

Hawk-Eye™ & EYAS Systems

Autonomously & Continuously, 24/7

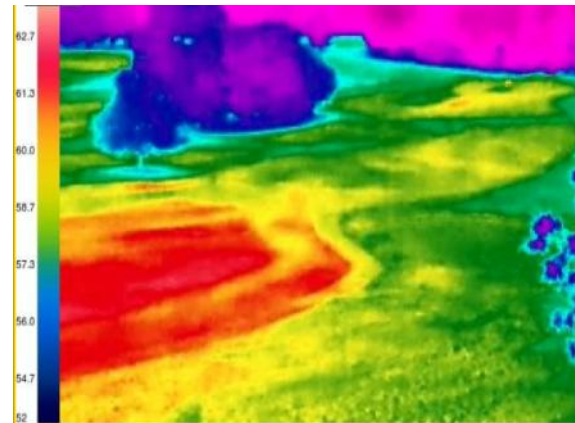
Visualizes and Measures Turf

Measures

Color



Temperature



Hawk-Eye™
Camera Set

EYAS
Camera Set

Computes

Heat & Stress Indices & Quality Indices

Reports Actionable Information in Real-Time

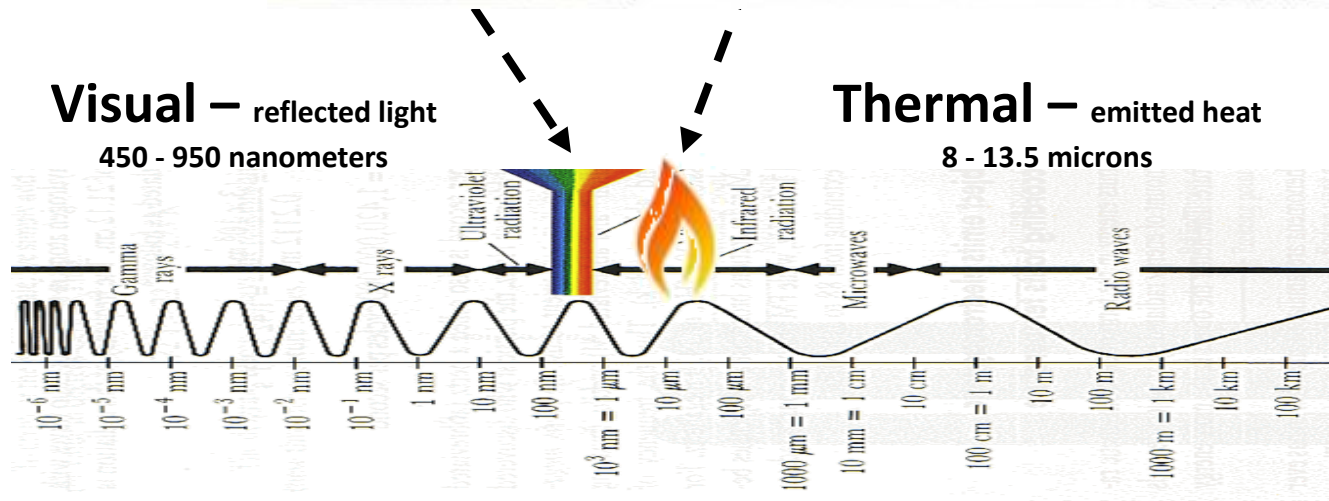
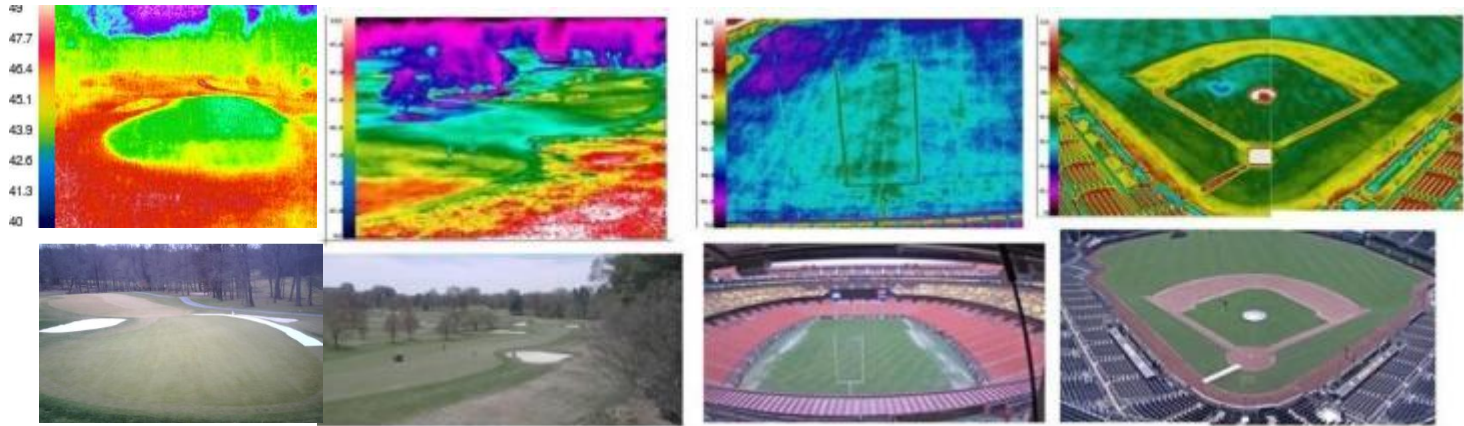
Jim Etro

CEO ItriCorp & Turf-Vu[®]

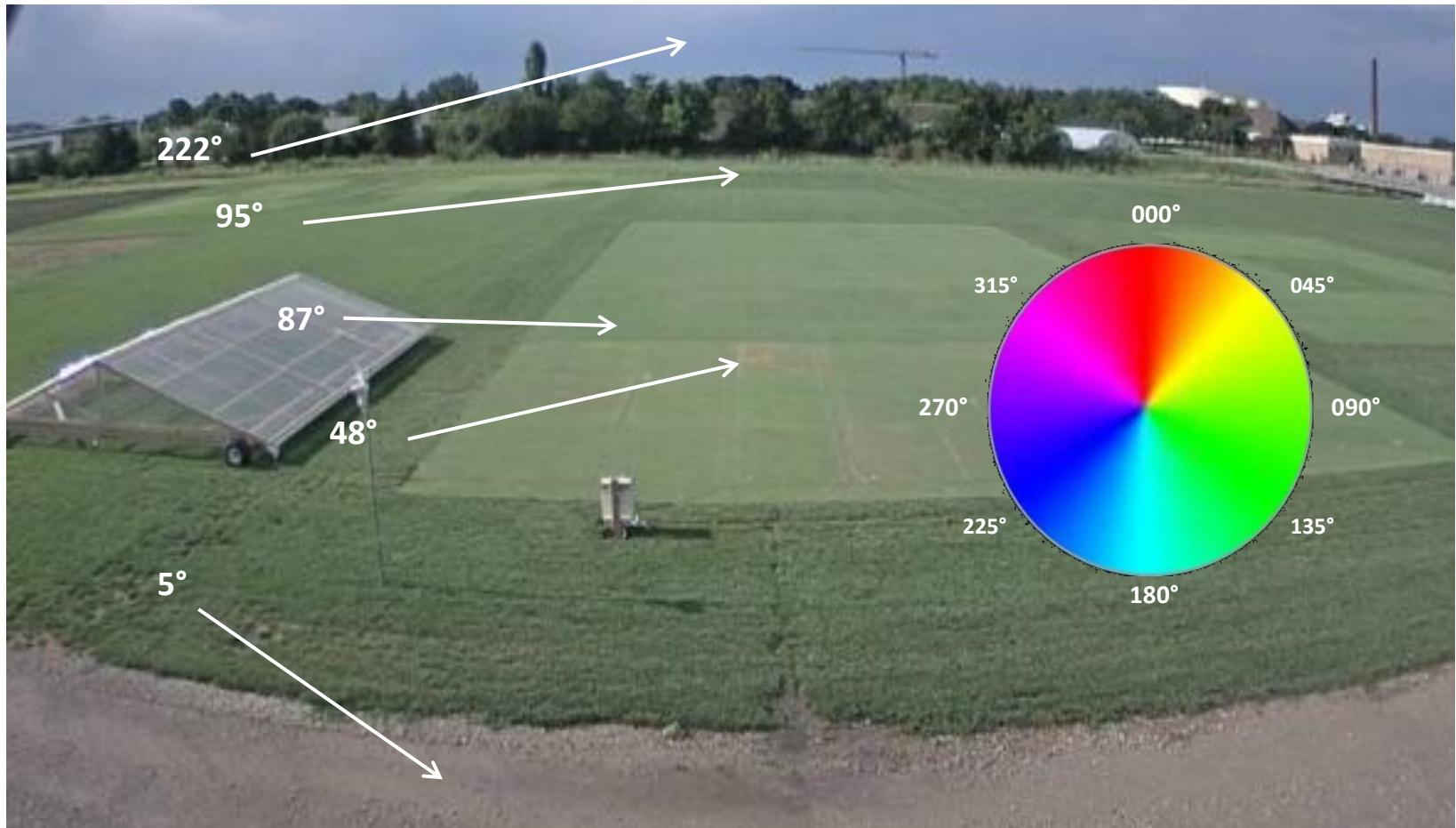
jim.etro@itricorp.com

www.itricorp.com

The Turf Imaging Spectrum



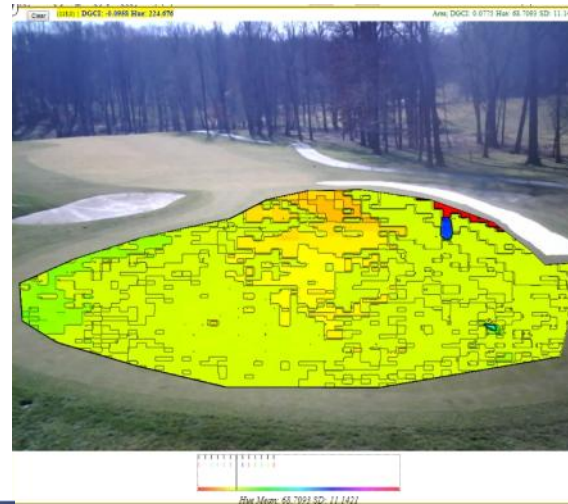
Hue/Color Measurement



Visual Image Data

Color & Uniformity (Std-Dev of Color) = QUALITY

Calculated every time step of image data



green, 40° - 160°



Uniformity of 'Green' Area

Hue:
SD: 6.6024
Mean: 68.6689
Skewness: 0.3086
Kurtosis: 16.2044

DGCI:
SD: 0.0247
Mean: 0.0774
Skewness: 0.4957
Kurtosis: 3.0626

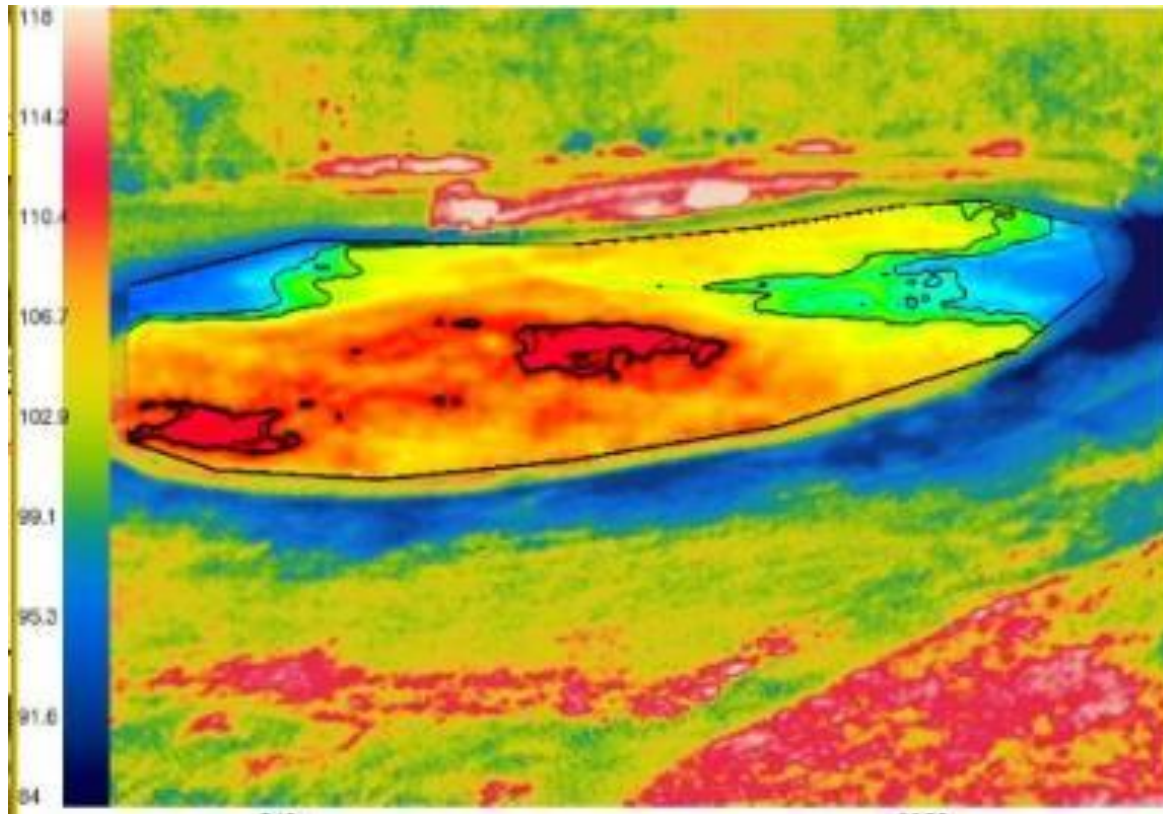
- 'Green' Area: Hue between 40 & 160
- Area Colorization:
 - Blue: Non-Green
 - Red: Hue Outlier +/- 2 SD
 - Yellow: DGCI Outlier +/- 2 SD
 - Aqua: Hue & DGCI Outlier
- Skewness:
 - For a normal distribution = zero, Symmetric data close to 0
 - Negative values skewed left (lower data values)
 - Positive values skewed right (higher data values)
 - Skewed right/left the tail is long relative to the other
- Kurtosis:
 - Normal distribution has a kurtosis of zero. (Excess Kurtosis +/-3)
 - Positive kurtosis indicates a 'heavy-tailed' distribution
 - Negative kurtosis indicates a 'light tailed' distribution

Thermal Image Data



Day and Night

Measuring Temperature Infers
Photosynthesis & Respiration & Evaporation



The measure of STRESS

Calculated every time step of image data

Temperature of the Canopy is a Function of:

Thermal @ Day

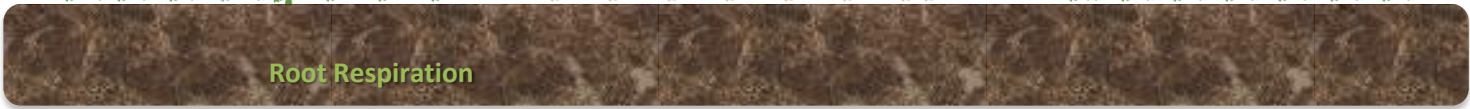
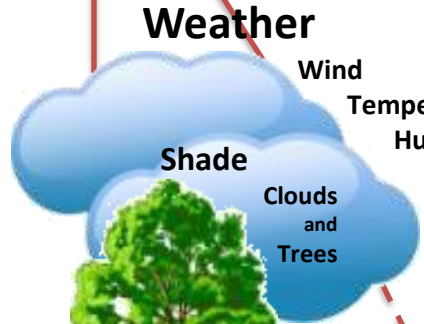
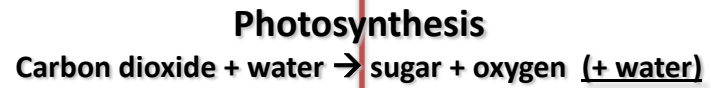


Air Temperature
Sunlight
 Absorbed, Reflected, Scattered, Shaded

Latent Heat of Vaporization
 Cooling effect during Transpiration

Energy Into System
 Sunlight Is used in Photosynthesis
 Ambient Air Temperature
 Heat from Respiration

Energy out of System
 Green Reflected
 Near-IR Scattered by Chlorophyll
 Far-IR (Heat) Emitted from Plant





Thermal[@] Night

Temperature of the Canopy is a Function of:



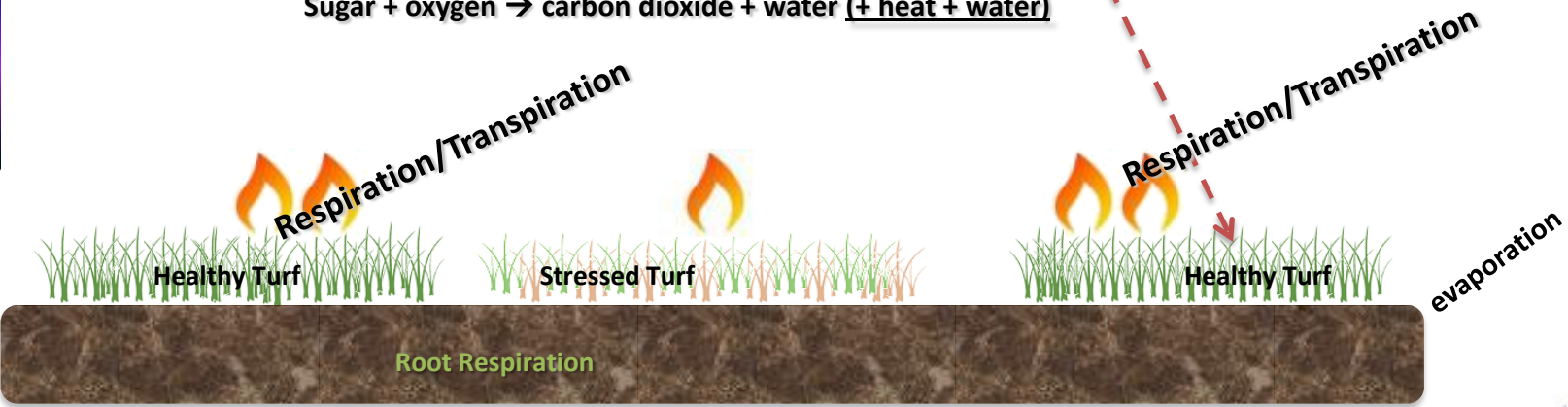
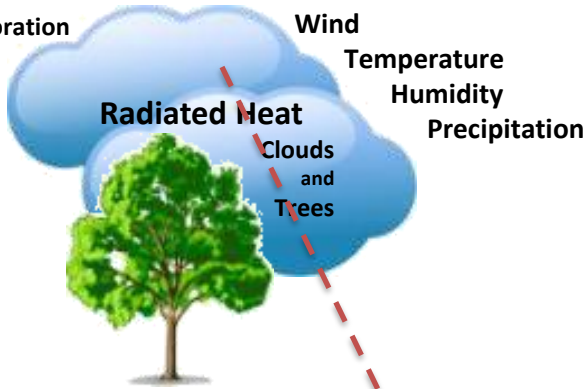
- Air & Soil Temperature
- Heat Released during Respiration
- Latent Heat of Vaporization
- Cooling effect during Respiration and Evaporation

- Energy Into System
- Ambient Air Temperature
- Radiated Heat
- Heat from Respiration

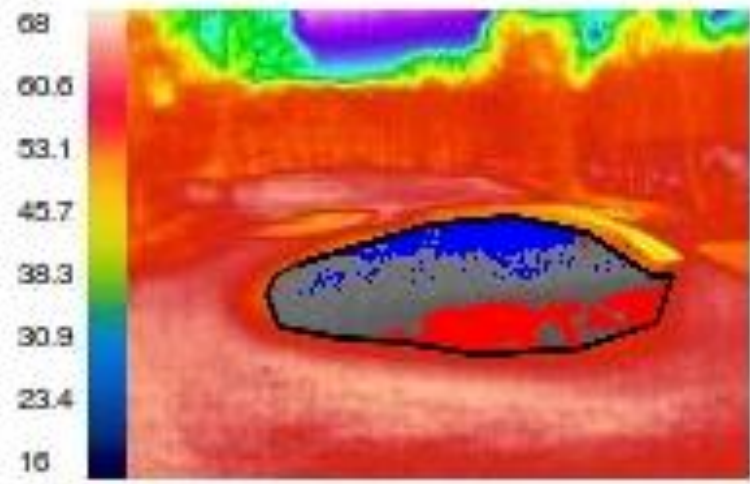
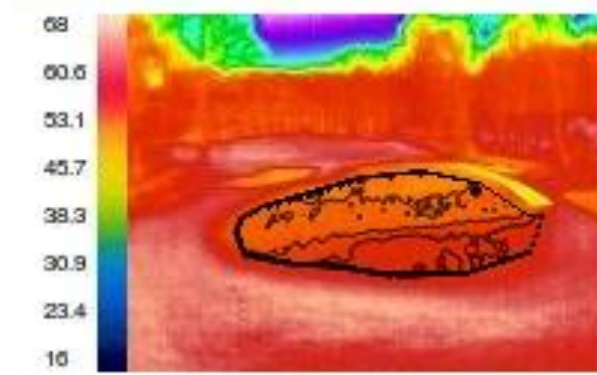
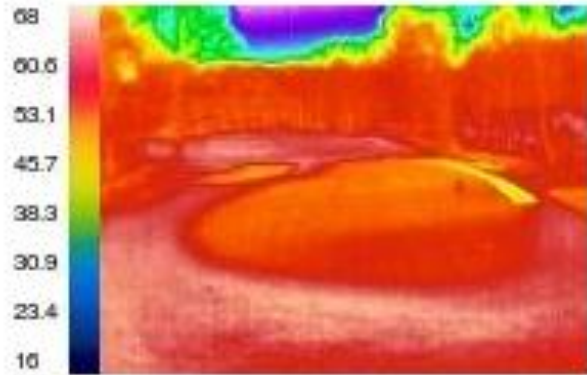
- Energy out of System
- Far-IR (Heat) Emitted from Plant



Weather



Thermal Image Data



Uniformity of Area Temperature:

SD: 1.5419
 Mean: 57.7964
 Skewness: 0.184
 Kurtosis: 1.6343

- Area Colorization:
 - Red: Temp High Outlier +1 SD
 - Blue: Temp Low Outlier -1 SD
- Skewness:
 - For a normal distribution = zero, Symmetric data close to 0
 - Negative values skewed left (lower data values)
 - Positive values skewed right (higher data values)
 - Skewed right/left the tail is long relative to the other
- Kurtosis:
 - Normal distribution has a kurtosis of zero. (Excess Kurtosis +/-3)
 - Positive kurtosis indicates a 'heavy-tailed' distribution
 - Negative kurtosis indicates a 'light tailed' distribution

Temperature and Stress

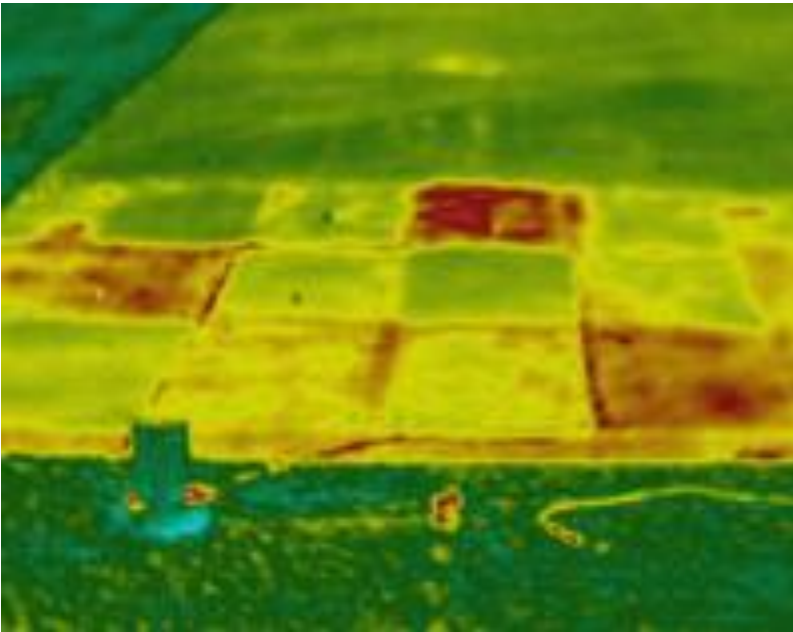
Stress is function of $\int (\Delta T_{[\text{canopy} \cdot \text{air}]}, T_{\text{CanopyLowerLimit}}, \& T_{\text{CanopyUpperLimit}})$

Image Stress between sunrise ==>thru ==> sunset

Daily Stress Average of daytime image stresses calculated every day at sunset

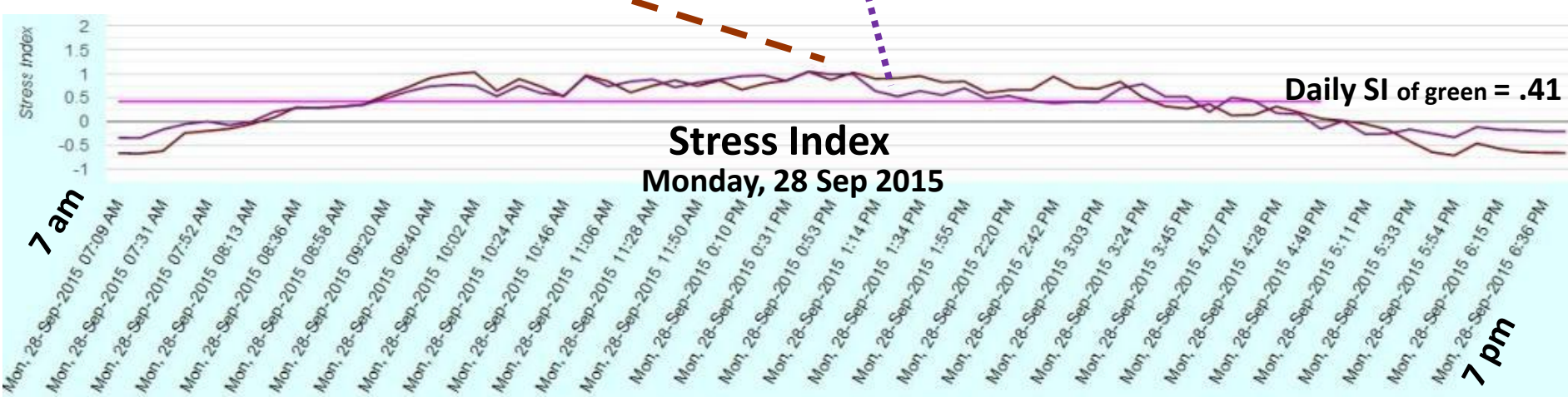
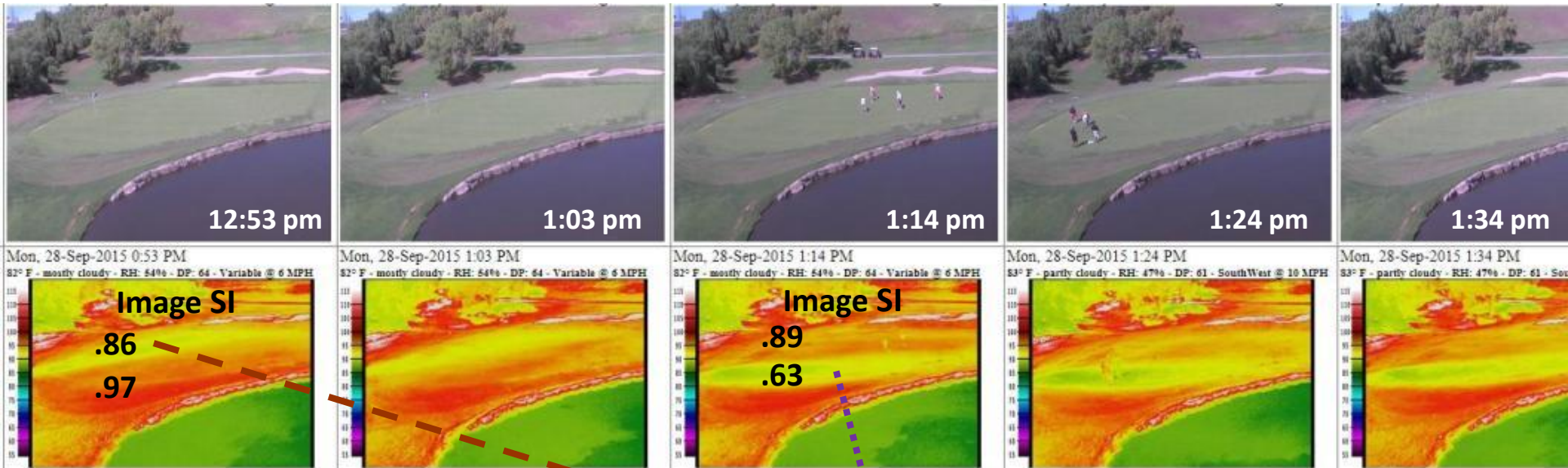
Daily Stress is used for irrigation guidance

1. Jackson RD, Idso SB, Reginato RJ, Pinter PJJ. 1981. Canopy temperature as a crop water stress indicator. *Water Resources Research* 17, 1133–1138
2. J. Miguel Costa, Olga M. Grant, M. Manuela Chaves, 2013. Thermography to explore plant–environment interactions. *Journal of Experimental Botany* doi:10.1093/jxb/ert029



<https://vimeo.com/177699460>

Stress Indexing (SI)



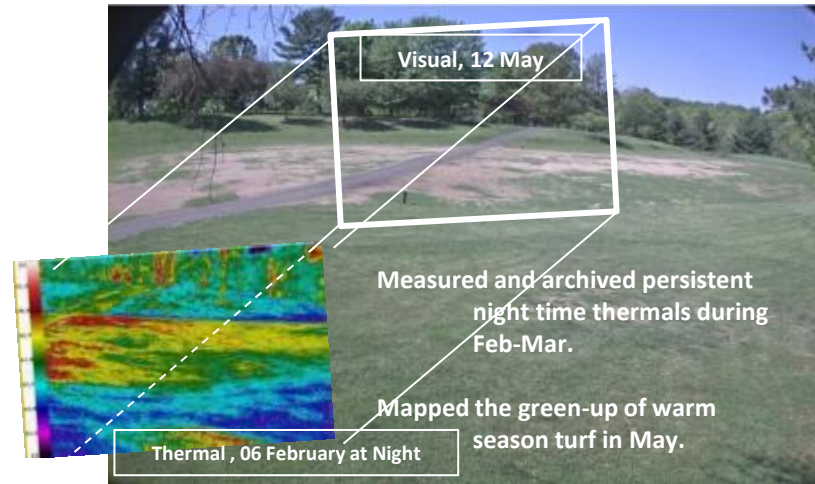
Watch Stress Change all Day: <https://vimeo.com/177699460>

Persistence is Important

The thermal character (stress) of the turf changes minute-to-minute.

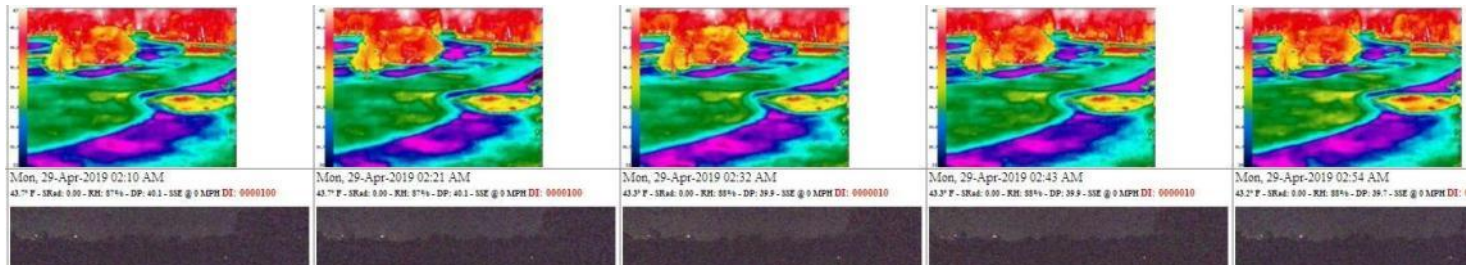
Daily, weekly, monthly snapshots are not representative of the character of the turf.

Persistence IDs Winterkill before green-up



<https://vimeo.com/269639967>

Persistence IDs points to where Drainage is Needed



<https://vimeo.com/34042902>

Snapshots are misleading

Hawk-Eye™ Systems



Hawk-Eye™
Camera Set

EYAS
Camera Set

Set it up.

Tell it what you want to know.

It is autonomously measuring the turf and the local weather.

It alerts you when the conditions you wanted to know about occurs.

Pattern Recognition for:

Evaluating drainage

Early ID of disease, pest, and water pressures

Alerts to:

Changes in color

Changes in uniformity

High canopy temperatures

High Stress events

Indices and Alerts to Guide:

Irrigation

Hydronics

Fans

Persistently, Autonomously

Day & Night

Day & Night

Real-Time Results 24/7

Thermal

Visual

Enhanced Visual

Visual

It's Data

Alert
Zone 2
Thinning
Canopy
Increasing
Yellow

Notice
Irrigate
Zone 3 = 2"

Alert
During last 30
minutes
Zone 2
Canopy = 36"

Listen to the turf.

Target labor and actuate irrigation and other precision equipment.

Hawk-Eye™ Lab



<https://hawkeye.itricorp.com/hawkeye/HawkEye.html?connect>

Account: demo
Password: demo

ItrI Corp Hawk-Eye™ Latest Site Images

Search Image Data Archive | Logoff | Set Alerts | Weather Sites

All Images Sized to 40% | Refresh Latest Images | Layout: Site Down/Time Across | Site Across/Time Down

RoD-Cntr - Plot01 Lab - Site Time: Tue, 26-Jan-2021 09:43 AM

Grid of images showing site conditions over time (e.g., Sun, 24-Jan-2021 05:41 PM to Sun, 24-Jan-2021 05:11 PM).

Forecast & Notifications: Tue, 26-Jan-2021 09:50 AM
Temp: 33°F | RH: 100% | DewPt: 34°F
Precip-Prob: 53% | WindSpd: 3 (MPH) | WindDir: 110°

Image Data and Site Weather

[-] Charts

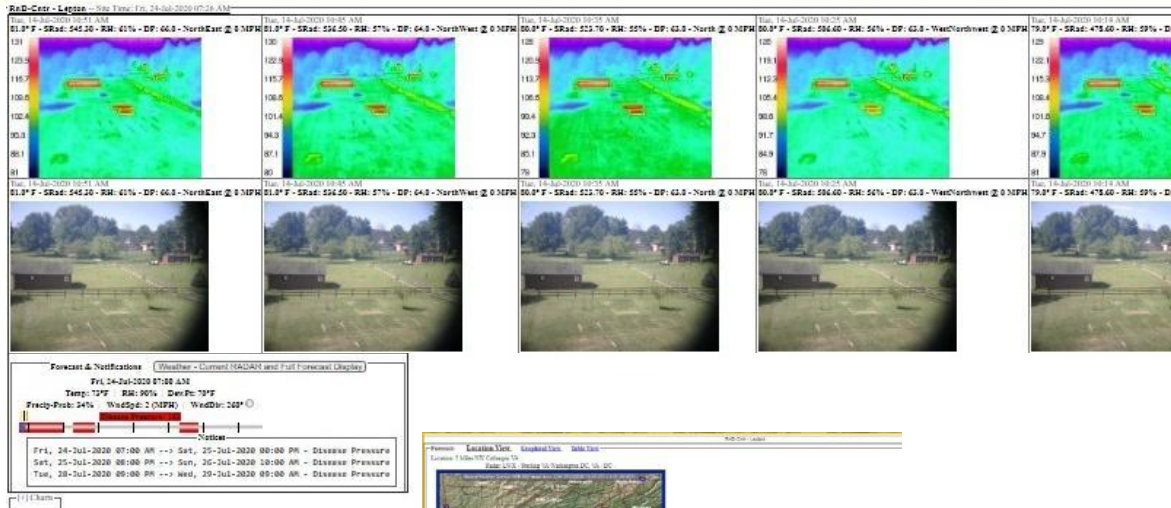
- RoD-Cntr-Plot01 Lab - Visual Image Hue: Bar chart showing hue values for various image timestamps.
- RoD-Cntr-Plot01 Lab - Image Region Temperature Ranges: Line graph showing temperature ranges for different image regions.
- RoD-Cntr-Plot01 Lab - Stress Indices: Line graph showing stress indices for different image regions.

Getting to Hawk-Eye[™] & EYAS Data

Opening Page - one Site

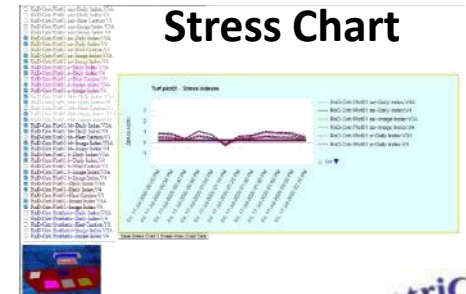
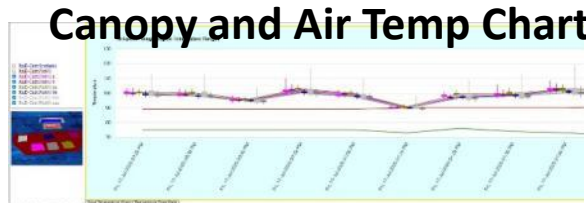
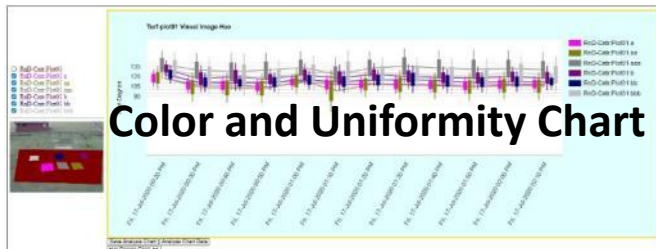
[Search Image Data Archive](#) [Logoff](#)
[Set Alerts](#)
[Weather Sites](#)

**Real-Time
Image Data
&
Weather**



**7 Day Weather & Disease Pressure Forecast,
Real-Time Radar**

+ Charts

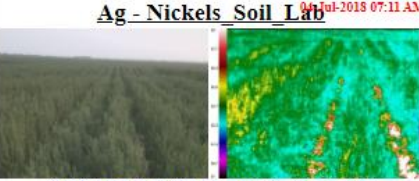
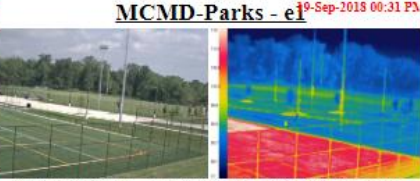
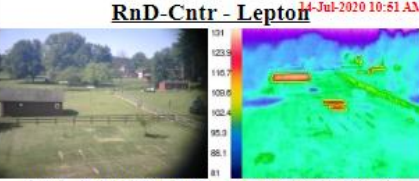
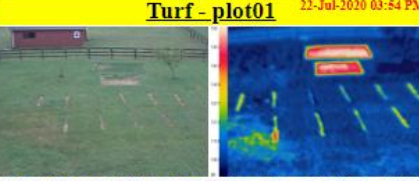
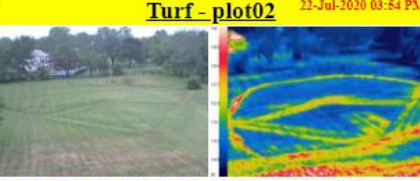
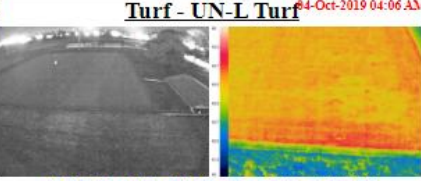
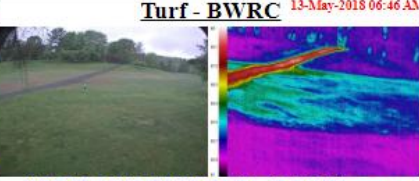
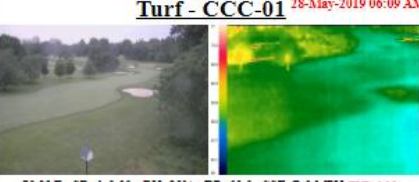
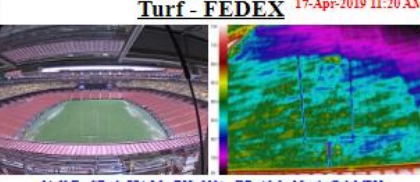
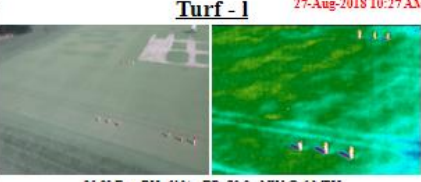
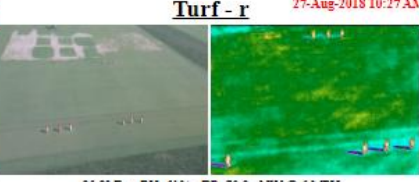


Opening Page – Multiple Locations


Hawk-Eye™
 Latest Site Images

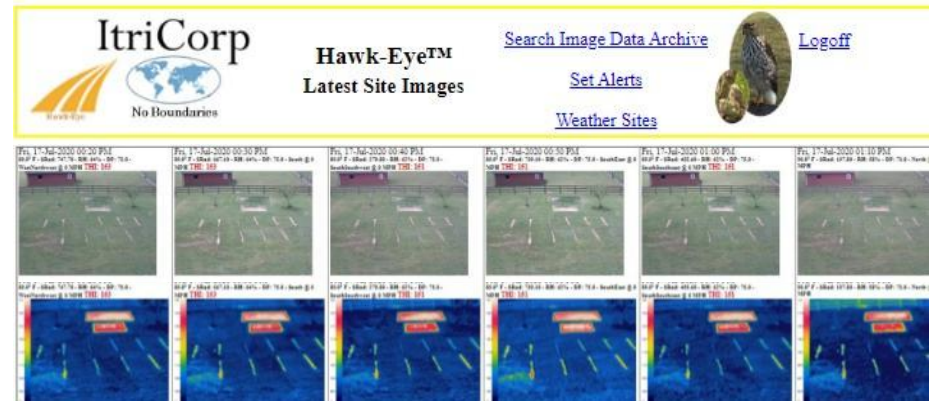
[Search Image Data Archive](#)
[Set Alerts](#)
[Weather Sites](#)



<p>Ag - Nickels_Soil_Lau 07-Jul-2018 07:11 AM</p>  <p>58.1° F - SRad: 75.48 - RH: 83% - DP: 53.1 - East @ 4 MPH</p>	<p>MCMD-Parks - e1 19-Sep-2018 00:31 PM</p>  <p>80.1° F - SRad: 97.50 - RH: 72% - DP: 70.2 - ESE @ 0 MPH THI: 152</p>	<p>MCMD-Parks - Laytonia No Images for Site!</p>	<p>RnD-Cntr - Lepton 14-Jul-2020 10:51 AM</p>  <p>81.0° F - SRad: 545.30 - RH: 61% - DP: 65.0 - NorthEast @ 0 MPH</p>
<p>Turf - plot01 22-Jul-2020 03:54 PM</p>  <p>72.0° F - SRad: 0.00 - RH: 99% - DP: 72.0 - SouthEast @ 0 MPH Precip: 0.14 THI: 171 DE: 16010000000</p>	<p>Turf - plot02 22-Jul-2020 03:54 PM</p>  <p>72.0° F - SRad: 0.00 - RH: 99% - DP: 72.0 - SouthEast @ 0 MPH Precip: 0.14 THI: 171 DE: 16010000000</p>	<p>Turf - UN-L Turf 04-Oct-2019 04:06 AM</p>  <p>44.6° F - SRad: 0.00 - RH: 96% - DP: 45.5 - North @ 2 MPH</p>	<p>Turf - BWRC 13-May-2018 06:46 AM</p>  <p>63.5° F - SRad: 33.57 - RH: 96% - DP: 62.4 - SE @ 0 MPH THI: 160</p>
<p>Turf - CCC-01 18-May-2019 06:09 AM</p>  <p>70.2° F - SRad: 0.00 - RH: 85% - DP: 65.5 - SSE @ 0 MPH THI: 155</p>	<p>Turf - FEDEX 17-Apr-2019 11:20 AM</p>  <p>64.6° F - SRad: 774.26 - RH: 50% - DP: 45.5 - North @ 1 MPH</p>	<p>Turf - l 27-Aug-2018 10:27 AM</p>  <p>85.8° F - RH: 61% - DP: 70.9 - NW @ 6 MPH</p>	<p>Turf - r 27-Aug-2018 10:27 AM</p>  <p>85.8° F - RH: 61% - DP: 70.9 - NW @ 6 MPH</p>

Setting-Up Measurements

1. Decide what area(s) you want to measure.
2. Select (click on) an image to put polygons in.
 Use thermal and visual to describe area(s).



3. Open the Area Selection Tool [...]
4. Select Draw by clicks
5. Draw your polygon
6. Save it with a short name

The screenshot shows the 'Area Selection' tool interface. The tool is set to 'Huescale' and 'Display Huescale Contour'. The 'Area Selection Path' is set to 'By Clicks'. A green polygon is drawn on the grass in the lower portion of the image. The tool's settings are visible on the left, and a data overlay shows coordinates and measurements like DGCI and Hue.

Setting Alerts

Opens Measurement Areas for Selection



Turf-plot01 - Temperature Area: RaD-Cntr-Plot01 a
Area Notification [Edit] [Remove]

To remove criteria clear "Trigger On" entry only.

Criteria [AND] (1)

Trigger On: Stress: Daily: V3A
When: Greater Than or Equal To
Value: 25
Average value is maintained for: 10 Minutes (Value Period) ?

Schedule
 Always Between (Time) Between (Solar)
(Not) Active between: [Sunset] -1 Hr and [Sunset] 0 Hr

Notify
j.etro@turf-vu.com, 7034889507@vtext.com
Don't re-notify for at least 600.00 Minutes
[a add: 25] [Enter a COMMENT replacing the default]

OK Close

Drop Down Menu for Alert Criteria

Turf-plot01 - Visual Area: RaD-Cntr-Plot01 aa
Area Notification [Edit] [Remove]

To remove criteria clear "Trigger On" entry only.

Criteria [AND] (2)

Trigger On: Hue - SD
When: Greater Than or Equal To
Value: 0
Average value is maintained for: 120 Minutes (Value Period) ?

Schedule
 Always Between (Time) Between (Solar)
(Not) Active between: [Solar Noon] 0 Hr and [Solar Noon] 2 Hr

Notify
j.etro@turf-vu.com
Don't re-notify for at least 600.00 Minutes
Plot01 aa Uniformity and Color [Enter a COMMENT replacing the default]

OK Close

Alerts are Set

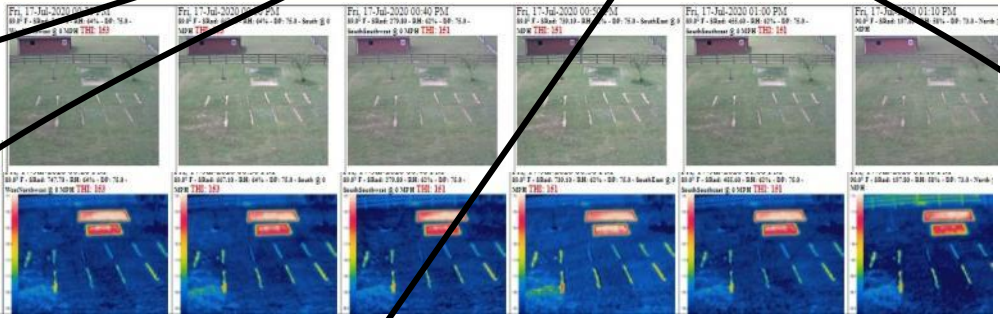
Visual - RaD-Cntr:1-aa [Add]										
	Trigger On	When	Value	Value Period	Schedule	Notify	Re-Notify Threshold	Notify Subject	Notify Comment	Last Notificat
Edit	Hue - SD	Greater Than or Equal To	0	120 min	Between Solar Noon and Solar Noon +2 hr.	j.etro@turf-vu.com	600.00 Min.	Plot 1-aa Lepton Uniformity and Color		Mon, 29-Jun-2020 (
	Hue - Avg	Greater Than or Equal To	20	120 min						
Visual - RaD-Cntr:1-bb [Add]										
	Trigger On	When	Value	Value Period	Schedule	Notify	Re-Notify Threshold	Notify Subject	Notify Comment	Last Notifica
Edit	Hue - SD	Greater Than or Equal To	0	120 min	Between Solar Noon and Solar Noon +2 hr.	j.etro@turf-vu.com	600.00 Min.	Plot 1-bb Lepton Uniformity and Color		Mon, 29-Jun-2020 (
	Hue - Avg	Greater Than or Equal To	20	120 min						
Visual - RaD-Cntr:Plot01 [Add]										
	Trigger On	When	Value	Value Period	Schedule	Notify	Re-Notify Threshold	Notify Subject	Notify Comment	Last Notificati
Edit	Hue - SD	Greater Than or Equal To	0	120 min	Between Solar Noon and Solar Noon +2 hr.	j.etro@turf-vu.com	600.00 Min.	Plot 01 Lepton Uniformity and Color		Mon, 29-Jun-2020 01
	Hue - Avg	Greater Than or Equal To	20	120 min						

Alerts go to phone(s) and/or e-mail(s)



You can go to the archive.

- If areas were set, all the measurements in the designated areas will be there.
- If no areas were set the image data and corresponding weather data will be there.



Location	Date	Time	Weather
Turf - plot01	Tue, 19-Sep-2017	11:39 AM	US Eastern
Turf - plot01	Tue, 19-Sep-2017	11:39 AM	Wed, 22-Jul-2020 03:34 PM
Turf - BWRG	Thu, 11-Jan-2018	06:19 AM	Sun, 13-May-2018 06:46 AM
Turf - CCC-01	Tue, 12-Mar-2019	06:23 AM	Tue, 28-May-2019 06:09 AM
Turf - CCC-02	Thu, 14-Jun-2019	09:59 PM	Sat, 23-May-2019 03:04 PM
Turf - CCC-03	Tue, 19-Mar-2019	07:44 AM	Sat, 25-May-2019 03:04 PM
Turf - FEDEX	Sat, 06-Apr-2019	06:32 AM	Sat, 25-May-2019 03:04 PM
Turf - left	Wed, 07-Jul-2017	10:03 AM	Fri, 24-Aug-2017 03:01 PM
Turf - right	Wed, 07-Jul-2017	10:03 AM	Fri, 24-Aug-2017 03:01 PM
Turf - UNL Turf	Mon, 02-Sep-2018	11:39 AM	Fri, 04-Dec-2018 4:06 AM
Turf - UNL Turf02	Wed, 02-Oct-2018	03:19 PM	Tue, 17-Dec-2018 07:47 AM
Turf - UNL UNGA Green	Fri, 14-Apr-2017	03:04 AM	Tue, 03-Jul-2017 03:04 PM

Image Selection: Show Time in archive - Use Site Location

Image Type: Temperature Visual

Date Range: Min: Max:

Time Range: and

Closest (after) or Between: After Before and After Before

Return Analysis Details Only (no images)

(Source) -

Weather Selection:

Temperature (F) at or between: and

Sky: Clear Mostly clear Partly cloudy Mostly cloudy Overcast Clouded

Relative Humidity (%) at or between: and

Dew Point (F) at or between: and

Wind Speed (MPH) at or between: and

Wind Direction: North East South West Variable

[-] RaD-Ctr-Lepton

Site Notifications

Image Area Notifications:

- Temperature - RaD-Ctr:center - (Area Analysis Ind. Switched Off)
- Temperature - RaD-Ctr:plot01 - (Area Analysis Ind. Switched Off)
- Temperature - RaD-Ctr:plot01 a0 - (Area Analysis Ind. Switched Off)
- Temperature - RaD-Ctr:plot01 na0 - (Area Analysis Ind. Switched Off)
- Temperature - RaD-Ctr:plot01 bb0 - (Area Analysis Ind. Switched Off)
- Temperature - RaD-Ctr:Synthetic - (Area Analysis Ind. Switched Off)
- Temperature - RaD-Ctr:Synthetic Lepton1
- Temperature - RaD-Ctr:Synthetic Lepton2
- Temperature - RaD-Ctr:test cold - (Area Analysis Ind. Switched Off)
- Temperature - RaD-Ctr:test right - (Area Analysis Ind. Switched Off)
- Temperature - RaD-Ctr:stress right - (Area Analysis Ind. Switched Off)
- Visual - RaD-Ctr:l-aa - (Area Analysis Ind. Switched Off)
- Visual - RaD-Ctr:l-bb - (Area Analysis Ind. Switched Off)
- Visual - RaD-Ctr:Plot01 - (Area Analysis Ind. Switched Off)
- Visual - RaD-Ctr:stress left - (Area Analysis Ind. Switched Off)

You can set up alerts for your designated measurement areas.

Using Archive

[-] Search Criteria

Site Selection

Site	Min Date-Time	Max Date-Time	Timezone
<input type="radio"/> Ag - Nickels_Soil_Lab	Fri, 03-Jul-2018 05:01 PM	Wed, 04-Jul-2018 07:11 AM	US/Pacific
<input type="radio"/> MCMC-D-Parks - e1	Thu, 23-Sep-2018 07:54 AM	Wed, 19-Sep-2018 00:31 PM	US/Eastern
<input type="radio"/> RnD-Cntr - Lepton	Wed, 05-Feb-2020 11:09 AM	Tue, 14-Jul-2020 10:51 AM	US/Eastern
<input checked="" type="radio"/> Turf - plot01	Tue, 19-Sep-2017 11:59 AM	Wed, 22-Jul-2020 03:54 PM	US/Eastern
<input type="radio"/> Turf - plot02	Tue, 19-Sep-2017 11:59 AM	Wed, 22-Jul-2020 03:54 PM	US/Eastern
<input type="radio"/> Turf - UN-L Turf	Mon, 04-Jun-2018 11:29 AM	Fri, 04-Oct-2019 04:06 AM	US/Central
<input type="radio"/> Turf - BWRC	Thu, 11-Jan-2018 06:19 AM	Sun, 13-May-2018 06:46 AM	US/Eastern
<input type="radio"/> Turf - CCC-01	Tue, 12-Mar-2019 06:25 AM	Tue, 28-May-2019 06:09 AM	US/Eastern
<input type="radio"/> Turf - FEDEX	Sat, 06-Apr-2019 06:32 AM	Wed, 17-Apr-2019 11:20 AM	US/Eastern
<input type="radio"/> Turf - 1	Fri, 24-Aug-2018 03:36 PM	Mon, 27-Aug-2018 10:27 AM	US/Central
<input type="radio"/> Turf - r	Fri, 24-Aug-2018 03:36 PM	Mon, 27-Aug-2018 10:27 AM	US/Central

Select the Site

Get Results
Image Data, Charts, and/or Download CSV Data Files

Image Selection (Date Time is relative to the site timezone)

Image Type: Temperature Visual

Date Range: Min. Tue, 19-Sep-2017 and Wed, 22-Jul-2020

On Between Through

Time Range:

Closest (after) or Between:

AM PM and or AM PM

+/- Hrs from Solar Noon

Hrs. (-) < Solar Noon (+) Hrs.

Return Analysis Datafile Only (no images)

Search - Result Layout: Time Across - Time Down

Put in Search Criteria
Day(s)/Time Ranges

[-] Weather Selection

Temperature (F) at or between and

Sky: clear mostly clear mostly cloudy overcast

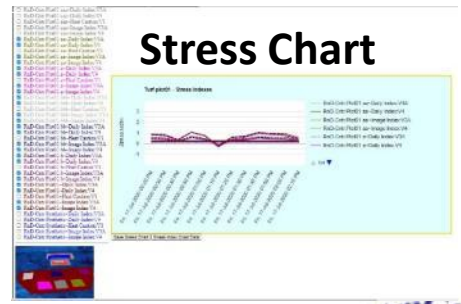
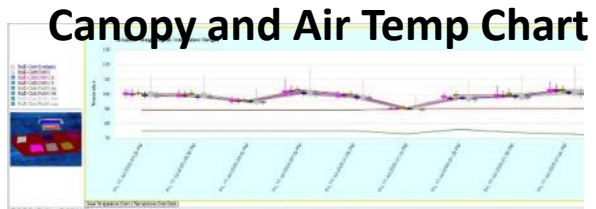
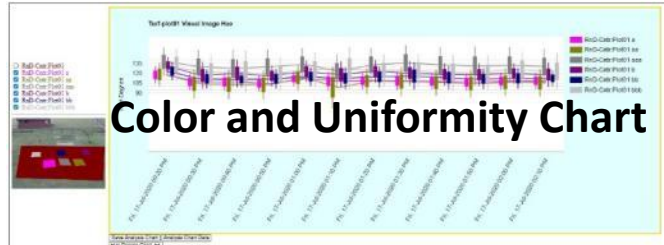
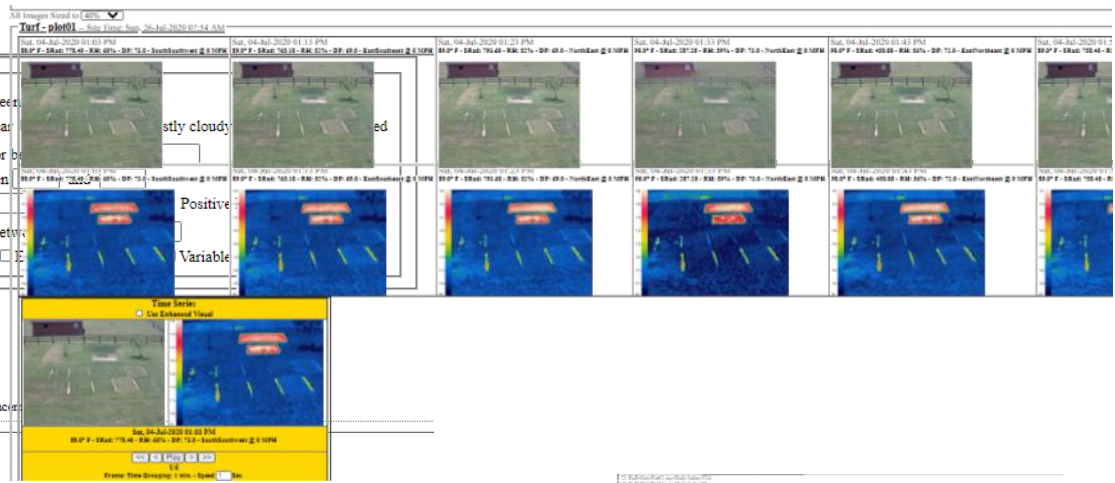
Humidity (%) at or between and

Dew Point (F) at or between and

TH-Index at or between and

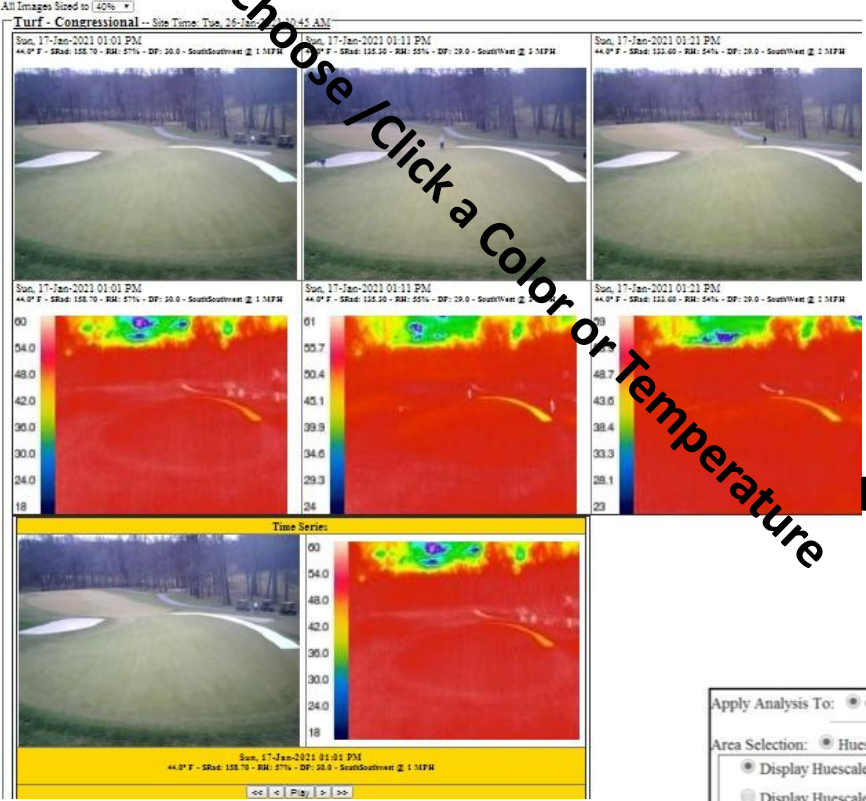
Wind Speed (MPH) at or between and

Wind Direction: North East South West



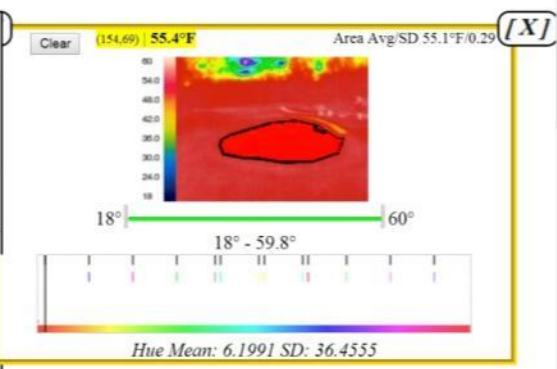
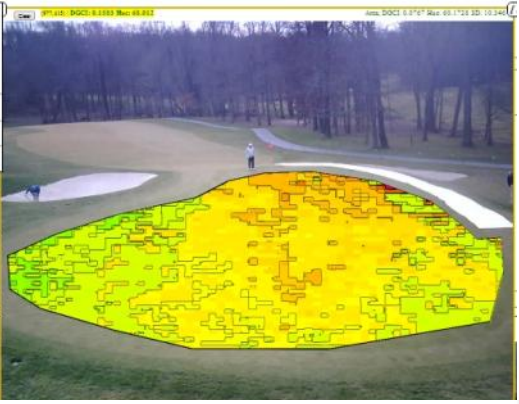
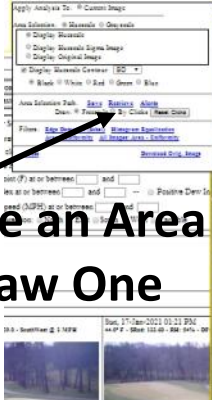
[Send results as an e-mail link to Colleagues](#)

Image Enhancements



Choose / Click a Color or Temperature

Retrieve an Area or Draw One



Dive Deeper by Selecting "Area-Uniformity" Or "All Image: Area-Uniformity"

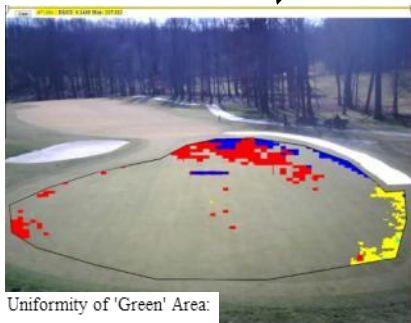
Image Enhancements

Dive Deeper by Selecting

“Area-Uniformity” Or “All Image: Area-Uniformity”

Makes a single enhancement of image data

Makes a Movie of the enhanced image data
Opens in new tab



Uniformity of 'Green' Area:

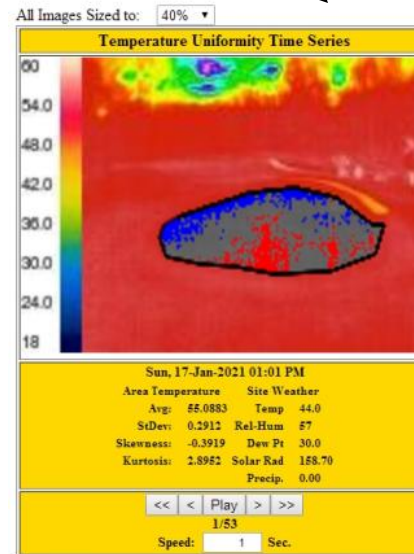
Color Legend

- Hue:
SD: 8.9023
Mean: 64.1699
Skewness: -0.6063
Kurtosis: 3.0608
- DGCI:
SD: 0.0265
Mean: 0.087
Skewness: 0.3281
Kurtosis: 2.4781
- 'Green' Area: Hue between 40 & 160
 - Area Colorization:
 - Blue: Non-Green
 - Red: Hue Outlier +/- 2 SD
 - Yellow: DGCI Outlier +/- 2 SD
 - Aqua: Hue & DGCI Outlier
 - Skewness:
 - For a normal distribution = zero, Symmetric data close to 0
 - Negative values skewed left (lower data values)
 - Positive values skewed right (higher data values)
 - Skewed right/left the tail is long relative to the other
 - Kurtosis:
 - Normal distribution has a kurtosis of zero. (Excess Kurtosis +/-3)
 - Positive kurtosis indicates a 'heavy-tailed' distribution
 - Negative kurtosis indicates a 'light tailed' distribution

1pm-2pm 13-24jan21

<https://vimeo.com/504408872>

Uniformity Image Analysis Turf - Congressional



Temperature Legend

- Area Colorization:
 - Red: Temp High Outlier +1 SD
 - Blue: Temp Low Outlier -1 SD
- Skewness:
 - For a normal distribution = zero, Symmetric data close to 0
 - Negative values skewed left (lower data values)
 - Positive values skewed right (higher data values)
 - Skewed right/left the tail is long relative to the other
- Kurtosis:
 - Normal distribution has a kurtosis of zero. (Excess Kurtosis +/-3)
 - Positive kurtosis indicates a 'heavy-tailed' distribution
 - Negative kurtosis indicates a 'light tailed' distribution







Overnight 16-17jan2021

<https://vimeo.com/501399421>

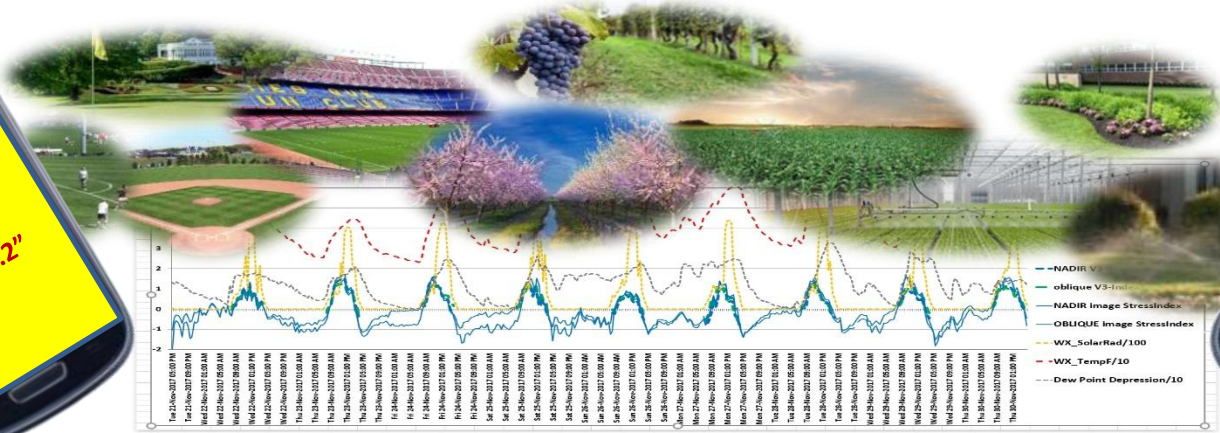
	Sun, 17-Jan-2021 01:01 PM	Sun, 17-Jan-2021 01:11 PM	Sun, 17-Jan-2021 01:21
Avg	55.0883	55.2627	53.6596
StDev	0.2912	0.3417	0.2951
Skewness	-0.3919	-0.558	-0.4752
Kurtosis	2.8952	2.726	2.4965
WX Site	KMDPOTOM38: Potomac MD	KMDPOTOM38: Potomac MD	KMDPOTOM38: Potoma
Temperature	44.0	44.0	44.0
Rel-Hum	57	55	54
Dew Pt.	30.0	29.0	29.0
Solar Rad.	158.70	135.30	133.60
Precip.	0.00	0.00	0.00

Evolution of the Hawk-Eye™/EYAS System

→ Observe → Build → Test → Observe → Build → Test → Observe → Build →

<p>\$\$\$\$\$\$</p>  <p>2006</p> <p>Version 1 Thermal 320 X 240 Visual 1280 X 1024</p> <p><i>Out of Production</i></p>	<p>\$\$\$</p>  <p>2012</p> <p>Version 4 Thermal 320 X 240 Visual 1280 X 1024</p> <p><i>Out of Production</i></p>	<p>\$\$\$\$</p>  <p>2014</p> <p>Version 4.1 Thermal 320 X 240 Visual 1280 X 1024</p> <p><i>Out of Production</i></p>	<p>\$\$</p>  <p>2018</p> <p>Version 6 Thermal 640 X 510 Visual 3840 X 2160</p>	<p>\$\$</p>  <p>2018</p> <p>Version 6.1 Thermal 336 X 256 Visual 3840 X 2160</p>	<p>\$\$/10</p>  <p>2020</p> <p>EYAS Thermal 160 X 120 Visual 1280 X 1024</p>
--	--	---	--	--	--

Autonomously 24/7/365

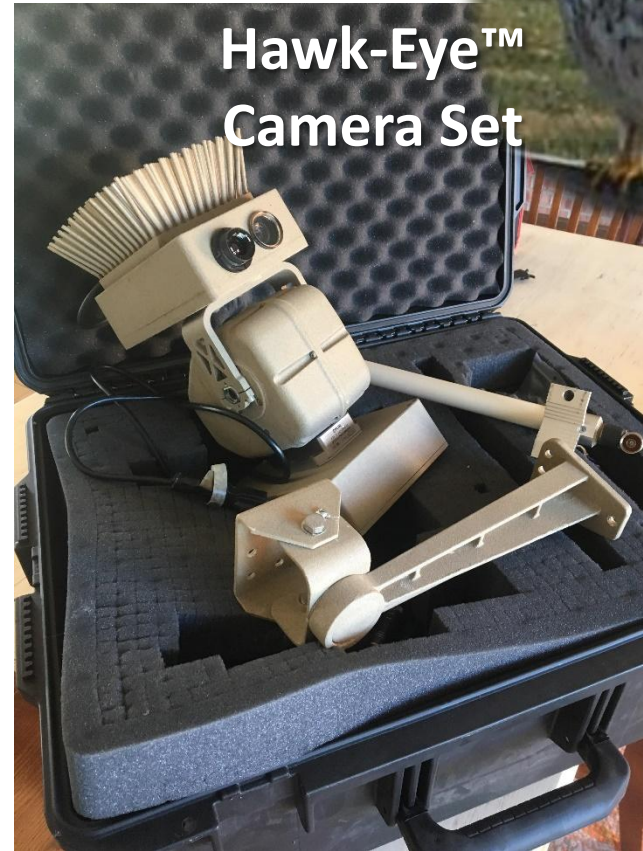




**EYAS
Camera Set**



**Hawk-Eye™
Camera Set**



Applying Hawk-Eye™ & EYAS Systems

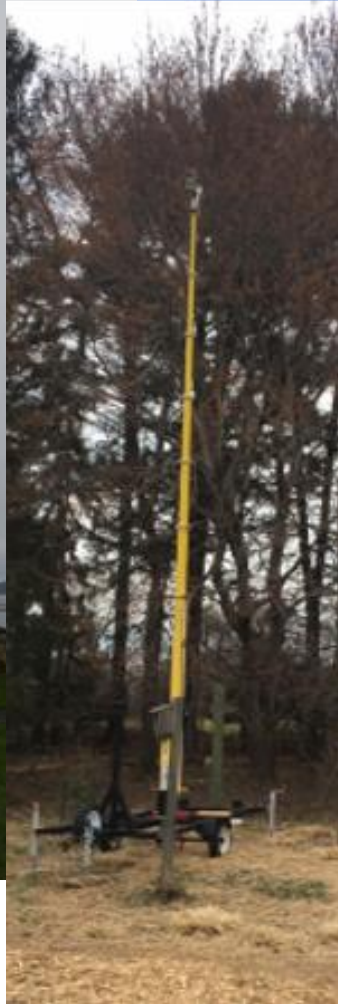
Complement/Augment the Use of Measurement & Testing Tools

- **Check Drainage and Irrigation Patterns**
- **Guiding Irrigation with Prescriptions, zone-by-zone**
- **Precision Scouting for**
 - Stress
 - Pest
 - Disease
 - Shade
 - Traffic/Compaction
- **Early ID of Winterkill**
- **Set-Up Fan Placement & Aim, Manage Fan Use**
- **Assess Use & Timing of Grow Lighting**
- **Precision Application of Treatments (only treat where needed)**
- **Preparation of Cultivation Practices**
 - Application of Beneficial Stress (deficit irrigation)
 - Guide Syringing
 - Assess Organic Matter in Sand Bases
 - Aeration Decision Aid
- **Synthetic Turf**
 - Heat Exhaustion
 - Maintenance



Turf-Vu[®]
Beautifully Healthy Turf
A Division of ItriCorp

Semi Permanent or Mobile Set-Ups



Hawk-Eye™ & EYAS Systems

Autonomously, 24/7

Measures Computes Visualizes



Hawk-Eye™
Camera Set



EYAS
Camera Set

It's a lot of data and information.
But - The autonomous alerts call attention
to what needs to be seen.



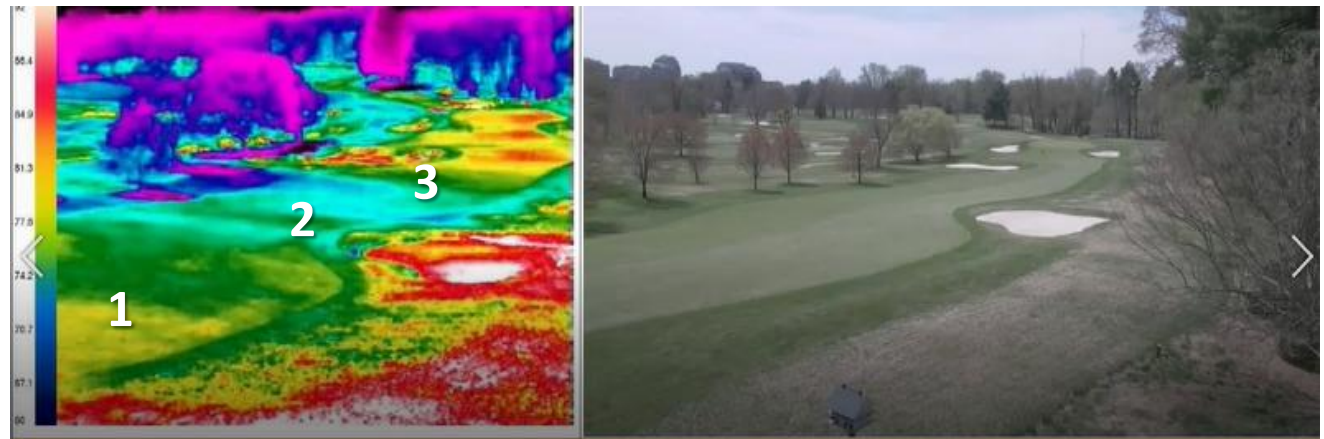
Reports Actionable Information in Real-Time

Establishing & Checking Irrigation Zones

1. Set-Up System to measure area.
2. Collect autonomously for more than a week.
3. Review data for pattern by watching snippets of more than a week around solar noon.

Image Data for 8 Days,
Around Solar Noon

Shows 3 Zones

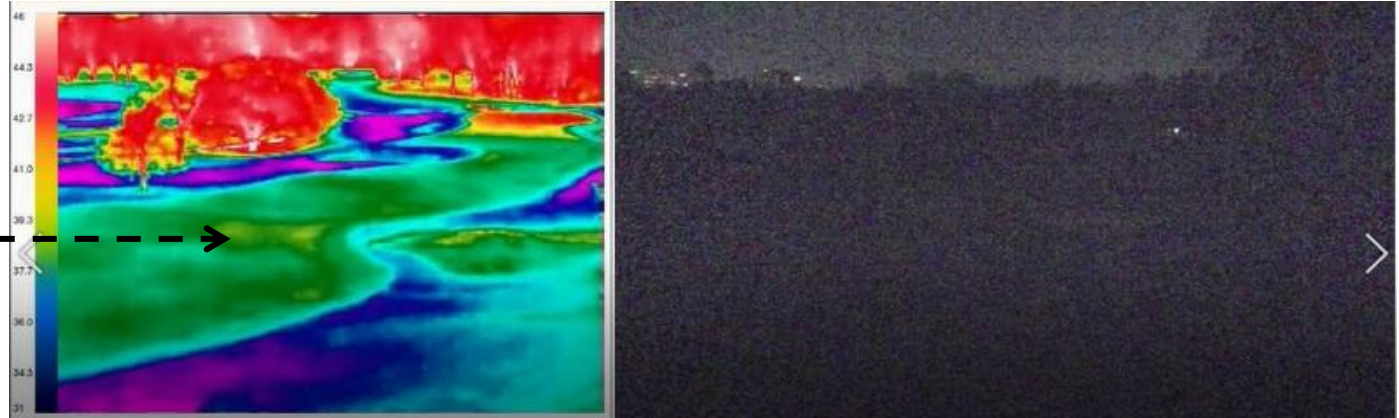


<https://vimeo.com/441761155>

Evaluating Drainage

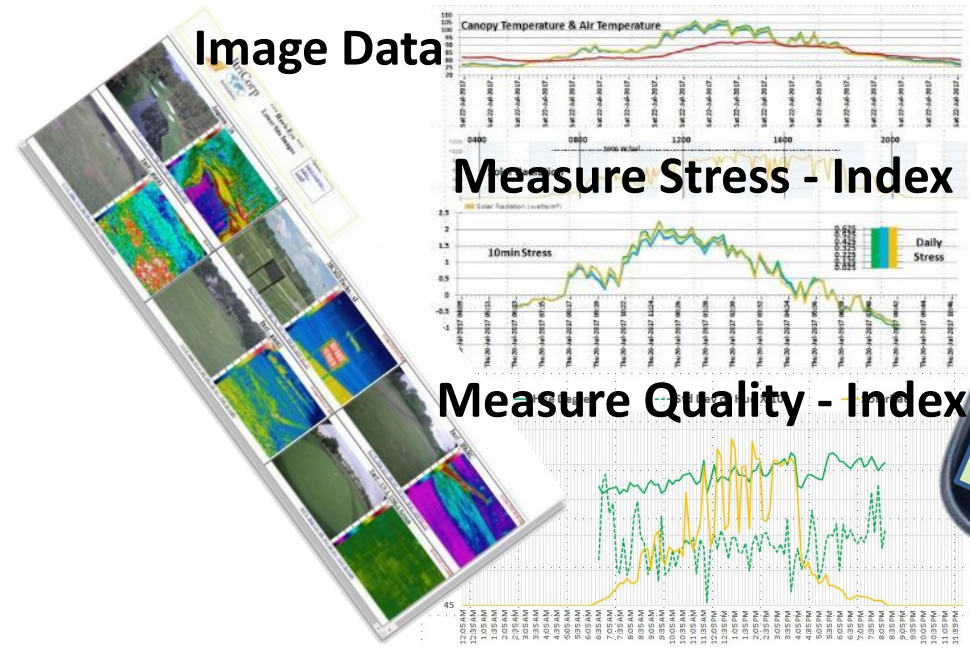
1. Set-Up System to measure area.
2. Collect autonomously for
3. Check observations by examining one full day about a day after rain event or heavy irrigation if system is on. The Night Time Imagery is Most Valuable.

One Full Day
After Rain
Check Drainage



<https://vimeo.com/441761428>

Guiding Irrigation



Only provide what the turf needs.

On the day that the Daily Stress and Quality Index exceed the established thresholds

Cross check Stress and Quality

Apply a pre-determined amount that does not bring the area to field capacity.

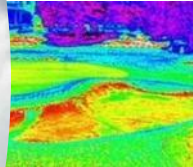
Daily Irrigation Index measurements continue.

The next day the Index crosses the threshold the predetermined amount of water is applied.

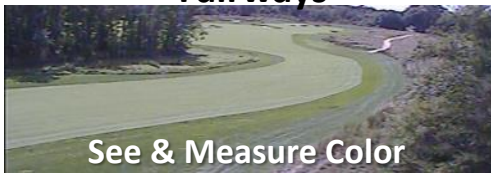
Measuring Thermal and Visual Image Data Computing Stress & Variance in Quality for **Scouting** and to **Guide Irrigation**



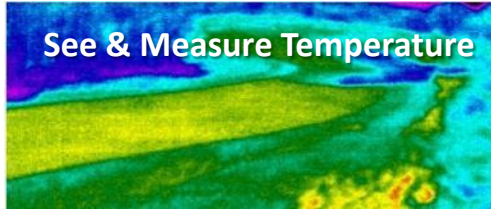
Greens



Fairways

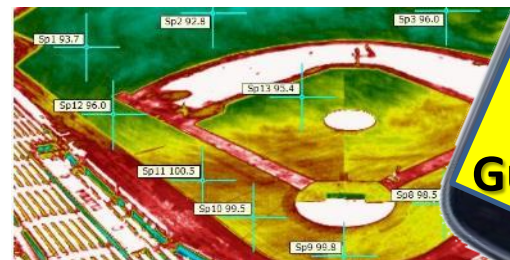
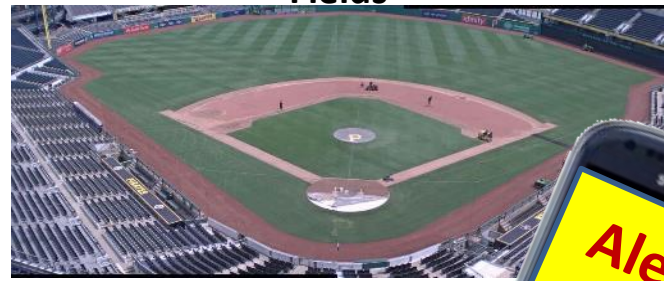


See & Measure Color

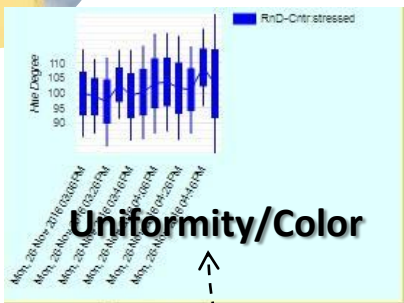


See & Measure Temperature

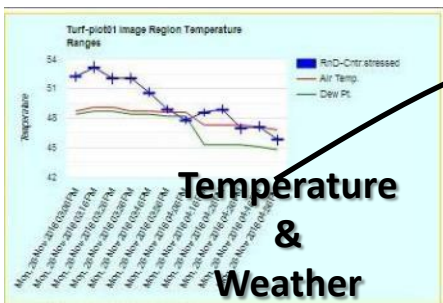
Fields



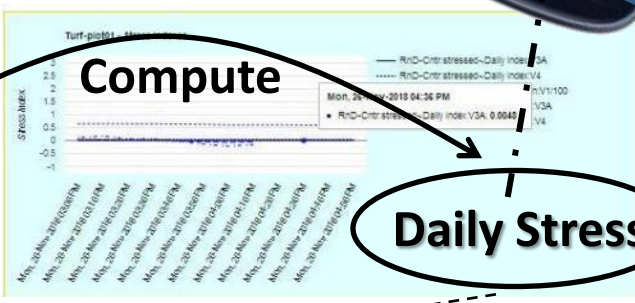
Autonomously, 24/7
 It talks to You



Uniformity/Color



Temperature & Weather



Daily Stress

Compute

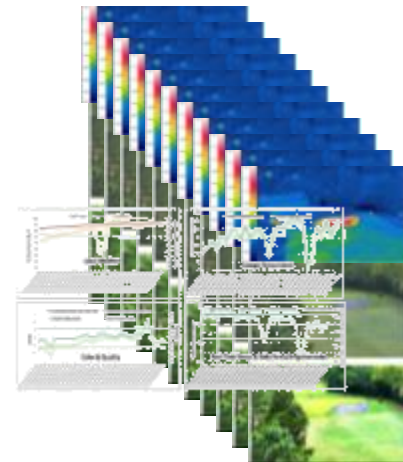
Check

Guiding Irrigation

You See it.

**Hawk-Eye™ Measures it
 All Day.**

**Then Notifies You
 When it is Time to Irrigate.**



Trigger On	When	Value	Value Period	Schedule	Notify	Re-Notify Threshold	Notify Subject
Stress: Image Day: V3A	Greater Than or Equal To	.3	11 min	Between Sunset -1 hr. and Sunset	j.etro@turf-vu.com	600.00 Min.	Zone01 Irrigate 0.2"
Stress: Image Day: V3A	Greater Than or Equal To	.3	11 min	Between Sunset -1 hr. and Sunset	j.etro@turf-vu.com	600.00 Min.	Zone02 Irrigate 0.2"
Stress: Image Day: V3A	Greater Than or Equal To	.3	11 min	Between Sunset -1 hr. and Sunset	j.etro@turf-vu.com	600.00 Min.	Zone03 Irrigate 0.2"

Irrigation Index (irrigate zone with .5") = **Daily SI > .26** and check if **Uniformity > 6**

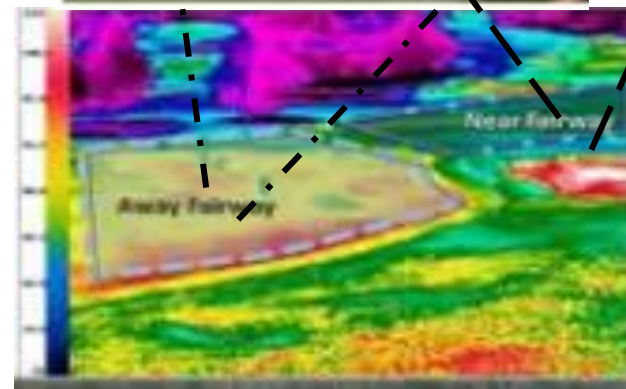
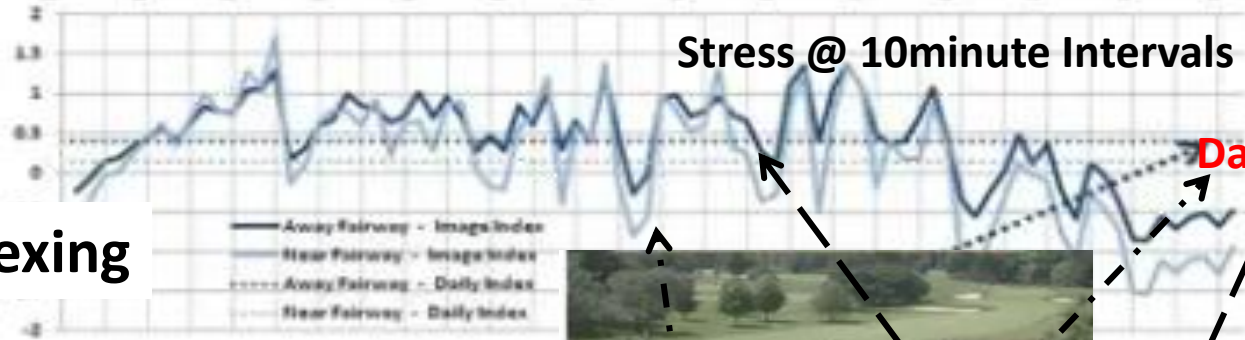
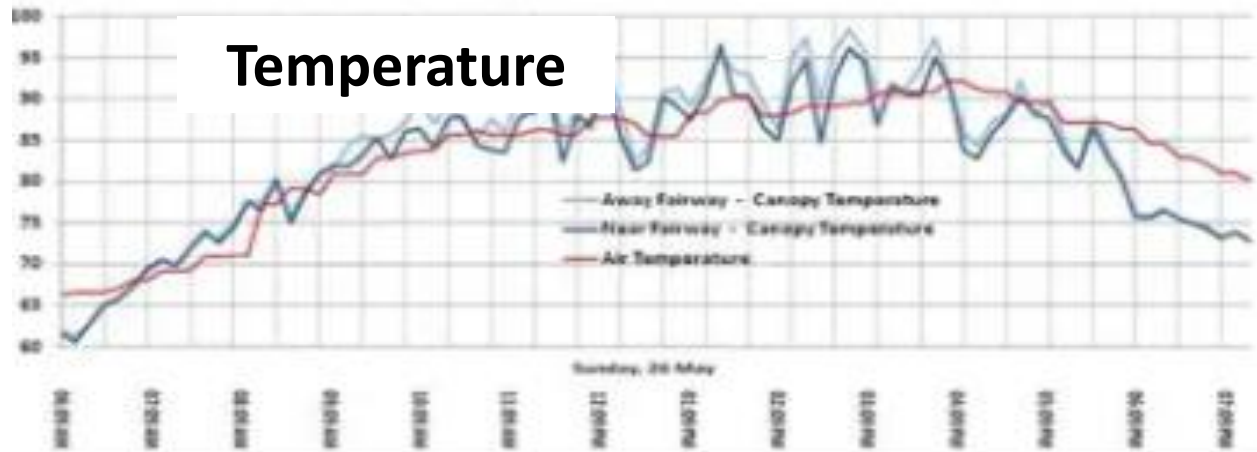
2020-06-17 20:49:00 EDT
Zone01 Irrigate 0.5"
Zone03 Irrigate 0.5"

Scouting Stress

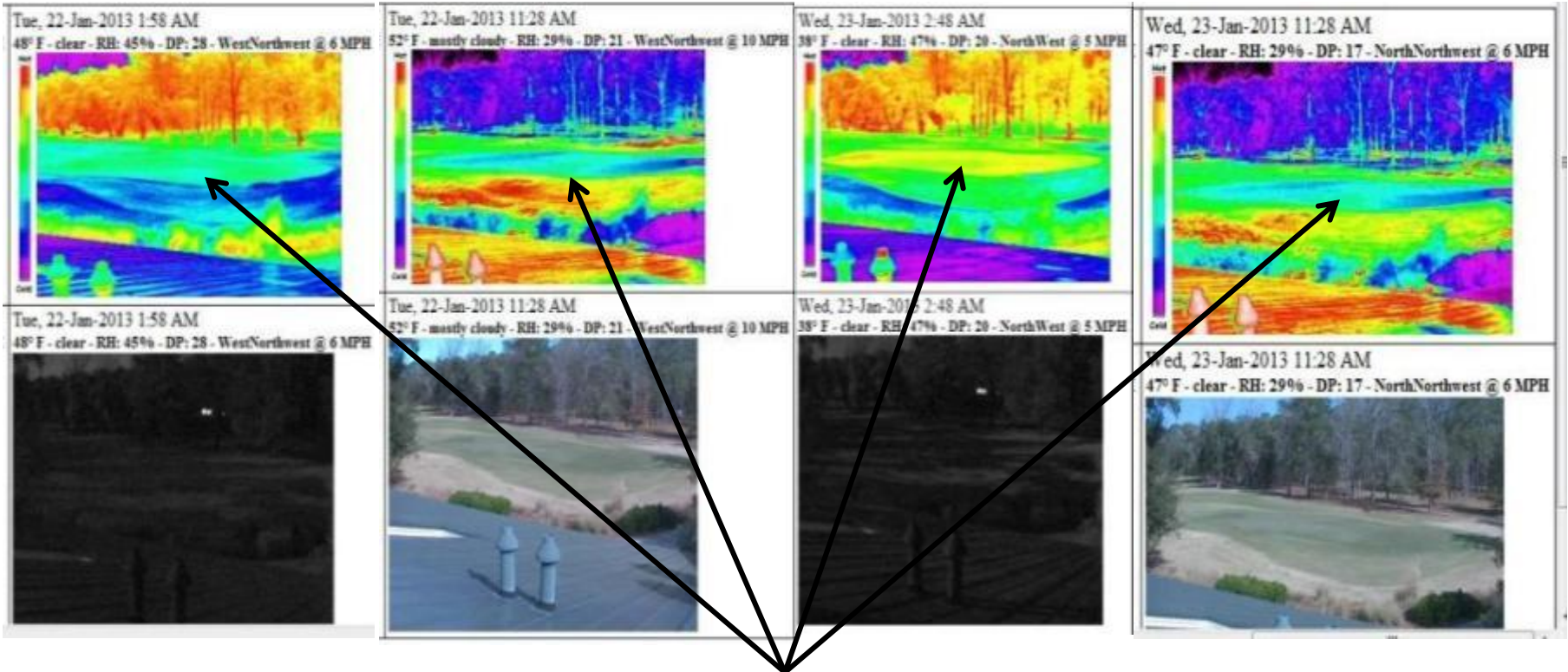
A simple drive by or snapshot from a thermal camera doesn't tell the story.

Stress Indexing

Accumulation of Stress becomes evident in a persistent time series.
<https://vimeo.com/163604044>



Scouting Pests



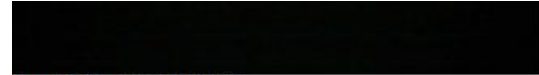
Persistent Pattern
Cooler at night
Warmer during day (sunshine)

See disease and pest caused stresses, before they are a problem

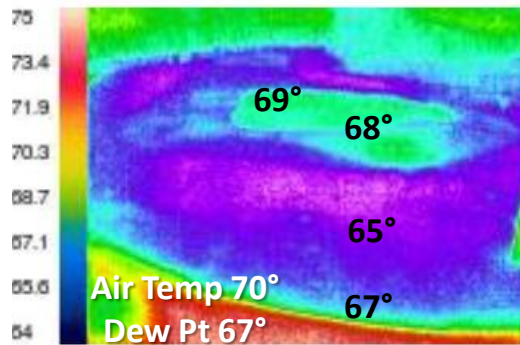
Dew Formation and Leaf Wetness and Canopy Temperatures

Scouting Disease Susceptibility

06 Oct 9:56pm



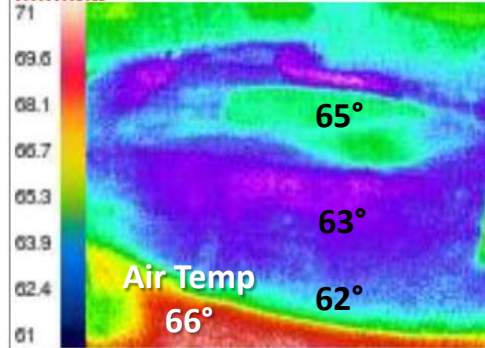
Tue, 06-Oct-2020 09:56 PM
 70.0° F - SRad: 0.00 - RH: 92% - DP: 67.0 - EastSoutheast @ 0 MPH THI: 162



Dew is forming on thin bermuda

07 Oct

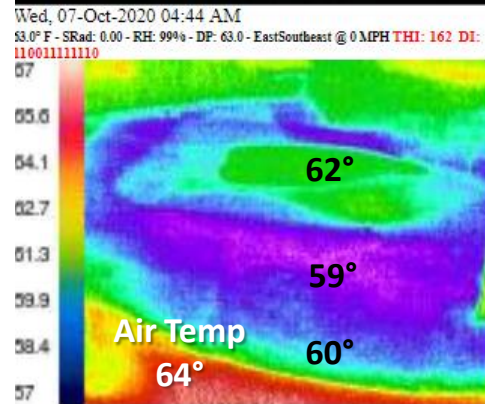
Wed, 07-Oct-2020 01:51 AM
 66.0° F - SRad: 0.00 - RH: 98% - DP: 65.0 - EastSoutheast @ 0 MPH THI: 164 DI: 000000001011



Dew is forming on bent grass green

07 Oct

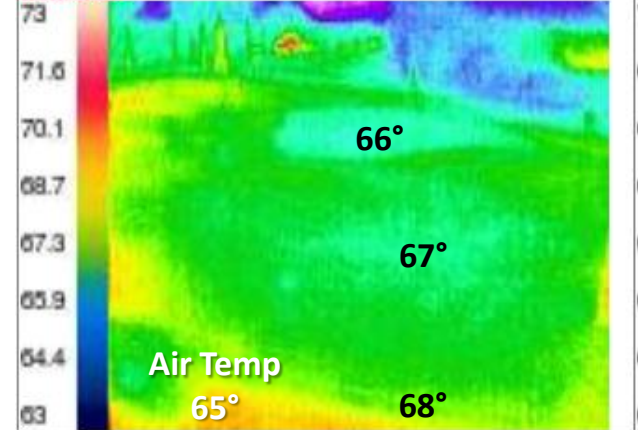
Wed, 07-Oct-2020 04:44 AM
 53.0° F - SRad: 0.00 - RH: 99% - DP: 63.0 - EastSoutheast @ 0 MPH THI: 162 DI: 110011111110



Dew Pt 64°

07 Oct

Wed, 07-Oct-2020 08:50 AM
 65.0° F - SRad: 48.60 - RH: 99% - DP: 65.0 - EastSoutheast @ 0 MPH THI: 164 DI: 110110111111



Wed, 07-Oct-2020 09:50 AM
 65.0° F - SRad: 48.60 - RH: 99% - DP: 65.0 - EastSoutheast @ 0 MPH THI: 164 DI: 110110111111



Wet Canopy Report & Pythium Blight Alert on Bent Grass

Pythium blight may develop when night temperatures exceed 65°F in cool-season and leaves are continually wet for 12 to 14 hours for several consecutive nights.

Read more at: <https://www.turffiles.ncsu.edu/diseases-in-turf/pythium-blight-in-turf/>

Turf-ChampionsRetreat - Temperature Area: Champions Retreat:2 island T
Area Notification (Edit/Remove)
To remove criteria clear 'Trigger On' entry only:

Criteria (2)

Trigger On:	<input type="text" value="Dew Point-Canopy Temp (F)"/>
When:	<input type="text" value="Greater Than or Equal To"/>
Value:	<input type="text" value="0"/>
Average value is maintained for:	<input type="text" value="12"/> <input type="text" value="Hours"/> (Value Period) ?

Trigger On:	<input type="text" value="Air Temperature (F)"/>
When:	<input type="text" value="Greater Than or Equal To"/>
Value:	<input type="text" value="65"/>
Average value is maintained for:	<input type="text" value="12"/> <input type="text" value="Hours"/> (Value Period) ?

Don't re-notify for at least Minutes

<input type="text" value="DEW/Condensate on #2 Island + Pythium Alert"/>	<input type="text" value="Enter a COMMENT replacing the default"/>
--	--

Wet Canopy Report & Pythium Blight Alert on Bermuda Grass

Pythium blight may develop when night temperatures exceed 50°F in warm-season turf and leaves are continually wet for 12 to 14 hours for several consecutive nights.

Read more at: <https://www.turffiles.ncsu.edu/diseases-in-turf/pythium-blight-in-turf/>

Turf-ChampionsRetreat - Temperature Area: Champions Retreat:2 island T
Area Notification (Edit/Remove)

To remove criteria clear 'Trigger On' entry only:

Criteria (2)

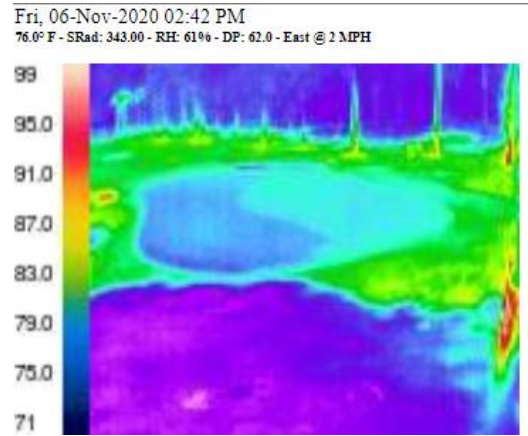
Trigger On:
When:
Value:
Average value is maintained for: (Value Period) ?

Trigger On:
When:
Value:
Average value is maintained for: (Value Period) ?

Don't re-notify for at least

Evaluating Shade and its Impact

During fall and spring shade covers the green causing a low light grass growing condition.

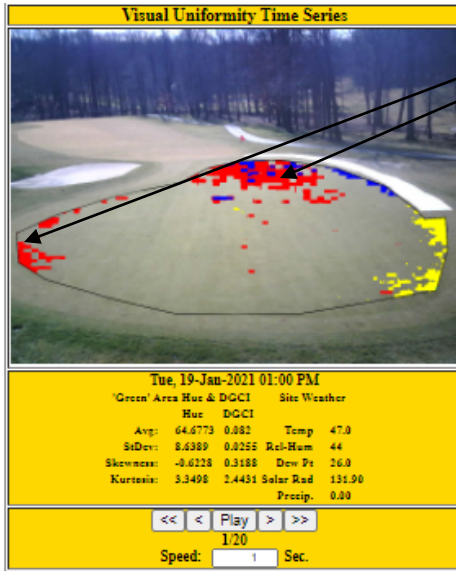


18 November video showing sun and shade on the green: <https://vimeo.com/481221892>
 Looks like this at night: <https://vimeo.com/481225268>





Compaction / Turf Damage



Video of the enhancement mid-day (no shade) visual image data to highlight damage to a green from walk-on/off of players and maintenance persons.

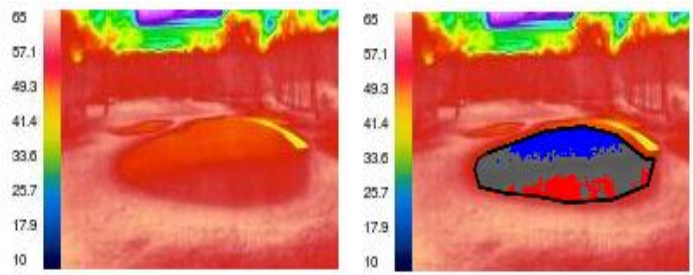
nr09Gold 1pm-2pm 13-24jan21

<https://vimeo.com/504408872>

	Tue, 19-Jan-2021 01:00 PM	Tue, 19-Jan-2021 01:10 PM	Tue, 19-Jan-2021 01:20 PM	Tue, 19-Jan-2021 01:30 PM	Tue, 19-Jan-2021 01:40 PM	Tue, 19-Jan-2021 01:50 PM	Tue, 19-Jan-2021 02:00 PM
Hue Avg	64.6773	63.4393	63.2536	63.9695	64.1815	63.9227	64.08
Hue StDev	8.6389	8.6139	8.7848	9.2167	8.9362	9.196	9.1131
Hue Skewness	-0.6228	-0.6591	-0.6659	-0.5543	-0.5978	-0.5831	-0.472
Hue Kurtosis	3.3498	2.6343	2.5404	3.0299	3.0366	2.9137	3.7015
DGCI Avg	0.082	0.0792	0.0805	0.0848	0.087	0.0886	0.0891
DGCI StDev	0.0255	0.0252	0.0259	0.0269	0.0265	0.0267	0.0265
DGCI Skewness	0.3188	0.2451	0.3119	0.3394	0.3293	0.3373	0.3238
DGCI Kurtosis	2.4431	2.3635	2.428	2.4966	2.481	2.5377	2.5203
WX Site	KMIDPOTOM38: Potomac MID	KMIDPOTOM38: Potomac MID	KMIDPOTOM38: Potomac MID	KMIDPOTOM38: Potomac MID	KMIDPOTOM38: Potomac MID	KMIDPOTOM38: Potomac MID	KMIDPOTOM38: Potomac MID
Temperature	47.0	48.0	48.0	49.0	50.0	49.0	49.0
Rel-Hum	44	43	39	39	36	33	32
Dew Pt.	26.0	26.0	24.0	25.0	24.0	21.0	20.0
Solar Rad.	131.90	85.40	371.30	353.60	330.60	330.90	301.00
Precip.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Small Differences in Winter are Exaggerated in Summer

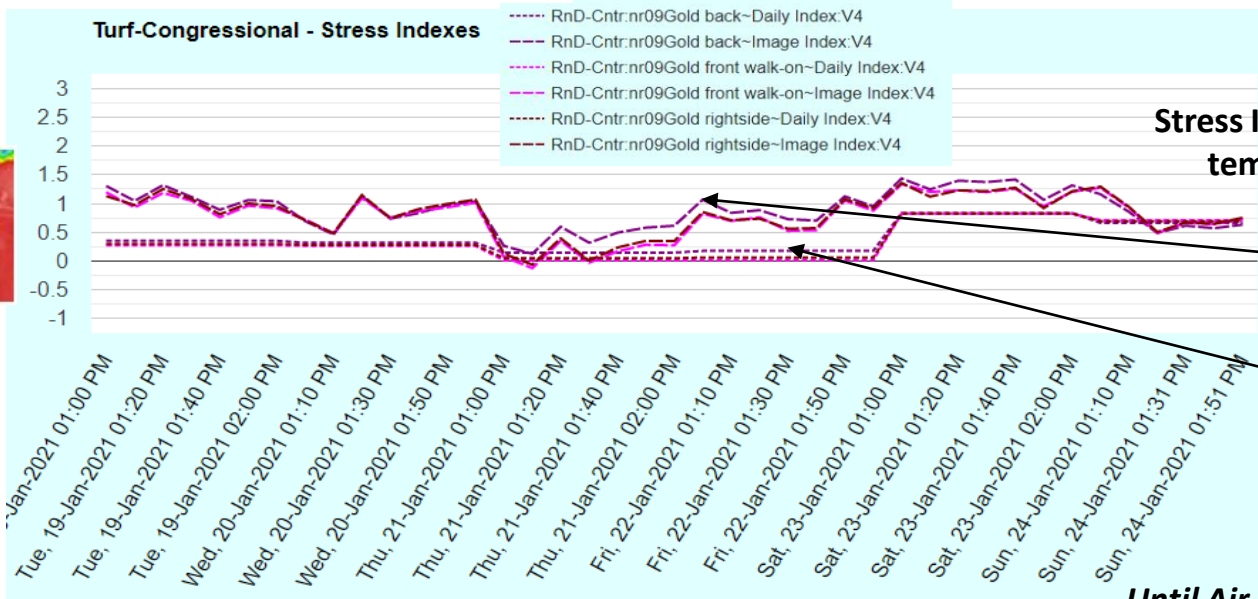
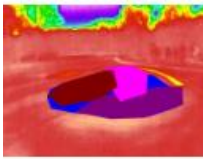
Prevalent Temperature Pattern



Uniformity of Area Temperature:

SD:	1.8308
Mean:	56.8149
Skewness:	-0.1324
Kurtosis:	1.5265

Back is warmer than the front and right side.
 More moisture in front and right side due to evaporation .
 The green slopes down from the back to front causing water to run down hill.
 Use less water on the front in summer months.
 Watch for desiccation at the back in winter.

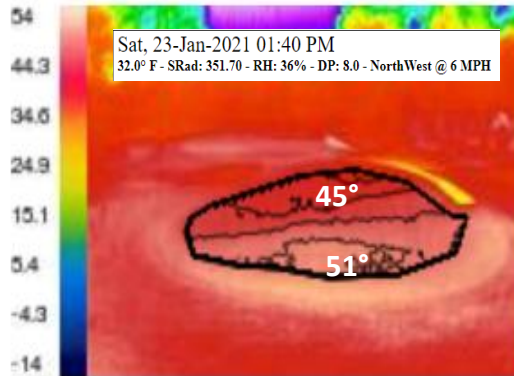


Stress Index mirrors the temperature pattern.

Image Stress BACK (every 10 minutes)
Daily Stress BACK (24hour period)

Until Air Temperature gets to 32°F

A Little Bit of Soil Moisture Leads to Frost/Ice



<https://hawkeye.itricorp.com/hawkeye/HawkEye.php?getemallink=DAKo8Y6wDmBEnvQtBjrvoQOb19mcXNjz/A0hv2J405jIUGvT5WmAihXo>

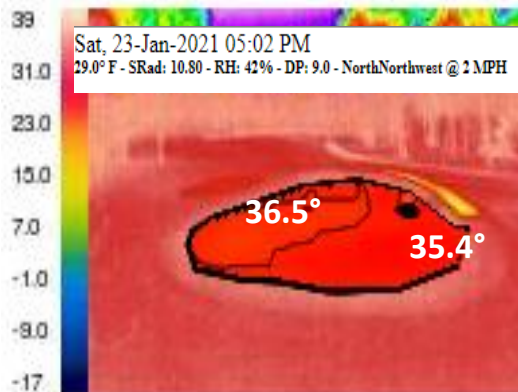
Until the Air Temperature gets to 32°F

Rationale:

There is more moisture in the front and right-side vs the left and back of the green. Respiration also adds some water and heat as well ($C_6H_{12}O_6 + CO_2 \rightarrow 6 CO_2 + 6 H_2O + \text{heat}$) to the whole green, but the front and right-side has more moisture so it is cooling more than the less moist part of the green. When the air temperature cools to 32° it starts to form frost/ice (mainly from deposition of the vapor) and evaporation shuts down. That causes the canopy to heat up slightly because it has lost the evaporative cooling and as the ice/frost sublimates it also adds heat. The phenomenology is interesting.

Impact:

The slight amount of ice/frost may leave a small amount of moisture (less than dew) in the thatch when it melts, and it may become a [winter turfgrass disease](#) issue? There is also likely some root damage due to the freezing of the roots near the surface?

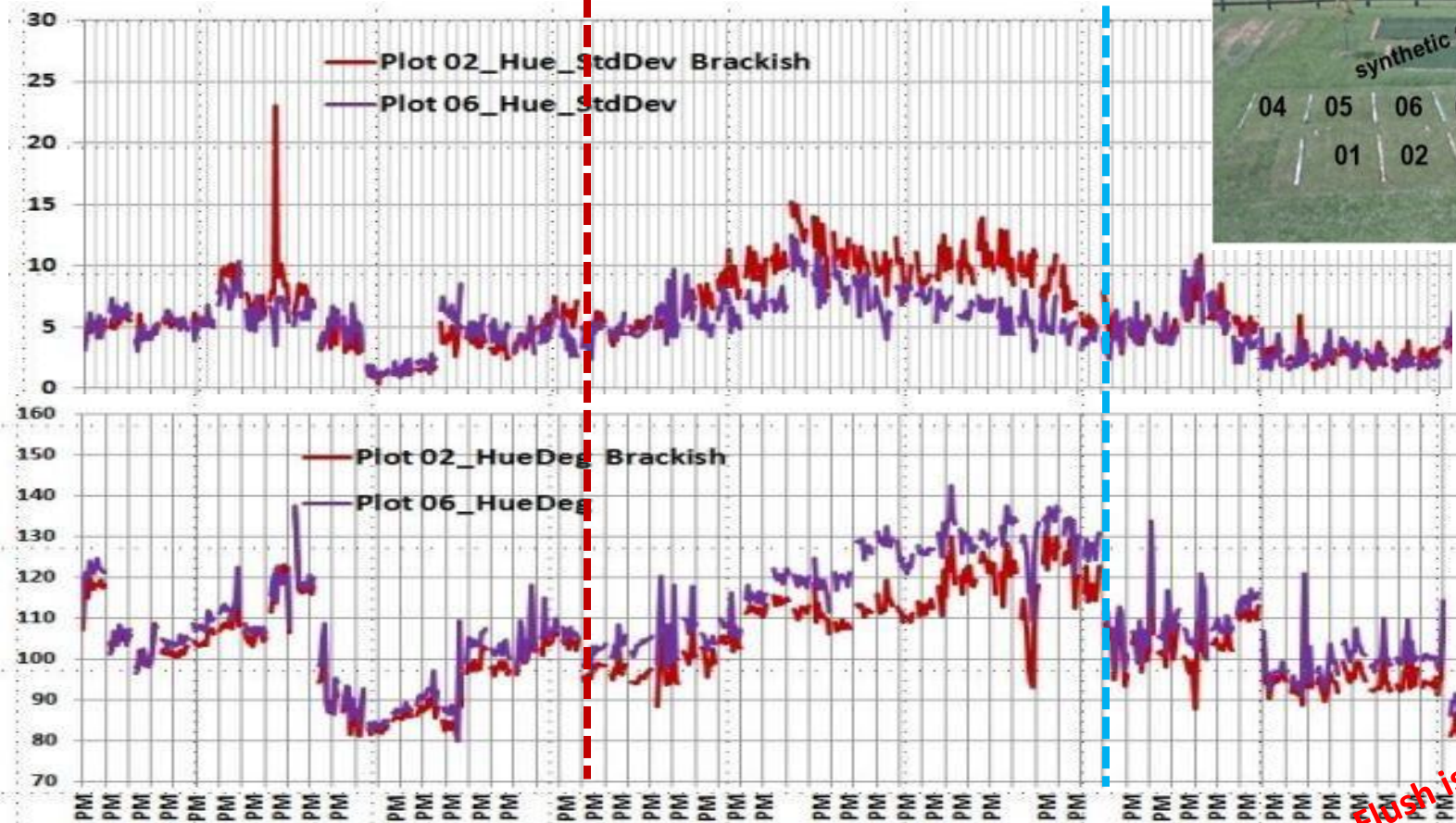
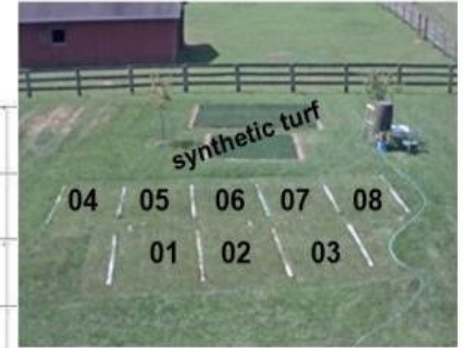


<https://hawkeye.itricorp.com/hawkeye/HawkEye.php?getemallink=JQjUqxDMBqdQcGaPijFHR5113jyKqTffEhZE7BTUROW9nlo6xhf1IC>

Using Quality to Assess Water Quality

Brackish Water Applied

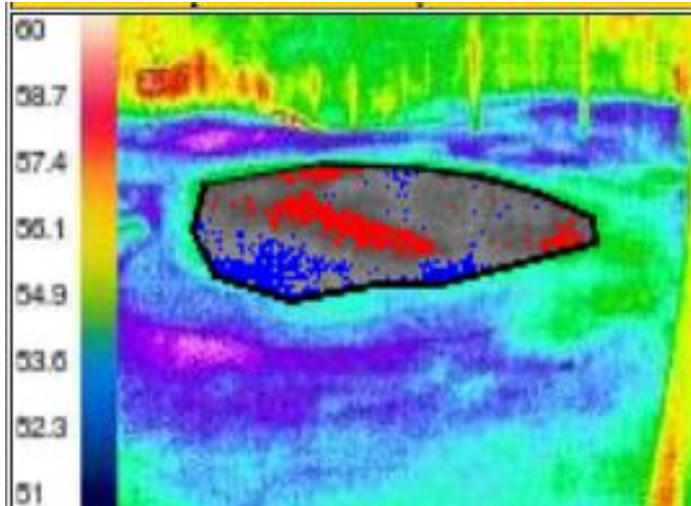
Rainwater Flush



Trigger On	When	Value	Value Period	Schedule	Notify	Re-Notify Threshold	Notify Subject	Notify Comment	Last Notification
Hue - SD	Greater Than or Equal To	12	120 min	Between Solar Noon -1 hr. and Solar Noon +1 hr.	j.etro@turf-vu.com	120.00 Min.	Quality Alert		
Hue - Avg	Less Than or Equal To	100	120 min						

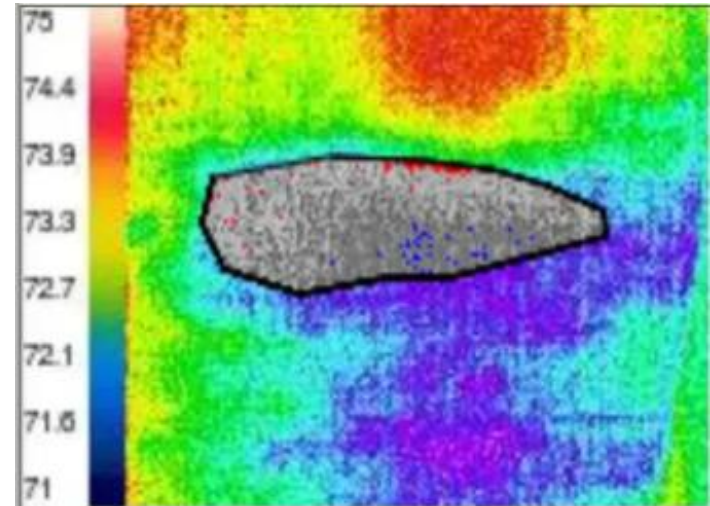
Alert set to Notify When a Flush is Needed

Organic Matter



<https://vimeo.com/486806452>

Temperature early PM 04Nov-02Dec



<https://vimeo.com/486796545>

Temperature early AM 04Nov-02Dec

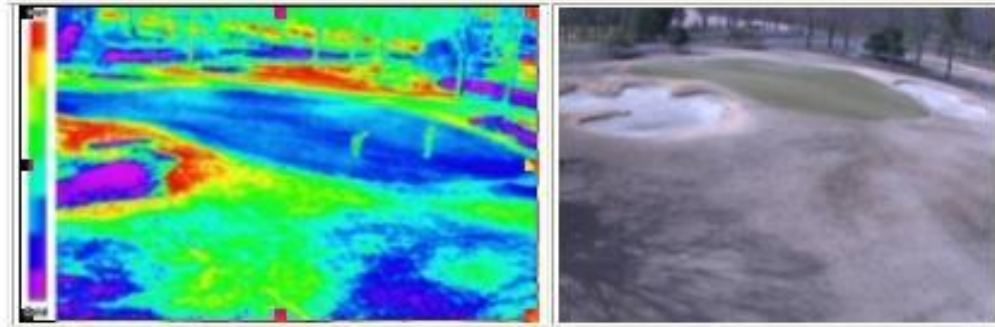
Moist soil is warmer after sunset because the water retains the warmth of the sun. It loses the heat as the evening progresses so the green becomes more uniform.

On a USGA green, sand based, organic matter retains more water.

Winter Desiccation/Wind Stress

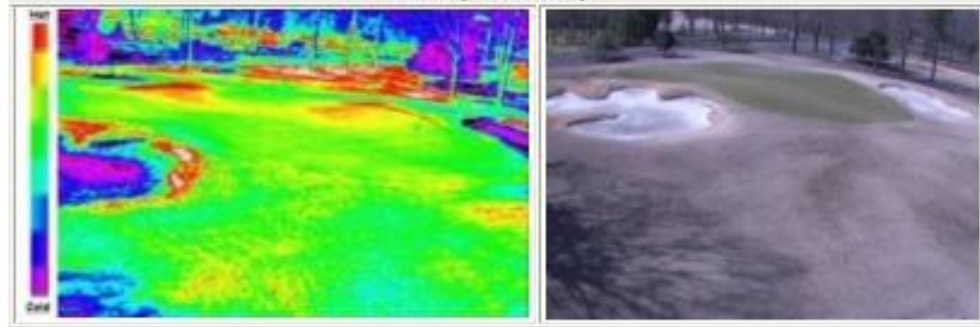
Thermal Fri, 24-Feb-2012 0:08 PM
Partly Cloudy/55°F/Calm

Visual Fri, 24-Feb-2012 0:09 PM



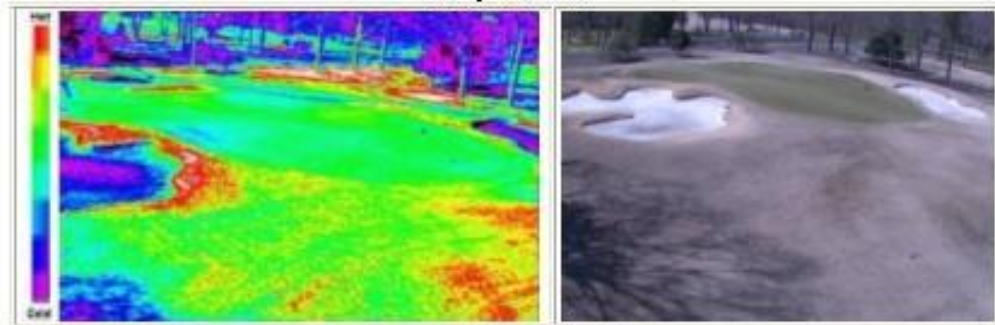
Thermal Sat, 25-Feb-2012 0:02 PM
Sunny/45°F/Windy

Visual Sat, 25-Feb-2012 0:09 PM



Thermal Sun, 26-Feb-2012 0:02 PM
Sunny/45°F/Calm

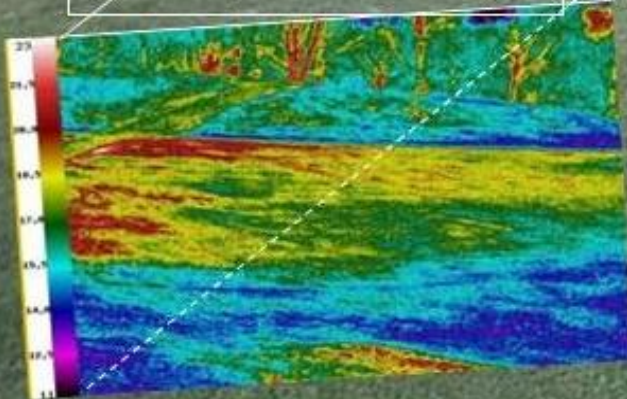
Visual Sun, 26-Feb-2012 0:09 PM



<https://vimeo.com/269227998>

Scouting Green-Up (months in advance)

Thermal, February at Night



Visual, 07 May, 10AM

Measured and archived persistent night time thermals during Feb-Mar.

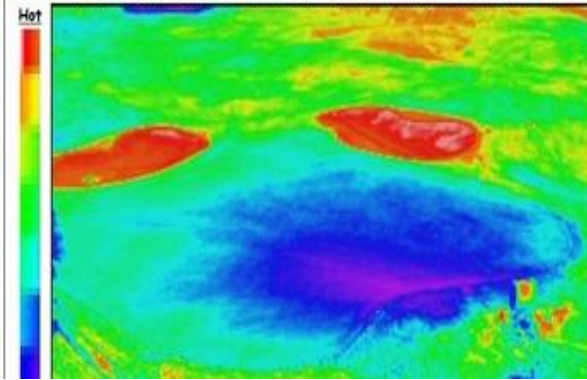
Mapped the green-up of warm season turf in May.

Positioning and Aiming Fans

good location & aim

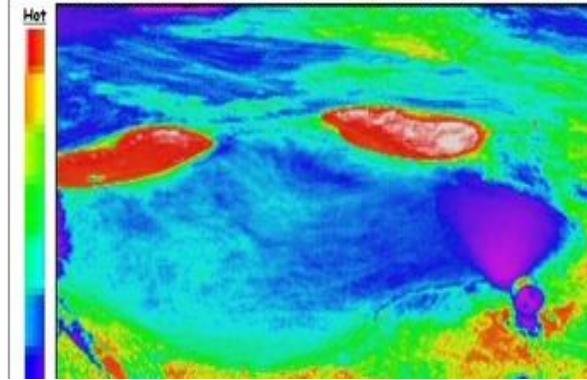
Wed, 21-Aug-2013 1:30 PM

87° F - mostly cloudy - RH: 65% - DP: 74 - SouthEast @ 3 MPH **THI: 152**



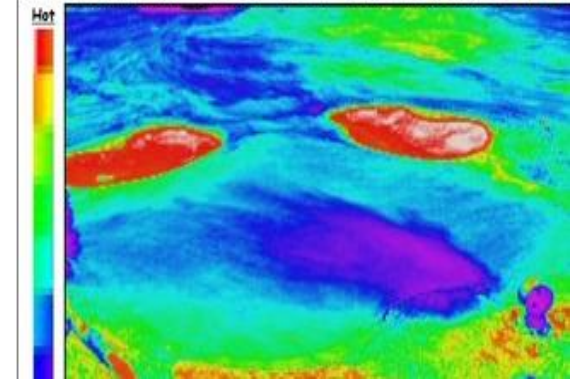
Wed, 21-Aug-2013 1:40 PM

87° F - mostly cloudy - RH: 65% - DP: 74 - SouthEast @ 3 MPH **THI: 152**



Wed, 21-Aug-2013 1:50 PM

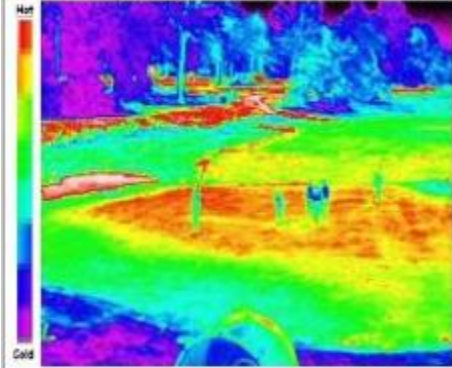
87° F - mostly cloudy - RH: 65% - DP: 74 - SouthEast @ 3 MPH **THI: 15**



not so good

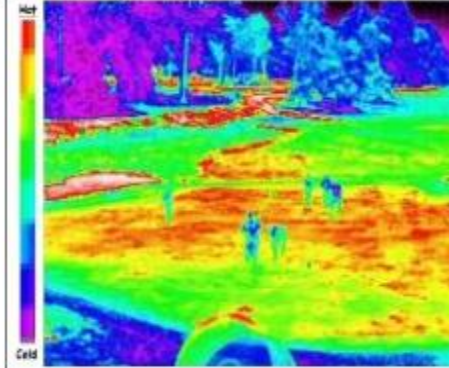
Sun, 21-Jul-2013 2:06 PM

89° F - mostly cloudy - RH: 49% - DP: 68 - SouthSouthwest @ 10 MPH



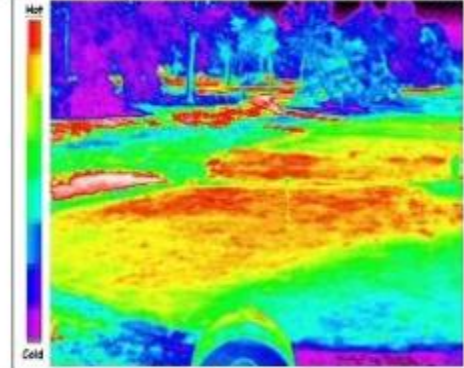
Sun, 21-Jul-2013 2:16 PM

89° F - mostly cloudy - RH: 49% - DP: 68 - SouthSouthwest @ 10 MPH

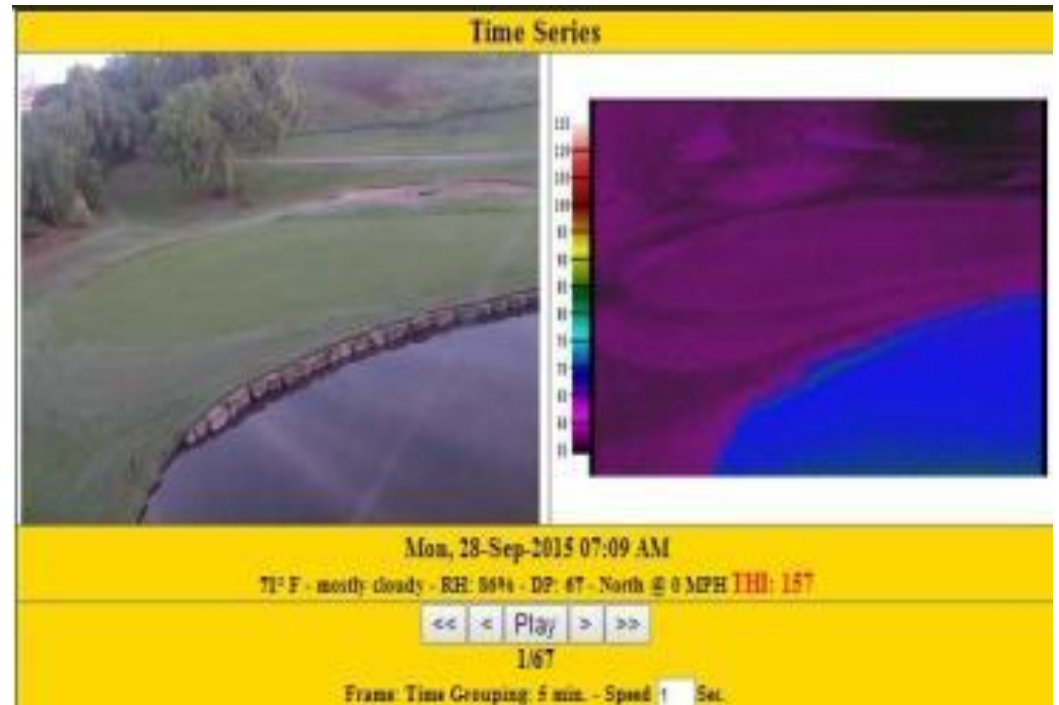
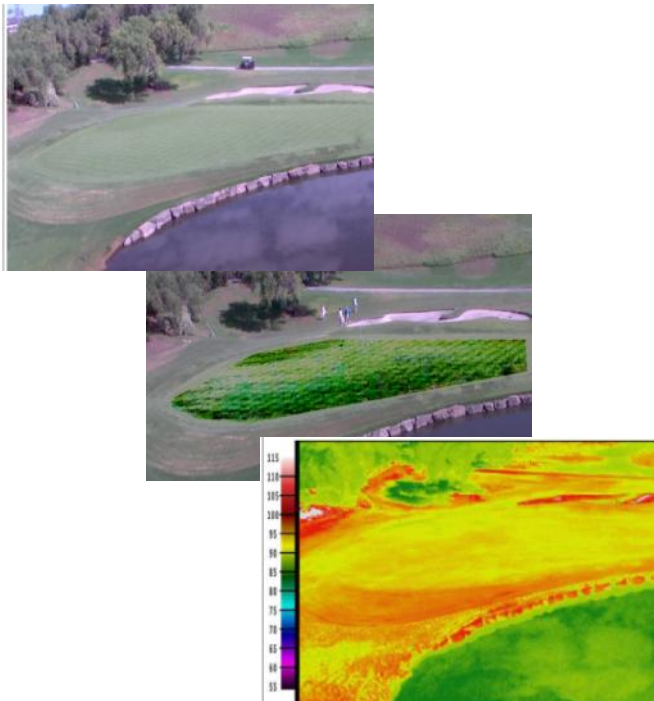


Sun, 21-Jul-2013 2:26 PM

89° F - mostly cloudy - RH: 48% - DP: 67 - SouthSouthwest @ 7 MPH



This set of information was used by a Superintendent to justify his need for fans.



<https://vimeo.com/163604044>

Pairing with Fans to help guide day/night use

<p>Sun, 28-Jul-2013 4:17 PM 70° F - overcast - RH: 87% - DP: 66 - Variable @ 5 MPH Precip: 0.00 THI: 157</p>	<p>Sun, 28-Jul-2013 4:07 PM 70° F - overcast - RH: 87% - DP: 66 - Variable @ 5 MPH Precip: 0.00 THI: 157</p>	<p>Sun, 28-Jul-2013 3:57 PM 70° F - overcast - RH: 87% - DP: 66 - Variable @ 5 MPH Precip: 0.00 THI: 157</p>
<p>Sun, 28-Jul-2013 4:19 PM 70° F - overcast - RH: 87% - DP: 66 - Variable @ 5 MPH Precip: 0.00 THI: 157</p>	<p>Sun, 28-Jul-2013 4:09 PM 70° F - overcast - RH: 87% - DP: 66 - Variable @ 5 MPH Precip: 0.00 THI: 157</p>	<p>Sun, 28-Jul-2013 3:59 PM 70° F - overcast - RH: 87% - DP: 66 - Variable @ 5 MPH Precip: 0.00 THI: 157</p>

**On this Day
Turn it Off**

<p>2013 2:06 PM cloudy - RH: 49% - DP: 65 - SouthSouthwest @ 10 MPH</p>	<p>Sun, 21-Jul-2013 2:16 PM 89° F - mostly cloudy - RH: 49% - DP: 65 - SouthSouthwest @ 10 MPH</p>	<p>Sun, 21-Jul-2013 2:26 PM 89° F - mostly cloudy - RH: 49% - DP: 67 - SouthSouthwest @ 7 MPH</p>
<p>2013 2:09 PM cloudy - RH: 49% - DP: 65 - SouthSouthwest @ 10 MPH</p>	<p>Sun, 21-Jul-2013 2:19 PM 89° F - mostly cloudy - RH: 49% - DP: 65 - SouthSouthwest @ 10 MPH</p>	<p>Sun, 21-Jul-2013 2:29 PM 89° F - mostly cloudy - RH: 49% - DP: 67 - SouthSouthwest @ 7 MPH</p>

**Cross Wind
Aim Better
or
Another Location**


<p>Sat, 27-Jul-2013 1:57 PM 82° F - mostly cloudy - RH: 50% - DP: 62 - South @ 9 MPH</p>	<p>Sat, 27-Jul-2013 2:07 PM 82° F - mostly cloudy - RH: 50% - DP: 62 - South @ 9 MPH</p>	<p>Sat, 27-Jul-2013 2:17 PM 82° F - mostly cloudy - RH: 50% - DP: 62 - South @ 9 MPH</p>
<p>Sat, 27-Jul-2013 1:59 PM 82° F - mostly cloudy - RH: 50% - DP: 62 - South @ 9 MPH</p>	<p>Sat, 27-Jul-2013 2:09 PM 82° F - mostly cloudy - RH: 50% - DP: 62 - South @ 9 MPH</p>	<p>Sat, 27-Jul-2013 2:19 PM 82° F - mostly cloudy - RH: 50% - DP: 62 - South @ 9 MPH</p>

**On this Day
Turn it On**

<p>6-2013 02:40 AM 81° F - mostly cloudy - RH: 64% - DP: 69 - SouthWest @ 9 MPH</p>	<p>Sat, 20-Jul-2013 02:30 AM 81° F - mostly cloudy - RH: 64% - DP: 69 - SouthWest @ 9 MPH</p>	<p>Sat, 20-Jul-2013 03:00 AM 81° F - mostly cloudy - RH: 64% - DP: 69 - SouthWest @ 9 MPH</p>
<p>6-2013 02:28 AM 81° F - mostly cloudy - RH: 64% - DP: 69 - SouthWest @ 9 MPH</p>	<p>Sat, 20-Jul-2013 02:31 AM 81° F - mostly cloudy - RH: 64% - DP: 69 - SouthWest @ 9 MPH</p>	<p>Sat, 20-Jul-2013 02:34 AM 81° F - mostly cloudy - RH: 64% - DP: 69 - SouthWest @ 9 MPH</p>

**On this Night
Turn it Off**

Guiding Fans



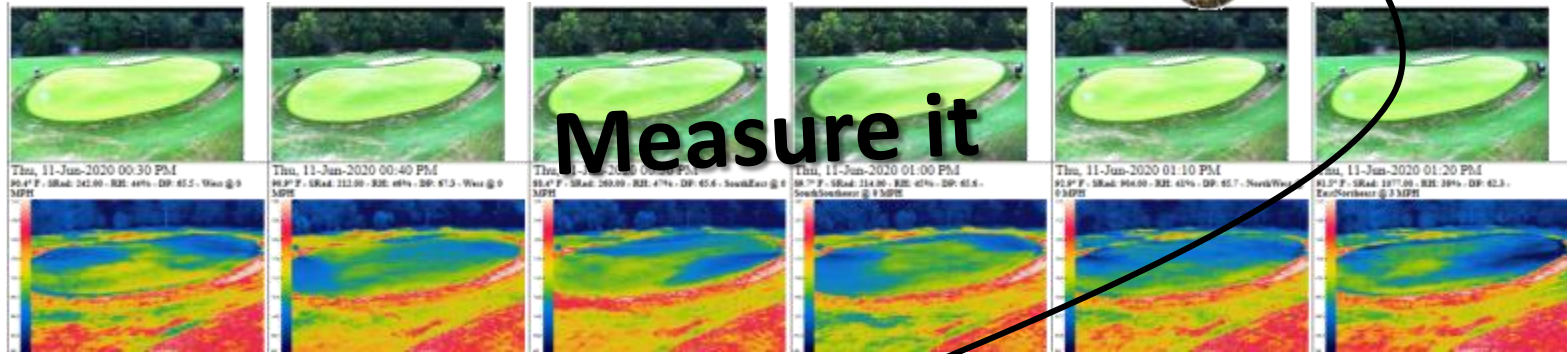
Hawk-Eye™

Latest Site Image Data

[Set Alerts](#)

[Search Image Data Archive](#)

[Logoff](#)



Measure it

Temperature - jim:15-green Add

	Trigger On	When	Value	Value Period	Schedule	Notify	Re-Notify Threshold	Notify Subject	Notify Comment	Last Notification
Edit	Dew Point-Canopy Temp (F)	Greater Than or Equal To	-5	60 min	Always	jim.etro@itricorp.com	60.00 Min.	Don't Use Fan on nr15		Fri, 12-Jun-2020 09:01 AM
Edit	Average Canopy Temperature (F)	Less Than or Equal To	91.99	20 min	Between Sunrise +2 hr. and Sunset +1 hr.	jim.etro@itricorp.com	60.00 Min.	FAN OFF nr15		Fri, 12-Jun-2020 00:31 PM
Edit	Average Canopy Temperature (F)	Greater Than or Equal To	92	20 min	Always	jim.etro@itricorp.com	20.00 Min.	FAN ON nr15		Fri, 12-Jun-2020 01:11 PM

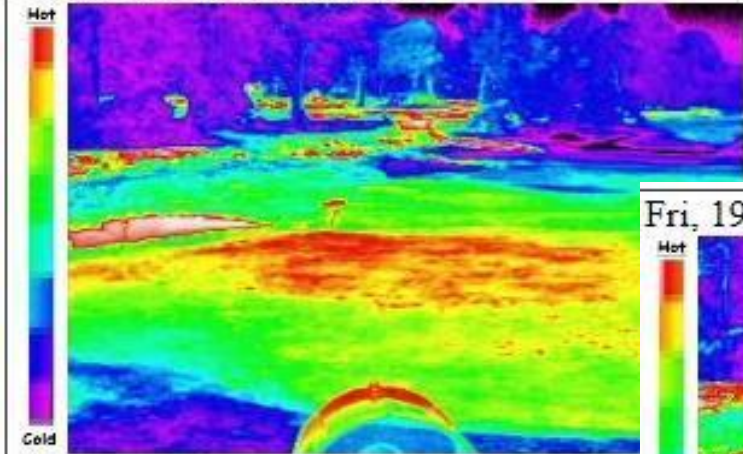
Visual Augments Test15equalize Add

From	To	Subject	Received
hawkeye	Jim Etro	Hawk-Eye Alert: FAN ON nr15	Fri 6/12/2020 12:52 PM
hawkeye	Jim Etro	Hawk-Eye Alert: Uniform On nr15	Fri 6/12/2020 12:32 PM
hawkeye	Jim Etro	Hawk-Eye Alert: FAN OFF nr15	Fri 6/12/2020 12:32 PM
hawkeye	Jim Etro	Hawk-Eye Alert: FAN OFF nr15	Fri 6/12/2020 11:32 AM

Get on/off Notifications

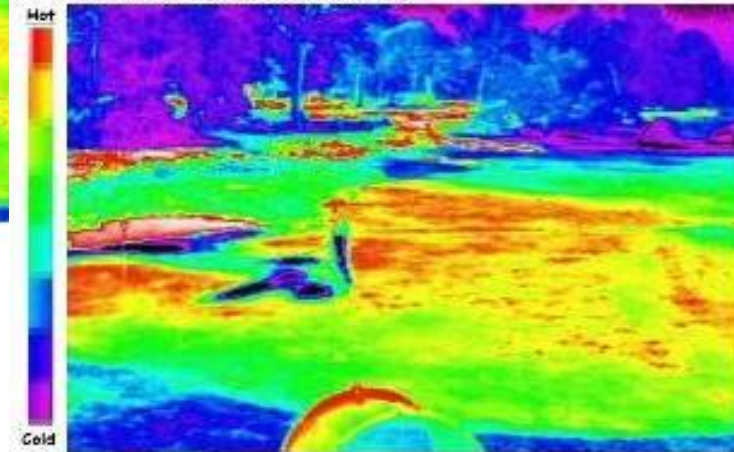
Syringing

Fri, 19-Jul-2013 2:57 PM

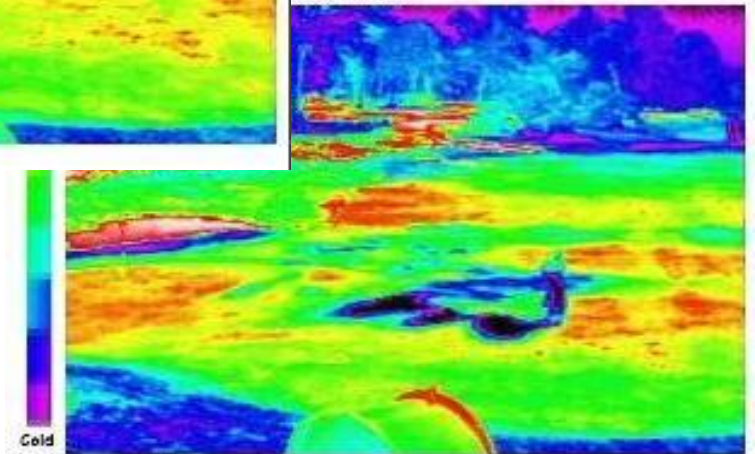


See exactly where you need it, or not.
See the result while you are doing it.

Fri, 19-Jul-2013 2:58 PM



:59 PM



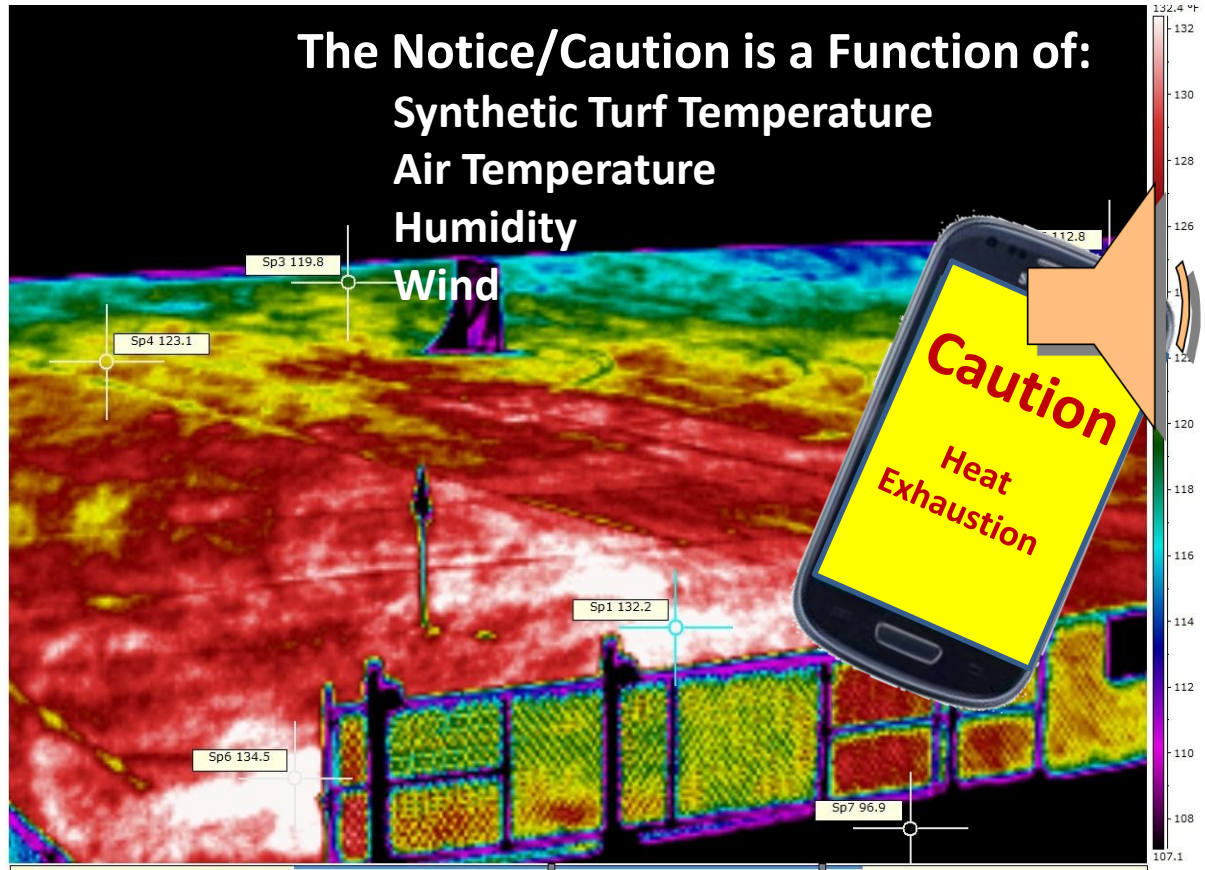
Synthetic Turf Applications

Personnel Heat Exhaustion Caution for Player & Referee Safety on Synthetic Turf

Caution = Air Temp X 0.7 + Dew Point X 0.6 - Wind Speed X 0.4 + (Synthetic Turf Temp - Air Temp) X 0.5



Always measuring and reporting when you need it.

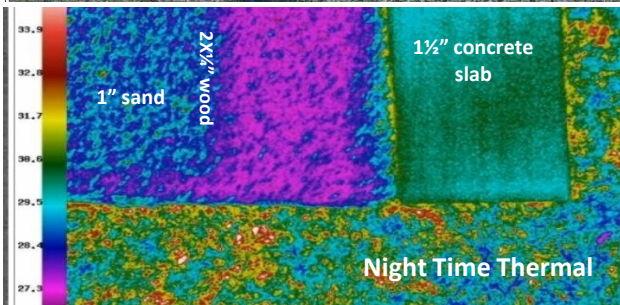


Hawk-Eye™ Cautionary Index
< 90 green
90 – 105 yellow
106 – 130 red
> 130 gray

Real-time notification by SMS and e-mail to: Coaches, Referees, &

Synthetic Turf Maintenance

Temperature Variations Highlight Non-Uniformity Underlying Turf



You can 'see' beneath the synthetic turf.

Distribution of Infill

