Do we need to measure mean radiant temperature: Comparison of $\bar{t}_r$ and t_a in mechanically conditioned spaces

Megan Dawe, Paul Raftery, Jonathan Woolley,
Fred Bauman, Stefano Schiavon

CBE Center for the Built Environment
An Industry/University Research Collaboration
University of California, Berkeley

Do we need to measure mean radiant temperature?

Objective

- Provide guidance on assumptions for mean radiant temperature ($\bar{t}_r$)

Approach

- Compared temperature measurements from three datasets in mechanically-conditioned spaces:
  - 5 FLEXLAB experiments
  - 5 CBE Field Studies
  - ASHRAE Global Thermal Comfort Database II (Comfort Database)

Funding

- CEC EPIC program
- CBE funding

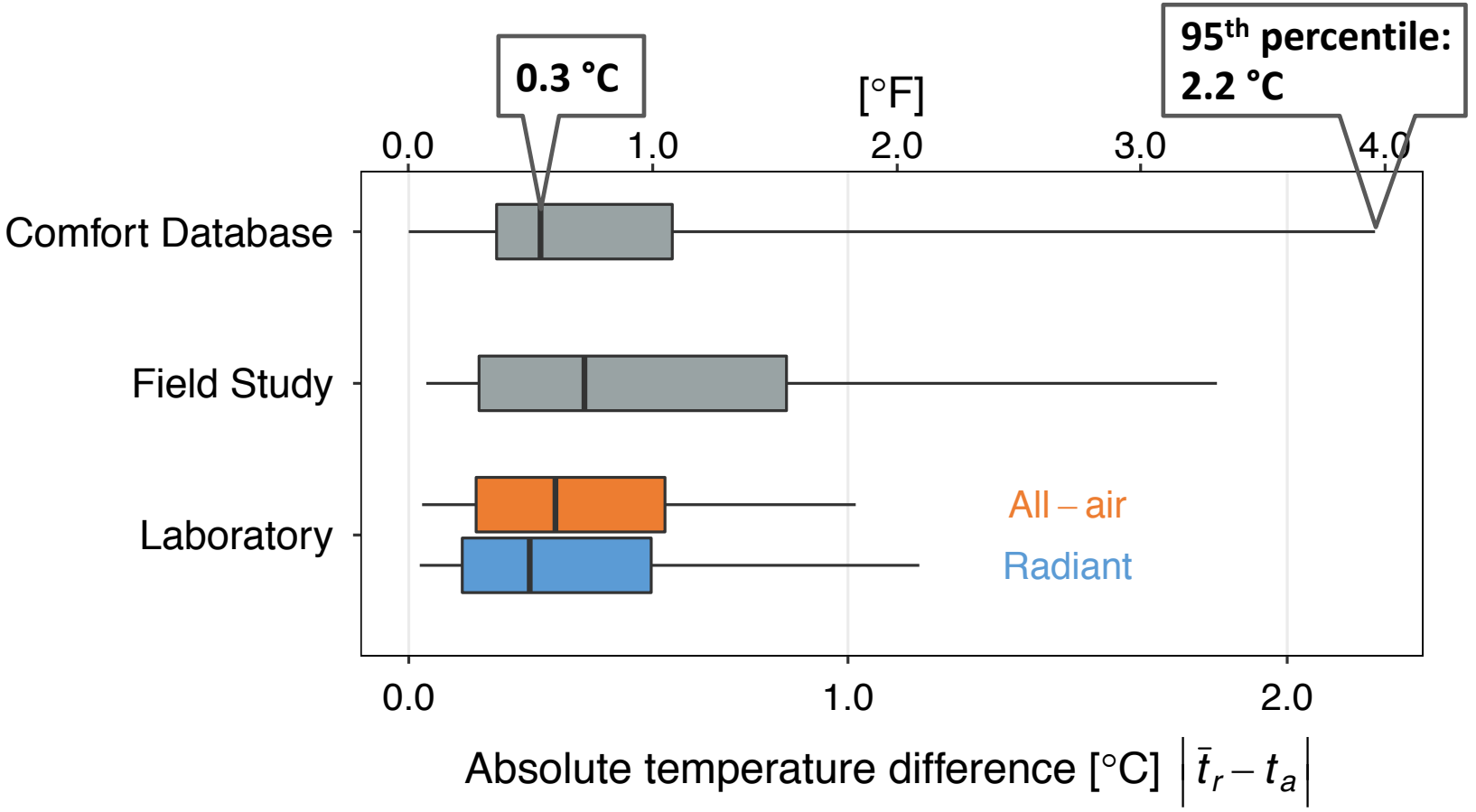
FLEXLAB
5-day experiments
Side-by-side radiant and all-air testbeds

CBE Field Studies
Various years and seasons
3 all-air, 2 radiant

Comfort Database
7 Countries, 59 buildings
13 Köppen Climates
Various Seasons

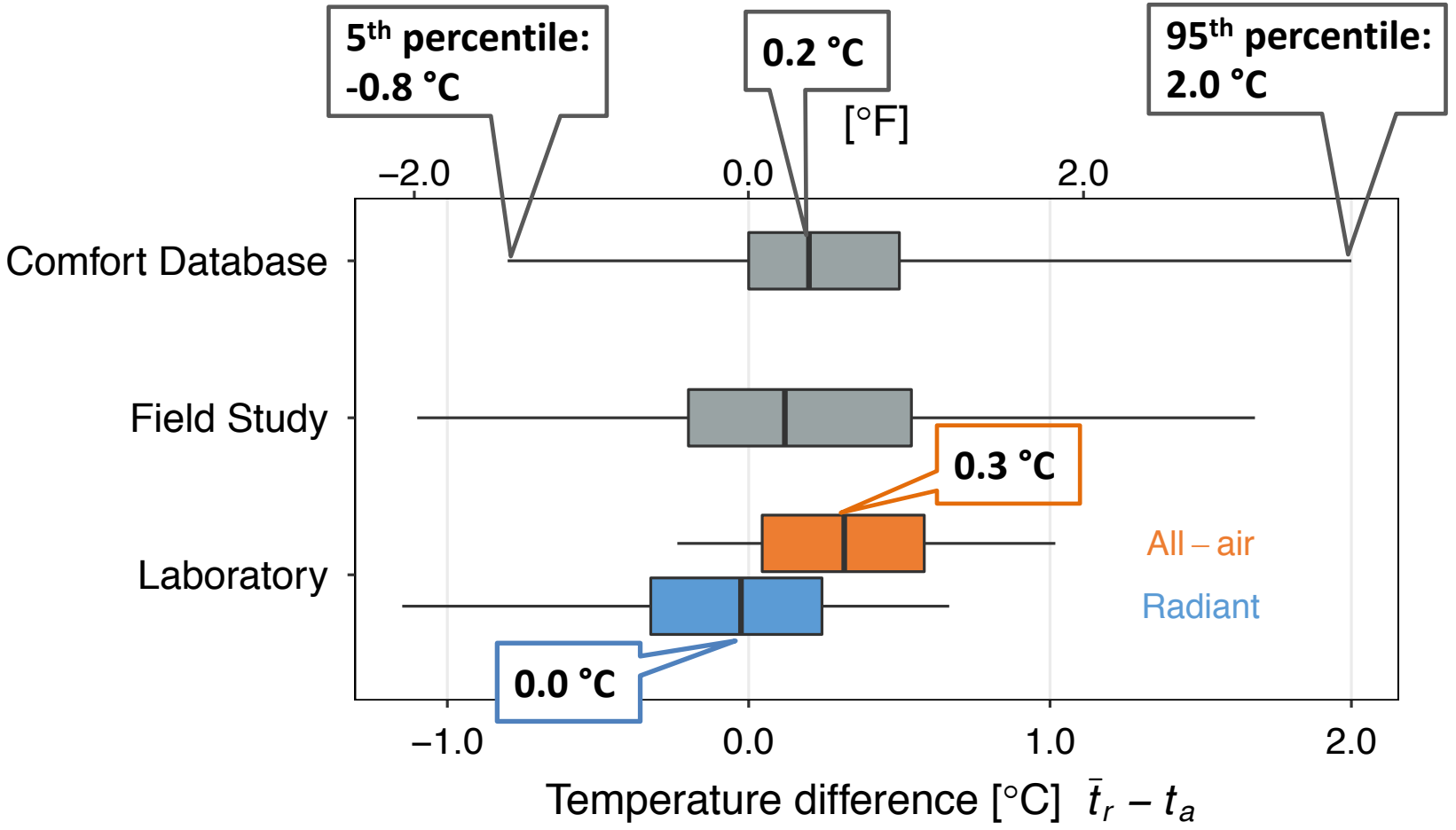
Absolute difference between $\bar{t}_r$ and t_a is small

- $\bar{t}_r$ typically $\pm$ **0.4 °C (0.7 ° F)** of t_a, based on median values from each dataset
- Some conditions are more extreme (possibly design day conditions, in direct solar exposure, or near cold surface)



Difference between $\bar{t}_r$ and t_a is small

- Median values from each dataset are:
  - 0.2, 0.1, 0.3, and 0.0 °C
  - (0.4, 0.2, 0.6, and 0.0 °F)
- 95th percentile of 2.0 °C aligns with ASHRAE 55 for direct-beam solar radiation
  - ($\bar{t}_r = t_a$ + 2.8 °C)
- $\bar{t}_r$ is closer to t_a in radiant testbed than all-air testbed



Recommendations for mean radiant temperature estimates

Modern construction has less heat transfer through envelope

Appropriate to use $\bar{t}_r = t_a$ under typical conditions

- Some conditions can have up to **2.0 °C** (**3.6 °F**) difference

Considerations before assuming $\bar{t}_r = t_a$

- Proximity to window
- Envelope performance (if existing building or highly glazed façade)
- At locations exposed to direct solar heat gain
- Design day conditions

Warren J. Baker Center for Science and Mathematics

Recommended changes to ASHRAE 55

Appendix A: Methods for Determining Operative Temperature

Operative temperature is permitted to be calculated per the following formula:

$$t_o = A t_a + (1 - A)\bar{t}_r$$

Where…

$\bar{t}_r$ = mean radiant temperature (Using the simple or detailed calculation procedures, see below ~~the "Thermal Comfort" chapter of the most current edition of *ASHRAE Handbook – Fundamentals*~~)

If all of the following conditions 1-3 are met, the simple calculation of $\bar{t}_r = t_a$ can be used, otherwise see the detailed calculation procedures in the "Thermal Comfort" chapter of the most current edition of *ASHRAE Handbook – Fundamentals*):

1. Average air speed is <0.2 m/s
2. Location does not receive direct-beam solar radiation (see Section 5.3.2.2.1)
3. Building envelope opaque surfaces (walls, floors, roofs) meet prescriptive U-factor requirements of ASHRAE 90.1

Thank you

Megan Dawe
megan.dawe@berkeley.edu

Paul Raftery
p.raftery@berkeley.edu

Fred Bauman
fbauman@berkeley.edu

Stefano Schiavon
schiavon@berkeley.edu