



# Update on Earth Networks Greenhouse Gas (GHG) Monitoring Network

Christopher Sloop and Bill Callahan



# Original Vision for Earth Networks January 2011



- 50 US, 25 Europe, 25 across the globe
- 5 year deployment



<https://www.youtube.com/watch?v=60s2S2-Aiio>

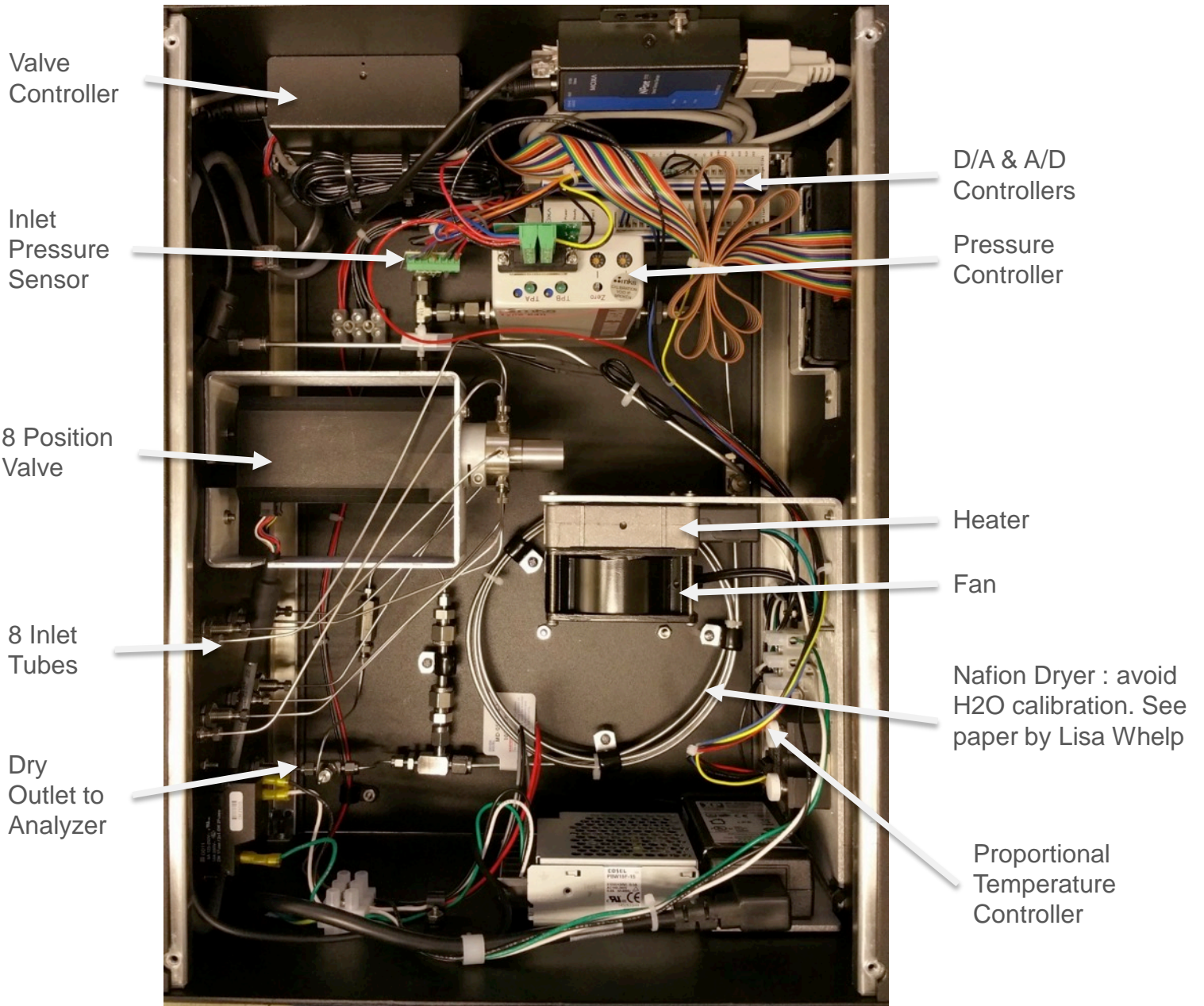
# Sampling towers

1. Two inlets at high point (>80m)
2. One inlet at 50m
3. Met data from high point



SCRIPPS INSTITUTION OF  
OCEANOGRAPHY  
GLOBAL DISCOVERIES FOR TOMORROW'S WORLD





Router w/  
Aircard and  
Power  
control

EN  
Calibration  
Module

Vacuubrand  
Pump

EN Pump  
Modules

Front View

Linux Mini PC  
GCWerks

Picarro  
G2301 or  
G2401

Calibration/  
Reference  
Tanks

UPS ~ 10  
minutes

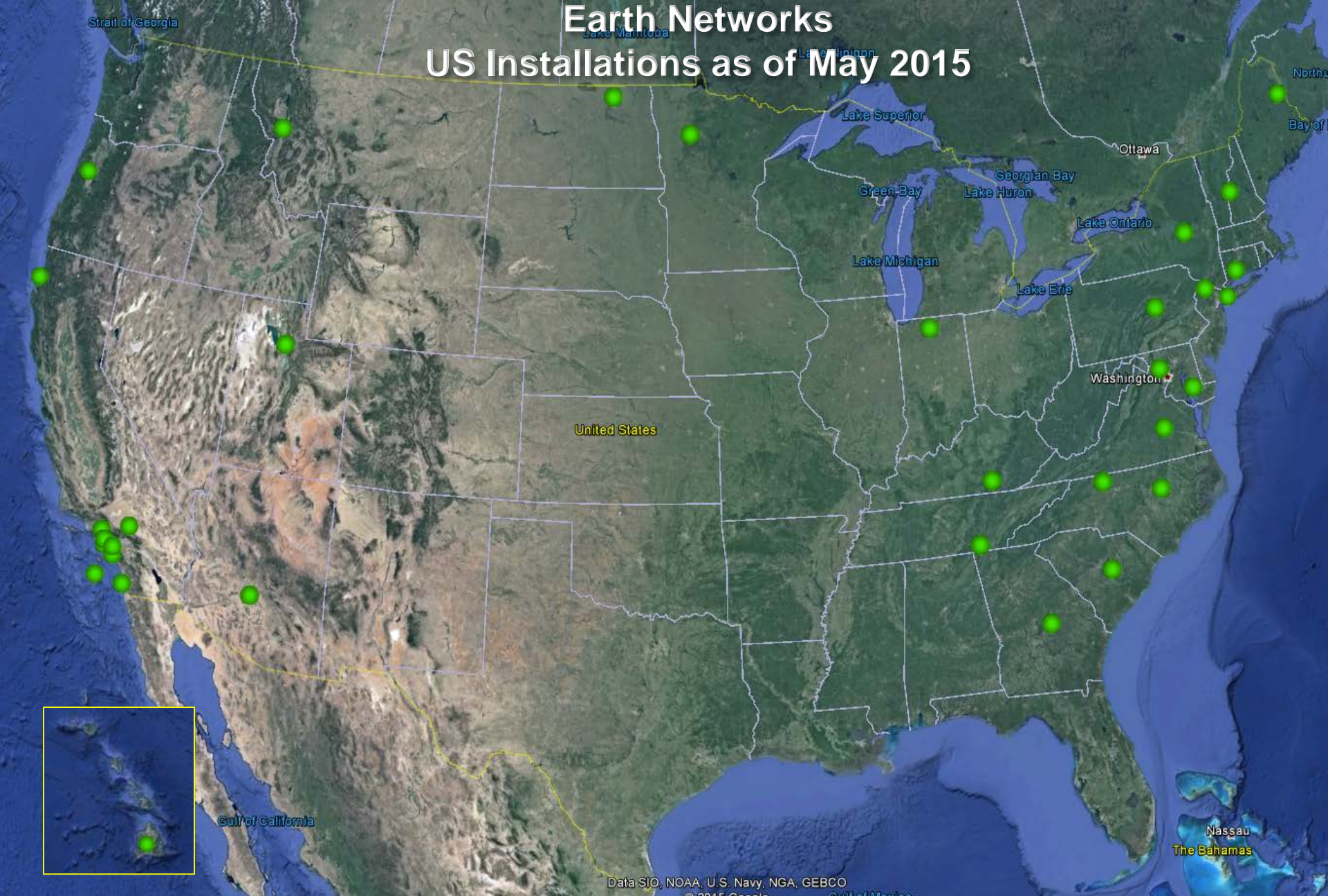
Rear View

# Data Collection

- GCWerks Data Collection Software
  - Controls the EN Sample Module
  - Ability to View and Plot all of the collected data parameters.
  - Ability to flag spurious samples.
  - Syncs collected data and configuration information with the GCWerks server and exports to Amazon S3 for distribution.
  - Monitors the status of the system and sends alerts when needed
  - Generates network summary for quick at a glance status of sites.
- Earth Networks Data Collection Software
  - Backs up raw Picarro data and daily spectra files to Amazon S3
  - Backs up Picarro configuration and metadata files and versions them.

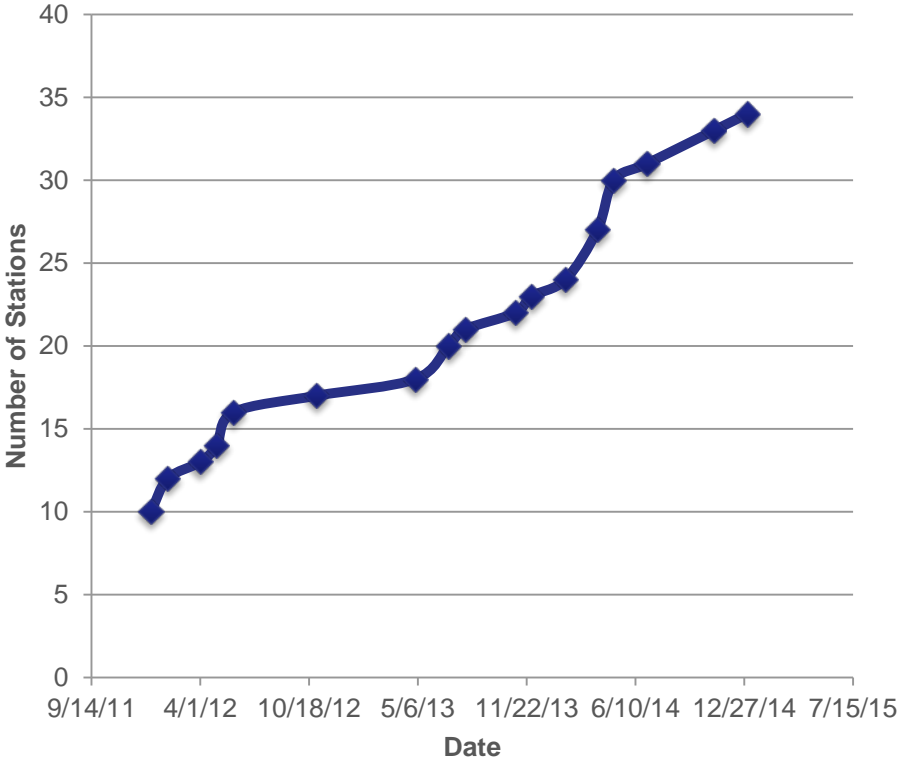


# Earth Networks US Installations as of May 2015

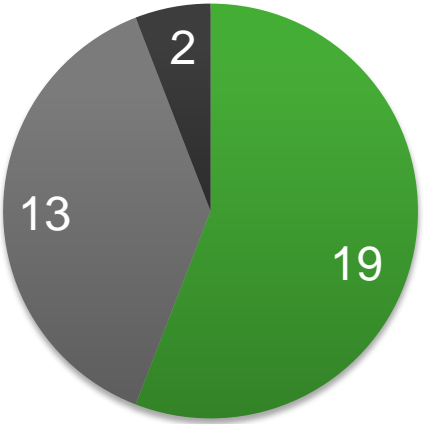


# Network Statistics

### GHG Installations over Time



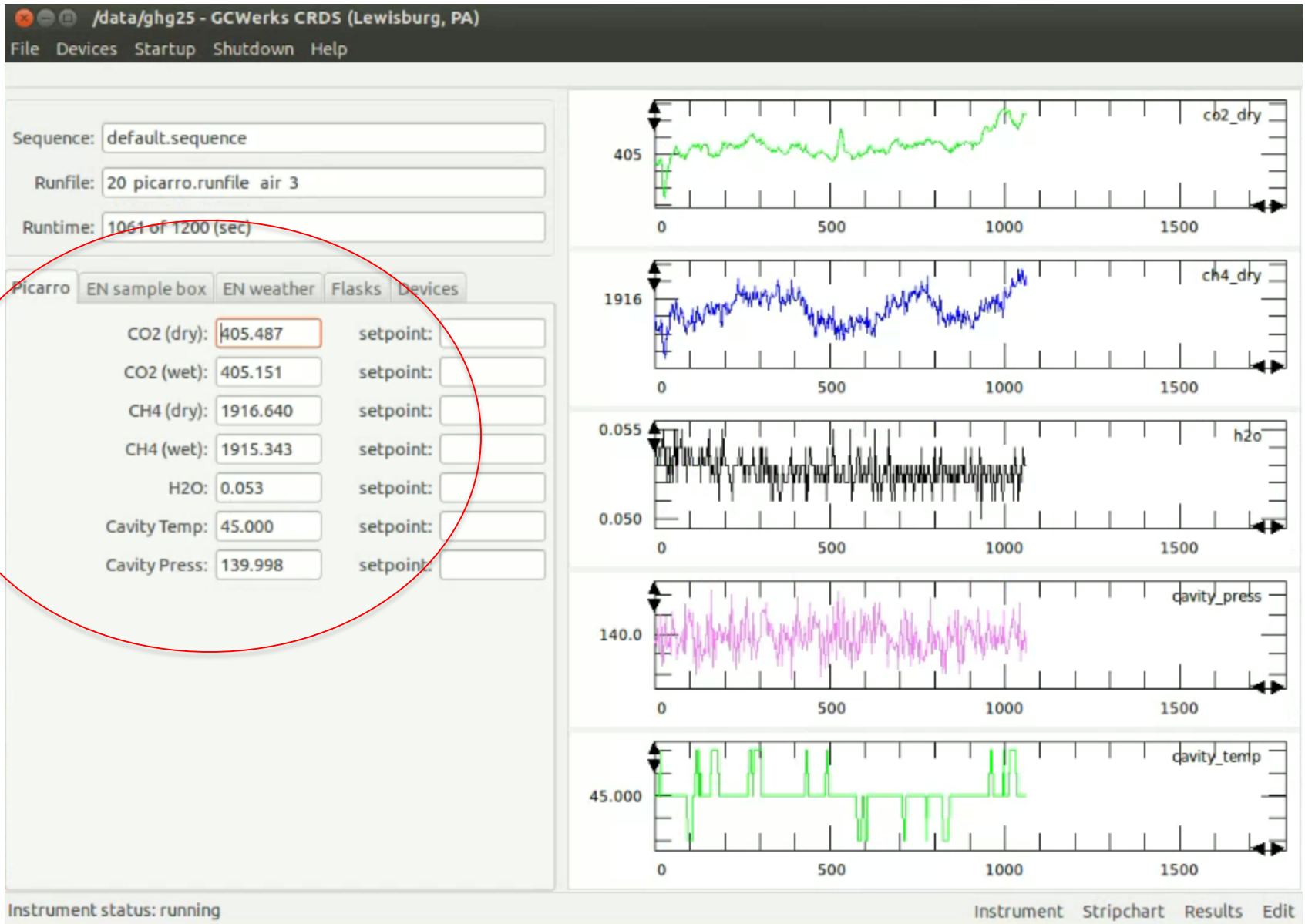
- Tower
- Building



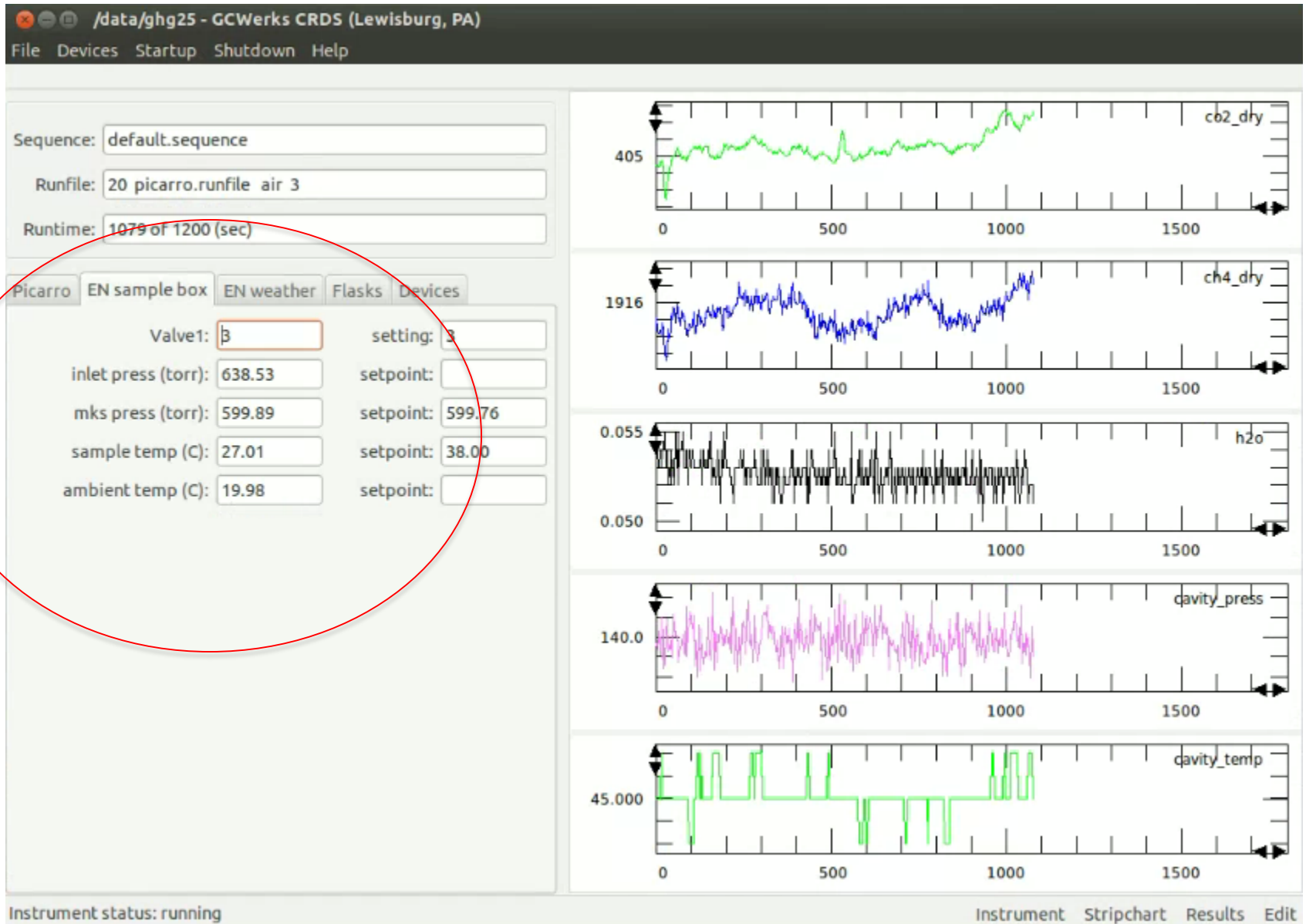
- Very Good
- Good
- Needs Work



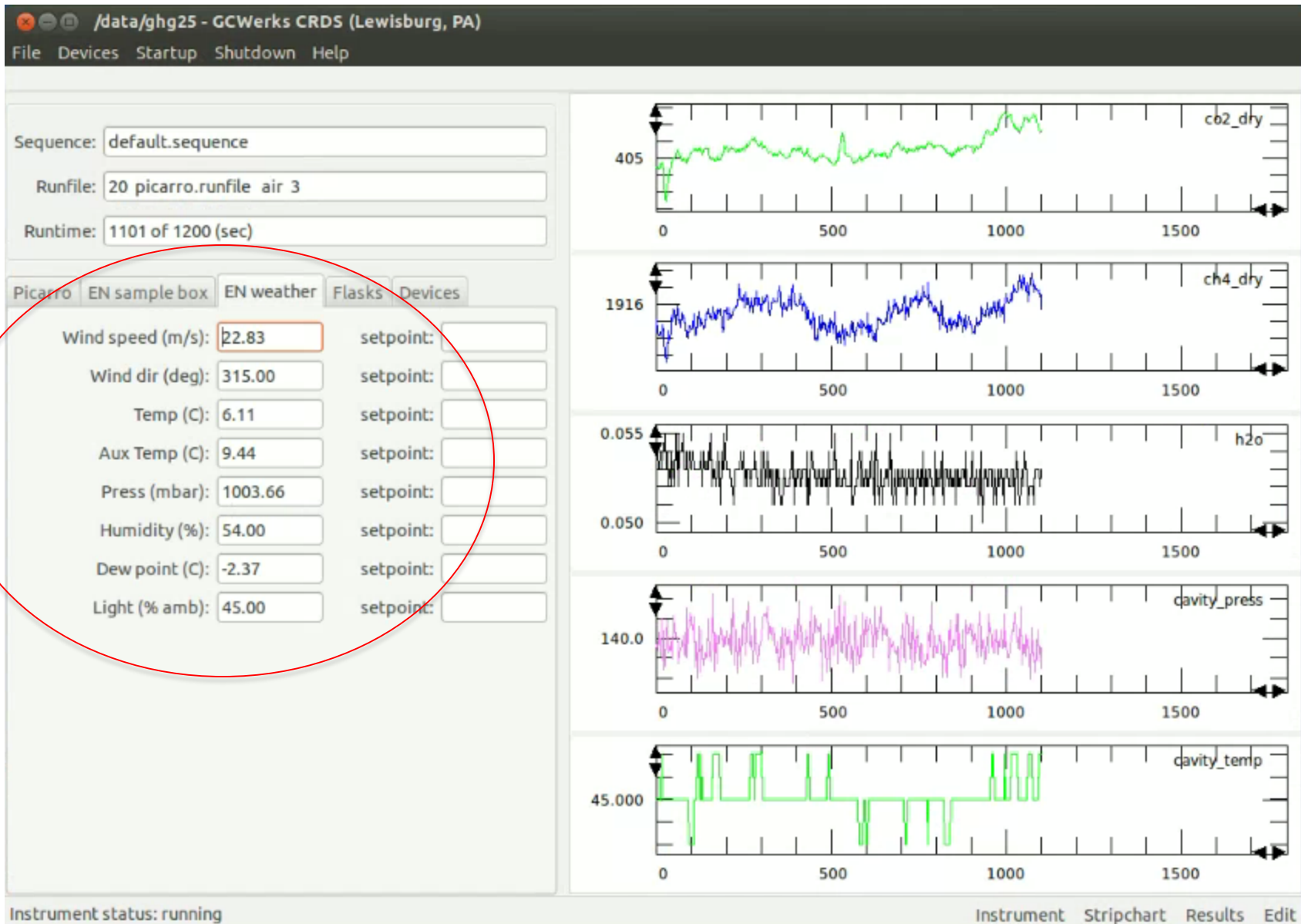
# Readings Gathered from Picarro G2301/G2401



# Readings Gathered from EN Sample Box

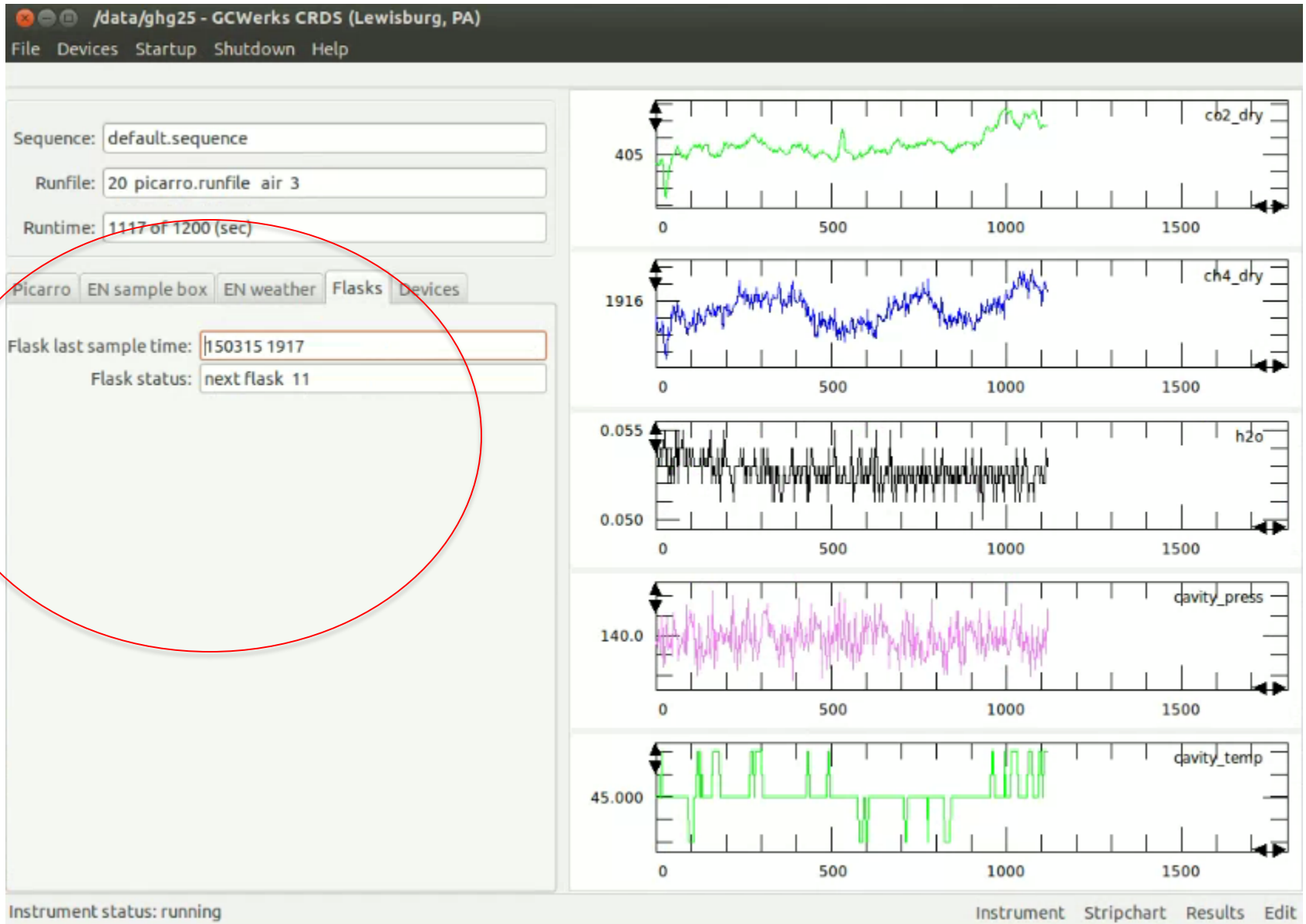


# Readings Gathered from EN Weather Station





# Interfacing with NOAA PFP Flasks



# Monitor UPS Battery to ensure proper shutdown during loss of power



# Regular System Monitoring and QC

=====  
/data/ghg47  
=====

-	-	-	-	-	-	-	-	-	-	-	-	-				
date	time	days_ago	port	sample	cycle	time	cavity	temp	cavity	press	cavity	press_stdev	h2o	co2	co2	co2
														dry	stdev	N
150520	0939	0.1	1	90m		3.11	45.000			139.999		0.015	0.124	410.80	0.320	369
150520	0959	0.1	2	90m		3.11	45.000			139.997		0.016	0.124	411.95	0.414	369
150520	1015	0.0	3	50m		3.10	45.000			139.999		0.015	0.124	412.93	0.550	200
150520	0124	0.4	4	JB03401		3.09	45.000			139.998		0.015	0.137	394.20	0.019	193
150519	1504	0.8	5	JB03390		3.10	45.000			139.997		0.015	0.133	394.34	0.018	193

GCWERKS CONTROLLED

=====  
/data/irv01  
=====

-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
date	time	days_ago	port	sample	cycle	time	cavity	temp	cavity	press	cavity	press_stdev	h2o	co2	co2	co2
														dry	stdev	N
150520	1038	0.0	1	S		2.96	45.000			140.000		0.017	0.100	421.50	2.966	282
150520	1053	0.0	2	W		2.98	45.000			140.000		0.018	0.100	421.67	2.006	281
150520	1104	0.0	3	N		2.97	45.000			140.001		0.017	0.100	422.13	1.027	101
150520	0155	0.4	4	JB03405		2.97	45.000			139.999		0.017	0.099	394.59	0.015	205
150519	2005	0.6	5	JB03387		2.97	45.000			139.998		0.017	0.099	394.55	0.015	204
150520	1023	0.0	8	E		2.98	45.000			140.000		0.017	0.100	418.62	1.332	284

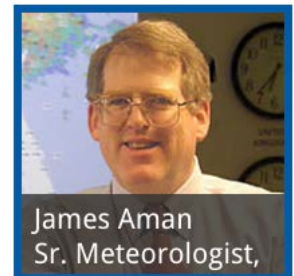
GCWERKS CONTROLLED

=====  
/data/lsn01  
=====

-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
date	time	days_ago	port	sample	cycle	time	cavity	temp	cavity	press	cavity	press_stdev	h2o	co2	co2	co2
														dry	stdev	N
150520	0958	0.1	1	SE		3.46	45.000			140.000		0.016	0.109	415.89	2.559	244
150520	1013	0.0	2	NW		3.45	45.000			140.001		0.016	0.109	419.96	10.074	245
150519	1924	0.7	4	JB03331		3.49	45.000			139.998		0.014	0.110	394.68	0.015	171
150520	0645	0.2	5	JB03203		3.46	45.000			140.000		0.015	0.110	394.36	0.016	175

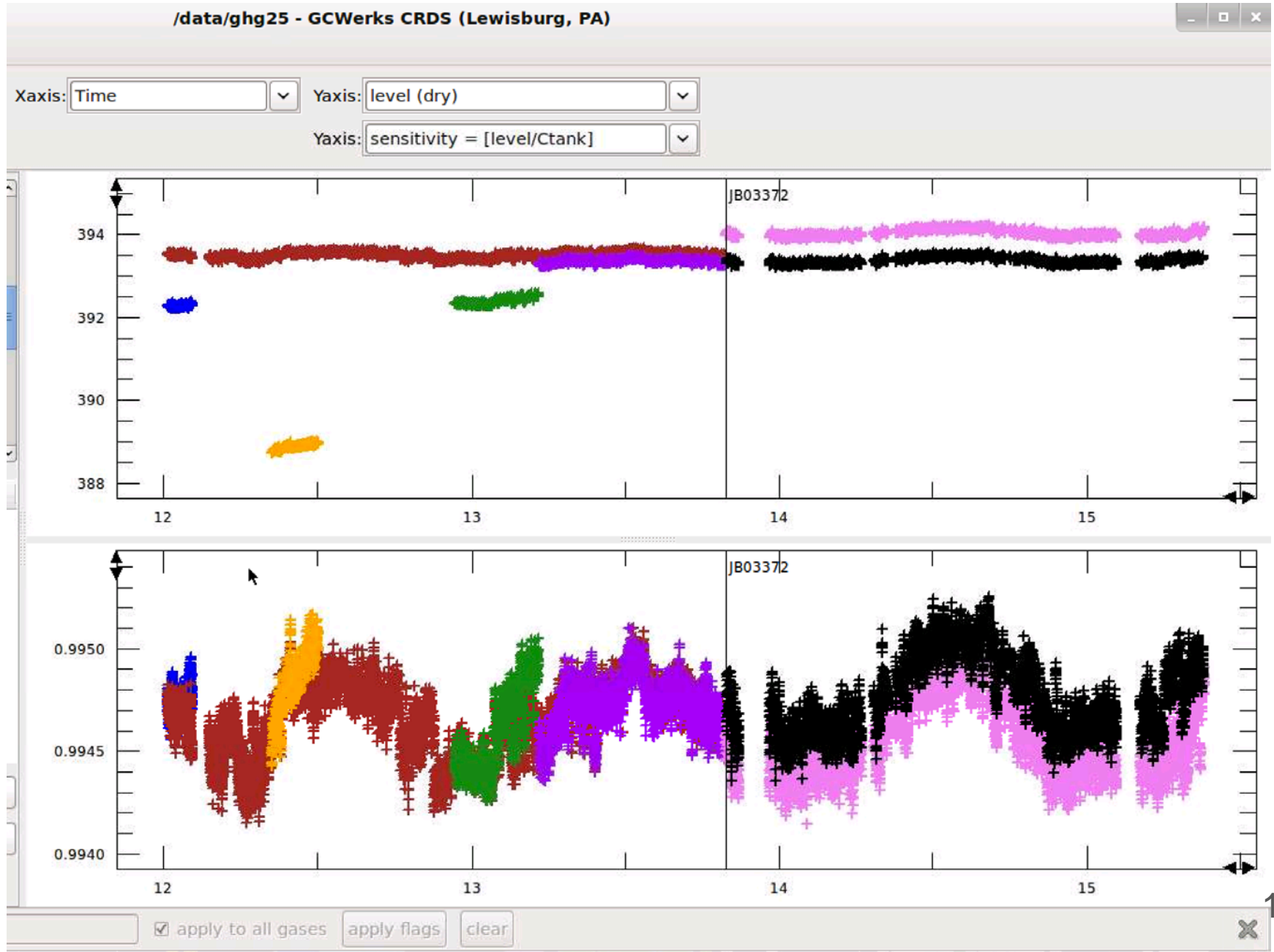
GCWERKS CONTROLLED

- Small team meets every 2 weeks to review status of network
- Identify issues, open “support tickets” for field technicians

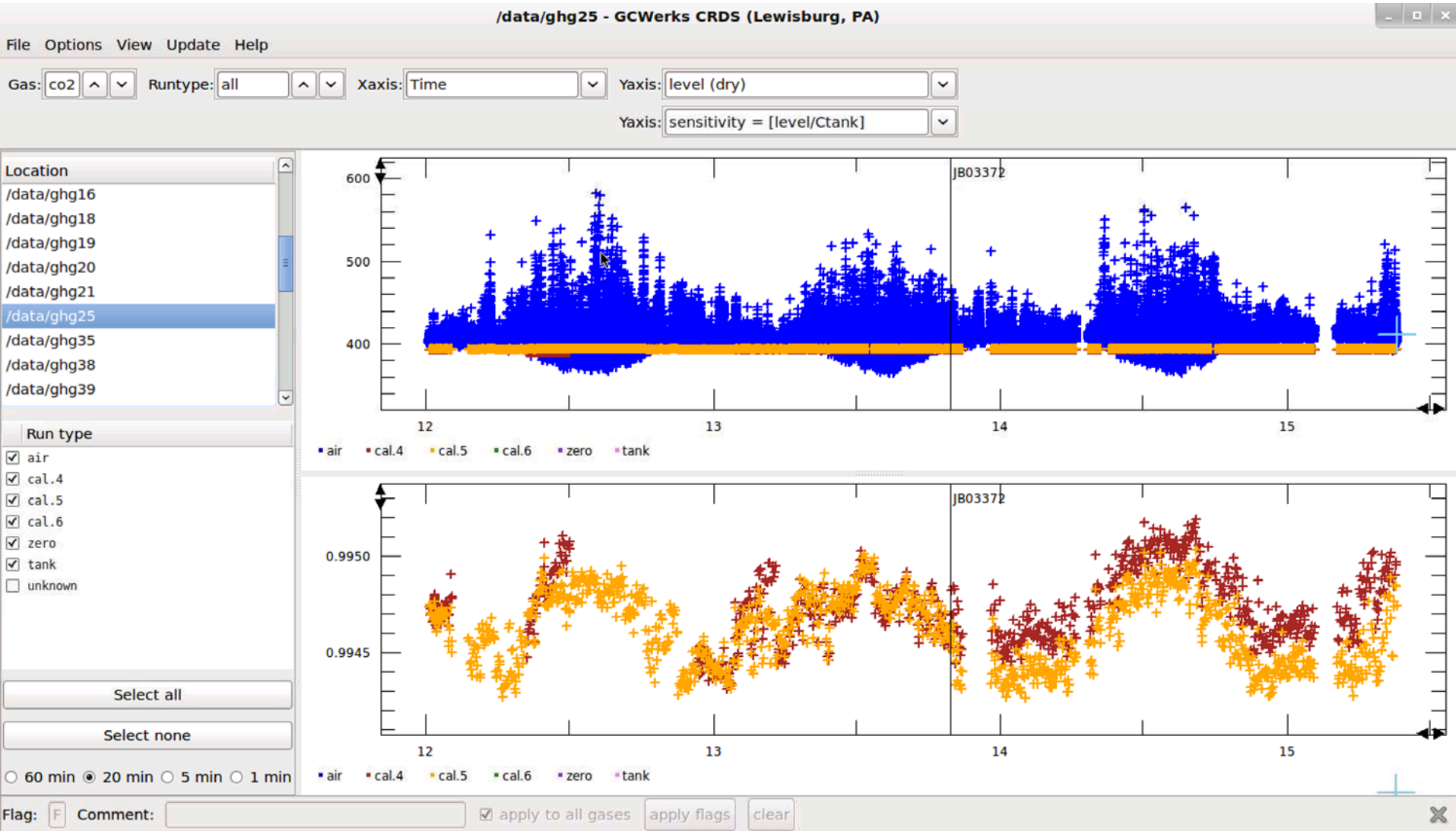




# Validating Calibration Runs









# Overall Data Sanity Checks








# Data Availability

Calibrated Data Sets Generated Nightly to Amazon S3

 AWSHQ.csv	25.51 MB	CSV File	5/20/2015 7:50:46 AM	STANDARD
 AWSHQ-1Minute.csv	423.17 MB	CSV File	5/20/2015 7:52:03 AM	STANDARD
 AWSHQ-Cal.csv	218.51 KB	CSV File	5/20/2015 7:50:47 AM	STANDARD
 AWSHQ-Cal-1Minute.csv	5.15 MB	CSV File	5/20/2015 7:52:18 AM	STANDARD
 AWSHQ-Ref.csv	309.65 KB	CSV File	5/20/2015 7:50:48 AM	STANDARD
 AWSHQ-Ref-1Minute.csv	6.84 MB	CSV File	5/20/2015 7:52:20 AM	STANDARD

Raw Picarro Data Sets Immediately Available on S3

Path: / ObsData/ GHG/ AWSHQ/ PicarroData/ G2000/ Log/ Archive/

File	Size	Type	Last Modified	Storage Class
 ..				
 DataLog_Private/				
 DataLog_User_Backup/				
 EventLogs/				
 RDF/				

Those interested in access to the data sets should email me  
[cdsloop@earthnetworks.com](mailto:cdsloop@earthnetworks.com)



## Some work in progress.....

- Developing a global standards database
  - Latest time-stamped values from NOAA (2301s) or SIO (2401s)
  - Tank ID includes fill date or NOAA fill letter (A, B)
- Develop more automated data filters and alerts (e.g. cavity press / temp / H2O out of range)

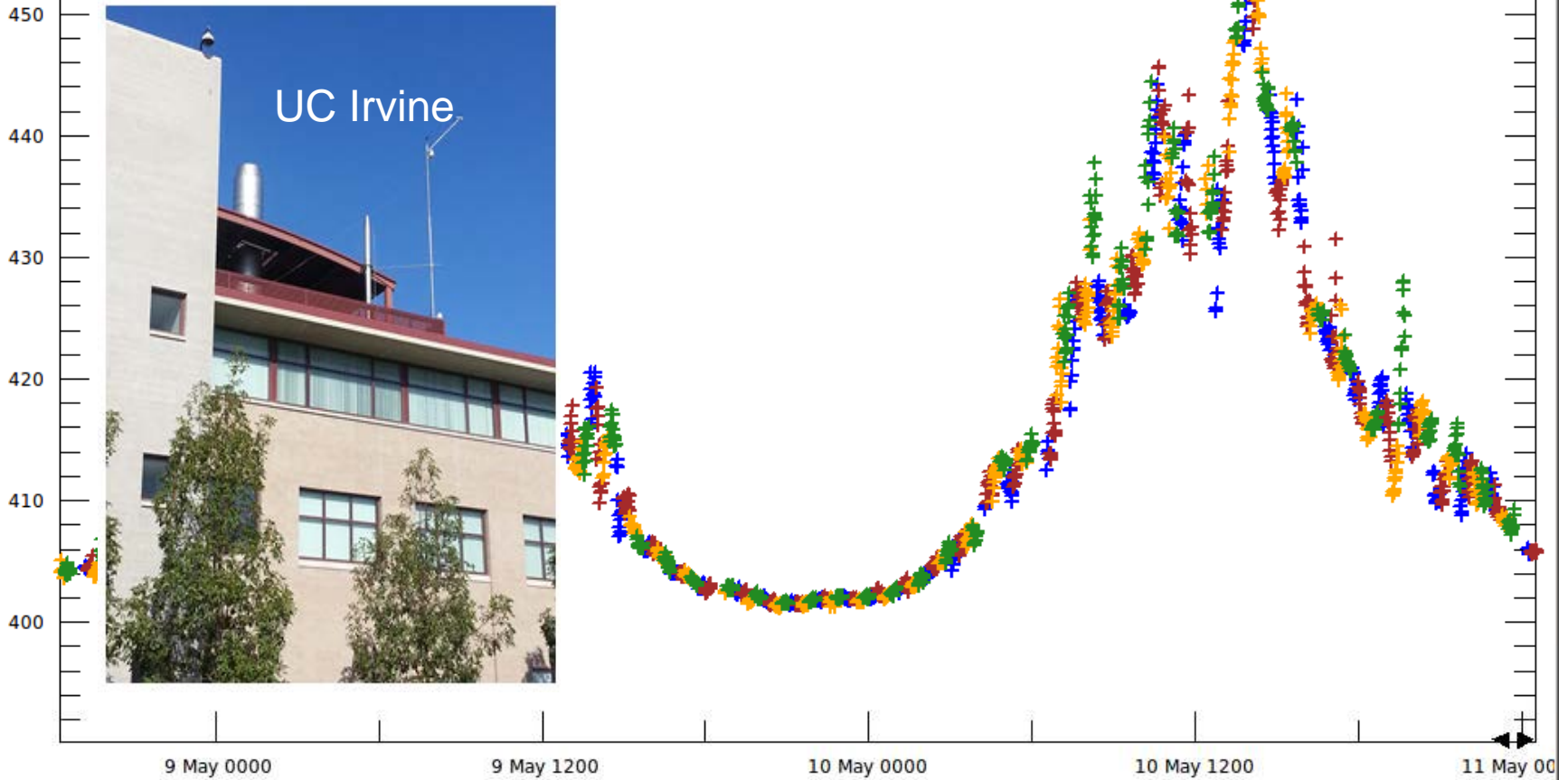
# Thank You! Questions?

Chris Sloop : [cdsloop@earthnetworks.com](mailto:cdsloop@earthnetworks.com)

Bill Callahan : [bcallahan@earthnetworks.com](mailto:bcallahan@earthnetworks.com)

# Rooftop Installations

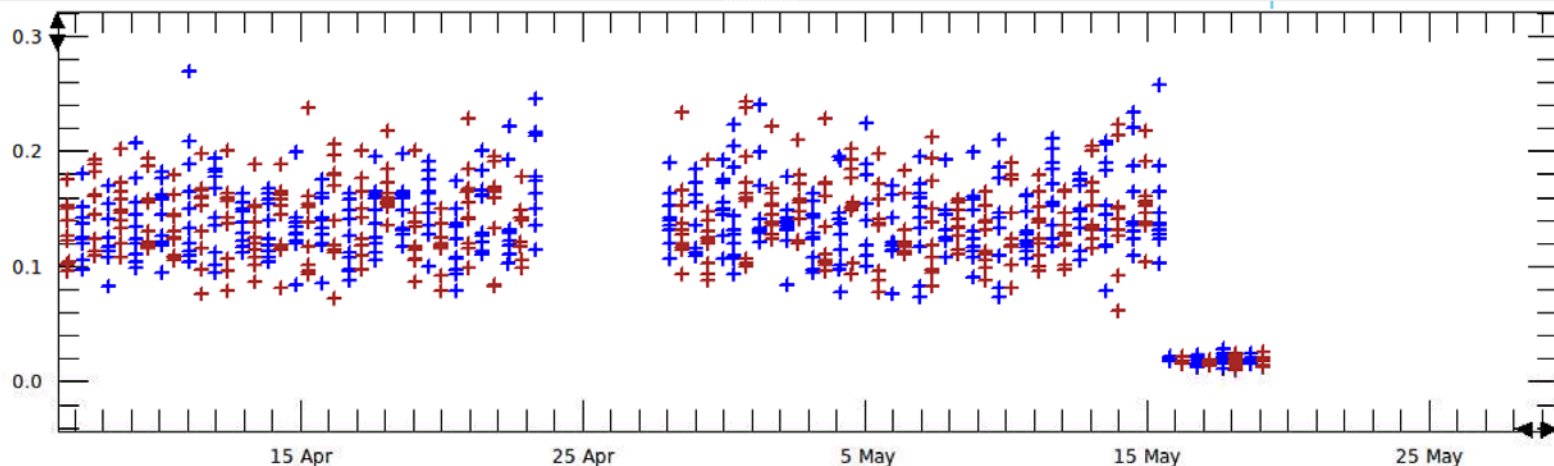
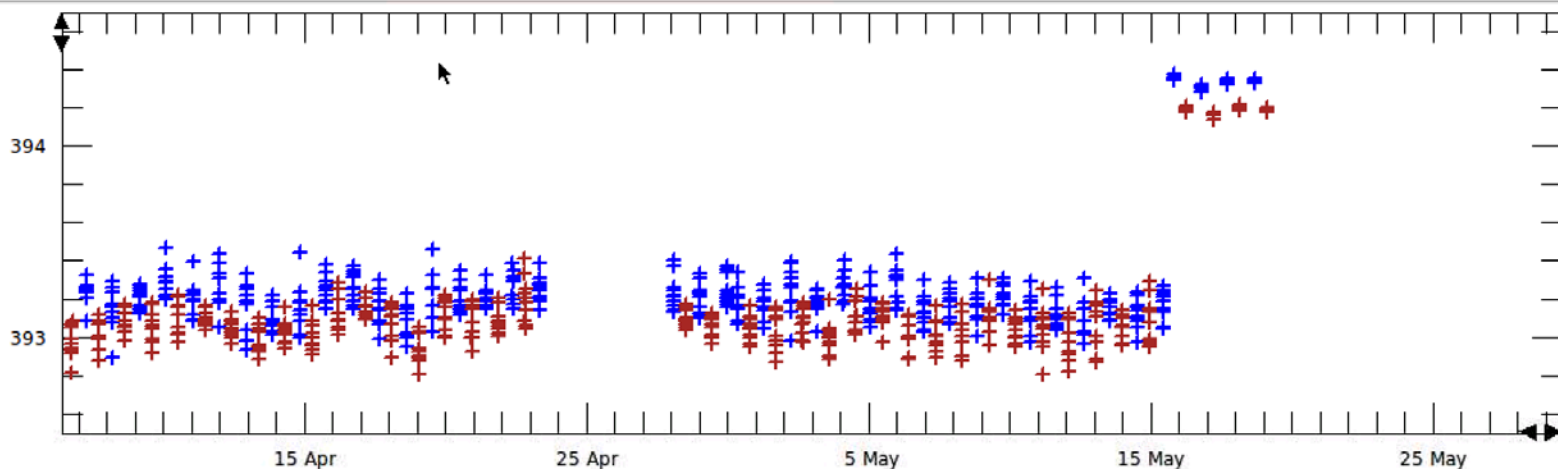
1. Four Inlets: One at each corner of the building
2. Met data from each corner



# Importance of Tracking Calibration Standard Deviations

/data/ghg47 - GCWerks CRDS (Mineola, NY)

Axis:  Yaxis:   
Yaxis:



apply to all gases

apply flags

clear

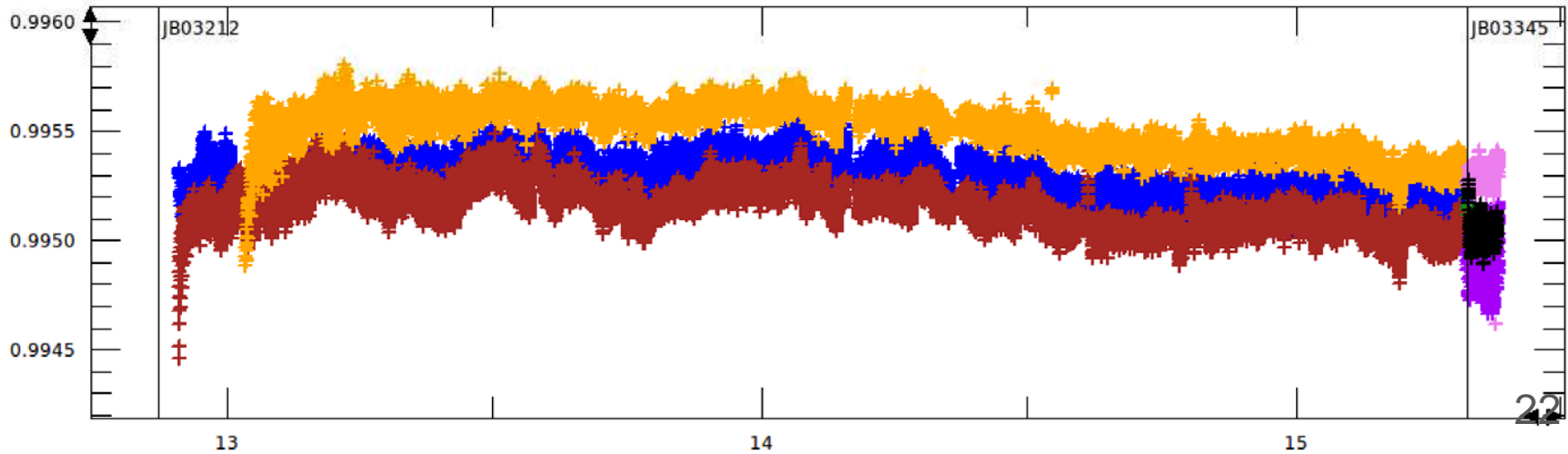
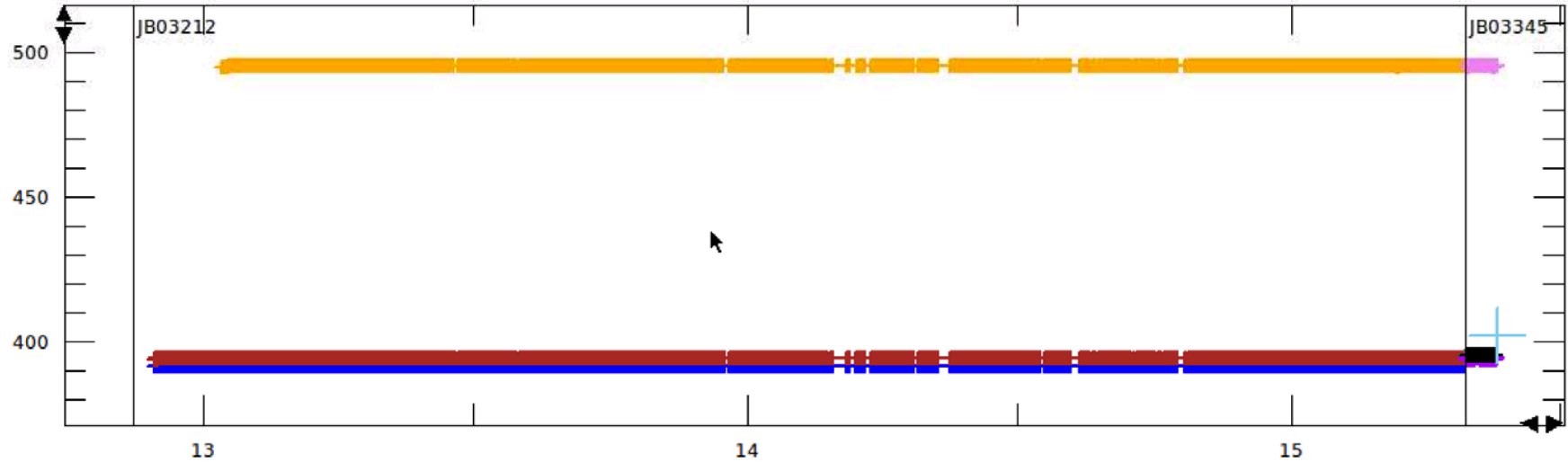
X



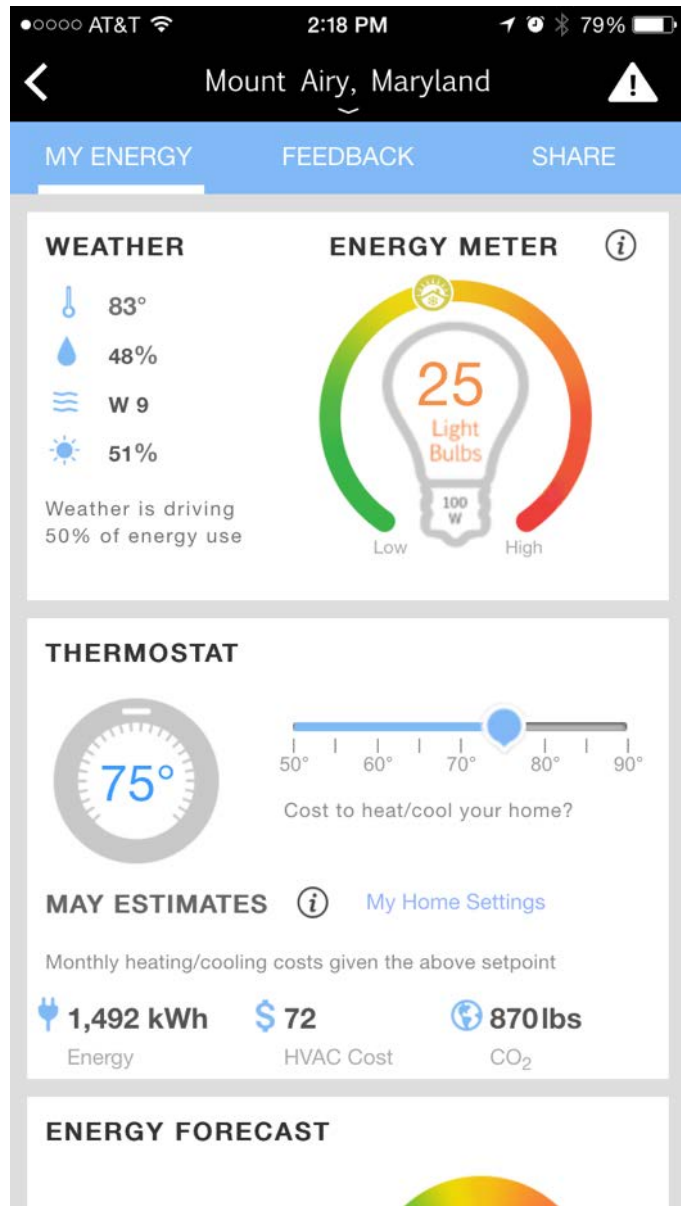
# Validating Calibration Runs

/data/ghg40 - GCWerks CRDS (Mauna Loa, HI)

Xaxis: Time Yaxis: level (dry)  
Yaxis: sensitivity = [level/Ctank]

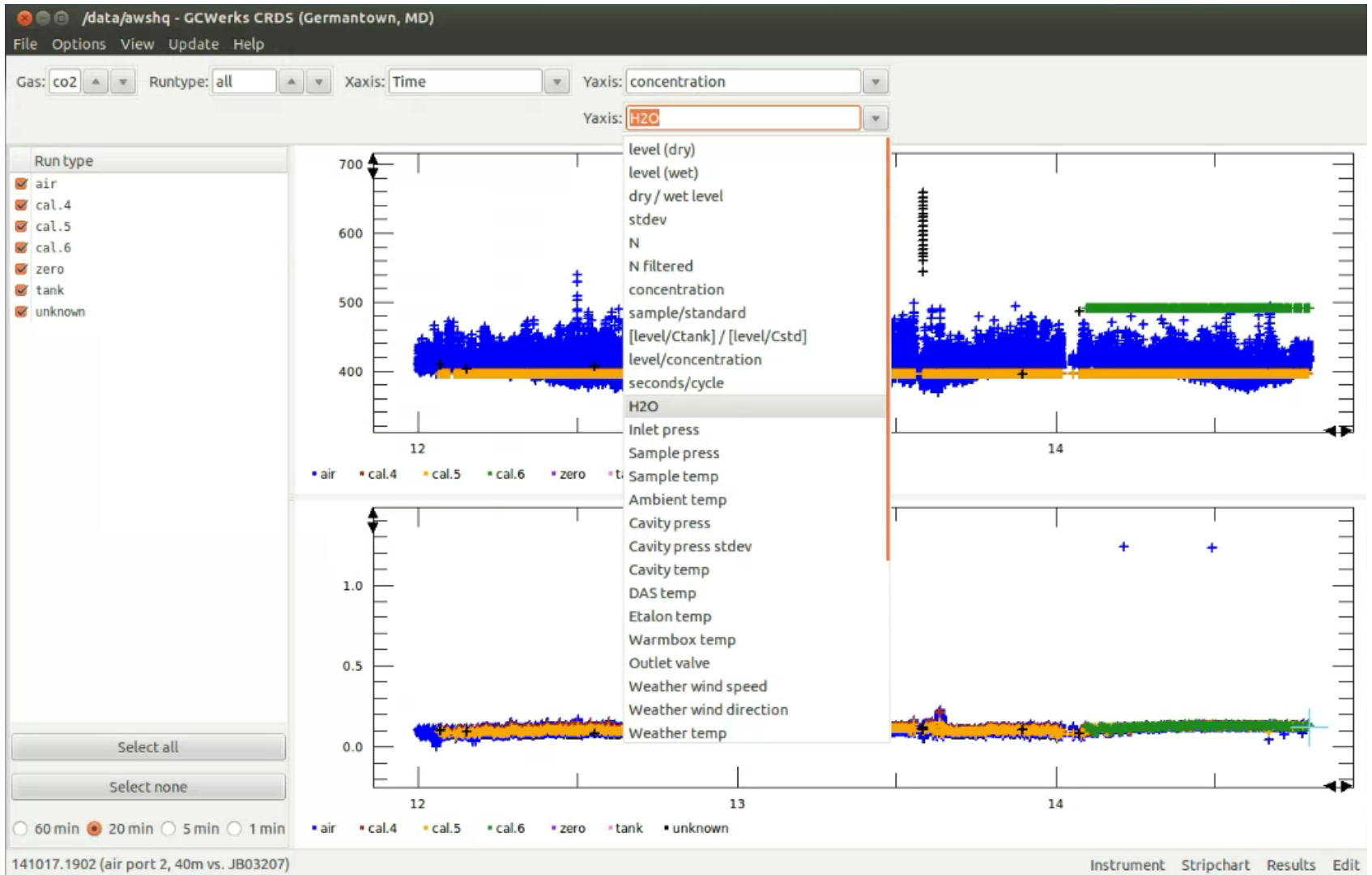


# Educating Consumers about their CO2 impact of HVAC

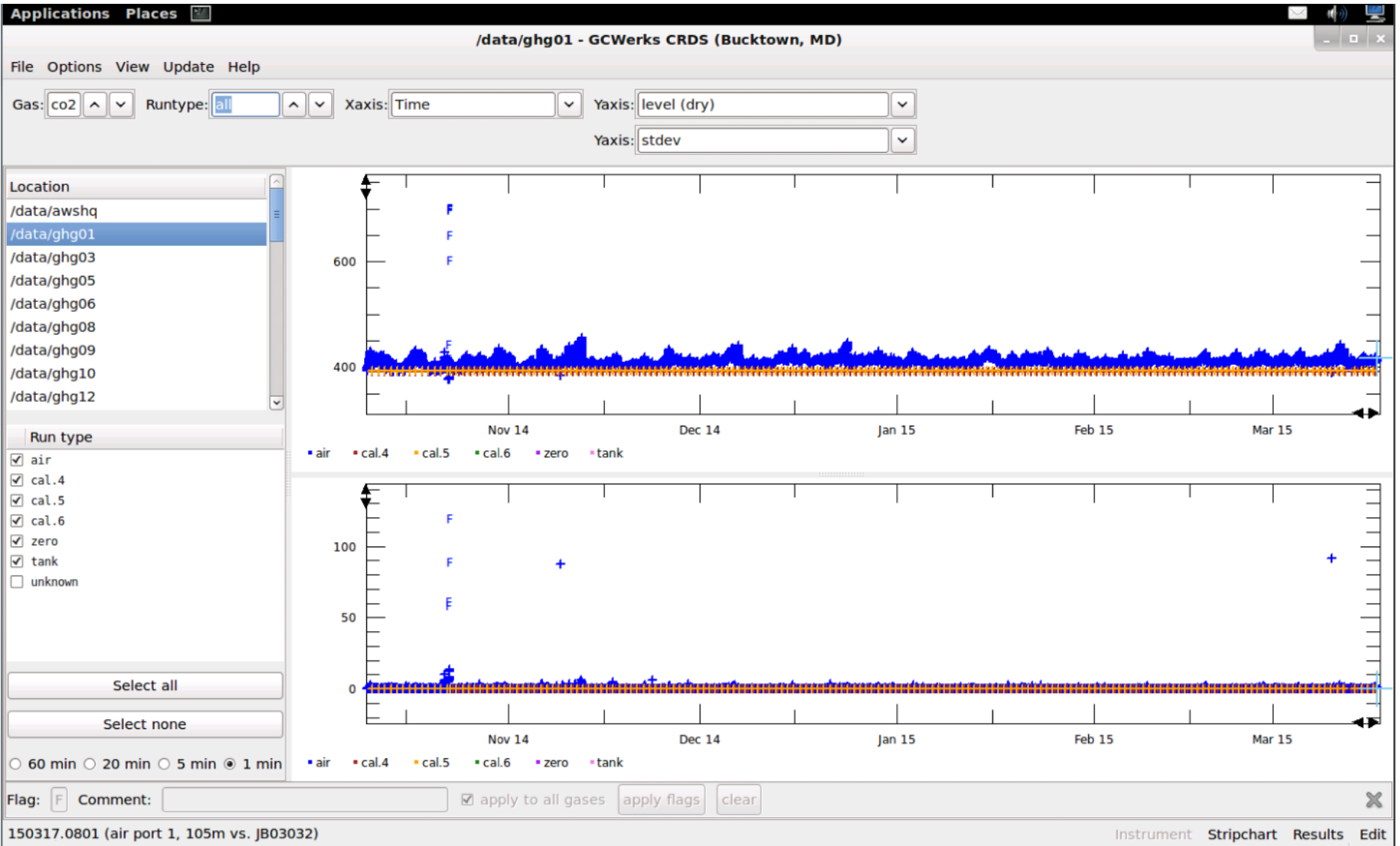


- Get rid of the CO2 usage display. I'm not a global warming nutjob.
- It seems to have a very hard slant to the thought of global warming. Why are you going political? Don't care for this as a whole.
- I think what you offer now is very informative. Comparisons to different systems that would help save money and lower our carbon footprint would be even more amazing. Thanks!
- I would like to see what planting trees and shrubs around my home will do for my carbon footprint and energy bill









Save As Save Changes Delete File

Directory

- operations log
- ports log
- runfiles
- menu runfiles

File

0000

```
#
# Date Time Port Tank Regulator Type Reject
#-----
110101 0000 1 105m - air 1
110101 0000 2 50m - air 1
#110101 0000 3 50m - air 1

110101 0000 4 JB03077 - cal 10

130104 0000 4 JA02470 - cal 10
110101 0000 5 JB03032 - std 10
```

```
#{ "CalBoxAttrs": [{"CH4CalConcentration": "", "CO2CalConcentration": "", "COCalConcentration": "", "CalTankID": "", "SampleHeight": "105", "SampleType": "Ambient", "Valve": "1"},
#{ "CH4CalConcentration": "", "CO2CalConcentration": "", "COCalConcentration": "", "CalTankID": "", "SampleHeight": "50", "SampleType": "Ambient", "Valve": "2"},
#{ "CH4CalConcentration": "", "CO2CalConcentration": "", "COCalConcentration": "", "CalTankID": "", "SampleHeight": "", "SampleType": "Empty", "Valve": "3"},
#{ "CH4CalConcentration": "1871.36", "CO2CalConcentration": "393.448", "COCalConcentration": "", "CalTankID": "JA02470", "SampleHeight": "", "SampleType": "Calibration", "Valve": "4"},
#{ "CH4CalConcentration": "1867.578", "CO2CalConcentration": "394.853", "COCalConcentration": "", "CalTankID": "JB03032", "SampleHeight": "", "SampleType": "Calibration", "Valve": "5"},
#{ "CH4CalConcentration": "", "CO2CalConcentration": "", "COCalConcentration": "", "CalTankID": "", "SampleHeight": "", "SampleType": "Empty", "Valve": "6"},
#{ "CH4CalConcentration": "", "CO2CalConcentration": "", "COCalConcentration": "", "CalTankID": "", "SampleHeight": "", "SampleType": "Empty", "Valve": "7"},
#{ "CH4CalConcentration": "", "CO2CalConcentration": "", "COCalConcentration": "", "CalTankID": "", "SampleHeight": "", "SampleType": "Empty", "Valve": "8"}],
#"NetworkID": "GHG", "PicarroType": "G2301", "StationID": "GH01"}
```

I

Save As

Save Changes

Delete File

Directory

- data processing log
- standards
- flags
- range flags

File

standards

tank	co2	ch4
#		
JB03077	387.662	1845.25
JA02470	393.448	1871.36
JB03032	394.853	1867.578

```
#{ "CH4CalConcentration": "1871.36", "CO2CalConcentration": "393.448", "COCalConcentration": "", "CalTankID": "JA02470", "SampleHeight": "", "SampleType": "Calibration", "Valve": "4" },  
#{ "CH4CalConcentration": "1867.578", "CO2CalConcentration": "394.853", "COCalConcentration": "", "CalTankID": "JB03032", "SampleHeight": "", "SampleType": "Calibration", "Valve": "5" },
```

I

# Earth Networks Design Summary

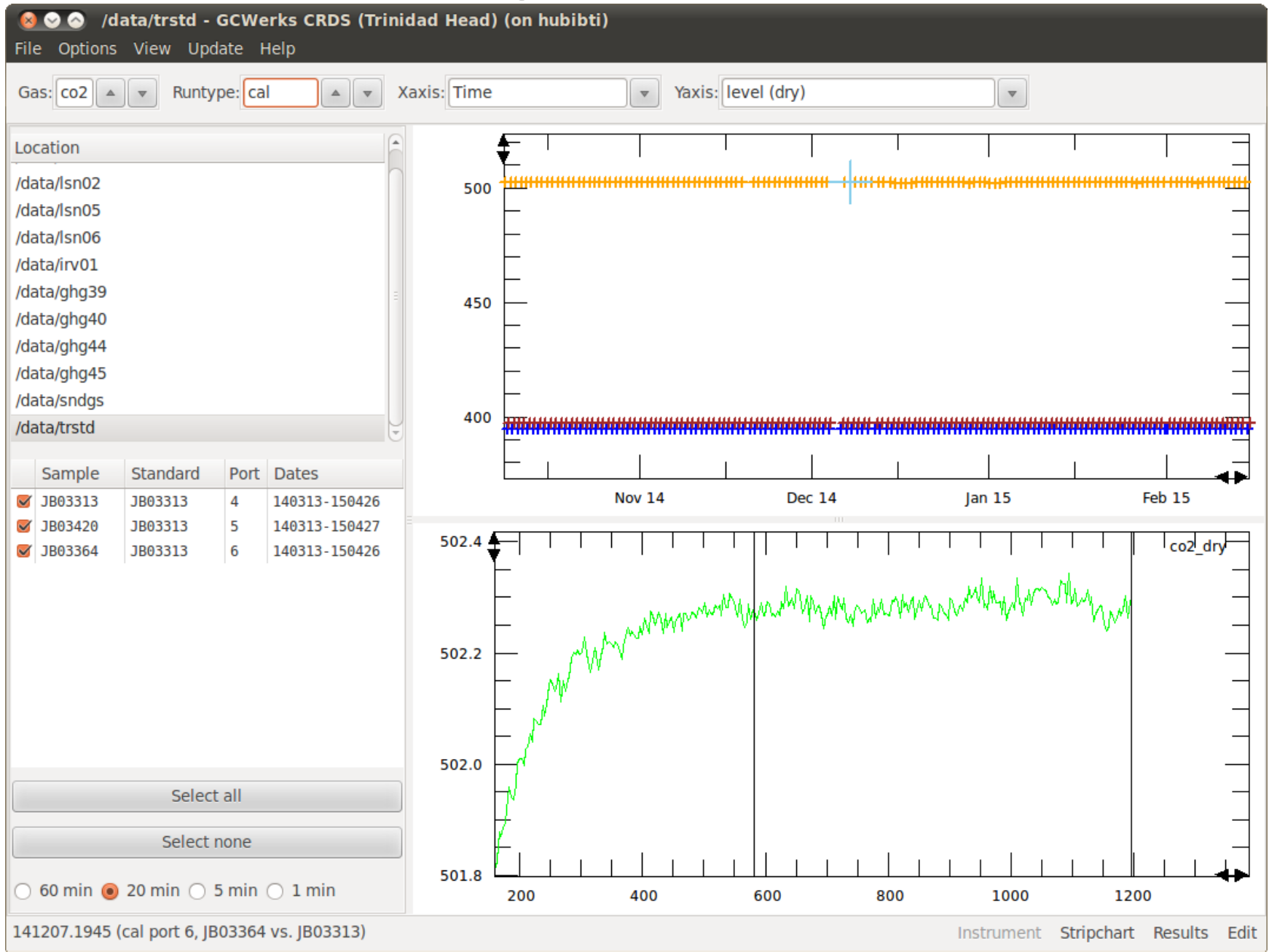
- Hardware design finalized based on Picarro 2301
- Avoid instrument-by-instrument calibration of H<sub>2</sub>O correction via pressure-controlled Nafion system.
- Tested H<sub>2</sub>O-induced CO<sub>2</sub> permeation through Nafion - effects smaller than 0.05 ppm CO<sub>2</sub>.
- Proposed 2-point calibration system using ambient air and pure N<sub>2</sub> - still being tested.



# Calibration and diagnostics

- Compare two near-ambient cal tanks and high tank (track drift, assess nonlinearity)
  - Sensitivity =  $[\text{level} / C_{\text{tank}}]$
  - Relative sensitivity =  $[\text{level} / C_{\text{tank}}] / [\text{level} / C_{\text{std}}]$
- Compare Picarro dry value with calibrated value
  - Level / concentration
- Other diagnostics
  - Cycle time
  - Cavity press stdev (and cavity temp stdev)

# Mean of high frequency cal data



# GCWerks Megacities data flow



- Linux mini-computer on site
- Controls sequence and acquires high-frequency data from Picarro, cal box, weather station (with email alarms)
- Data pulled hourly by EN server (rsync)
- Results updated nightly, exported to yearly CSV files
- Pulled by JPL from EN server (rsync, check all years)
- GCWerks available for data exploration via VNC

# Data Acquisition – PicarroSender App

Earth Networks: Picarro Data Sender (V1.3.0)

StationID:

**Picarro Data**

Data Time:

CO2:

CH4:

H2O:

PressureIn (Torr):

PressureMKS (Torr):

Valve Position:

Cal Box Temp (F):

Computer Time:

**Weather Data**

Station Name:

Data Time:

Temperature (F):

Wind Speed (mph):

Wind Direction:

Pressure (Torr):

Humidity:

**Settings**

Picarro IP:  Port:

Valco IP:  Port:

Moxa In IP:

Moxa Out IP:

Valve Position:

**Control**

**Schedules**

Sampling Schedule	Calibration Schedule	Currently Running
2011-11-01 00:00 ----- SampleTopTwo 2011-11-01 12:00 ----- Sample50M 2011-11-01 13:00 ----- SampleTopTwo 2011-11-02 01:00 ----- Sample50M 2011-11-02 02:00 ----- SampleTopTwo 2011-11-03 00:00 ----- SampleTopTwo 2011-11-03 12:00 ----- Sample50M 2011-11-03 13:00 ----- SampleTopTwo	2011-11-01 00:00 ----- FullCalibration 2011-11-02 11:00 ----- FullCalibration 2011-11-04 08:00 ----- FullCalibration 2011-11-05 03:00 ----- FullCalibration 2011-11-06 22:00 ----- FullCalibration	<input type="text" value="SampleTopTwo"/>

**Status**

Picarro Raw Data:

Server Status:

11/11/01 18:05:05.337;397.016;396.407;1.946;1.943;0.095;140.273;45.000;3.000;1.000;0.000;20994.295;45.000;45.095;37.375;8091.000;22846.000;146.881;



