerical weather prediction, which estimates future conditions, reanalysis products reflect past conditions, often for several decades. Today, most of the input data in numerical weather prediction and reanalysis comes from satellites. However, some ground observations are always required, either to calibrate the satellite products, or as input in the meteorological models (prediction, reanalysis) themselves.

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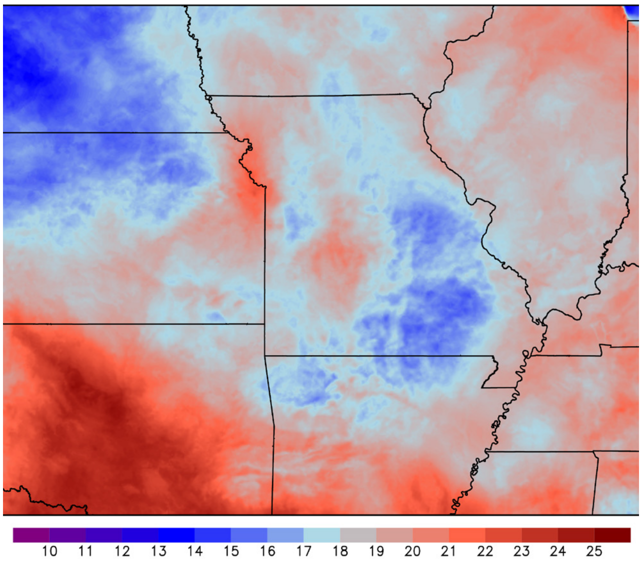
"THESE DATASETS, CALLED 'REANALYSIS' DATASETS, PROVIDE A DYNAMICALLY CONSISTENT ESTIMATE OF THE CLIMATE STATE AT EACH TIME STEP."

Like all models, reanalysis data models have certain limitations, but for agriculture monitoring, where the main objective is to capture the cumulated effect of the weather throughout the crop season, they are a very valuable asset.

The choice between raw satellite technology and reanalysis datasets depends on what the resulting data is going to be used for. For example, satellite data is often a better choice for precipitation, because precipitation (especially convective precipitation) is the result of sub-grid scale processes, which are not directly simulated in weather models. To take a different example, air temperature from reanalysis tends to be more accurate than air temperature provided by satellite data, because satellites only measure skin temperature, which then has to be converted to air temperature at a certain reference height.

Figure 4: Corrected Maximum Temperature (F) June July August 2012



Source: ZedX, Inc.

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