When Measurements Matter: Principles of Measurement for Flux Systems

ChinaFlux 2023: Seth Berger

Campbell SCIENTIFIC

When Measurements Matter

Focus Points

- Why is this measurement important?
- How is this measurement made?

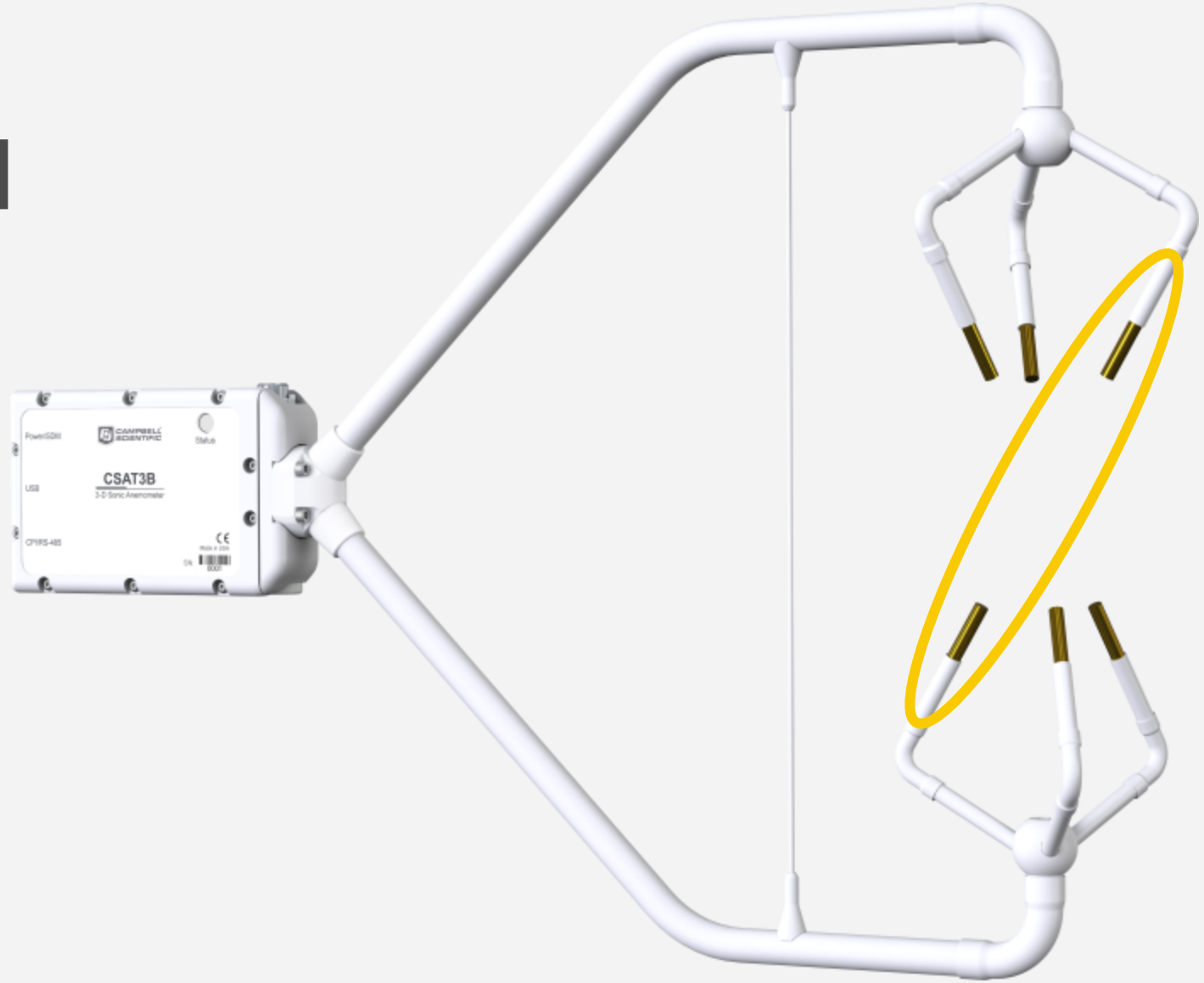
Sonic Anemometers

3-D Wind Speed

Frequency Response

Vertical Windspeed

- Footprint analysis
- Coordinate rotation
- Data quality grading



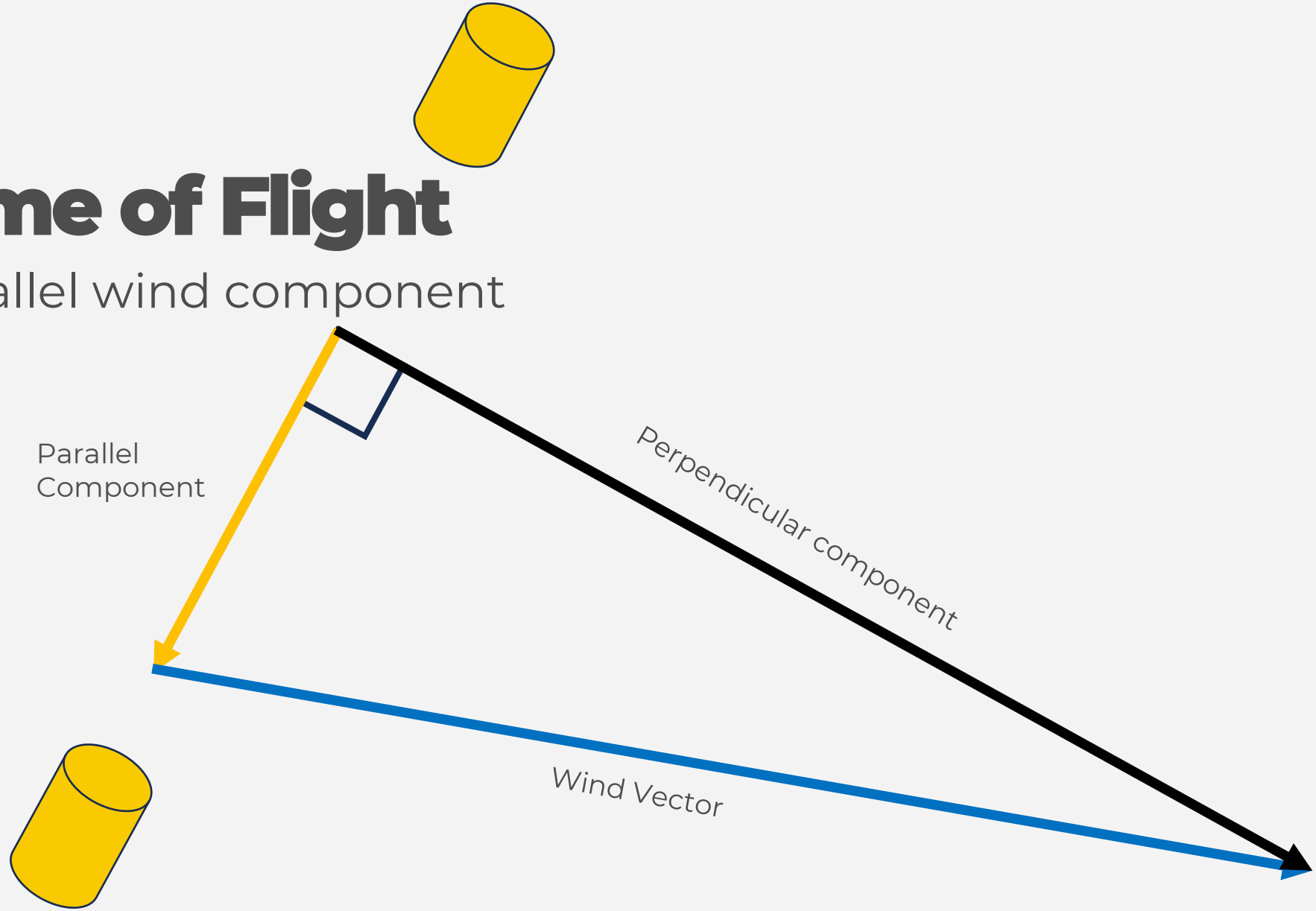
Time of Flight

$t = d/(c + U_A)$

c- speed of sound
U_A-parallel component of wind

Time of Flight

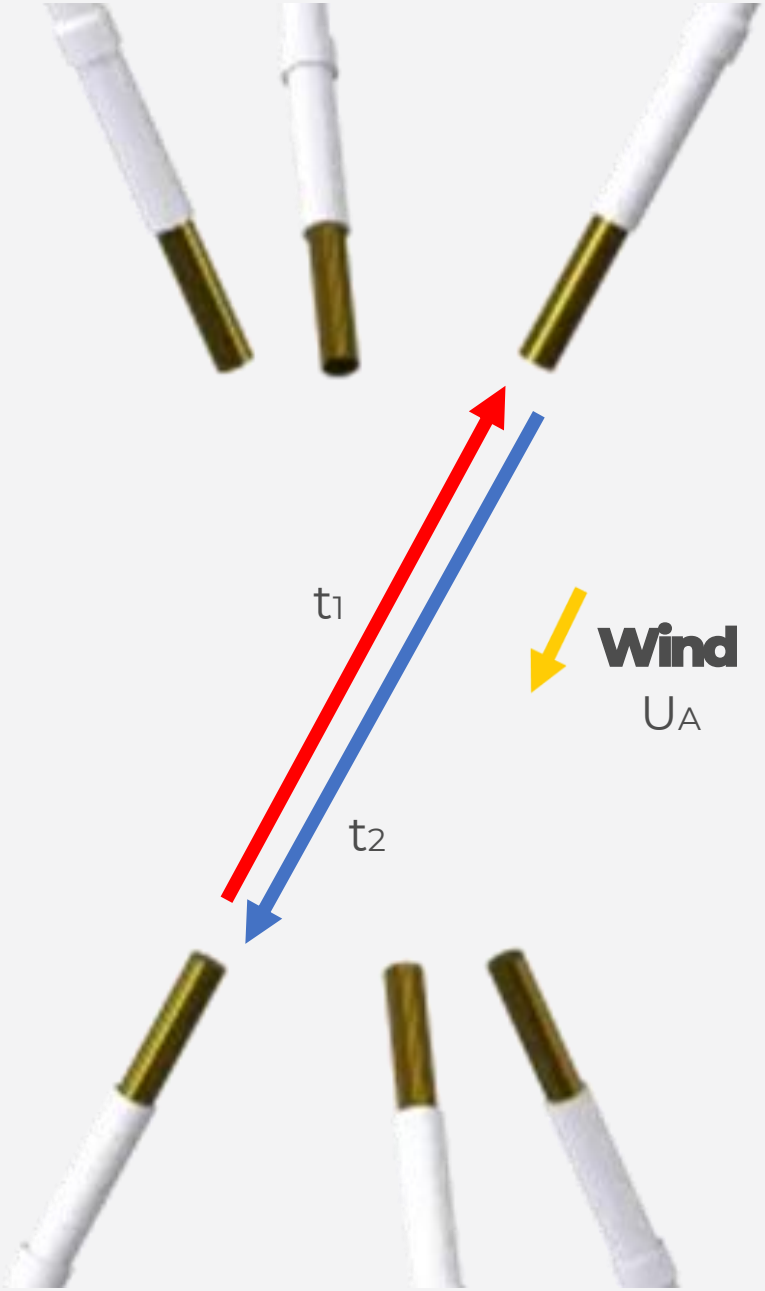
Parallel wind component



Time of Flight

$$t_1 = d/(c + U_A)$$
$$t_2 = d/(c - U_A)$$

$$U_A = d/2\,(1/t_1 - 1/t_2)$$
$$c = d/2\,(1/t_1 + 1/t_2)$$



Sonic Temperature

Speed of Sound

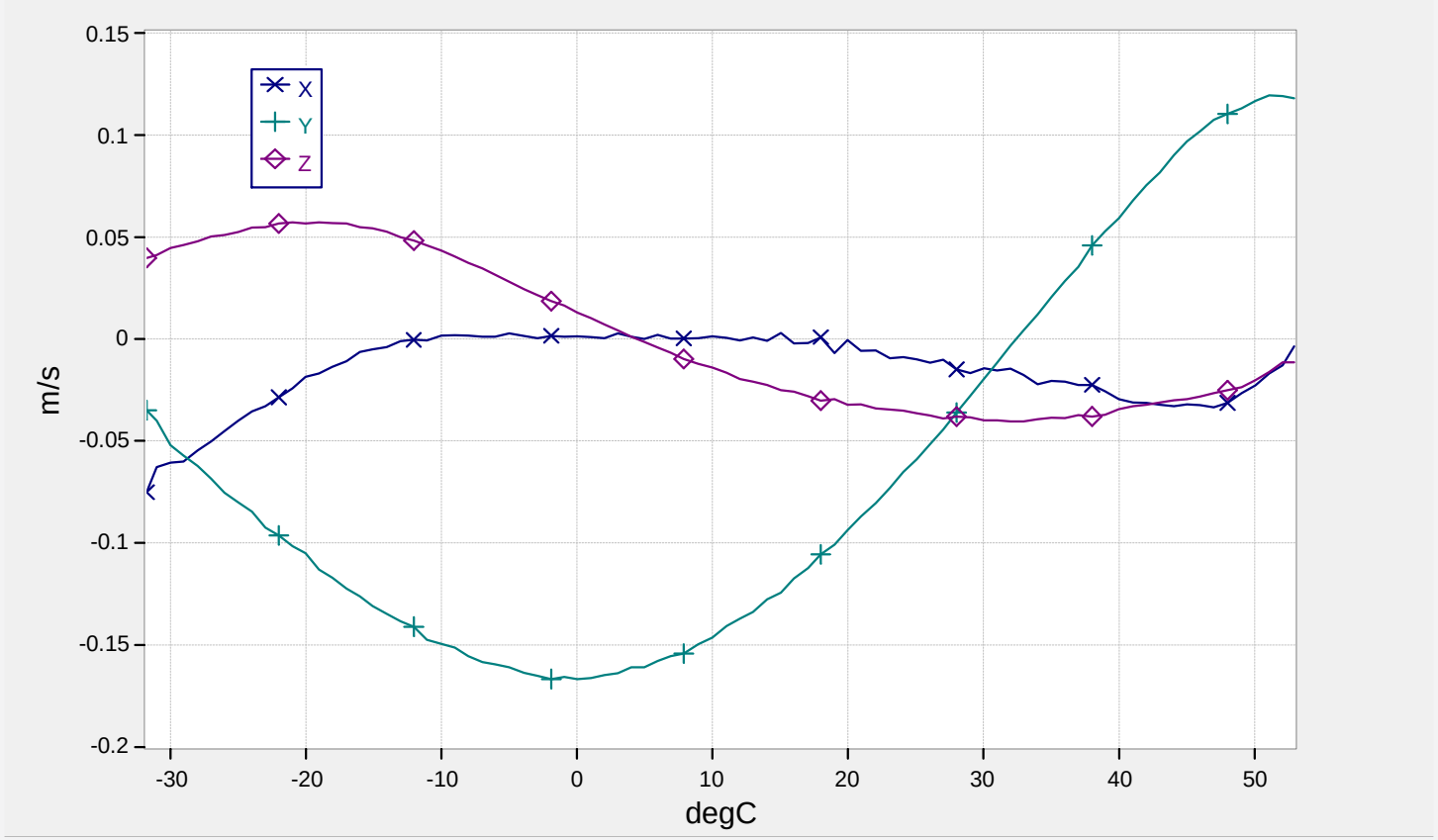
Pressure

Water Vapor

$$c = \sqrt{\frac{\gamma \cdot P}{\rho}}$$

Sonic Transducers

Transducer delay

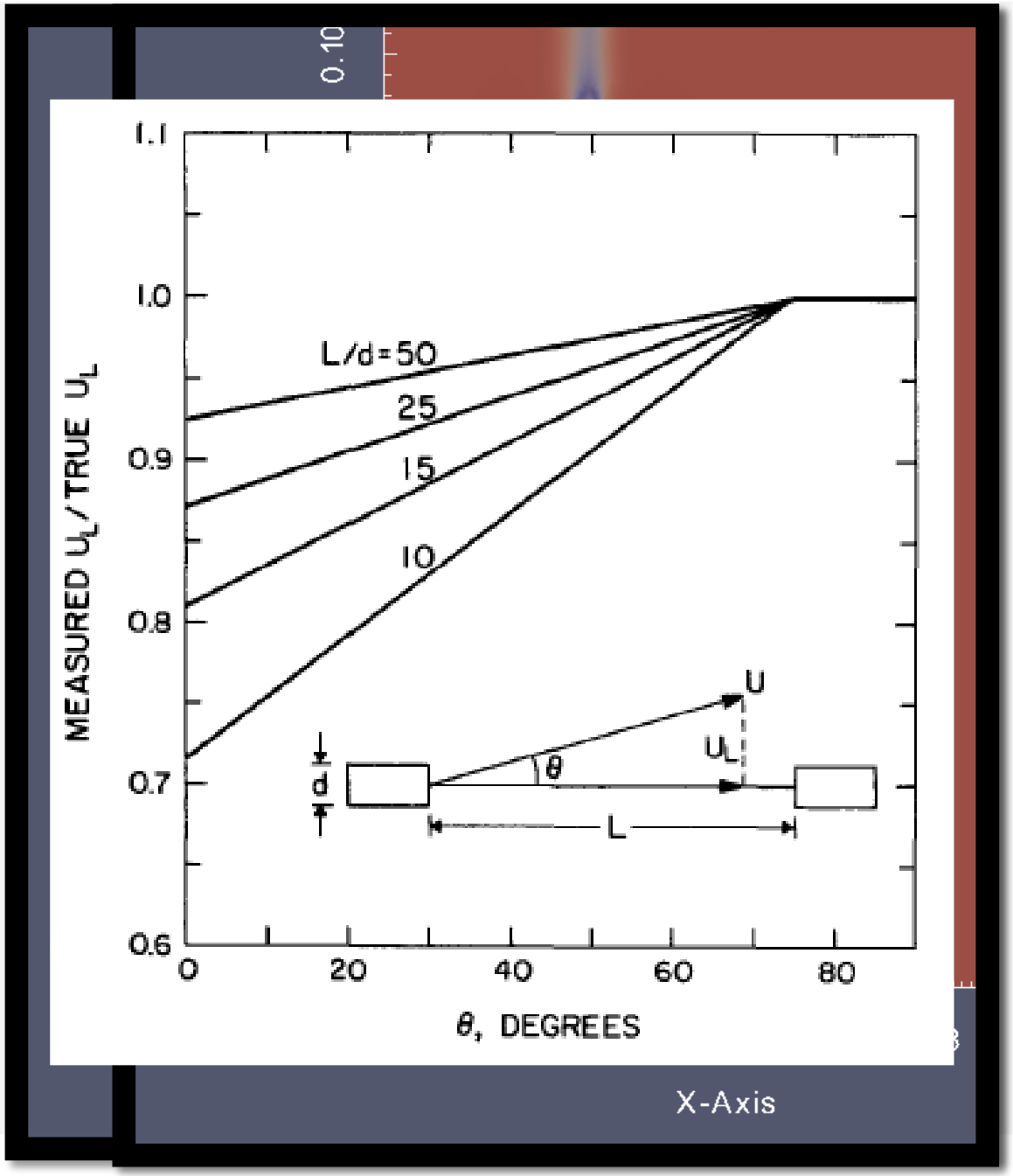


Shadowing

Transducer diameter

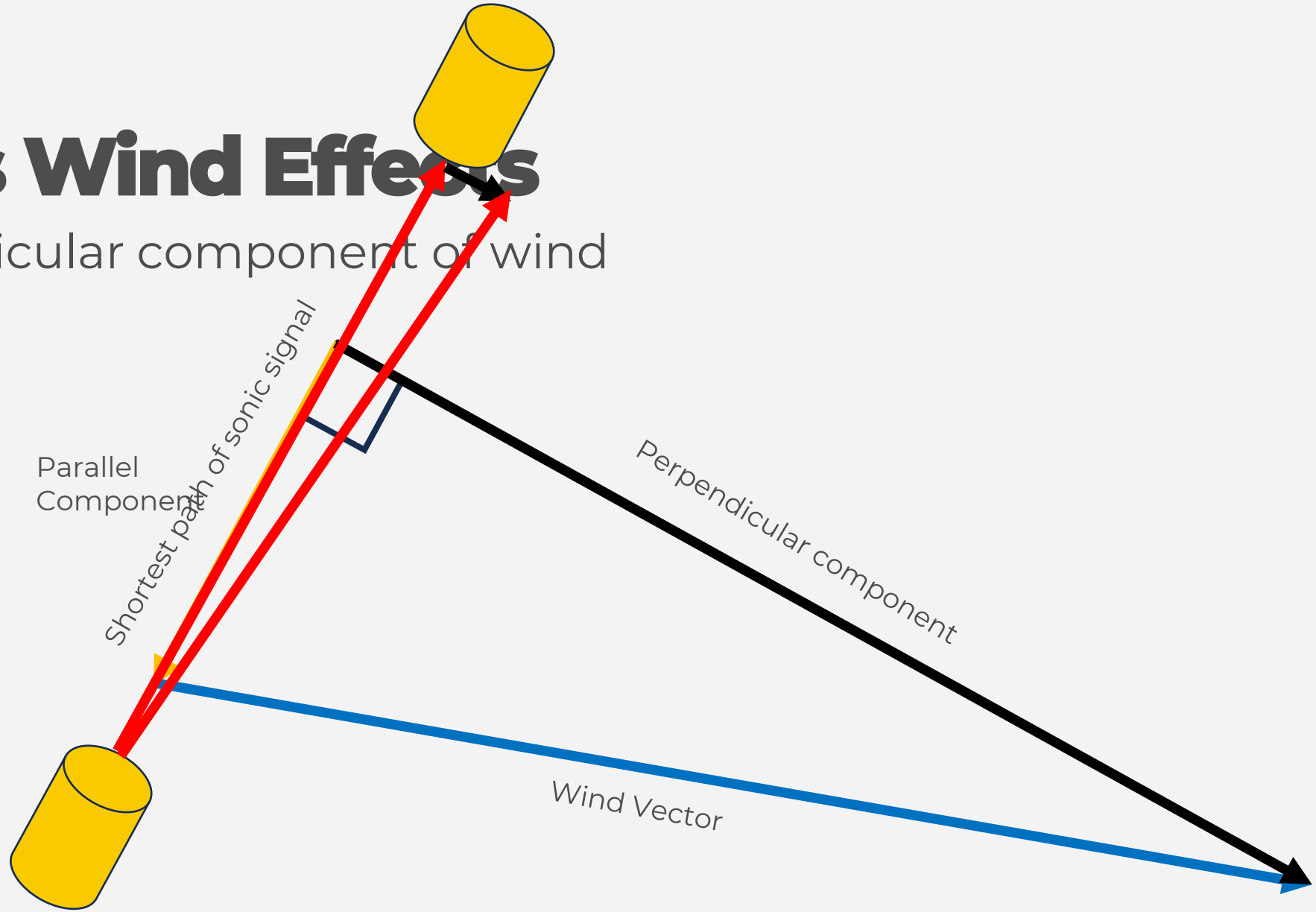
Measurement distance

Corrections



Cross Wind Effects

Perpendicular component of wind



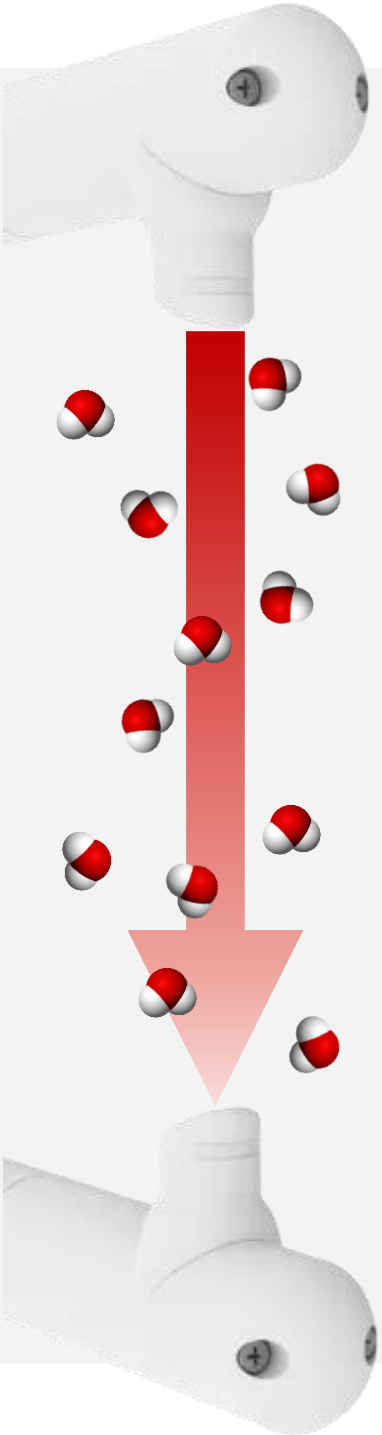
Gas Analyzers

Gas Concentration

Absorbance

Beer-Lambert Law

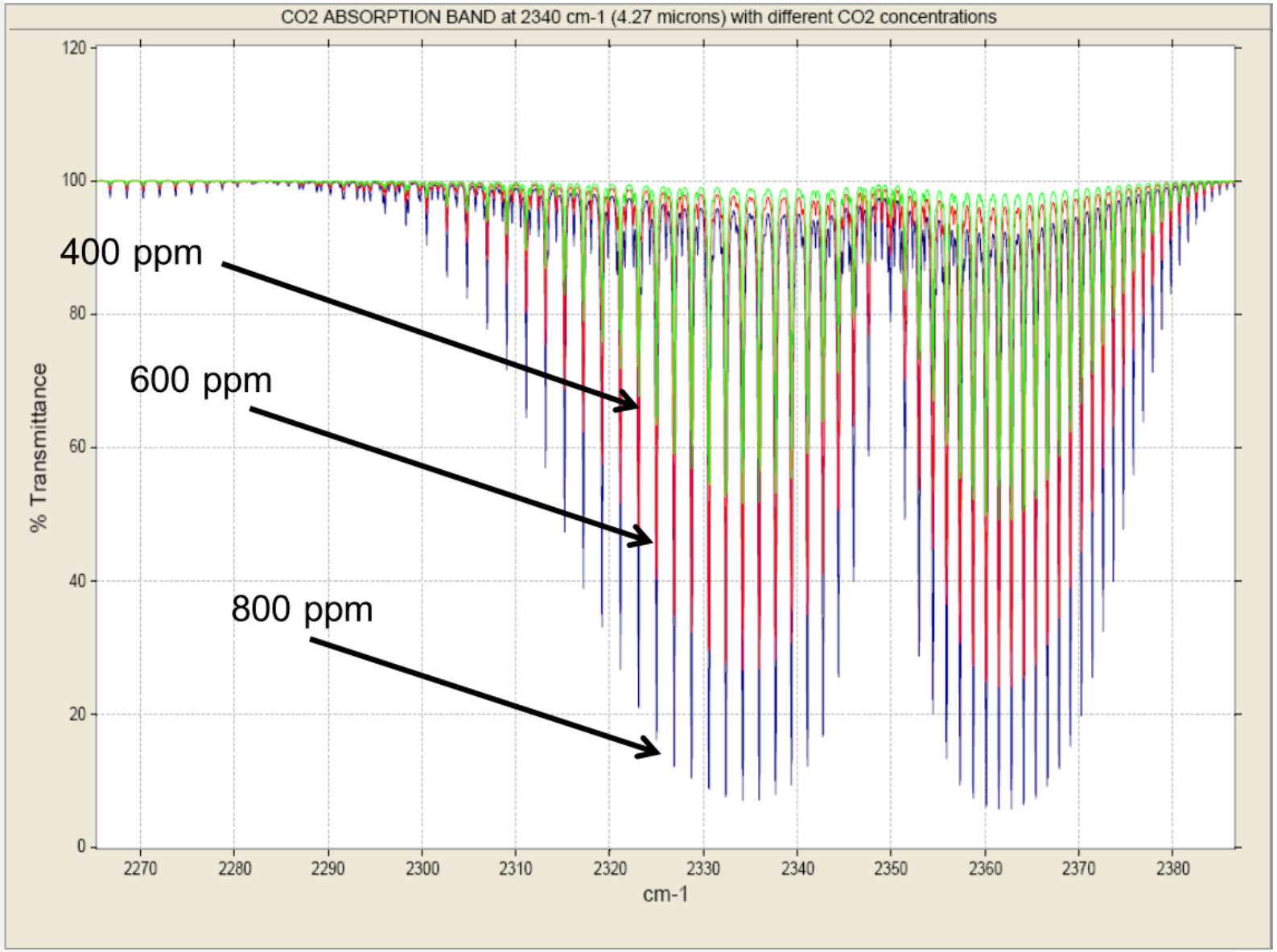
$$A = \varepsilon \cdot l \cdot C$$

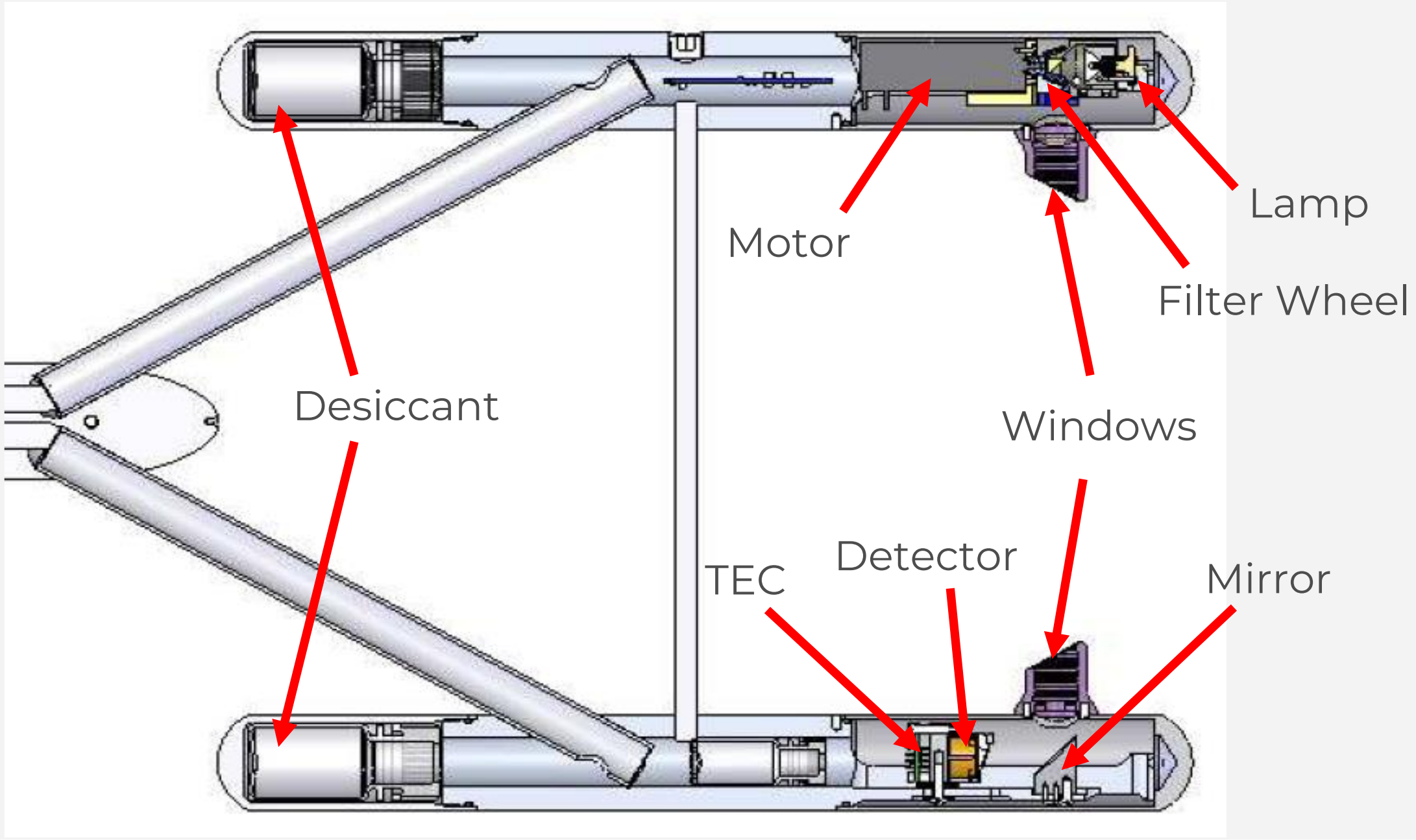


Absorbance

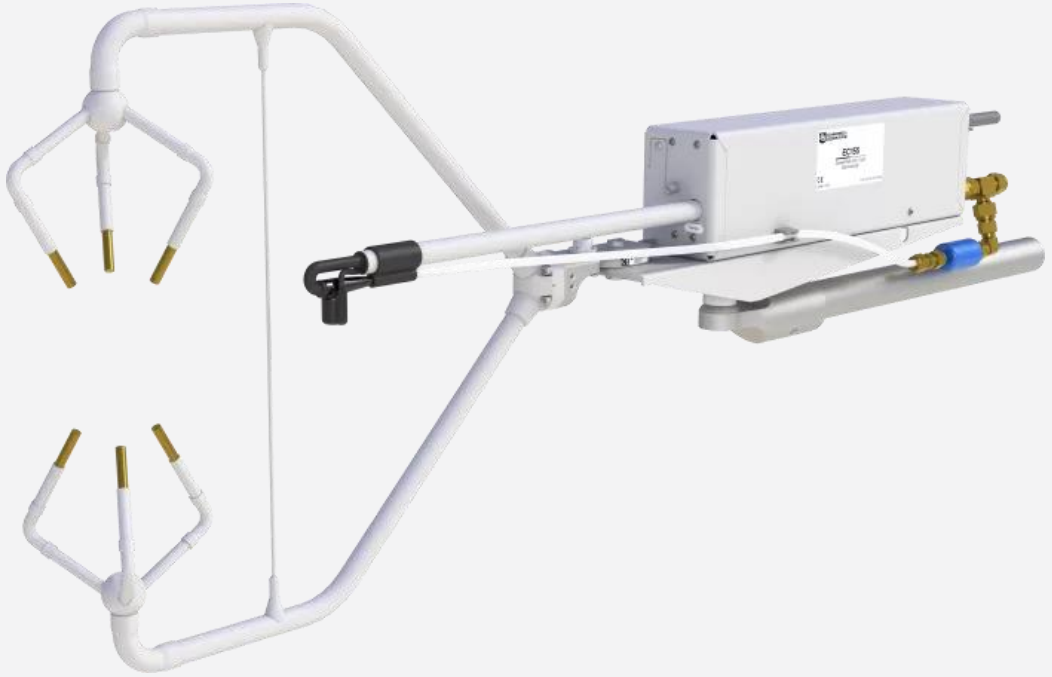
Signal Wavelength

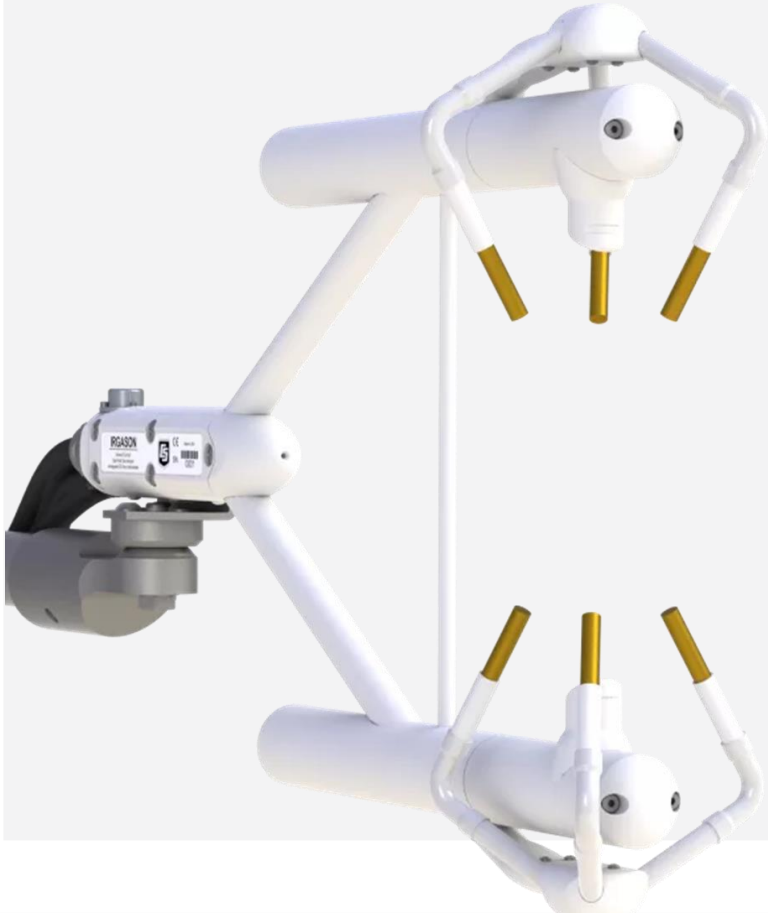
Reference Wavelength




Desiccant
Motor
Lamp
Filter Wheel
Windows
TEC
Detector
Mirror

Open vs. Closed Path



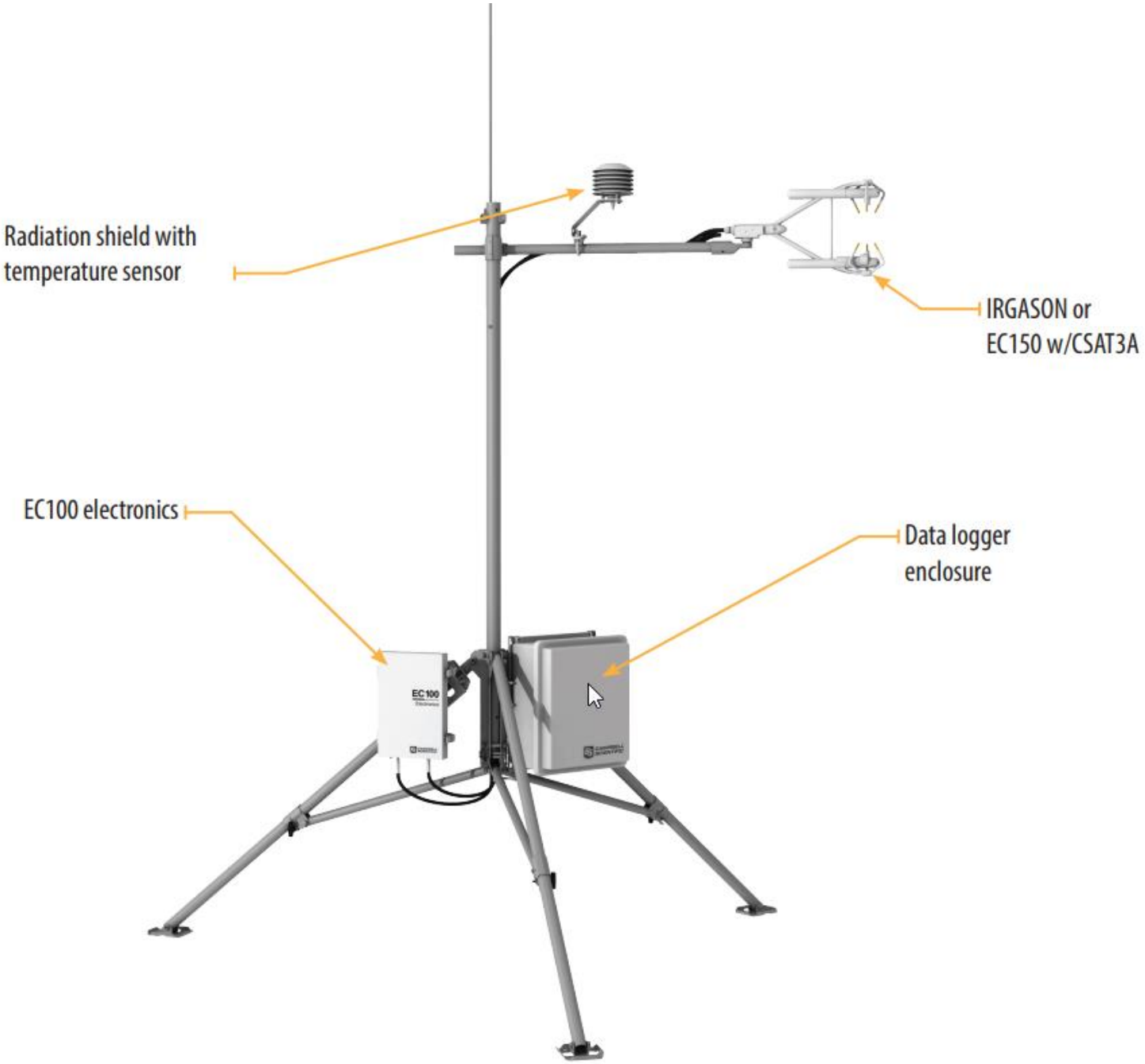


OPEC

Low Cost

Low Power Consumption

Excellent Frequency Response



CPEC

Control sample cell pressure and temperature

Less vulnerable to environmental contaminants

Automated zero and span

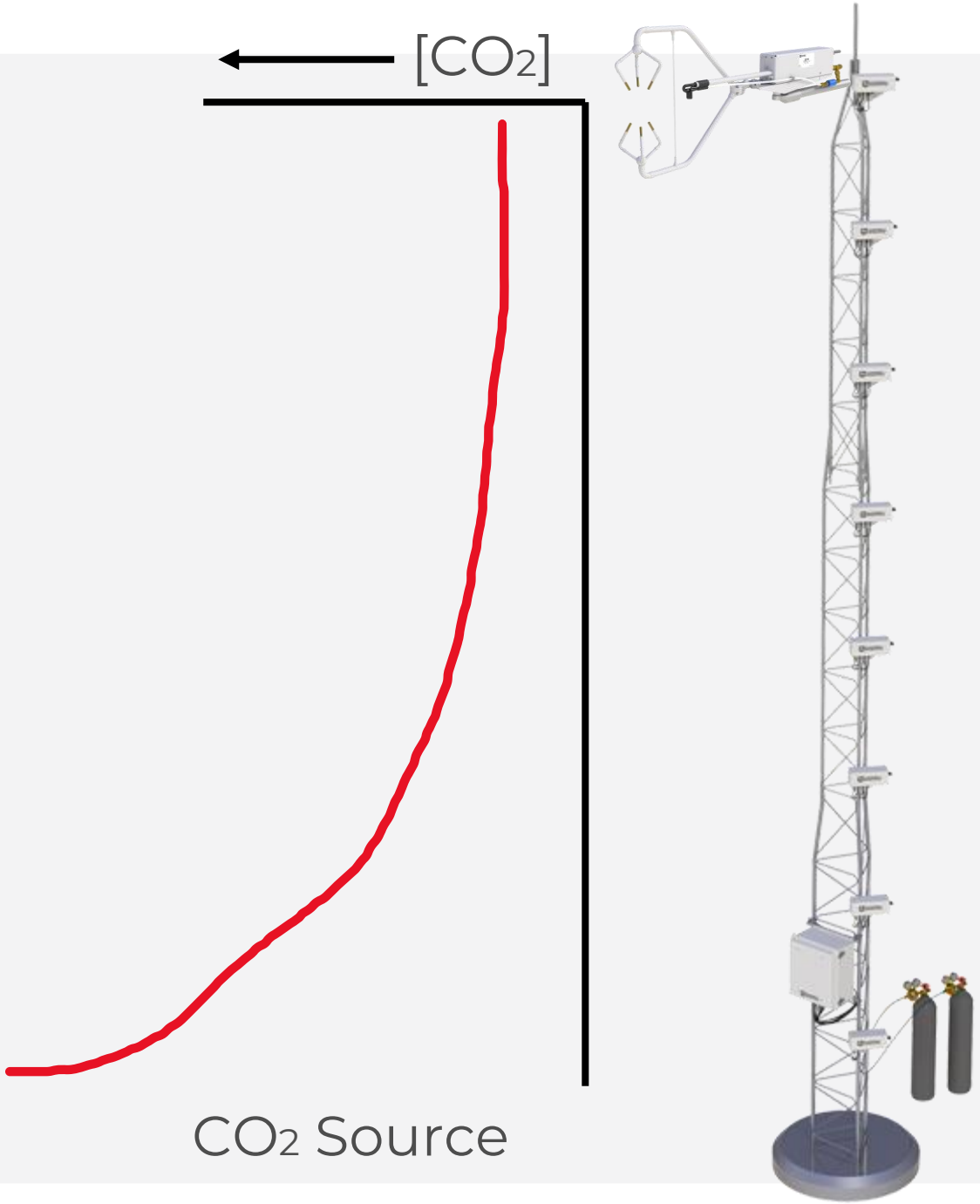
Profile Systems

Gas Concentration

Absorbance

Storage

Stable Conditions



Environmental Measurements

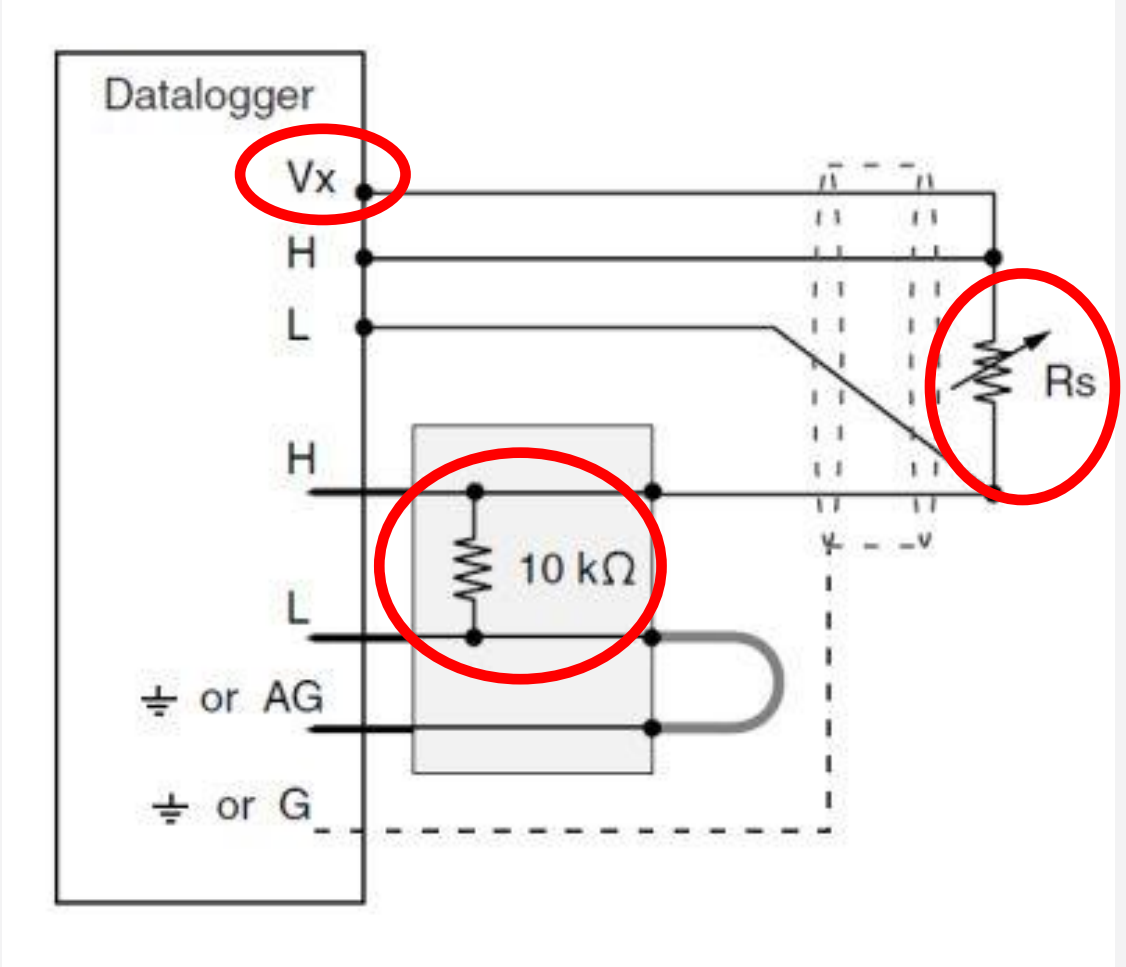
Corrections & Comparisons

Temperature

Half-Bridge Measurements

PRT

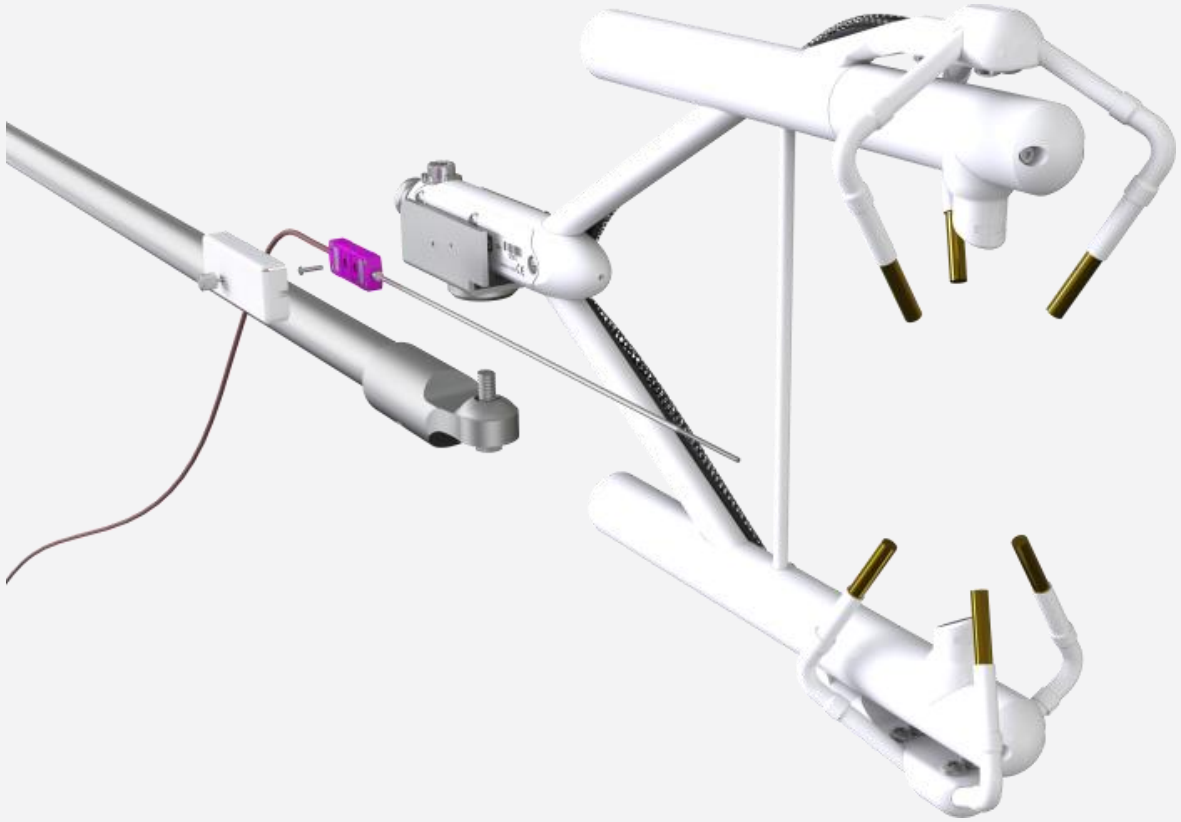
Thermistor



Temperature

Voltage

Fine-Wire Thermocouple



Relative Humidity

Capacitance measurement

Dew Point

Vapor Pressure Deficit

$$RH = \frac{Partial\ Pressure\ H2O}{Saturation\ Vapor\ Pressure} \text{ x } 100\%$$

Atmospheric Pressure

Capacitive pressure cell

Air density

Environmental Measurements

Energy Balance Calculations

Energy Balance

$$RN = LE + H + G$$

RN- net radiation

LE- latent heat flux

H- sensible heat flux

G- ground heat flux

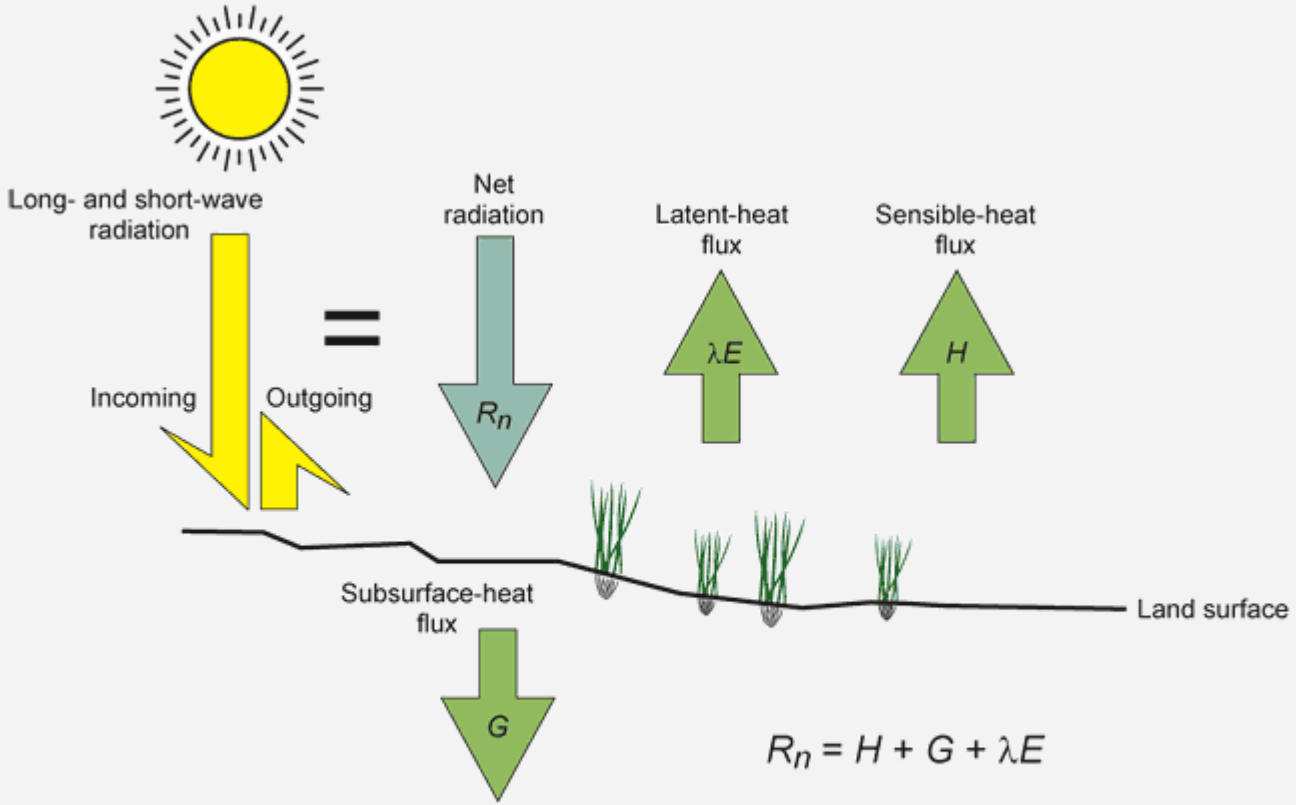


Figure 1: see end note citation

(Modified from DeMeo and others, 2003)

Net Radiation

Four Components

Thermopile

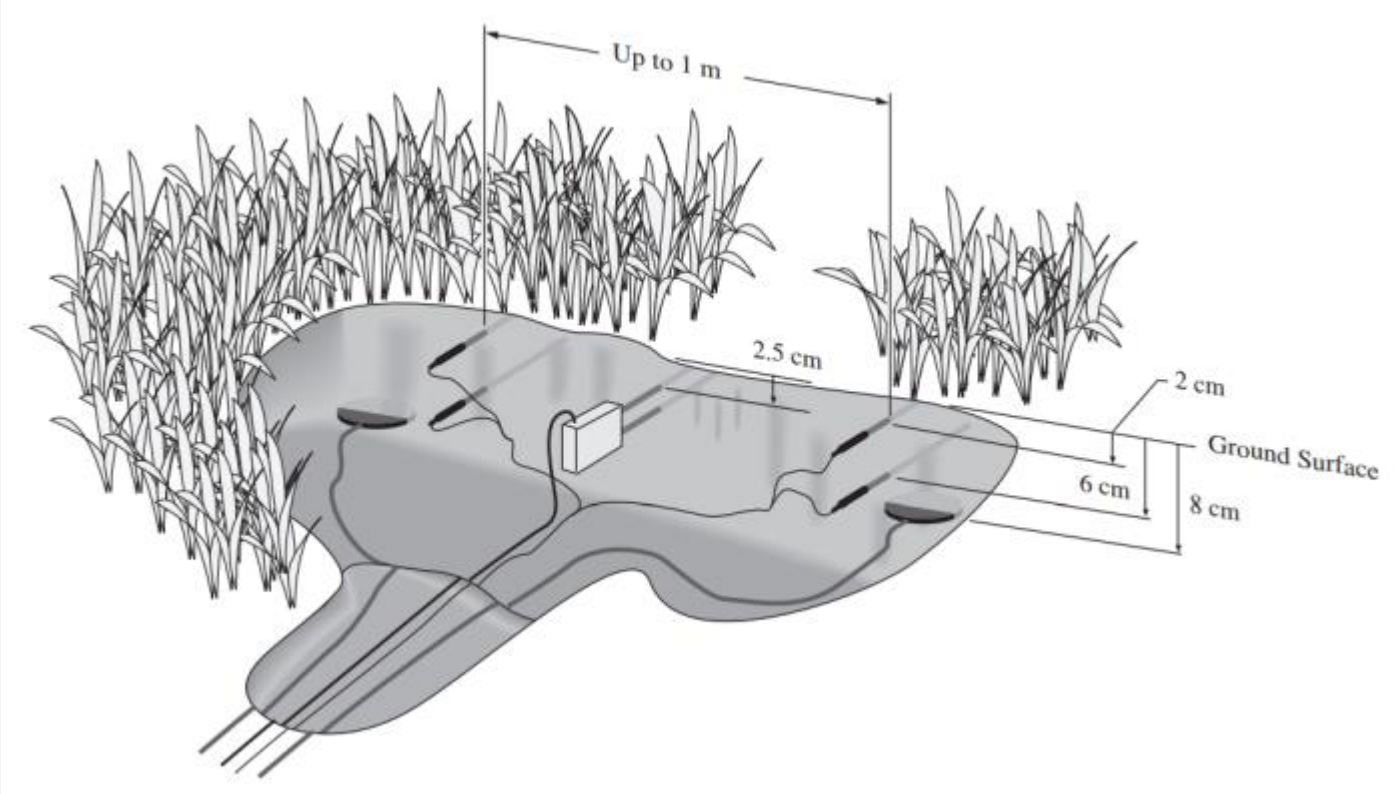
$$RN = SWin + SWout + LWin + LWout$$

Ground Heat Flux

Soil Moisture

Soil Temperature

Heat Flux



Heat Flux Plates

Heat transfer to deeper soil

Thermopile

Soil Water Content

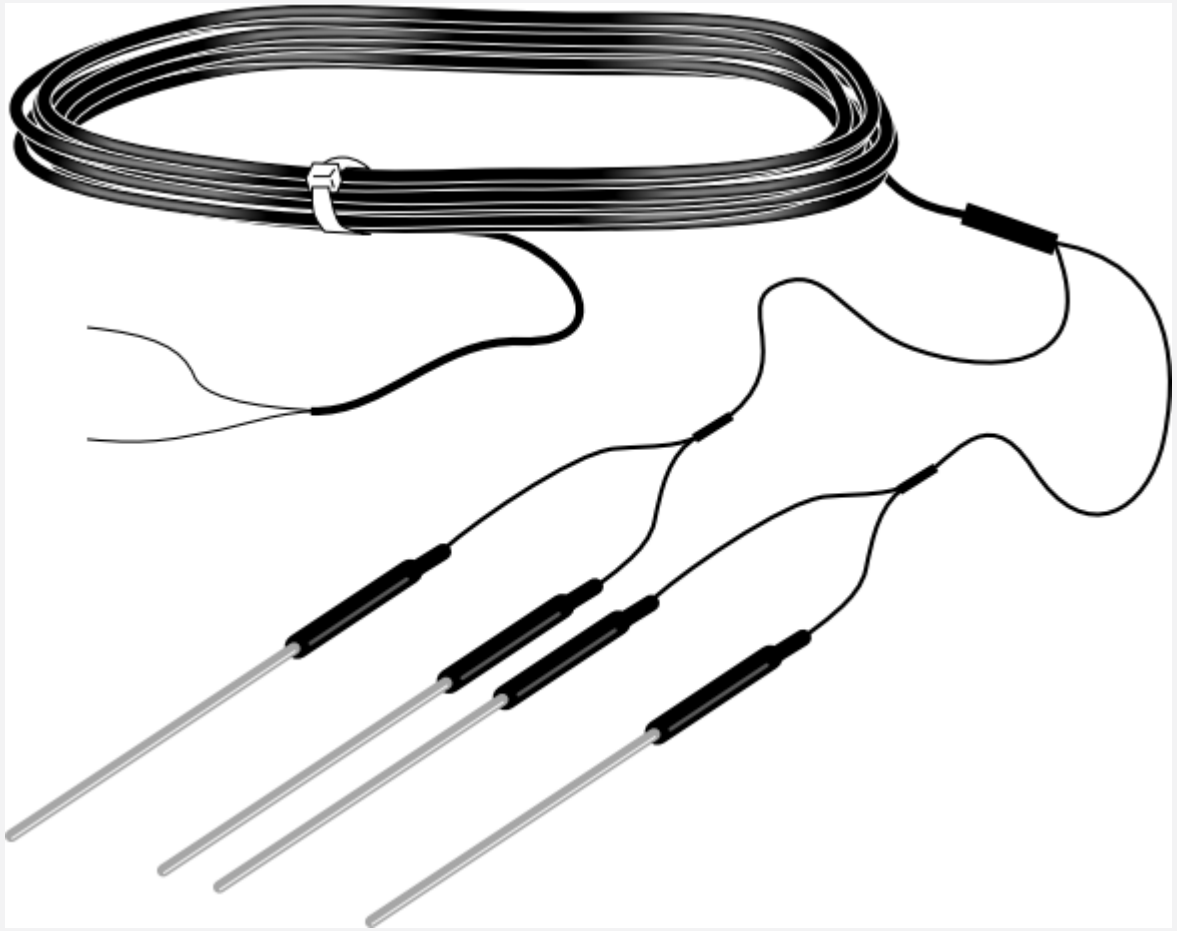
Heat capacity of soil

Water content reflectometer

Soil Temperature Probes

Heat storage in shallow soil

Thermocouple



Environmental Measurements

Other Ancillary Sensors

PAR

Photosynthetically active radiation

Thermopile

Precipitation

Tipping Bucket

Switch Closure

Wind Speed & Direction

Low level AC sign wave

Potentiometer

Thank you to my colleagues Xinhua Xhou, Bai Yang, Ed Swiatek for inspiration for and contributions of materials for this presentation

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Figure1:USGS, D. *Scientific Investigations Report 2006–5043*. Evapotranspiration by phreatophytes along the Lower Colorado River at Havasu National Wildlife Refuge, Arizona. https://pubs.usgs.gov/sir/2006/5043/figure3.html