Space Geodesy and Geochemistry Applied to Monitoring and Verification of Carbon Capture and Storage

Award # DE-FE0002184
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U.S. Department of Energy
National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Developing the Technologies and Building the Infrastructure for CO_2 Storage
August 21-23, 2012

Presentation Outline

- What is the Award For?
- What Research Work is being Supported?
- Geochemical Research

What is the Award For?

- Provides Support for the Training of Two Graduate Students
  - Student 1: Involved in analysis of SAR images
  - Student 2: Involved in modeling of sub-surface geochemistry and application of models for policy decisions
- PhD projects are typically 5 years
- Both students are at the end of 2 years
- Award will provide 3 years of support (no tuition), the University will provide the additional 2 years.

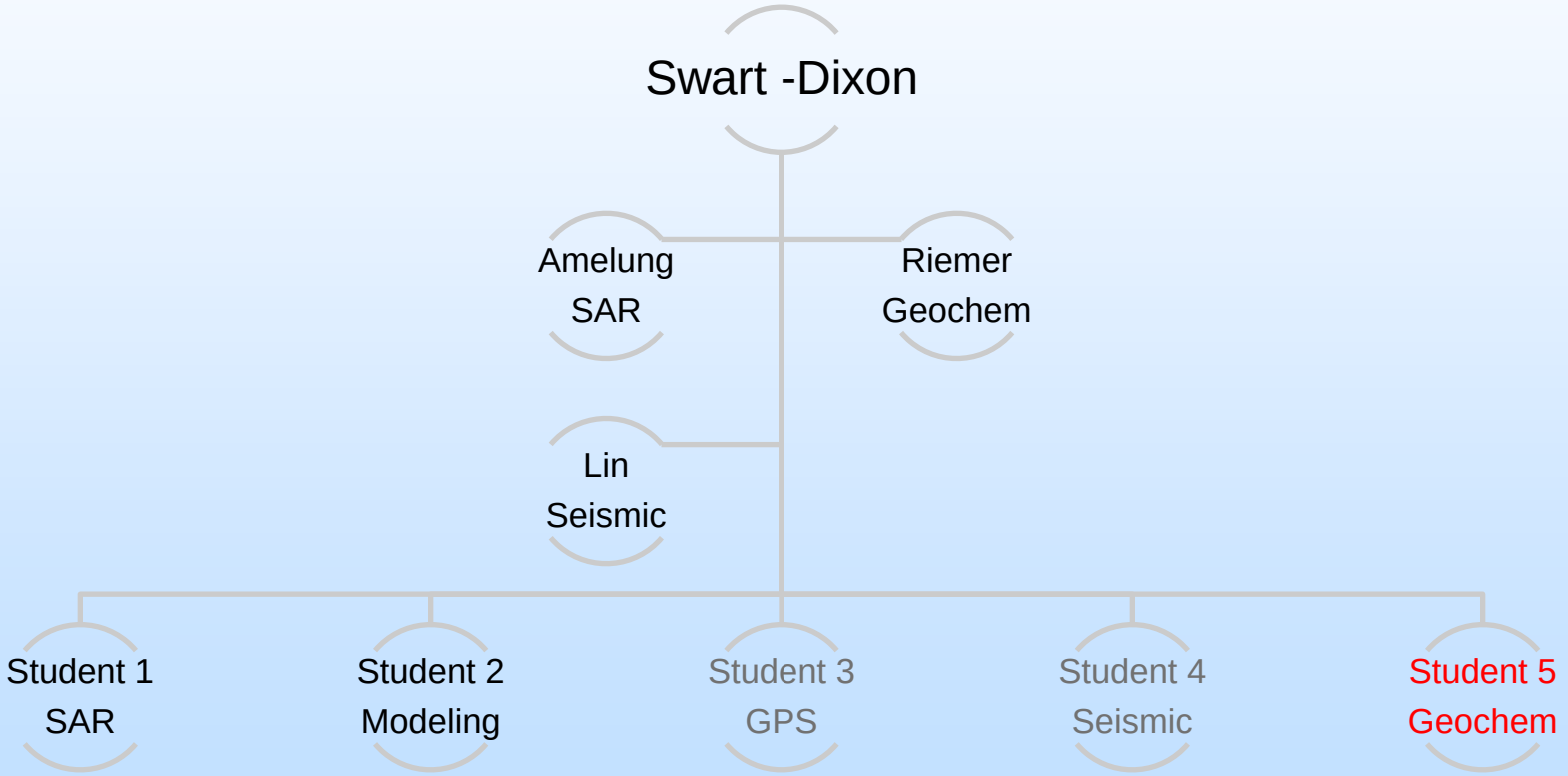
What Research Work?

- The use of the funds for this project are simple, that is to support the stipend of two students.
  - The goals of these students are integrated into the award.
- Space Geodesy and Geochemistry Applied to Monitoring Verification of Carbon Capture and Storage
  DE-FE0002184

Benefit to the Program

- Graduate students are being produced which are directly familiar with the problems and issues in the technology of CCS.
  - SAR
  - GPS
  - Modeling
  - Seismic
  - Geochemistry
  - Policy
- Next Generation of CCS scientists and policy makers

Organization Chart



Project Milestones

A	Kickoff meeting	03/31/10	12/04/09
B	Educational Program	06/30/10	6/1/10
C	Semi-annual Progress Report	09/30/10	7/30/10
D	Yearly Review Meeting	03/31/11	2/1/11
E	Yearly Review Meeting	03/31/12	2/1/12

Project Milestones

G	Complete analysis of existing Sites	12/31/10	12/31/10
H	Order SAR at specified test site	09/30/11	Underway
I1	Complete analysis of 1st yr of SAR at specified test site	10/31/11	
I2	Complete analysis SAR at specified test site	12/31/12	
J1	Literature Review of Geochemical Reactions completed	10/31/11	Underway

Project Milestones

J2	Assessment of Host Rocks for sequestration potential completed	12/31/12	Underway
K	Numerical geochemical model completed	12/31/12	Underway
L	Integration of GPS, InSAR, and Geochemical data	12/31/12	Underway

Schedule

	FY10-BP1				FY11-BP2				FY12-BP3			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 1.Project Management, Planning, and Reporting	A	B	C		D				E			
Task 2. Investigation of InSAR Data Subtask 2.1- Subtask 2.2- Etc				G H				I1				I2 L
Task 3. Investigation of Geochemical Data					J1		J2			K		L

Deviations from Gantt Chart

- Grant was awarded in December, but students usually start in August, hence 6-9 month delay.
  - One student started Sep 2010
  - One student started Jan 2011
- Problem finding appropriate site, hence objectives have been delayed
- Funds for acquiring SAR images were exhausted

Student Activities

- 36 Course Credits
- 24 Research Credits
- Comprehensive Examination
- Dissertation Proposal
- Qualify Examination

Other Activities

- IEAGHG Summer school with industry, academic and government representatives from 27 countries
- Attended TOUGH2 course at LBNL (9/11)
- Attended ODP Workshop on Carbon sequestration in Oman

Meeting Attendance

- Goldschmidt 2010
- AGU 2010
- AGU 2011

Bibliography

- Abstracts
  - Augustin, C., Swart, P.K. Broad, K.2011, The role of stakeholders in developing an international regulatory framework for carbon capture and storage . AGU Fall Meeting
  - Augustin, C., Swart, P.K. Riemer, D., Dixon, T. 2010 . Application of computational software to model the geochemical and geomechanical interactions in geologic carbon sequestration sites, AGU Fall Meeting

Accomplishments to Date

- Hired 2 Excellent graduate students
- Students are taking courses, attending meeting, and writing research proposals

Technical Status

Instrument

- Two Picarro
- Delivered May-July 2010
- Problems
  - Did not give the same numbers
  - Problem with integration time
  - Problem with Methane Interferences

U Miami calibration

- Calibration
  - Three gases made up using zero air
  - Cross Calibrated with conventional IRMS
- 16 Position Manifold
  - 13 positions
  - 3 Standards
- Remote Operation

Location

Regional Airport providing weather data

Denbury Offices

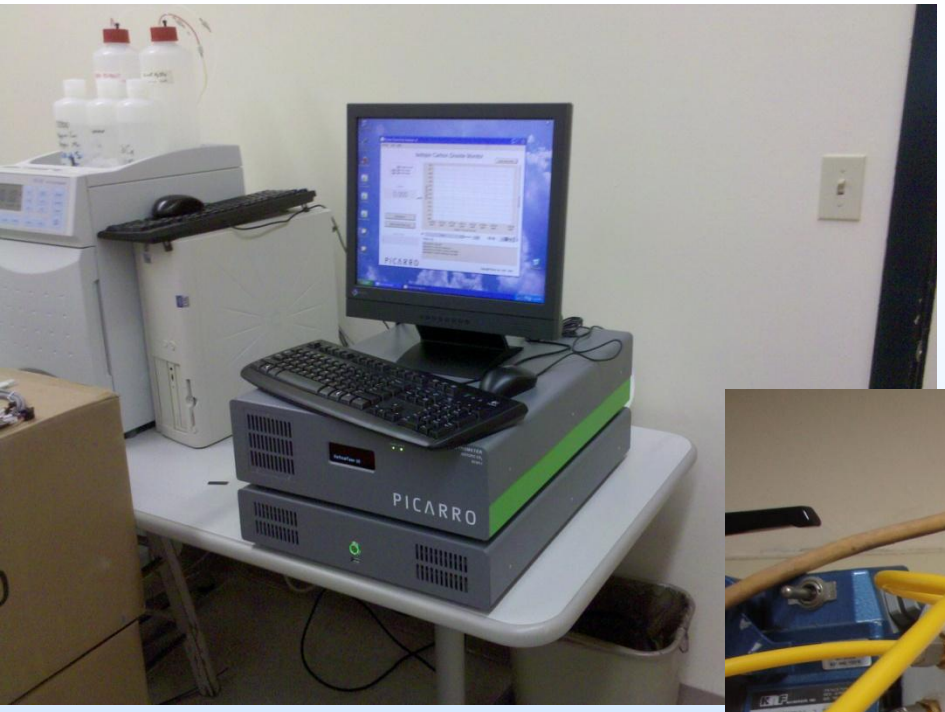
Location

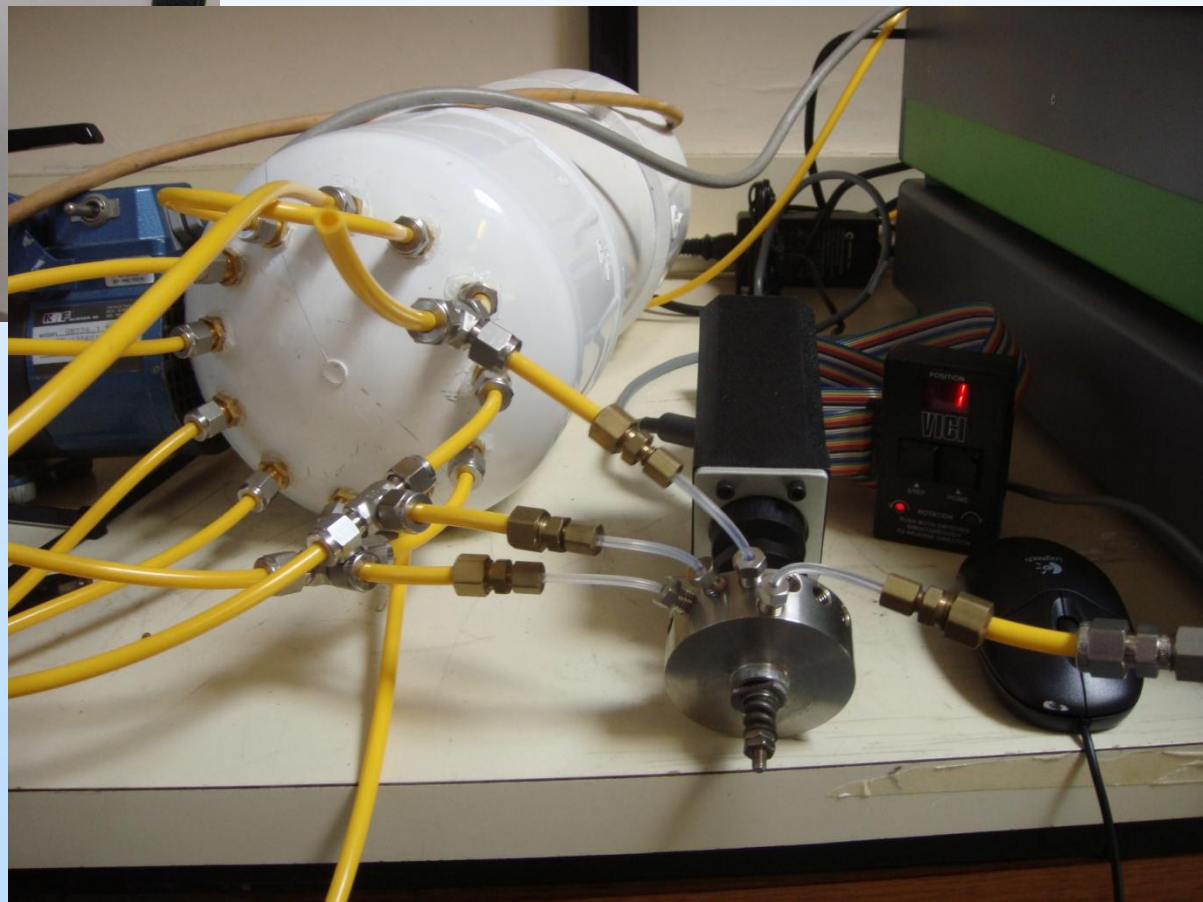

Position 10
10
Position 11
11
Position 9
9
Position 12
12
Shed
1
Position 1
Position 2
2
Site 3
Position 8
8
Position 7
7
Position 6
6
Position 5
5
Position 3
3
Position 4
4
© 2012 Google
Google earth
Imagery Date: 3/10/2011
1944
29°29'36.42" N 95°15'20.06" W elev 41 ft
Eye alt 1327 ft

Installation

Stainless steel and treated plywood foundation with lag screws aligned to cross beams have provided excellent wind resistance

Equipment





Core equipment consists of one CRDS instrument, 16 position valve, manifold, vacuum pump, and data connection.

Installation

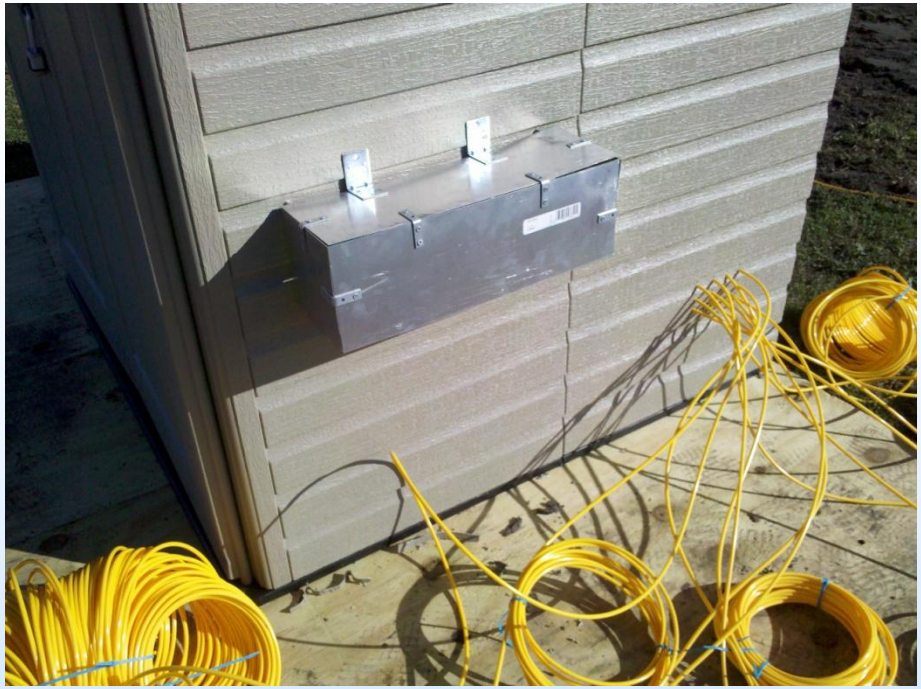
Top rack: Monitor, battery backup unit

2nd rack for CRDS

3rd rack holds the 3 cylinders for gas standards

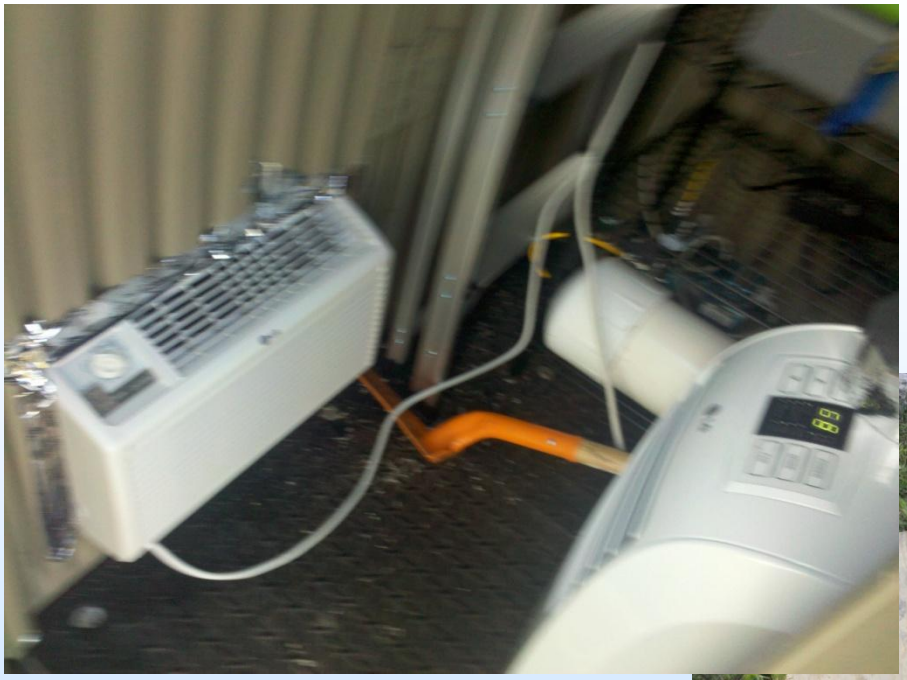
Bottom rack holds manifold, valve and valve actuator, as well as the vacuum pump

Installation



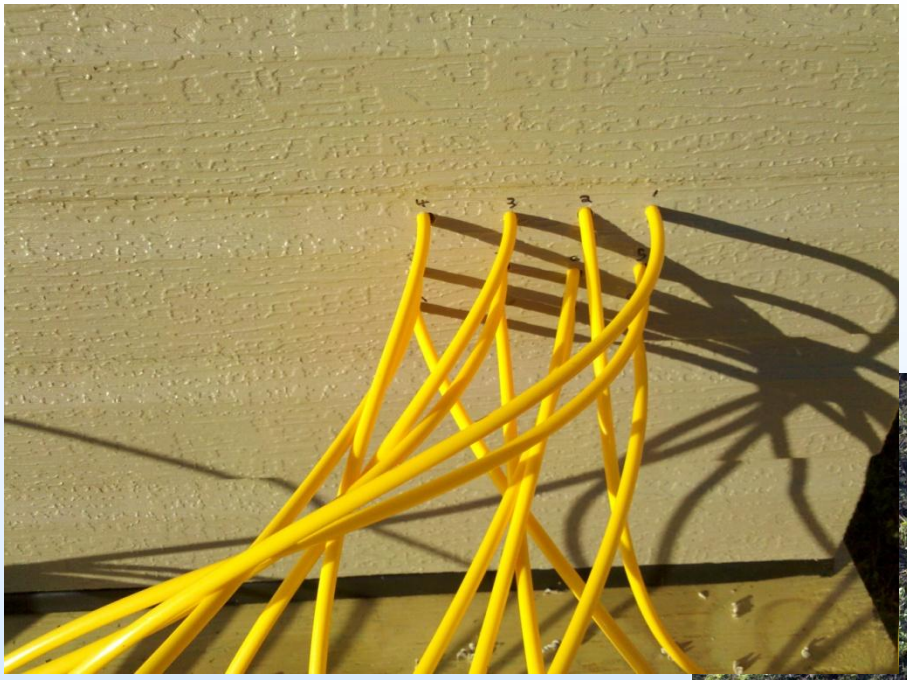
Thermostat controlled 9000 BTU unit provides extra cooling when needed in afternoon and also serves as temperature display

Installation



5000 BTU unit run full time for needed base cooling

Installation



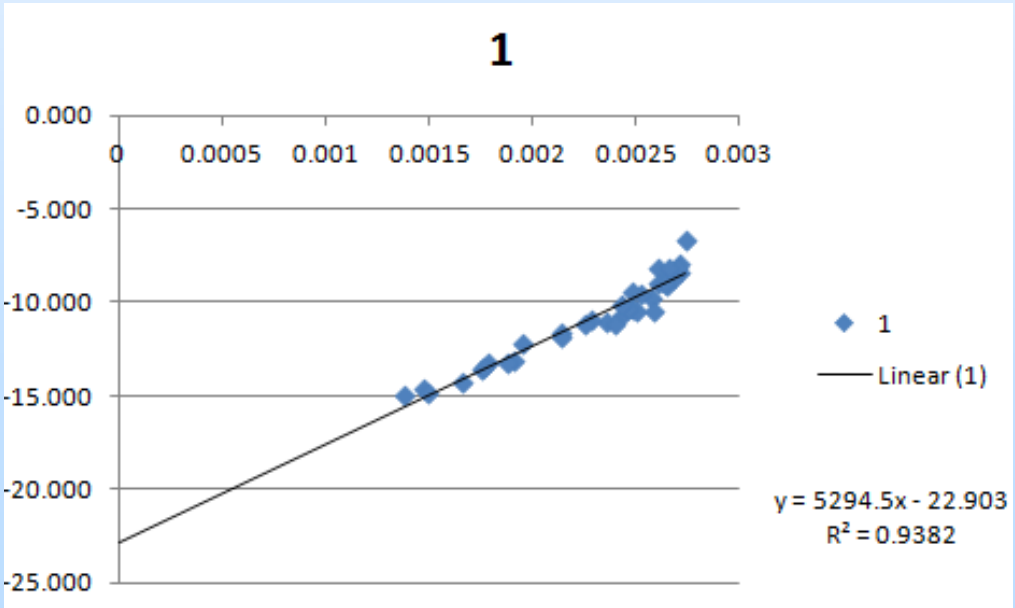
12 Sample lines exit the south side of the shed and run to each sampling point, where it is connected to a 2 foot deep hole capped by a PVC pipe for sampling

Current work

- Daily, CRDS files are downloaded, processed, analyzed, and added to weekly composite files along with weather data.

- Weekly overall and Keeling summaries are generated to examine long-term trends

- Soil samples recently collected from each site, with 6 samples across a 2 foot deep gradient being analyzed for carbon and nitrogen isotopic content. Representative plant species also collected for analysis, as well as discrete gas samples for GC-MS analysis



Data analysis macros

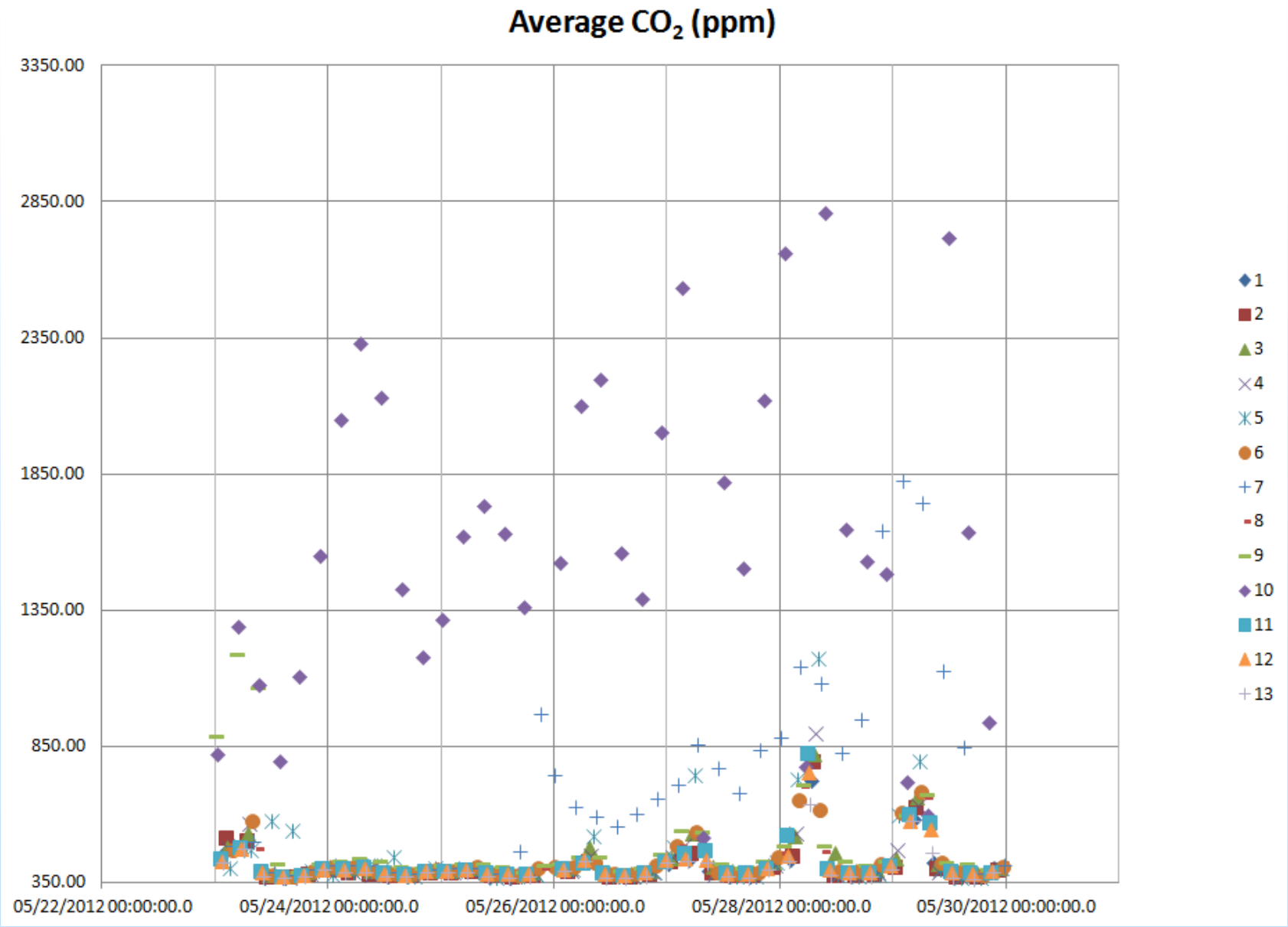
- The instrument runs 24 hours a day, recording 40 different data points every second, resulting in 3.5 million cell spreadsheet being generated every day

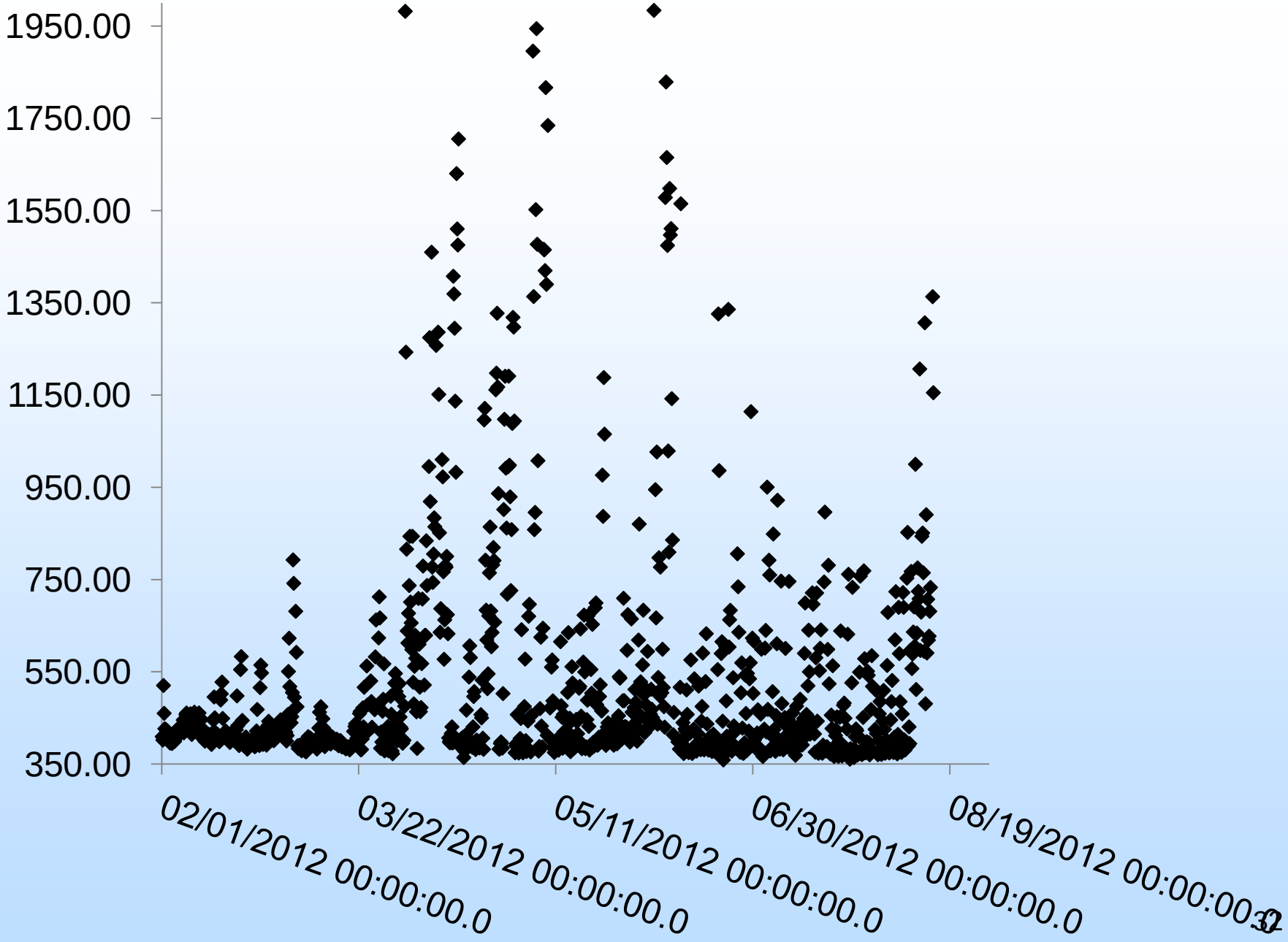
- Instrument is connected to the internet via a 3G/4G device, with failsafe systems installed to force a system restart to restore service should connectivity be lost

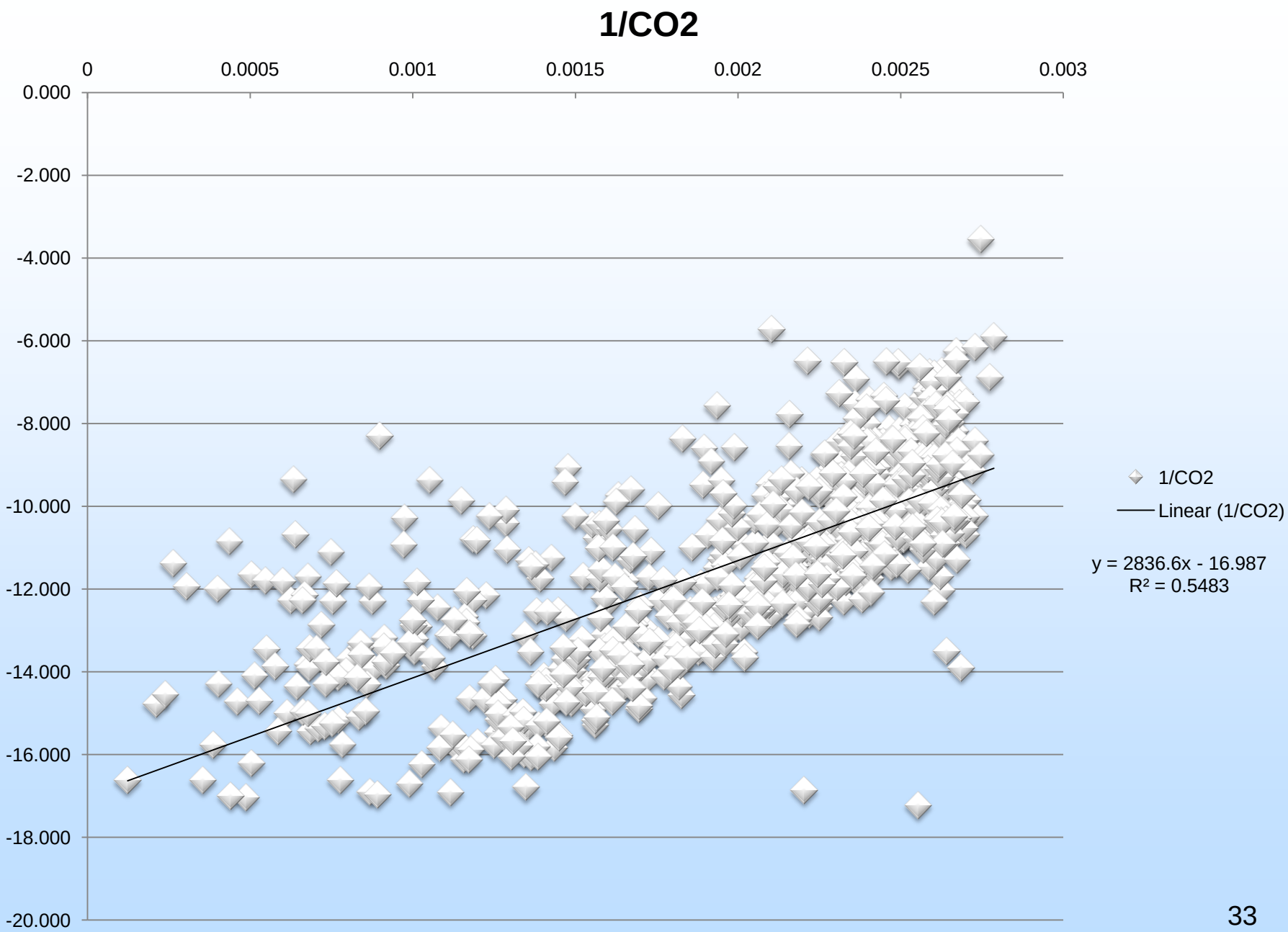
- Macro programs now import, sort, analyze, and graph daily CRDS files, produce weekly reports, and provide weather data in any desired time window

Appendix

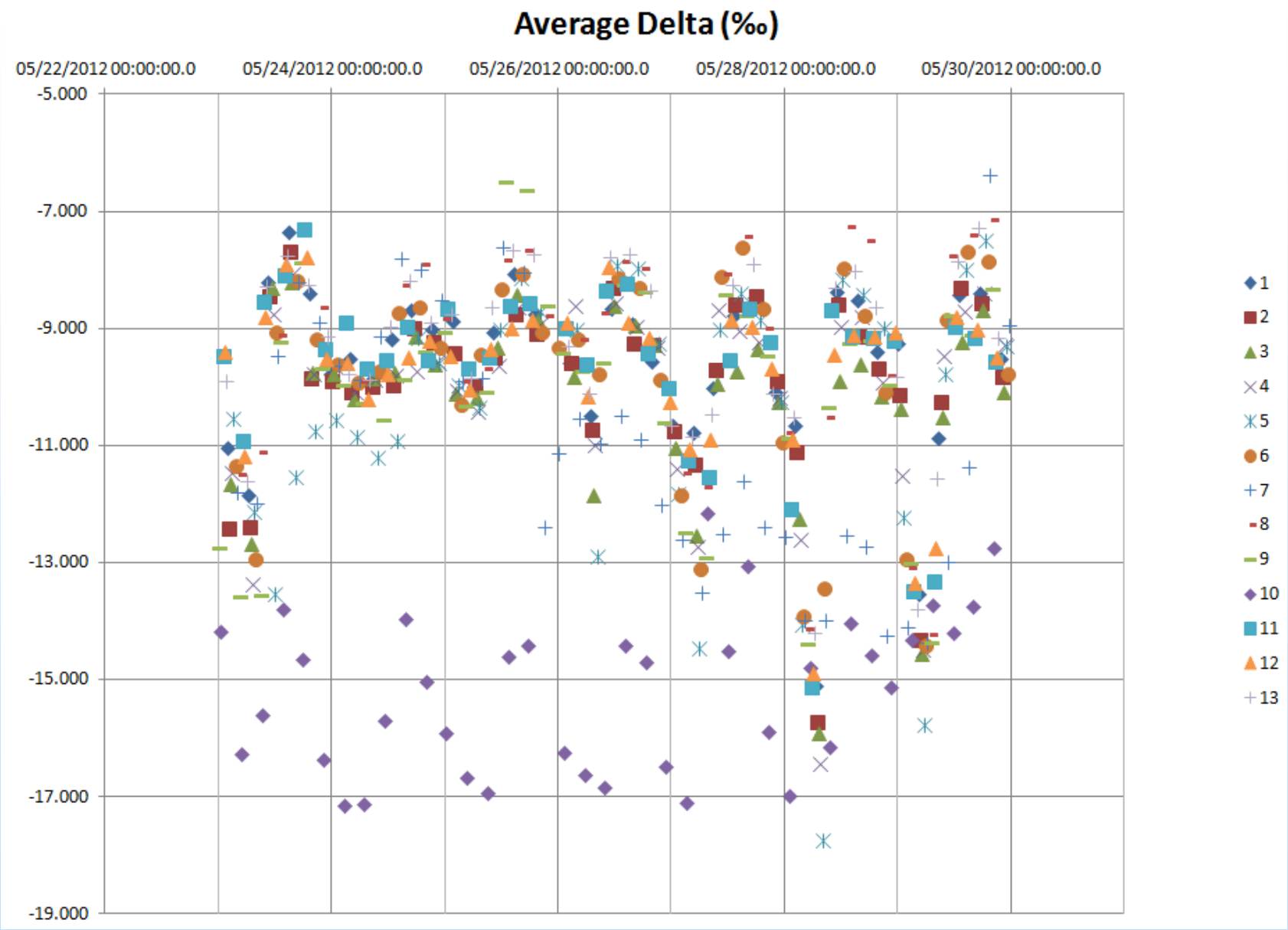
Weekly File


Average CO_2 (ppm)
3350.00
2850.00
2350.00
1850.00
1350.00
850.00
350.00
05/22/2012 00:00:00.0
05/24/2012 00:00:00.0
05/26/2012 00:00:00.0
05/28/2012 00:00:00.0
05/30/2012 00:00:00.0
1
2
3
4
5
6
7
8
9
10
11
12
13


1950.00
1750.00
1550.00
1350.00
1150.00
950.00
750.00
550.00
350.00
02/01/2012 00:00:00.0
03/22/2012 00:00:00.0
05/11/2012 00:00:00.0
06/30/2012 00:00:00.0
08/19/2012 00:00:00.0

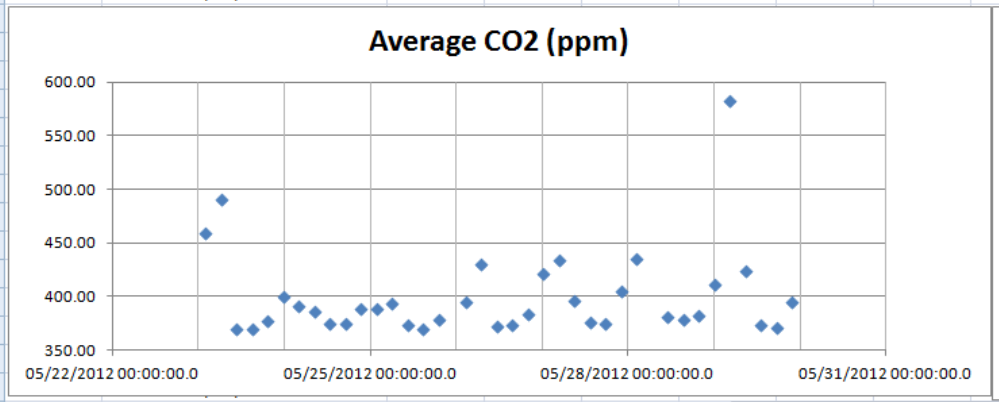

1/CO2
0
0.0005
0.001
0.0015
0.002
0.0025
0.003
0.000
-2.000
-4.000
-6.000
-8.000
-10.000
-12.000
-14.000
-16.000
-18.000
-20.000
1/CO2
Linear (1/CO2)
y = 2836.6x - 16.987
R² = 0.5483

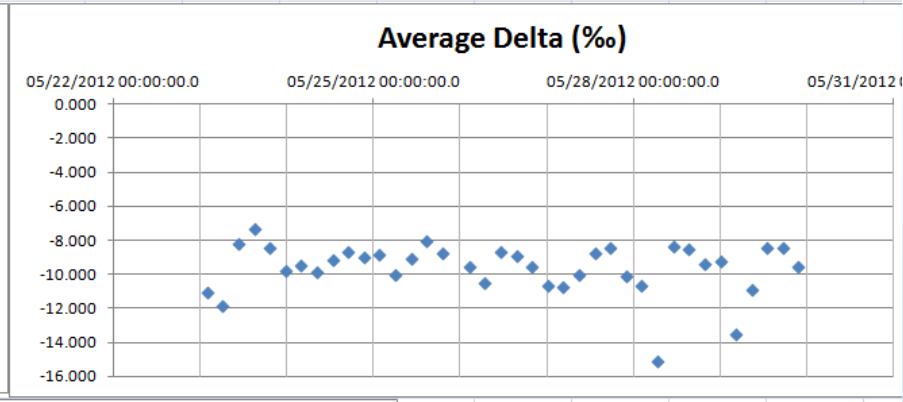
Weekly File

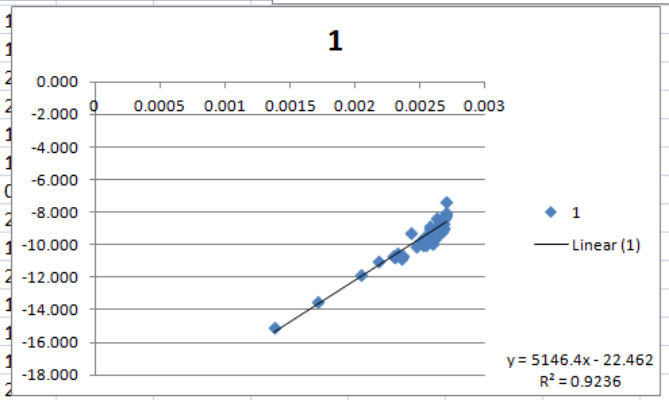

Average Delta (‰)
05/22/2012 00:00:00.0
05/24/2012 00:00:00.0
05/26/2012 00:00:00.0
05/28/2012 00:00:00.0
05/30/2012 00:00:00.0
-5.000
-7.000
-9.000
-11.000
-13.000
-15.000
-17.000
-19.000
1
2
3
4
5
6
7
8
9
10
11
12
13

Weekly File

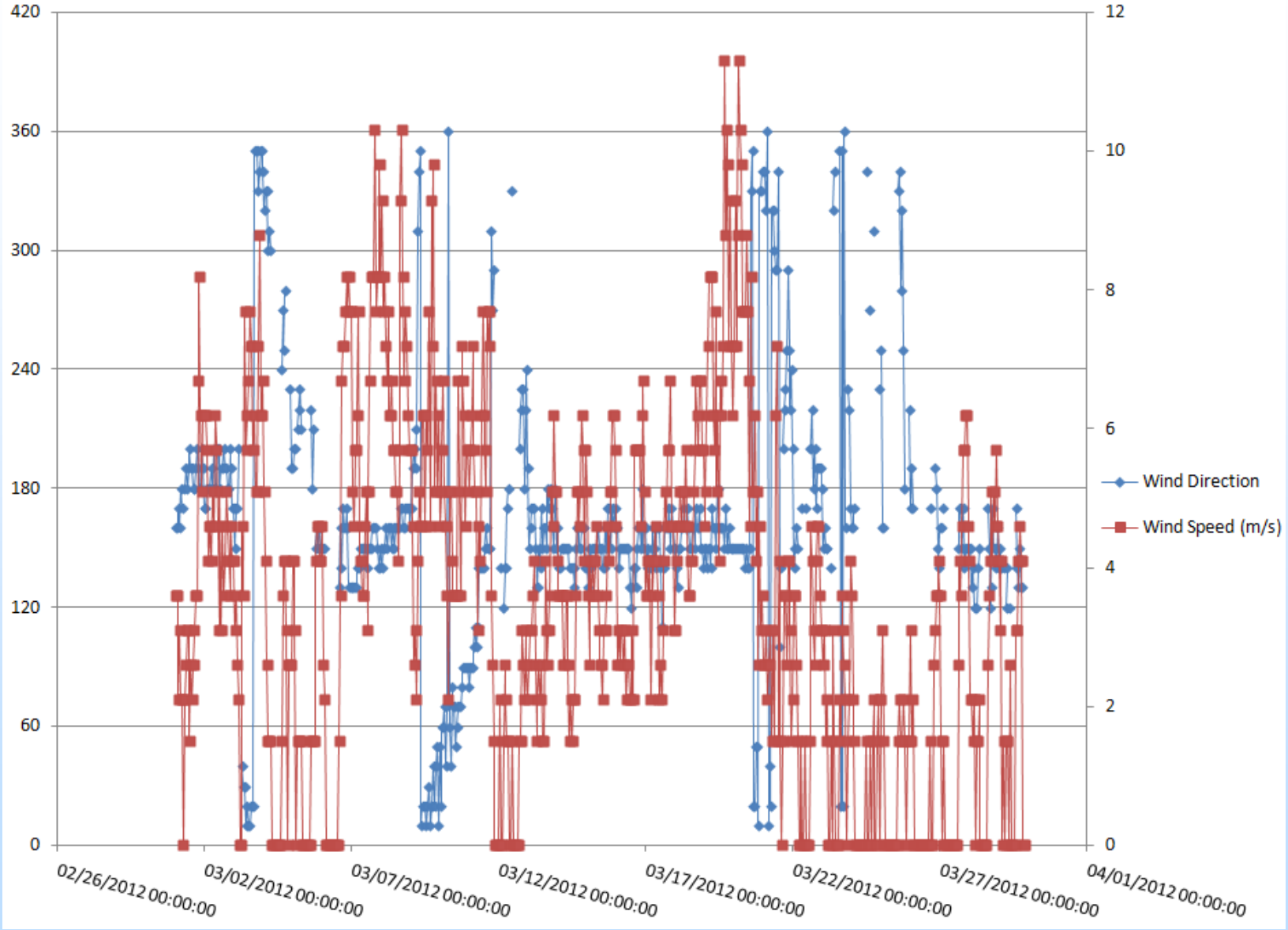
	A	B	C	D	E	F	G	H	I
7	1	05/23/2012 23:42:21.0	399.72	2.22	-9.772	1.974	2.04	405	0.002502
8	1	05/24/2012 04:02:34.1	391.39	2.21	-9.512	1.835	1.65	405	0.002555
9	1	05/24/2012 08:22:50.5	385.49	2.24	-9.907	1.626	2.27	405	0.002594
24	1	05/27/2012 04:37:14.7	433.89	2.09	-10.768	1			
25	1	05/27/2012 08:57:31.1	396.09	2.41	-10.008	1			
26	1	05/27/2012 13:17:50.1	375.37	2.29	-8.771	2			
27	1	05/27/2012 17:38:11.4	375.19	2.64	-8.462	2			
28	1	05/27/2012 21:58:25.0	405.13	2.14	-10.097	1			
29	1	05/28/2012 02:18:39.7	435.57	2.23	-10.649	1			
30	1	05/28/2012 06:38:53.5	725.10	2.00	-15.102	0			
31	1	05/28/2012 10:59:07.7	381.24	2.22	-8.366	2			
32	1	05/28/2012 15:19:23.1	378.11	2.10	-8.529	1			
33	1	05/28/2012 19:39:42.0	381.80	2.27	-9.403	2			
34	1	05/29/2012 00:04:36.0	411.56	2.23	-9.256	1			
35	1	05/29/2012 04:20:13.8	583.07	2.11	-13.543	1			
36	1	05/29/2012 08:40:30.1	423.86	2.33	-10.884	1			
37	1	05/29/2012 13:00:45.5	373.51	2.38	-8.432	2			
38	1	05/29/2012 17:21:00.2	371.26	2.73	-8.404	2.312	1.64	404	0.002694



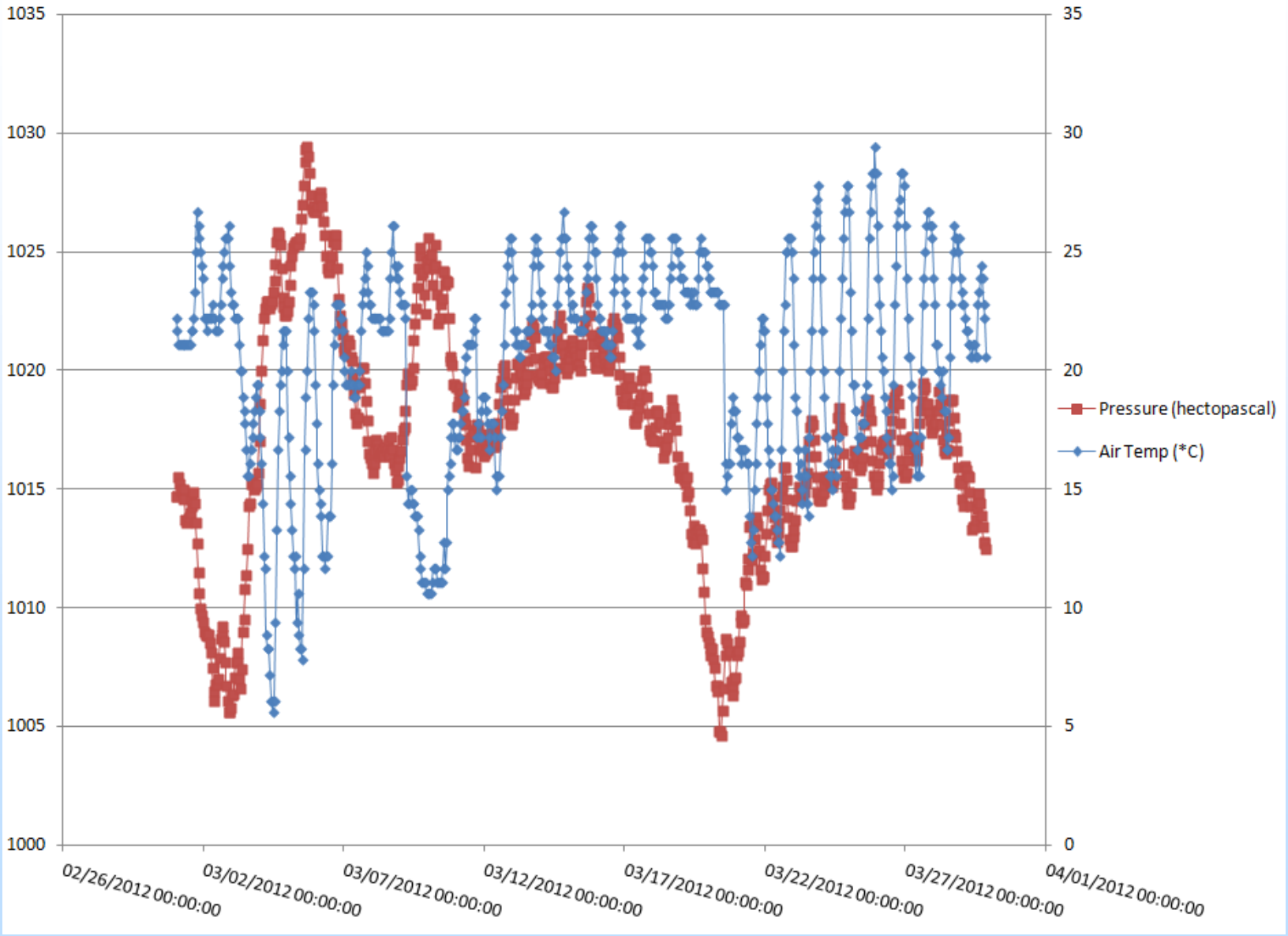




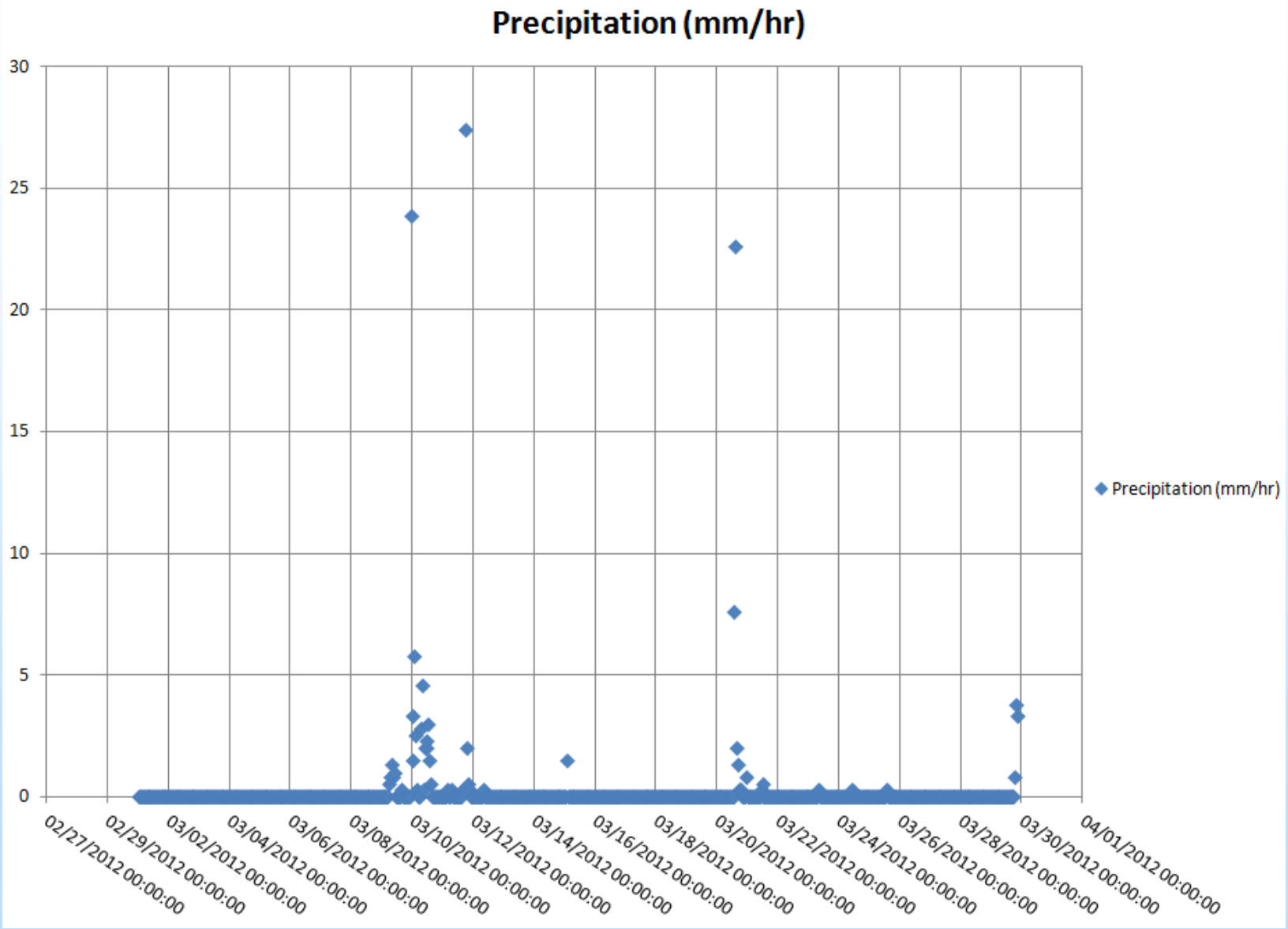
Weather File



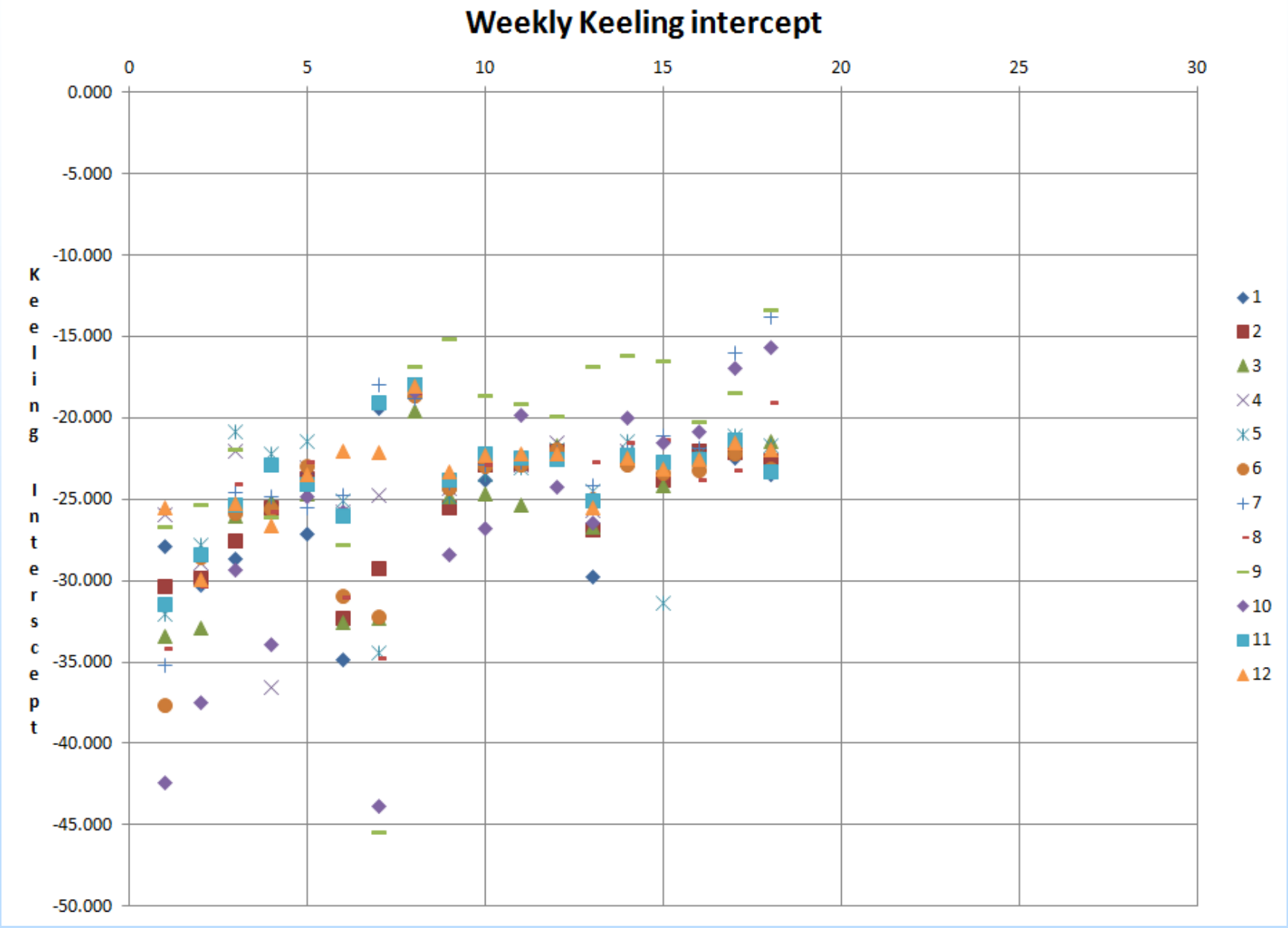
Weather File



Weather File



Keeling Summaries



Results

- Most commonly, all sites trend closely to one another on diurnal cycles of varying intensity

- Certain sites occasionally display high CO_2 concentrations and depleted δ values for time periods ranging from days to weeks

- Rare spikes in concentration across all sampling sites are seen

- Decrease in CO_2 efflux and diurnal trending during and immediately following the 3 large and most minor precipitation events, likely due to the physical processes outlined in Sotta et al (2004) and Jassal et al (2005)

- 06/01 as potential leak day

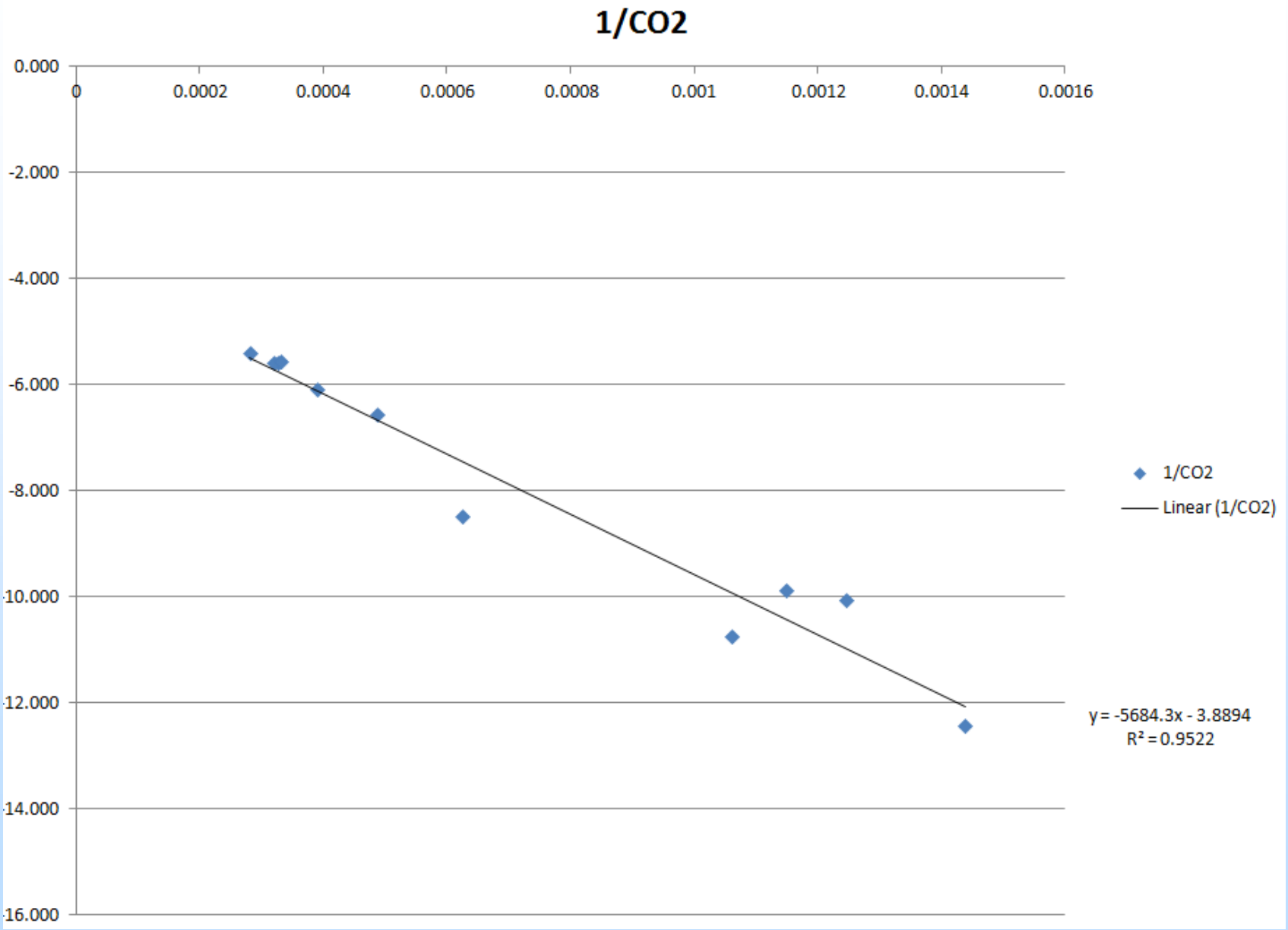
06/01/2012

- From 3:30 to 7:00 AM, CO_2 concentration spiked across all sampling positions

- Delta values became more enriched rather than following the standard trend of becoming depleted, Keeling plot indicates contaminate gas has isotopic content of about -3.88 with well fit line

- Methane increases from standard 1-2 ppm to over 150 ppm, indicating gas is coming from the ground rather than surface contamination

06/01/2012


1/CO2
0.000
-2.000
-4.000
-6.000
-8.000
-10.000
-12.000
-14.000
-16.000
0
0.0002
0.0004
0.0006
0.0008
0.001
0.0012
0.0014
0.0016
1/CO2
Linear (1/CO2)
y = -5684.3x - 3.8894
R² = 0.9522