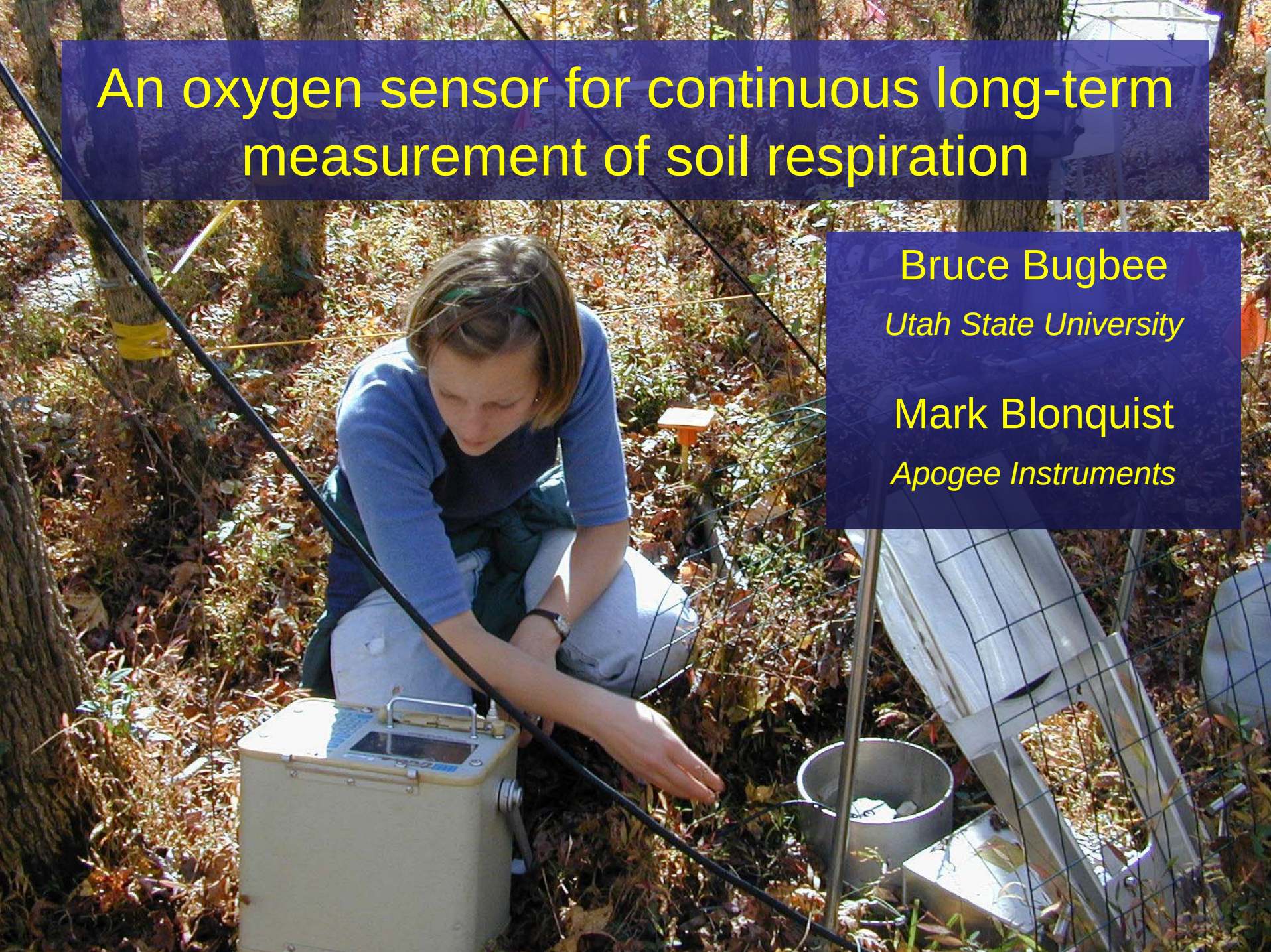
An oxygen sensor for continuous long-term measurement of soil respiration

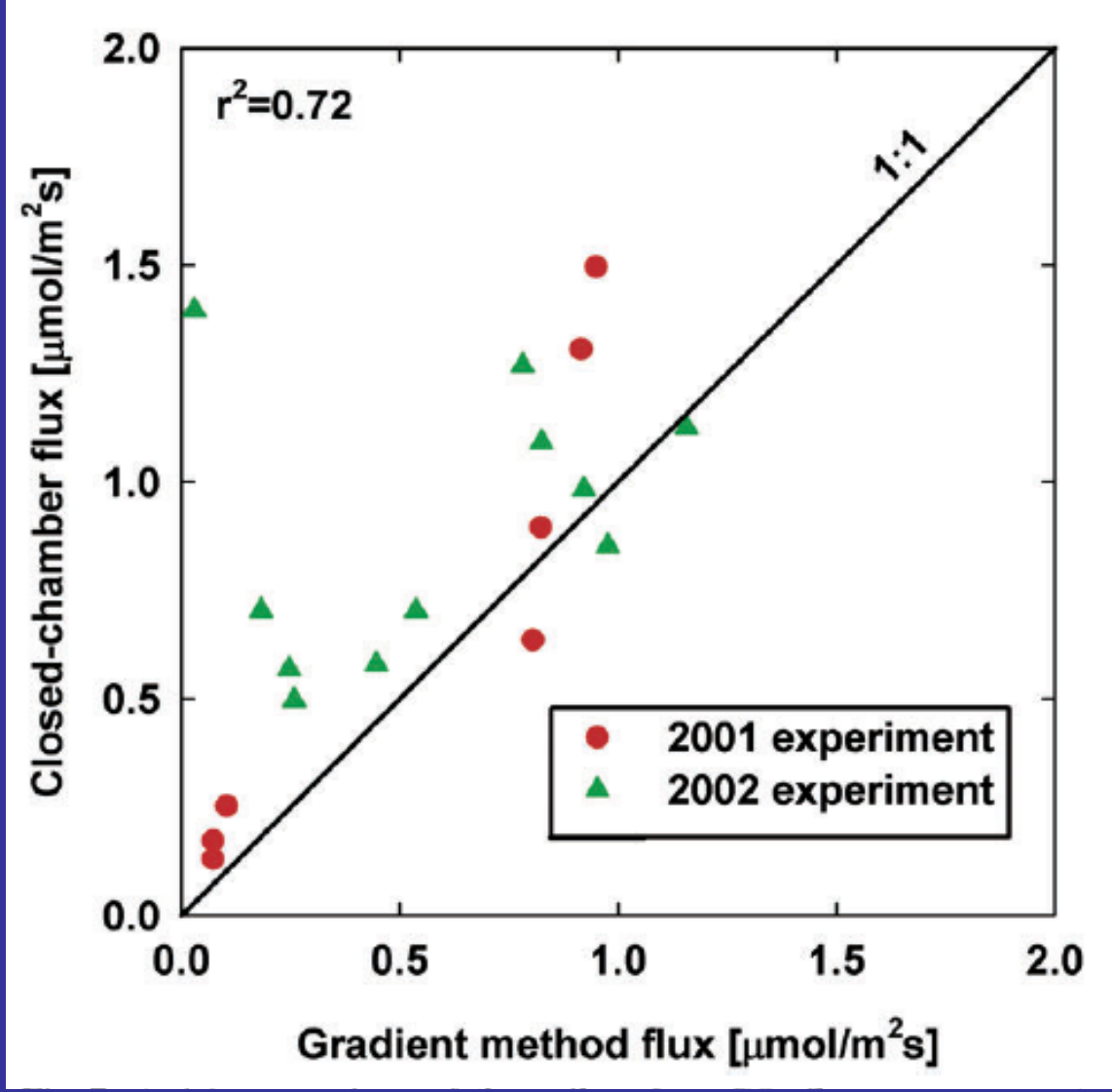


Bruce Bugbee

Utah State University

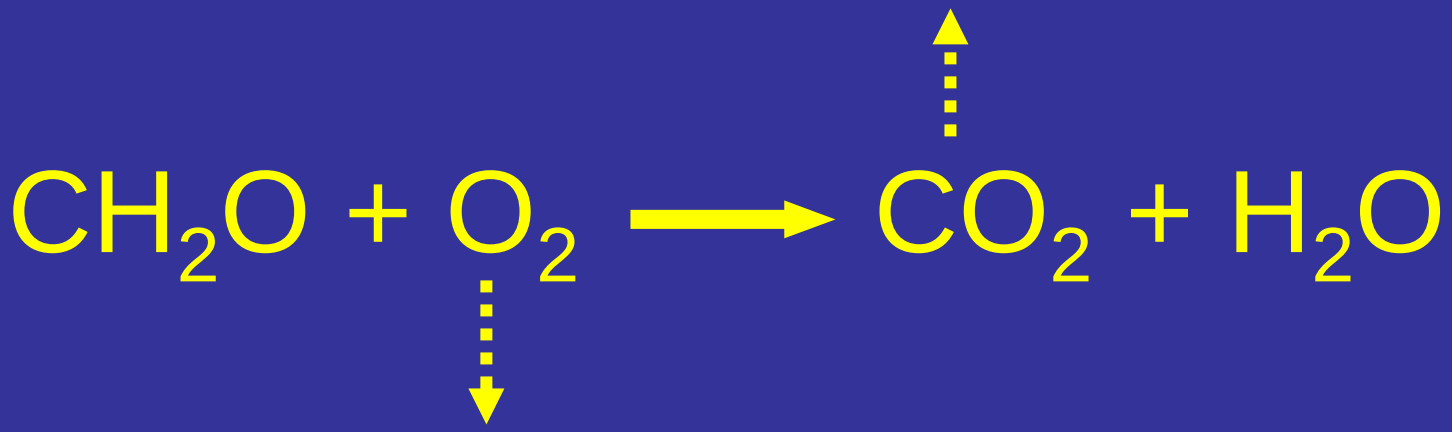
Mark Blonquist

Apogee Instruments



Continuous Soil Carbon Dioxide and Oxygen Measurements and Estimation of Gradient-Based Gaseous Flux

Vasile E. Turcu, Scott B. Jones, and Dani Or*



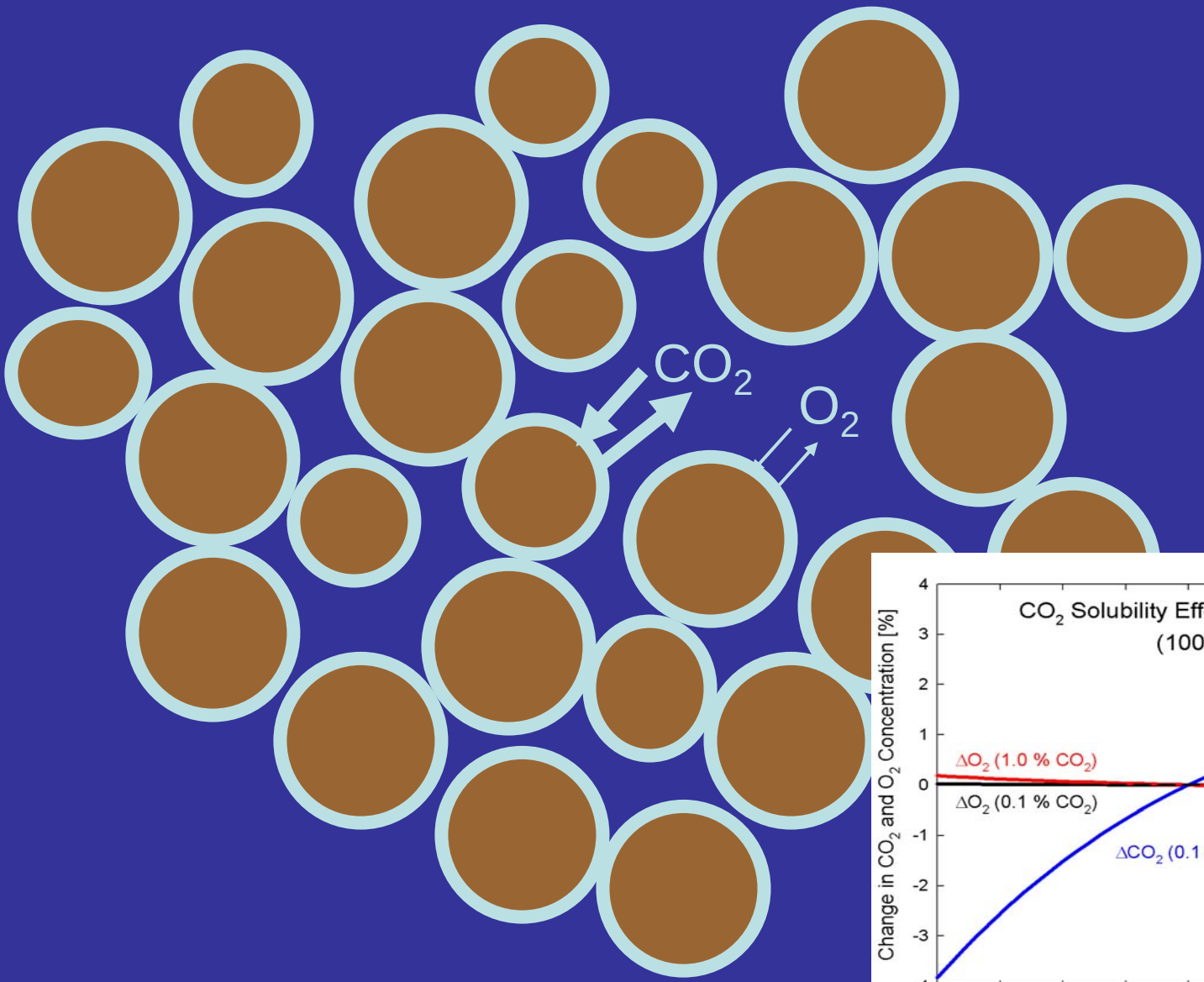
Advantage of measuring CO_2

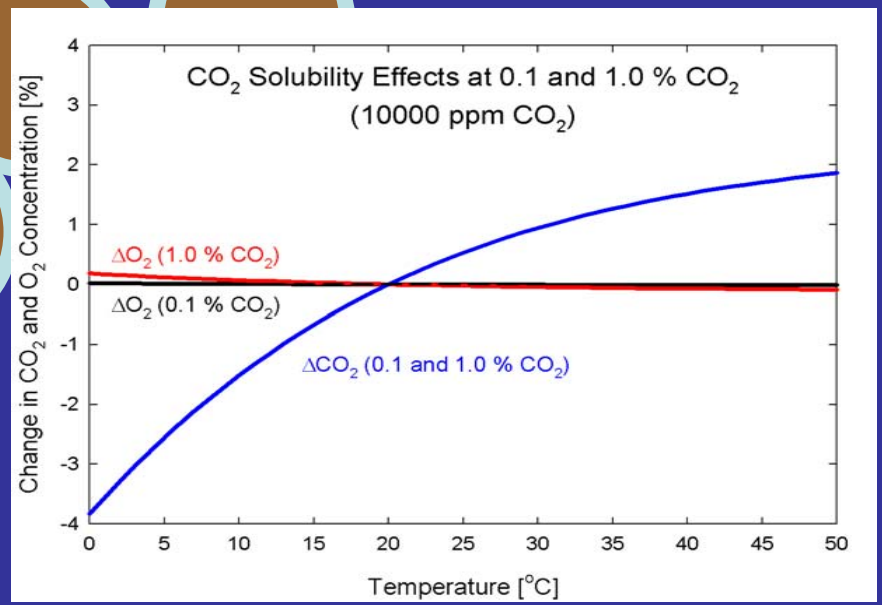
$$\frac{O_2 = 20.95\%}{CO_2 = 0.04\%} = 520 \text{ x}$$

Advantage of measuring O_2

CO_2 is 30 times more soluble in water than O_2

CO_2 is 30 times more soluble in water than O_2





Respiratory quotient: CO_2 / O_2

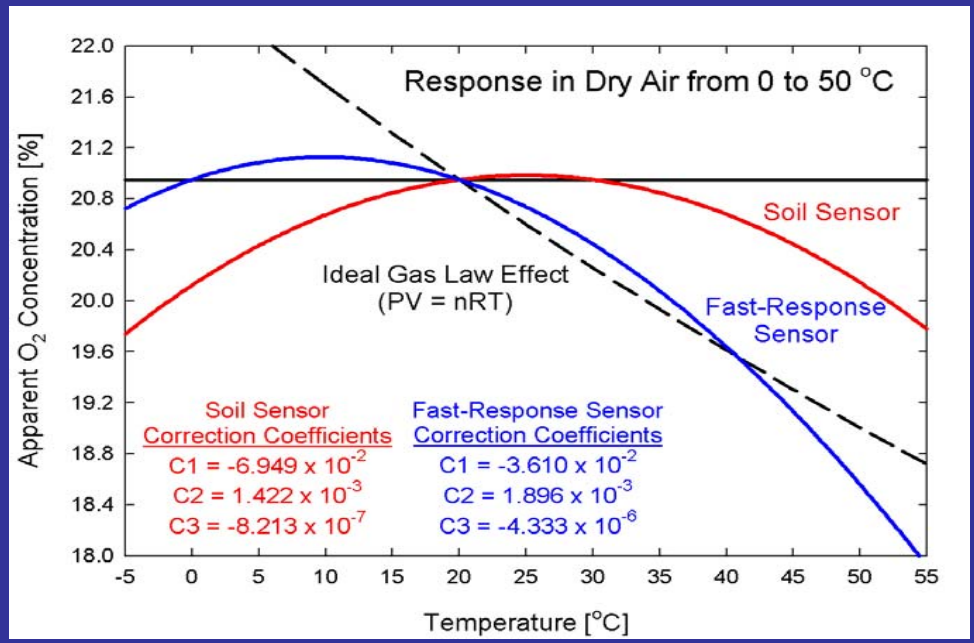
Carbohydrate	= 1.0
Protein	= 0.8
Fat	= 0.6
Lignin	= 0.2

Nitrification: RQ = *0.0*

$$NH_4 + 2O_2 \rightarrow NO_3 + 2H^+ + H_2O$$

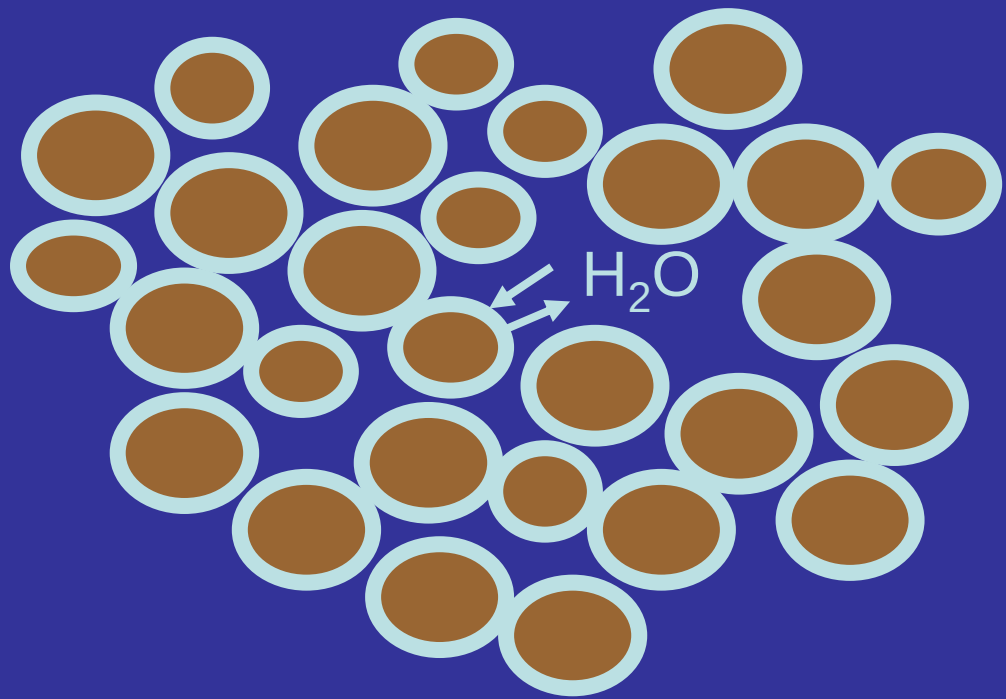
Factors affecting gas concentration in soil

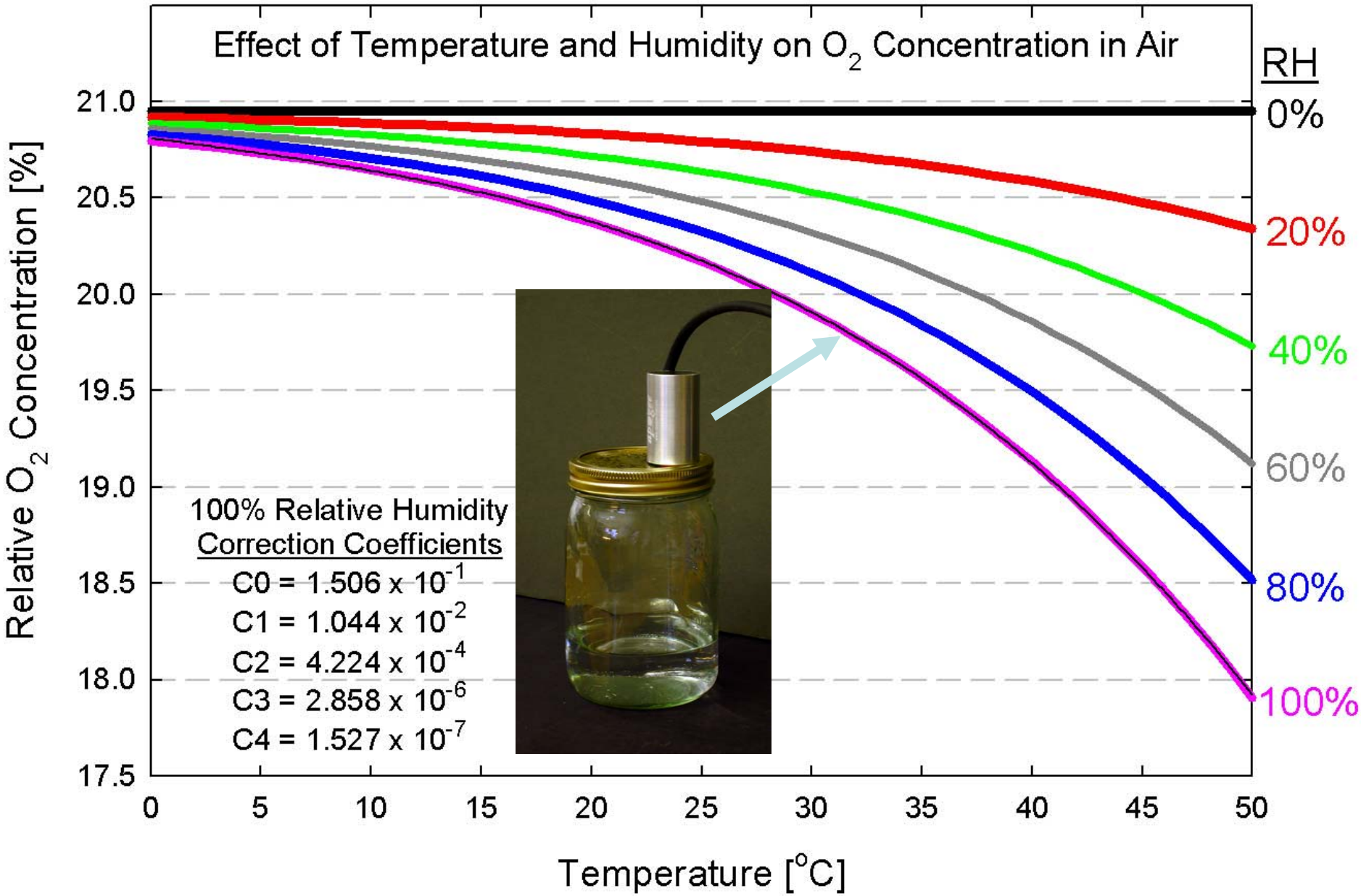
- Temperature
  - gas / liquid partitioning
  - effect on molar density and sensor electronics



Factors affecting gas concentration in soil

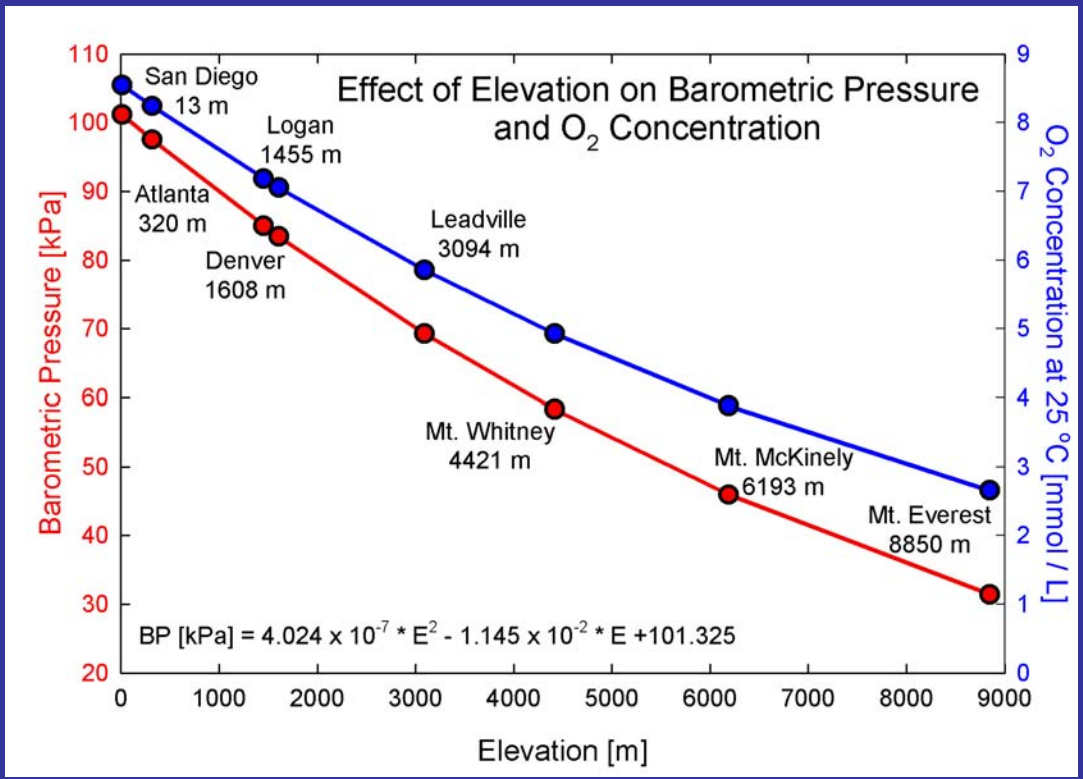
- Humidity

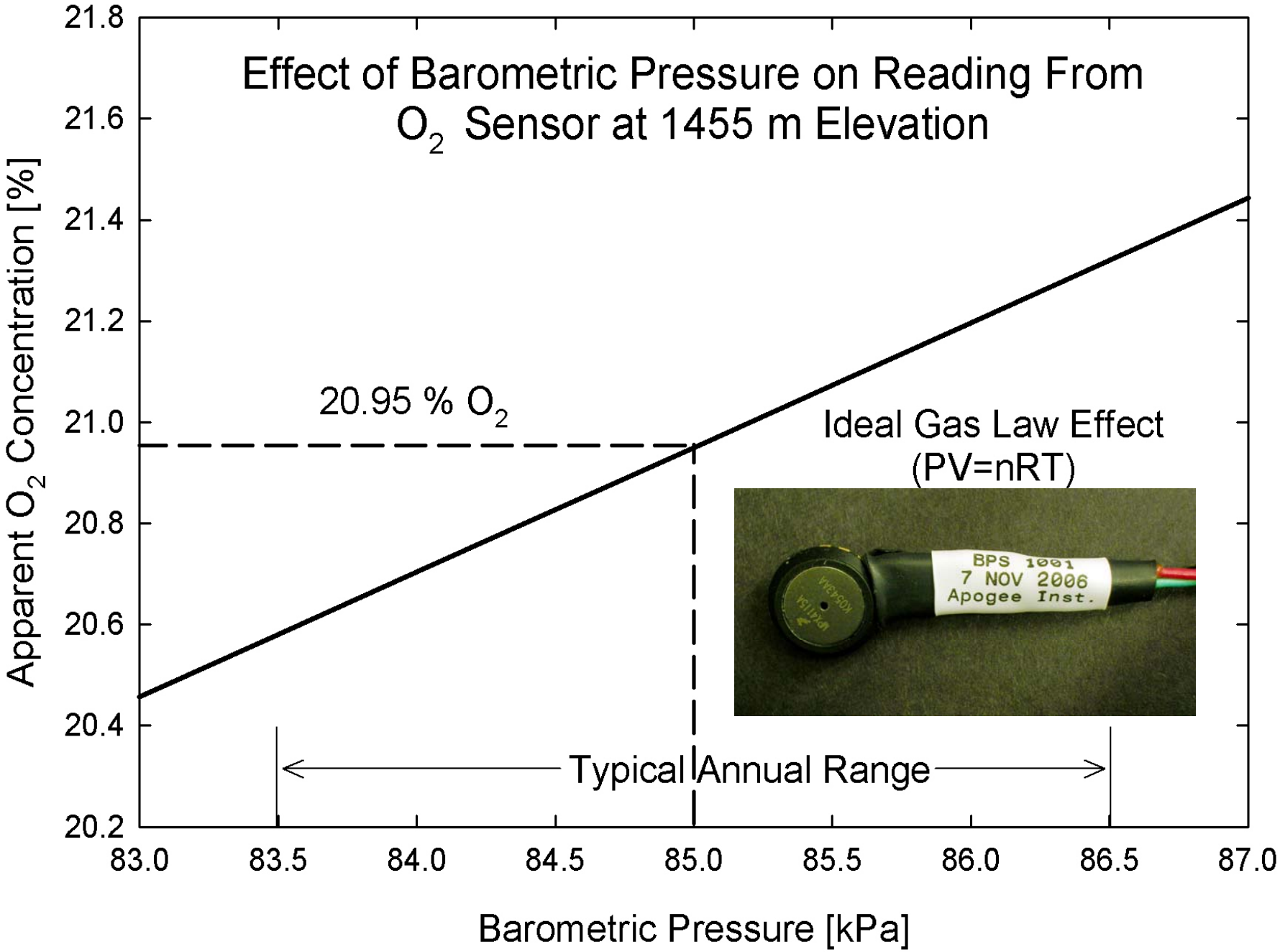


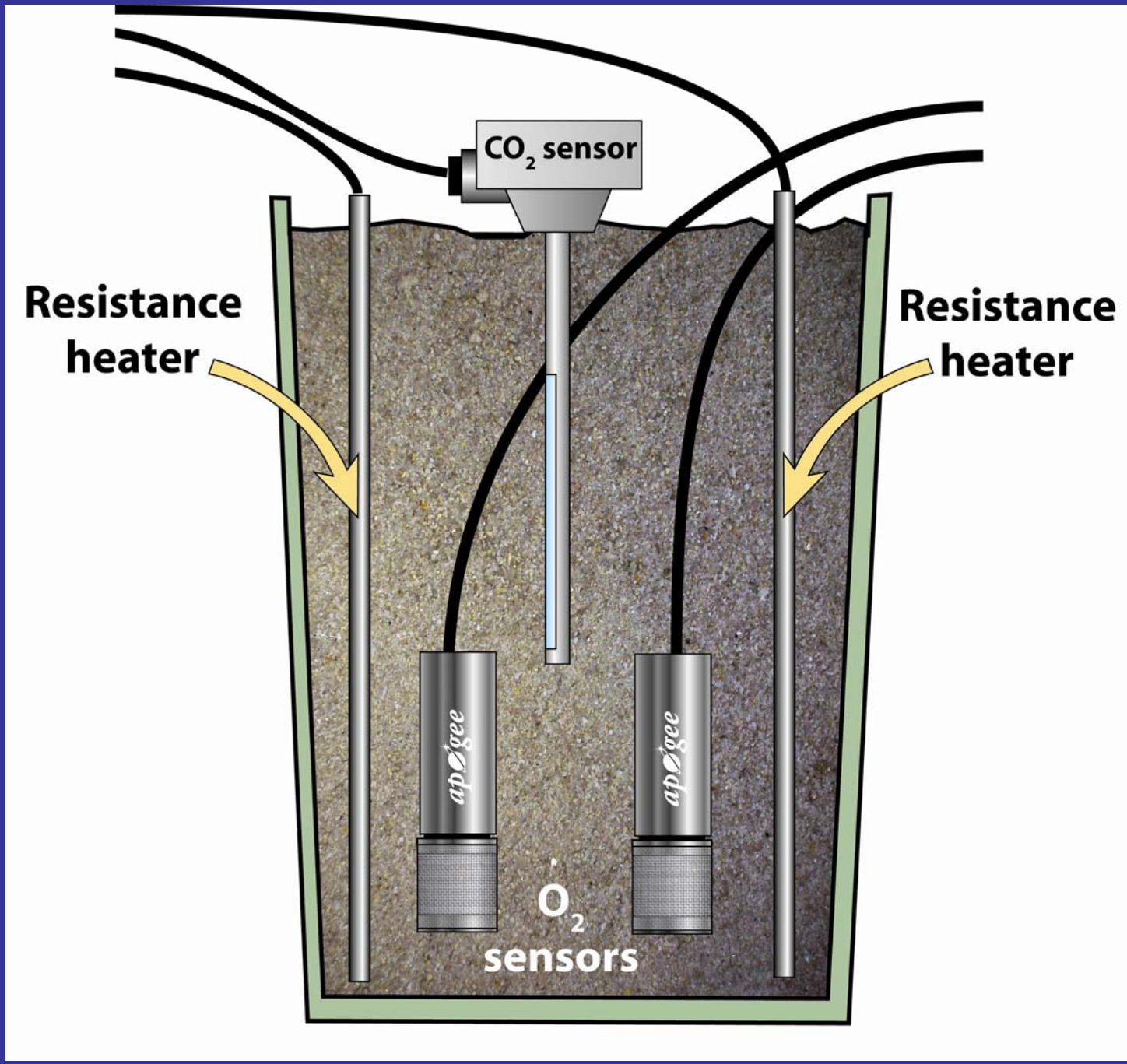

Effect of Temperature and Humidity on O_2 Concentration in Air
RH
0%
20%
40%
60%
80%
100%
Relative O_2 Concentration [%]
21.0
20.5
20.0
19.5
19.0
18.5
18.0
17.5
0
5
10
15
20
25
30
35
40
45
50
Temperature [°C]
100% Relative Humidity
Correction Coefficients
C0 = 1.506 x 10^{-1}
C1 = 1.044 x 10^{-2}
C2 = 4.224 x 10^{-4}
C3 = 2.858 x 10^{-6}
C4 = 1.527 x 10^{-7}

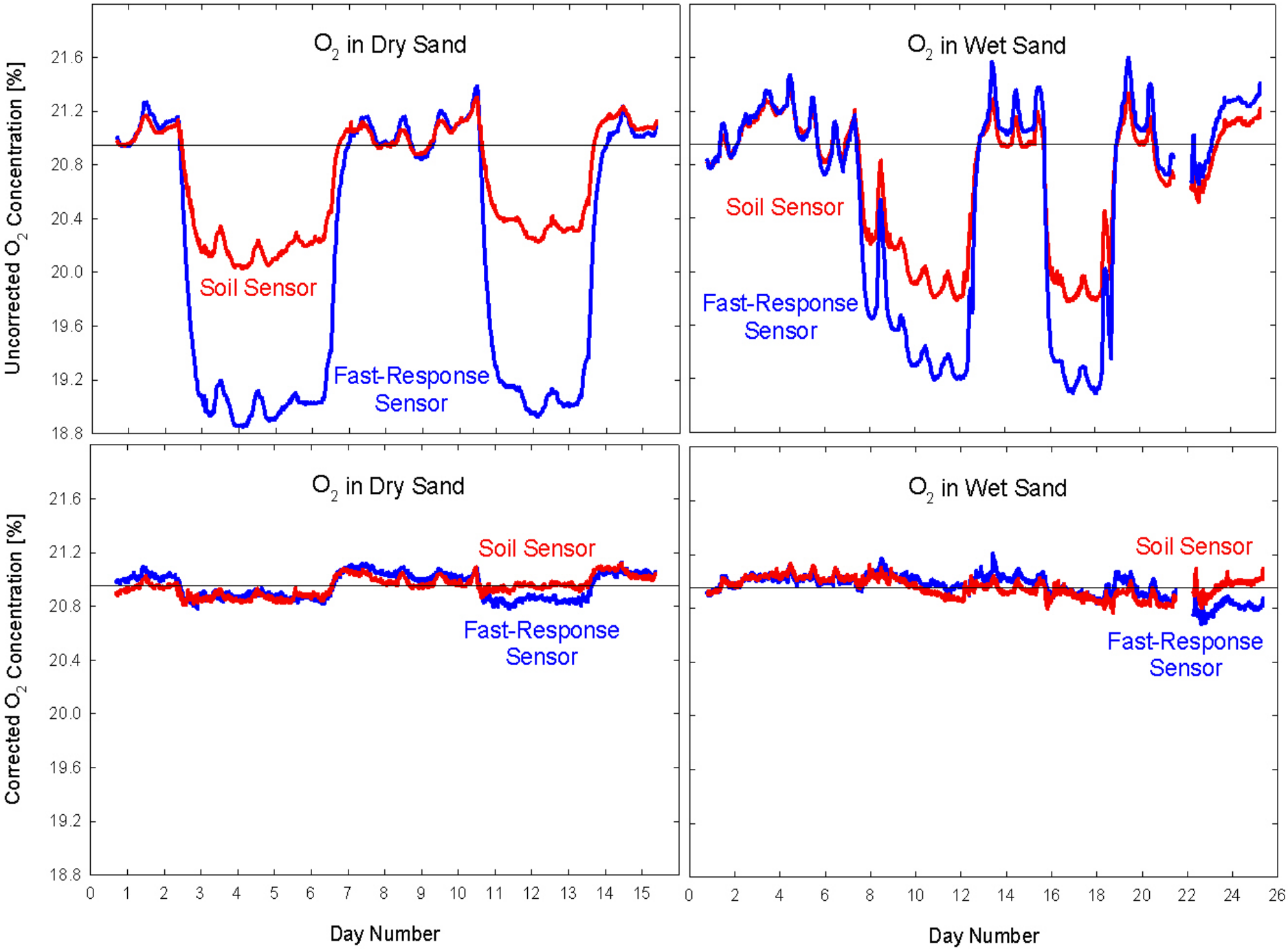
Factors affecting gas concentration in soil

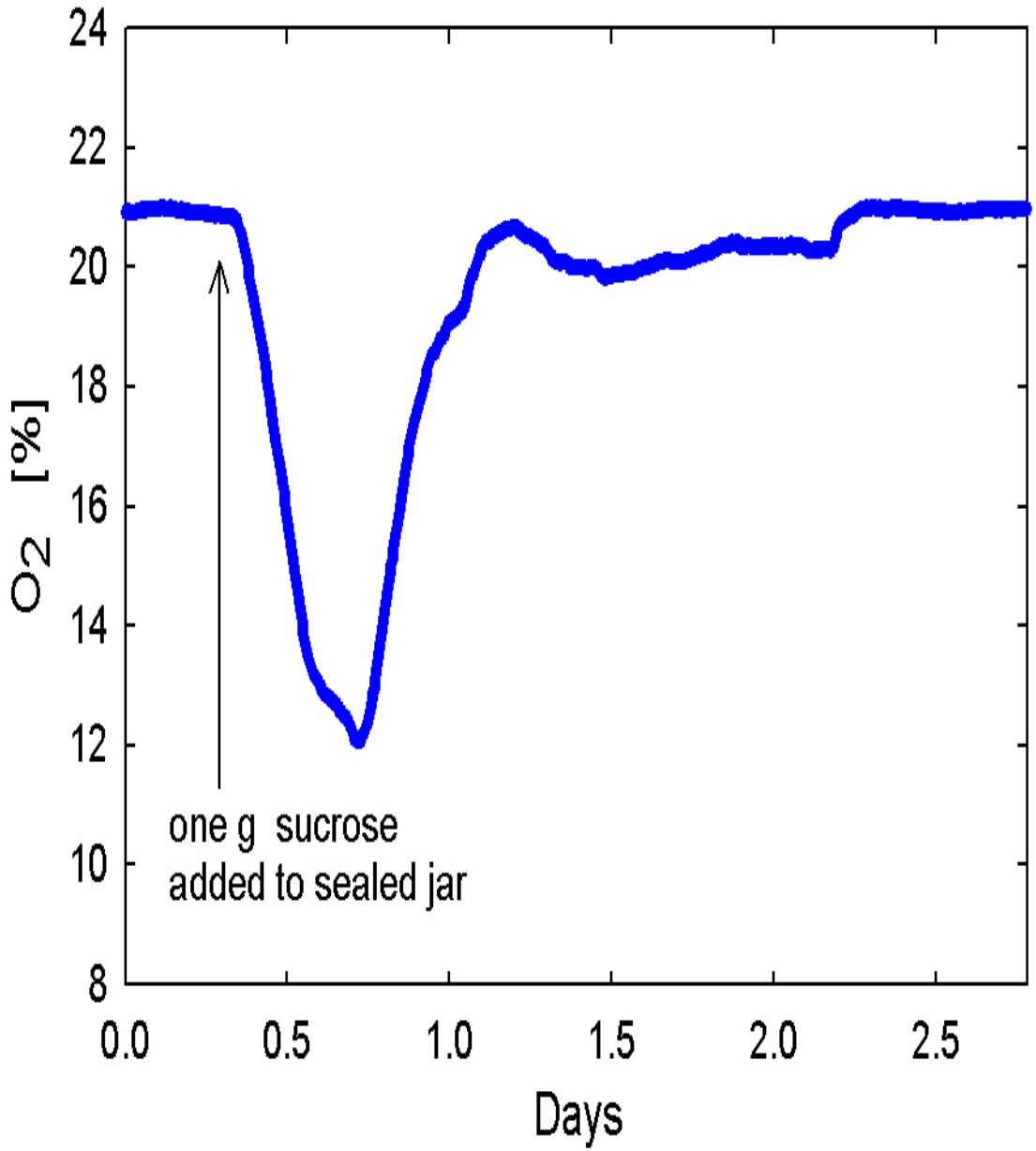
- Atmospheric pressure




Effect of Barometric Pressure on Reading From
O_2 Sensor at 1455 m Elevation
Apparent O_2 Concentration [%]
21.8
21.6
21.4
21.2
21.0
20.8
20.6
20.4
20.2
20.95 % O_2
Ideal Gas Law Effect
(PV=nRT)
BPS 1001
7 NOV 2006
Apogee Inst.
Typical Annual Range
83.0
83.5
84.0
84.5
85.0
85.5
86.0
86.5
87.0
Barometric Pressure [kPa]


CO_2 sensor
Resistance heater
Resistance heater
apogee
apogee
O_2 sensors


O2 in Dry Sand
O2 in Wet Sand
Soil Sensor
Fast-Response Sensor
Uncorrected O2 Concentration [%]
Corrected O2 Concentration [%]
21.6
21.2
20.8
20.4
20.0
19.6
19.2
18.8
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
0 2 4 6 8 10 12 14 16 18 20 22 24 26
Day Number


24
22
20
18
16
14
12
10
8
O2 [%]
0.0
0.5
1.0
1.5
2.0
2.5
Days
one g sucrose
added to sealed jar


apogee

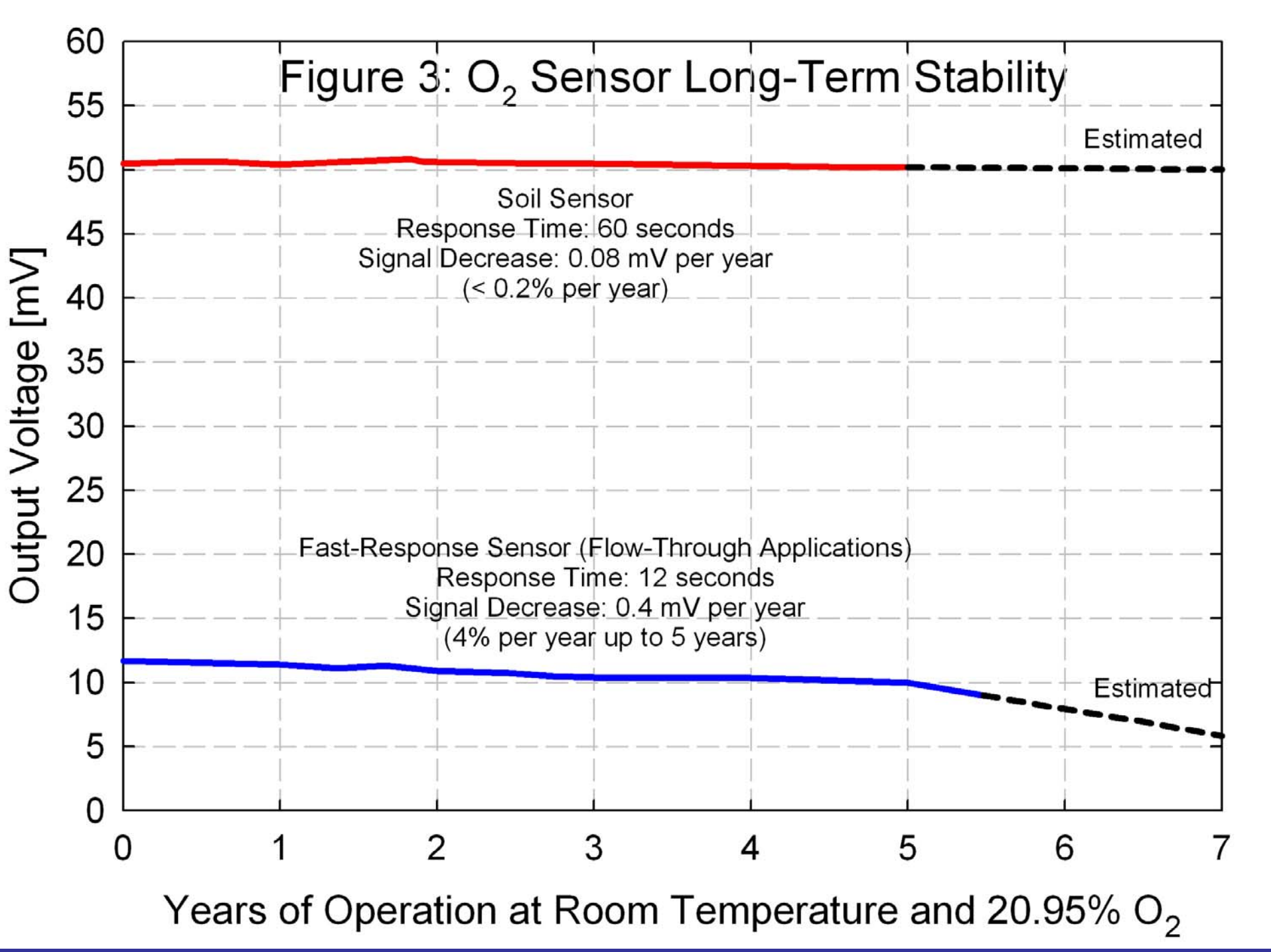


Figure 3: O2 Sensor Long-Term Stability
Estimated
Soil Sensor
Response Time: 60 seconds
Signal Decrease: 0.08 mV per year
(< 0.2% per year)
Fast-Response Sensor (Flow-Through Applications)
Response Time: 12 seconds
Signal Decrease: 0.4 mV per year
(4% per year up to 5 years)
Estimated
Output Voltage [mV]
Years of Operation at Room Temperature and 20.95% O2
0
5
10
15
20
25
30
35
40
45
50
55
60
0
1
2
3
4
5
6
7