Building science measurements for the Hospital Microbiome Project

ASHRAE Winter Conference 2014, New York, NY
Tuesday, January 21, 2014
Seminar 28: *A comprehensive look at infectious disease and air filtration in healthcare facilities*

Hospital
Microbiome

PI: Jack Gilbert, Argonne National Laboratory and University of Chicago
http://hospitalmicrobiome.com

ALFRED P. SLOAN FOUNDATION

Built
Environment
Research
@ IIT

www.built-envi.com
Twitter: @built_envi

Brent Stephens, Ph.D.
Civil, Architectural and Environmental Engineering
Illinois Institute of Technology
brent@iit.edu

Session learning objectives and AIA disclaimer

Learning objectives

- Describe the steps involved in transmission of microorganisms within healthcare facilities
- Understand risk factors and overall prevalence of healthcare associated infections (HAIs) in U.S. healthcare facilities
- List at least one strategy aimed at prevention of HAIs involving environmental reservoirs of microorganisms in air, water and on surfaces.
- Learn up-to-date control strategies and indoor air quality (IAQ)
- Learn about life cycle costs analysis for air filters in healthcare facilities, including real-life example of operating cost savings in health care facilities.
- Comprehend types of issues and requirements that impact selection of air cleaning technologies.

Disclaimer

- ASHRAE is a Registered Provider with The American Institute of Architects Continuing Education Systems. Credit earned on completion of this program will be reported to ASHRAE Records for AIA members. Certificates of Completion for non-AIA members are available on request. This program is registered with the AIA/ASHRAE for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product. Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Acknowledgments

- Jeffrey Siegel, University of Toronto
- Jack Gilbert, University of Chicago and Argonne National Laboratory
- Tiffanie Ramos, Parham Azimi, and Laurit Dide, Illinois Institute of Technology
- Funding from the Alfred P. Sloan Foundation

HMP Building Science Project Team

The Hospital Microbiome Project (HMP)

The Hospital Microbiome Project (HMP) is collecting microbial samples from surfaces, air, staff, and patients from the University of Chicago's new hospital pavilion in order to better understand the factors that influence bacterial population development in healthcare environments

The Hospital Microbiome Project (HMP)

The HMP provides a unique opportunity to sample in a newly constructed hospital environment …

… immediately prior to occupation and for nearly one year afterward

Biological sampling

- Both culture (agar plates for antibiotic resistant bacteria) and culture-independent methods (16S rRNA, 18S rRNA, and fungal ITS on Illumina HiSeq, as well as qPCR on a sub-section of samples) are being used to process over 12,000 microbial swab samples over the course of 1 year
  - 1 month prior to the hospital opening and 11 months after

Patient sampling

Patient room sampling

Floor, Bedrail, Cold water tap, Glove Box, and Air Filter*

Biological sampling

Staff sampling

Nose, Hand, Phone, Pager, Uniform Cuff, Shoe

Nurse's station sampling

Countertop, Computer Mouse, Phone, Chair, Corridor Floor, Hot Water Tap, Cold Water Tap

Building science measurements in HMP

- We are also working to characterize a number of building environmental and operational characteristics of the hospital during the yearlong HMP
  - Within 10 patient rooms
  - Within mechanical rooms serving each floor

- Our goal was to define a set of building science parameters that may have implications for biological findings
  - And that we could measure (within budget) robustly and accurately

- Many recent indoor microbial studies have not adequately characterized the indoor environments and operational parameters of buildings in which sampling takes place

HVAC systems

Patient rooms
5 rooms on 10th floor
5 rooms on 9th floor

Mechanical rooms

- Three measurement locations in each of 2 sets of mechanical systems
  - AHU 6 (located on the 11th floor)
    - Serves 10th floor (~50,000 cfm)
  - AHU 11, 12, 13, and 14 (located on 11th and 12th floors)
    - All connected to serve 8th and 9th floors (total of ~200,000 cfm)

LEVELS 08 & 09 INPATIENT FLOORS
CAPACITY = 45,000 CFM EACH AHU

12   14   12th floor (mechanical room)

11   13   11th floor (mechanical room)

LEVELS 08 & 09 INPATIENT FLOORS
CAPACITY = 45,000 CFM EACH AHU

10th floor (oncology)

9th floor (patient rooms)

8th floor (patient rooms)

AHU 11-14 (all connected)

11th floor (mechanical room)

6   LEVEL 10 HEM/ONC
CAPACITY – 45,000 CFM
TWO FANS AT 22,500 CFM EACH

10th floor (oncology)

9th floor (patient rooms)
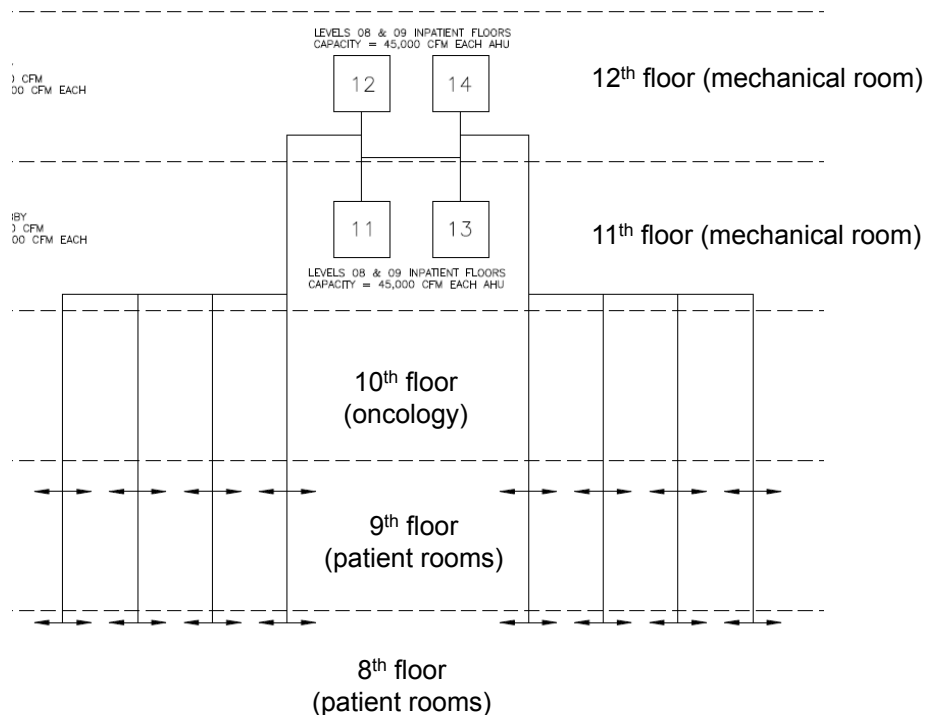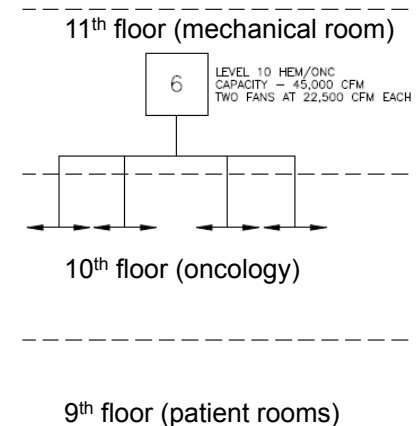
AHU 6 (alone)

Mechanical room measurements

- Outdoor air ventilation fraction (%OA) delivered to each floor
  - Each floor is served by a different HVAC system
  - CO_2 measurements in return, supply, and outdoor airstreams
  - Outdoor T and RH
    - 5-minute intervals

$$F_{OA} = 1 - \frac{C_{supply} - C_{out}}{C_{return} - C_{out}}$$
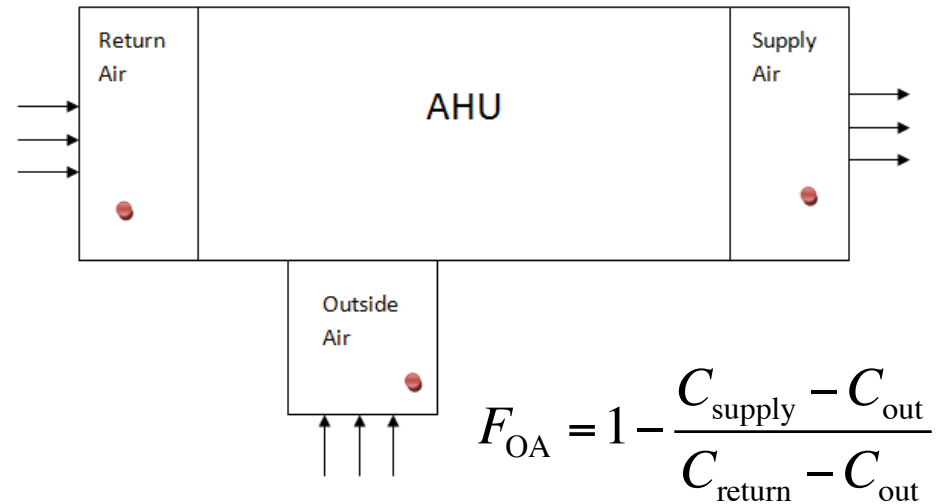
AHU 6: 50,000 cfm

Outside Air

Supply Air

13

CO₂ in OA

CO₂ in SA

CO₂ in RA

HVAC systems

Patient room measurements

- Supply, return, and exhaust airflow rates (constant flow)
    - Measurements made during early stages of project
    - Estimates made using CO_2 mass balance throughout project

- Temperature + relative humidity + light intensity
    - Data loggers at 5-min intervals
        - Also at nurse stations

- Human occupancy
    - Beam break IR sensor at doorway (total breaks at 5 min intervals)
    - Patient room CO_2 concentrations (5 min intervals)

- Room pressurization (with respect to hallway)
    - Pressure transducers (5 min intervals)

- Air sampling via HVAC filter media
    - Periodic (weekly) → the only air sampling in the project

Patient rooms

Return Air
400 cfm

Bathroom
exhaust
100 cfm

Supply Air Slot Diffuser 500 cfm
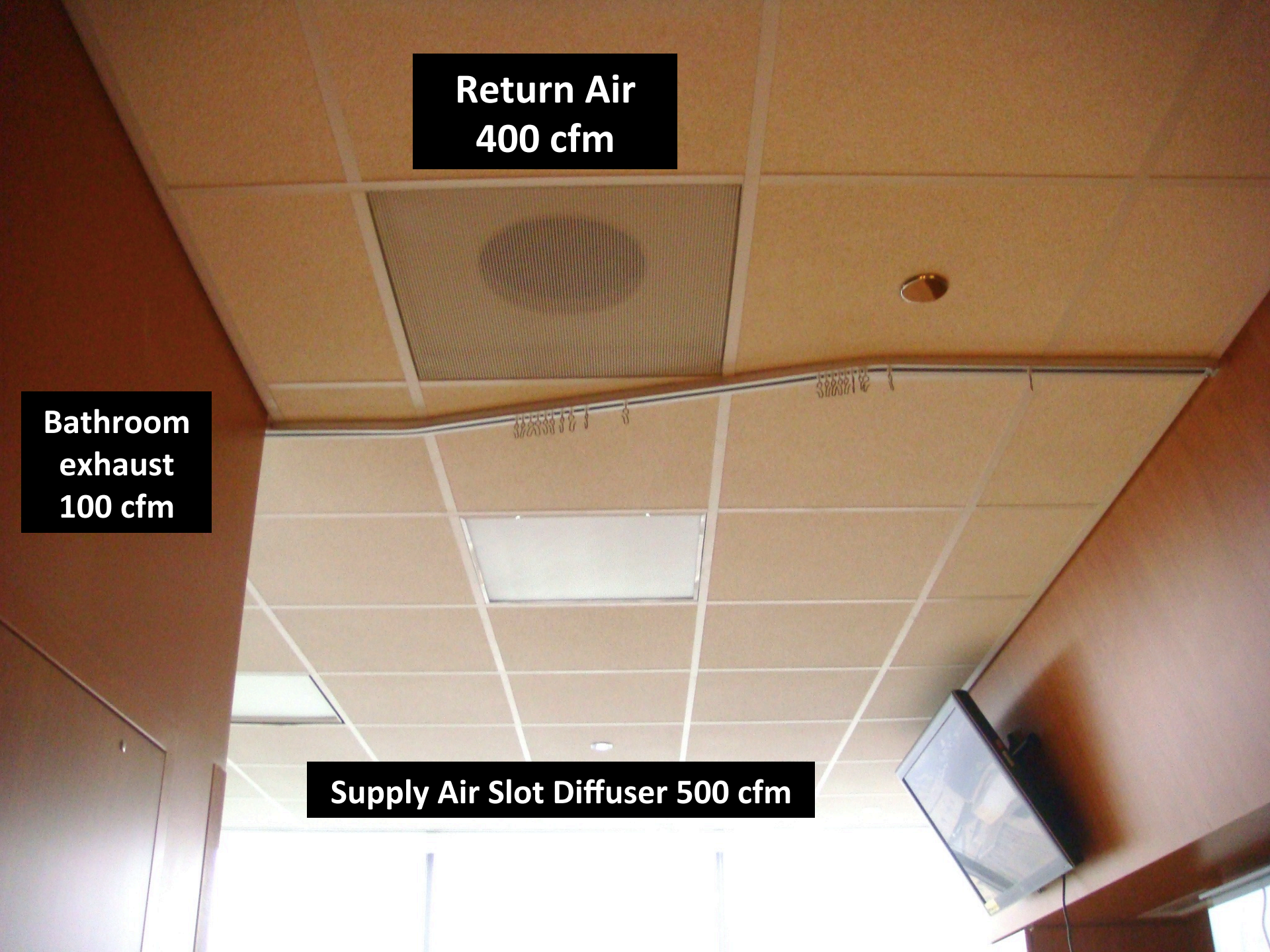
Supply Air Slot Diffuser ~500 cfm w/ reheat coils

Data Logger (attached with adhesive) measuring temperature, relative humidity and light

Differential Pressure Sensors (in black box with batteries, attached with adhesive), data logger, clear tube running to outer door frame
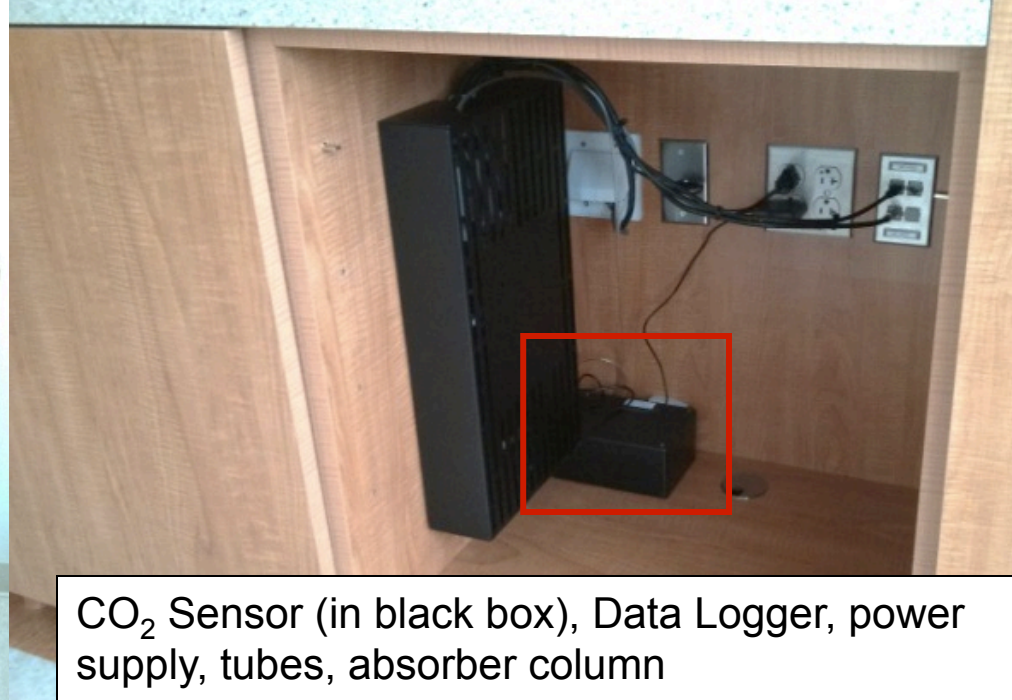
CO$_2$ Sensor (in black box), Data Logger, power supply, tubes, absorber column
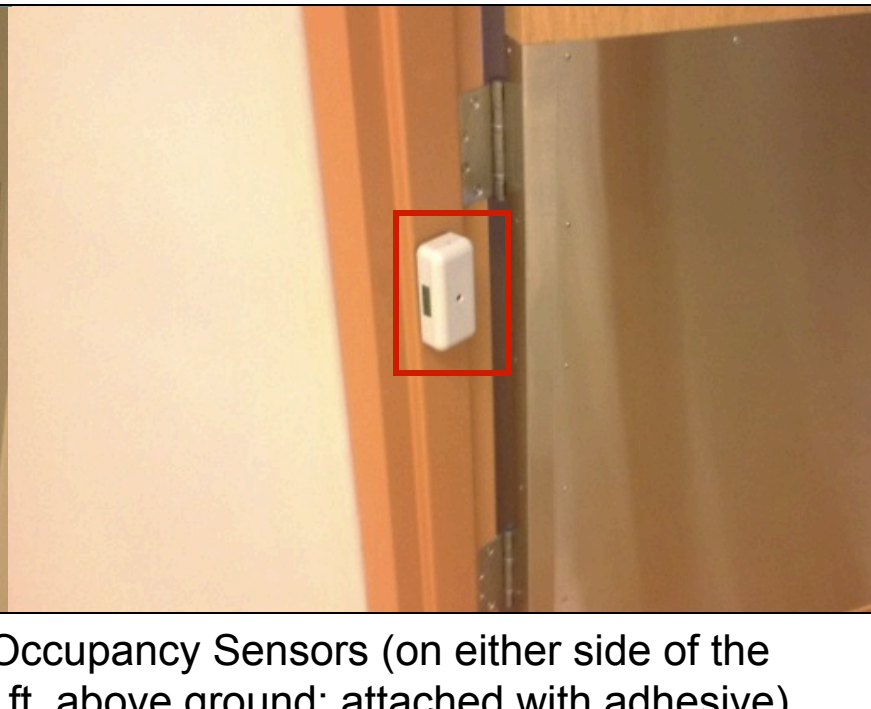
Beam-break Occupancy Sensors (on either side of the door frame, 2 ft. above ground; attached with adhesive)

Status update

- Weekly visits for data download and general maintenance
  - We just finished data collection on January 15th
  - Both biological sampling and building science measurements

- Still working to process data and QA/QC
  - Will end up with about 70 measures with about 100,000 data points each
  - Primary purpose is to provide measures for bio team to compare diversity and abundance to
    - Secondary purpose is simply to quantify some detailed operational characteristics of a new hospital

- Very important note for future projects:
  - Initial experimental plan was fully developed but was not approved by IL Department of Public Health in time to implement
  - **Poor communication among relevant parties**

PRELIMINARY BUILDING SCIENCE DATA

Data snapshot: Patient room air temperatures
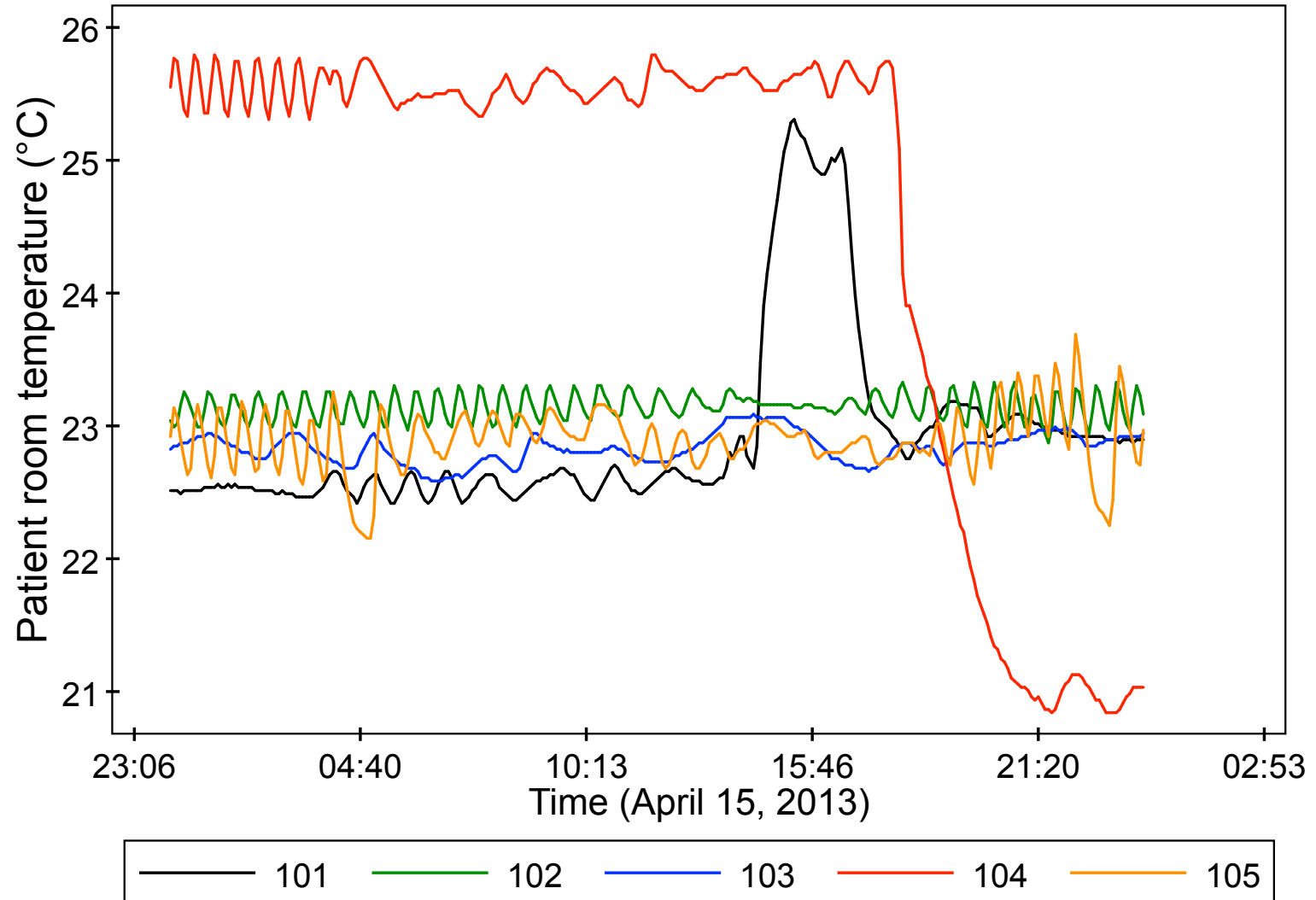
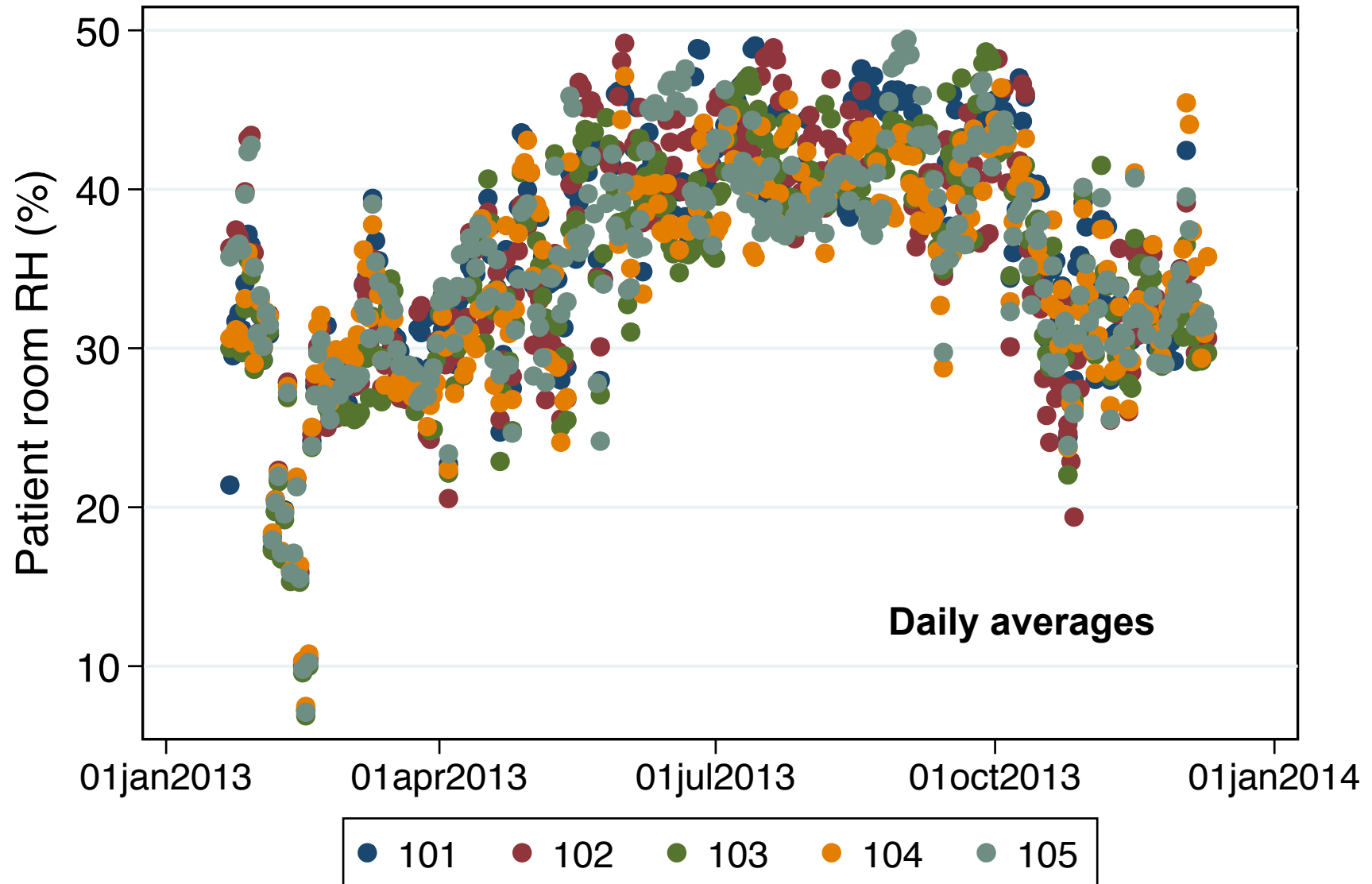*Considerable variation in temperatures both between and within rooms*

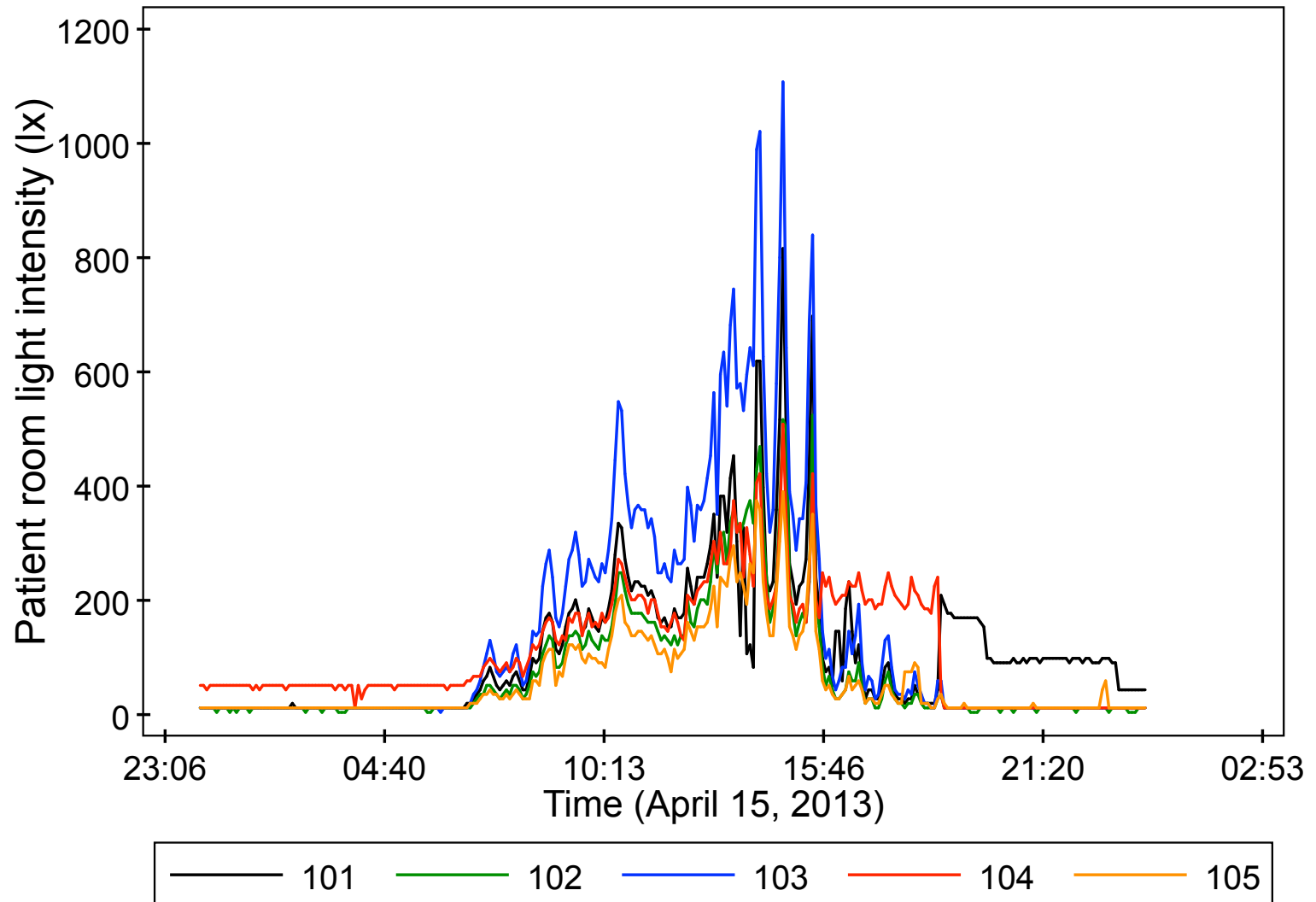# Data summary: Patient room air temperatures
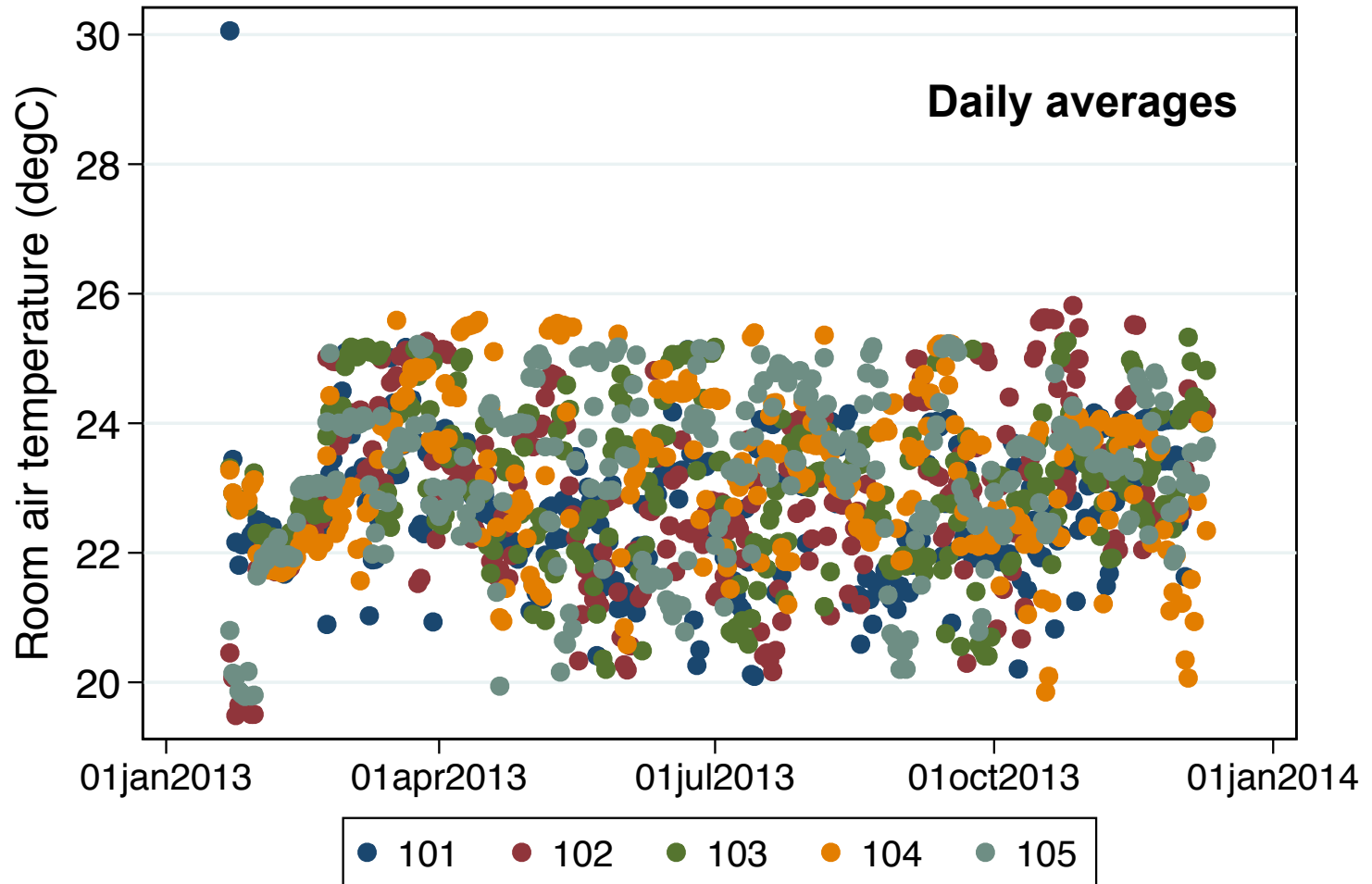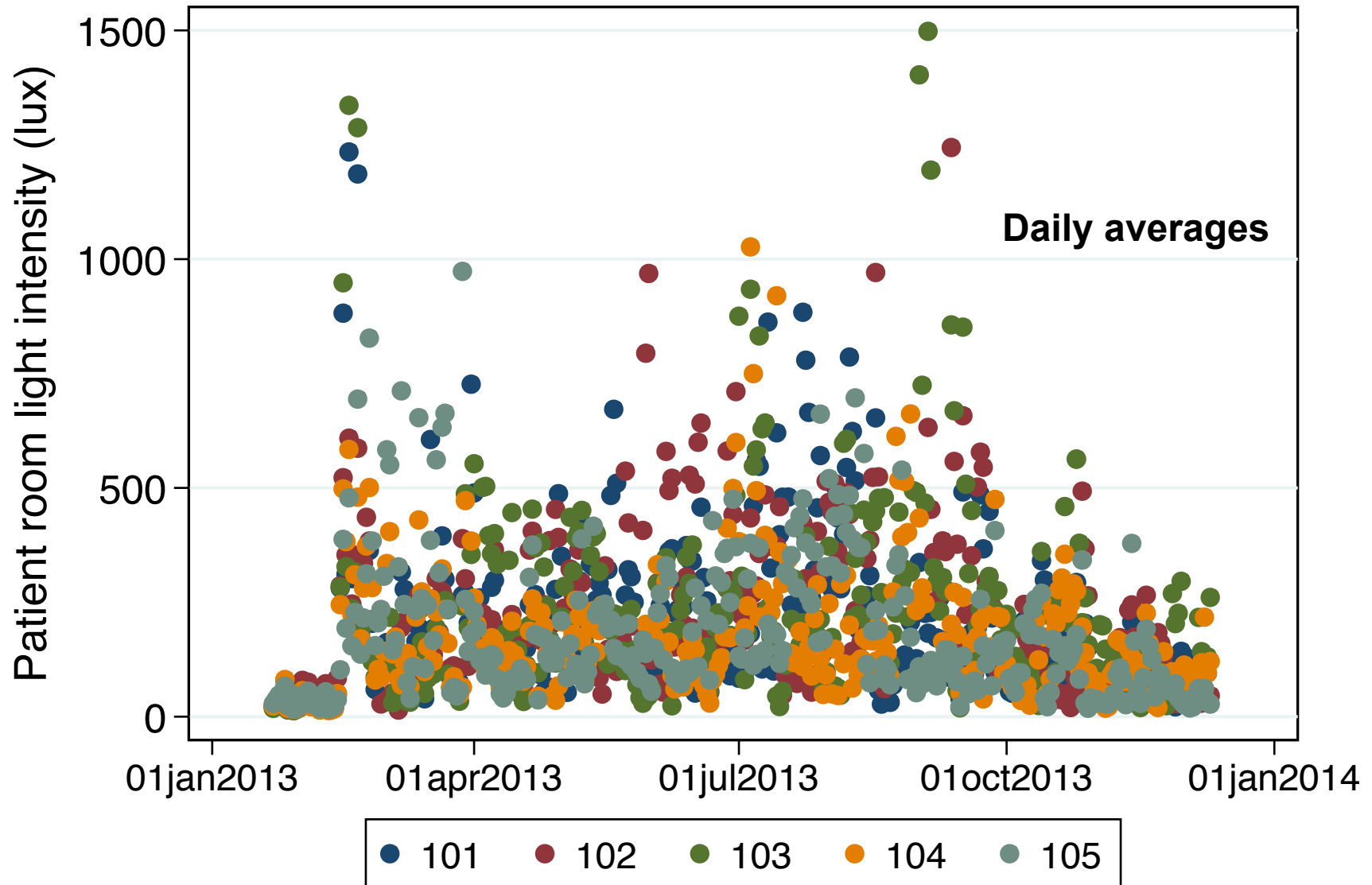
Data snapshot: Patient room RH

Data summary: Patient room RH
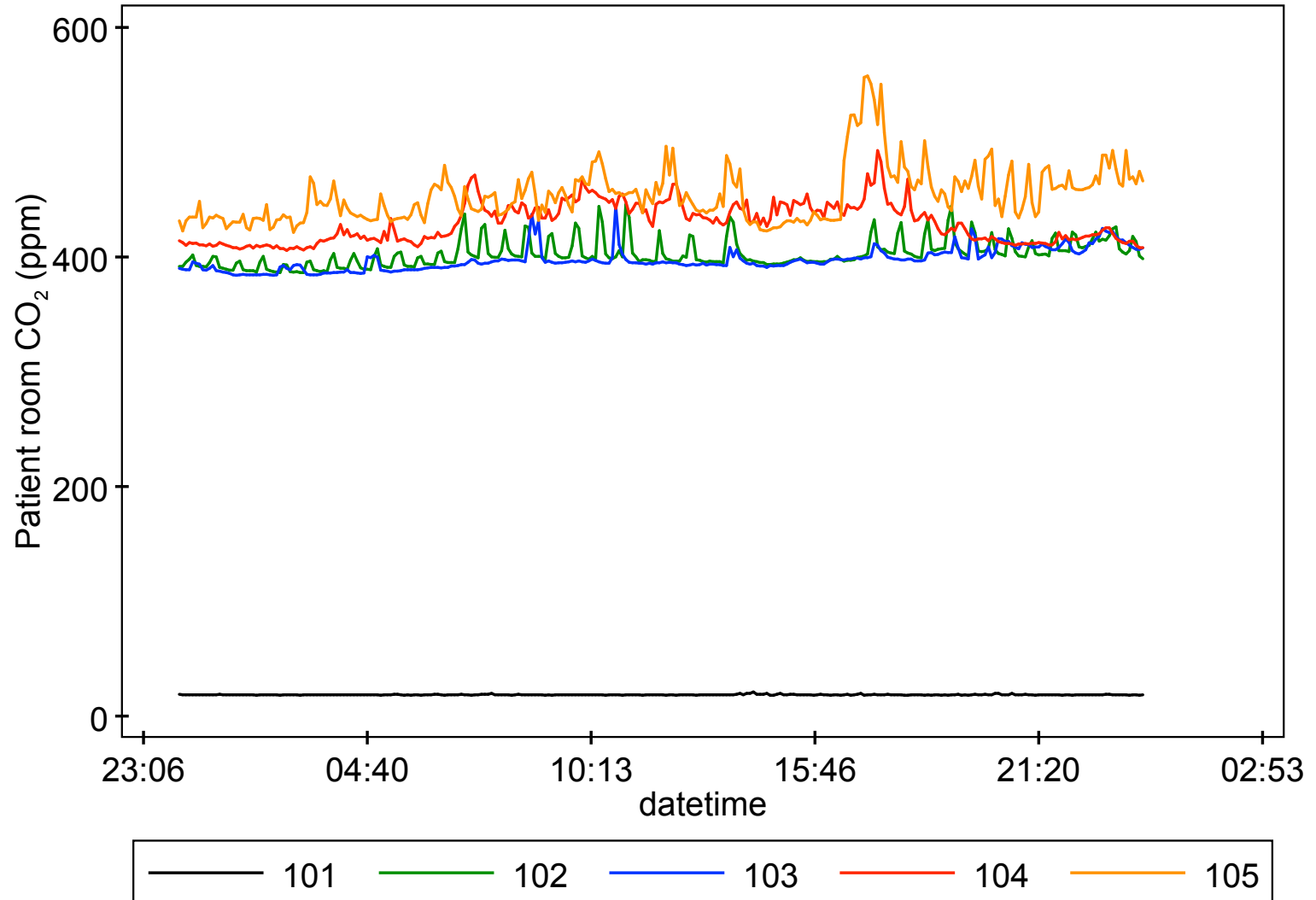
Daily averages

Legend: 101, 102, 103, 104, 105
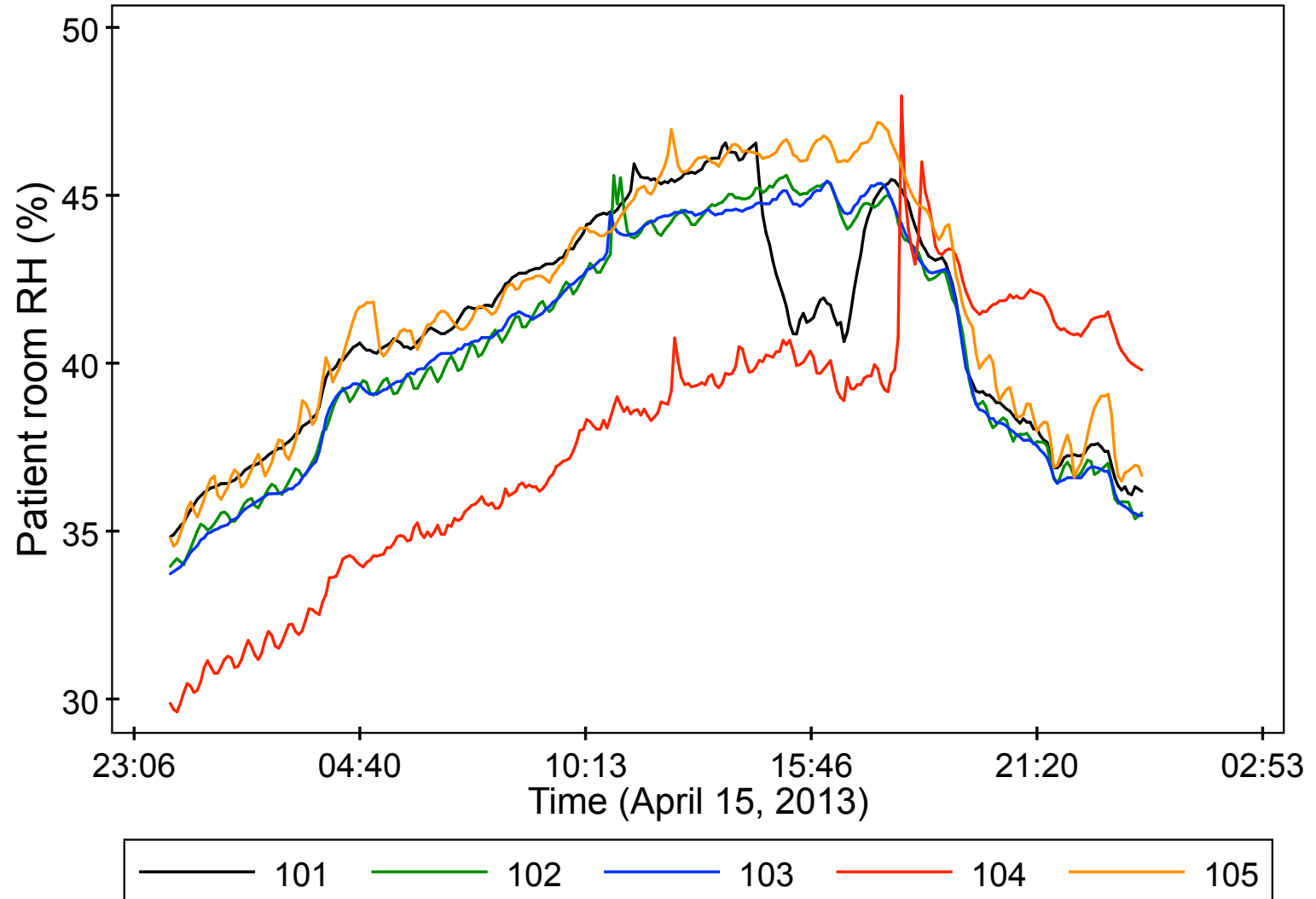
Data snapshot: Patient room light intensity

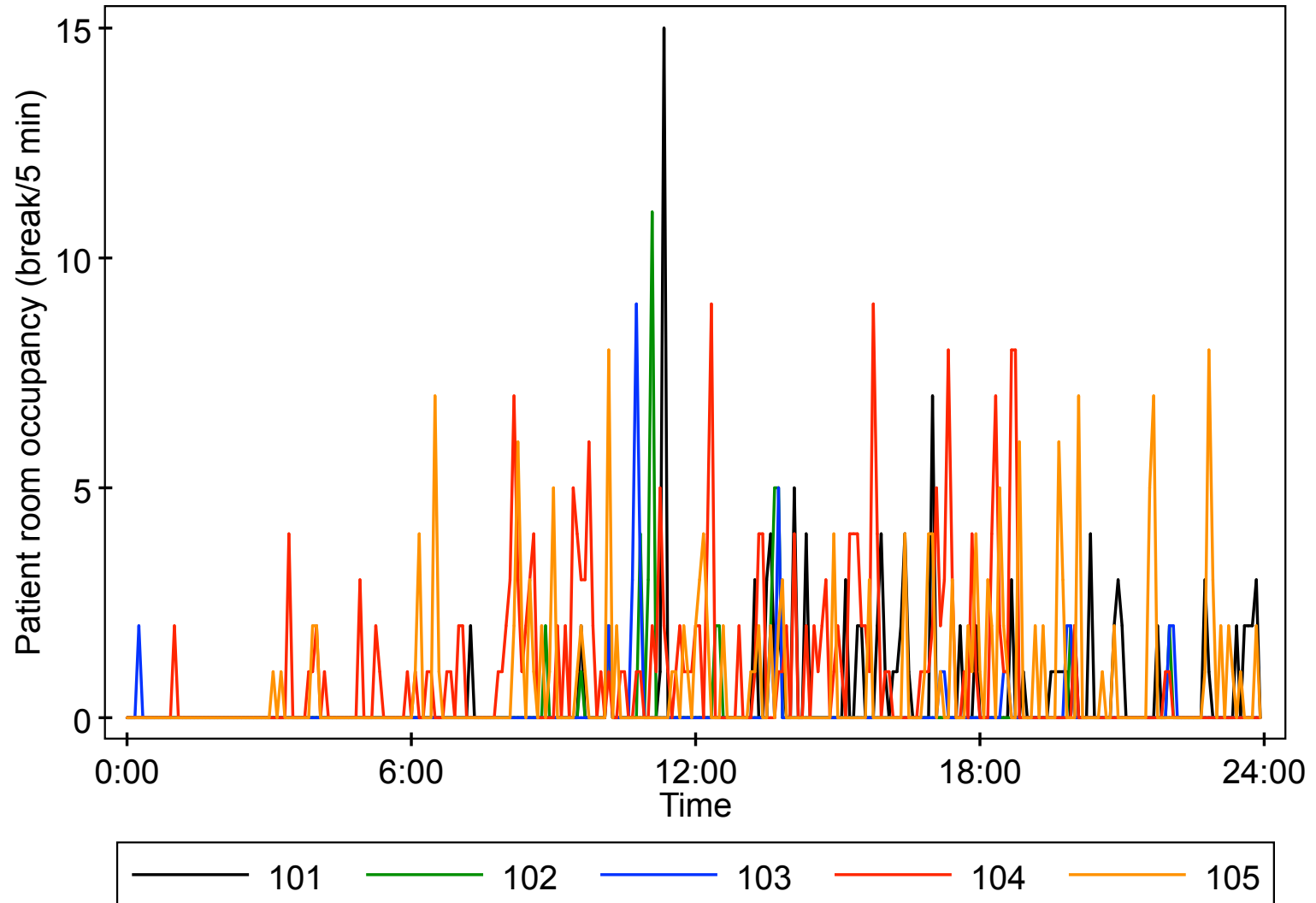Data summary: Patient room light intensity

Data snapshot: Patient room CO$_2$

legend: 101, 102, 103, 104, 105

Data snapshot: Occupancy sensors

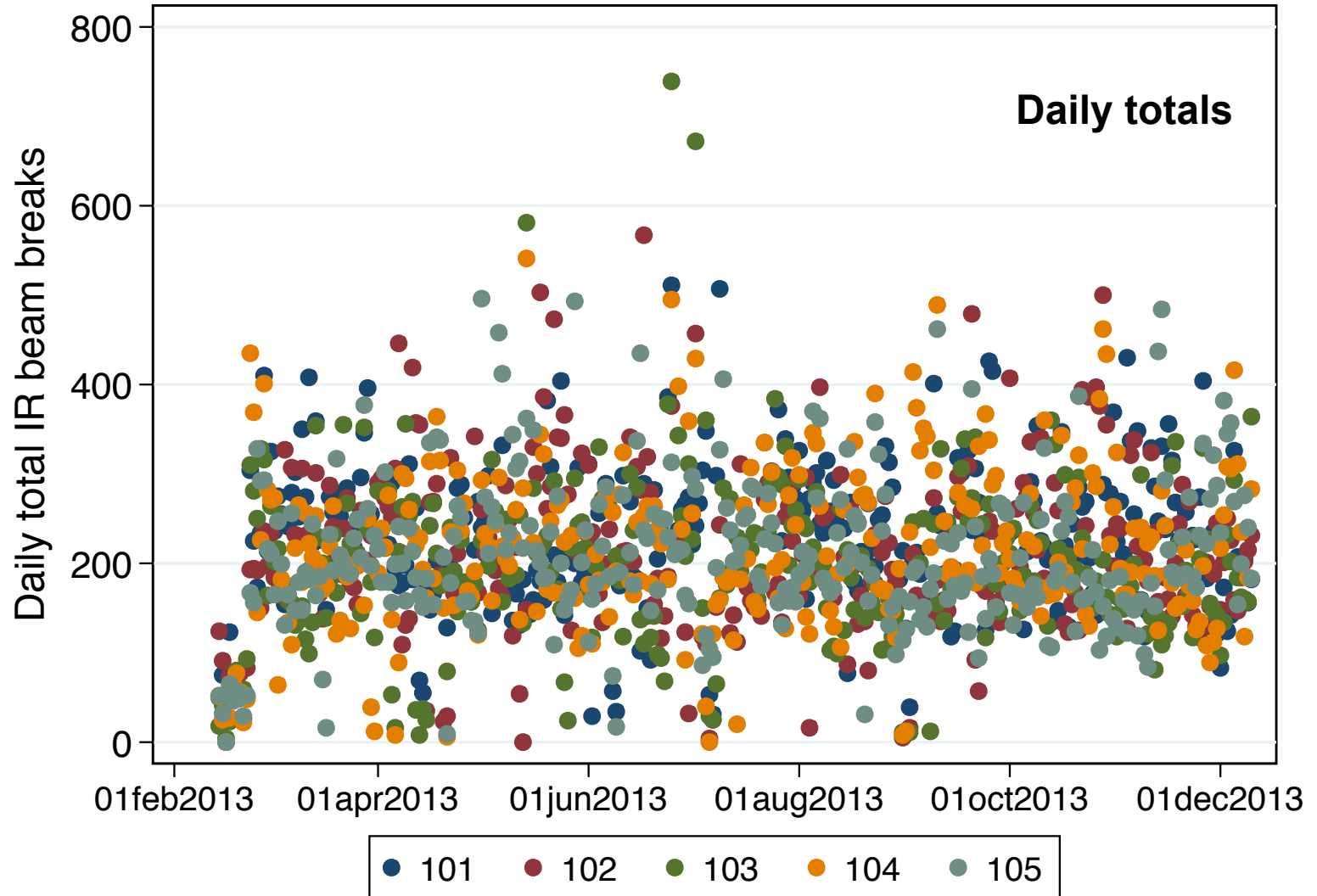Total beam breaks over 24-hour period (April 15, 2013)
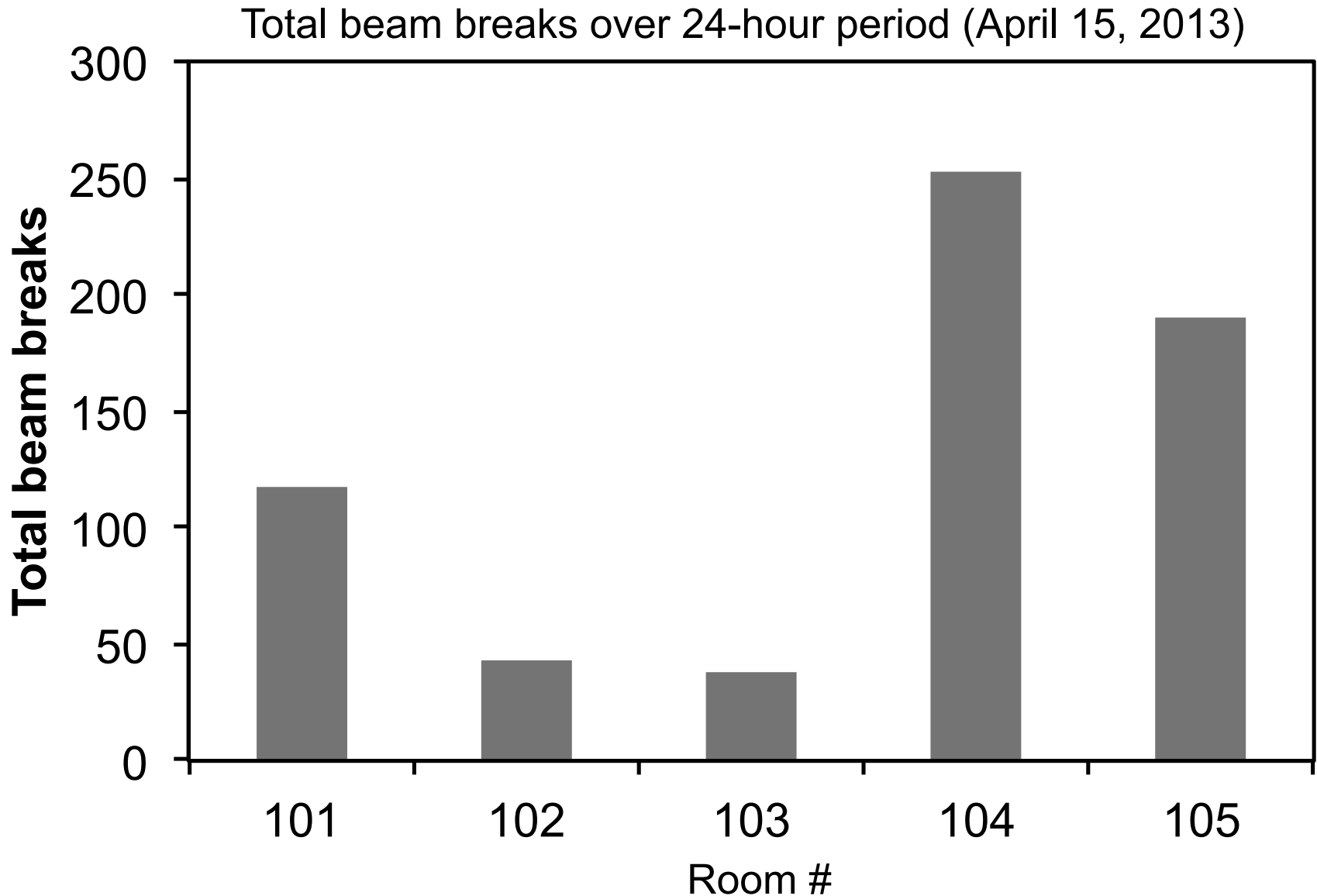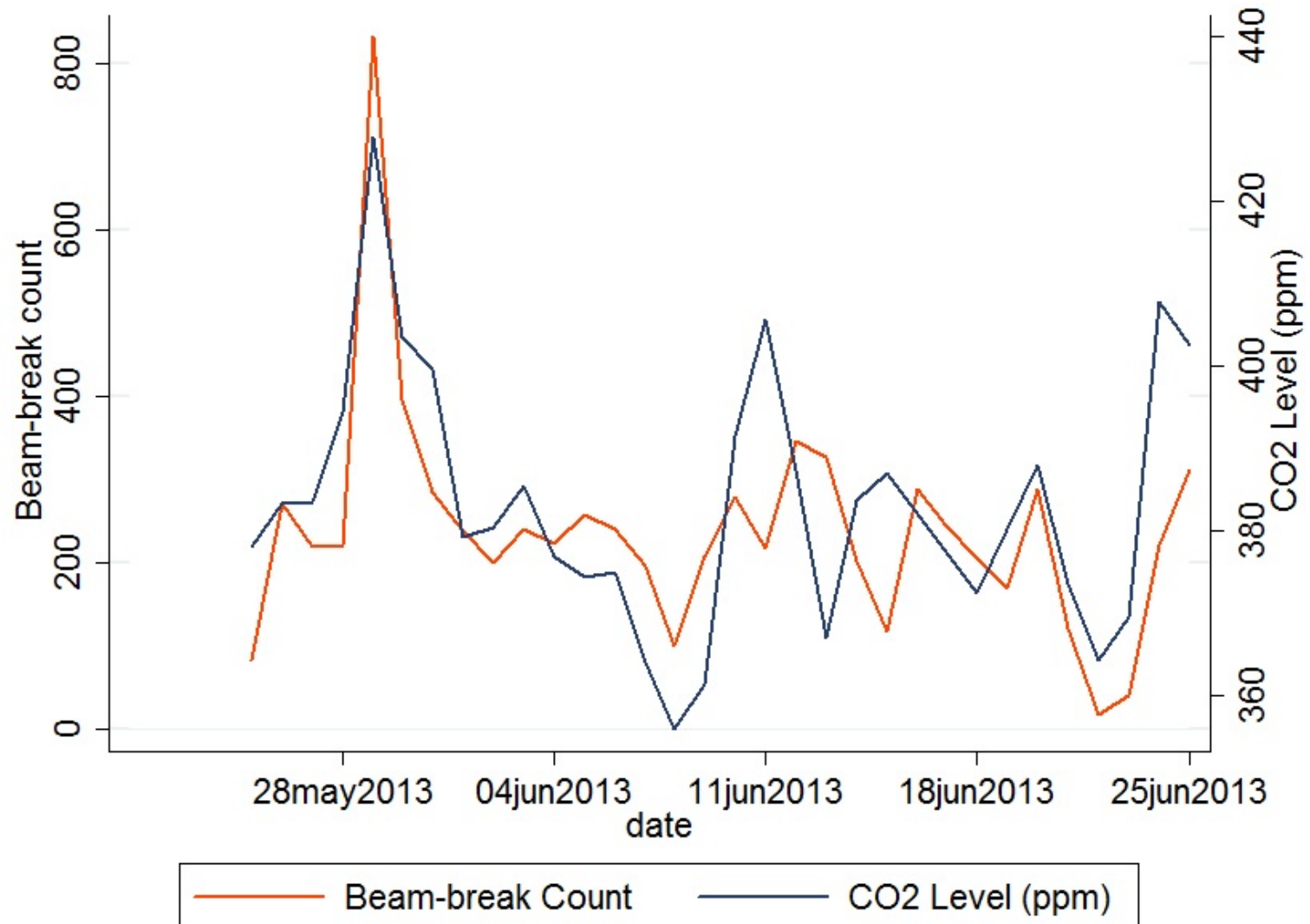
Data snapshot: Occupancy sensors

5-min beam breaks over 24-hour period (April 15, 2013)
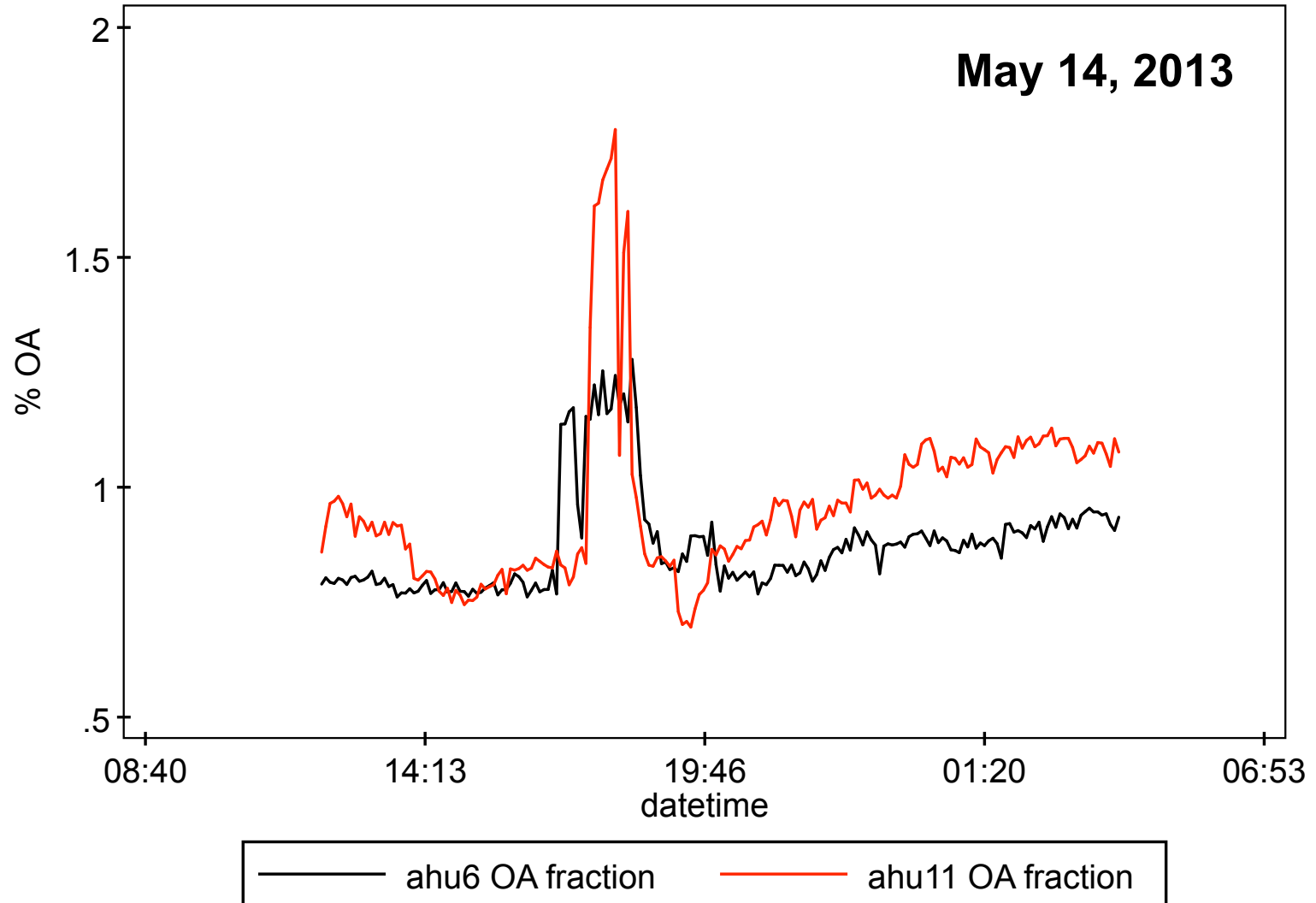
Data summary: Occupancy sensors
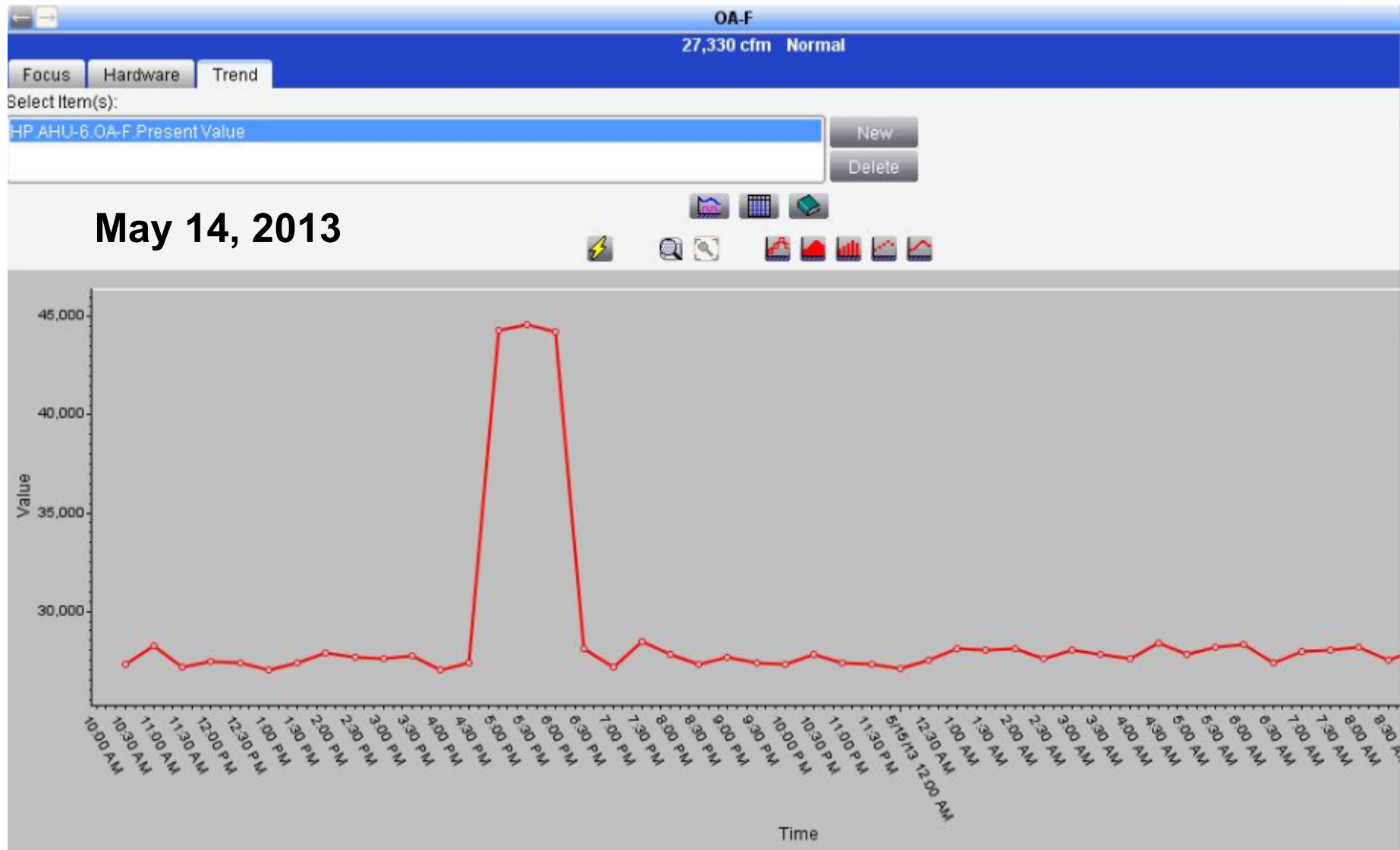
Occupancy: CO2 + IR beam break sensor data

We're seeing decent correlations between daily beam breaks and average CO_2 concentrations
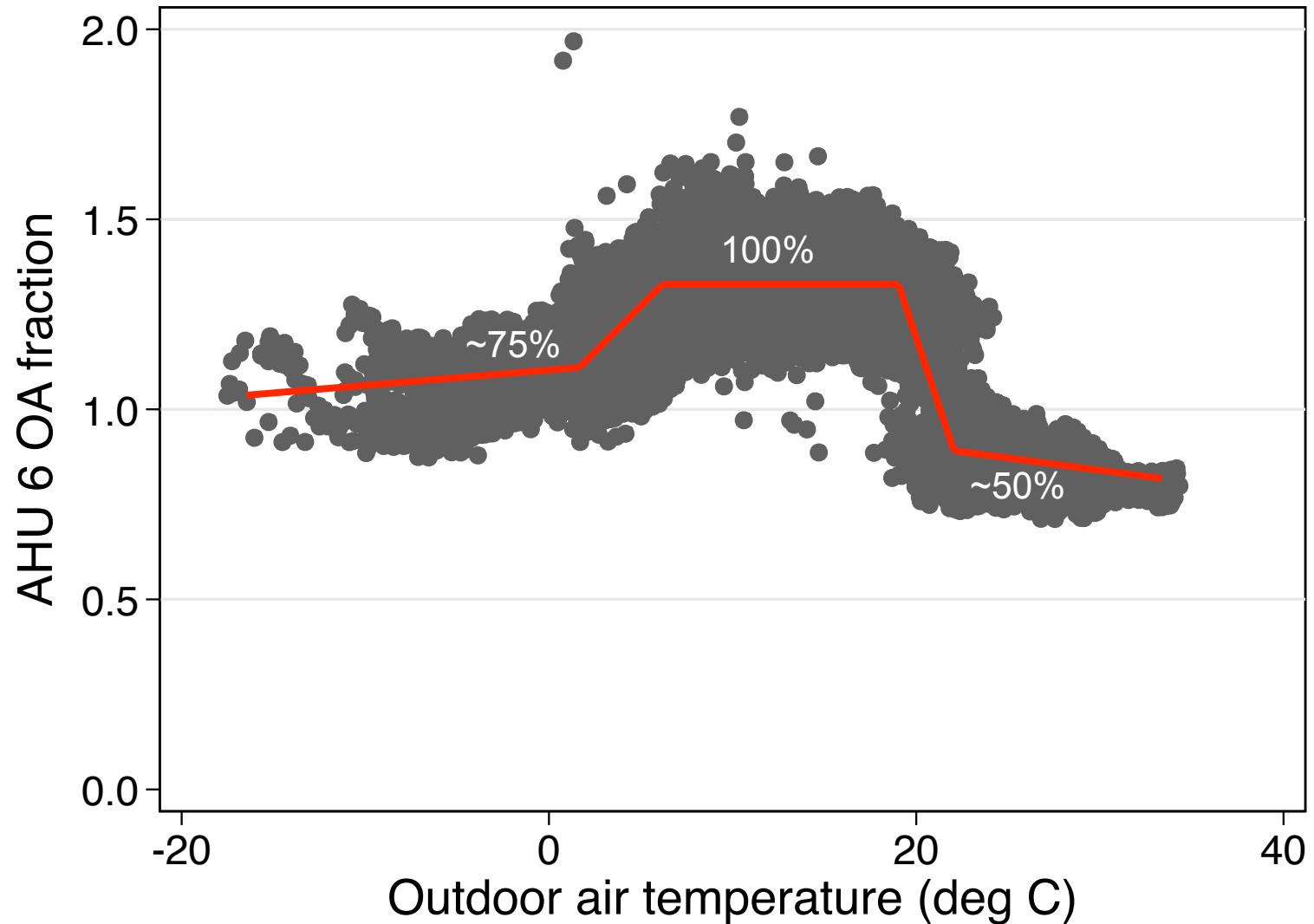
Data snapshot: % outdoor air

May 14, 2013

Issues with scaling due to low RA CO_2 concentrations

Data snapshot: Hospital plant OA flow

Calibrating OA measurements: %OA vs. outdoor T

HVAC filter bioaerosol 'sampler'

Magnetic filter frame

- Sterilized and replaced weekly in all 10 patient rooms
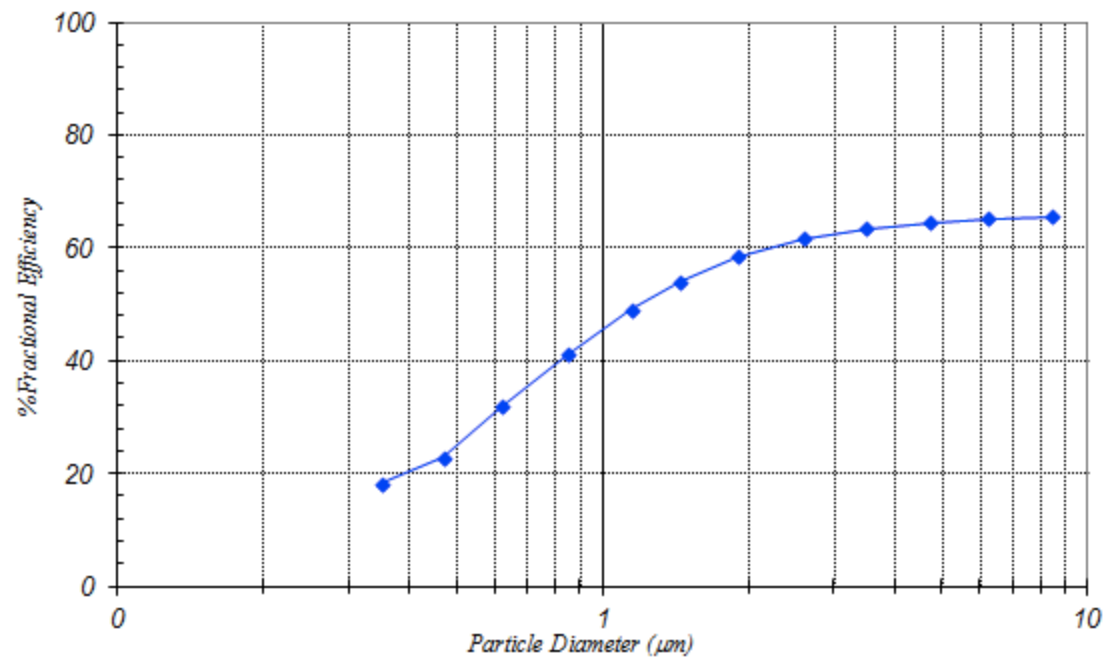
*Courtesy of Kevin Kinzer

Summary

- Environmental conditions (T/RH/light) vary more than expected both between rooms and within rooms

  - So does occupancy/activity

- CO_2 + single direction beam break sensors appear to work reasonably well for occupancy detection

  - Dual beam break would be better

- OA fractions are difficult to determine accurately

  - But likely do not matter much because of HEPA filtration on supply air

- Room pressurization is neutral in the sample locations

  - Likely minimal impact between rooms and hallways

Brent Stephens

brent@iit.edu