Glenda Project – Executive Summary - 2016

Glenda Project – Purpose

The primary mission of the Glenda Project is to provide the capability to rapidly gather previously inaccessible localized microclimate data from altitudes ranging from ground level to over 100,000 feet and to return this data for immediate use.

The Glenda Project is mix of adaptable ground stations combined with a reusable sounding rocket delivery system, and rapidly deployable weather balloons which are designed to place instrument packages into areas previously considered to be to hazardous or inaccessible using traditional platforms such as aircraft, helicopters, kites, etc.

Glenda Project – Data Capabilities

The Glenda Project has the capability to collect temperature, humidity, barometric pressure, wind speed and other types of environmental data from ground level to over 100,000 feet.

Glenda payloads are designed to be launched into thunderstorms, tornados, and other volatile weather environments and to return intact with its collected data.

Glenda Project – Engineering / Remote Sensing

David Davis – Everett, WA – Engineering - Brings decades of experience from engineering work in private industry and United States government in rocket research, and aerospace. Extensive background in electronics, mechanics, communications, computing, and storm spotting. Member of the National Association of Rocketry since 1983, and been involved with hobby related rocketry since the 1960's.

CERTIFIED SKYWARN SPOTTER

Robert Pullman – Ponchatoula, LA - Remote Sensing - Has three decades of experience in video / media communication and the computer industry and his expertise is world renown. His work has enabled governments to formulate policies and legislation in international, national and local forums. He has developed products that are used by universities for seminars, by corporations for internal operations to meet government regulations, by scientists for research work in field and laboratory conditions, by government departments for device operations and maintenance, and by the military for use in battlefield activities.

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Glenda Project – Media Communications / Public Relations

Tim Quigg in Dayton, WA brings a unique mix of personal background and professional experience to the Glenda Project. Quigg has over two decades of experience in customer service and media relations. He is the former Assistant Editor of Extreme Rocketry Magazine (2000 to 2007), as well as a freelance writer of numerous articles for Sport Rocketry Magazine. He is a current member of the National Association of Rocketry, and is the 2001 recipient of the National Association of Rocketry’s President’s Award, in recognition of his work with youth in model rocketry on a national level. He has also written a book on the topic of high power rocketry; "A Guide to Level One Certification" currently published by ARA Press. With over 33 years in law enforcement, he’s currently the Civil Deputy for the Columbia County Sheriff's Office.

CERTIFIED
SKYWARN
SPOTTER

Glenda Project – Columbia County, WA - Intercept Teams

John Quigg in Dayton, WA, brings to the project a mix of skills ranging from high tech computing, to storm spotting field abilities. As the head of our field operations Intercept Team, John plans the missions, deploys the field assets, and collects the data. A SKYWARN trained storm spotter, and a master behind the camera, John continues to bring back amazing photos, and video from the field on our continuing storm intercept operations.

CERTIFIED SKYWARN SPOTTER

Glenda Project – Data Collection Methods

Glenda has several methods for collecting data:

- Rocket Launched - Active Flight Data Collection Systems – Transmitters
- Weather Balloon Launched – Active Flight Data Systems - Radiosondes
- Rocket Launched - Passive Flight Data Collection Systems – Dataloggers
- Ground Stations

Glenda Project – Typical Flight Vehicles

9875 Booster

- 4” diameter booster, 3” diameter capsule
- RS92 Digital Radiosonde Active Payload with GPS
- GPS, and Temperature dual data logger payload
- 2,000 to 20,000 ft altitude envelope

FAR 101 Booster

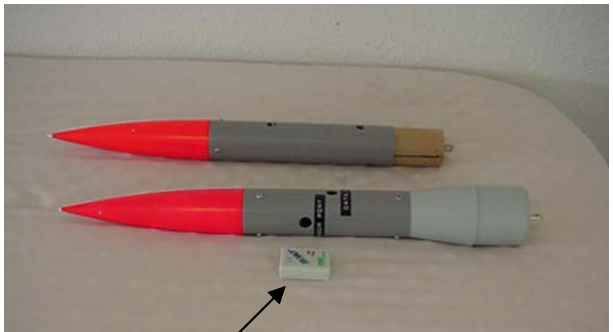
- 3” diameter booster, 2.125” diameter capsule
- GPS, and Temperature dual data logger Payload
- 2,500 foot altitude envelope
- Exempt from FAA Waiver Constraints

5475 Booster

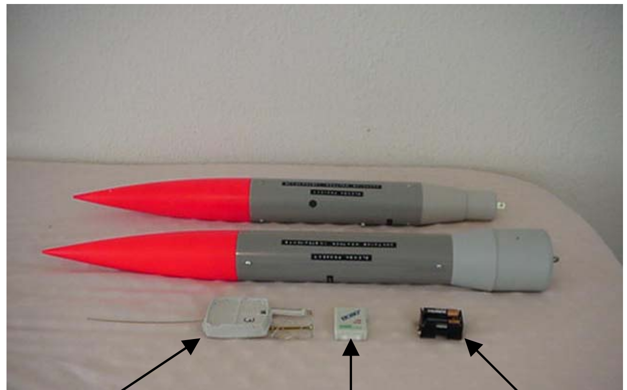
- 2.125” diameter booster, 3” diameter capsule
- RS92 Digital Radiosonde Active Payload with GPS
- GPS, and Temperature dual data logger payload
- 2,000 to 15,000 ft altitude envelope

Glenda Project – Typical Flight Payloads

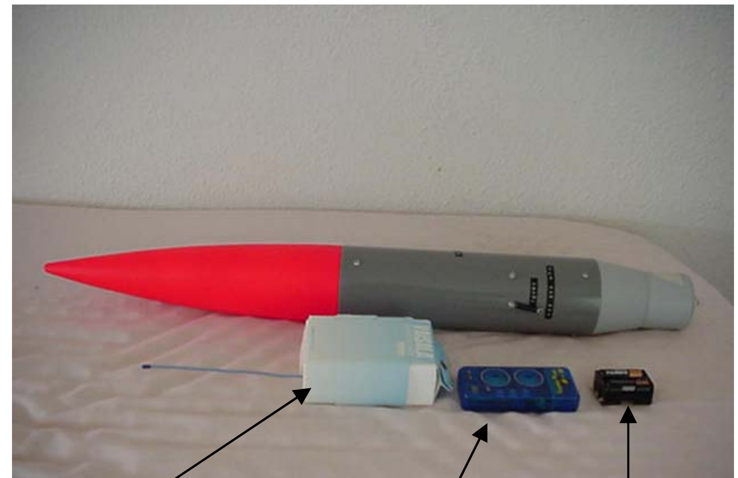
The Glenda project uses several different payload capsule configurations carrying a variety of instrumentation in order to gain weather related information, and other micro-climate data



Datalogger



RS92 Digital Radiosonde Datalogger Battery Pack



RS80 Analog Radiosonde Locator Beacon Battery Pack

54mm (2.125”) Capsules

- Datalogger Payloads
- Measures Temperature & RH values at 1 second intervals.
- Used by 54mm & 75mm boosters.

75mm (3”) Capsules

- Datalogger Payloads
- Measures Temperature & RH values at 1 second intervals.
- RS92 Digital Radiosondes transmitting temperature, RH, barometric pressure, and GPS coordinates.
- Used by 54mm & 98mm boosters.

98mm (4”) Capsule

- RS80 Analog Radiosonde transmitting temperature, RH, and barometric pressure.
- Audio location beacon
- Used by 75mm boosters.

Glenda Project – Typical Flight Profile

2 – Intercept Phase

3 – Data Collection Phase

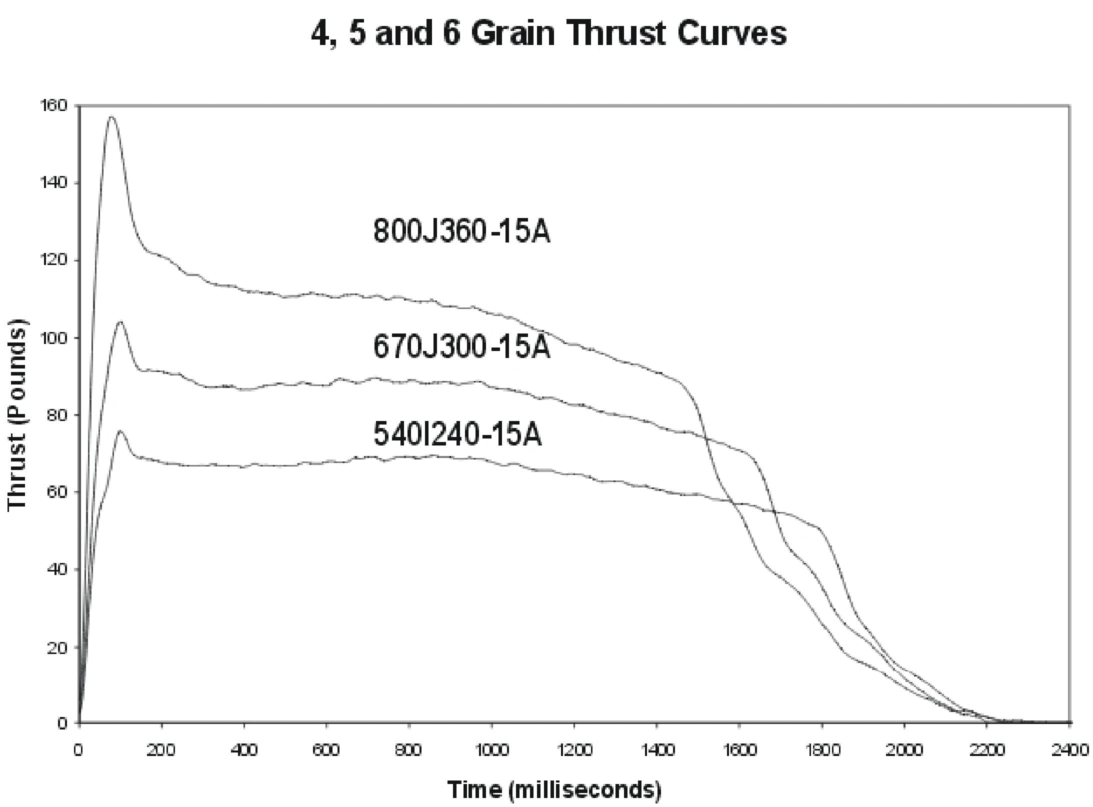
4 – Recovery Phase

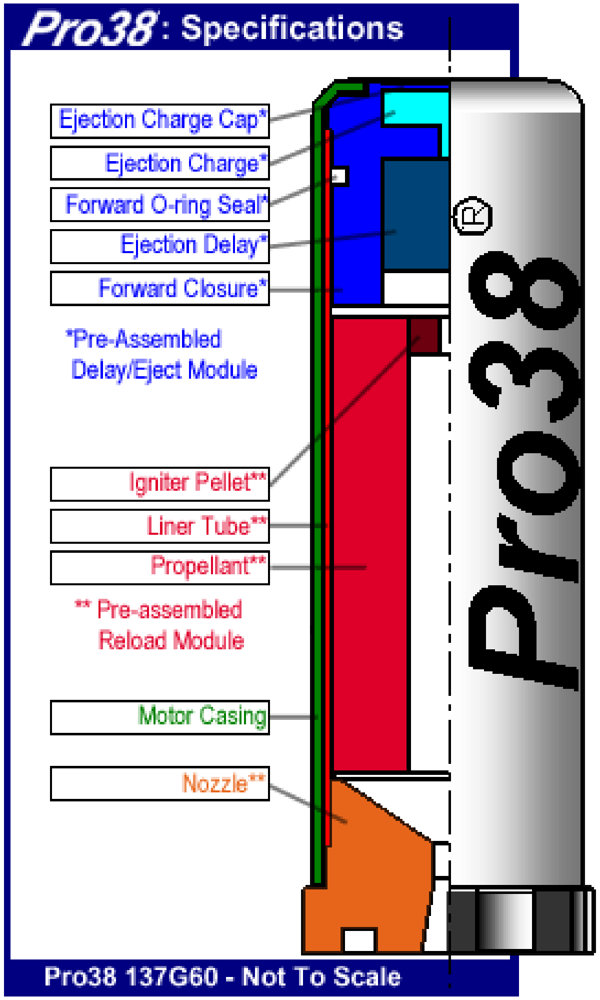
1 – Launch Phase

Note: Propulsion is provided by reloadable /reusable rocket motors giving the capability of rapid turnaround between flights.

Glenda Project – Propulsion

The Pro38 / Pro54 rocket motor propulsion system is the first commercial thermoplastic propellant-based solid rocket motor and is produced by Cesaroni Technology Inc. of Toronto Canada. The Pro38 / Pro 54 is a modular, reloadable Solid propellant rocket motor system designed primarily for use in launching small experimental payloads by universities, colleges, research institutes and sport rocketry enthusiasts.

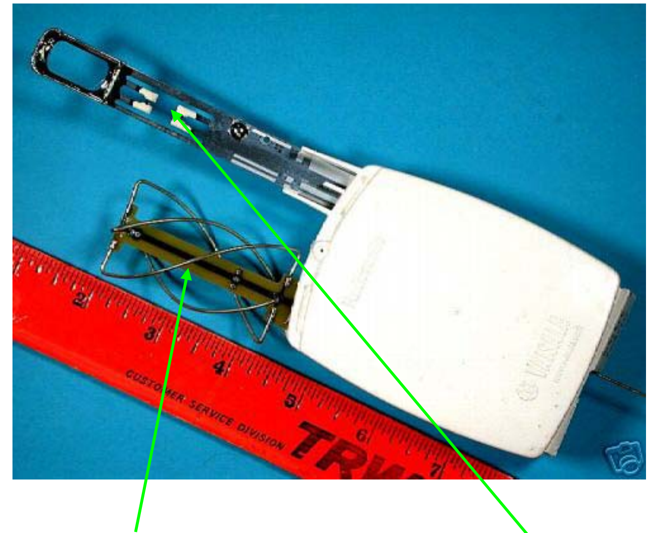




Glenda Project – Active Payloads - Transmitters

Converted Radiosonde Payloads

The Glenda Project uses converted radiosondes that are designed primarily for use with weather balloons. The circuitry and sensors function properly under thrust loads of the Glenda boosters and are compatible with NOAA / NWS radiosonde receiver systems.



The radiosonde contains instruments capable of making direct measurements of air temperature, humidity and pressure. These observed data are transmitted immediately to the ground station by a radio transmitter located within the instrument package.

Vaisala RS92 Radiosonde

Radiosonde Specifications:

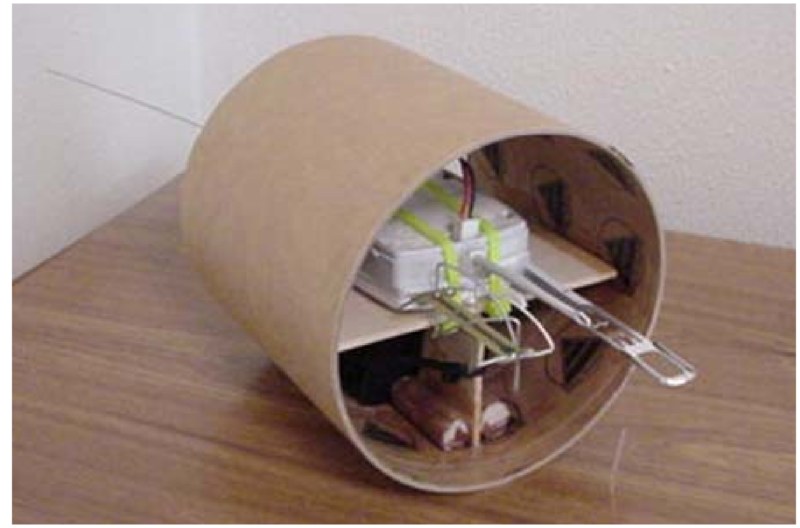
- Pressure range 3mb to 1060mb +/- .1mb
- Operating temperature range of -90°C to +60°C
- Relative Humidity from 0 to 100%
- Sampling Rate of once per second for the sensor suite
- Provides positioning data via GPS for payload location and wind velocity

Glenda Project – Active Payloads - Transmitters

Booster Launched Payload - Data Acquisition Flow Diagram

Sensor Data Transmitted from Capsule

- Barometric Pressure Sensor Data
- Temperature Sensor Data
- Relative Humidity Sensor Data
- GPS - Payload Position Data



Active Payload cushioned within the flight capsule

Ground Receiver and Antenna System

Data recorded into Laptop and graphically displayed

GPS – Ground Station / Chase Vehicle Position Data

Glenda Project – Active Payloads - Application

A Typical Booster Launched Payload Configuration

Mobile Ground Station / Intercept Vehicle

Isolated Laptop
Power Supply

Telemetry
Receiver

Cellular Modem
w/ internet connection

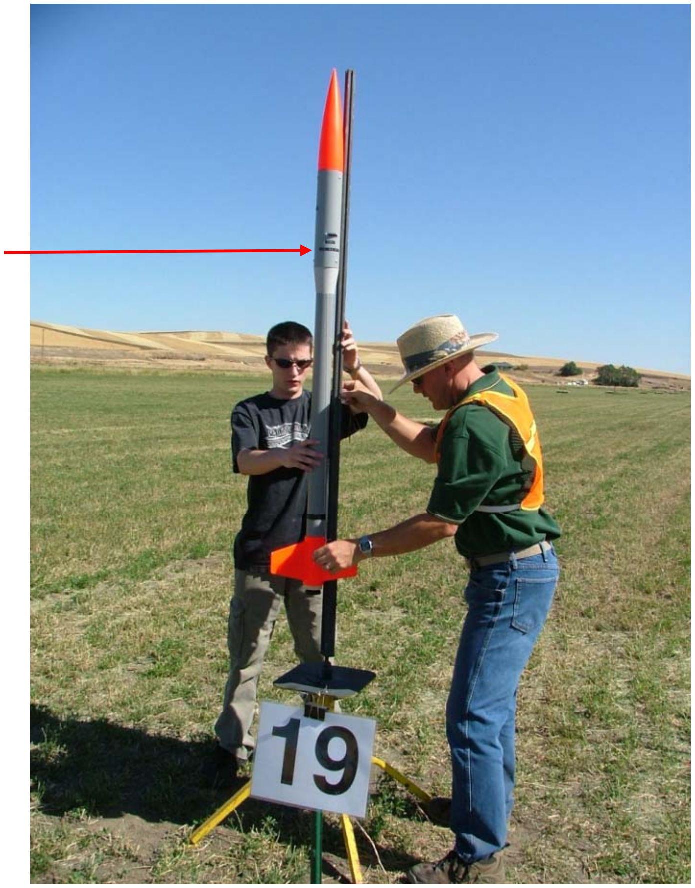
Laptop

Not Shown:

a) External Telemetry Receiver Antenna
b) External GPS Antenna
c) External Cellular Modem Antenna

Flight Vehicle

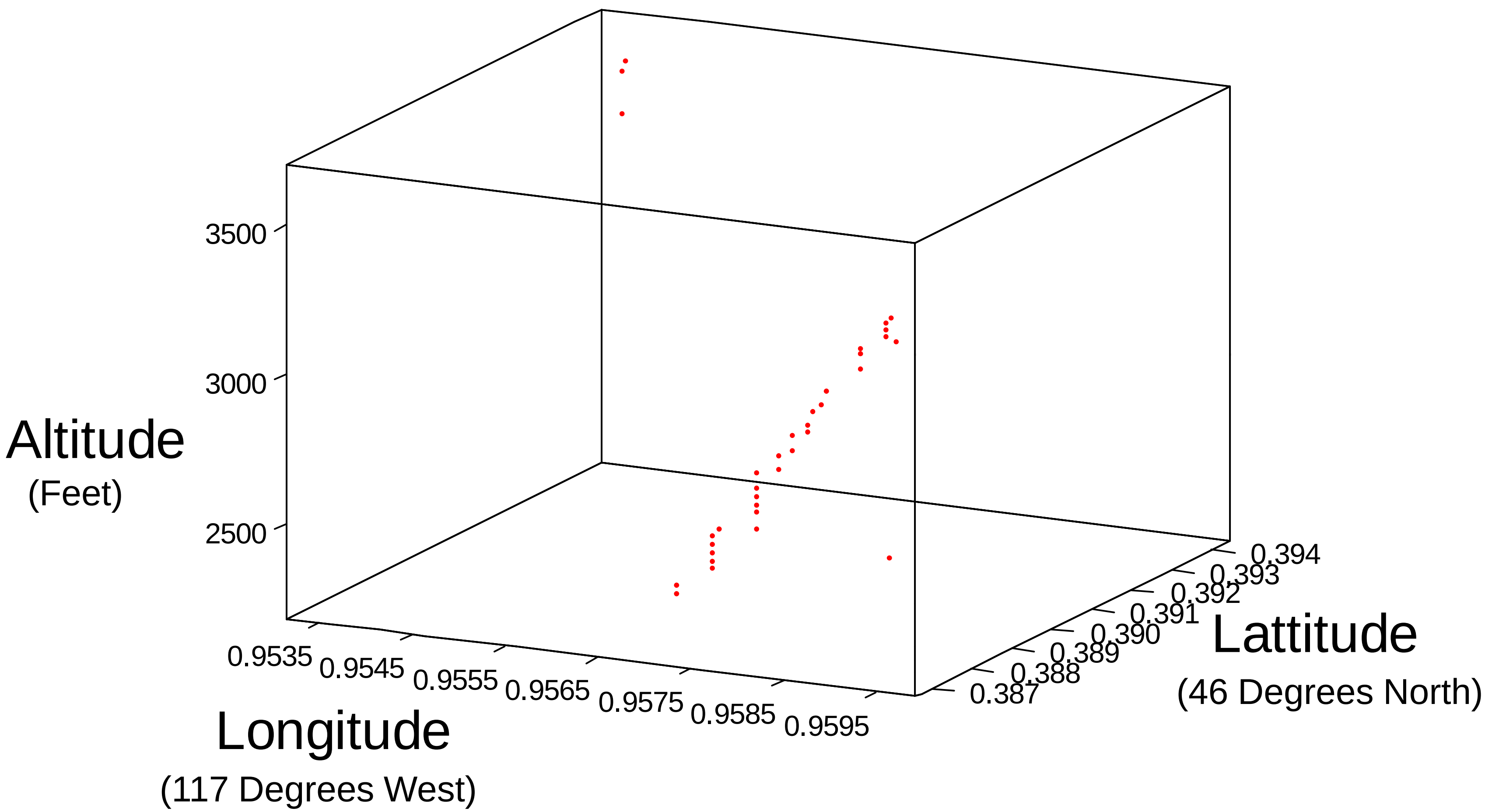
Payload
Capsule



Length: 65”
Diameter: 3”
Dry Weight: 3.5 Pounds
Attainable Altitudes: 2,000 feet
to 20,000 feet

Glenda Project – Active Payloads - Application

"Lone Tree" Launch Site – June 11th, 2011
Lattitude / Longitude / Altitude / Motion



Note: After an initial shift at altitude, due to the winds aloft, recovery was nominal

Glenda Project – Active Payloads - Transmitters

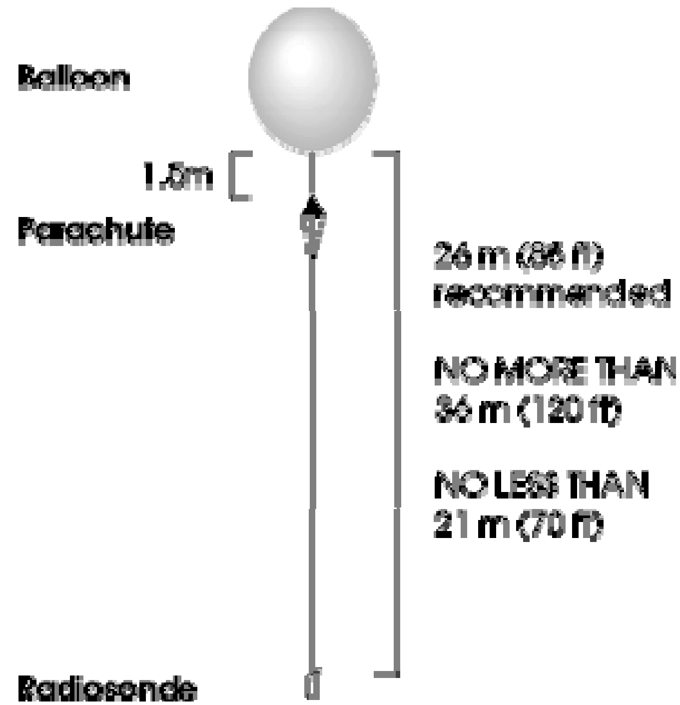
Balloon Launched Payloads – Radiosondes

In 2013, the Glenda Project expanded our flight capability to conduct actual weather balloon launches with the intent to expand our flight envelope to over 100,000 feet. The most significant challenge was the development of the ground support equipment and infrastructure.

The signal / data processing systems were already in place which made the transition to actual balloon launches rather seamless.

100 gram and 150 gram balloons

Parachute and Radiosonde de-reeler



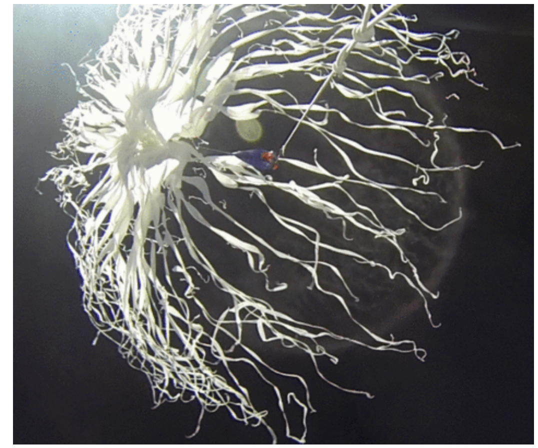
Glenda Project – Active Payloads - Transmitters

Balloon Launched Payloads – Typical Flight Profile

2 – Data Collection Phase

At 100,000 feet, the temperature is around -40 degrees F with air pressure close to a vacuum

3 – Balloon Burst



1 – Launch Phase

4 – Recovery Phase

Glenda Project – Active Payloads - Transmitters

Ground Support Equipment (GSE) in support of balloon inflation

Pressure Regulator with connector to Helium Tank

15 foot connection hose

Balloon “Stinger” with flow control / shut off valve

Un-inflated weather balloon on “Stinger”.

Radiosonde Launch Platform

Glenda Project – Active Payloads - Application

April 22nd , 2016 – Balloon Launched Payload – Storm Intercept

On April 22nd, 2016, the Glenda Project launched its latest iteration weather balloon system deploying a Vaisala RS-92 SGP radiosonde payload, combined with our updated antenna and receiver ground station.

The April 22nd flight featured a 400 gram balloon filled with 50 cubic feet of helium. Projected flight altitude was approximately 90,000 feet. The RS-92 payload contained a GPS positioning system plus a weather sensor suite telemetry package. Ground wind speed was around 10 mph with temperatures in the 70's.

The radiosonde ground station featured our existing Sirio WY400-10N Yagi antenna combined with our new Uniden BC-125AT Narrow Band FM (NFM) receiver.

Shortly after 3:15pm, a thunderstorm passed through the area and the weather balloon and its associated payload were ingested into the storm system for a successful storm intercept.

Flight performance was impressive and we achieved a viable data set from launch to balloon burst at just over 50,000 feet, continuing on under parachute until loss of signal at 41,000 feet due to the level of turbulence from the storm cell combined with earth curvature and local terrain.

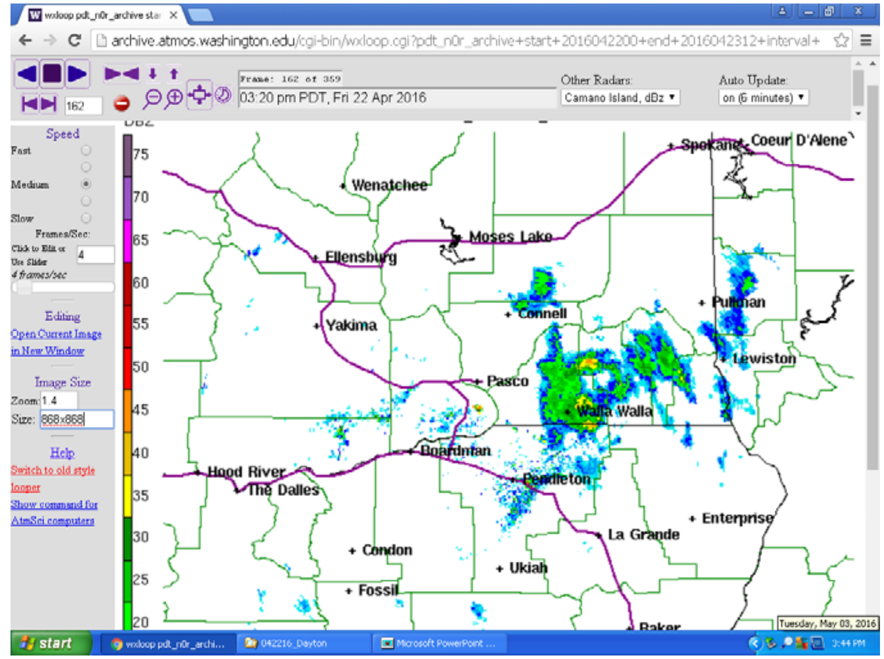
The following slides display the data collected from the flight.

Glenda Project – Active Payloads - Application

April 22nd , 2016 – Balloon Launched Payload – Storm Intercept

Photo Courtesy of Liz Quigg

Visual of Storm Intercept

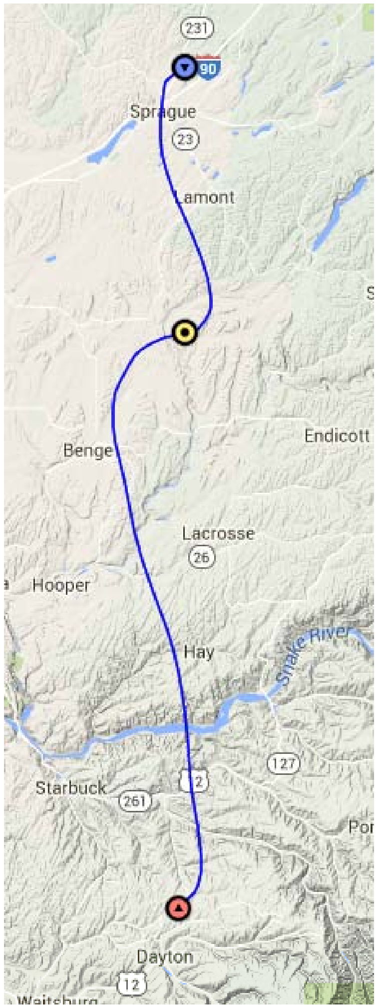


Pendleton, OR – Radar Track

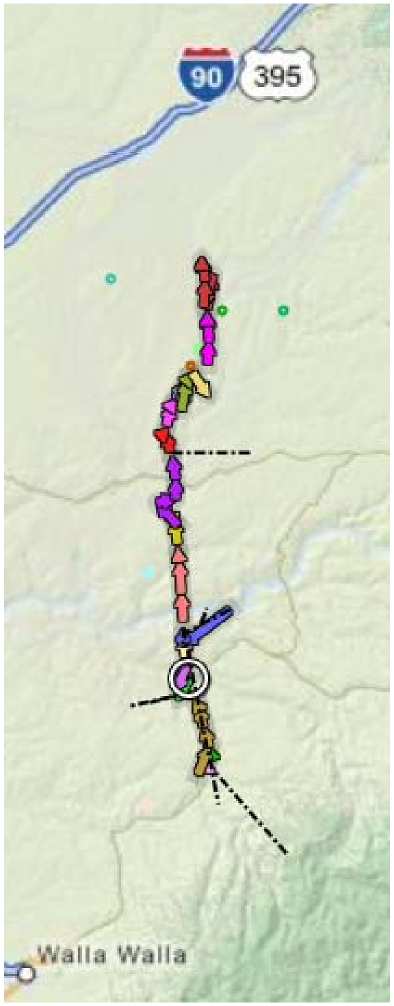
The storm cell that was intercepted, was tracked on Pendleton, OR radar and visually by the intercept team. Our mobile ground station collected a viable data set and that data is shown in the following slides as well.

Glenda Project – Active Payloads - Application

April 22nd, 2016 – Balloon Launched Payload – Ground Track



Flight Simulation



Actual Flight Path

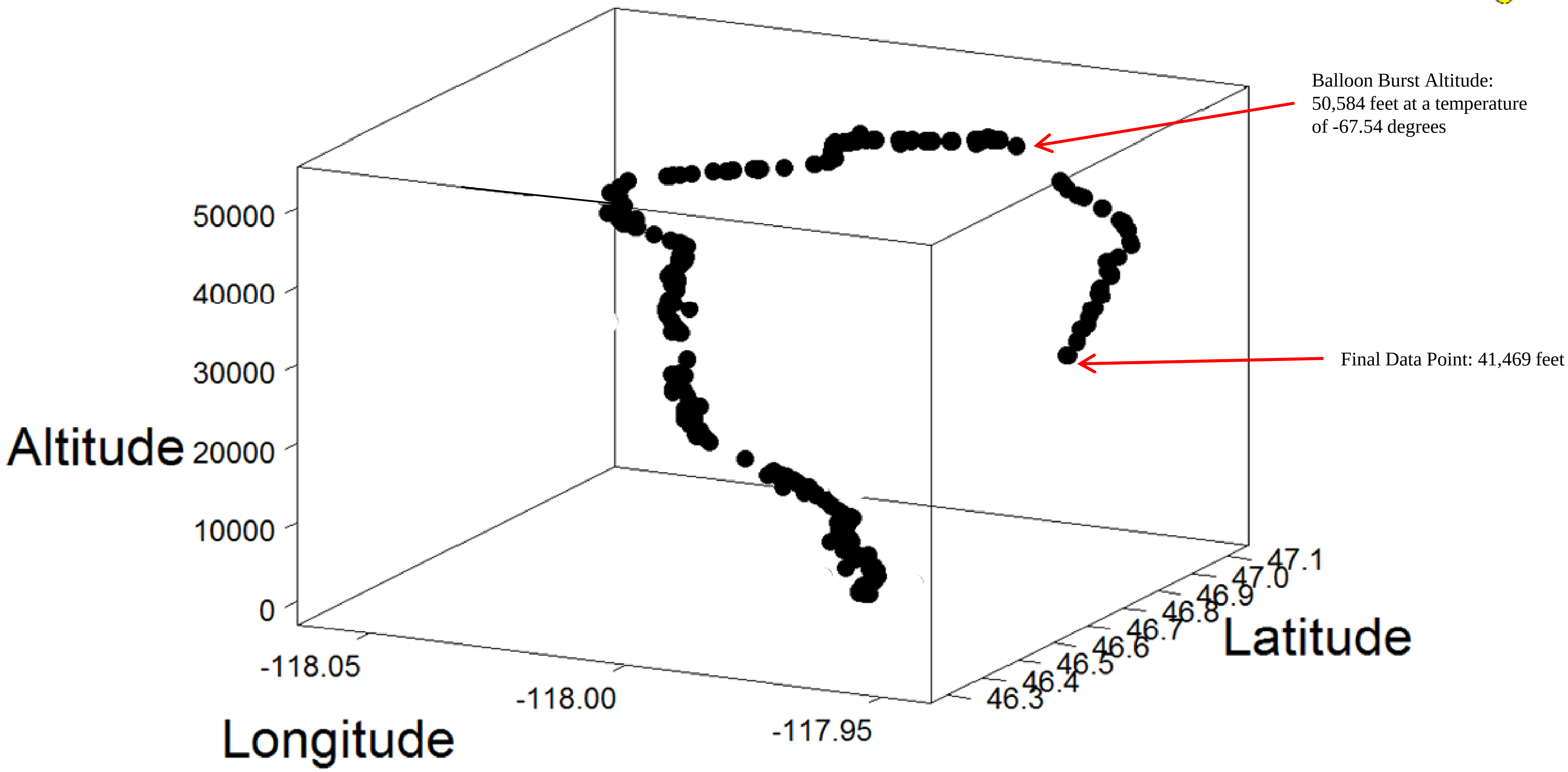
The actual flight trajectory ground track measured just over 60 miles before loss of signal and aligned very well with the pre-flight simulation.

After transition from launch conditions, the balloon was ingested into the passing storm system and followed its south to north storm track.

Ground wind speed exceeded 30 mph, while the storm ground track was close to 40 mph.

Glenda Project – Active Payloads - Application

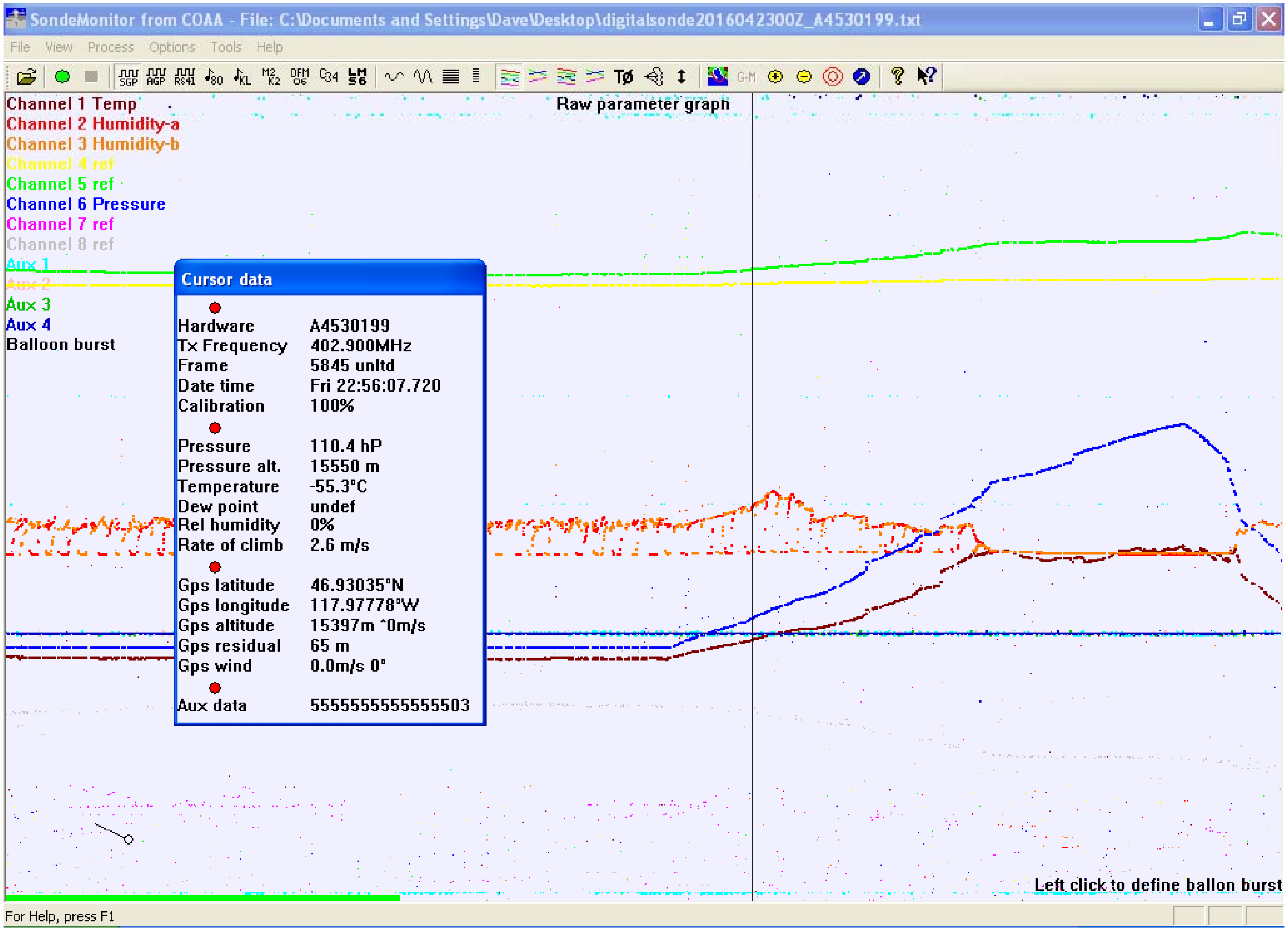
April 22nd, 2016 – Balloon Launched Payload – Altitude Track



While the balloon ground track appears linear, the balloon and its payload followed the circulation of the storm cell and hovered along the top of the cell while also moving in a south to north path.

Glenda Project – Active Payloads - Application

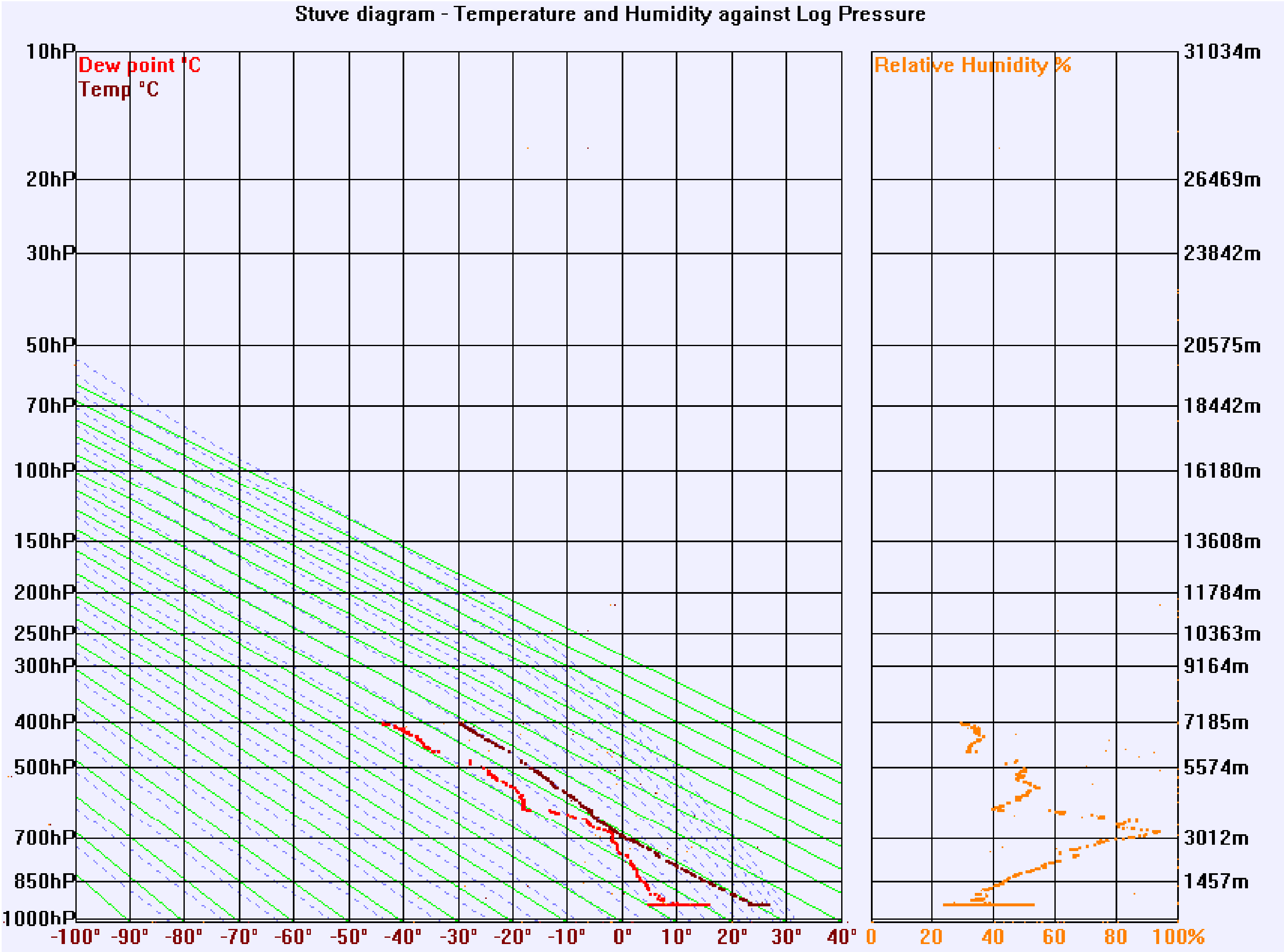
April 22nd, 2016 – Balloon Launched Payload – Software



The Sondemonitor software performed flawlessly providing data capture collected via the upgraded antenna and receiver.

Glenda Project – Active Payloads - Application

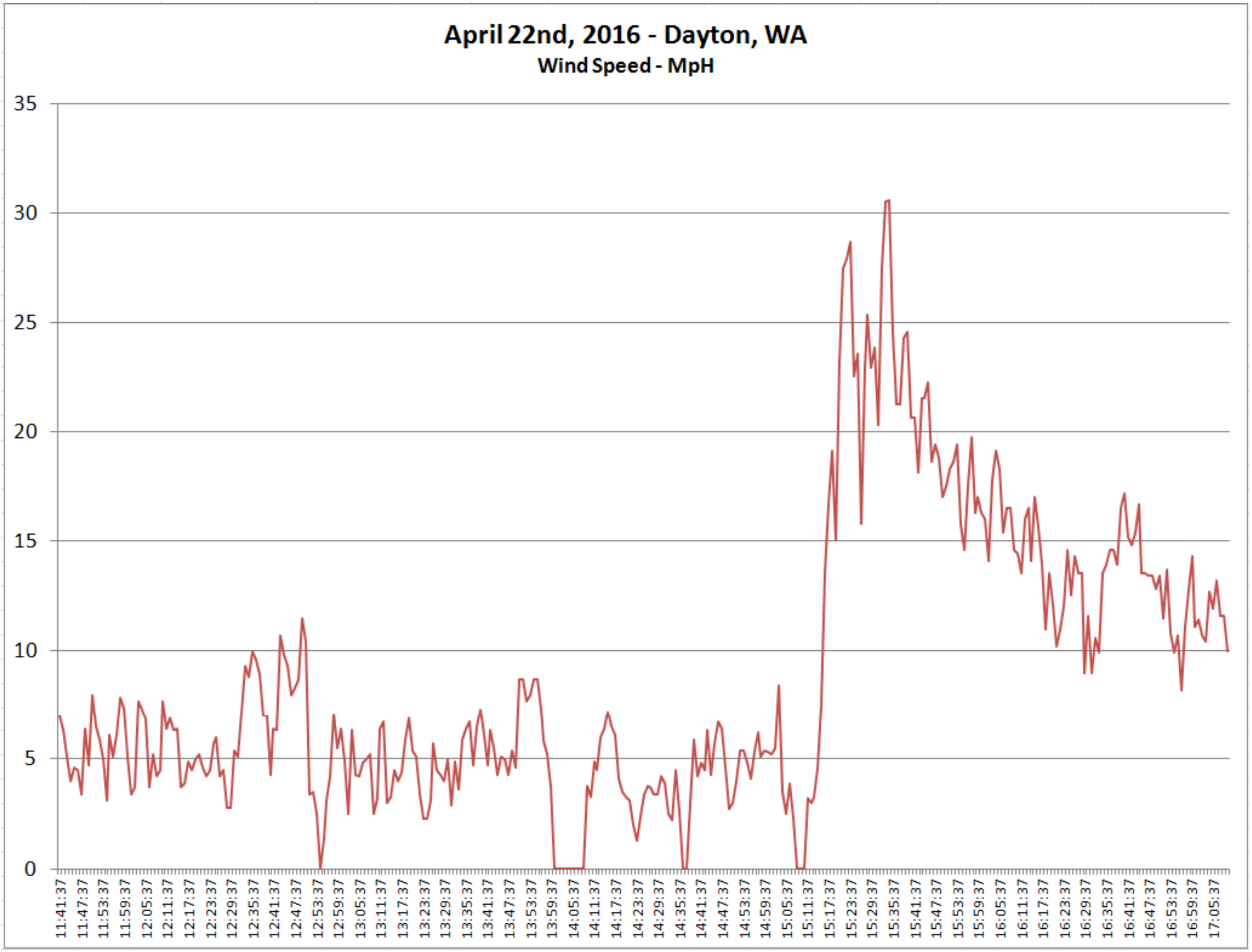
April 22nd, 2016 – Balloon Launched Payload – Weather Sensor Data



The Sondemonitor software also provides Temperature, Dew Point, and Relative graphing capability vs pressure / altitude.

Glenda Project – Active Payloads - Application

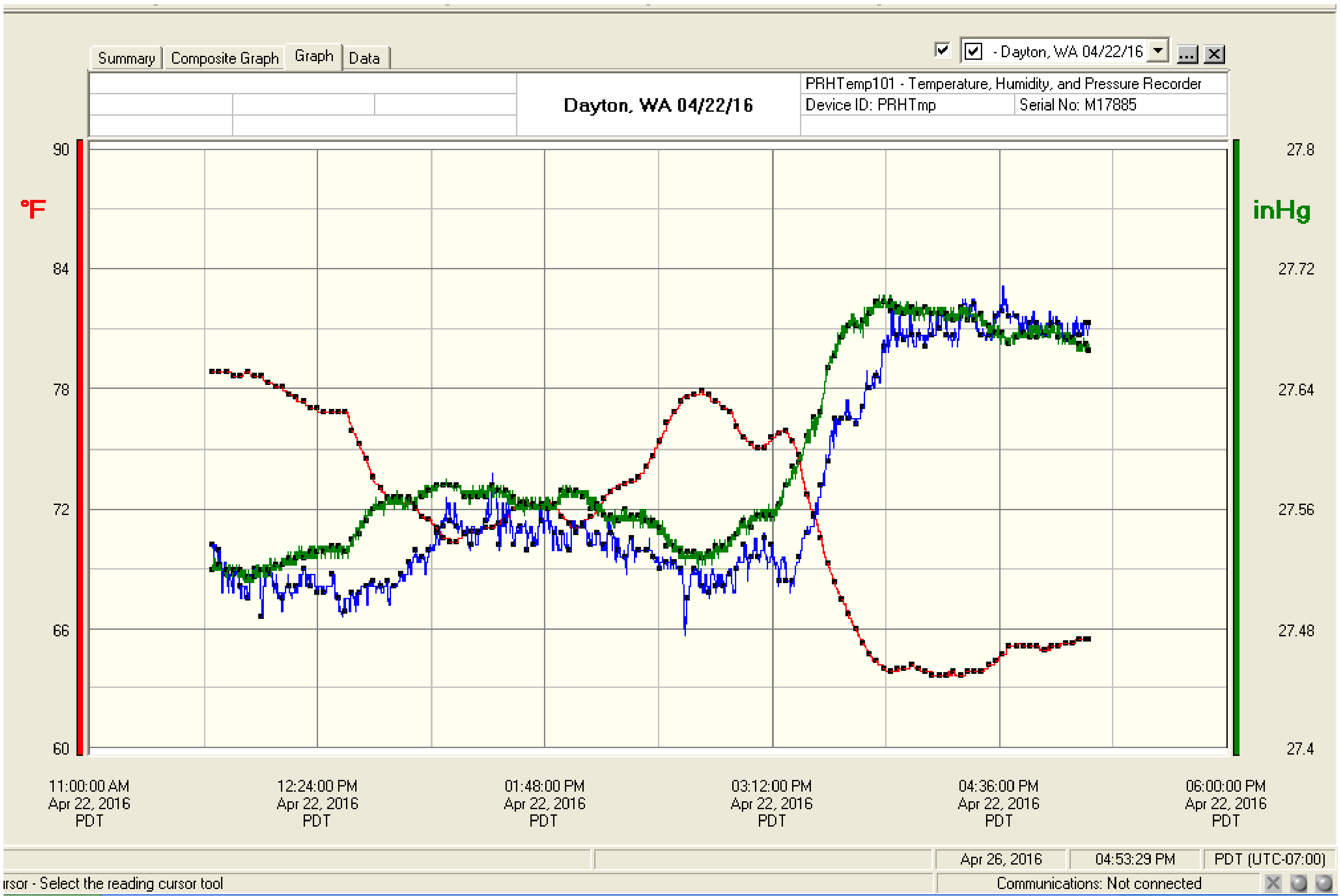
April 22nd, 2016 – Ground Station Data – Wind Speed



In parallel with the balloon launch, Glenda was also capturing ground condition data. The storm cell impacted our collection site just after 3:15 pm as the balloon payload was being ingested into the storm cell. Winds in excess of 30 mph were recorded. While not as impressive as our June 2012 storm intercept, it is still a significant accomplishment as we've now added the balloon intercept capability.

Glenda Project – Active Payloads - Application

April 22nd, 2016 – Ground Station Data – Temp, Baro, RH



Temperature, Barometric Pressure, and Relative Humidity data were also being collected in real time at less than 2 second intervals during the storm intercept as well. A noticeable shift can be seen in the data as the storm cell passes over the collection site.

Glenda Project – Active Payloads - Application

April 22nd, 2016 – Balloon Launched Payload – Lessons Learned / Next Steps

The results of this flight establishes the capability of the Glenda Project to launch balloon deployed payloads into thunderstorms, and tornadic systems.

The flight was an operational success, as it verified that the Uniden BC125AT combined with the Sirio Yagi is an efficient and effective combination. A side effect of this receiver / antenna combination, is that we no longer need the additional omni-directional antenna.

While the intent of the flight was to extend the flight envelope from our existing 35,000 foot altitude range, we were able to achieve our first successful storm intercept with a balloon launched payload. While we did not achieve our maximum targeted altitude of 80,000 feet, between the balloon icing up, storm turbulence, and the age of the balloon, 50,000 feet is still a significant accomplishment.

The existing mature ground station data collection performed very well and captured a solid data set.

An interesting side effect was that we found that our existing alkaline batteries perform very will at extremely low temperatures (-67 degrees F) and should serve us well in the future, in that, we'll no longer be needing Lithium cells.

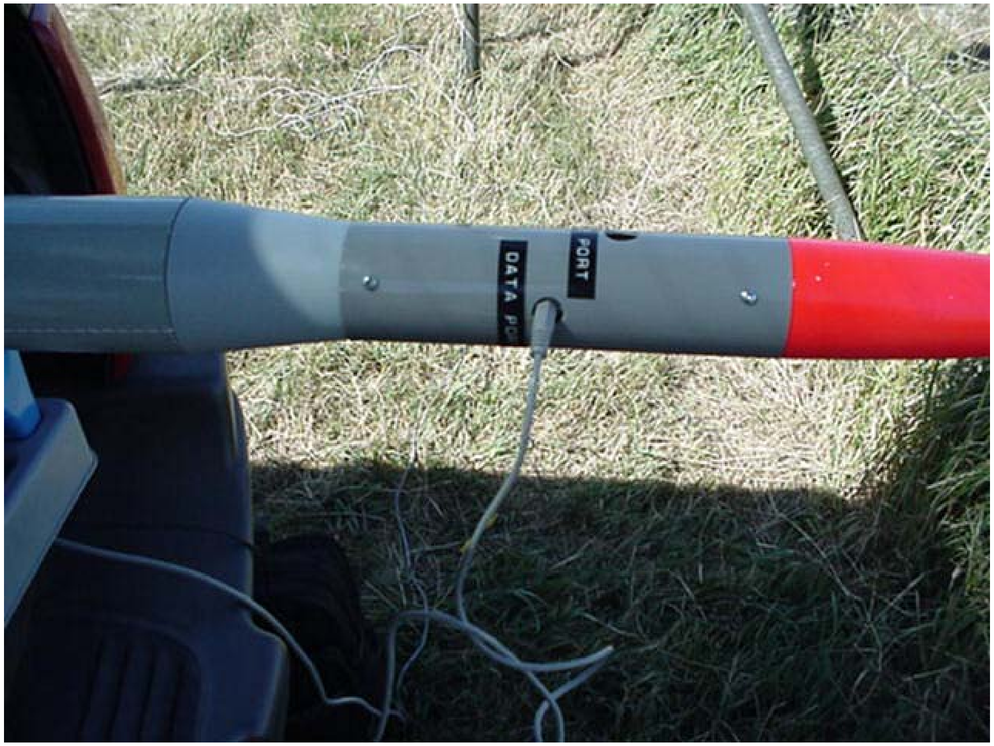
The success of this launch culminates over 15 years of development and operational maturity. Additional launches are planned further extending the flight envelope as our systems continue to grow and evolve.

Glenda Project - Passive Payloads – Data Loggers

A data logger is an electronic instrument that records measurements over time. Typically, data loggers are small, battery-powered devices that are equipped with a microprocessor, data storage and sensors. Most data loggers utilize software on a personal computer to initiate the logger and view the collected data.

Prior to a Glenda launch, the data logger is connected to a laptop computer. Then, systems software is used to select logging parameters (sampling intervals, start time, etc.) and initiate the logger. The logger is then disconnected from the laptop and installed inside the Glenda payload capsule. Upon launch, the logger records each measurement and stores it in memory along with the time and date.

Post recovery, the logger is then reconnected to the laptop computer and the software is used again to readout the data and see the measurements as a graph, showing the profile over time. The tabular data can be viewed as well, or exported to a spreadsheet for further manipulation.



Glenda Project - Passive Payloads – Data Loggers

Canmore GT-740FL GPS Data Logger

The GT-740FL is a single board GPS receiver / data logger featuring surface mount components and power supply designed to with stand the high flight loads of the Glenda boosters.

Data Logger Specifications:

- 48 track verification channels
- SiRF IV low power chipset
- Adjustable sampling rates from 1 second +
- Satellite signal reception sensitivity: -163dbm
- Position: +/- 2.5 meters CEP
- Data compatible with Google Earth
- Size/Weight: .625 x 1.17 x 2.75" (16 x 30 x 70 mm)/approx. 2.5 oz.(71 grams)
- Time to reposition: < 0.1 second average
- Time to boot: <34 seconds (cold), 1 sec (hot)
- Ultra low power consumption; over 17/56 hours continuous use
- Water resistant to IPX6 standard

Glenda Project - Passive Payloads – Data Loggers

MicroLite Temperature Data Logger

The MicroLite USB Data Logger is a small electronic device for monitoring and recording temperature. Manufactured to stringent IP68 standards, the MicroLite logger is dustproof and is only 4.3” long and 1” thick. The data logger features a three digit LCD display, direct USB connection, wide temperature range, high accuracy and large sample memory. Data can be displayed on the small numeric screen or downloaded to the MicroLab Lite software via the USB 2.0 connector.

Data Logger Specifications:

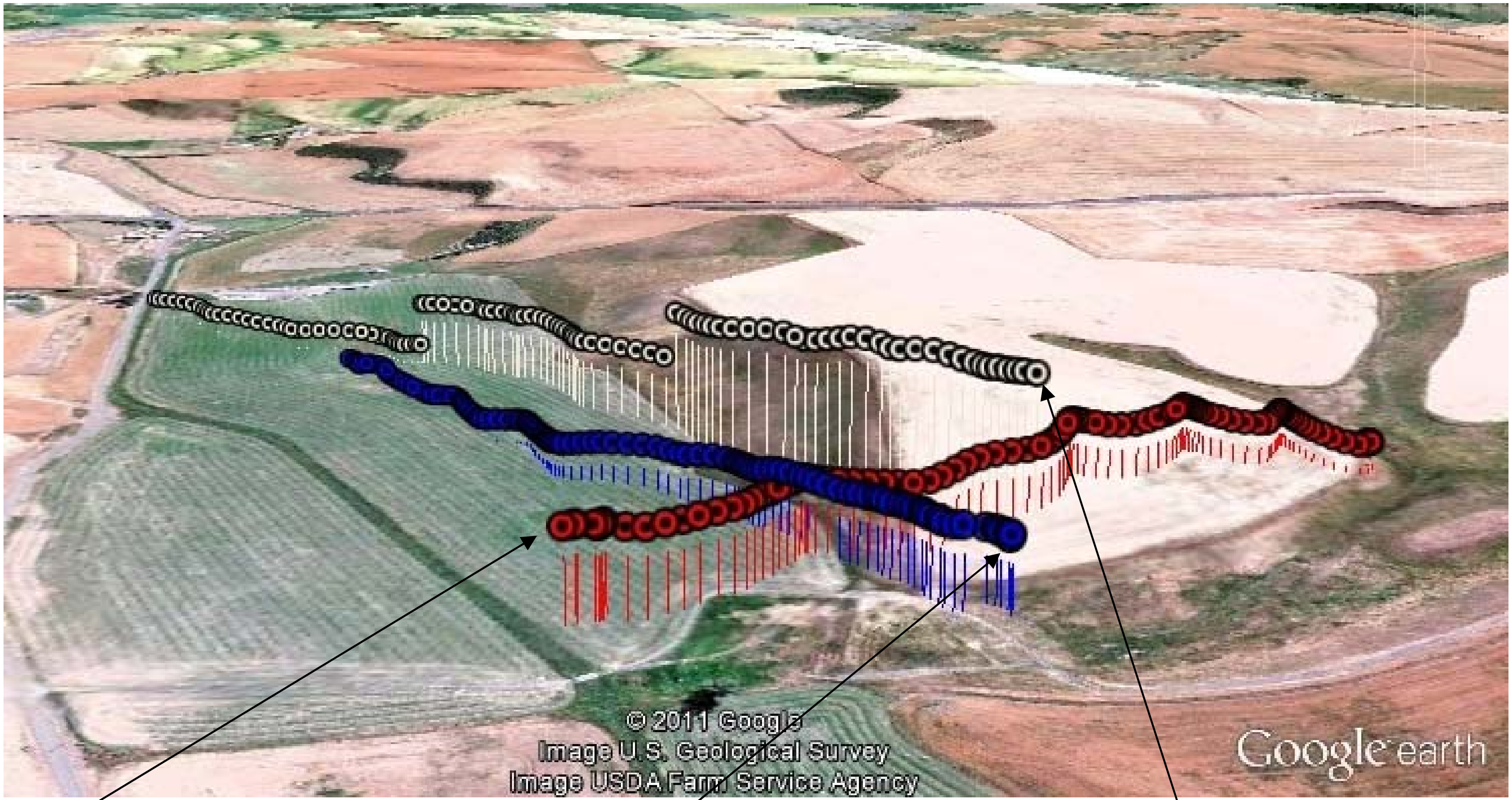
- Internal Temp Sensor: -40°C to 80°C Thermal Conductor enabling a fast sensor response time
- Sampling Resolution A/D Resolution: 16Bit 0.1°C
- Data Storage Capacity: 16,000 Samples
- Sampling Rate: 1 per second to 1 per 2 Hours
- Battery: Replaceable 3V Lithium Battery - CR2032
- Battery Life: 2 Years at 1 second Sampling Rate
- Dimensions: 11cm x 3.9cm x 2.6cm (4.3" x 1.5" x 1.0")
- Weight: 45.5 grams (1.6oz)
- Software: MicroLab Lite for Windows
- Standard Compliance: IP68, NEMA6 (30 Minutes for 0.5 meter Depth) CE, FCC

Glenda Project - Passive Payloads – Application

GPS Data Logging

4D wind current mapping over local terrain.

(4D is latitude, longitude, elevation and velocity)



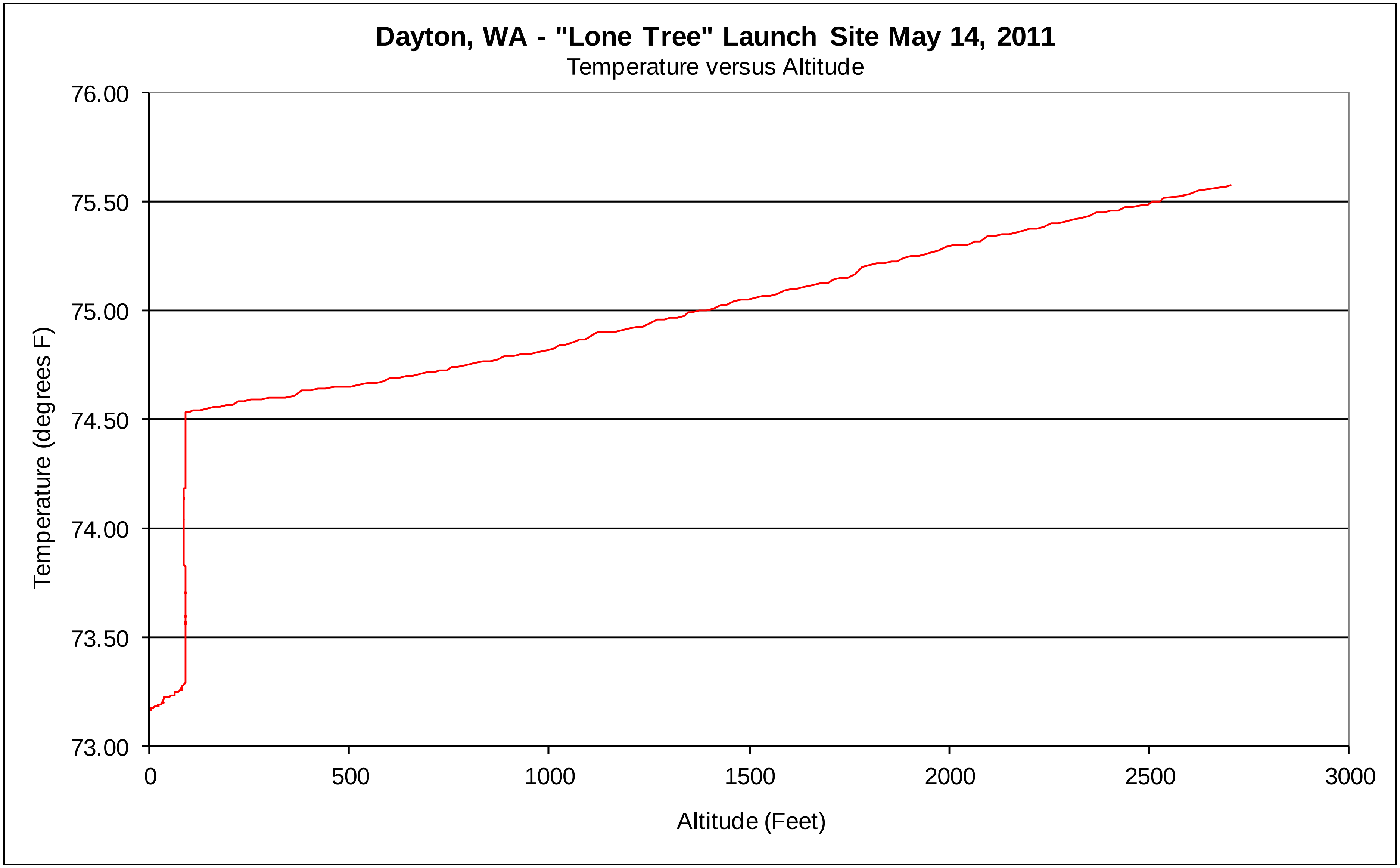
May 14th
7554 Booster – Aerotech I211
"Thunderstorm Intercept"
Apogee: 2,706 Feet
Ground Level Wind Speed: 4.5 mph

June 11th
9875 Booster – CTI I170
Apogee: 2,211 Feet
Ground Level Wind Speed: 10 mph

October 1st
7554 Booster – Aerotech I211
Apogee: 2,354
Ground Level Wind Speed: 14.5 mph

Glenda Project - Passive Payloads – Application

Temperature / GPS Data Logger – Temperature vs Altitude
"Lone Tree" Launch Site – May 14th, 2011



Glenda Project – Video Payloads

In May 2007, the Glenda Project deployed its “First Generation” camera probe called “Ranger Intercept” named from the lunar photographic missions from the 1960’s.

While successful, the payload did not gather the high resolution images required for viable analysis.

Since 2007, cameras and optics have matured to the point where high definition / high resolution images are now possible from compact / light weight payloads.

In September 2014, Glenda successfully deployed a High Definition digital movie camera as an auxillary camera “pod” into our existing payload capsule. This increased resolution now provides a visual record of the environment captured by the on-board sensor suite.

May 2007 – “First Generation” Camera Flight

September 2014 – “Second Generation” Camera Pod

Glenda Project - Video Payloads – Application

September 13th, 2014 – Deployment of the Second Generation “Ranger Intercept” Video Payload

2. Mid - Boost

Photo Courtesy of Jon Preston

3. Apogee

4. Descent

5. Final Approach

1. Launch

Photo Courtesy of Jon Preston

6. Landing

Glenda Project – Ground Stations

The Glenda Project has found that, over time, without knowing ground level weather conditions, there is no effective baseline to measure from as we launch instrument packages into severe weather systems.

This acknowledgement has driven the development of several different types of mobile ground station where their usage can be adapted based on our mission and data requirements.

Some typical examples:

a) Digital Chart Recorders

b) Recording Anemometers

c) TMQ-34 Mobile Military system

d) Coastal Environmental WeatherPak 400 Wireless ground station

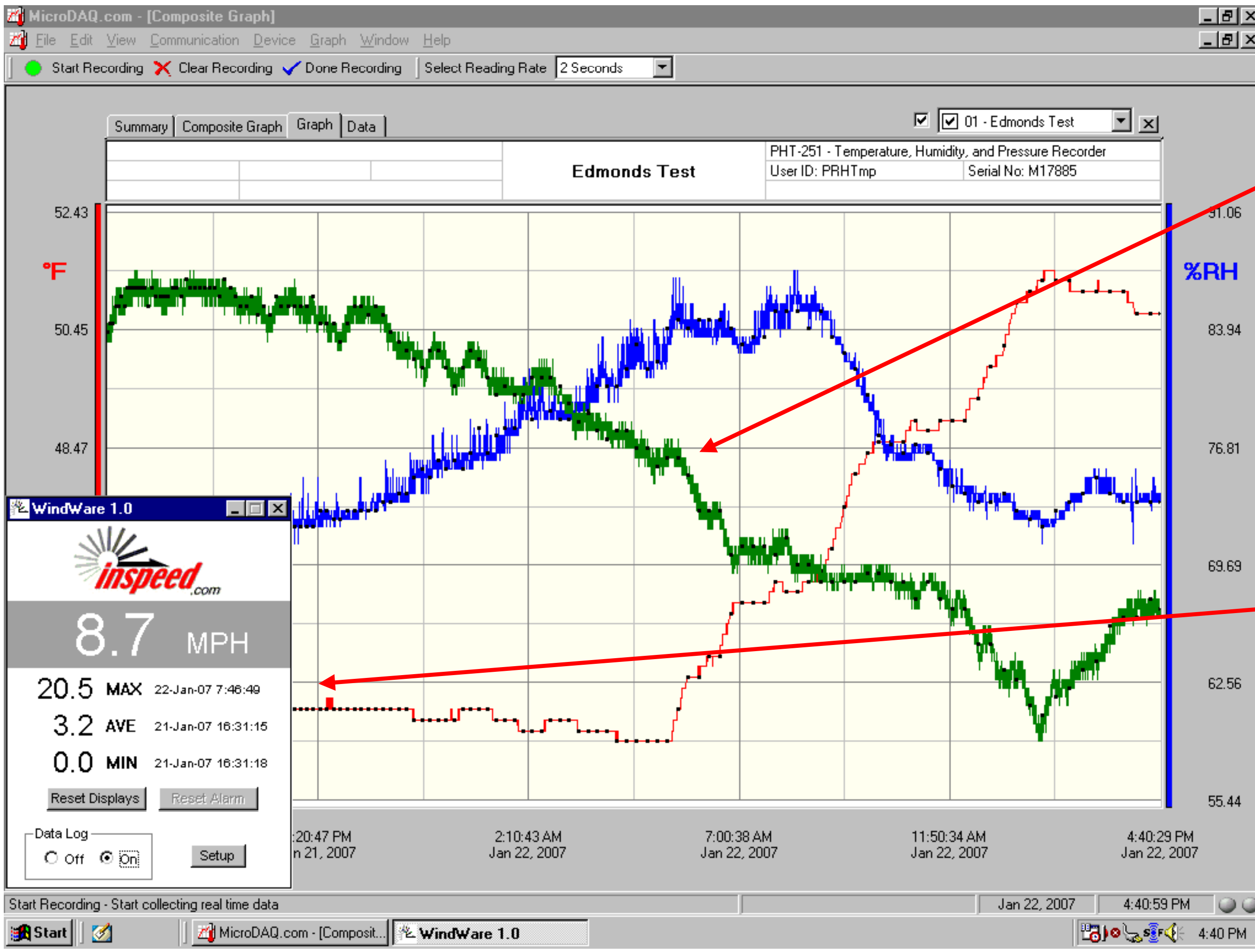
e) Mobile Mesonet ground stations

Glenda Project – Ground Stations

Digital Chart Recorders

Glenda Project utilizes sensors combined with ground based laptops to provide a digital based chart record of ground baseline conditions mapped over time.

The basic example below is a digital chart record of temperature, humidity, barometric pressure and wind speed at a test site.



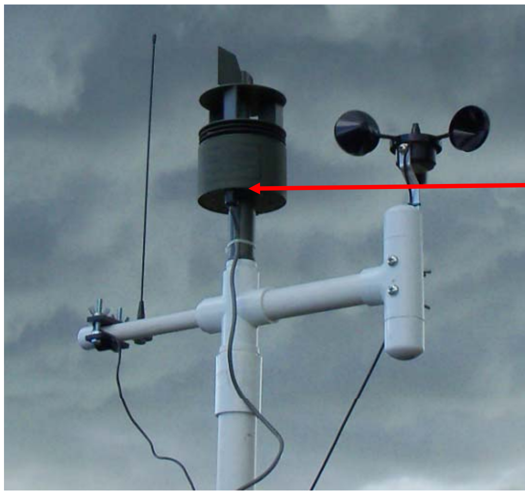
Temperature, Relative Humidity, & Barometric Pressure data using a Madgetech data logger with supporting software

Wind Speed data using InSpeed Anemometer and supporting software

Glenda Project – Ground Stations

AN/TMQ-34 Military Ground Station

Glenda also has an operational portable military weather station. This acquisition further enhances the projects ground condition data collection capabilities.



Sensor Module

Computer Module

The TMQ–34 is a military self contained portable weather measuring system that is powered by a rechargeable Ni CAD battery.

The TMQ–34 alphanumerically displays wind speed and direction, peak wind, temperature, dew point, barometric pressure, 3-hour pressure change, and the minimum and maximum temperature.

The entire TMQ–34, including the system case, weighs about 20 pounds. The set contains a computer module with a pressure sensor, and the main sensor module with a red sensor for temperature, a white sensor for humidity, a wind direction compass, and an anemometer to measure wind speed.

The TMQ–34 can operate in temperatures ranging from a low of –59.5°F to 132°F. The TMQ–34 is intended for use in a tactical environment with an operating range of 100 feet below sea level to 10,000 feet above sea level.

Glenda Project – WeatherPak 400 TRx Ground Station

Coastal Environmental Wireless HazMat Weather Station

The Glenda Project now has several Coastal Environmental WeatherPak 400 TRx mobile vehicle mounted and wireless weather stations.

Some of its numerous features are:

- Wireless radio data Telemetry with a 5 mile range
- Self aligning Fluxgate Compass
- Complete sensor suite to record Temperature, Relative Humidity, Barometric Pressure, Wind Speed, and Wind Direction.
- Weighs less than 10 pounds and is deployable in less than 60 seconds
- Highly portable with its own transit case
- Serial data interface to support data logging and display
- Alternate Power Sources from 120VAC to 12 VDC
- Tested and designed for HazMat and severe environments
- Capability to measure “Sigma Theta” to determine atmospheric instability

Mobile Deployment

Vehicle Mounted

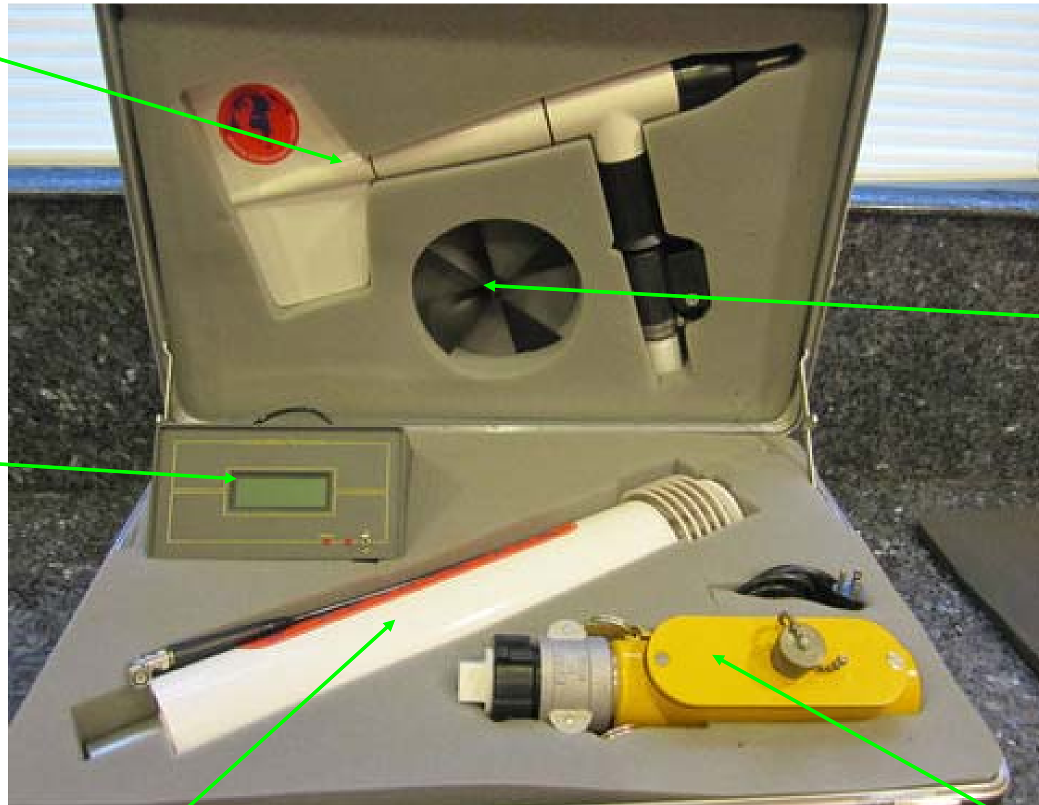
Glenda Project – WeatherPak 400 TRx Ground Station

Coastal Environmental Wireless HazMat Weather Station

System Components

Anemometer / Wind Direction Sensor

Telemetry Receiver Display



Anemometer Propeller

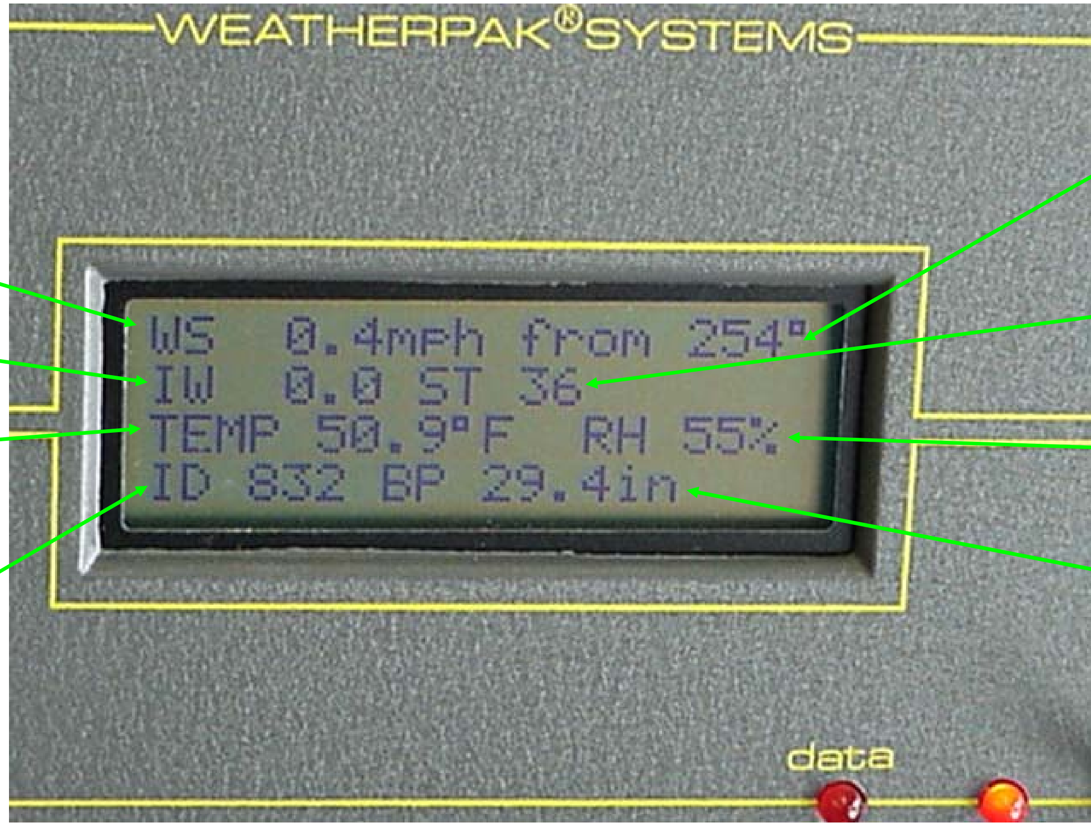
Sensor Suite Unit containing Temperature, Relative Humidity, Barometric Pressure and Telemetry Radio transmitter

Power Distribution Junction Box

Glenda Project – WeatherPak 400 TRx Ground Station

Coastal Environmental Wireless HazMat Weather Station

Receiver Display



Data samples are transmitted to the receiver every second with five minute average wind speed and Sigma Theta Values (atmospheric stability) calculated internally within the receiver.

Glenda Project – WeatherPak 400 TRx Ground Station

Coastal Environmental Wireless HazMat Weather Station

Sigma Theta Overview

“Sigma Theta” (ST) is a compound term with its origins coming from both the Statistical / Mathematic community and the Physical Sciences.

The term “Sigma” comes from the Statistical community and is a mathematical term used to define the concept / process called “standard deviation”. Standard Deviation is a process used to explain the amount of variability within a data set with the higher the deviation, the higher the level of variability within the data set.

“Theta” comes from the Physical Sciences / Weather community as the term defining the angle of wind direction.

“Sigma Theta” translated means the amount of variability of the changes in wind direction within a dataset.

Robert Yamartino developed the “standard” ST model back in the 1980’s and it has been adopted by the HazMat / EPA community as their preferred model for measuring atmospheric stability using ground based sensors and is based off of the following equations:

Step 1: Compute the average sine of wind direction, the average cosine, and epsilon

$$S = \frac{1}{N} \sum_{i=1}^{N} \sin \theta_i \qquad C = \frac{1}{N} \sum_{i=1}^{N} \cos \theta_i \qquad \varepsilon = \sqrt{1-(S^2 + C^2)}$$

Step 2: Compute sigma theta as the arcsine of epsilon, and apply a correction factor

$$\sigma_\theta = \arcsin(\varepsilon) \left[1 + \left(\frac{2}{\sqrt{3}} - 1 \right) \varepsilon^3 \right]$$

Glenda Project – WeatherPak 400 TRx Ground Station

Coastal Environmental Wireless HazMat Weather Station

Sigma Theta Overview

Frank Pasquill took the next step, and determined levels of Sigma Theta for differing degrees of atmospheric stability. He created a seven tiered system from “A” to “G”, where Class “G” reflects the most stable atmospheric condition, to Class “A” which reflects the highest level of atmospheric in-stability.

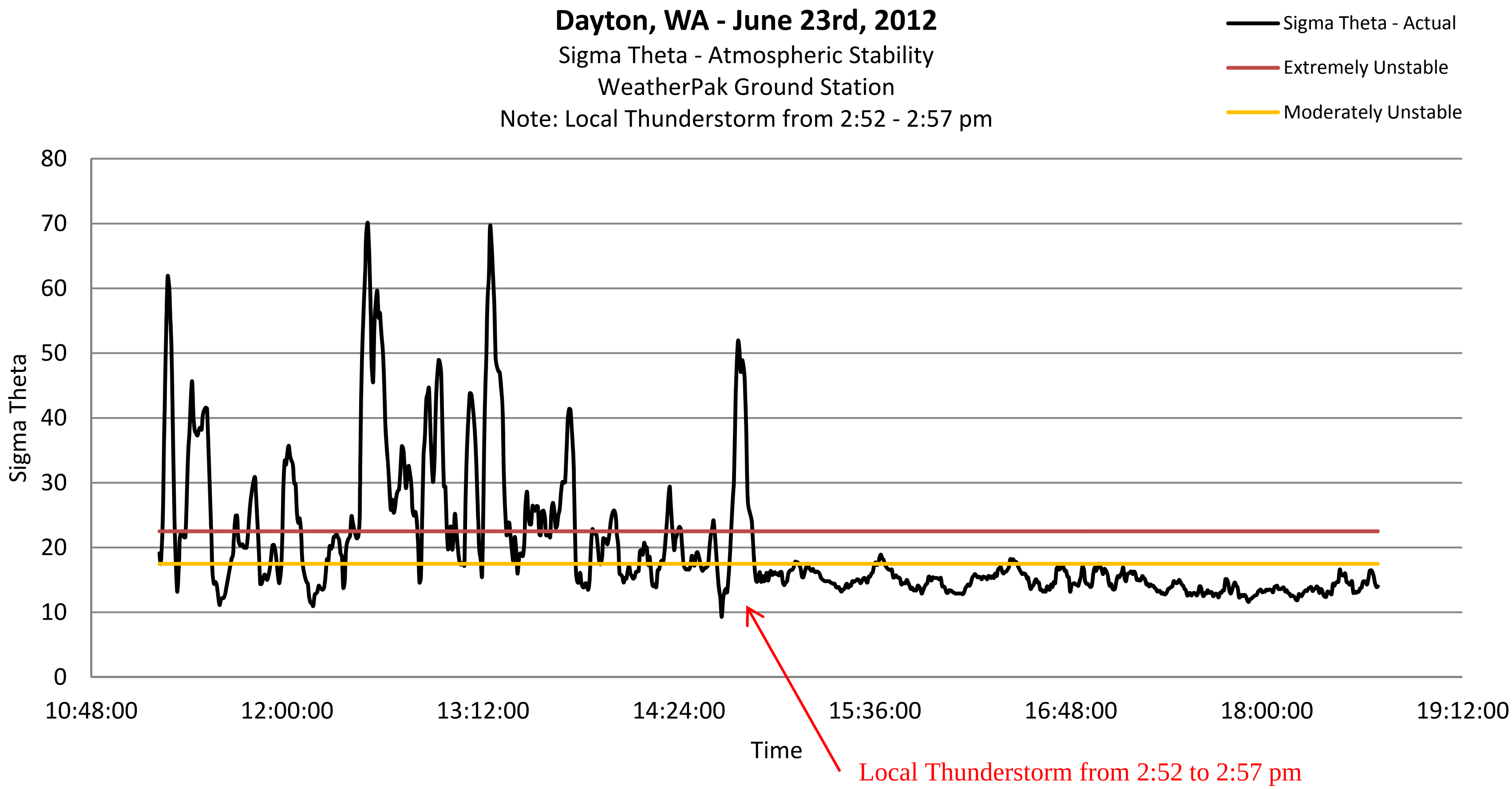
His results are shown in the table below:

Stability Class		Description	Definition
1	A	Extremely Unstable	$22.5 \leq \sigma_\theta$
2	B	Moderately Unstable	$17.5 \leq \sigma_\theta < 22.5$
3	C	Slightly Unstable	$12.5 \leq \sigma_\theta < 17.5$
4	D	Neutral	$7.5 \leq \sigma_\theta < 12.5$
5	E	Slightly Stable	$3.8 \leq \sigma_\theta < 7.5$
6	F	Moderately Stable	$2.1 \leq \sigma_\theta < 3.8$
7	G	Extremely Stable	$\sigma_\theta < 2.1$

Based on this Stability Class table, we can now make determinations of atmospheric stability based on ground station data and not have to rely on balloon launched radiosondes, or rocket launched payloads.

Glenda Project – Ground Station - Application

WeatherPak 400 TRx- Sigma Theta



On June 23rd, the WeatherPak 400 was deployed on the south ridgeline above the BMR "Lone Tree" launch site.

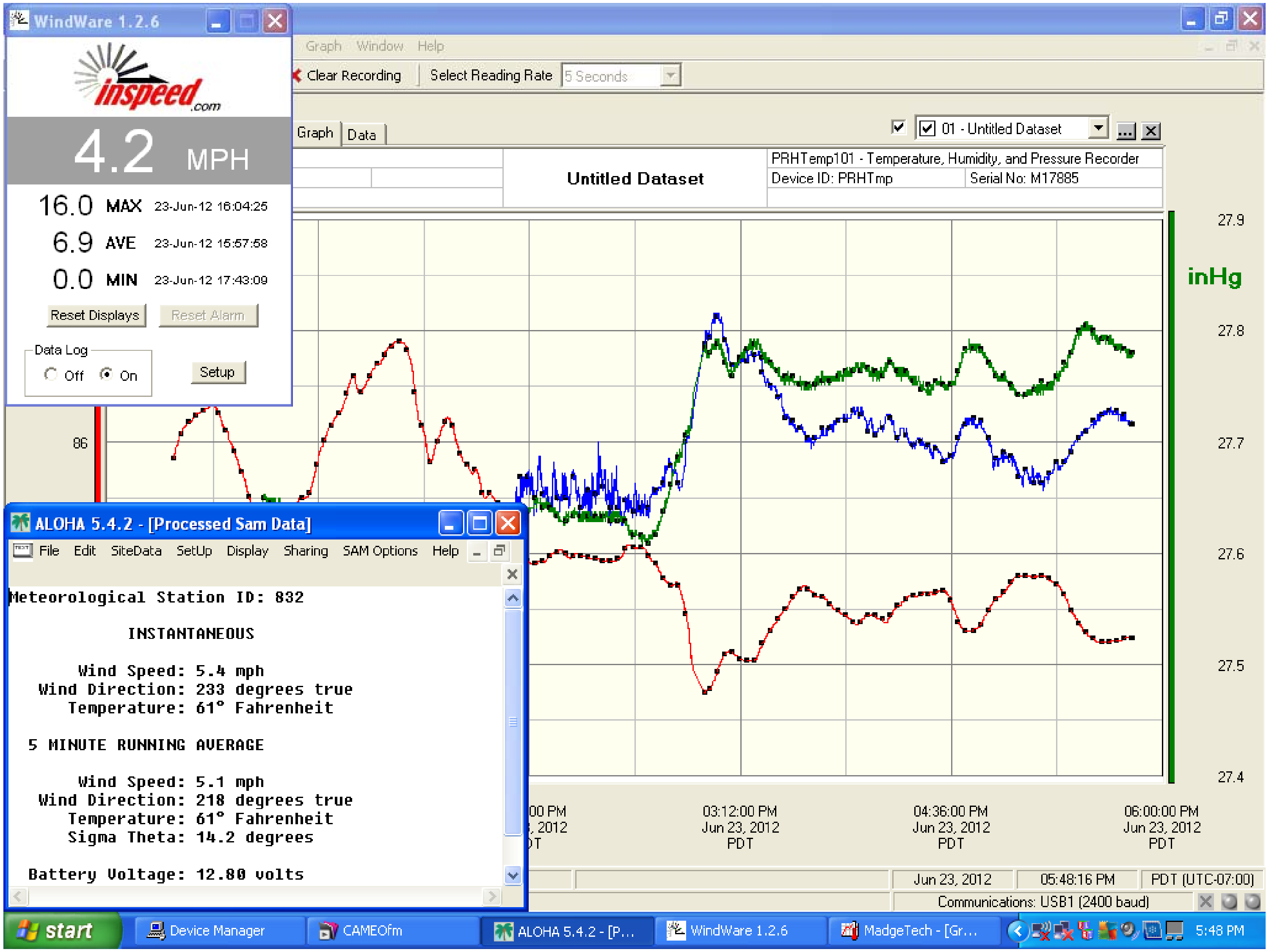
Sigma Theta values reflected "Extremely Unstable" conditions until the passage of a local thunderstorm from 2:52 to 2:57 pm where the Sigma Theta values returned to normal limits.

A case can now be made that Sigma Theta values can be used as a severe weather pre-cursor, and continued deployment opportunities are expected.

Glenda Project – Ground Station - Application

Dual Ground Station Deployment

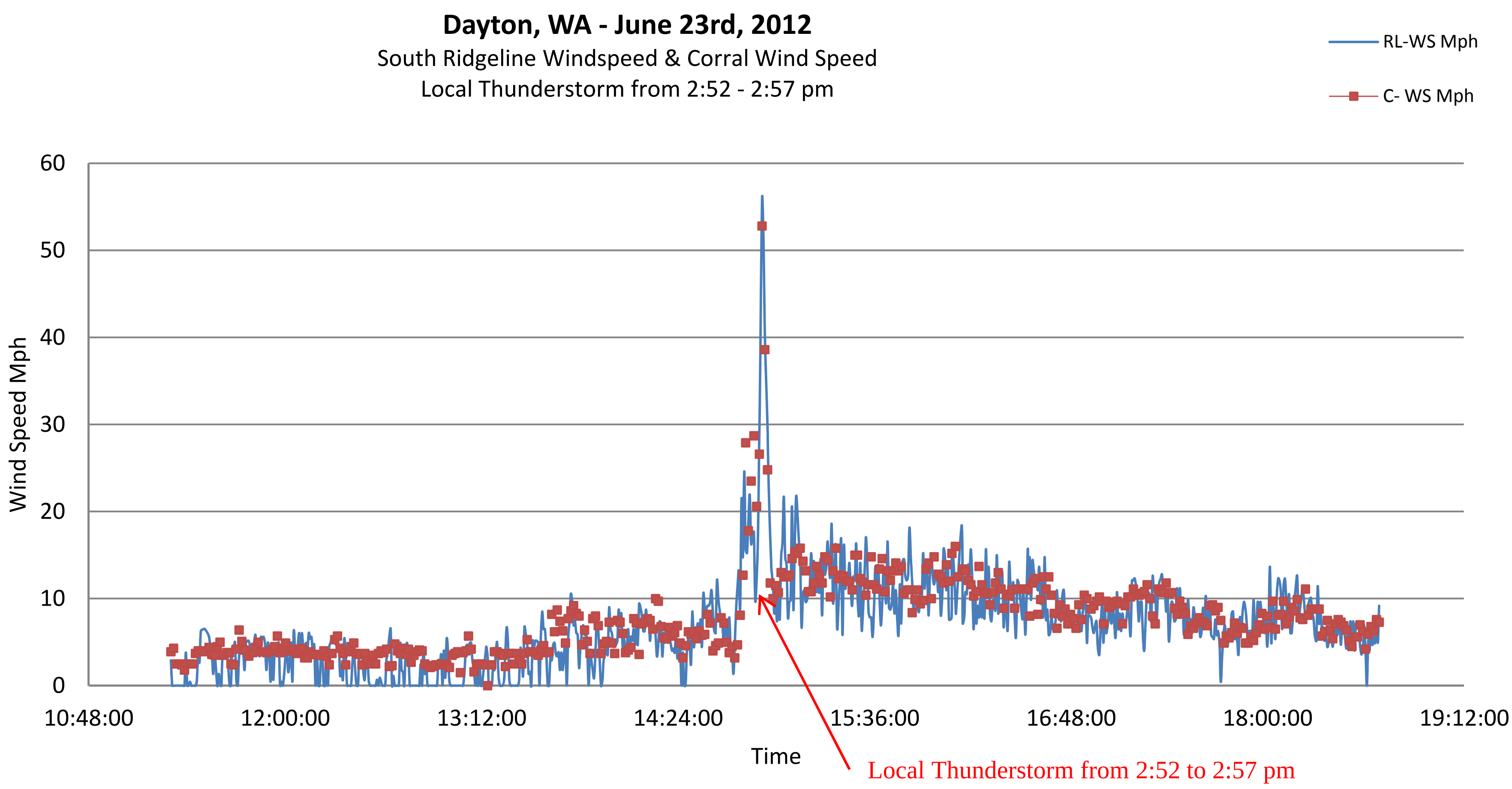
Dayton, WA – June 23rd, 2012



Data from both the wireless and mobile ground stations were displayed side by side on a common interface for seamless integration.

Glenda Project – Ground Station - Application

Dual Ground Station Deployment
Dayton, WA – June 23rd, 2012

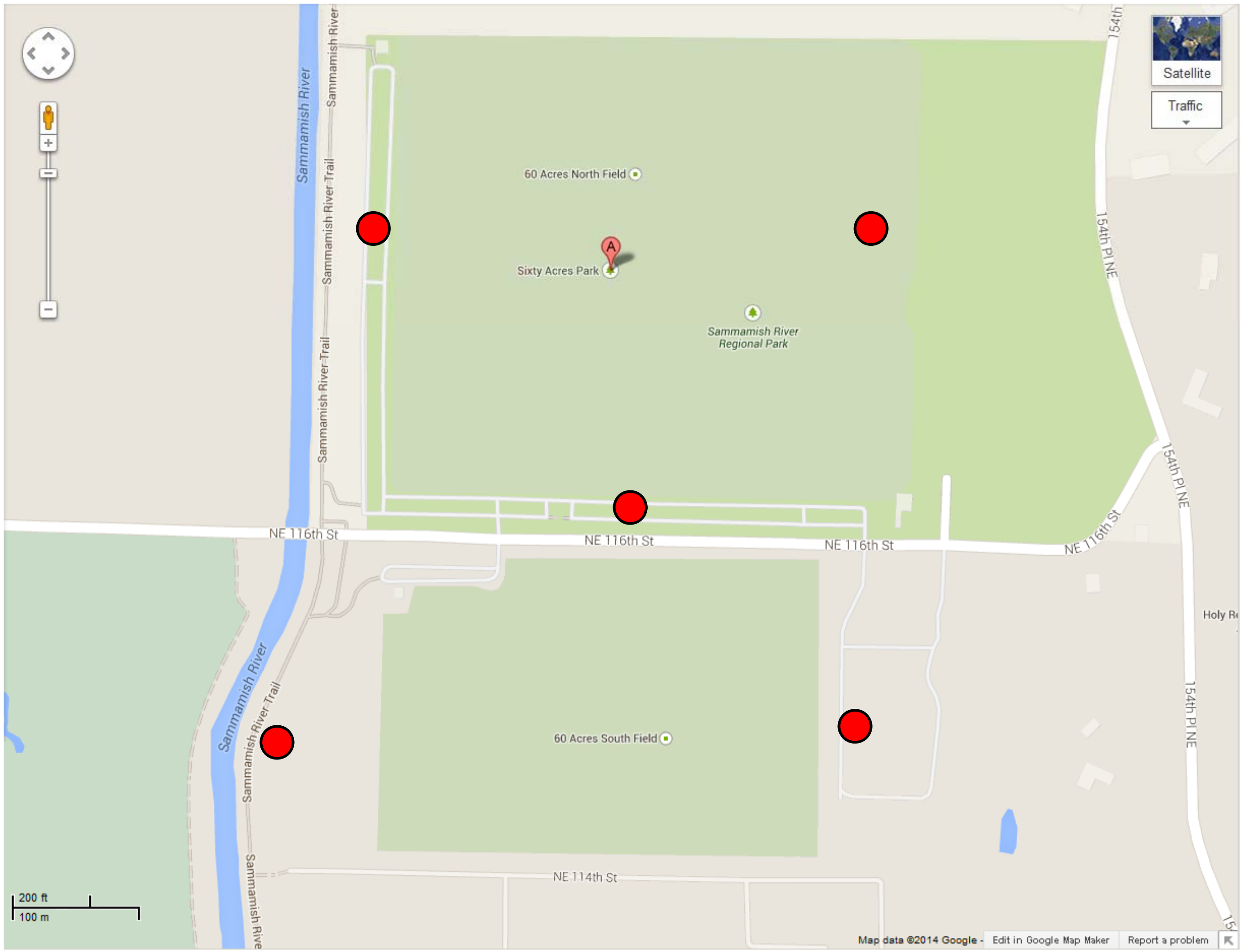


On June 23rd, our first dual deployment accoured as a thunder storm passed over two ground stations simultaneously with one station the wireless WeatherPak and the second, our hard wired mobile station.

Glenda Project – Ground Station – Application

GlendaNet – Integrated Ground Station Network

In September of 2014, the Glenda Project took the first of a series of steps by deploying the GlendaNet, a set of WeatherPak weather stations monitoring “conventional” weather variables. Two of the WeatherPaks were wireless, with the third, hard wired to an intercept vehicle.



In 2015, the Glenda Project added additional wireless WeatherPak systems.

A wireless ground station network allows for a highly flexible system that can easily adapt to rapidly changing field conditions, and provides a high level of confidence of data capture in the event a remote station is disabled during a severe weather intercept.

Glenda Project – Ground Station – Application

GlendaNet – Integrated Ground Station Network – WeatherPak MTR

In 2016, the Glenda Project was able to obtain a WeatherPak MTR system which provides additional system integration and data gathering capabilities. It also now adds GPS capabilities to our ground station network.

Glenda Project – Ground Station – Application

GlendaNet – Integrated Ground Station Network

The GlendaNet can monitor, and record multiple variables such as wind speed, wind direction, temperature, relative humidity, barometric pressure, and Sigma Theta (Atmospheric Stability).

In 2015. Glenda partnered with SMT Designs to consolidate the data feeds from the ground stations, so that only a single laptop is needed to record up to eight remote stations. SMT Designs developed an application program called MULCHER which is able to discern the individual data feeds from each station and store the data on the laptop.

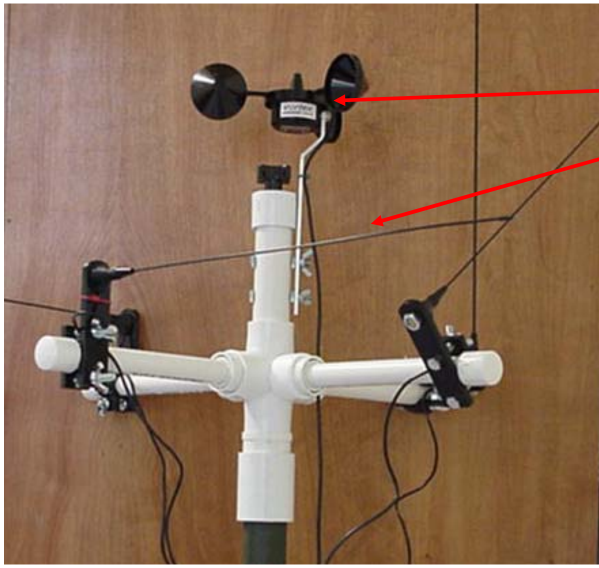
WeatherPak Receivers

Laptop Data Recorders

Multiple Ground Stations – Multiple Receivers – Multiple Data Recorders – Multi-Mission Supportability - All in a Mobile Environment

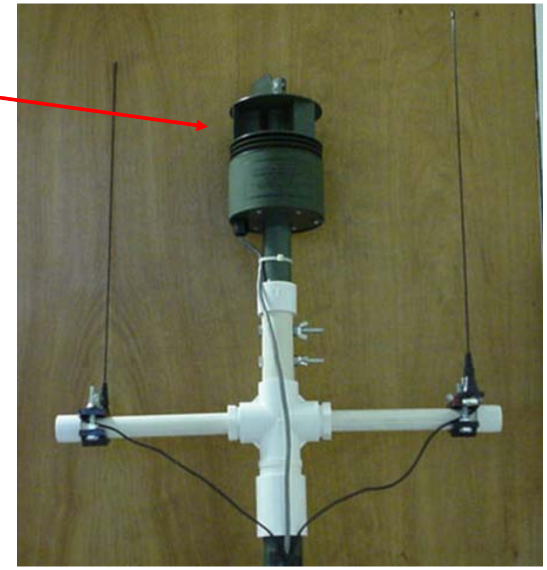
Glenda Project – Ground Stations

Mobile Ground Station Mast System



<u>Removable / Adaptable Mast Sensor Head</u>

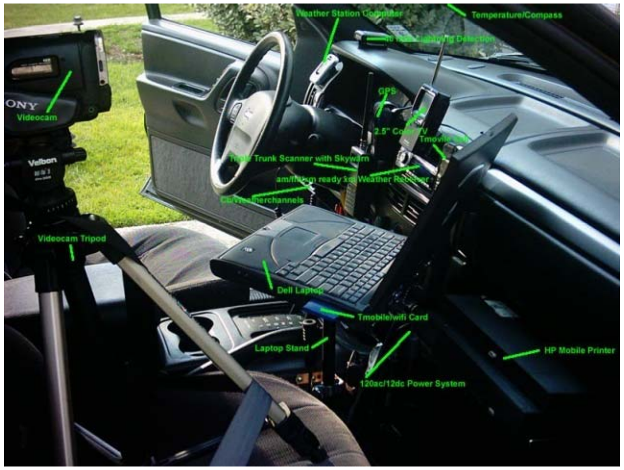
- In-Speed Anemometer / TMQ-34 Sensor
- Two / Four Wide Band Receiver Antennas for Radiosonde telemetry signals.
- Mast System Interface Adapter
- Light weight PVC / Fiberglass construction to reduce potential for lightning strike
- Antennas with 1.2 GHz capability allows multiple frequencies and multiple radiosonde reception
- Mast head integrates with man portable mast system



Glenda Project – Intercept Teams

In order to obtain data from dynamic weather phenomena it is necessary to seek out and intercept storms and to launch sensors into the heart of the disturbance, capture the data, and return the data for immediate processing and analysis. Hence the name, Intercept Team.

The Intercept Teams utilize Jeep Grand Cherokee 4 wheel drive units, and other heavy duty trucks, equipped with specialized tires and suspension to handle road debris situations and evasive maneuvers while on the go. When storm data is required, the teams immediately equip the vehicles with instrument packages and laptop computers inside the vehicle and attach to the roof, weather instrumentation, satellite dishes, sensors and communication gear. Portable rocket launching stands and weather rockets are loaded into the back of the jeep. Transforming from a ordinary vehicle to a fully operational weather pursuit vehicle takes as little as five minutes.



Glenda Project – Intercept Teams

Mobile Mesonet Ground Station Vehicles

Mobile Weather Chase Vehicle with ultra high definition dash cam with record and live broadcast; has160degree capture. Second cam Kodak waterproof, dustproof, etc. HD quality with live broadcast capability. iPhone for video conferencing, radar and location tracking, voice; dual band HT with APRS beacon in and messaging capability. External weather condition sensors. iPad with additional two way data transfer, and direct EMC connectivity including video conferencing. Total of four broadband, one ham data, one ham voice, and two cellular voice systems all working simultaneously.

Glenda Project – Intercept Teams - Application

Columbia County – Dayton, Washington

The Glenda Project principle Intercept Team is based in Columbia County Washington and is equipped with an extensive sensor suite from lightning detectors, GPS positioning data loggers, anemometers, to real time internet Doppler radar.

Using the Doppler radar coupled with its on-board GPS navigation system, the team can pinpoint their exact location in relation to storm systems, providing them the best possible opportunity to position themselves in relation to storm system movements. Unlike other storm "chase" teams, this capability allows the Dayton Intercept Team to concentrate less on chasing storms, and more on positioning themselves to intercept storms.

This intercept capability now allows the team to best support local first responders in order for them to pre-deploy assets into the field mitigating severe weather impacts when they occur.

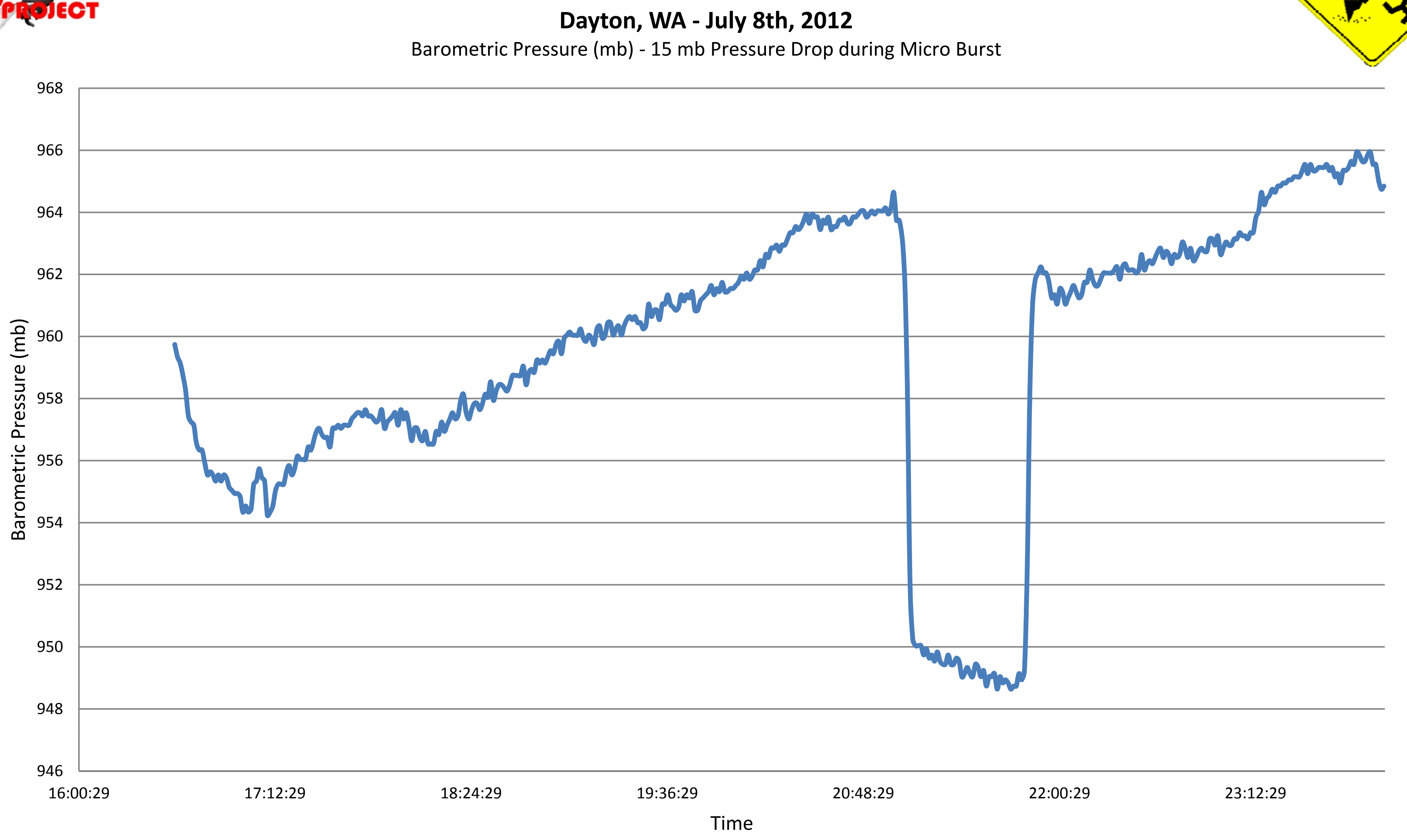
On July 8th, 2012 a severe weather incident created a micro-burst over the north residential area of the town of Dayton, Washington which was detected and recorded on the team's on-board data loggers. Responding to the affected area, the team was able to assist with, and coordinate emergency services response. They coordinated storm debris removal to assist with the response of fire, ambulance and law enforcement units, the evacuation of an elderly person trapped in their residence by storm debris, and assisted with crowd control until power was restored by the power company hours later. All information and storm observations were relayed by the intercept team in real time to the Pendleton National Weather Service and to the local Emergency Management office which resulted in local and regional severe weather alerts being issued.

Glenda Project – Intercept Teams - Application

Columbia County – Dayton, Washington

As a result of the team's response to the July 8th, 2012 storm emergency, subsequent meetings were held with local emergency services. The Dayton intercept team has been requested to assist regional emergency services in future storm events. The team has now been equipped with a BK digital radio system that operates over narrow band microwave in the 155 mhz range. This system allows them direct radio communications to regional law, fire, ambulance and emergency management field units as well as the regional 9-1-1 public safety communications center. The team's integrated real time Doppler and GPS capabilities have allowed them the opportunity to coordinate with local and regional fire departments during lightning storms to aid in the staging of fire assets to suppress lightning strike fires.

Glenda Project – Intercept Teams - Application



The Columbia County / Dayton, WA Intercept Team achieved a successful intercept of a microburst thunderstorm and recorded a 16 mb pressure drop during the event.

Glenda Project – Intercept Teams - Application

Columbia County – Dayton, Washington

In 2012, the Columbia County / Dayton, WA Intercept Team became the "eyes" for Emergency Management and First Responders in severe weather situations.

SKYWARN

Approaching Storms for Intercepts

Glenda Project – Intercept Teams

GPS Payload Tracking System

When payloads are launched into severe weather systems, one of the primary challenges, is their return.

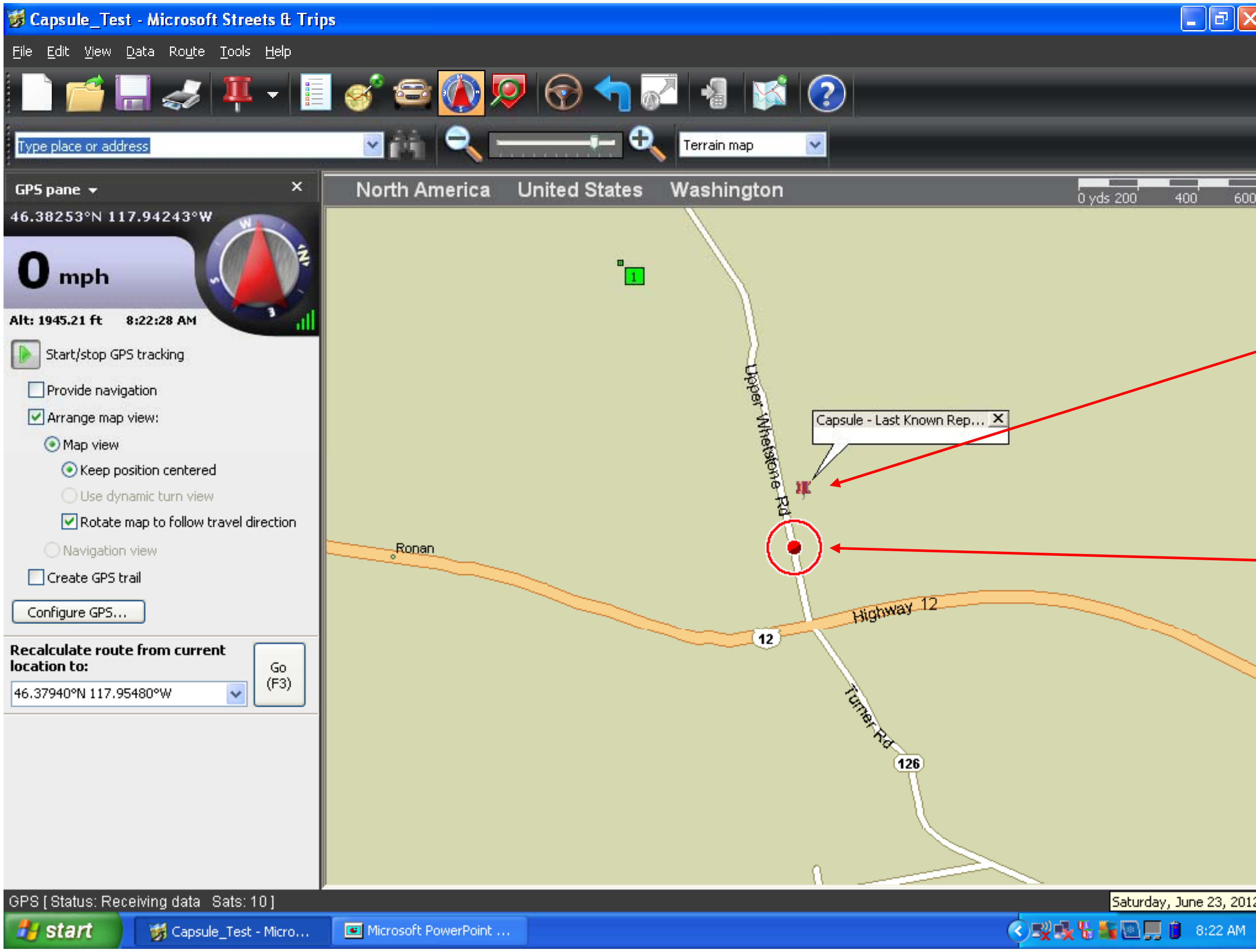
Glenda now has the capability to track payload positions using GPS in real time combined with real time display of the "intercept" vehicles position using "non-internet / non-cellular" driven GPS positioning.

The payload transmits its GPS position to the intercept vehicle, while that vehicle integrates its own position in relation to the moving capsule in real time.

This capability allows real time deployment capture and rapid return to flight for multiple intercepts with the same storm system.

Glenda Project – Intercept Teams - Application

GPS – Payload Tracking System Operational
Dayton, WA – June 23rd, 2012



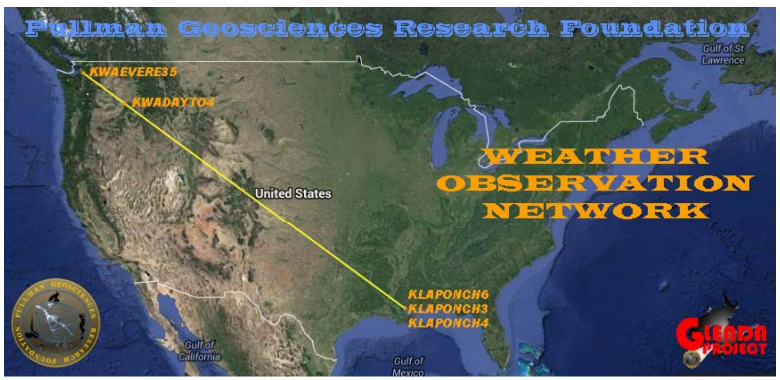
GPS positioning data from both the payload capsule and the intercept vehicle can now be displayed on a common screen in real time allowing for rapid intercepts and near real time return to flight.

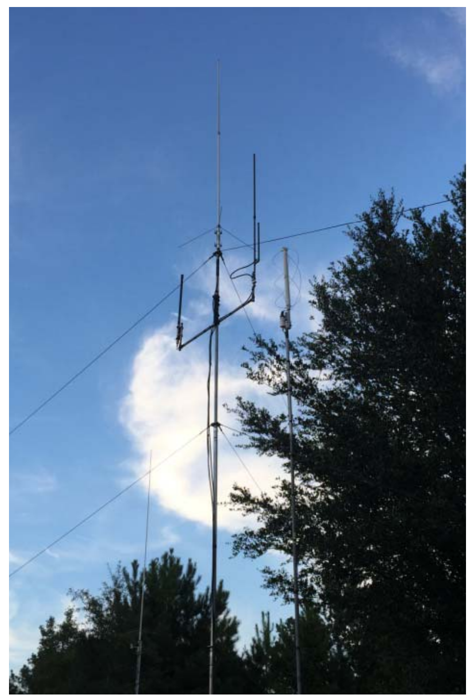
Glenda Project – Remote Sensing

Bayou Canada Research Facility – Ponchatoula, Mississippi

The Bayou Canada Weather Research Facility is located in Ponchatoula, Louisiana, roughly 60 miles north of the Gulf of Mexico.

Bayou Canada feeds out weather data in regular intervals as quickly as every two seconds depending on the need for data and weather conditions. We post real time data including radiation and EMF on our website, as well using both web and over the air radio transmissions. We feed directly to: NOAA and the National Weather Service, APRS via ham radio station KE5JJC both over the web and over 2 meter ham frequencies, Citizens Weather Observation Program, Hamweather, PRSWeather, WeatherBUG, and Weather Underground / The Weather Channel.

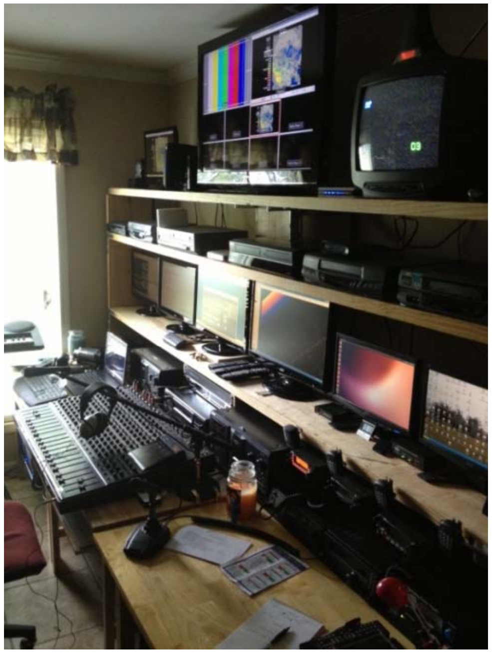


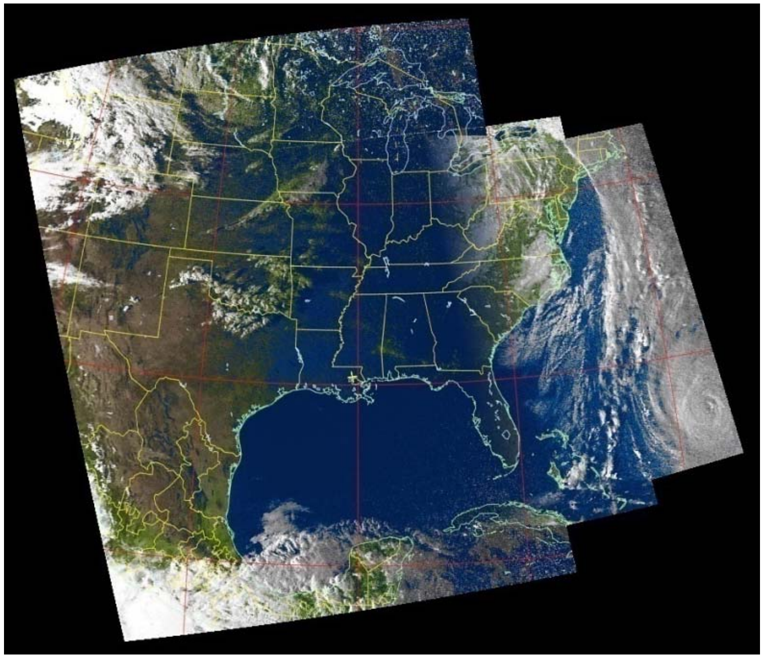


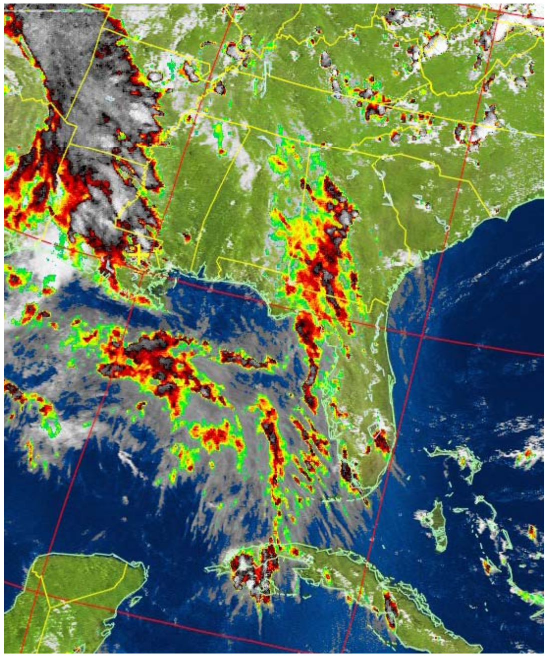
Glenda Project – Remote Sensing

Bayou Canada Research Facility – Ponchatoula, Mississippi

Weather information is fed automatically into various computer processing centers as well as the National Weather Services. Because our information is sent at much shorter intervals than most typical airport weather stations, the analysis of our data is quicker and affects the decisions and warning announcements issued by the National Weather Service. Because we can provide both mobile and base visuals, additional information can be sent to the National Weather Service via cell phone or ham radio transmissions. The NWS monitors particular ham radio frequencies for reports in major weather situations. The National Weather Service will issue watches and warnings both over the air (weather stations and public networks) and over the web based on the information that we and additional stations send them. The NWS is of course the official source for Emergency Management Centers.



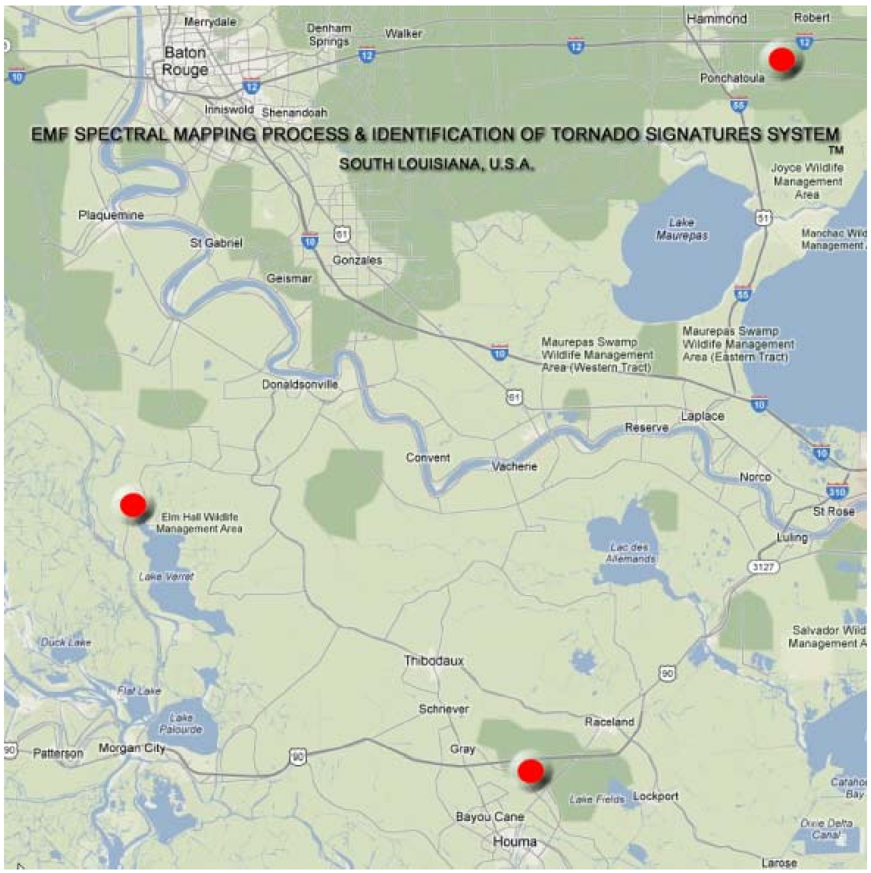


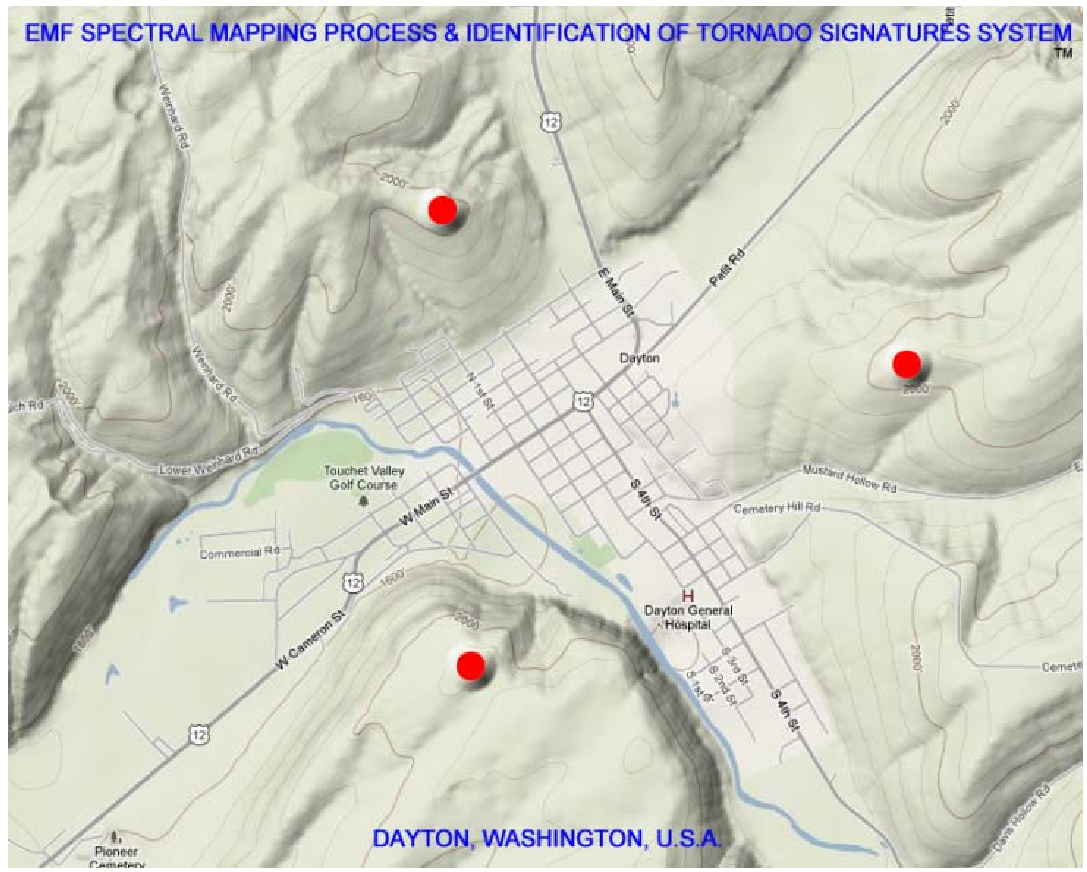


Glenda Project – Remote Sensing

Electro Magnetic Field Mapping and Identification of Tornadic Signatures

The Glenda Project is developing an Electro Magnetic Field Spectral Mapping Process and Identification of Tornado Signatures System. The system uses an integrated network of ground stations that automatically and continuously displays the bearings of both “conventional”, and energetic disturbances in the atmosphere. Using a standard triangulation methodology, combined with an advanced interlinked computer network for data analysis, 3D models of the atmosphere can be built reproducing the real time conditions.

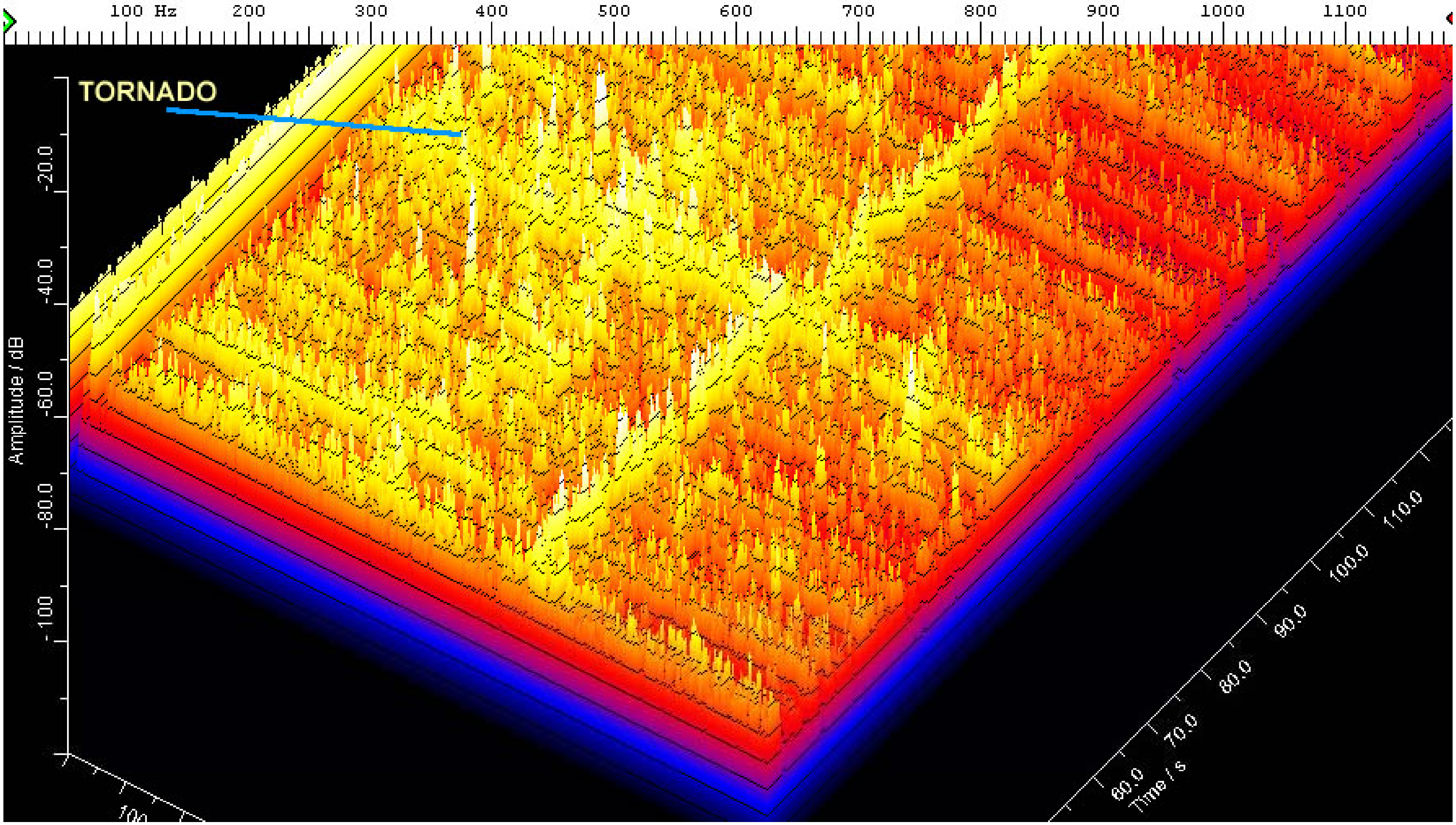




Glenda Project – Remote Sensing – Application

EM Field Mapping

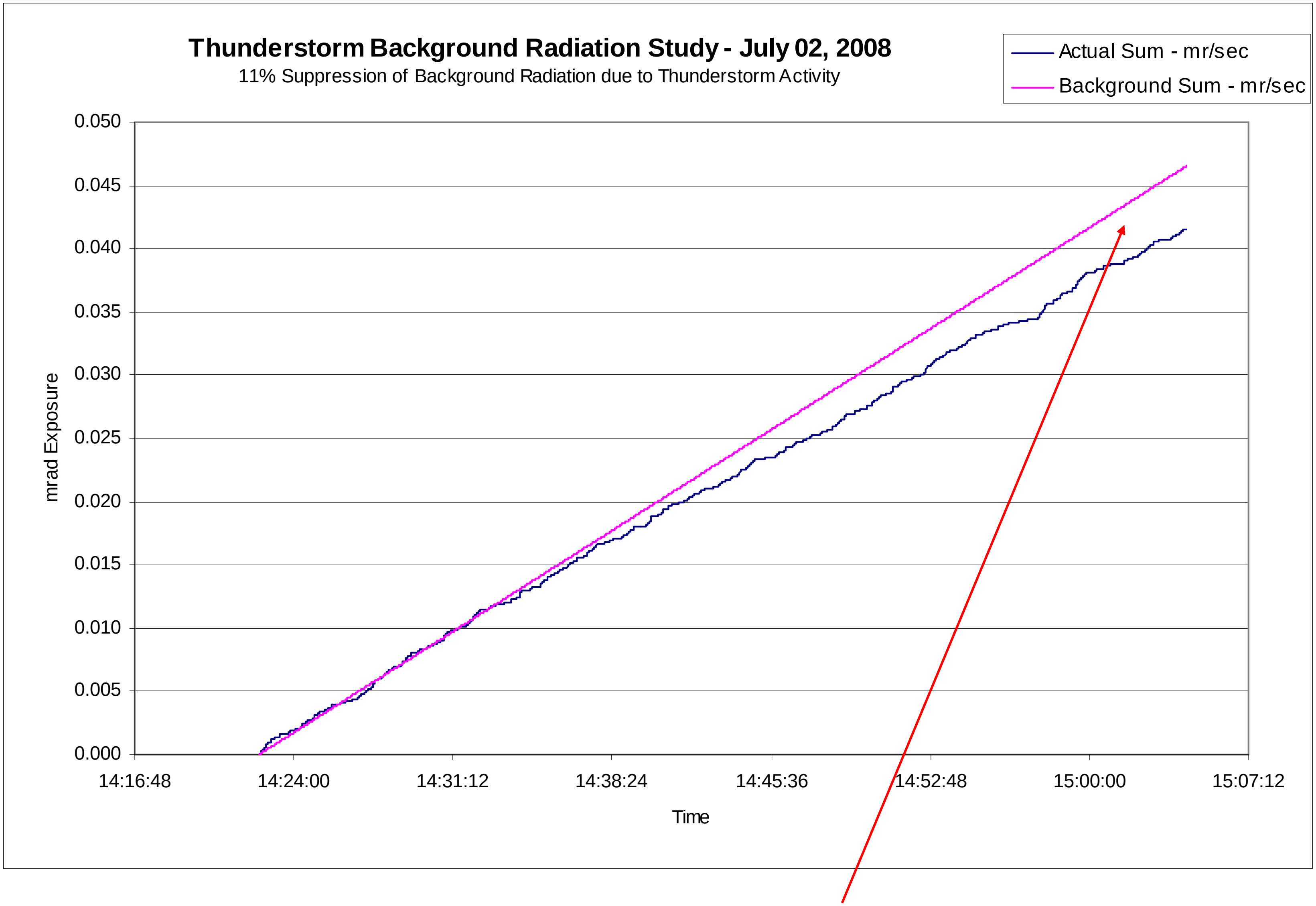
Combining Glenda computing and sensors allows the capability for advanced analysis and detection. Shown below is a 3D Electromagnetic Field (EMF) analysis of a tornado based off of a three second data capture. The circular effects of the funnel are easily visible and provide a snap shot of the electrical activity around a tornado.



Glenda Project – Remote Sensing – Application

Gamma Radiation Studies

Data collection capability of Gamma Ray Radiation during Thunderstorms



During this extensive Thunderstorm, lightning suppressed the “background” gamma radiation count by 11 percent

Glenda Project – 3 Dimensional Data Analysis Model

Based on Provisional Patent Number 60/903,881 - Multi-Dimensional Data Models for Tornado Prediction

(Enterprise, AL 03/01/07 - Tornado)

Glenda Project – 3 Dimensional Data Analysis Model

Introduction

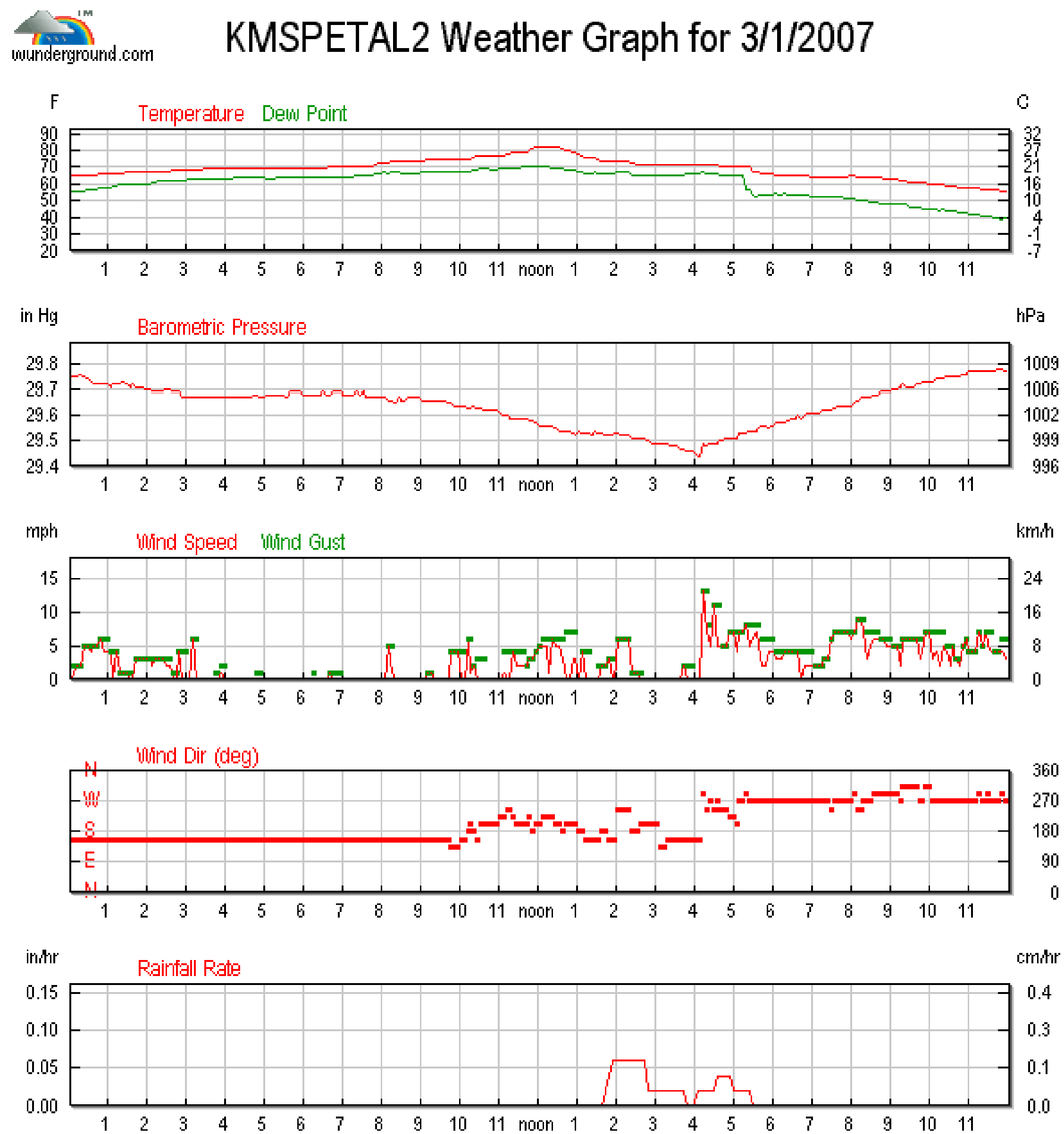
Weather services monitor various atmospheric factors such as temperature, barometric pressure, and relative humidity. Each is monitored in isolation as discrete variables and not how they interact with one another.

By using only a single variable analysis, warnings of severe weather are limited in time, and scope.

The use of a multi-dimensional data model will display how variables interact with one another and will provide a significant increase in warning time of severe weather events.

Traditional – Data Analysis Model

Traditionally, weather data is displayed in a linear fashion over time. While this method of visibility is very good for displaying trends, it does not display how the variables interact with one another.



Glenda Project – 3 Dimensional Data Analysis Model

The Glenda Project has taken a different approach at viewing the same data.

Rather than display each variable as a discrete entity, the 3D model displays multiple variables simultaneously as interdependent dimensions.

This multi-dimensional region of weather conditions can then be used to better predict severe weather occurrences.

Glenda Project – 3 Dimensional Data Analysis Model

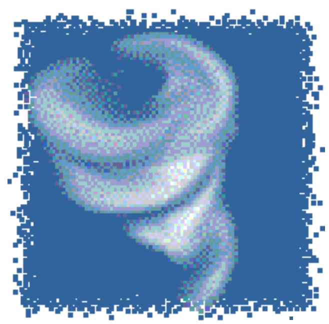
Tornado Prediction is Very Similar to A Slot Machine

While there are hundreds of combinations, there’s only a very narrow range of “jackpots” where tornados occur.

Glenda Project – 3 Dimensional Data Analysis Model

Baseline Data Model – Tornadic Precursor Conditions

Barometric Pressure – Temperature – Relative Humidity



Warning Signs:

- Temperature Rises
- RH Increases
- Barometric Pressure Drops

Barometric Pressure: ↓

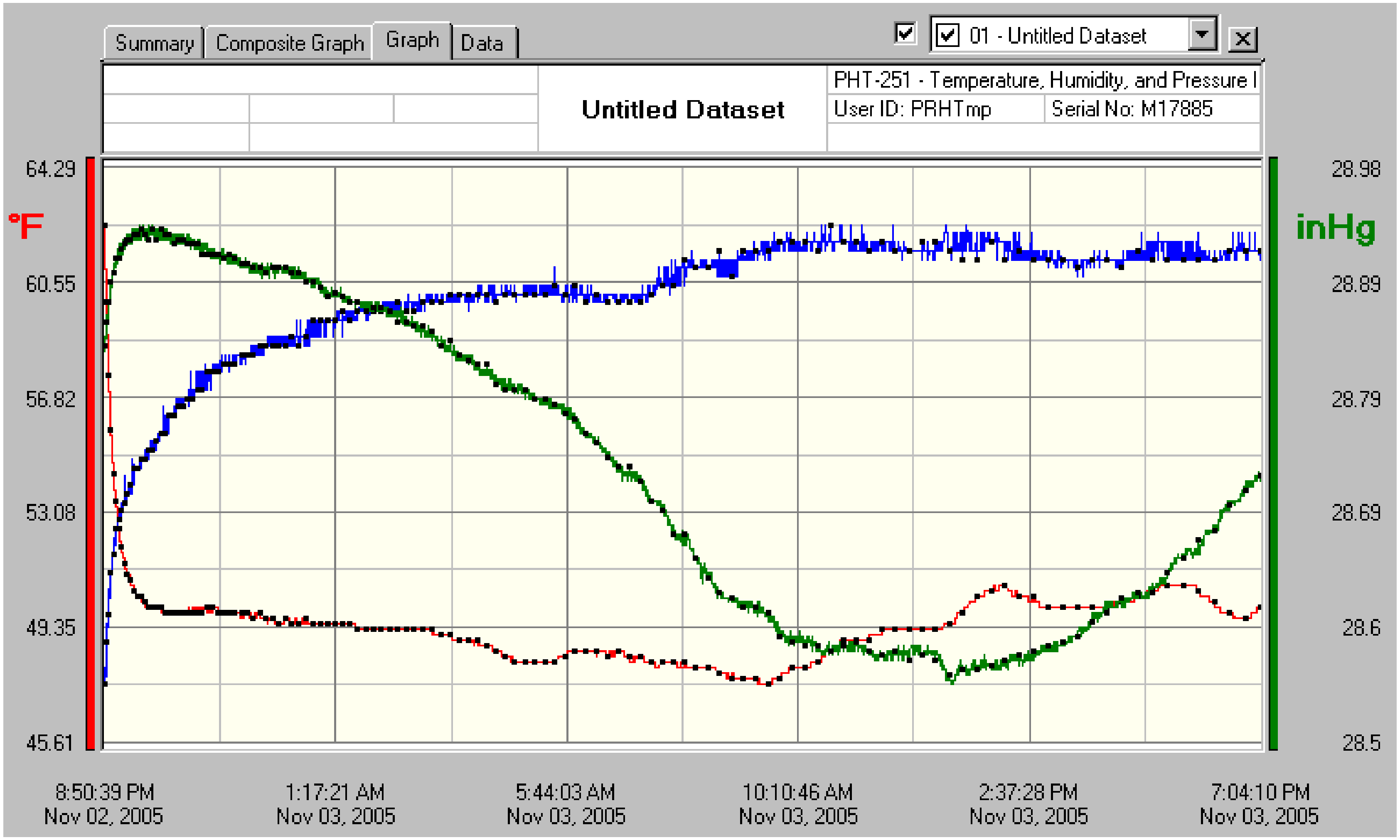
Relative Humidity: ↑

Temperature: ↑

Traditional – Data Analysis Model

11/02/05 – Edmonds, WA - Ground Station Data

Barometric Pressure – Temperature – Humidity



<u>Weather Situation</u>: A twenty hour lifecycle of an incoming storm with heavy rain to its transition back to a clearing condition.

This data format is typical of world wide weather organizations viewing each weather variable in a linear fashion without recognizing how the variables interact with one another.

Glenda Project – 3 Dimensional Data Analysis Model

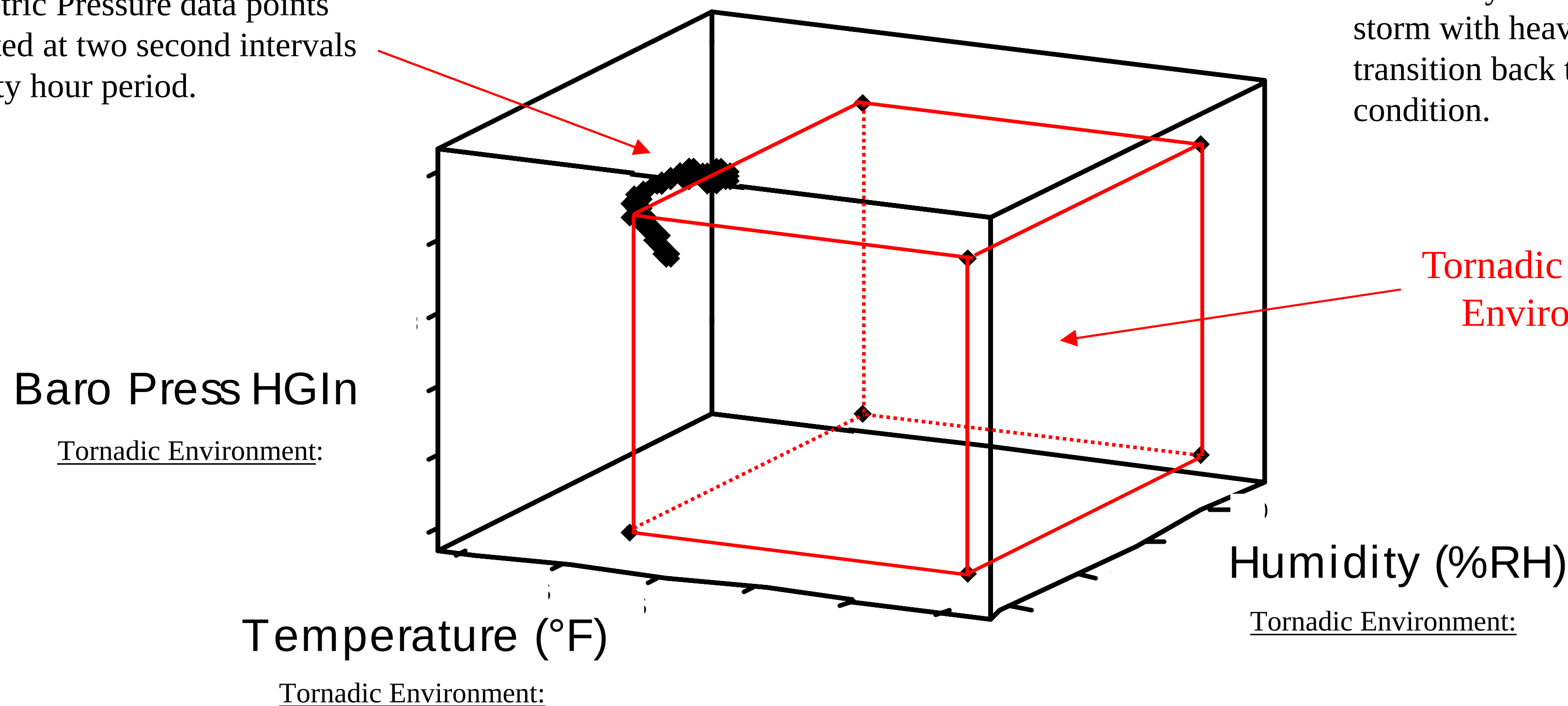
11/02/05 – Edmonds, WA - Ground Station Data Correlation Analysis

Barometric Pressure – Temperature – Humidity

Testing for Tornadic Conditions

Note: Temperature, Humidity, and Barometric Pressure data points were collected at two second intervals over a twenty hour period.

Weather Situation: A twenty hour lifecycle of an incoming storm with heavy rain to its transition back to a clearing condition.



The Glenda Project takes an entirely different approach. Looking at the same data. from the same storm system, and mapping it in multiple dimensions, an entirely different perspective appears. While this storm was highly volatile, and produced heavy rains, it did not generate the necessary energy to produce tornadic conditions.

Glenda Project – 3 Dimensional Data Analysis Model

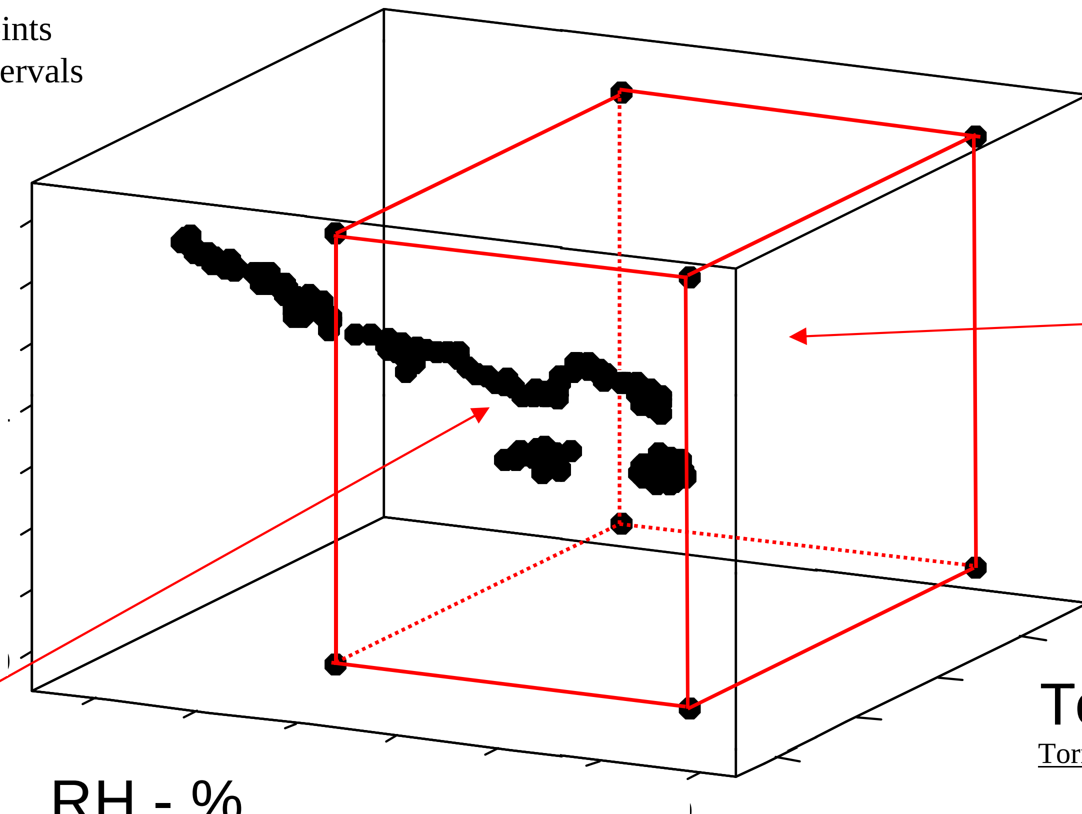
03/01/07 – Enterprise, AL - Ground Station Data Analysis

Barometric Pressure – Temperature – Humidity

Testing for Tornadic Conditions

Weather Situation: An eighteen hour lifecycle of a highly volatile storm which produced multiple casualties

Note: Temperature, Humidity, and Barometric Pressure data points were collected at five minute intervals over an eighteen hour period.



Tornadic Condition Environment

Baro - HgIn

Tornadic Environment:

Temp - F

Tornadic Environment:

Tornadic Precursor Signals – First Precursor Signal occurred at 02:13 am

RH - %

Tornadic Environment:

The first Glenda Tornadic Precursor occurred over 10 hours before touchdown in Enterprise

Time Line:

07:30 am – NWS/SPC Issues Tornado "Watch"
12:47 pm – NWS Issues Tornado "Warning"
01:00 pm – Local Tornado Sirens activated
01:05 pm – Tornado enters Enterprise

The Glenda Project 3D Model is the next step in tornado forecasting

Glenda Project – 3 Dimensional Data Analysis Model

Conclusion

The multi-dimensional data model has been tested in both the “false positive”, and “false negative” arenas using the determined threshold values without having a failure.

Using the multi-dimensional model to determine precursors of severe weather is a fundamentally new approach to forecasting and prediction and its use will increase warning times to the general public and will save lives.

Glenda Project – Micro Climate Convergence

Louisiana / Mississippi Gulf Coast - Introduction

Being located along the Louisiana Gulf Coast, the Glenda Project has a live testing environment that's constantly active, while also providing us numerous opportunities for testing.

The results of this continuous testing, combined with our advanced sensor suites and remote sensing capabilities has disclosed an interesting set of findings. Principally, that the Gulf Coast is a convergent microclimate which is a perfect breeding ground for severe storms and tornadic events, and is a significant contributor to "Dixie Alley" tornados .

The combination of warm temperatures, ground moisture, soil conductivity, magnetic anomalies, and other interacting factors contribute to this conducive environment.

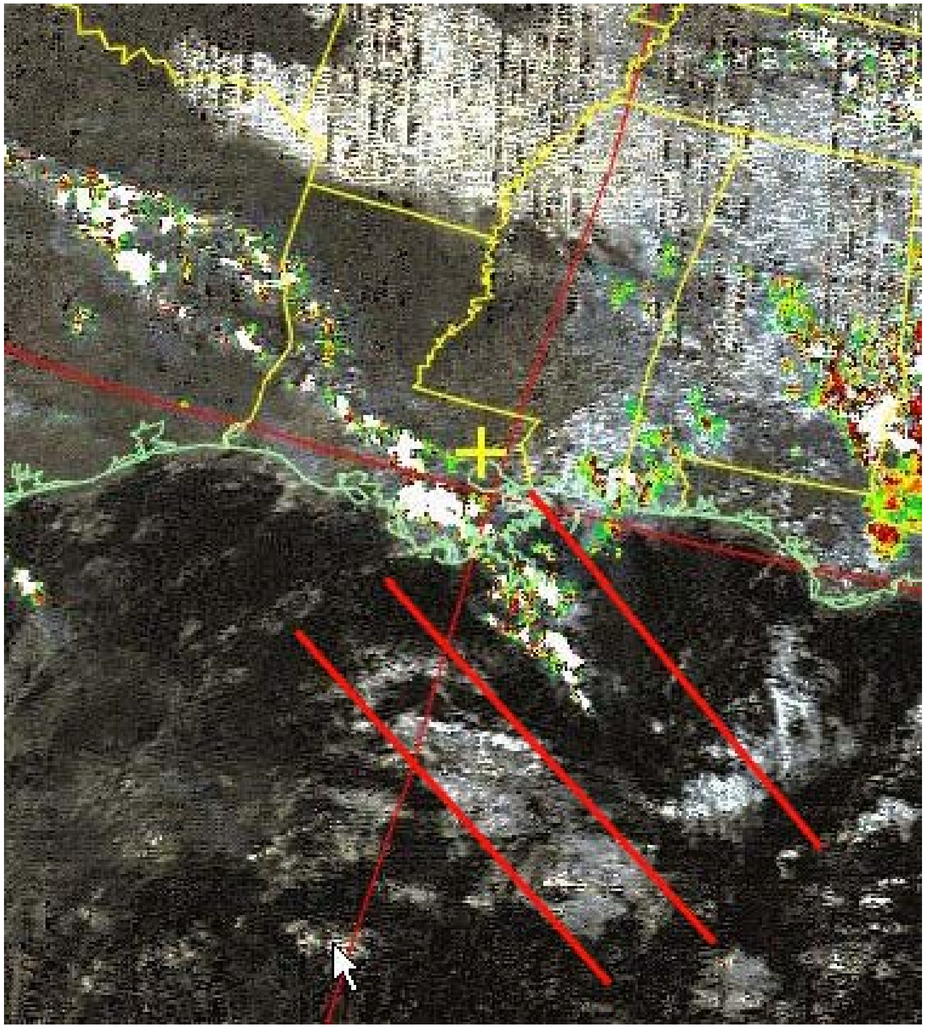
Glenda Project – Micro Climate Convergence

Louisiana / Mississippi Gulf Coast – Thermal Pockets

There exist two local thermal pockets of warm moist air with one centered around Petal Mississippi, and the second near Wiggins Mississippi. These localized thermal pockets run from southwest to northeast and change size constantly based on local temperature and moisture conditions.

Glenda Project – Micro Climate Convergence

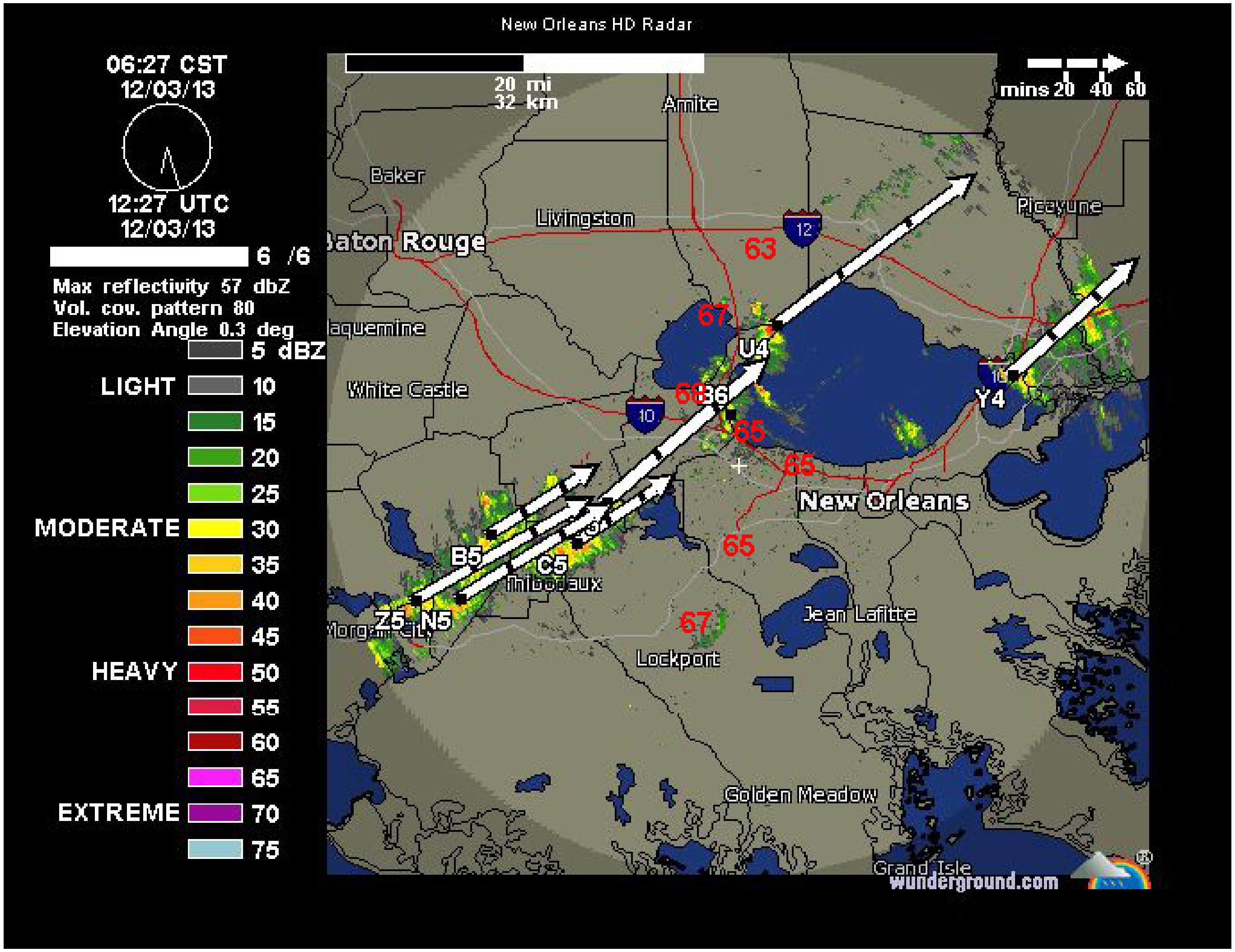
Louisiana / Mississippi Gulf Coast – Gulf of Mexico Moisture



Feeding these localized thermal pockets, are constantly incoming waves of warm moist air from the Gulf of Mexico. These incoming waves provide additional forward motion to the weather systems coming in from the southwest.

Glenda Project – Micro Climate Convergence

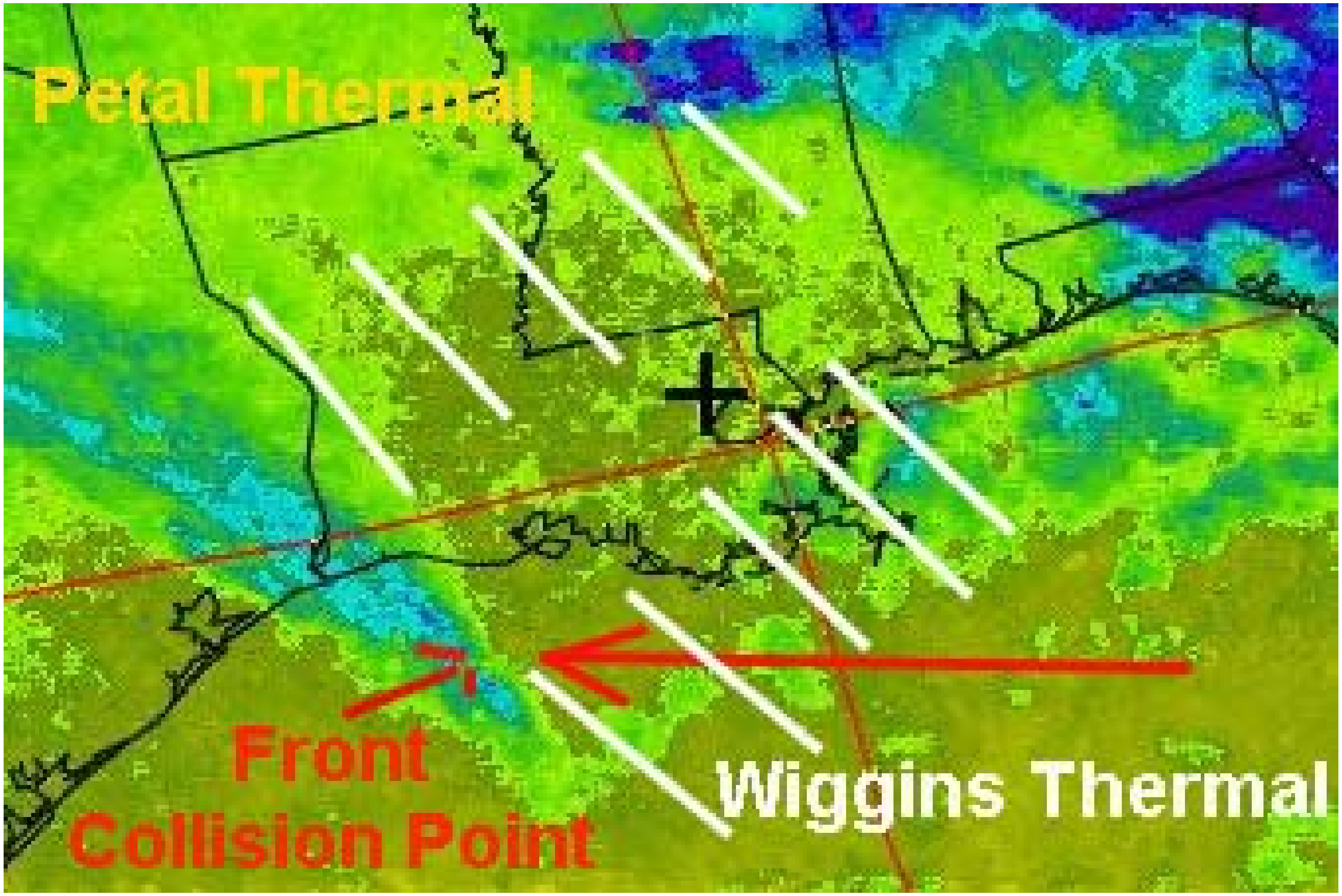
Louisiana / Mississippi Gulf Coast – Storm Trajectories



Storm Tracks ride these thermal pockets feeding on their ready supply of latent heat, and localized moisture combined with the injection of warm moist air from the Gulf of Mexico.

Glenda Project – Micro Climate Convergence

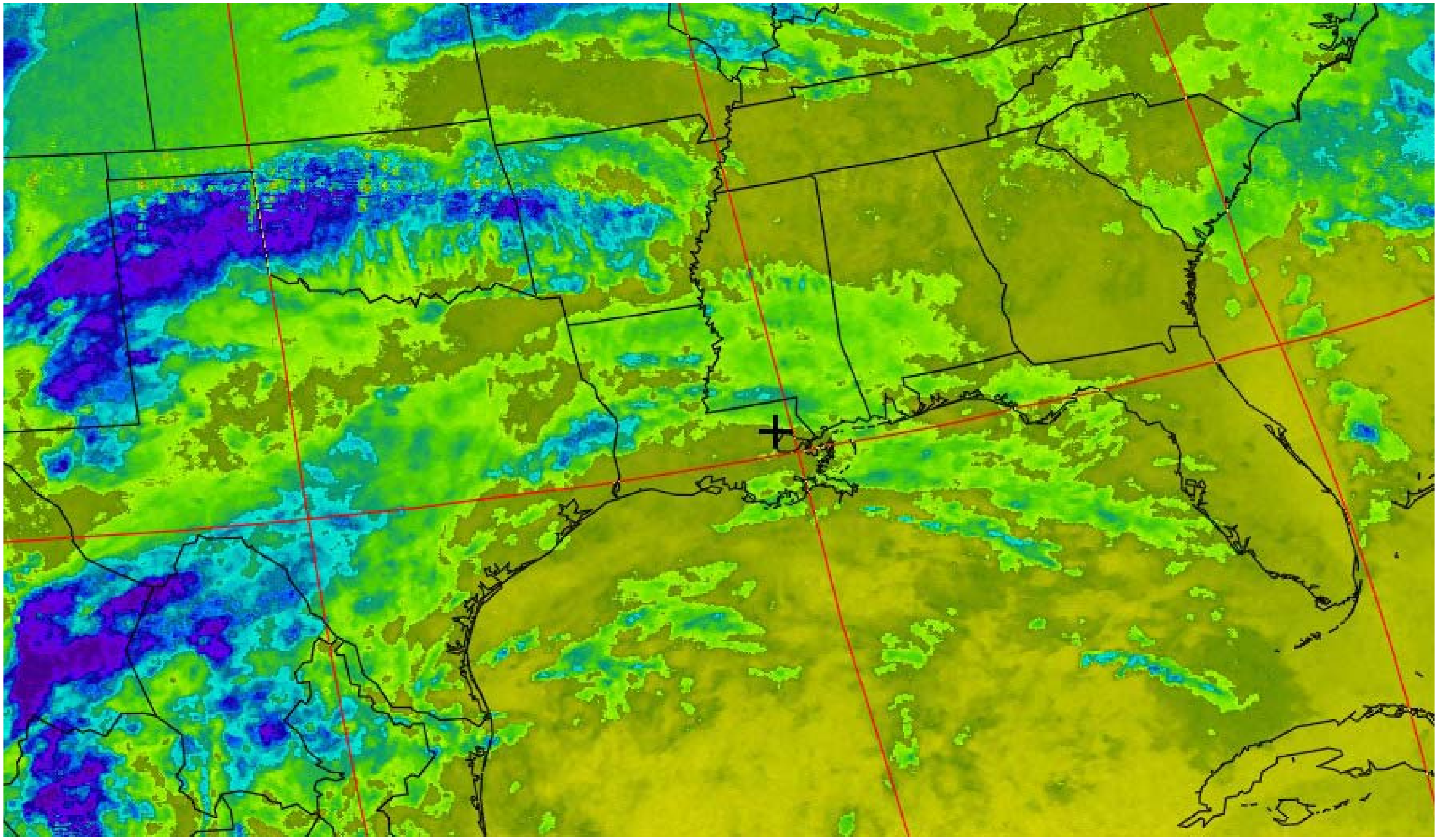
Louisiana / Mississippi Gulf Coast – Cold Front Collision



When a Cold Front approaches from the Northwest, at Right Angles to the thermal pockets, it creates spin onto the incoming storm systems. If energy levels are high enough, Water Spouts result over water, and tornados are created over land.

Glenda Project – Micro Climate Convergence

Louisiana / Mississippi Gulf Coast – Dixie Alley Trajectories



As these interacting factors merge, they gain strength and continue to spread across the southeast increasing the risks of wide spread severe weather.

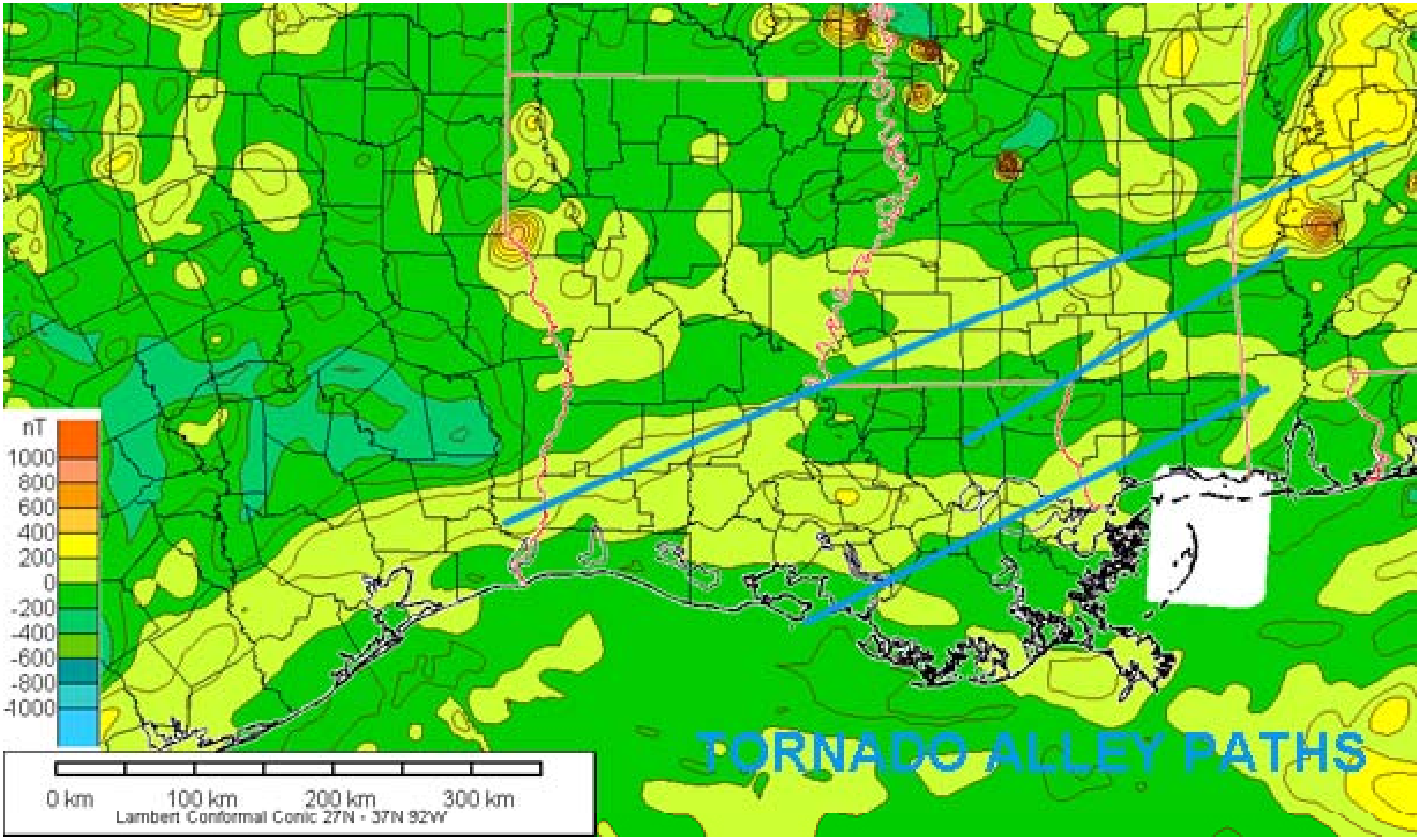
Glenda Project – Micro Climate Convergence

Louisiana / Mississippi Gulf Coast – Severe Weather Triggers

- The energy of the thermal pockets must be high enough to stay intact as the incoming storm front passes overhead
- If the thermal pocket stays strong and the incoming storm front movement is fast, Tornadoes will spawn
- When RH, Temperature and Barometric Pressure severe weather parameters are in place, tornadic systems will be triggered
- If the thermal pocket stays strong, and the incoming storm system movement is slow, there may not be sufficient energy to trigger tornadic conditions
- Petal and Wiggin thermal pockets may fire independently creating multiple storm tracks and tornadic systems
- The thermal pockets may move up or down in flow but will track within a general region supporting the valid concept of “Dixie Alley”
- Coastal Climate Zones may influence localized Thunderstorms and tornado development

Glenda Project – Micro Climate Convergence

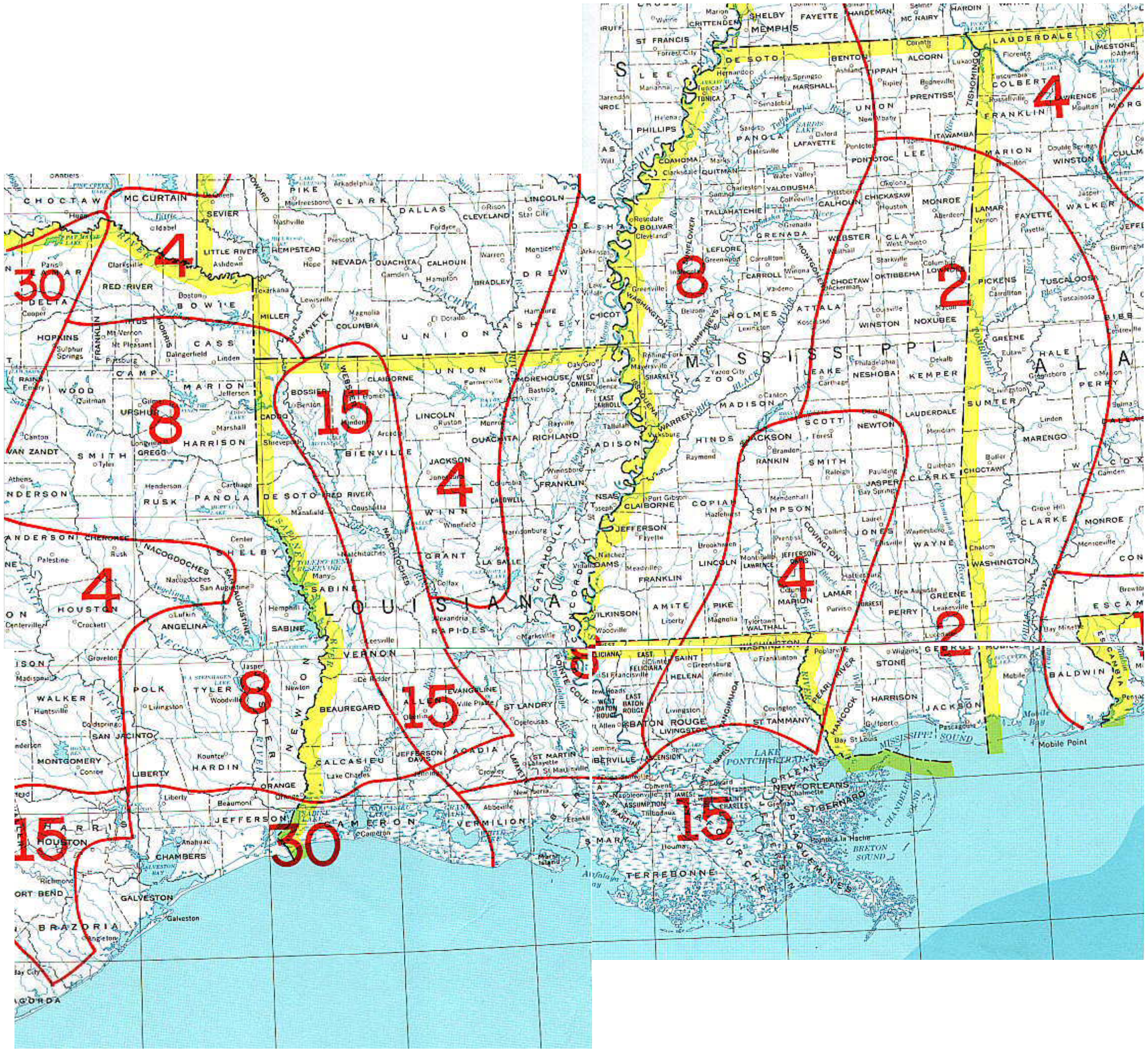
Louisiana / Mississippi Gulf Coast – Magnetic Field Concentrations



It has been shown that the storm tracks also follow along the local magnetic field concentrations, another factor in the micro-climate convergence.

Glenda Project – Micro Climate Convergence

Louisiana / Mississippi Gulf Coast – Soil Electrical Conductivity



Running hand in hand with the local magnetic fields, is the companion soil electrical conductivity. Measured in millisiemans per meter (mS/M), the storm tracks ride along and through areas of high soil conductivity.

Glenda Project – Micro Climate Convergence

Louisiana / Mississippi Gulf Coast – Conclusions

- There appears to be a direct correlation between the paths of the Tornadoes and the Conductive / Magnetic Patterns of the Locale

- The edges of a Conductive / Magnetic Zone can create a continuous Thermal flow in the atmosphere

- Conductive / Magnetic Zones may assist in creating the storm tracks and their trajectories

- The interaction of the localized thermal pockets combined with this additional magnetic and electrical energy serve as an established breeding ground of severe weather which impacts the entire southeastern portion of the country.

Glenda Project – Educational Outreach

Over many years, the Glenda Project has developed strong local community ties with educational and governmental groups ranging from the National Weather Service, museums, to local schools.

The Glenda Project provides mentorship support to the National Associate of Rocketry "Team America Rocketry Challenge " (TARC), and the NASA Student Launch Initiative (SLI) involving high school, and college student designed and launched payloads.

Glenda is also involved with the Science, Technology, Engineering, and Mathematics (STEM) programs at several local schools providing a ready built application.

Glenda Project – Educational Outreach

April 2014 – Museum of Flight, Seattle, WA – “Climate Day”

August 2014 – Museum of Flight, Seattle, WA – STEM “Science Fest”

June 2013 – NWS Pendleton, Oregon Open House

February 2014 – Edmonds, WA –
Westgate Elementary School “Science Night”

In Conclusion

The Glenda Project is a highly mobile data collection system designed to place instrument packages into areas previously considered to be to hazardous or inaccessible using traditional platforms such as aircraft, helicopters, kites, etc.

The operational Glenda Project shows the differences between Hollywood “fiction”, “Reality Television” publicity stunts, and engineering “fact”, from mapping local environments to a tornadic funnel with a full mission suite of sensors and cameras.

We have achieved multiple storm intercepts, deployed a wireless long range ground station network with Sigma Theta capability and built on sustaining relationships with emergency managers and first responders.

An operational balloon deployment capability for applications where booster launches are not feasible is now in place and we continue to expand the flight envelop of our sensors and ground stations.

The Glenda Project is up to the task.