

Ecologically-Valid, Multimodal Data Collection Platforms to Measure the Effects of Indoor Air Quality on Sleep Quality



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WHAT STARTS HERE CHANGES THE WORLD

Study Design

Indoor Environmental Monitor

Measure Bedroom IAQ

~250,000 data points

CO₂

TVOCs

CO

Temperature

PM

Relative Humidity

Smartphone App

GPS

ensure participant is home

Sleep Survey

(n = 177)

4 *subjective* sleep metrics

Wearable Fitness Tracker

Detect Sleep Events

(n = 263)

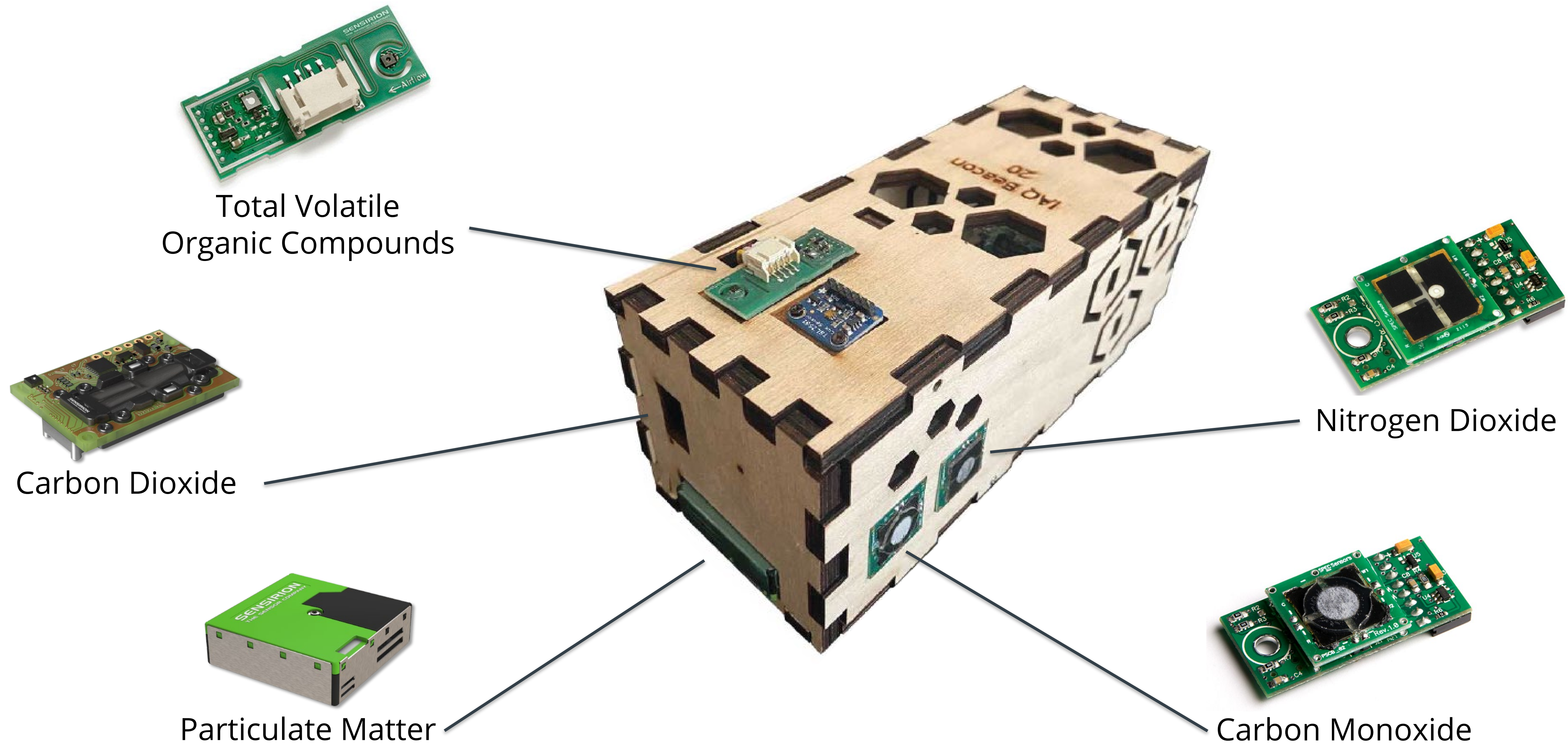
ensure bedroom is occupied

Sleep Monitoring

3 *objective* sleep metrics

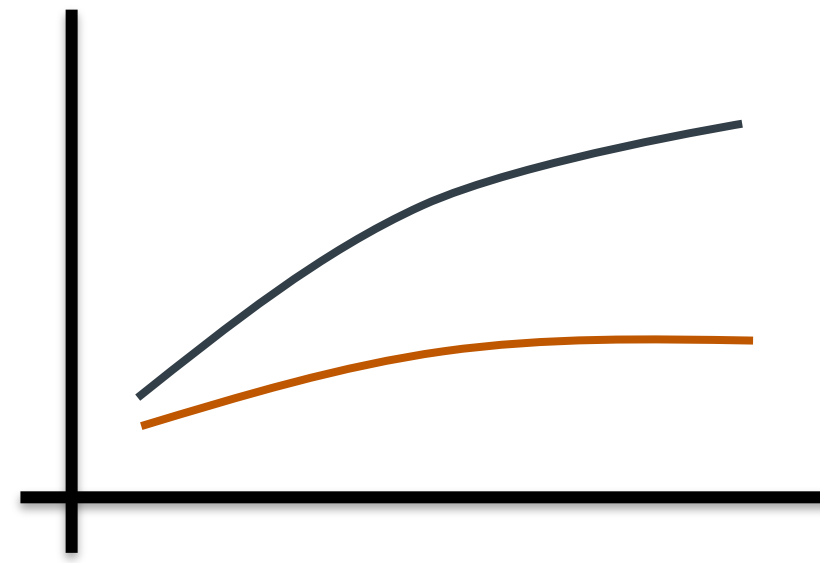
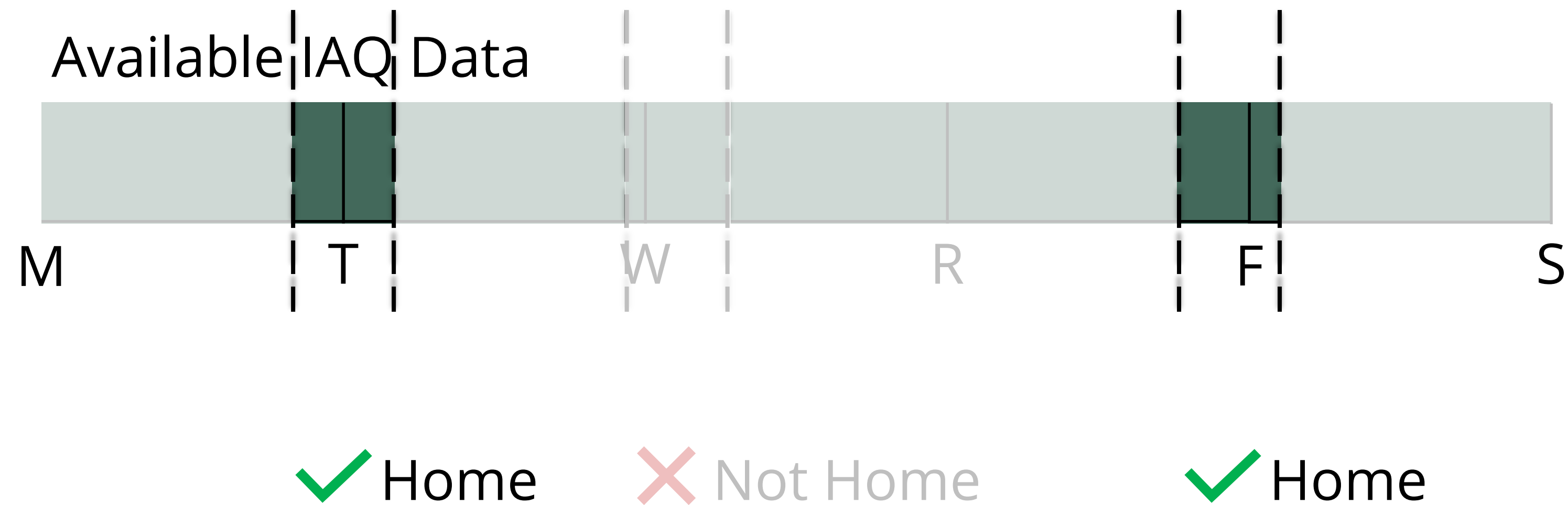
20 Participants

11 weeks during Summer 2020



Paper in review. All software, hardware, and design files available:
github.com/intelligent-environments-lab/bevo_iaq

Filtering IAQ Data



Wearable Fitness Tracker
Identify sleep events

Smartphone App
Compare GPS coordinates
to home address

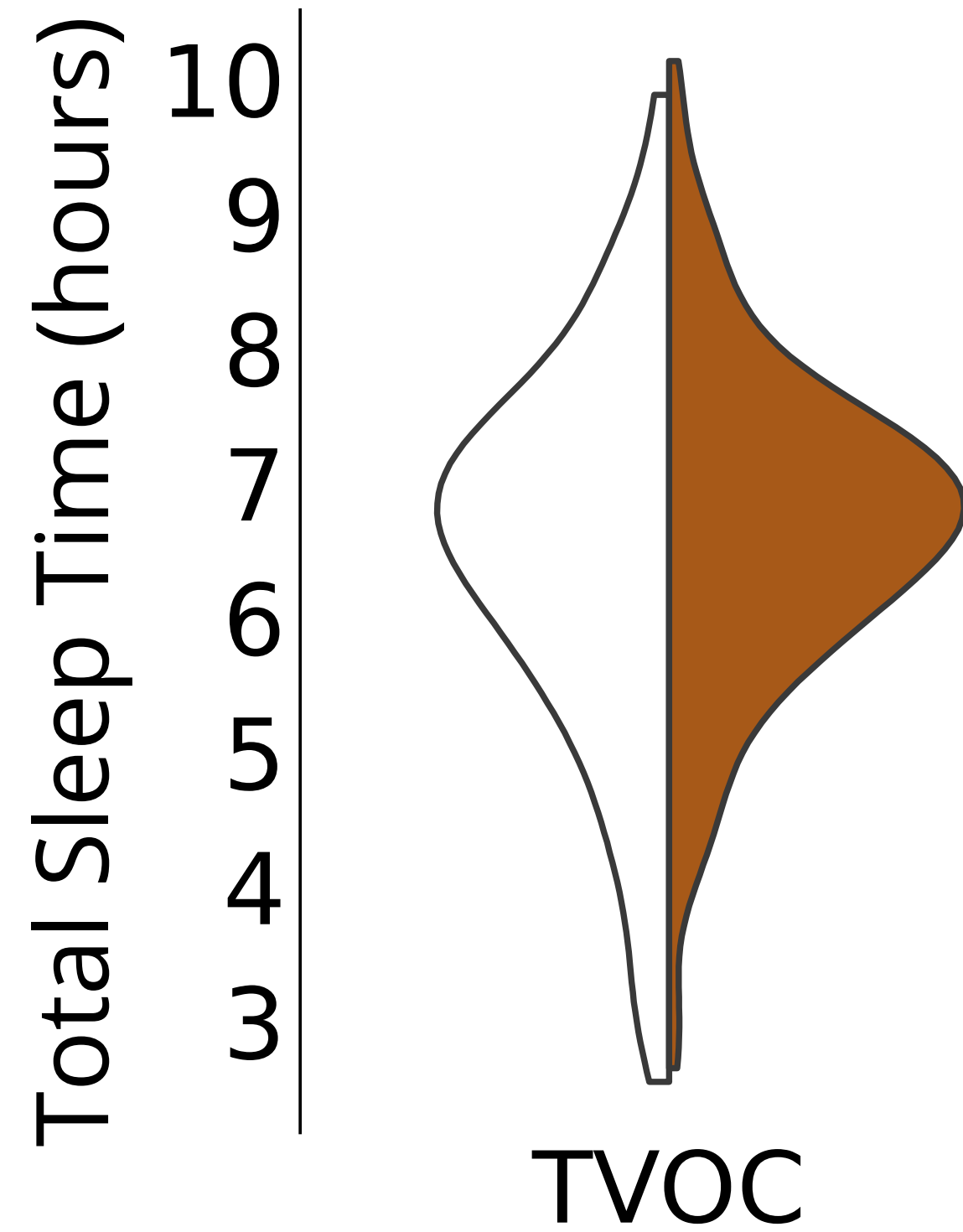
BEVO Beacon
Check CO₂ and T

Processing IAQ Data

Describe nightly IAQ measurements with median value

Compare to standards to determine nights with poor IAQ

Parameter	Threshold	From	Notes
TVOC	200 ppb	WHO	Twice sensory irritation
CO ₂	1100 ppm	ASHRAE	Based on Standard 62.2
CO	4 ppm	WHO	Maximum 24-hour exposure
PM _{2.5}	12 $\mu\text{g}/\text{m}^3$	US EPA	Half NAAQS annual exposure
Temperature	25.2°C (77.4°F)	This Study	median nightly concentration



Median Concentration



low



high

Summary of Results

Elevated TVOCs and PM_{2.5} associated with **improved** sleep quality

Elevated CO, CO₂, and T associated with **degraded** sleep quality

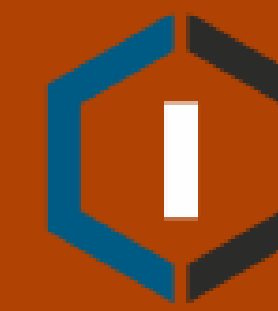
- SOL decreased when CO₂ or T was high

Elevated TVOCs and PM_{2.5} altered sleep staging

IAQ Parameter	Sleep Quality Metrics	
	Self-Report	Fitbit
↑ TVOC	–	↑ TST, ↑REM:nREM
↑ CO	↑ NAW	↓ TST, ↓ SE
↑ CO ₂	↓ restful, ↓ SOL	↓ TST
↑ PM _{2.5}	↑ restful, ↓ NAW	↑ SE, ↓REM:nREM
↑ T	↓ TST, ↓ NAW, ↓ SOL	↓ TST

TST: Total Sleep Time
NAW: Awakenings
SOL: Sleep Latency

SE: Sleep Efficiency
REM: Rapid-Eye-Movement



Conclusion

CGS for IAQ applications provide advantages over reference monitors:

- Affordability
- Scalable
- Availability
- Hassle
- Application

CGS can help address questions in an ecologically-valid manner

Data fusion helps improve accuracy/confidence of results

IAQ can affect objective *and* subjective measures of sleep

Fritz, Hagen, et al. "Data fusion of mobile and environmental sensing devices to understand the effect of the indoor environment on measured and self-reported sleep quality." *Building and Environment* 214 (2022): 108835.

Thank you!

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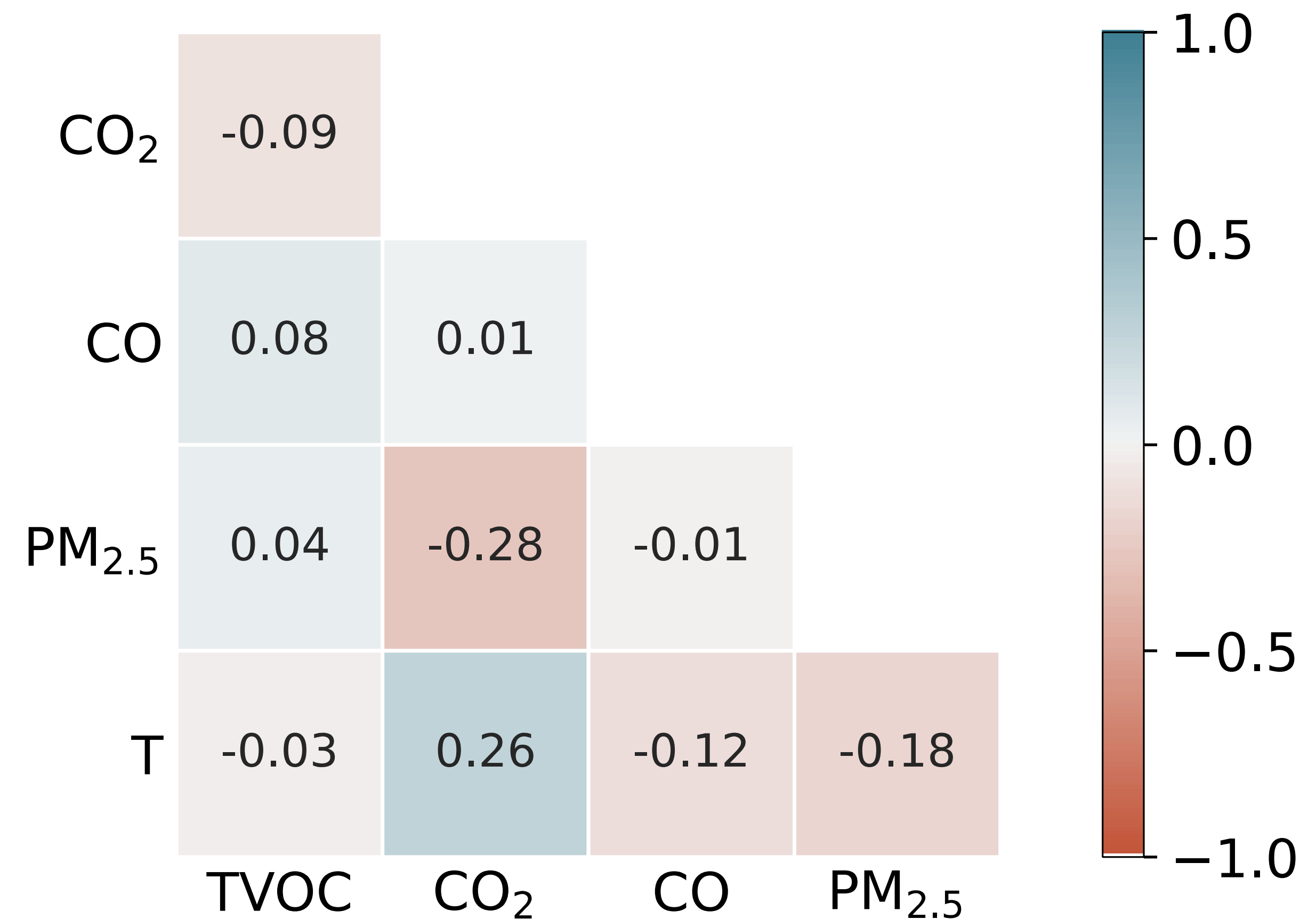
Melissa Miller

Reference Slides

Correlation Between IAQ Parameters

No significant relationships
between IAQ parameters

Factor analysis indicates that all
five parameters should be used
for analysis

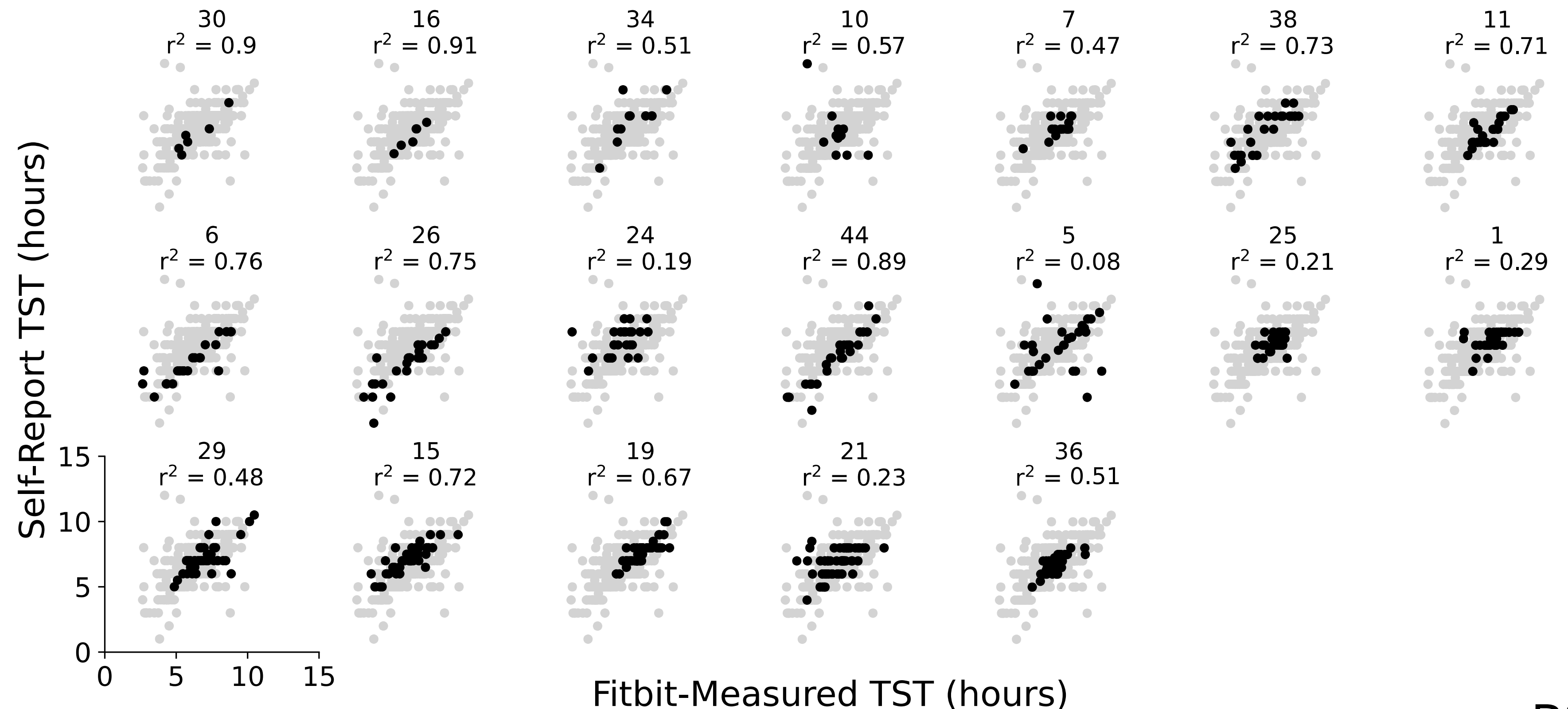


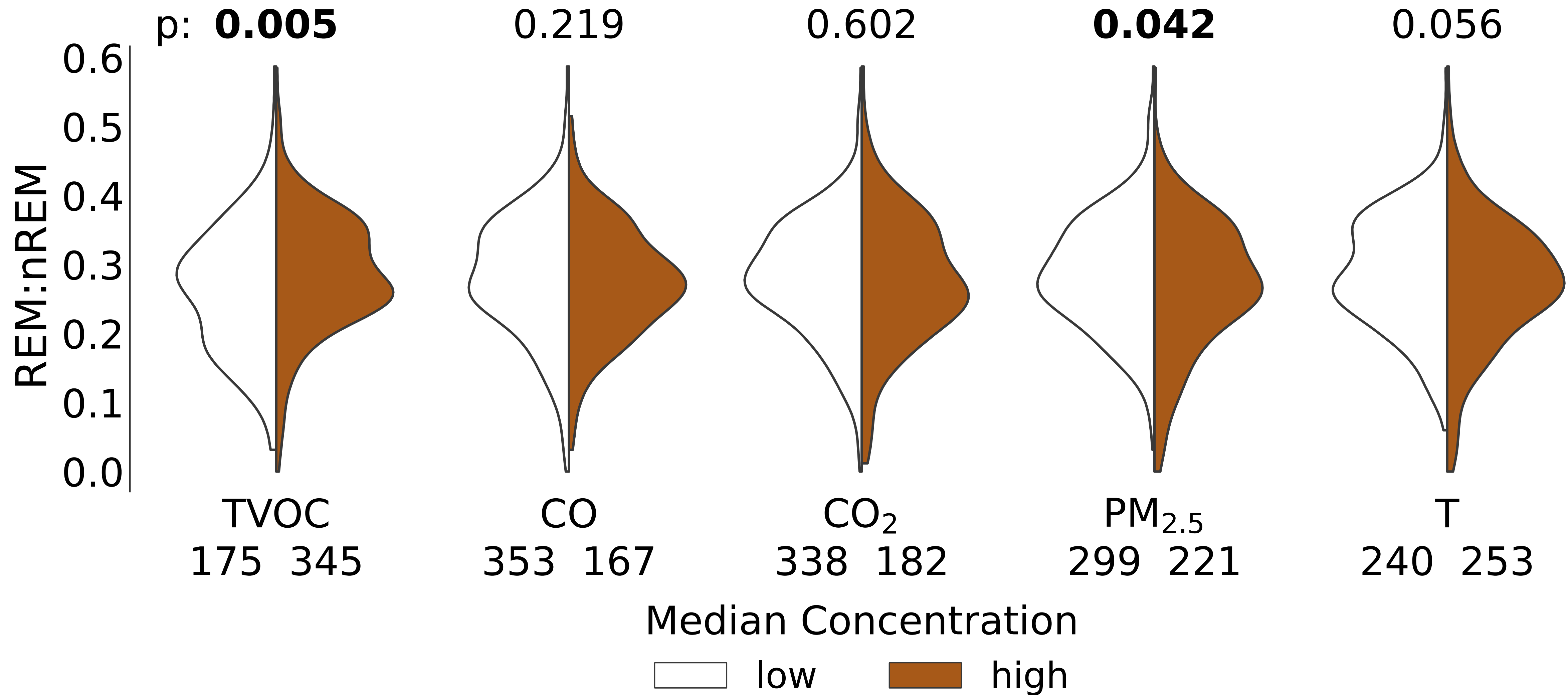
Sleep Quality and non-IAQ Parameters

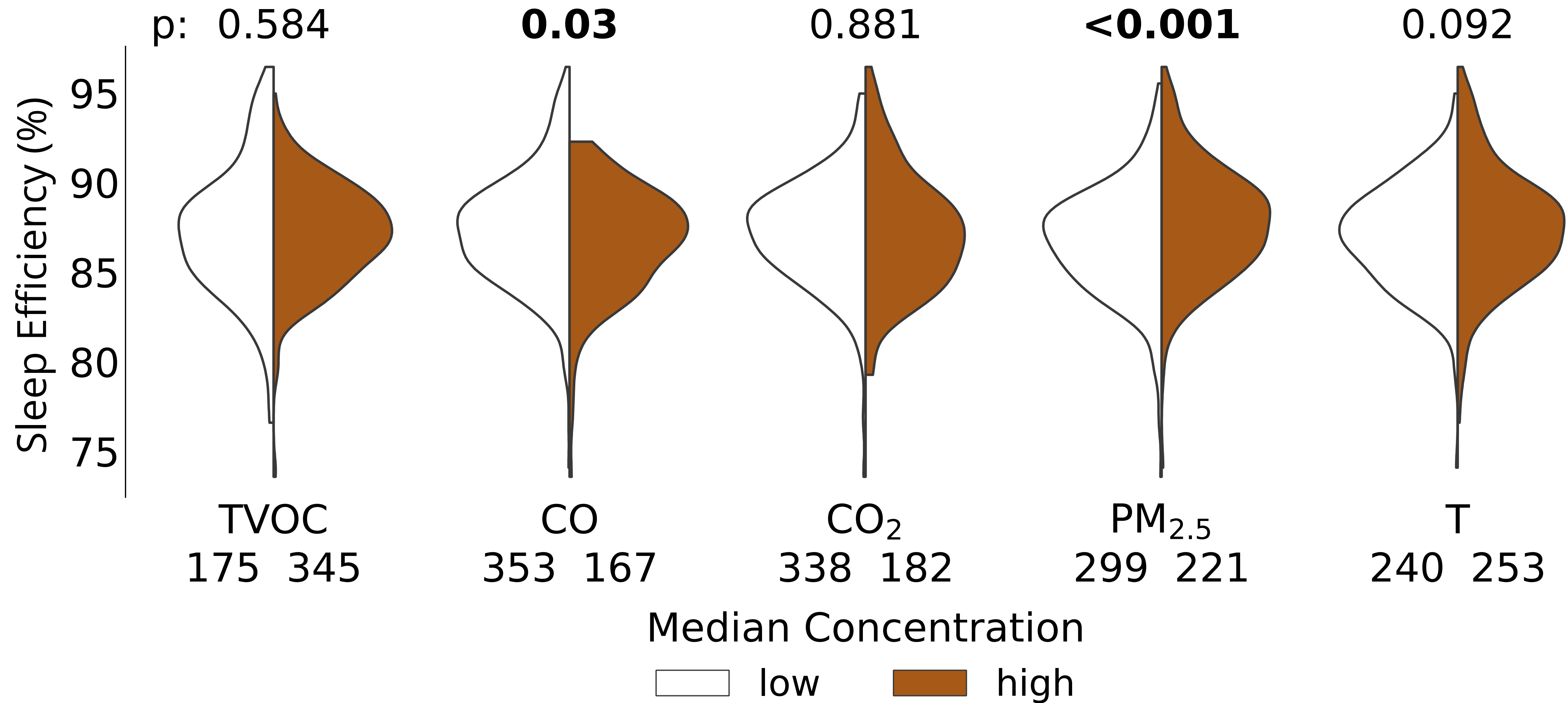
No significant relationships between sleep metrics and:

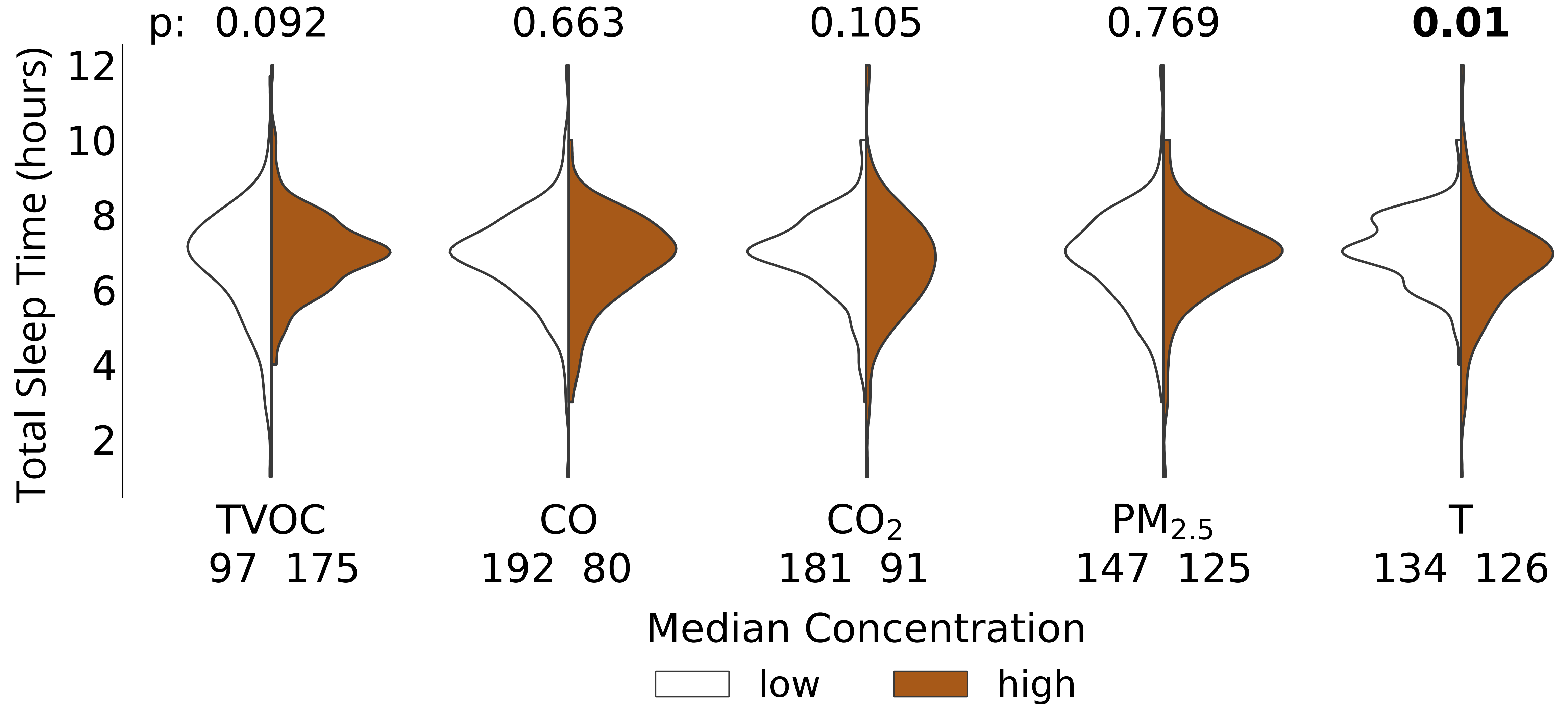
- Activity
- Mood

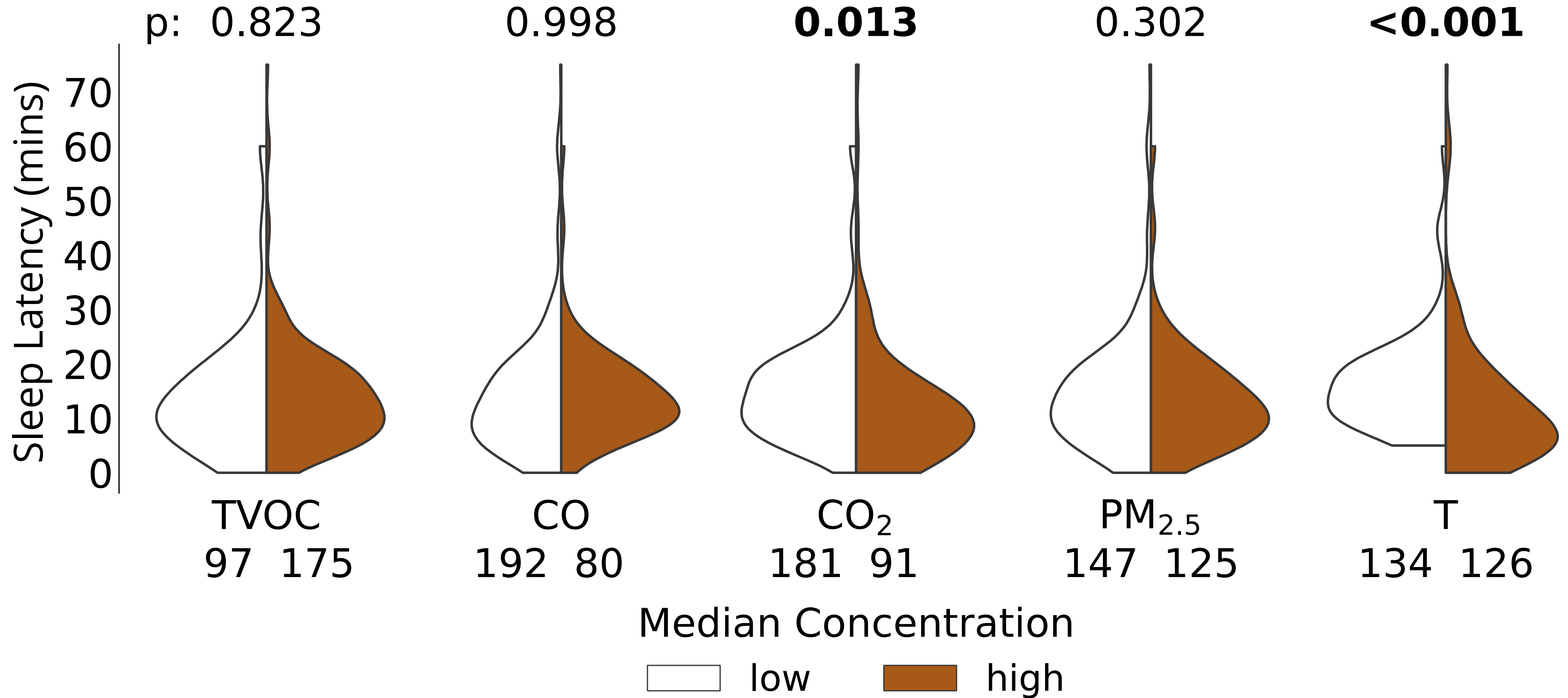
Only **TST** from Fitbit and EMAs are correlated

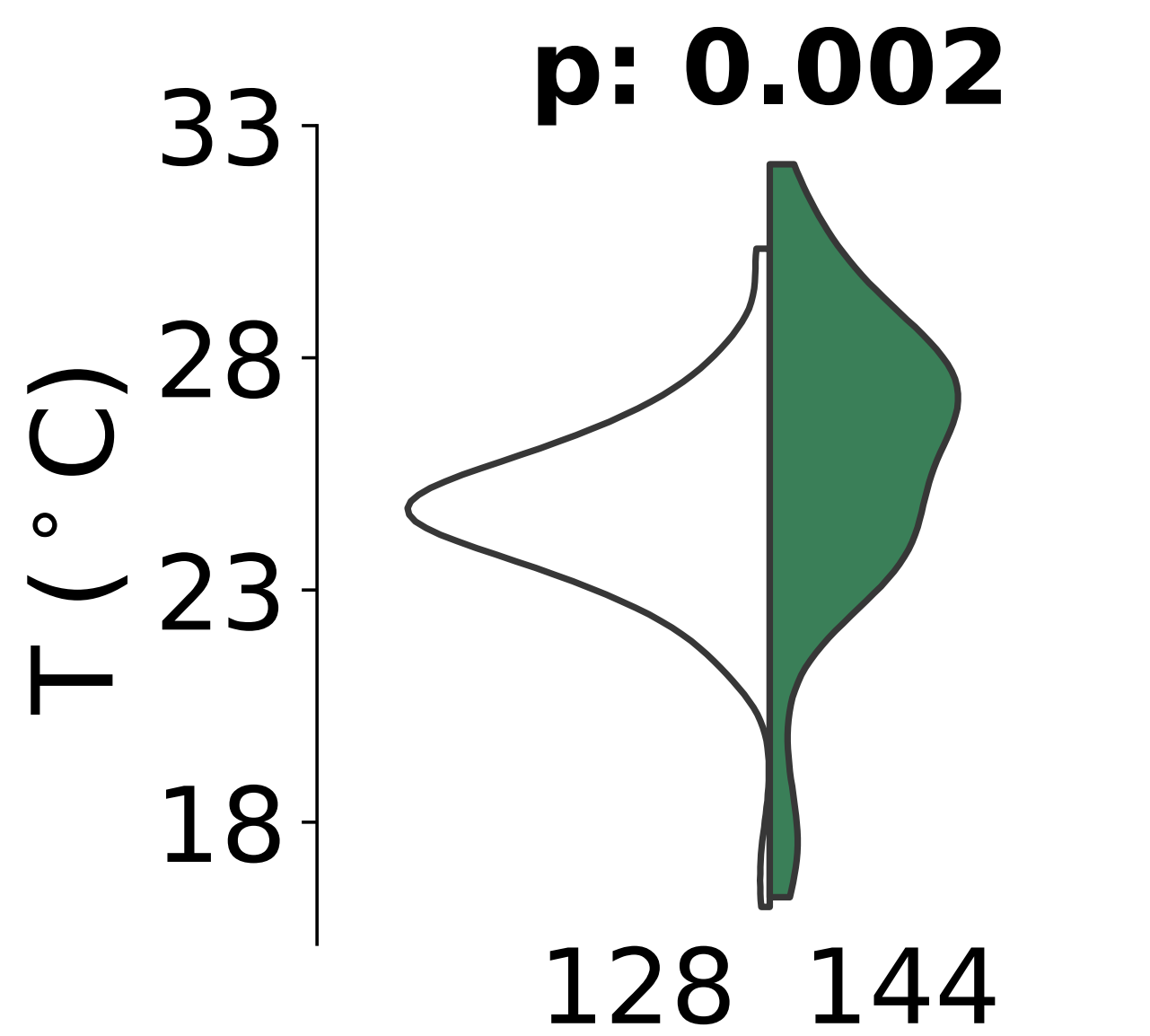
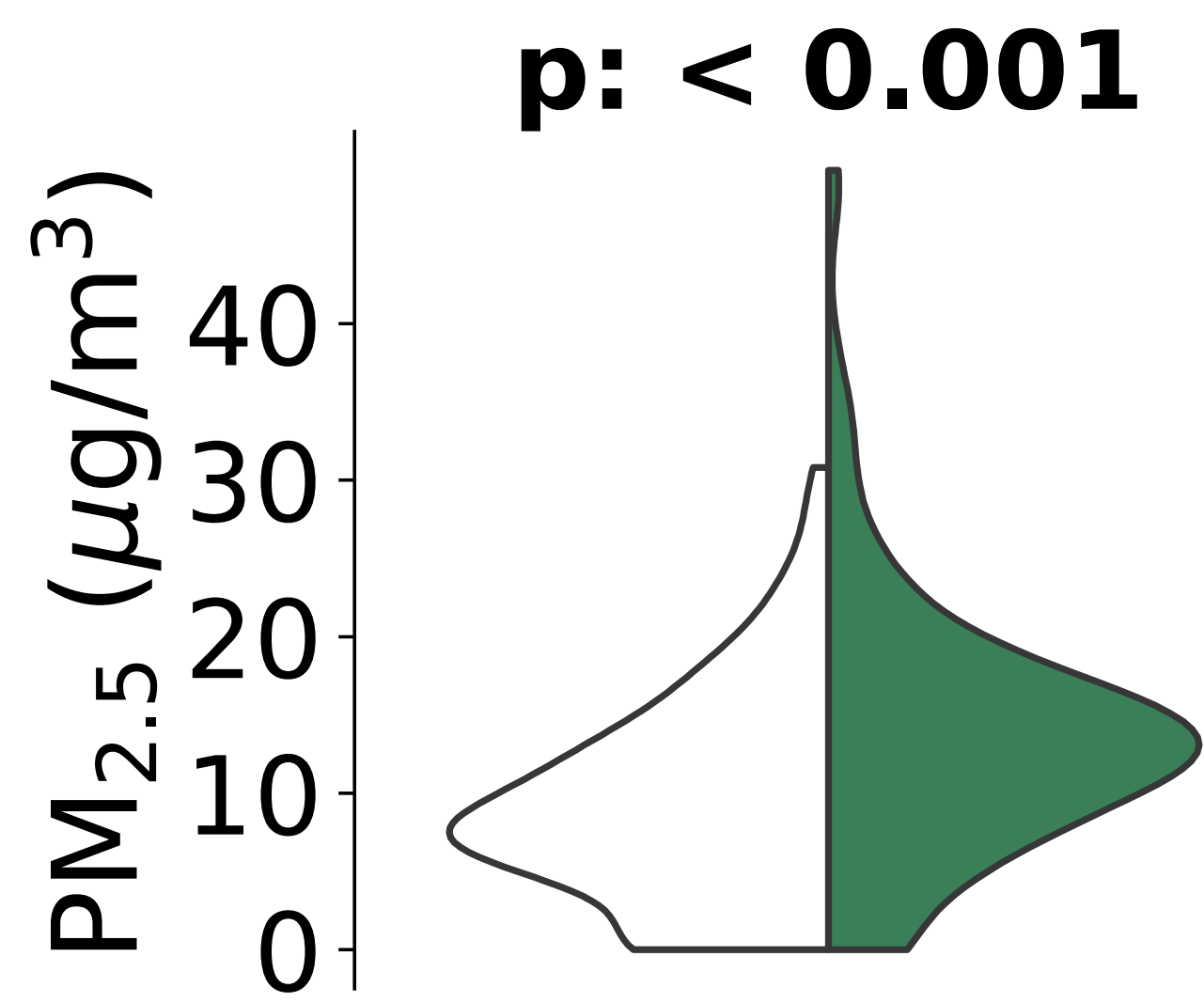
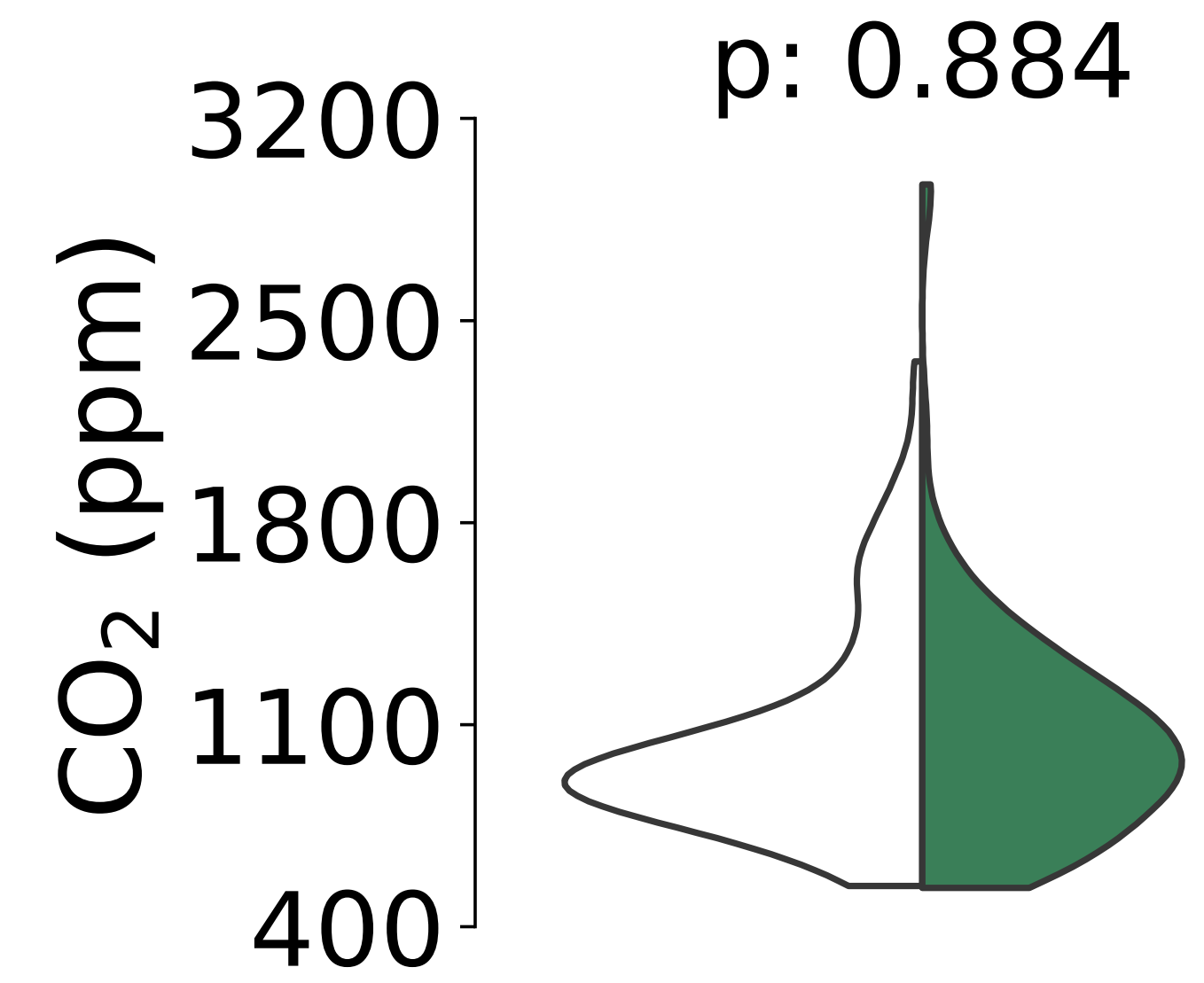
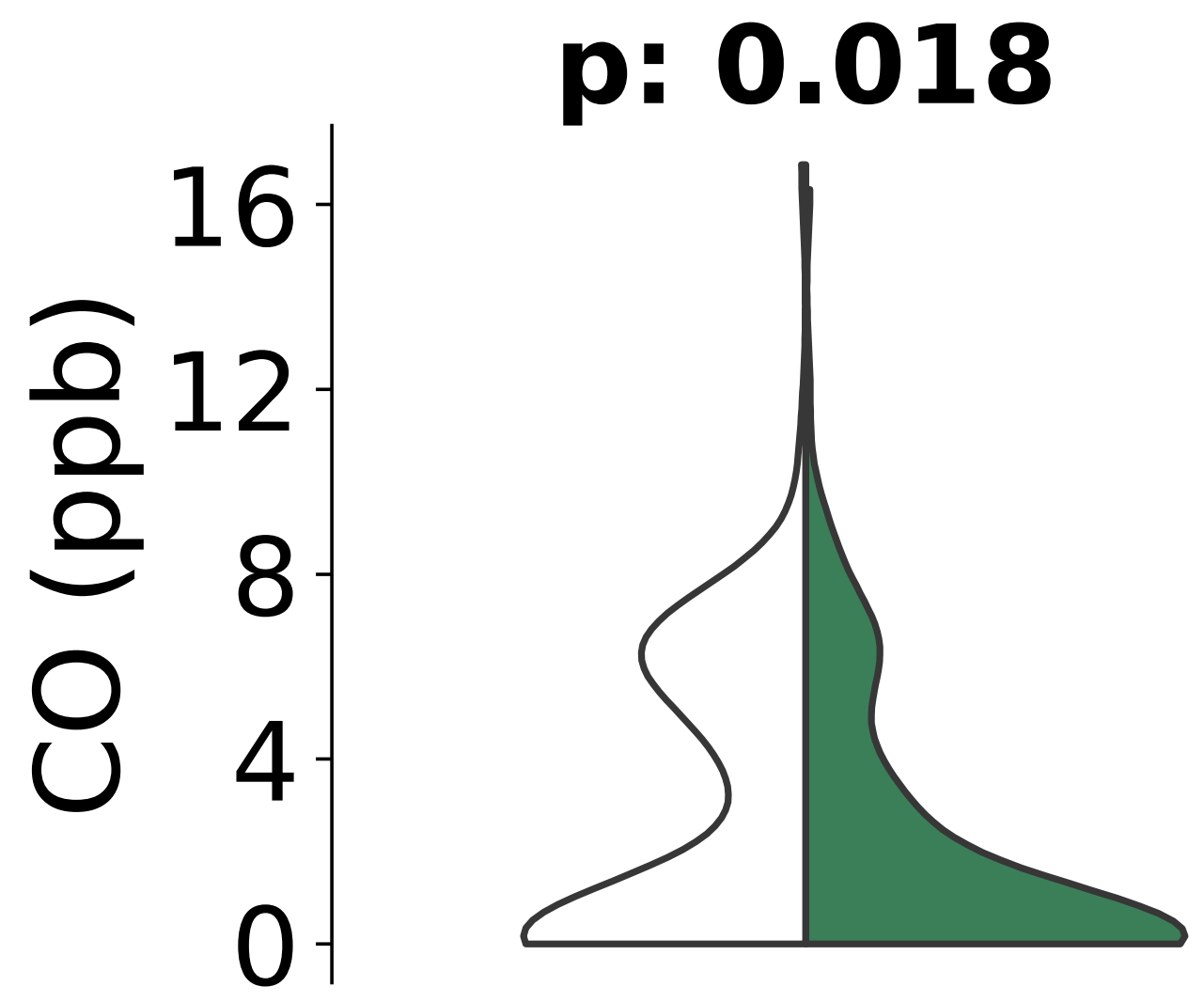
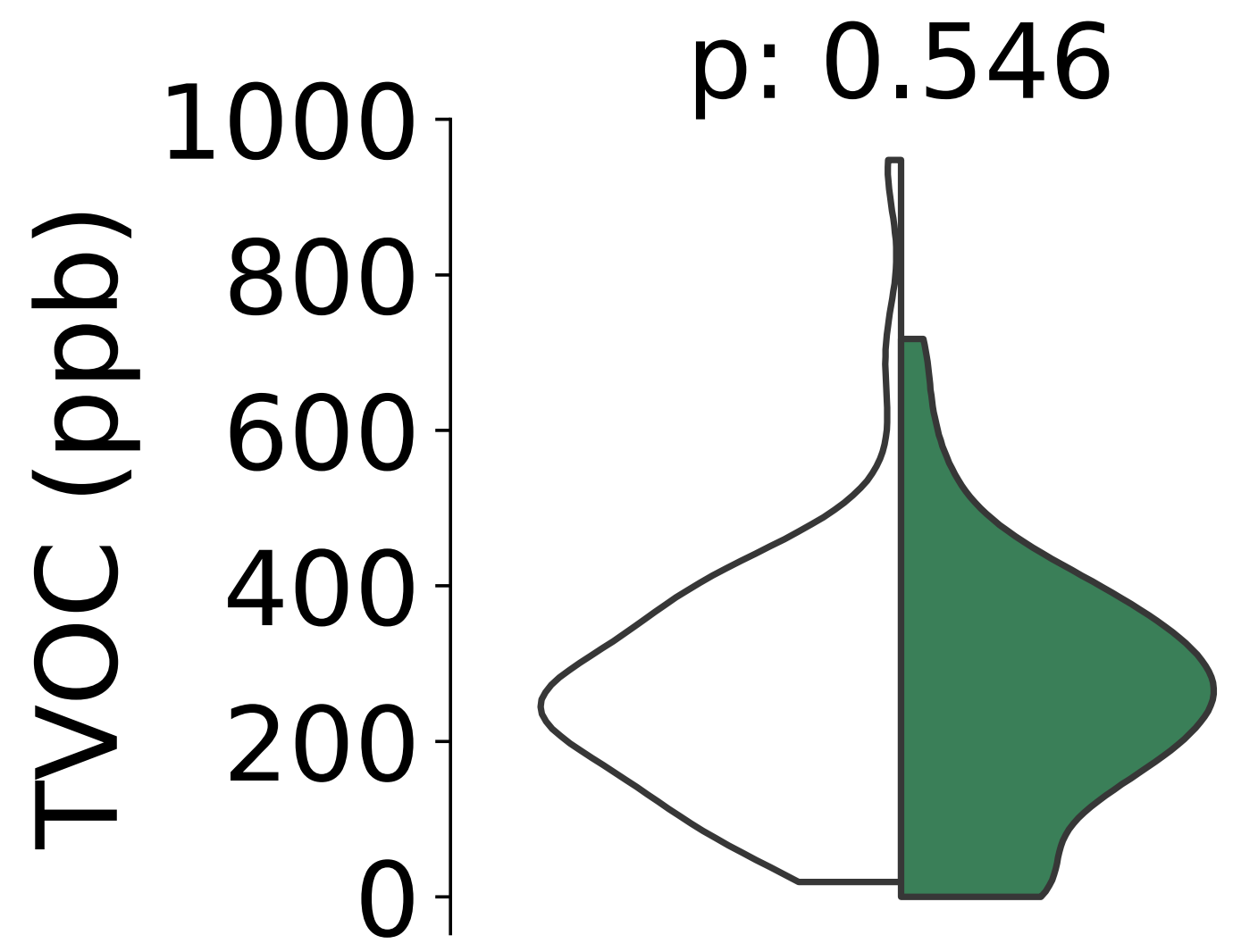










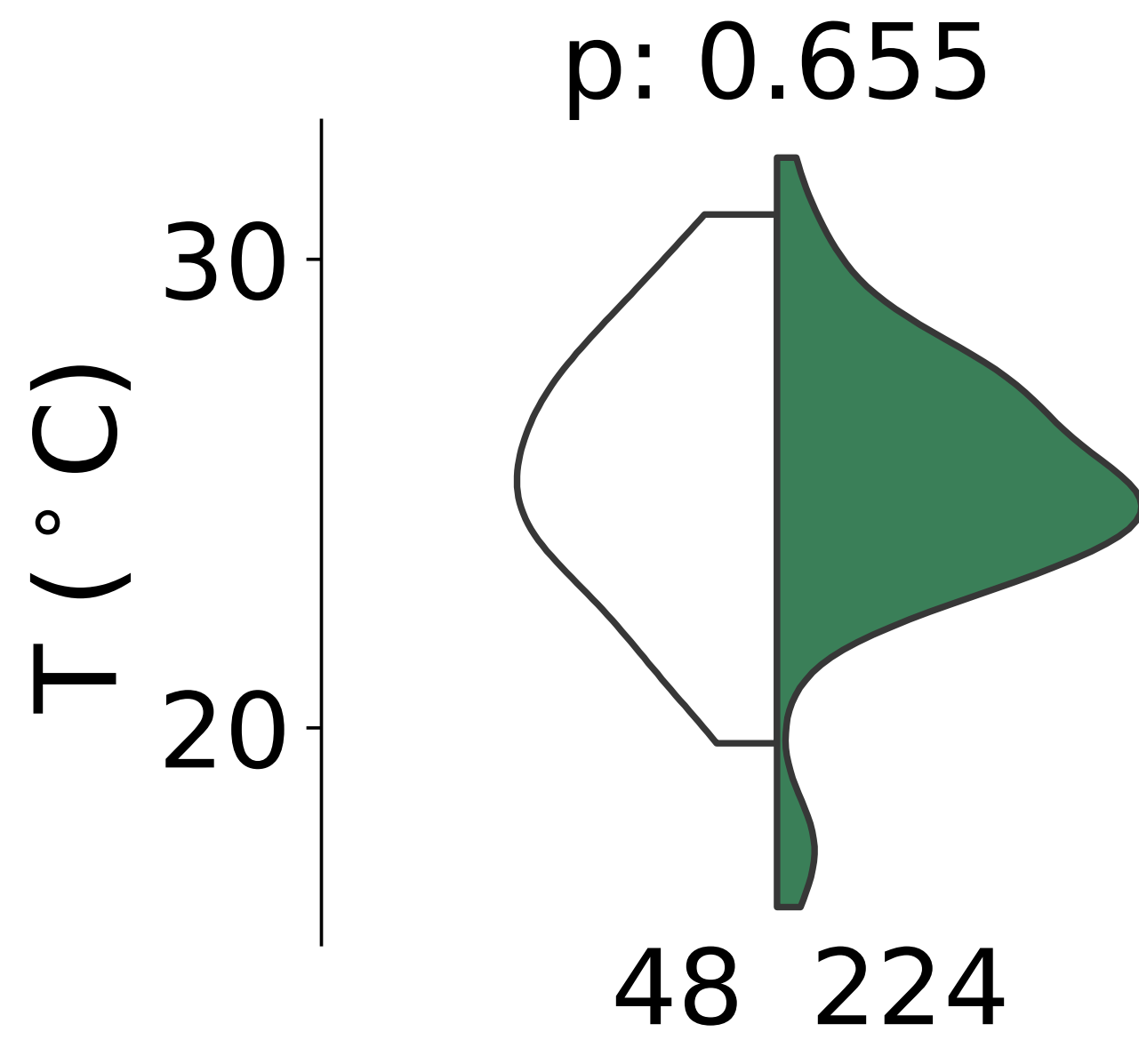
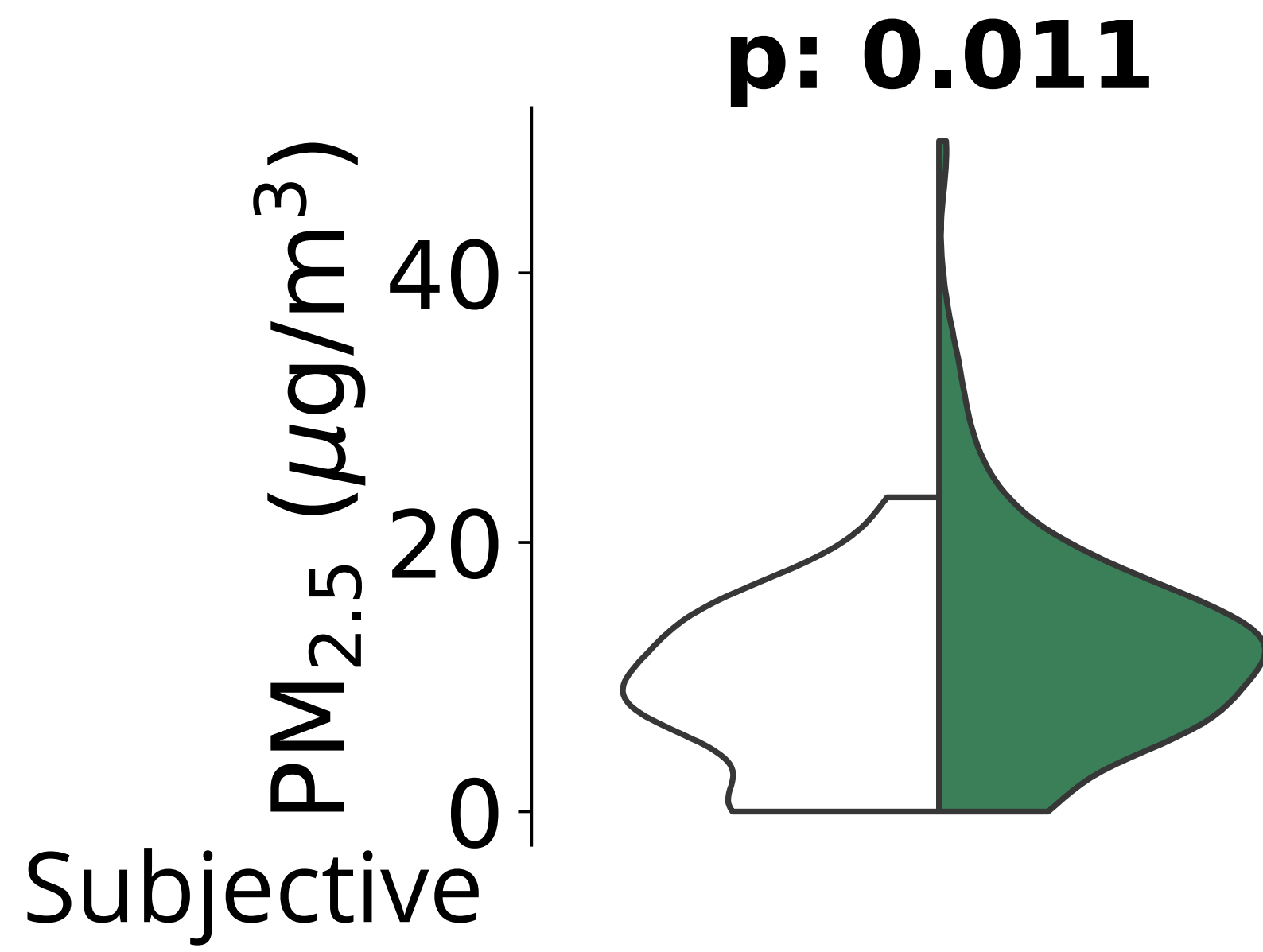
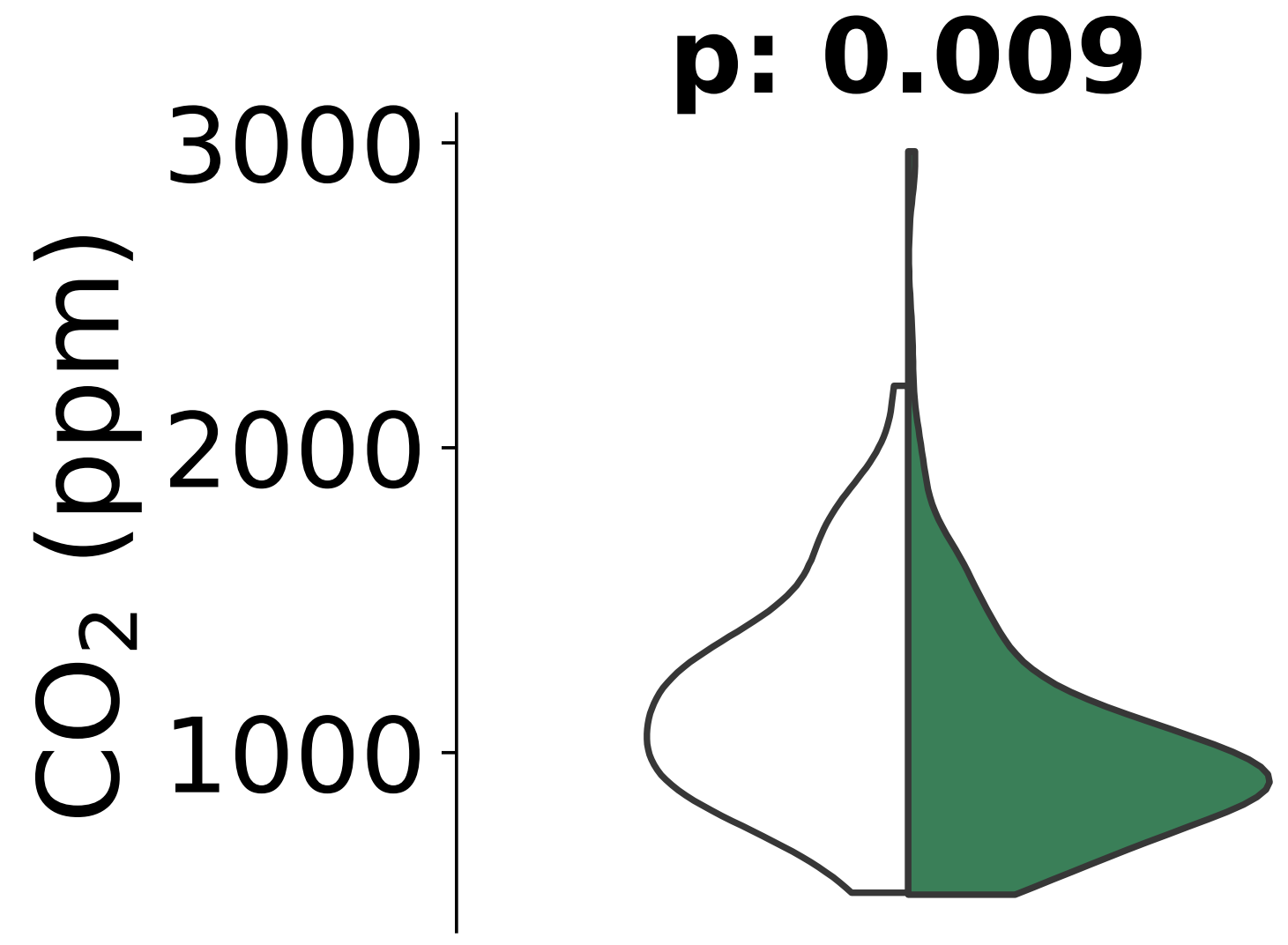
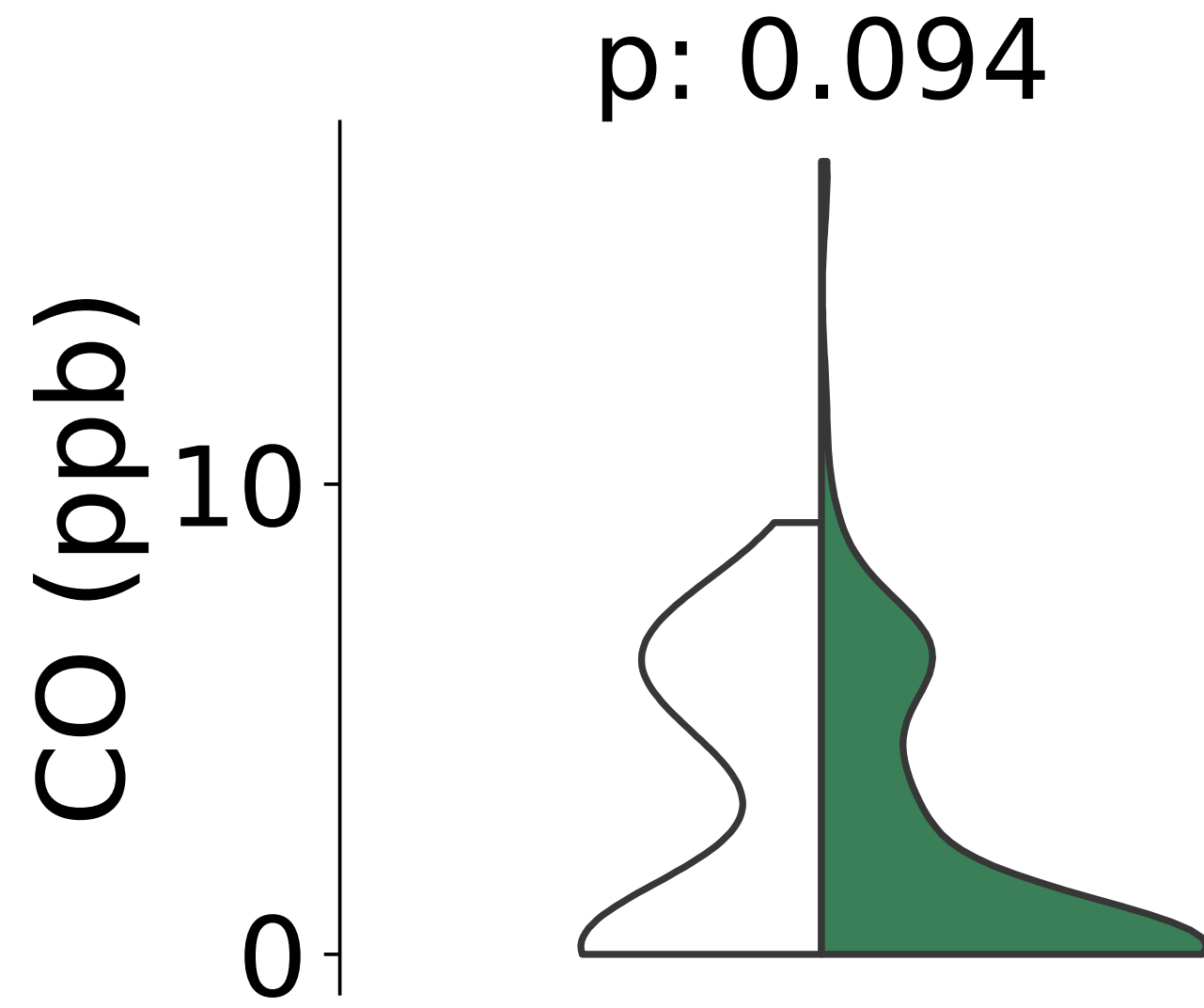
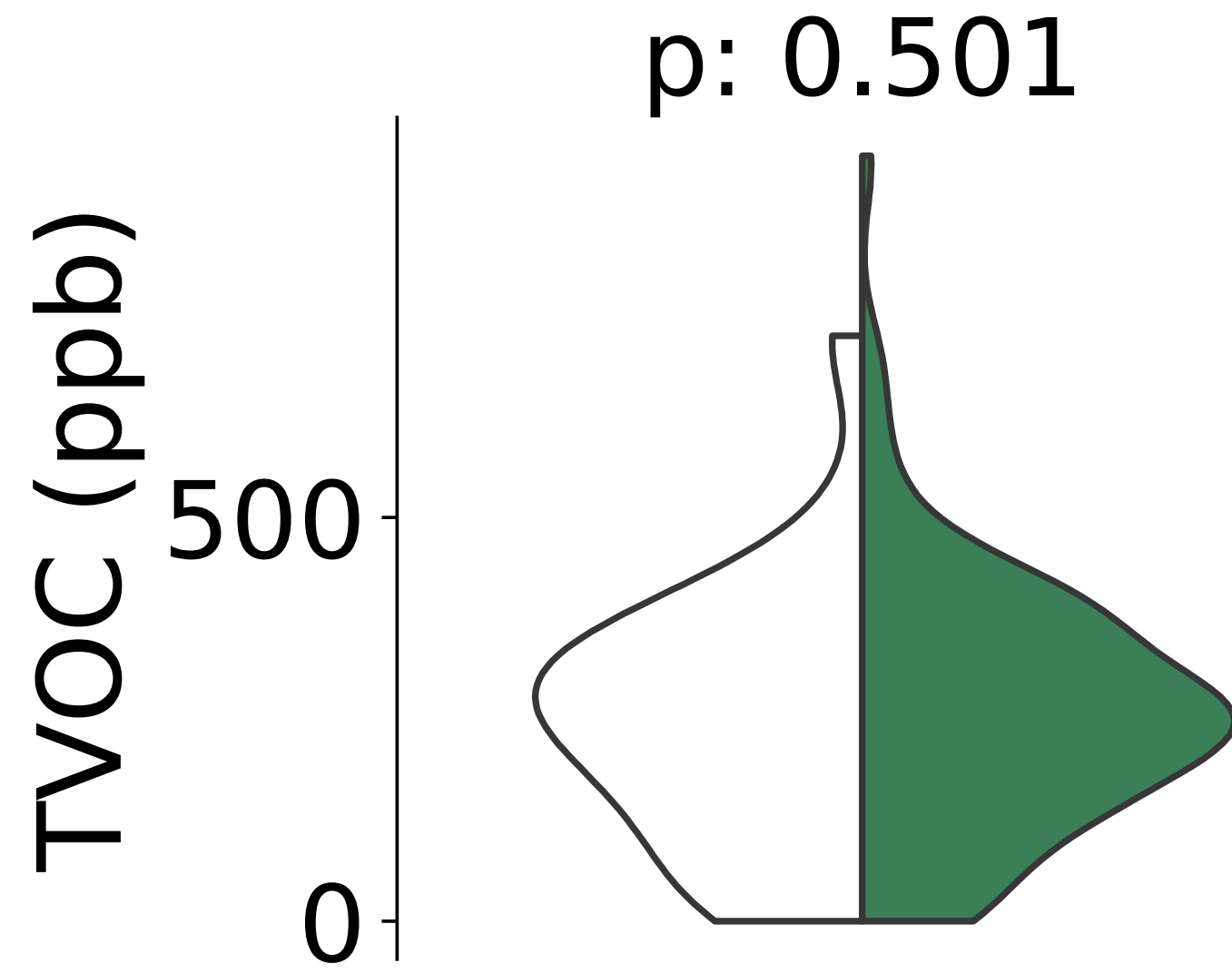




Number of
Awakenings

 High

 Low



Restfulness
Rating

 Negative

 Positive