Sensing Strategies and Software Tools to Help Farmers Adapt to Climate Change

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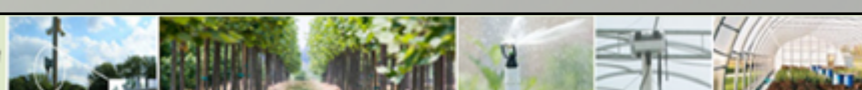
Smart Farms



SCRI-MINDS—Managing Irrigation and Nutrition via Distributed Sensing

saving water   increasing efficiency   reducing environmental impacts

USDA NIFA United States Department of Agriculture National Institute of Food and Agriculture

USDA-NIFA-SCRI Award no. 2009-51181-05768

Our New Tools and Methods

1. Sensor Networks – ground and cloud-based systems
2. “Our Toolbox”
3. Software Development – Translating Information into Decisions
   - *Automated Irrigation Control*
   - *Model Integration*
   - *Alert Capabilities*
4. Economic Impacts – Multiple and Synergistic
5. A Case-study in Risk Management – Frost monitoring

The Process

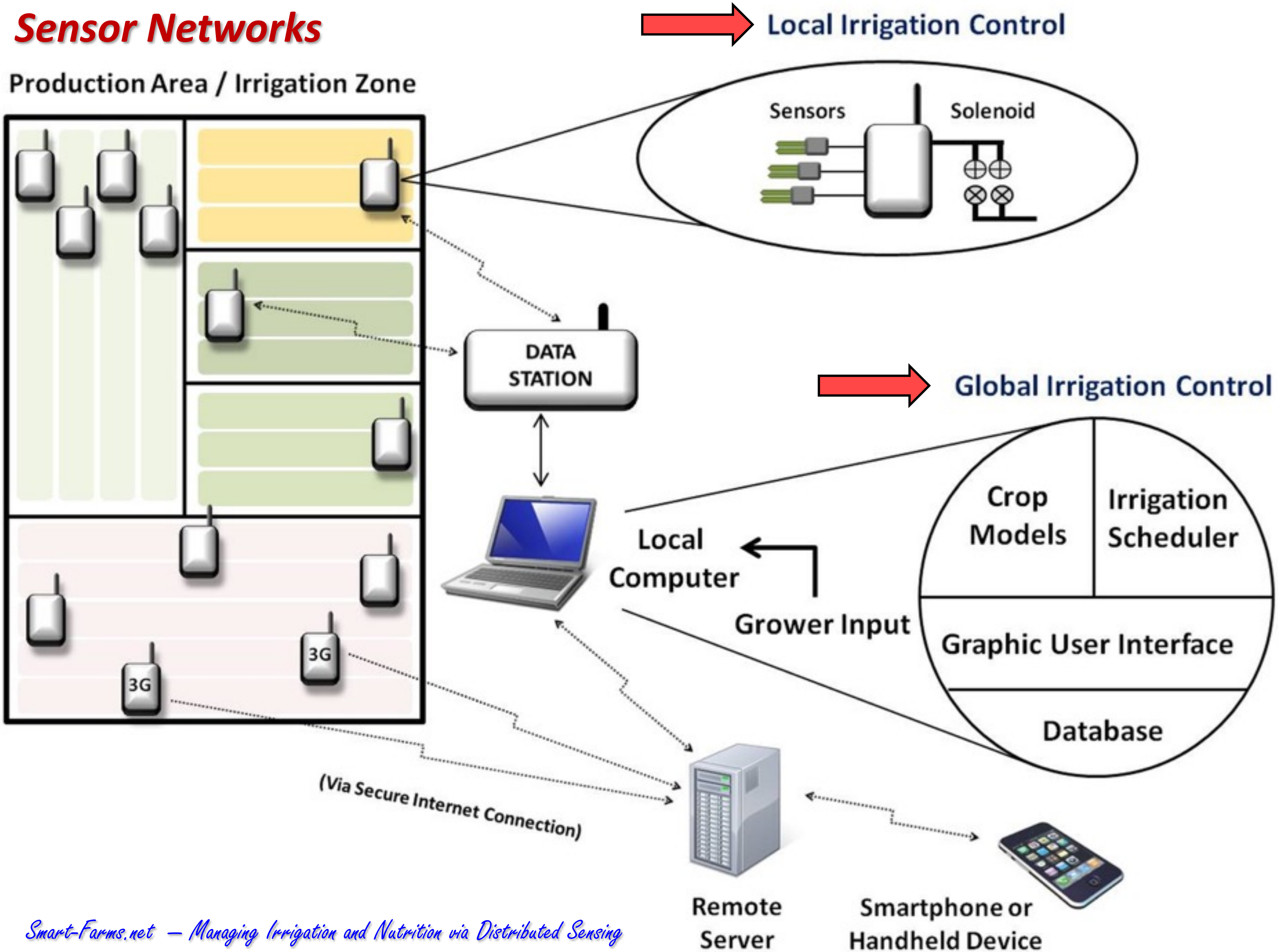
Data → Information → Knowledge → Action

The System

Sensors → Software → ‘Analyst’ → Decision-Maker

Intelligence Intelligence Intelligence

Sensor Networks



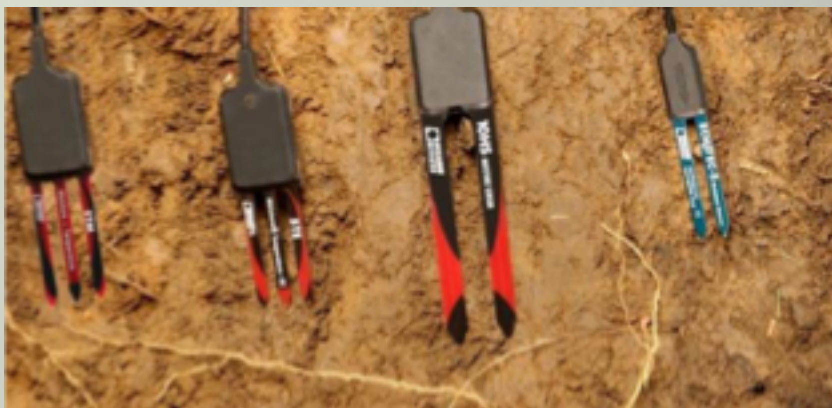
Radio Dataloggers

Monitoring
Node

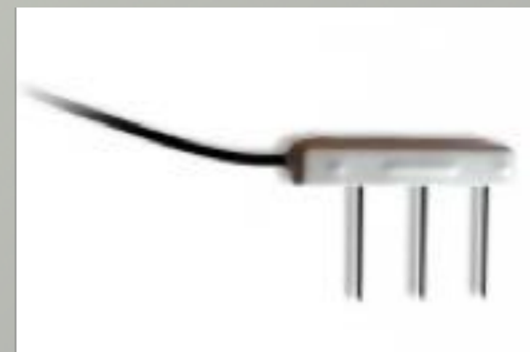
Control
Node

Cellular (3G)
Monitoring Node

Soil Moisture, EC Sensors



Various soil moisture sensors



GS3: EC, soil moisture, soil temperature

Line pressure

In-line/Tank EC

Water Potential

Environmental Sensors

Photosynthetic
and Total radiation

Wind speed
and direction

Precipitation

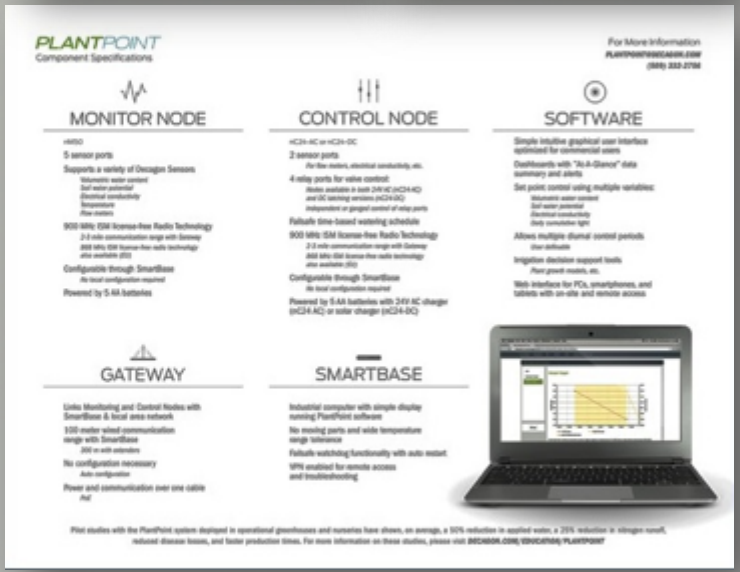
temperature, RH
and VPD

Sonic anemometer

Leaf wetness, Dew and Ice

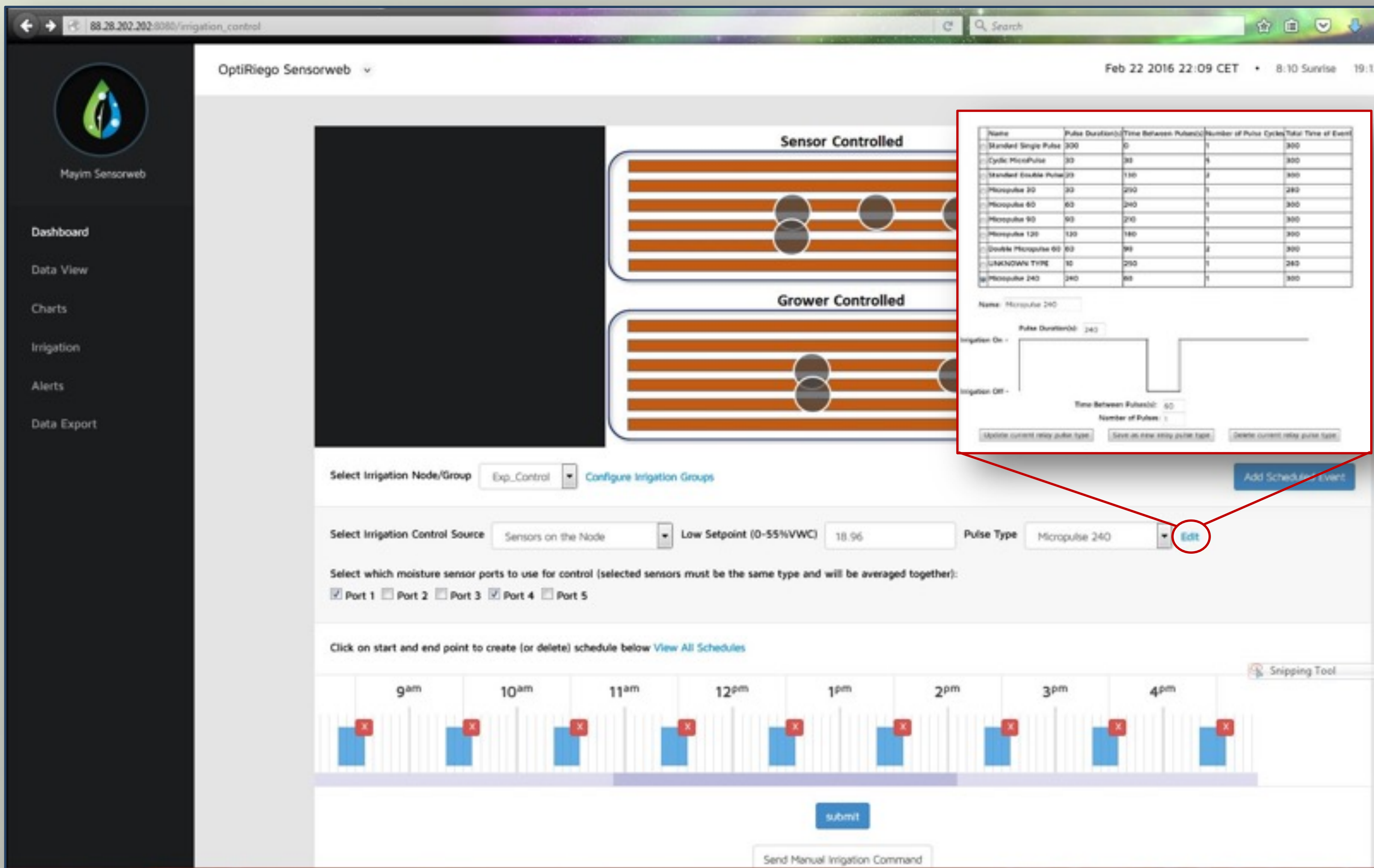
Automated Control Capability

- Developed an advanced node, capable of controlling irrigation and reading multiple sensors
- Data is used by growers in real-time to make decisions and monitor crop/field conditions
- Plant irrigation can be determined automatically based on set-points or using plant water use models
- Sensor data and irrigation control can be accessed remotely
- System is fault-tolerant and reliable



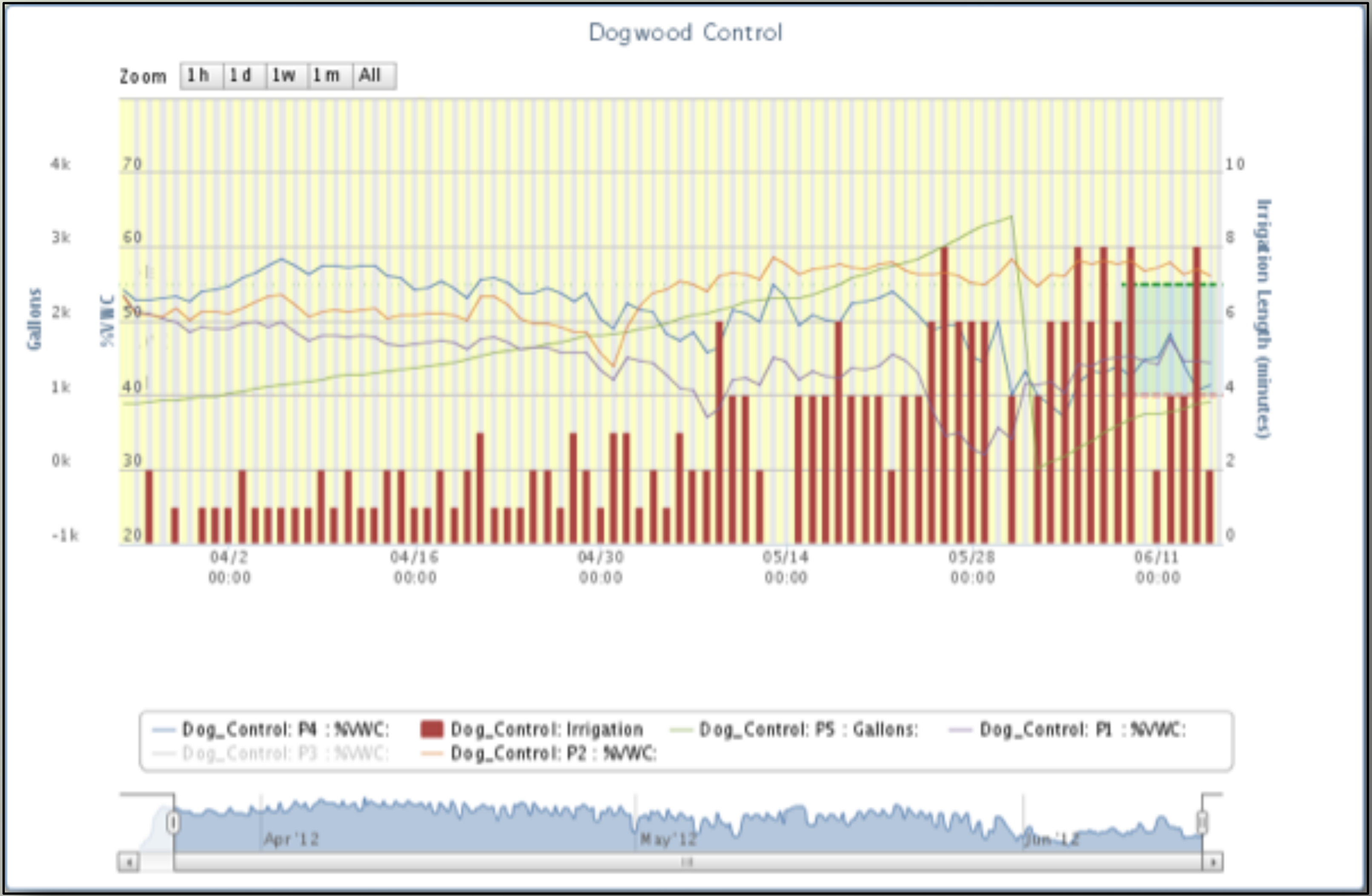
Kohanbash, Kantor, Martin and Crawford, 2013
HortTechnology 23: 725-734

SensorWeb Micro-Pulse Irrigation Scheduling Capability



- Sensor-based irrigation control scheduled for 15 minutes every hour
- Within each 15 minute period, able to irrigate up to three, 4-minute pulses (i.e. 240s on, 60s off)
- *Only irrigates* if the minimum soil VWC is reached (currently set at 19% VWC)

Sensor-Controlled Irrigation Scheduling



Belayneh, Lea-Cox and Lichtenberg, 2013. HortTechnology 23:760-769

Irrigation Efficiency – Water Savings

Irrigation Water Applied: March – Nov, 2012 (*Cornus florida*)

Irrigation Method	Total Water Applied (Liters / Row)	Average Water Application (L / Tree /Day)	Av. Efficiency (Timed vs. Control)	Water Savings (Control vs. Timed)
Grower: Timed, Cyclic	109,794	3.49	0.371	2.69
Sensor: Set-point Control	40,769	1.30		

Irrigation water applications reduced between 40 and 70% depending upon species, site-specific variables and time of year

Belayneh, Lea-Cox and Lichtenberg, 2013. HortTechnology 23:760-769

Irrigation Efficiency – Return on Investment

Table 4. Water price comparisons and returns from changing timed cyclic irrigation into sensor-controlled irrigation.

Costs and benefits	Water price [per 1000 gal (3.785 m^3)][z]			
	$0.17	$1.00	$2.00	$3.00
Benefits	2.7 year ROI			4-month ROI
Pumping cost savings	$ 8,137	$46,944	$94,189	$141,283
Management cost savings	$12,150	$12,150	$12,150	$12,150
Annual savings	$ 20,288	$59,094	$106,339	$153,433
Costs				
Annualized sensor system cost	$14,205	$14,205	$14,025	$14,025
Annual maintenance	$ 1,000	$1,000	$1,000	$ 1,000
Total sensor system cost	$15,205	$15,205	$15,025	$15,025
Annual net savings	$ 5,263	$44,069	$91,313	$138,408

[z]Corresponding water prices = $55, $326, $652, and $978 per acre-foot; $1/acre foot = $8.1071/hectare-meter.

Belayneh, Lea-Cox and Lichtenberg, 2013. HortTechnology 23:760-769

Fungal Disease Management

Gardenia 'radicans' - high shrinkage due to crop death/unmarketable final product.

Reduction in Production Times, Net Benefits

- ✓ 14-month production cycle collapsed to 8-month
- ✓ 30% loss to Disease reduced to virtually zero
- ✓ Economic Gain = $1.06 / ft^2 (total net revenue = $20,700 for crop)
- ✓ ROI < 3 months for $6,000 network

Lichtenberg, Chappell et al., 2013 HortTechnology 23:770-776

Economic Analysis of Cut-flower Production

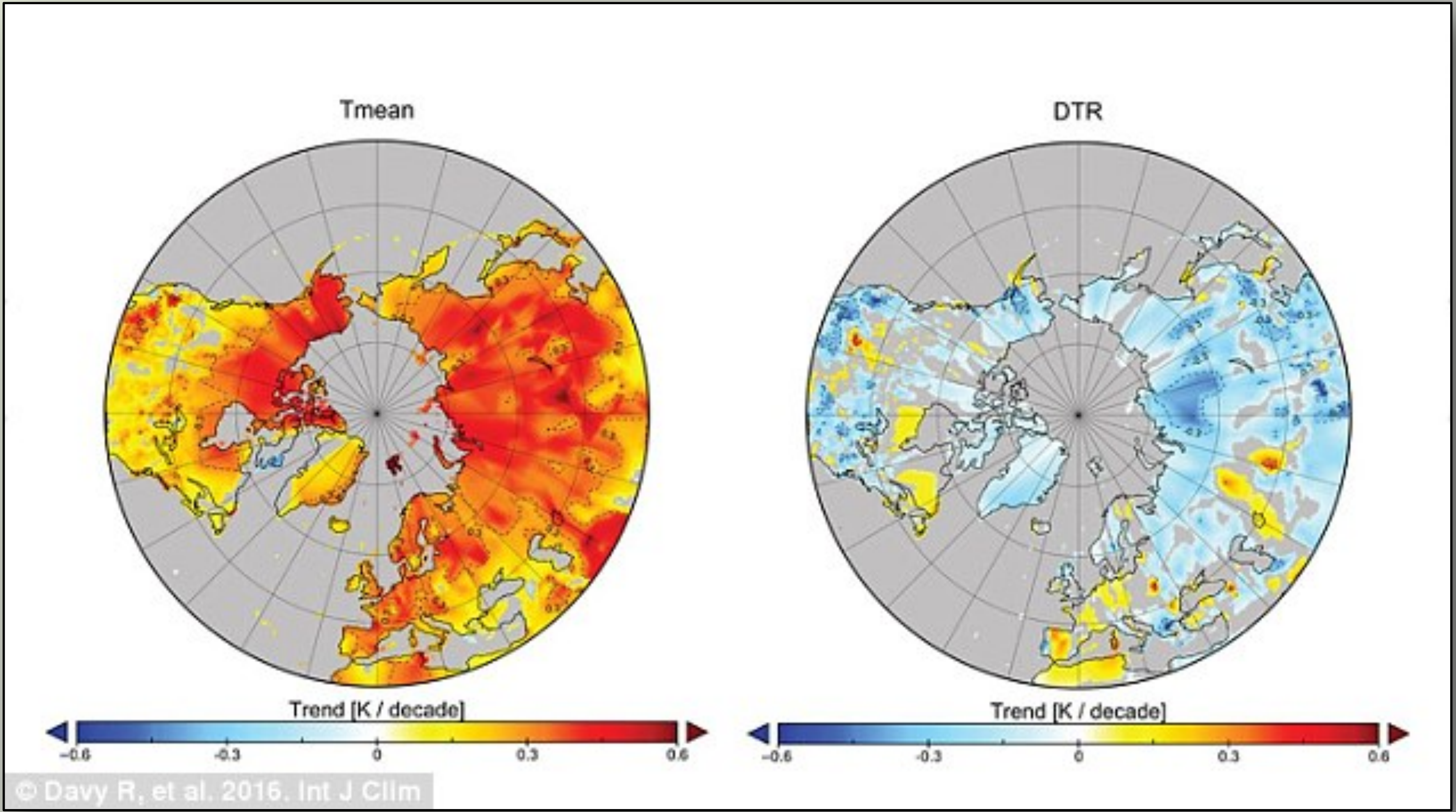
Pre-Sensor: (2007 – 2009) Post-Sensor: (2010 – 2012)

	2007 -2009	2010- 2012	Difference	Change
Crops/ year	37	38	1	1 %
Stems/ year	106,308	139,382	33,074	31 %
Price/ stem	$ 0.59	$ 0.62	$ 0.03	5 %
Labor costs	$ 15,905	$ 17,893	$ 1,988	12 %
Electricity	$ 4,109	$2,923	$ 1,186	-29 %
Sensor system	$ 0	$7,147	$ 7,147	---
Revenue	$63,094	$ 85,679	22,585	36 %
Profit	$43,080	$57,716	$14,636	34 %

Payback period on upfront costs: <16 months

Saavoss et al., 2016 Irr. Sci. 34:409-420

The Planetary Boundary Layer



Davey et al., 2016 Int. J. Clim.

The Planetary Boundary Layer

INTERNATIONAL
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RESEARCH ARTICLE

Diurnal asymmetry to the observed global warming

Richard Davy, Igor Esau, Alexander Chernokulsky, Stephen Outten,
Sergej Zilitinkevich

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ABSTRACT

The observed warming of the surface air temperature (SAT) over the last 50 years has not been homogenous. There are strong differences in the temperature changes both geographically and on different time frames. Here, we review the observed diurnal asymmetry in the global warming trend: the night-time temperatures have increased more rapidly than day-time temperatures. Several explanations for this asymmetric warming have been offered in the literature. These generally relate differences in the temperature trends to regionalized feedback effects, such as changes to cloud cover, precipitation or soil moisture. Here, we discuss a complementary mechanism through which the planetary boundary layer (PBL) modulates the SAT response to changes in the surface energy balance. This reciprocal relationship between

The Planetary Boundary Layer

PLANETARY BOUNDARY LAYER

According to climatologists, the reason for the rapid increase is a band of air close the ground, called the planetary boundary layer (PBL).

This thin layer of the Earth's atmosphere is distinct from the upper layers and changes in thickness over the course of the day-night cycle.

At night the solar radiation absorbed by the surface over the course of the day is released into space.

The researchers explain that as more carbon dioxide has been added to the atmosphere from man-made activities, such as burning fossil fuels, this has meant less heat escapes from the atmosphere at night, and the warmer atmosphere heats the thin PBL below.

Because the layer is so thin at night, the warming effect is much more pronounced, adding extra energy to the climate system

Agricultural Implications of Increased Night Temperatures

1. Increased respiration rates
   - Decrease in yield
   - Decrease in food quality

2. Disruptions in pollination, fruit set

3. Increase in soil temperatures, microbial respiration rates, decrease in organic matter content

4. Increase in relative humidity, fungal disease

5. Increased weed pressure

6. Increased number of pest life cycles

Wolfe et al., 2018 Climatic Change 146: 231-245

On-farm Weather Station

DS-2 Sonic Anemometer
Wind speed and direction

VP-4
Temp, RH, VPD,
Barometric Pressure

Pyranometer
Solar Radiation

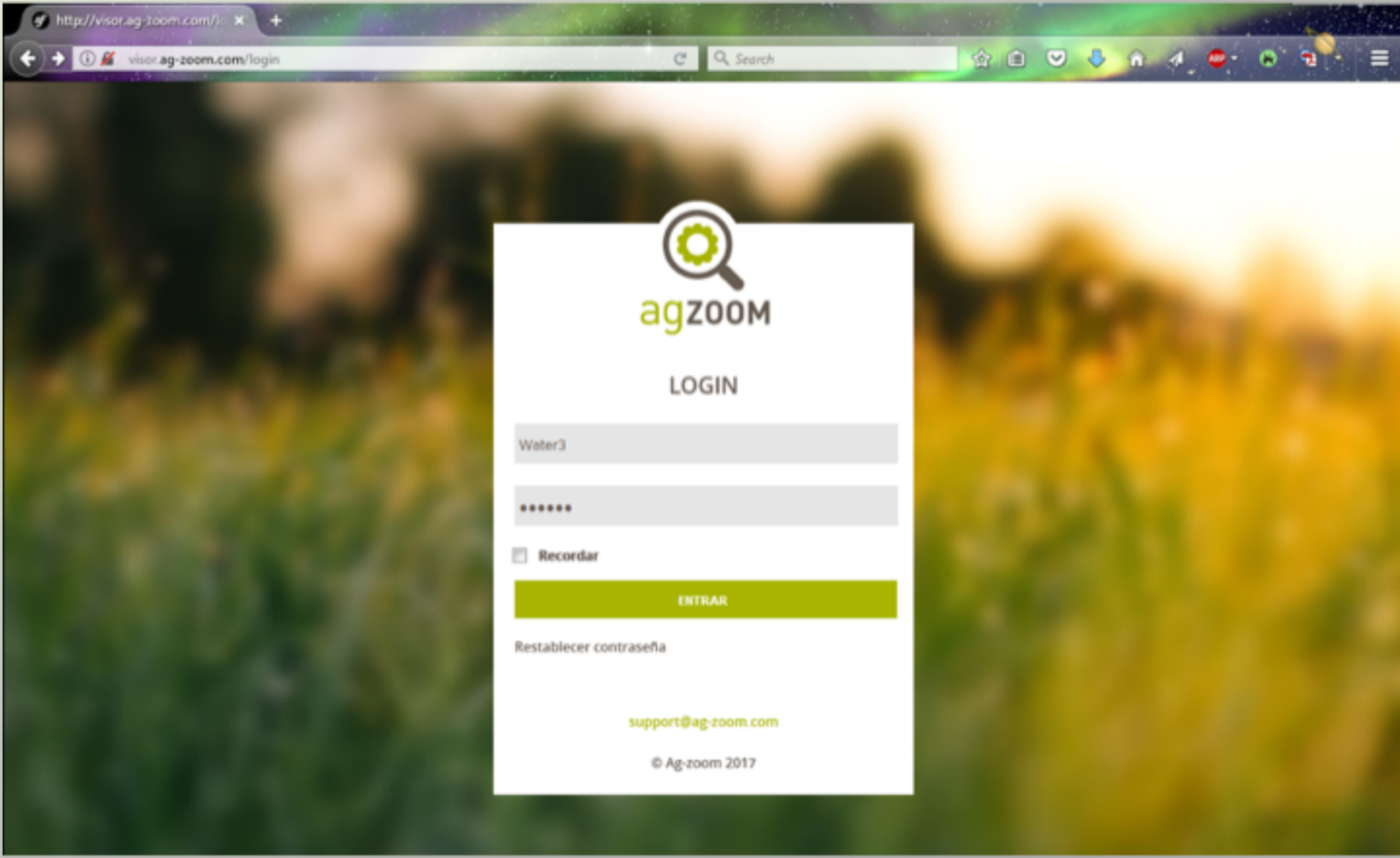
QSO-S PAR
PAR (visible light)

ECRN-100 Rain gauge
Precipitation

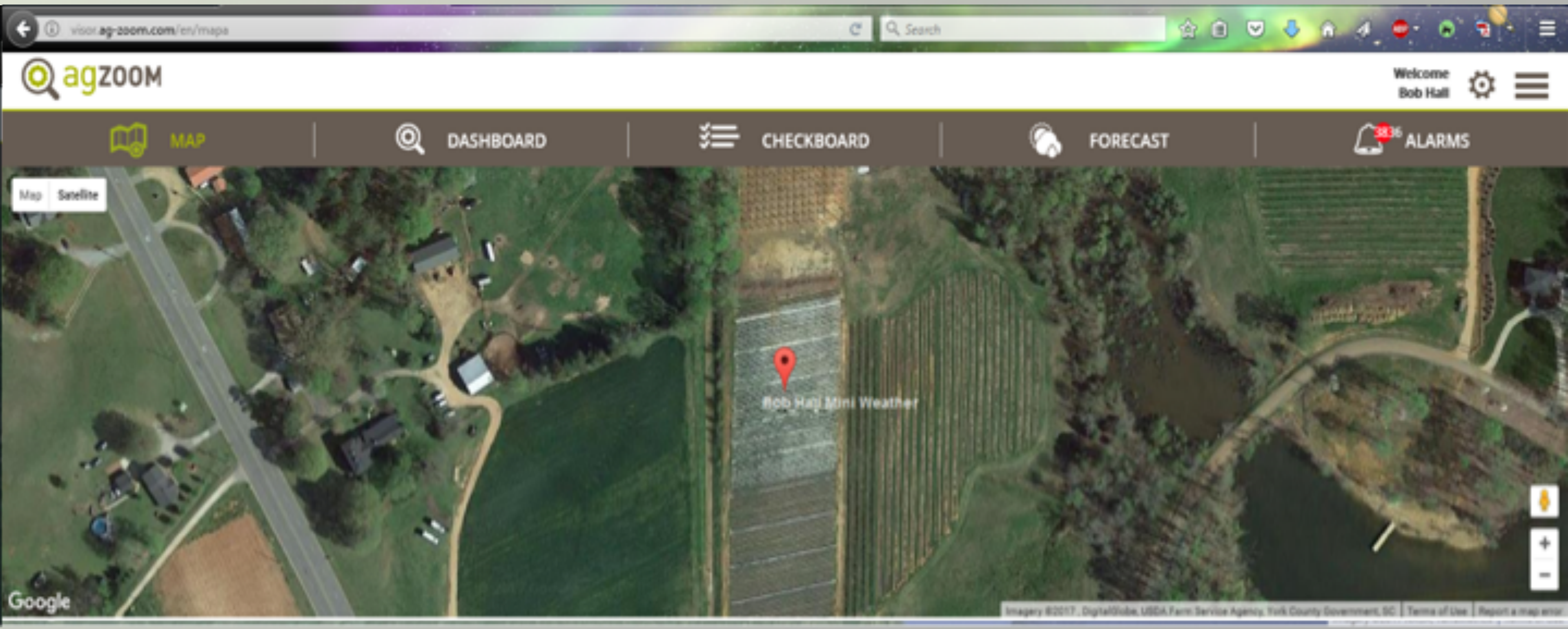
Em50G "cloud –based" data logger

3G Telemetry

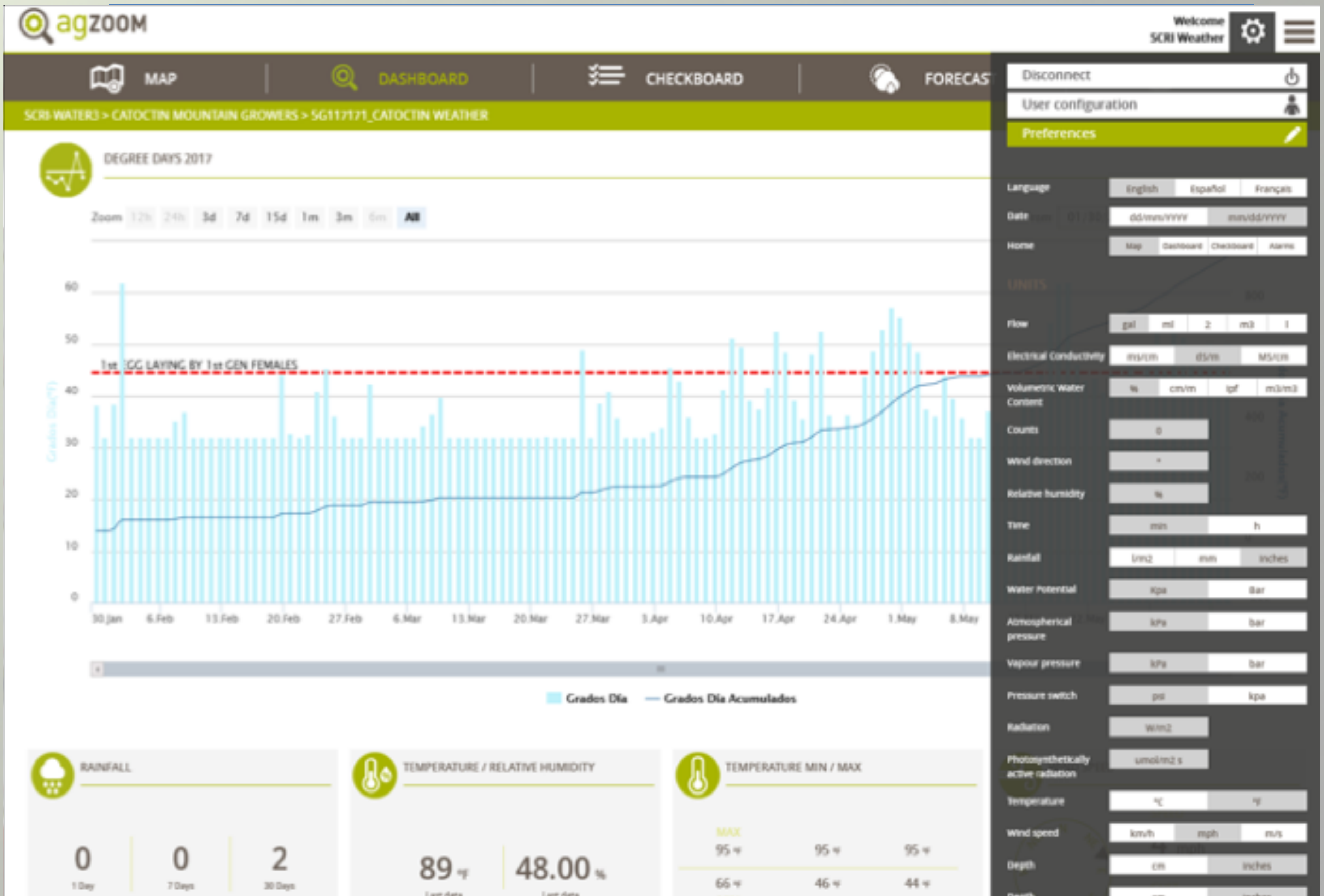
Cloud Software Capabilities: AgZoom



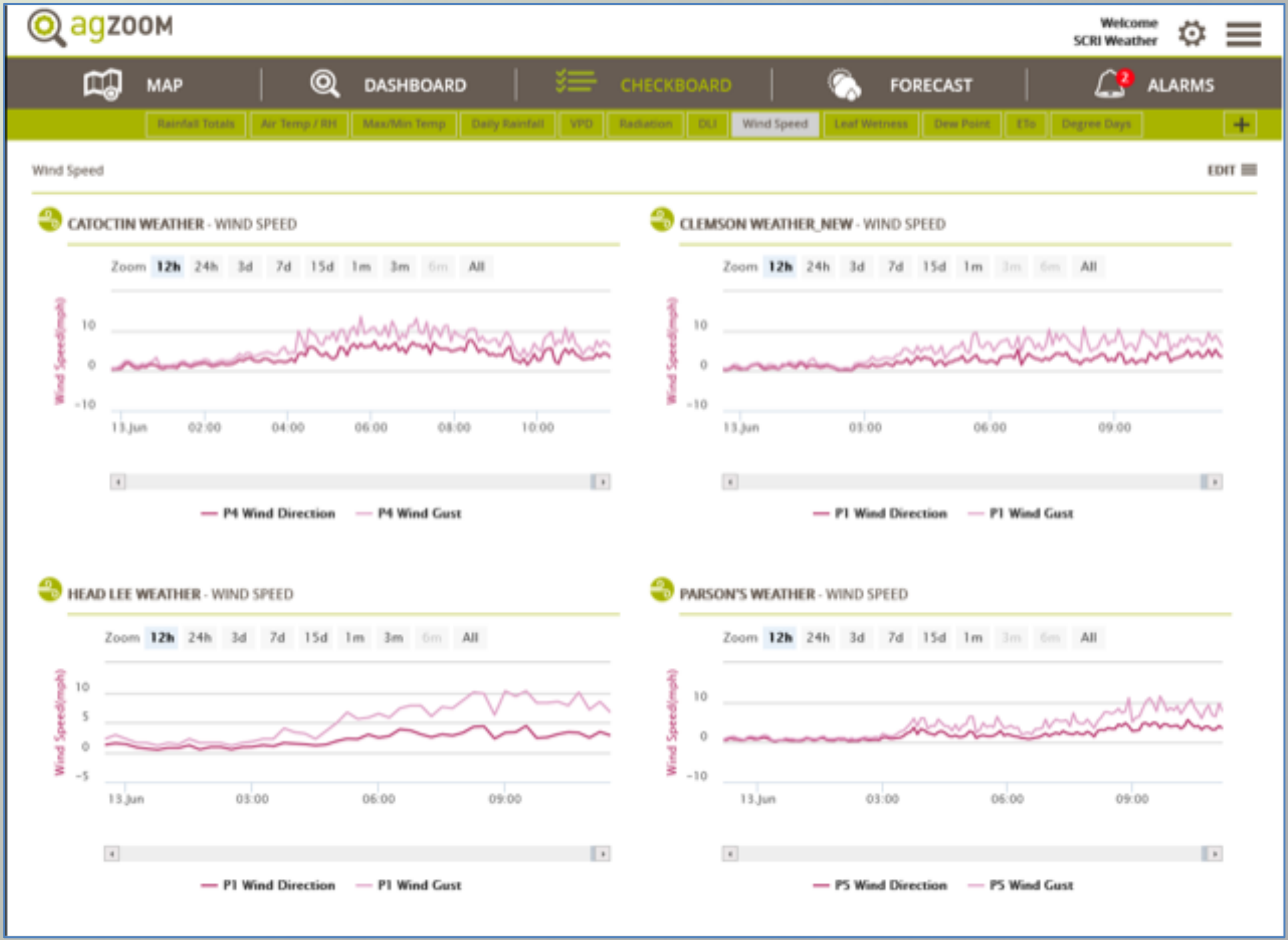
Geolocation of Cloud Dataloggers



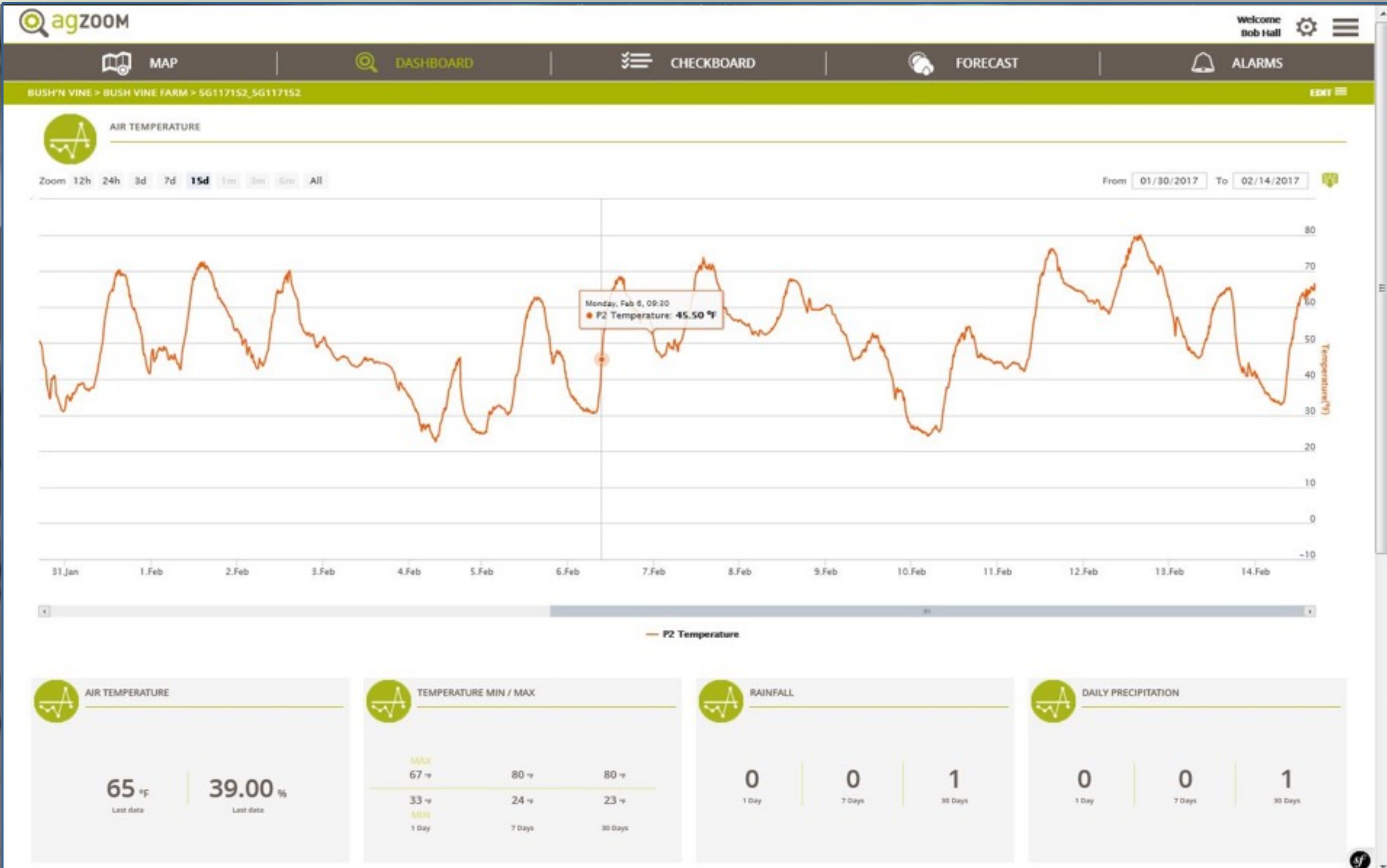
Dashboard – Single Node Data



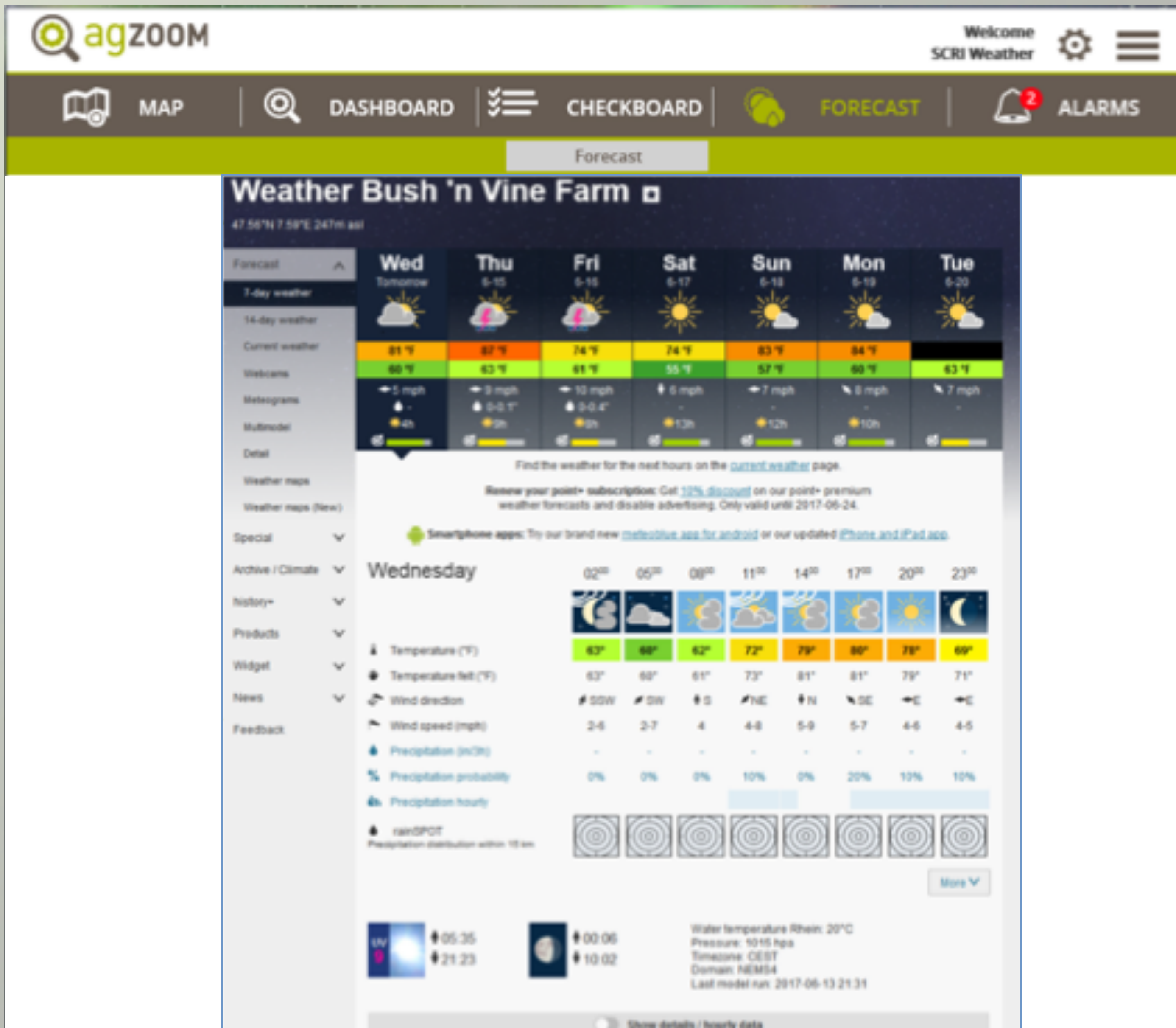
Checkboard – Aggregate Data



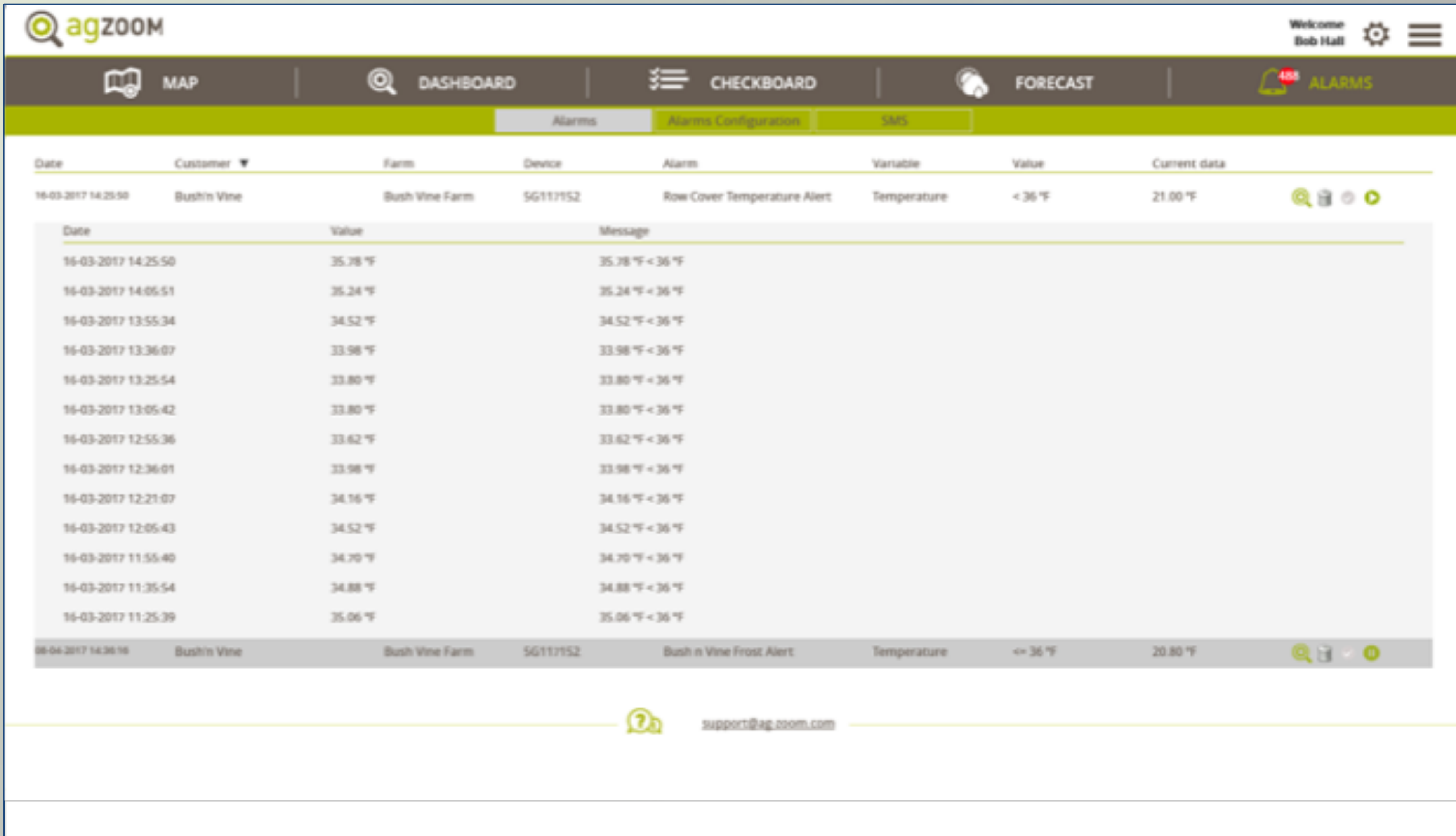
AgZoom Software



Geolocated 7-Day Weather Forecast



AgZoom – Alert Capability



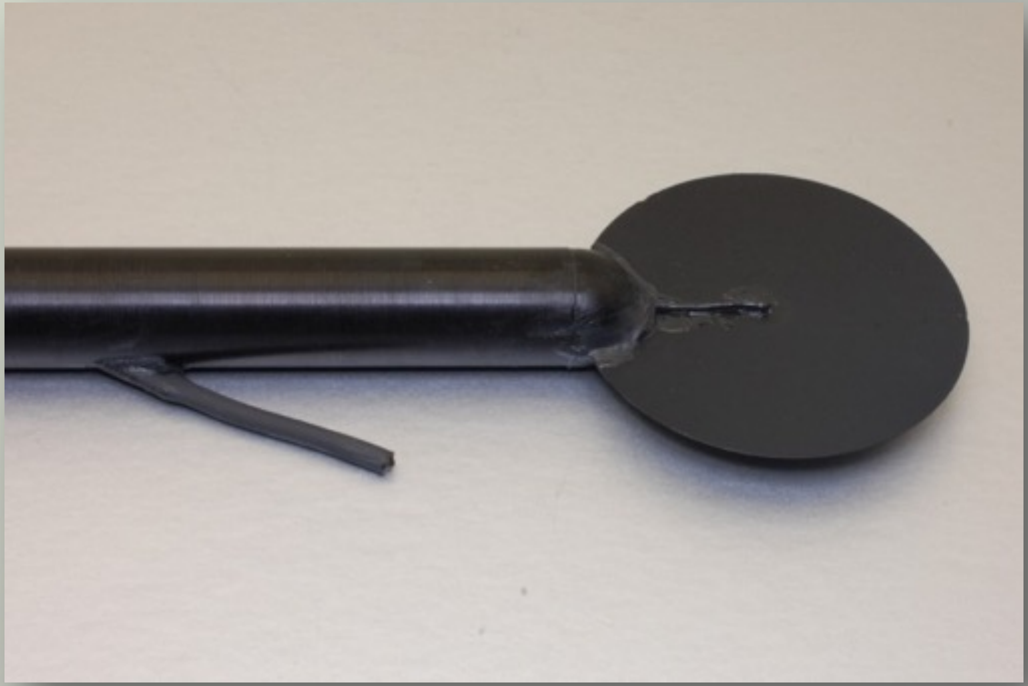
Frost Monitoring

→ Current frost prediction tool - Sky-Bit (Satellite data)

→ Air temperature is not a reliable predictor of frost events

→ Canopy temperature should be measured

→ Radiative frost: CT << AT on clear and calm nights



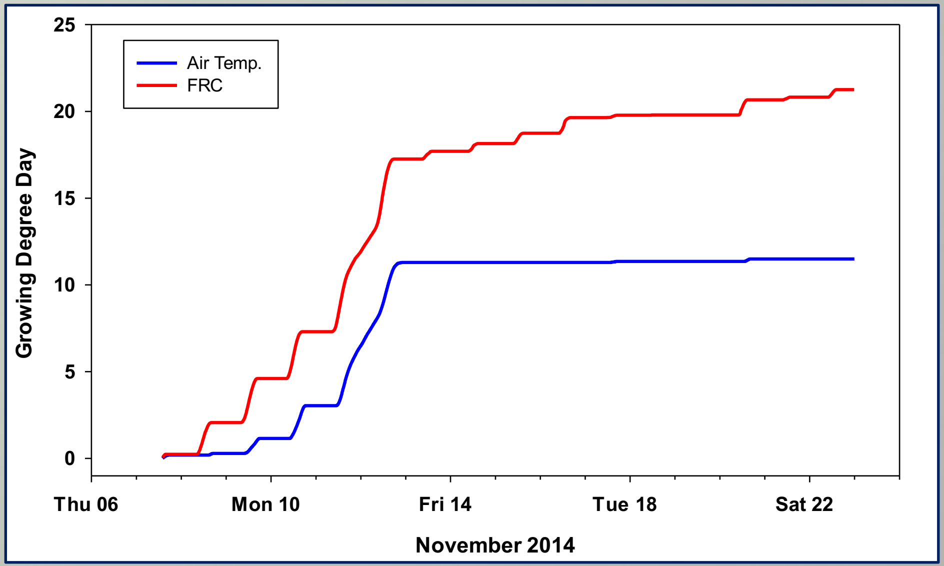
Apogee SF-110 Radiation Frost Sensor

- 2 precision thermistors
- Mimic plant leaf and flower bud
- Measurement Range: -50 to 70 °C
- Accuracy: ± 0.1 to ± 0.4 °C

Radiative Frost Sensor

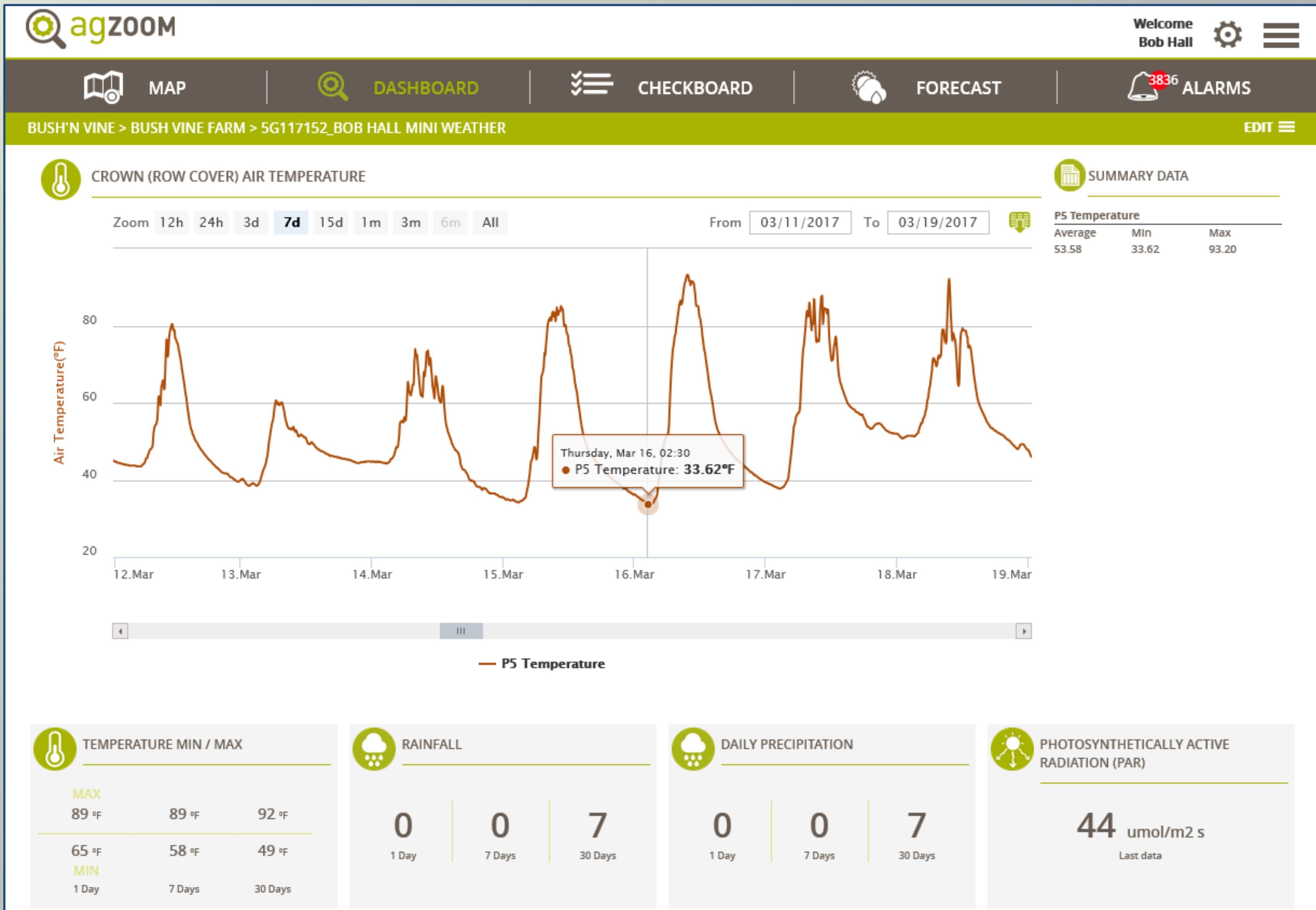
Flower bud and leaf thermistors (indicated with red arrows) on the SF-110 radiation frost sensor deployed within the plant canopy at Shlagel Farms

Floating Row Cover Use



Growing degree day (GDD) units recorded below and above floating row cover

Frost Events South Carolina – March 14-16, 2017



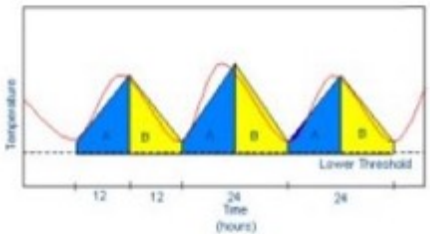
Predictive Tools for IPM, Disease Management

Agricultural Risk Management

Precision Farming is more than just GPS controlled harvesters. It also helps keeping track of pathogen development, optimize treatments to hit a disease dead on, warn of frost, and to produce as environmentally friendly as possible.

Growing Degree Days, Heat Units

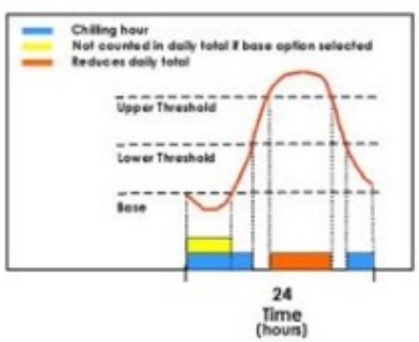
The growth and development of plants, insects, and many other invertebrate organisms is largely dependent on temperature.



In other words, a constant amount of thermal energy is required for the growth and development of many organisms, but the time period over which that thermal energy is accumulated can vary. Many organisms slow or stop their growth and development when temperatures are above or below threshold levels. The accumulation of thermal energy over time is known as degree-days or heat units. Degree-days and other heat unit measurements have been used for determination of planting dates, prediction of harvest dates, and selection of appropriate crop varieties.

Adcon's Heat Unit extension, which is part of our data visualization and distribution software addVANTAGE Pro, includes the most commonly used methods for calculating heat units. The user is able to create templates based on information found in published models. The templates can include the method of heat unit calculation and thresholds levels for alarms - crucial for precise management decisions.

Calculation methods | Cutoff method | Chilling Hours | User friendly model template | Download information

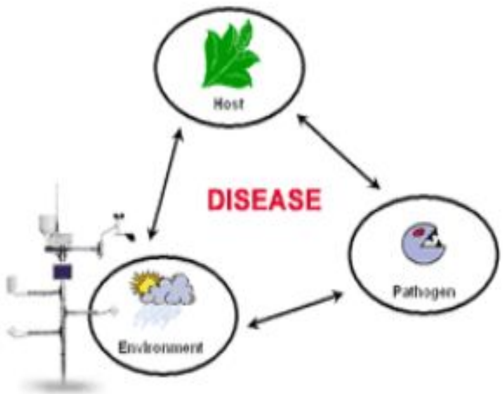


Chilling units values are used to predict several management factors. Fruit growers are the primary users of chilling hours. Decisions such as varietal selection, pruning, and other management factors related to potential yields can be aided by chilling hour calculations.

Agricultural Risk Management

Precision Farming is more than just GPS controlled harvesters. It also helps keeping track of pathogen development, optimize treatments to hit a disease dead on, warn of frost, and to produce as environmentally friendly as possible.

Decision Support



Plant disease initiation and development is a function of the interaction of several factors. That interaction is often referred to as the "Disease Triangle". Adcon Telemetry's plant disease risk assessments are based on the disease triangle. Adcon hardware (weather stations) in the field collects environmental data and delivers it to the receiver where it is available for processing by the addVANTAGE Pro software. The result is an up to date assessment of disease risk.

Treatment Recommendations | On-Time Treatments | **Model Validation** | Make better decision in many areas! | Download information

- Grape Bunch Rot
- Grape Downy Mildew
- Grape Downy Mildew V2.0
- Grape Powdery Mildew
- Heat Units
- Hops Downy Mildew
- Hops Powdery Mildew
- Lettuce Downy Mildew
- Main
- Maryblyt

Adcon Telemetry cooperates with leading academic, public sector, and industry researchers to validate the models incorporated into the addVANTAGE program. Adcon works actively as a partner in model validation to ensure that the models offered to our clients work well with Adcon hardware and software as well as being valid for specific areas and crops.

The screen shot to the left shows a short extract of the list of models that are available for addVANTAGE Pro, with more being added all the time.

Impacts

Synergistic Capabilities:

1. Precision Water and Nutrient Management
2. Timeliness of Decisions; Opportunity Costs
3. Intelligent Alerts
4. Better Predictive Capabilities

Can translate into Multiple Benefits:

1. Reduced Risk and Crop Losses
2. Reduction in Production Times
3. Increased Crop Yield and Quality

Project Information at http://smart-farms.net