

Seasonal Variation of Observed Indoor Air Concentrations Due to Vapor Intrusion

Redfield Site, Colorado

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The Issues

- If indoor air concentrations are seasonally variable:
 - Short-term indoor air samples may under-estimate or over-estimate long-term risk due to vapor intrusion
- Is seasonal variability of vapor intrusion significant?
 - Unmitigated buildings?
 - Mitigated buildings?
- Is seasonal variability predictable?
 - Should we bias testing toward winter months?

Redfield Site



- Quarterly indoor air measurements
 - at > 350 mitigated single-family homes
 - at 40 unmitigated single-family homes
- 1,1-DCE (limits background effects)
- Variable geology
 - Depth to groundwater – 7 to 40 feet
 - Sand, silt, clay, weathered sedimentary rock
- Variable building construction
 - Basement, crawlspace, slab on grade , combination
- Variable HVAC systems/operation

Temporal and Seasonal Factors

- Indoor air concentrations are affected to varying degrees by:
 - Outdoor temperature,
 - Wind speed and direction,
 - Barometric pressure,
 - Humidity,
 - Opening and closing of doors and windows,
 - Operation of HVAC equipment, and
 - Precipitation.

Radon Lessons?

- Radon levels are frequently highest during the winter months
- Short-term (2- to 7-day) radon measurements only predict long term concentrations to within a factor of 1.8 even after correcting for systematic biases (such as seasonality) (Price and Nero, 1996).

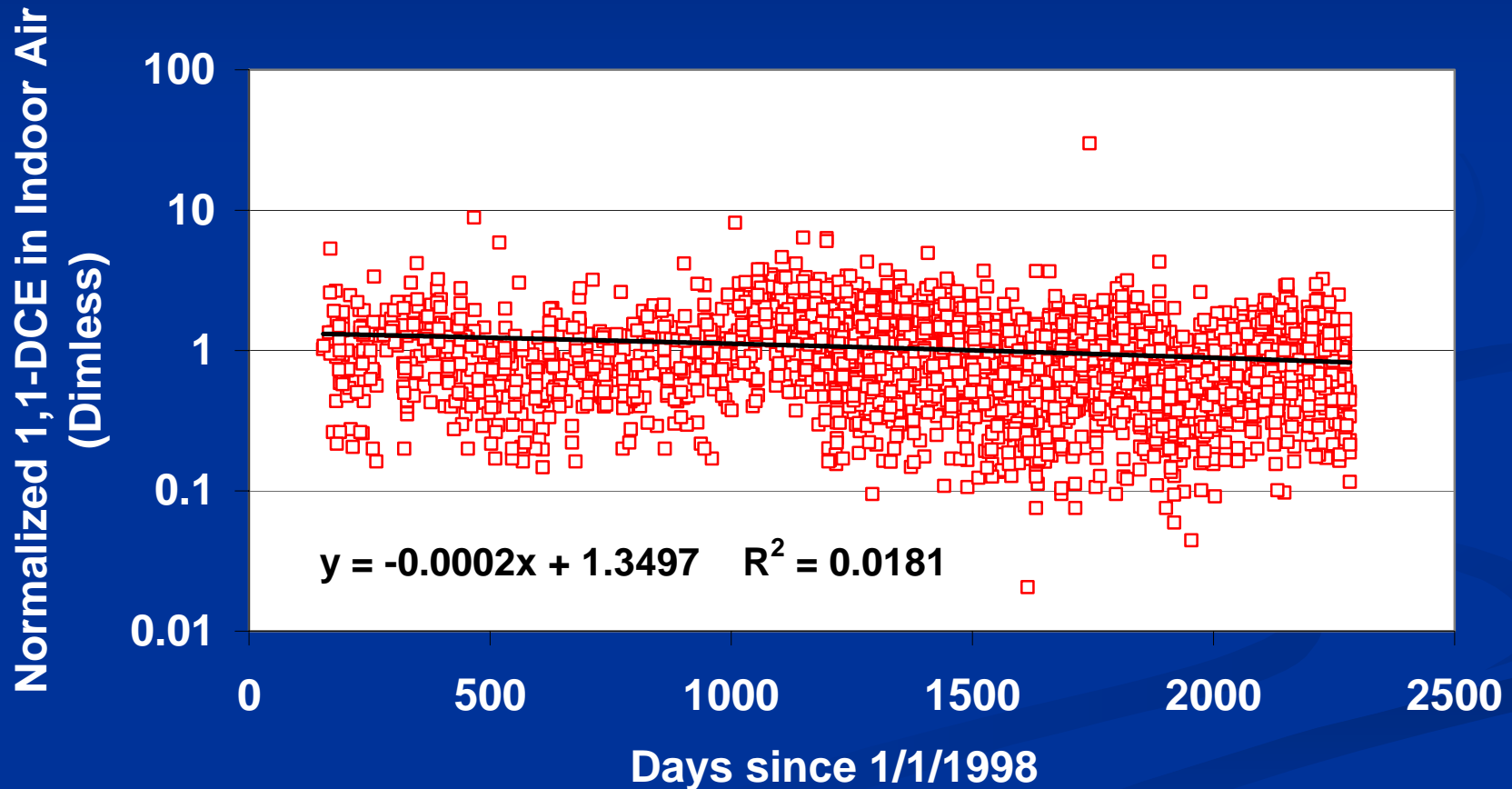
Radon (continued)

- Individual short-term radon measurements can be used to determine good mean values for an area (Price and Nero, 1996).
- Temporal and house-to-house variability is expected to exceed variability due to seasonality.

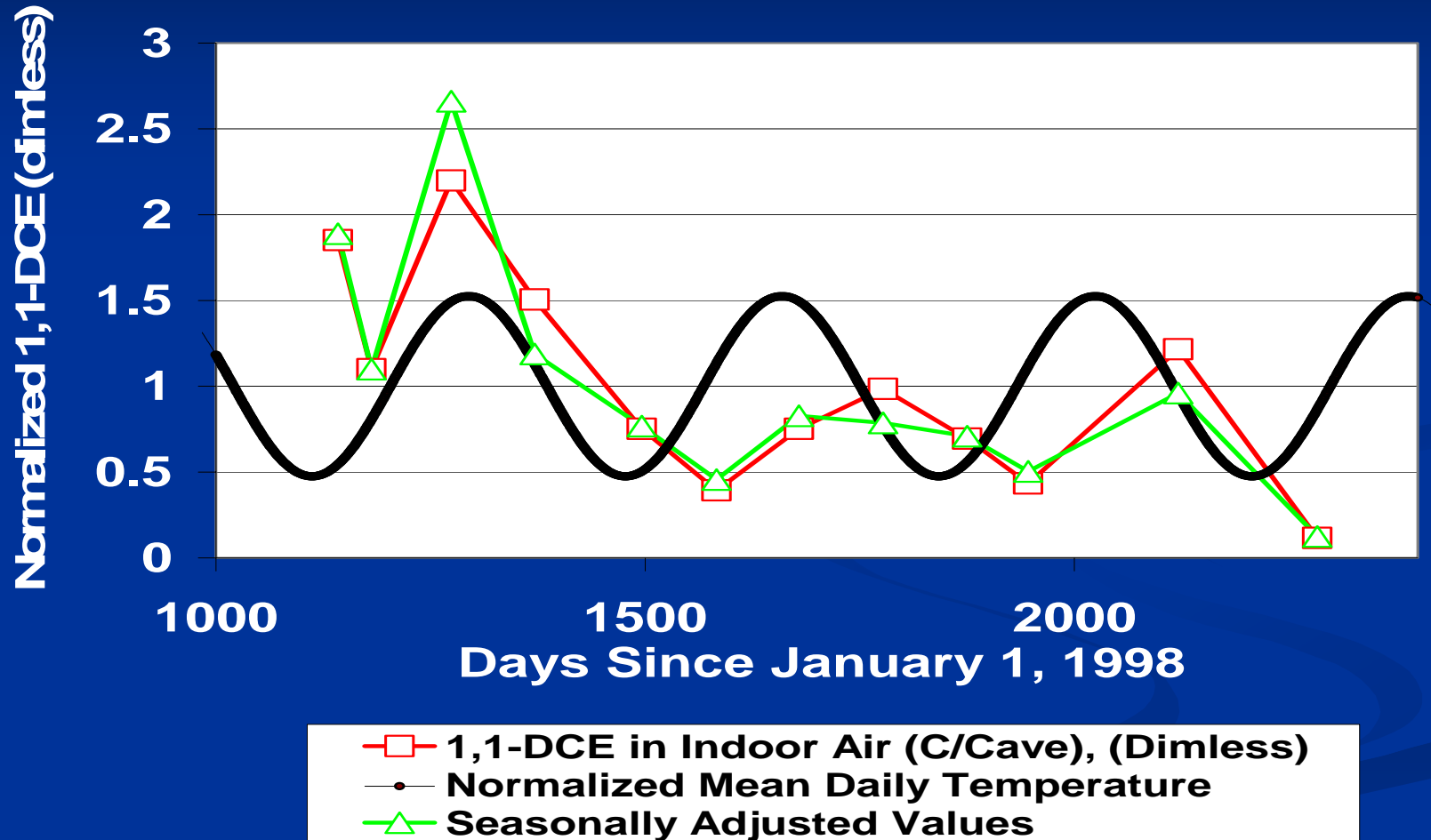
Redfield Site Evaluation

- Indoor air concentration values were normalized (divided) by the observed arithmetic average concentration at each house
- Values below detection were taken at half the detection limit.

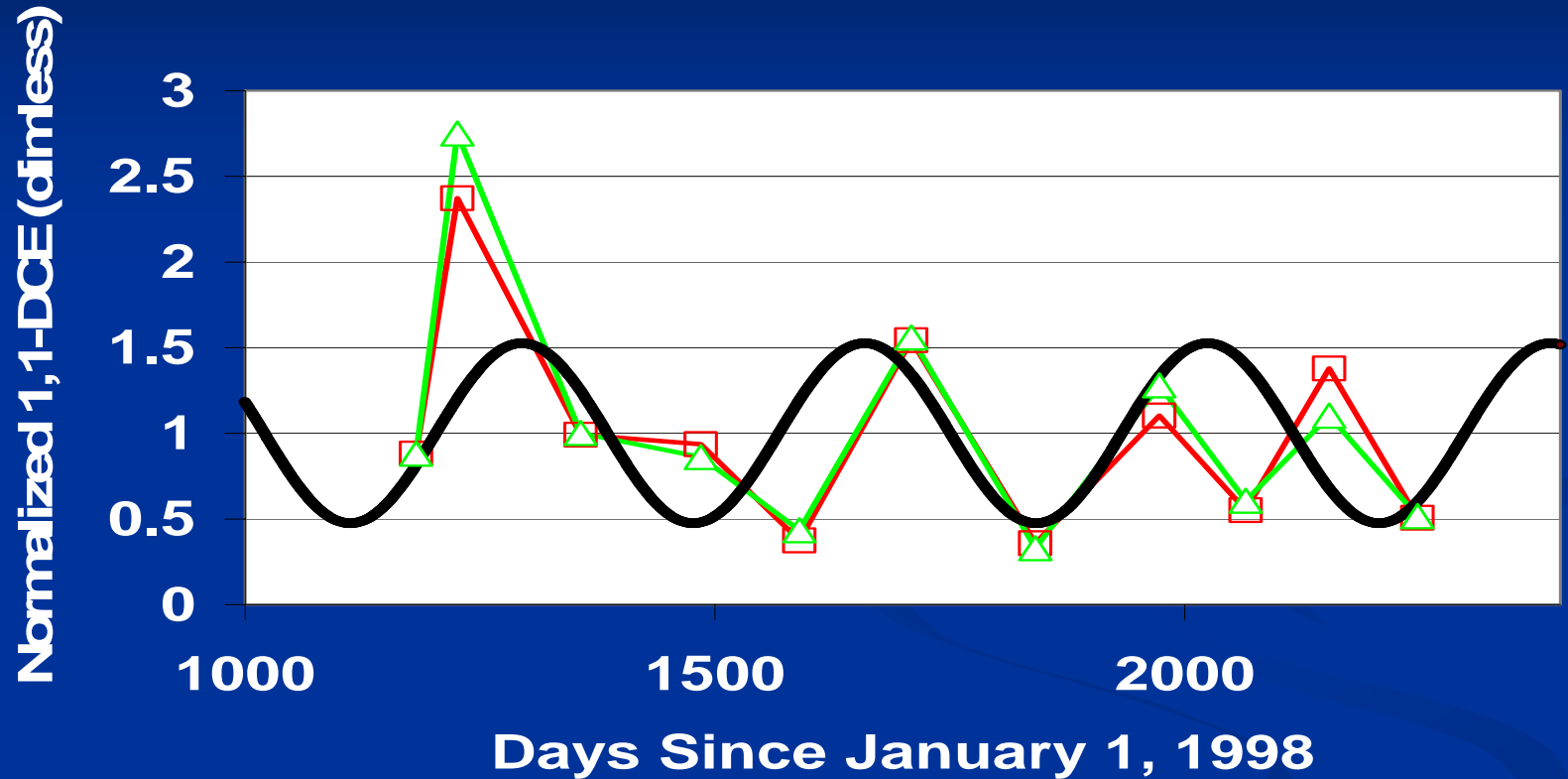
Normalized 1,1-DCE in Indoor Air Mitigated Homes



Location "F" Mitigated

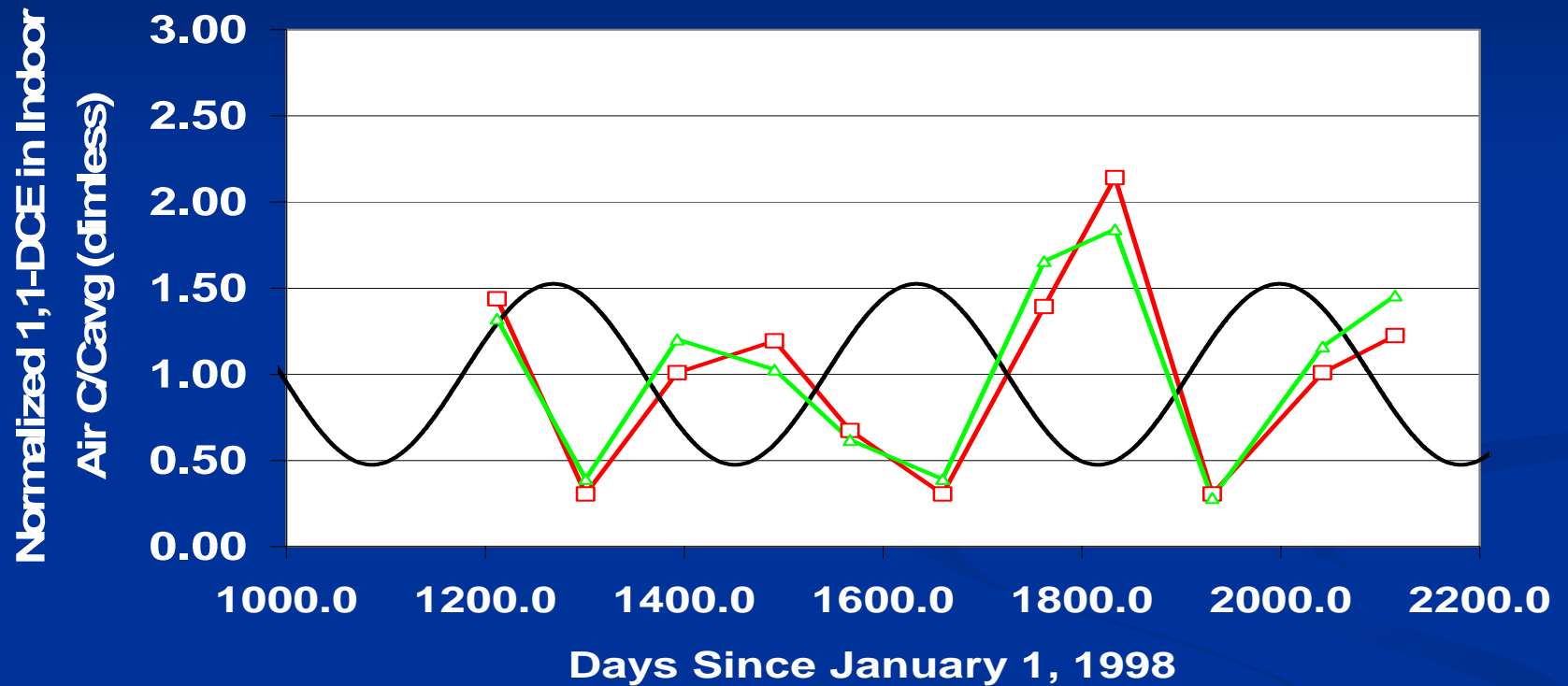


LOCATION "H" Mitigated



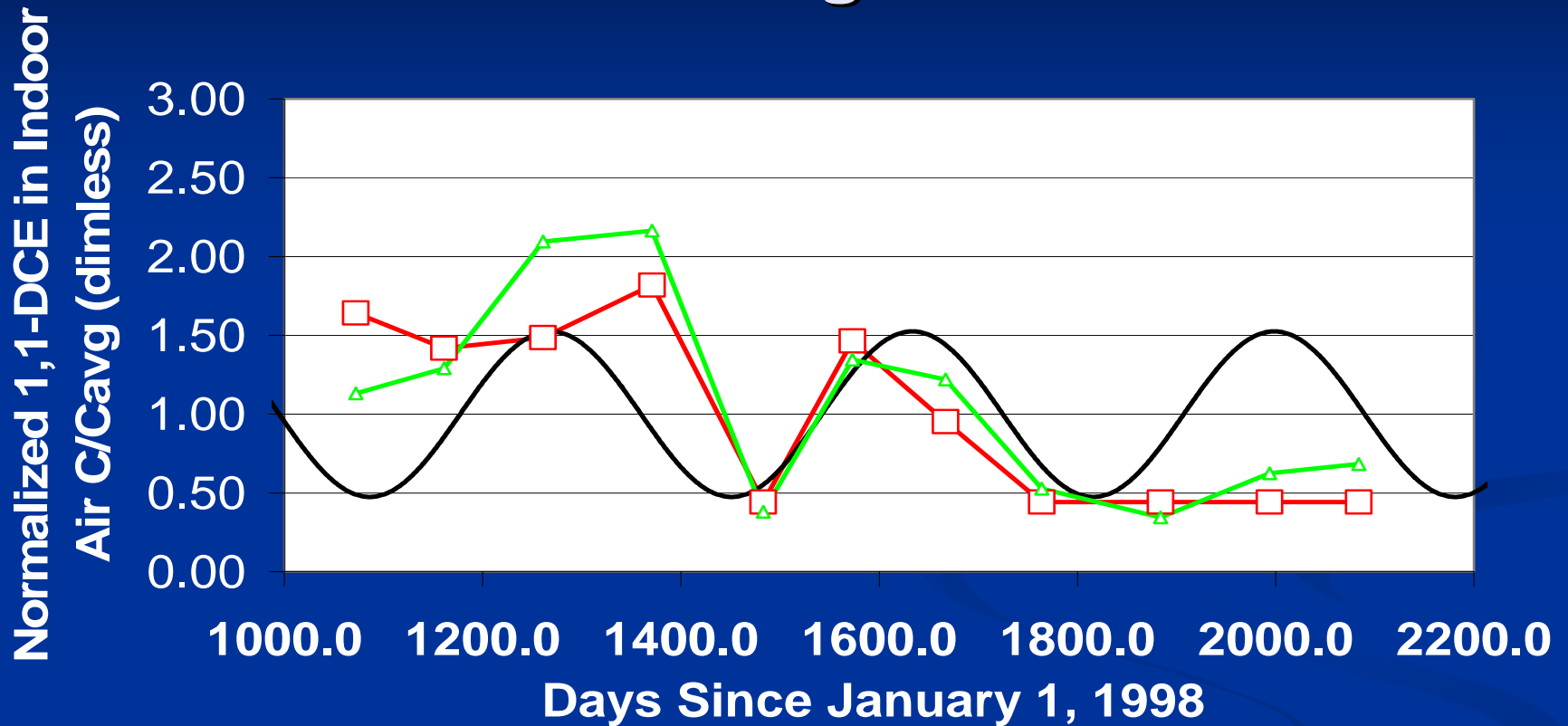
- 1,1-DCE in Indoor Air (C/Cave), (Dimless)
- Normalized Mean Daily Temperature
- △— Seasonally Adjusted Values

Location "A" Unmitigated



- Observed 1,1-DCE (C/Cave), (dimless)
- Normalized Mean Daily Temperature
- △— Seasonal Adjusted Values

Location "D" Unmitigated



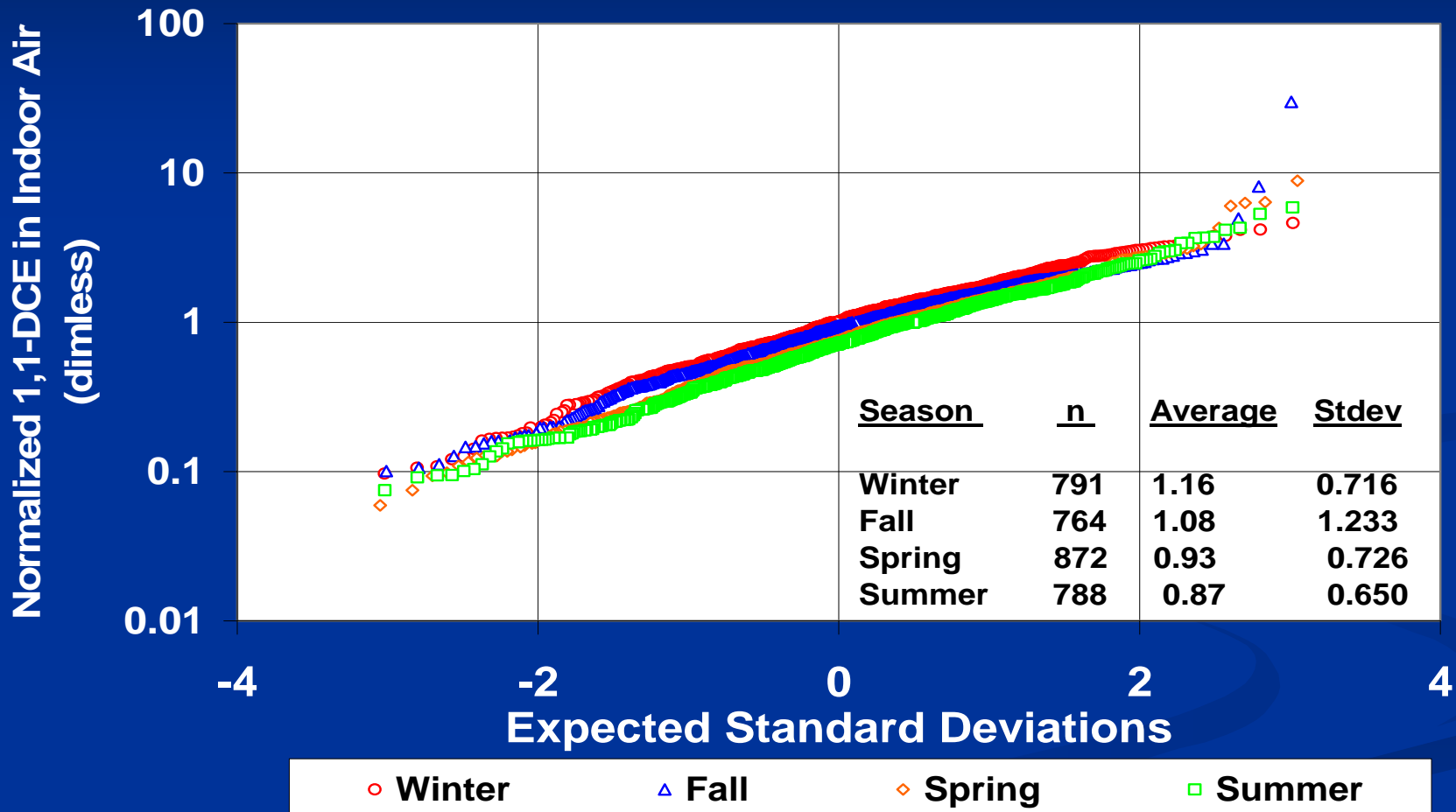
- 1,1-DCE in Indoor Air (C/Cave), (dimless)
- Normalized Mean Daily Temperature
- △— Seasonal Adjusted Values

Seasonal Probability Plots

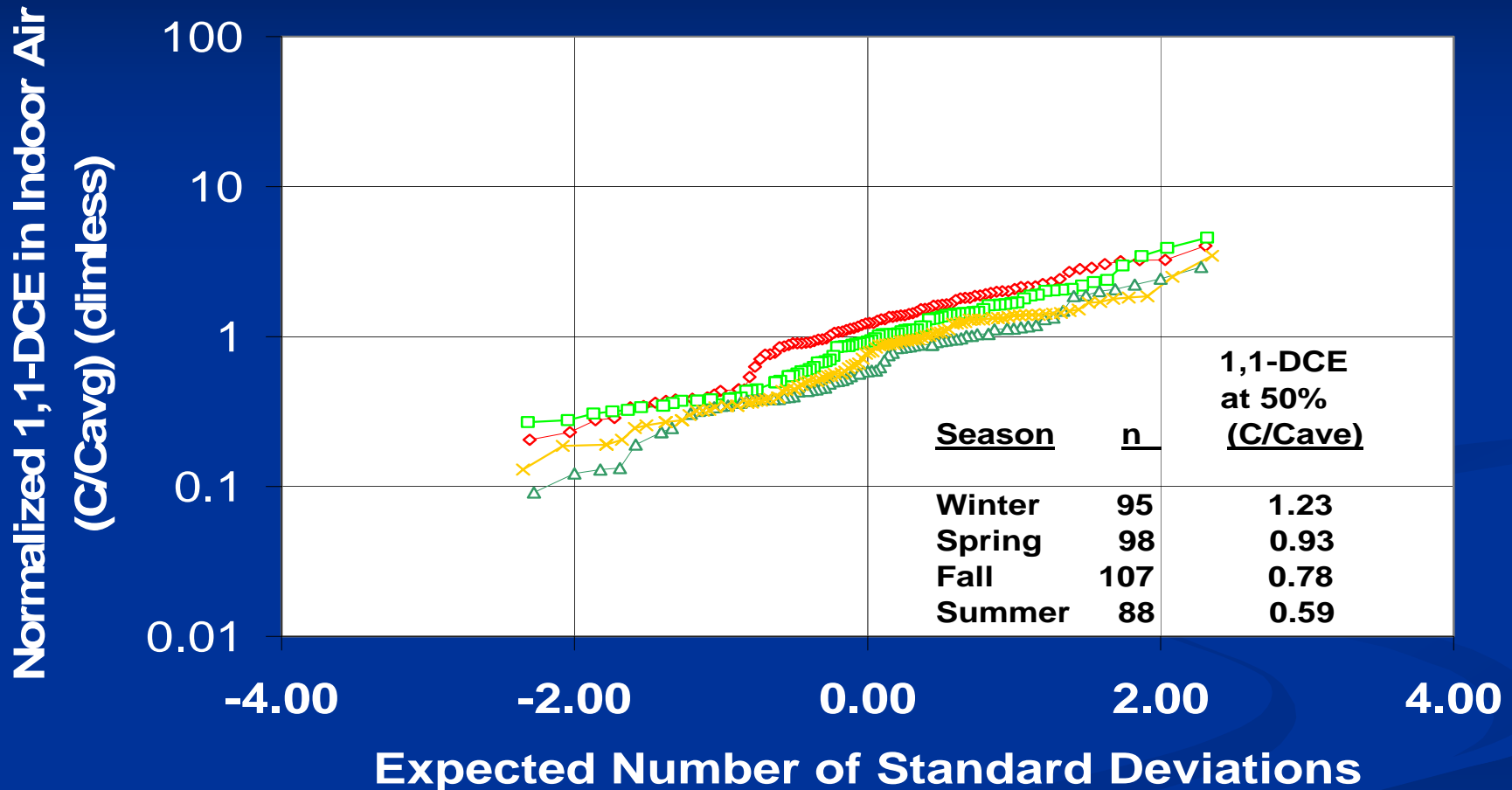
- Normalized 1,1-DCE values in indoor air are generally highest during winter and lowest during summer.

| <u>Description</u> | <u>Normalized 1,1-DCE</u> | |
|---------------------|---------------------------|------------------|
| | <u>Unmitigated</u> | <u>Mitigated</u> |
| Winter median | 1.23 | 1.16 |
| Summer median | 0.59 | 0.87 |
| Winter/Summer Ratio | 2.08 | 1.33 |

Seasonal Probability Plot Mitigated Homes



Seasonal Probability Plot Unmitigated Homes



◇ Winter (calendar)

□ Spring

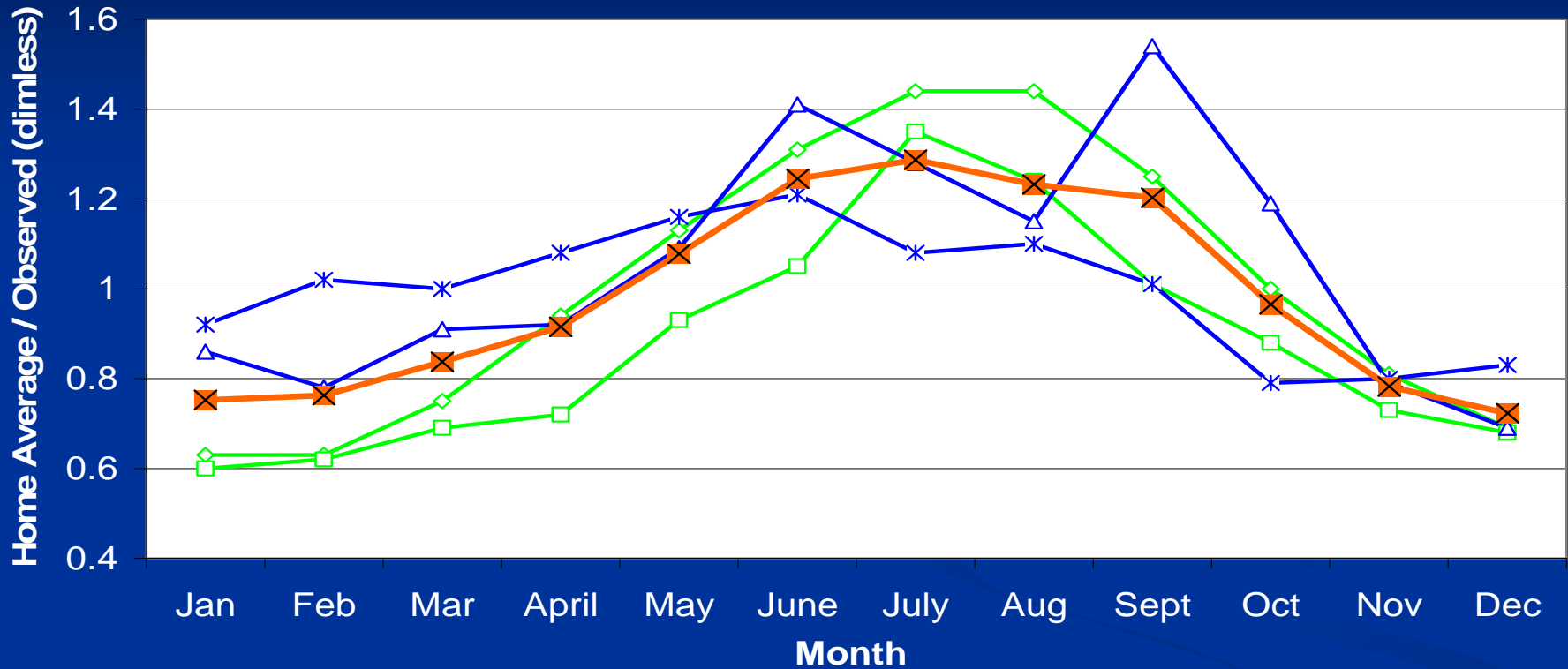
△ Summer

× Fall

Seasonal Adjustment

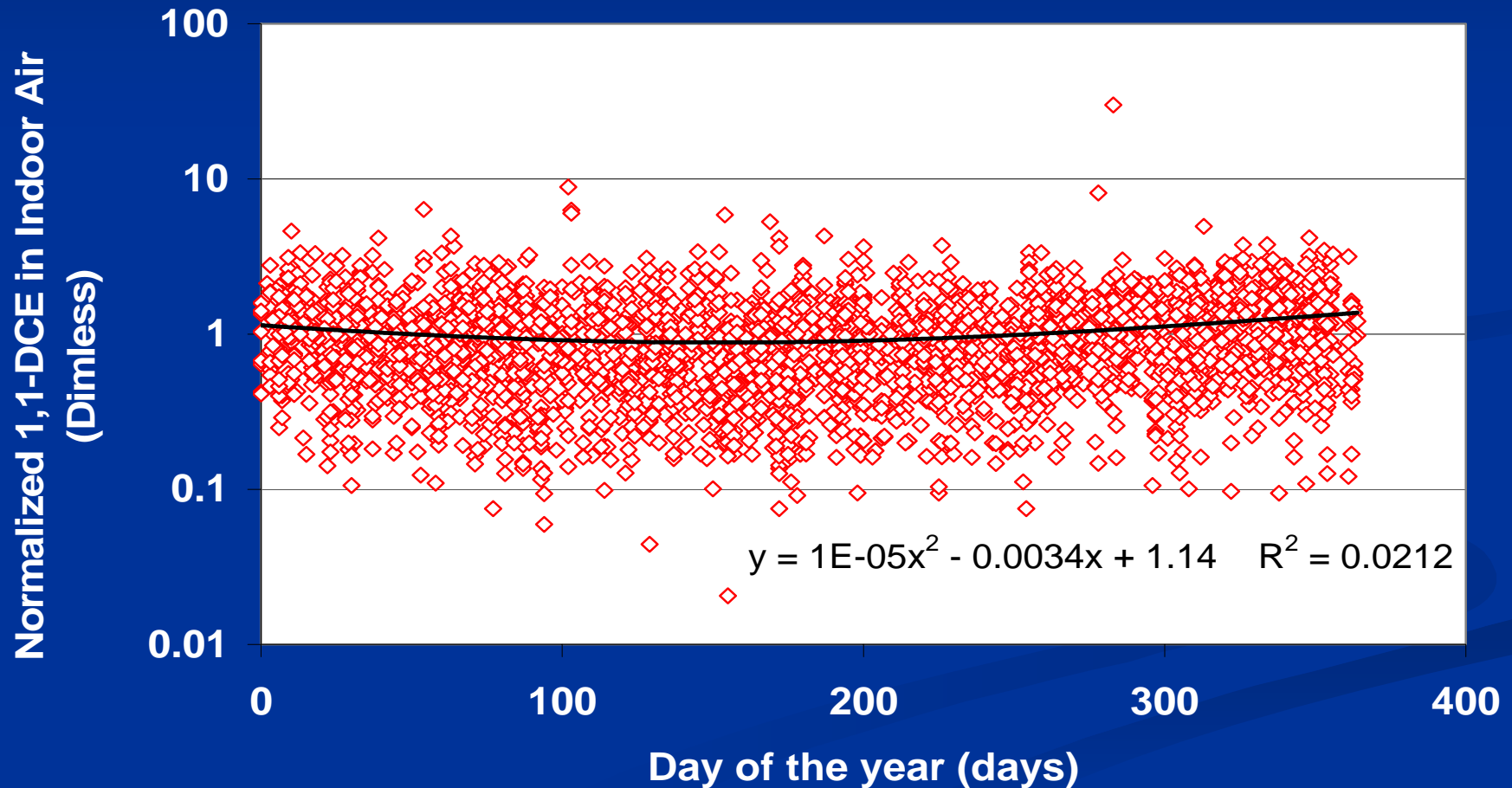
- Seasonal adjustment should not affect the average annual concentration.
- Seasonal adjustment successful if it reduces variance while maintaining the average concentration.
- Monthly seasonal adjustment factors were calculated for both mitigated and unmitigated homes at the Redfield Site.

Monthly Seasonal Factors

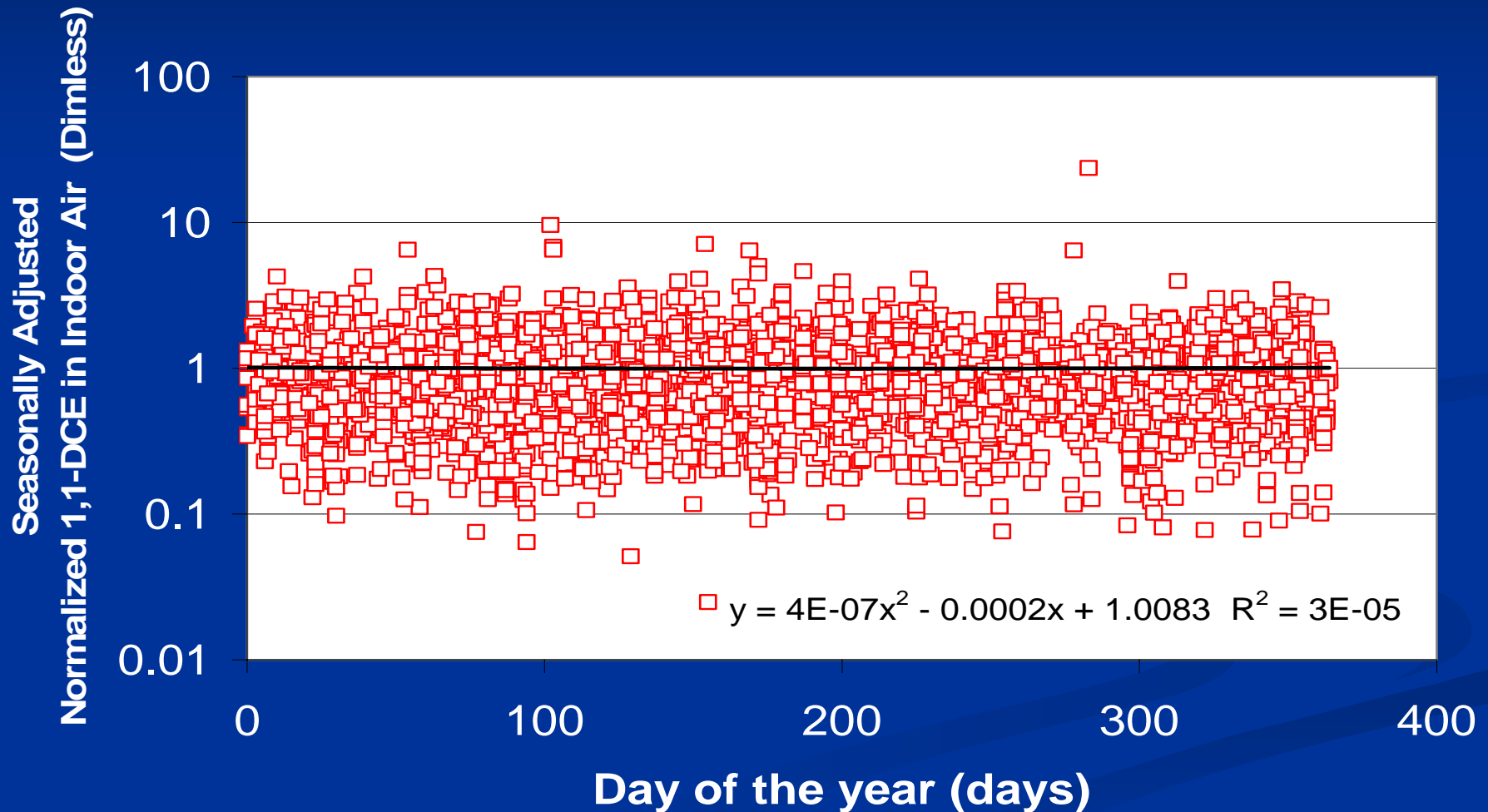


- ◇ Seasonal Cycle of VOCs in Apartments, Rehwagen et al 2003
- 6-day radon test, England
- △ 1,1-DCE in Indoor Air, Redfield Site - Denver, Colorado, unmitigated homes, 7/13/98 - 12/23/04
- * 1,1-DCE in Indoor Air, Redfield Site - Denver, Colorado, mitigated homes, 6/4/98 - 4/2/04
- × Group Average

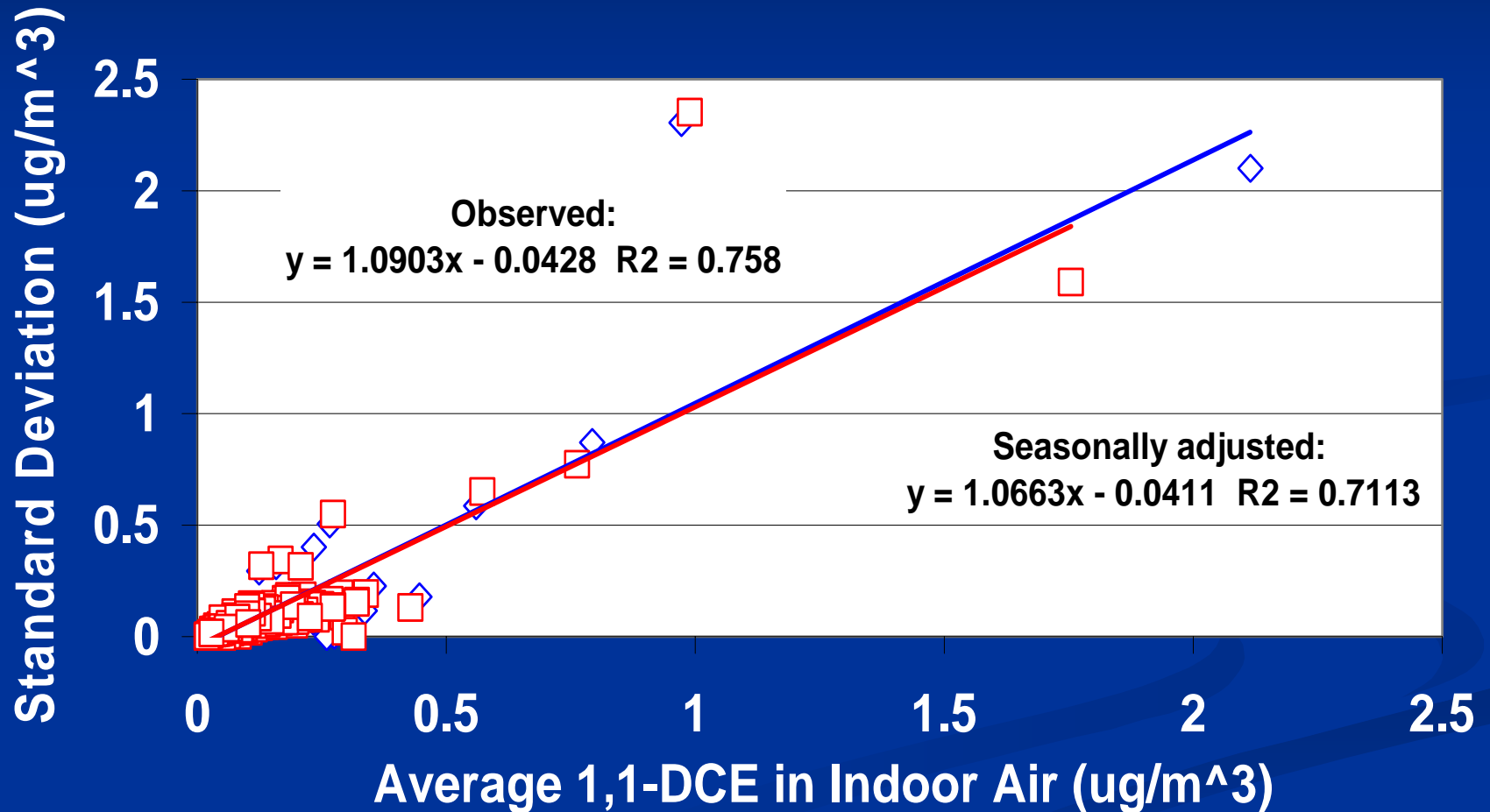
Normalized 1,1-DCE in Indoor Air Mitigated Homes



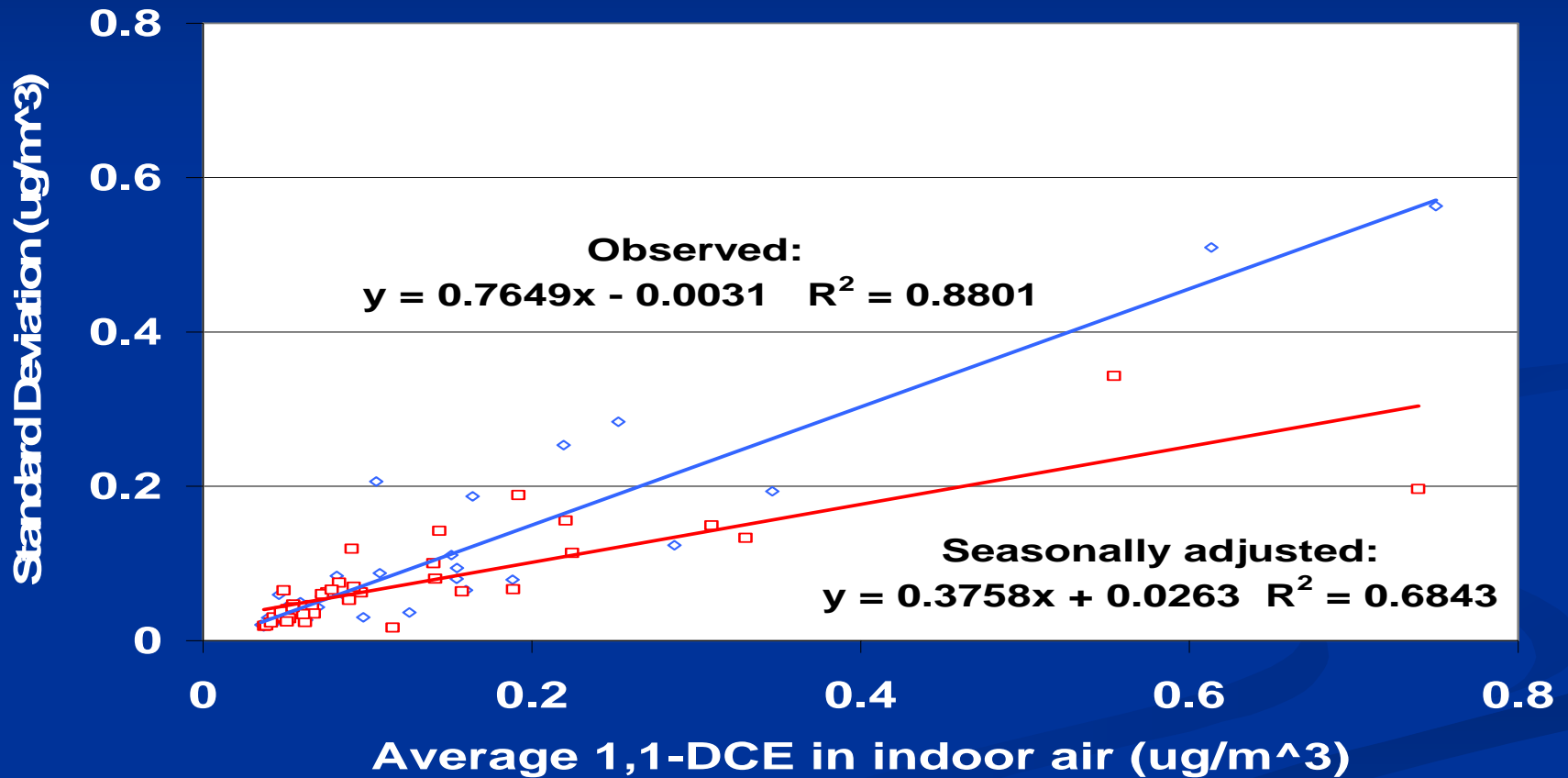
Normalized 1,1-DCE in Indoor Air Mitigated Homes Seasonally Adjusted



Standard Deviation vs Mean Mitigated Homes



Standard Deviation vs Mean Unmitigated Homes



Conclusions

- VOC concentrations in indoor air at mitigated properties at the Redfield Site exhibit seasonal variation.
- At mitigated homes the winter average value is approximately 1.3 times higher than the summer average value.
- At unmitigated homes the winter average value is approximately 2.1 higher than the summer average value.

Conclusions (continued)

- The behavior at individual homes varies
- Sub-slab depressurization systems attenuate seasonal variability
- Because seasonal variability is greater at unmitigated homes, seasonal adjustment may be more important at unmitigated homes than at mitigated homes.

Conclusions (continued)

- Seasonal adjustment factors may allow better prediction of long-term average indoor air on average, but individual results will vary.
- A long-term sampling procedure, if available and capable of providing acceptable detection limits, might produce concentration values closer to the annual average value and be more representative of actual risks than more precise short-term test procedures