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Measuring variability in urban meteorology using low-cost weather stations

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2. *Morgan State University*
3. *Temple X Schools*
4. *Baltimore Climate Resilience Coalition*

Baltimore Social-Environmental Collaborative (BSEC)

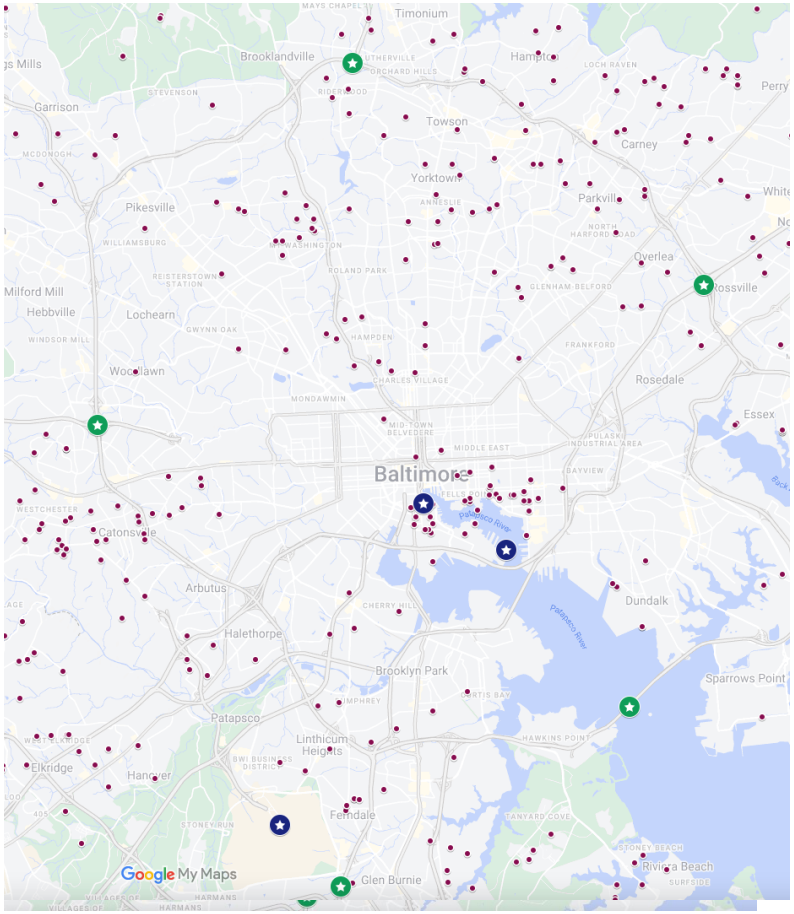
Introduction

Monitoring neighborhood-scale variability of weather is critical for understanding the causes of and developing equitable solutions for urban heat, flooding, and air pollution, especially as conditions are often worse in under-served neighborhoods.

However, there is lack of surface weather measurements within cities.

Citizen weather stations may provide solution, but

- Quality of instruments unknown
- Placement (e.g. roof vrs ground) unknown
- **Limited sampling in under-served neighborhoods**.



Federal, State.

Weather Underground weather stations.

BSEC

Introduction

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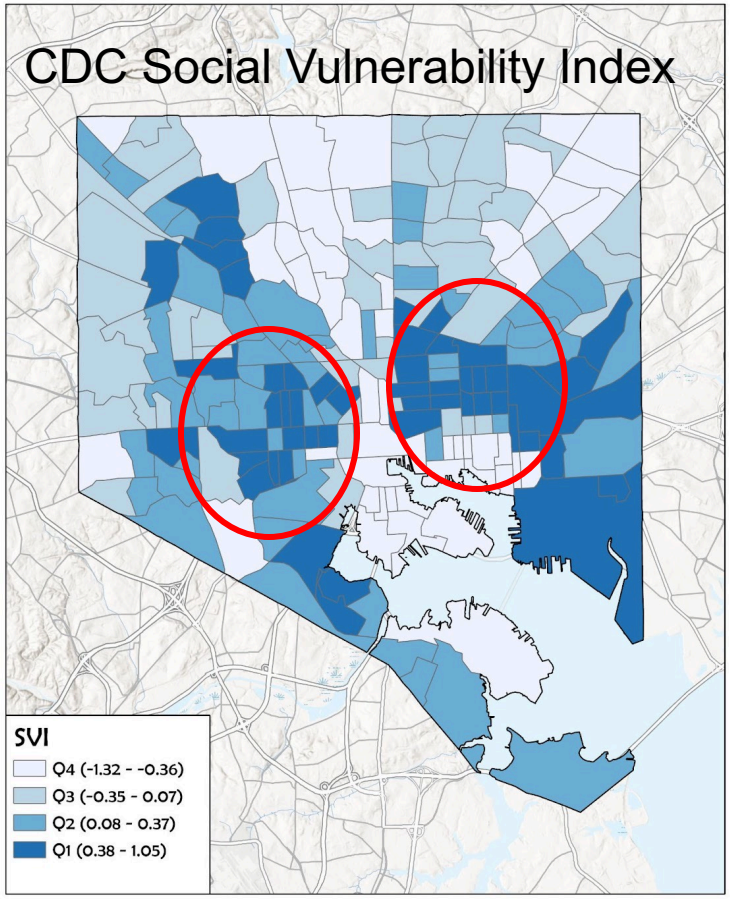

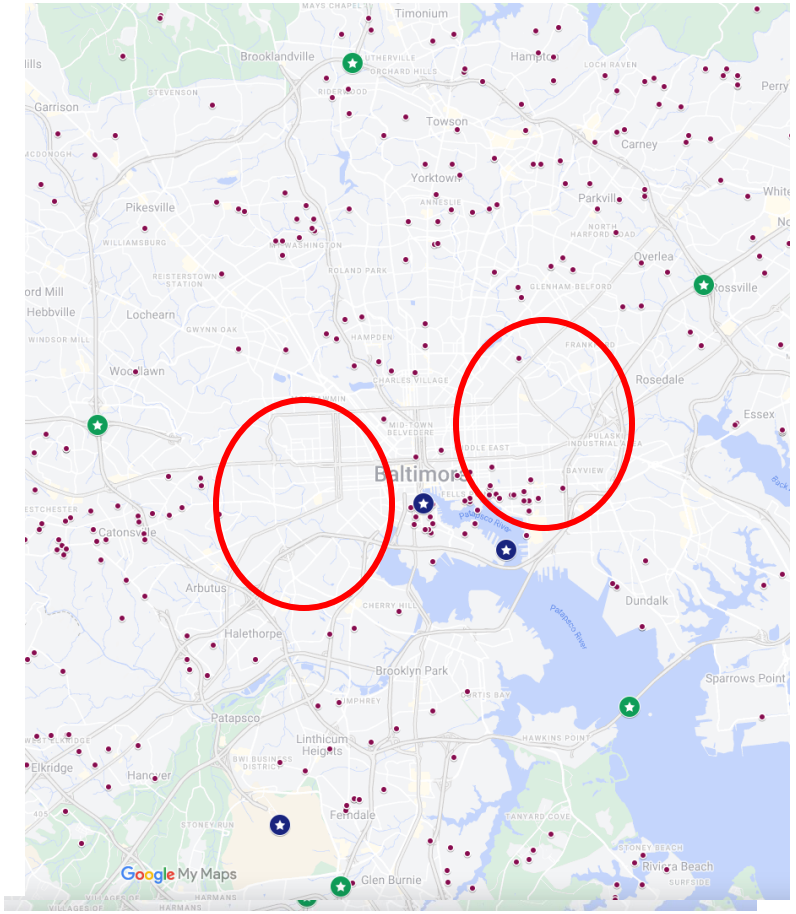

weather stations.

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BSEC Weather Stations

The Baltimore Social-Environmental Collaborative (BSEC) is filling this void by deploying networks of weather stations across Baltimore City, with a focus on under-served neighborhoods.

Three instruments:

- research-grade weather stations (OttHydromet/Lufft)
- Personal weather stations (Ambient Weather)
- ~~iButton thermometer/hygrometer~~

Are the low cost weather stations suitable for quantifying within city variability of weather conditions (at a fraction of the cost or with much greater spatial resolution than research-grade stations)?

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Instruments

Company	OttHydro	Ambient Weather
Model	Luft WS601-UMB Kipp&Zonen Lite2	WS-2902
Cost	Moderate-High ($6000)	Low ($200)
T, RH	Yes	Yes
Solar, Rain, Wind	Yes	Yes
Connectivity	Cell	WiFi
Data Storage	Internal, Web	Web
Installation	Moderate Full Sun Security	Easy Need Wifi Moderate Security

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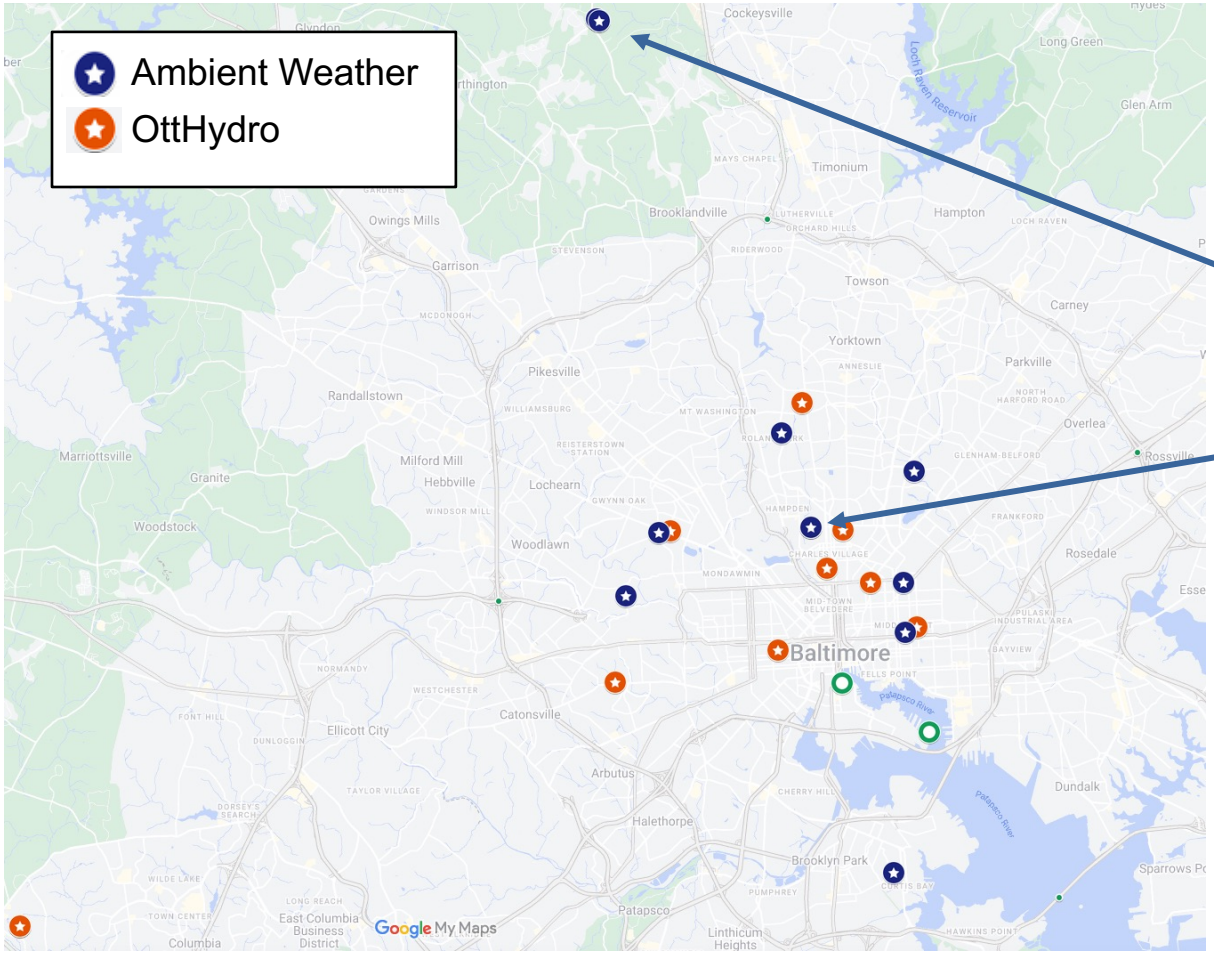
Community Partnerships

Weather stations installed in churches, community gardens, schools, private residences …

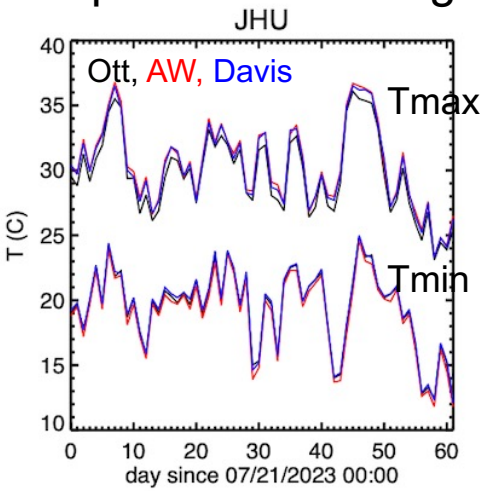
2023 Locations

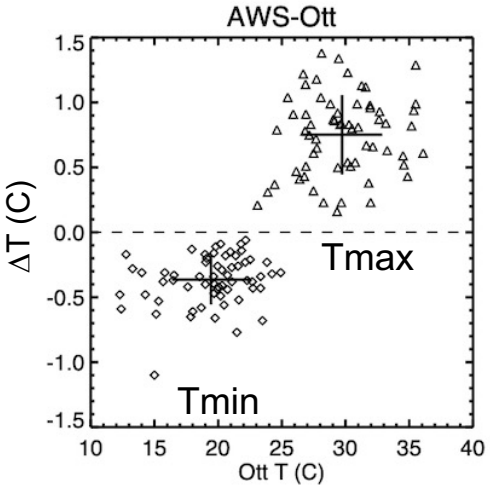


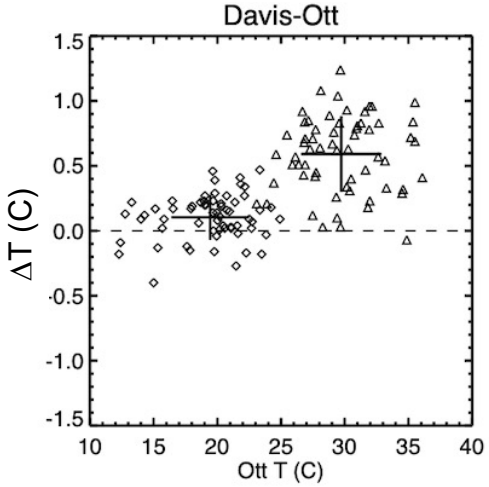
AW & OttHydro at COV & JHU sites

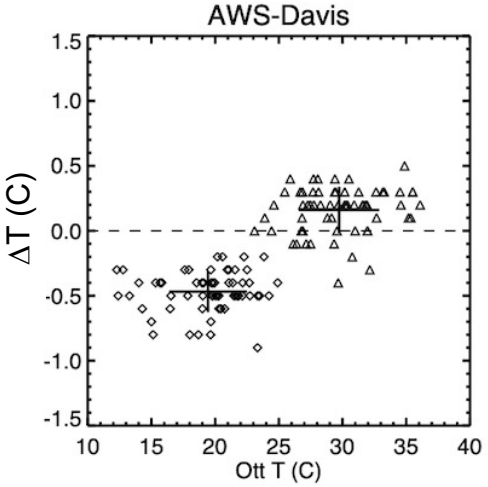
Comparison between weather stations

Ott and AW weather stations, as well as Davis station installed on roof top of JHU building.









AW overestimates Tmax (~1C) but underestimates Tmin (~0.3C) (c.f. OttHydro which is fan aspirated).

Davis has smaller overestimate of Tmax and Tmin similar to Ott.

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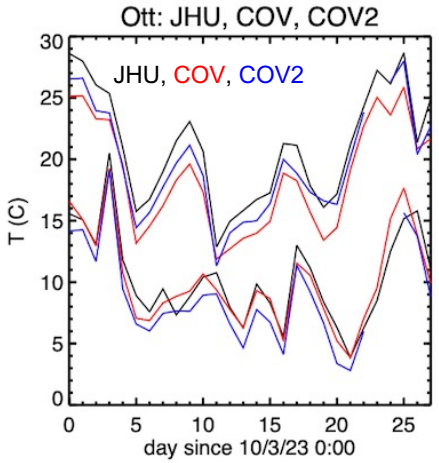
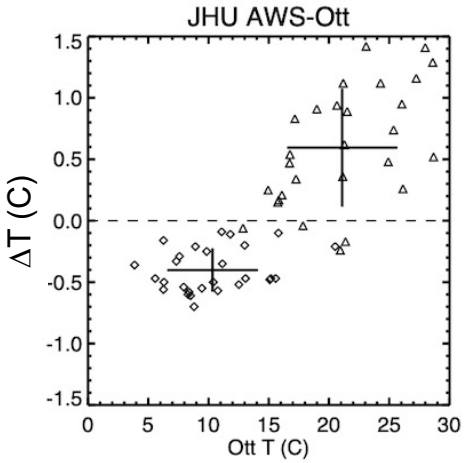
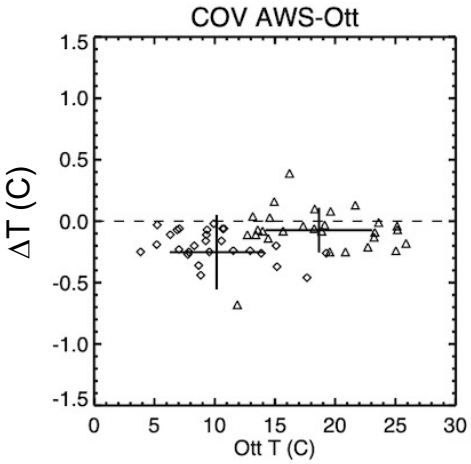
August 2023

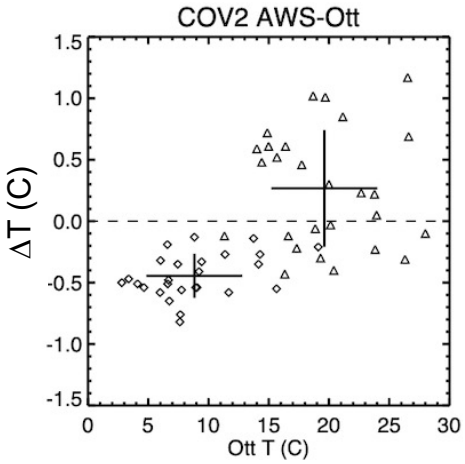
Comparison between weather stations: Different Locations

Magnitude of AWS-Ott bias depends on stations location









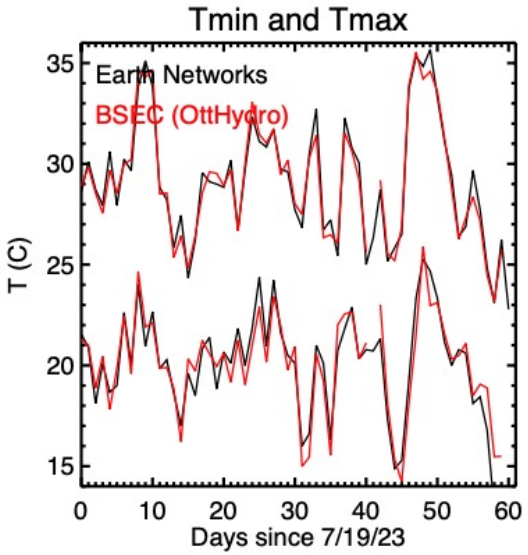
AWS-Ott difference similar for open rural field (COV2) and urban roof top (JHU), but smaller bias for wooded rural site (COV).

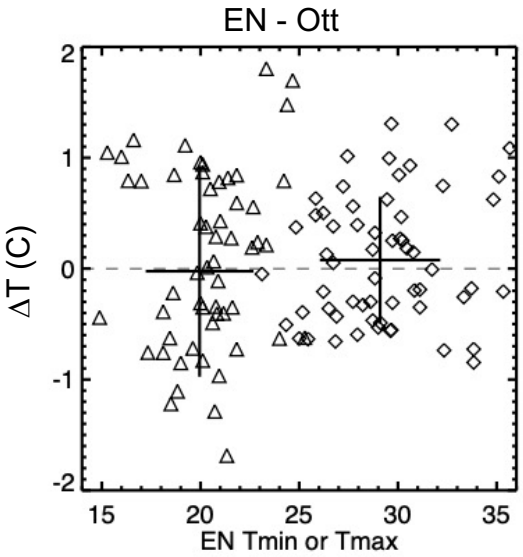
COV: wooded rural site
COV2: open rural field
~100 m apart

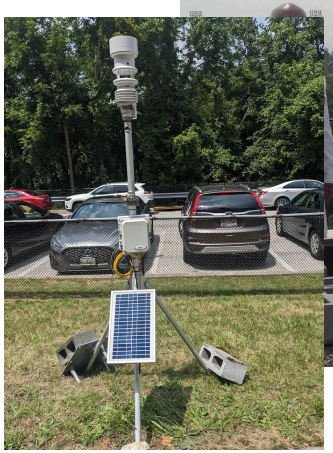
October 2023

Comparison between weather stations: OttHydro & Earth-Networks

Differences on given day as large as 2C but no mean bias.



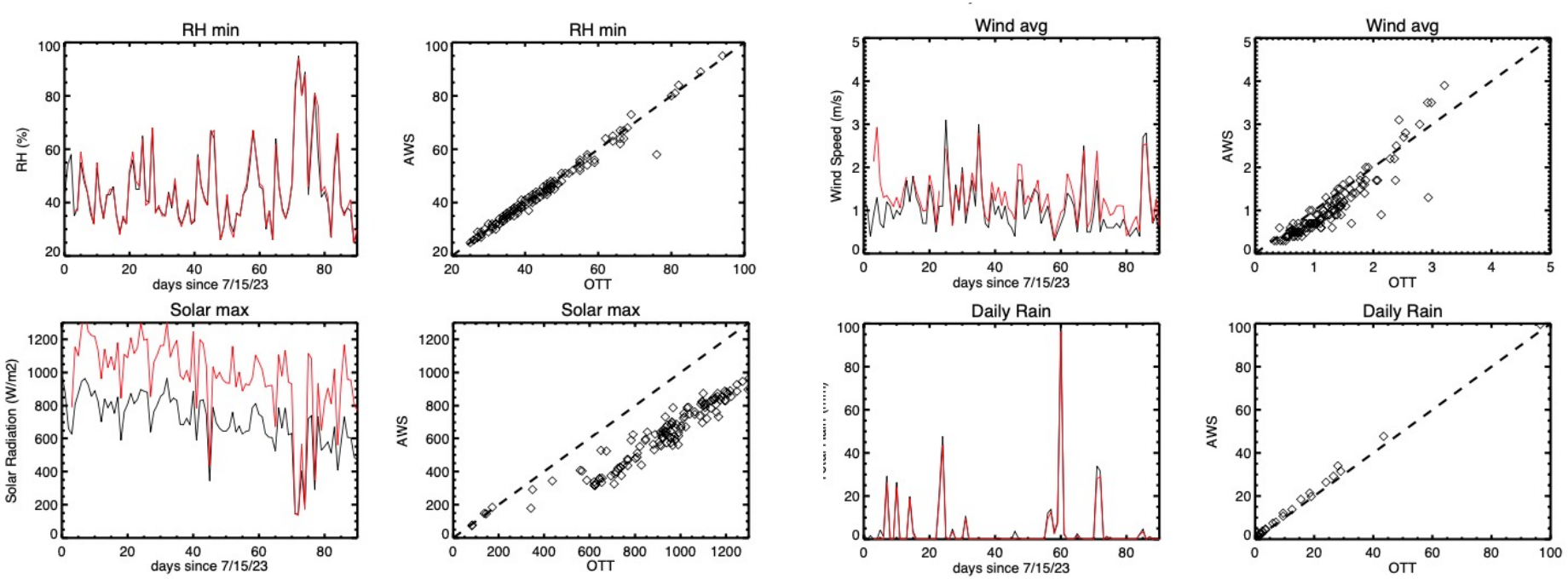




Earth Networks station on roof; OttHydro on the ground.

Other Quantities

Comparison of RH, Solar Radiation, Wind Speed and Precipitation from OttHydro (red) and AW (black) on JHU roof top.



Good agreement except for solar radiation
AW ~ 70% of Ott*

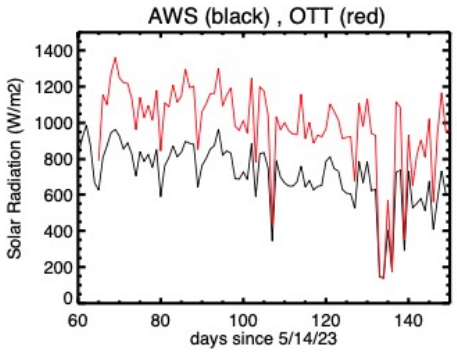
*Same bias found at both COV and COV2

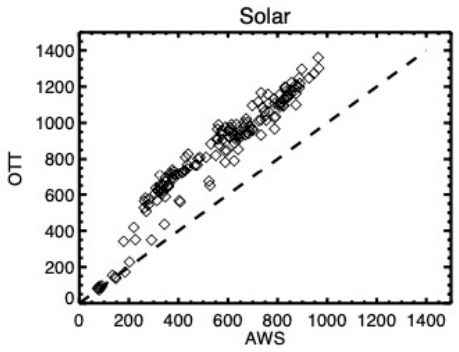
Solar Radiation

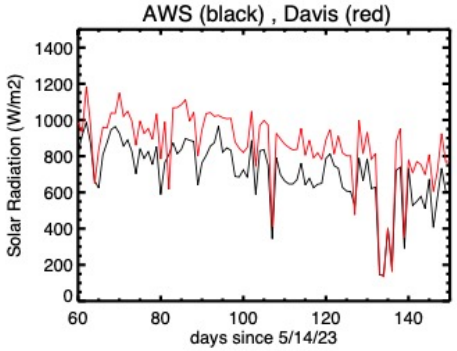
Solar Radiation from **OttHydro** is larger not only than the **AW** but also the **Davis** @ JHU and a Kipp & Zonen instrument at **MDE site in Essex** are all less than @ JHU

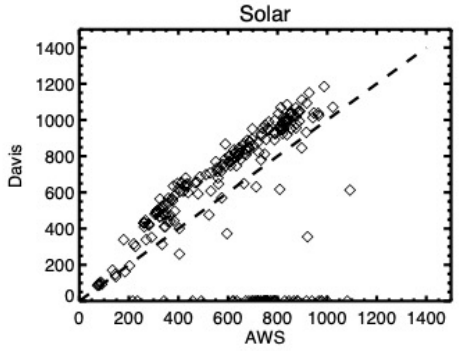
AWS close to MDE measurement.

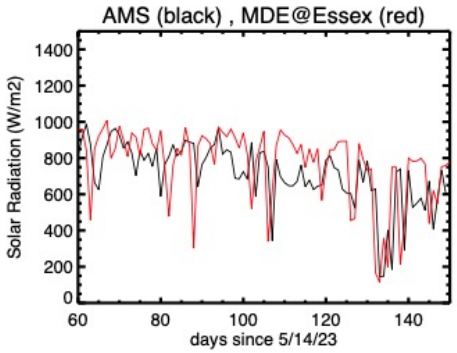
Truth???

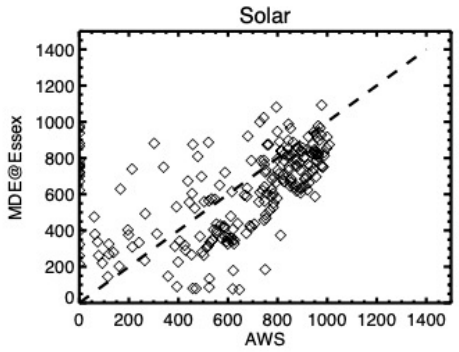












OTT ~1200 W/m^2 in July ?

Online calculator has maximum ~ 1000 W/m^2
https://www.meteoexploration.com/products/solarcalc.php

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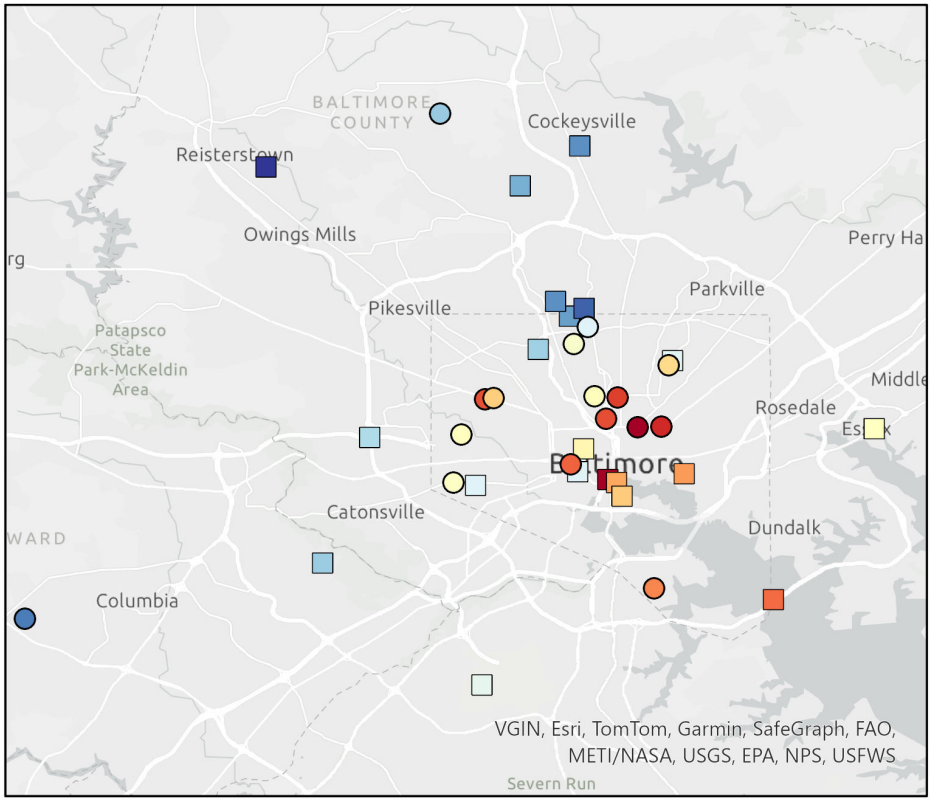
Combined Network: Tmin

Combine data from BSEC stations with other available weather station data: federal (NWS), state (MDE, MDoT), and private (Earth Network).

Consistency among networks, with decrease in Tmin from central city to NW suburbs. Also, similar decrease with increased vegetation and elevation.



Daily Minimum Temperature (°C)

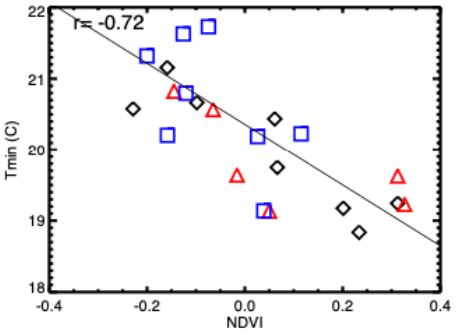
17 °C

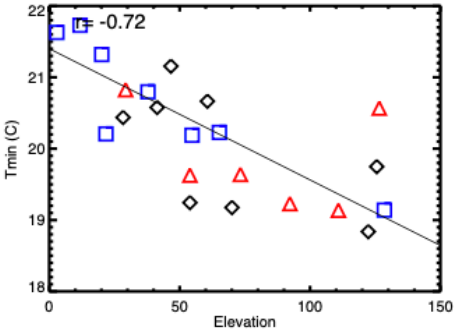
24 °C

AWS/OTT Station

Other Station

AWS, OttHydro, Other



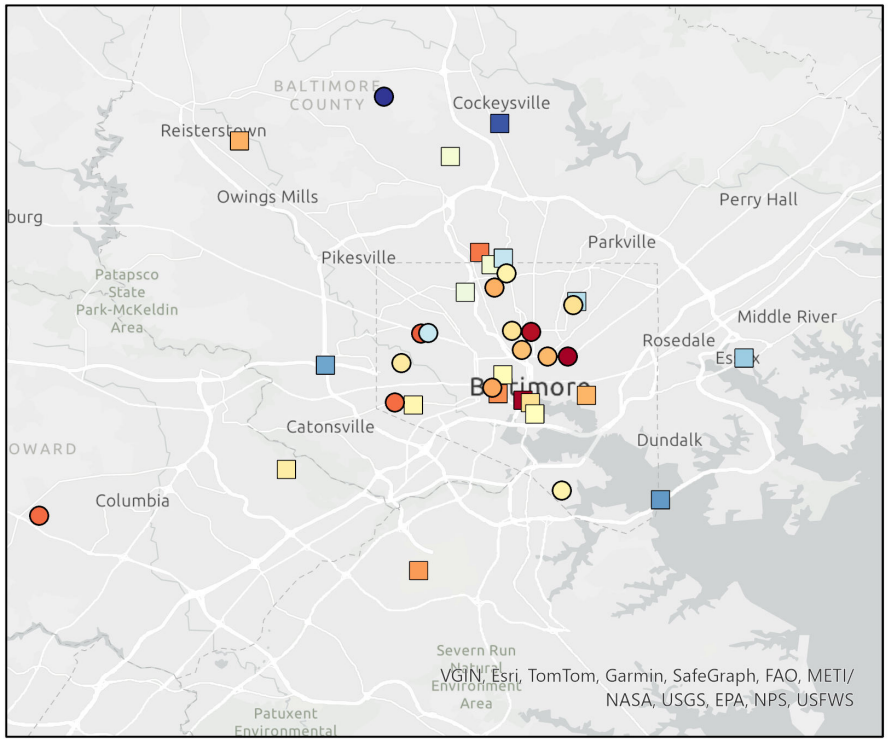


Tmin (August 2023)

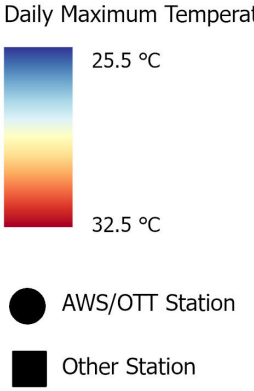
Combined Network: Tmax

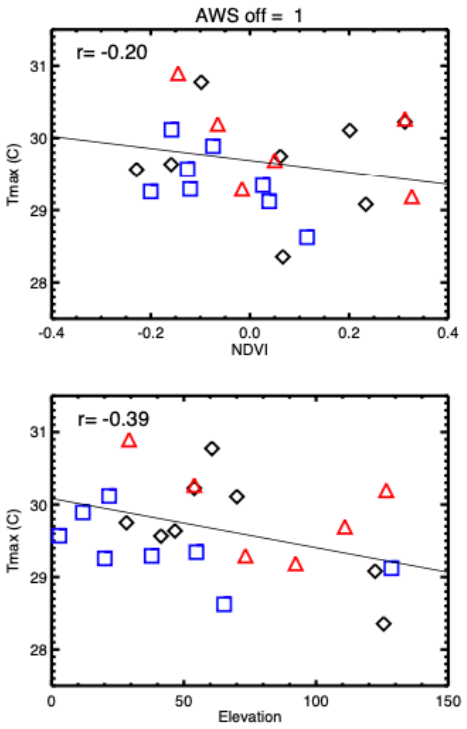
Combine data from BSEC stations with other available weather station data: federal (NWS), state (MDE, MDoT), and private (Earth Network).

Much large variability in Tmax – between networks and within networks, and weak relationship with vegetation and elevation.



Tmax (August 2023)





AWS, OttHydro, Other

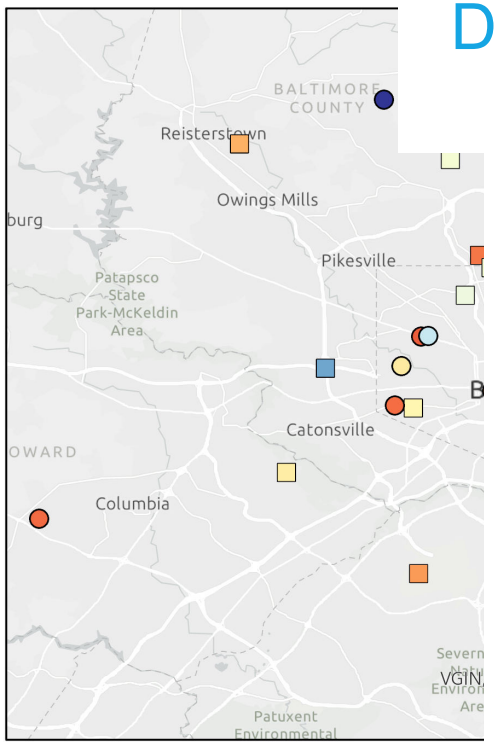
**** AWS Tmax bias corrected by 1 C ****

Combined Network: Tmax

Combine data from BSEC stations with other available weather station data: federal (NWS), state (MDE, MDoT), and private (Earth Network).

Much large variability in Tmax – between networks and within networks, and weak relationship with vegetation and elevation.

Due to micro-climate and varied siting of the weather stations?



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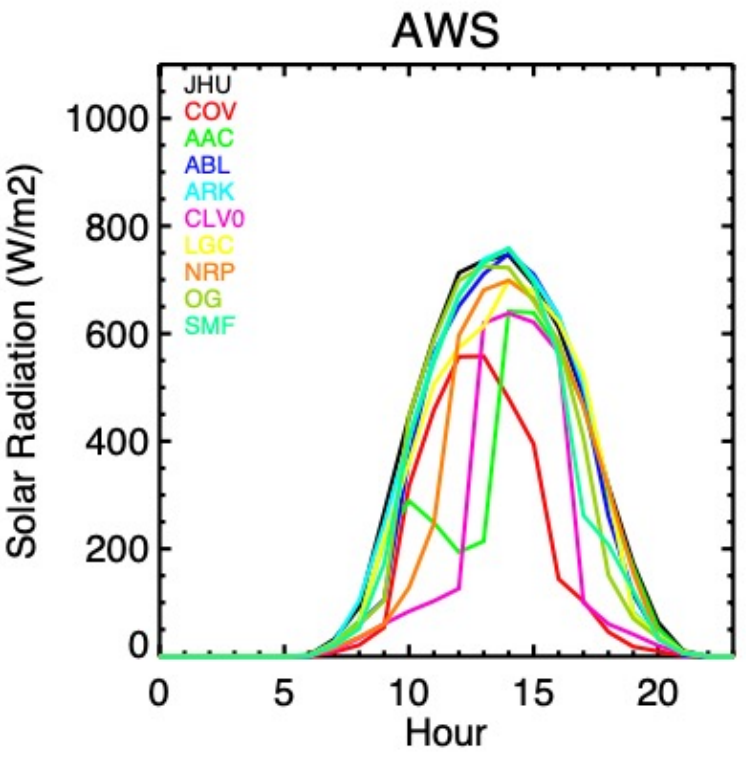

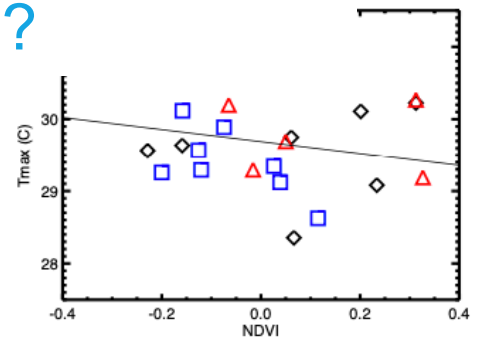

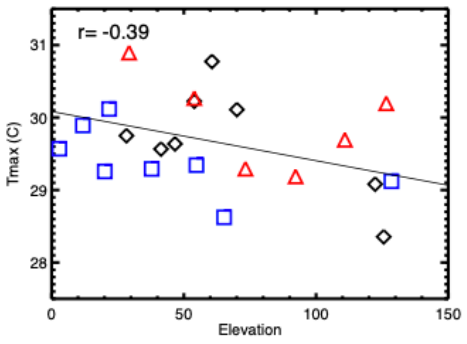

S, OttHydro, Other

*rected by 1 C **

Conclusions

Are the low cost (commercially available personal) weather stations suitable for quantifying within city variability of weather conditions (at a fraction of the cost or with much greater spatial resolution than research-grade stations)?

Yes.

However, may be some spatially varying biases, esp. Tmax, that needs to be better quantified and corrected for. Need for reference station(s).

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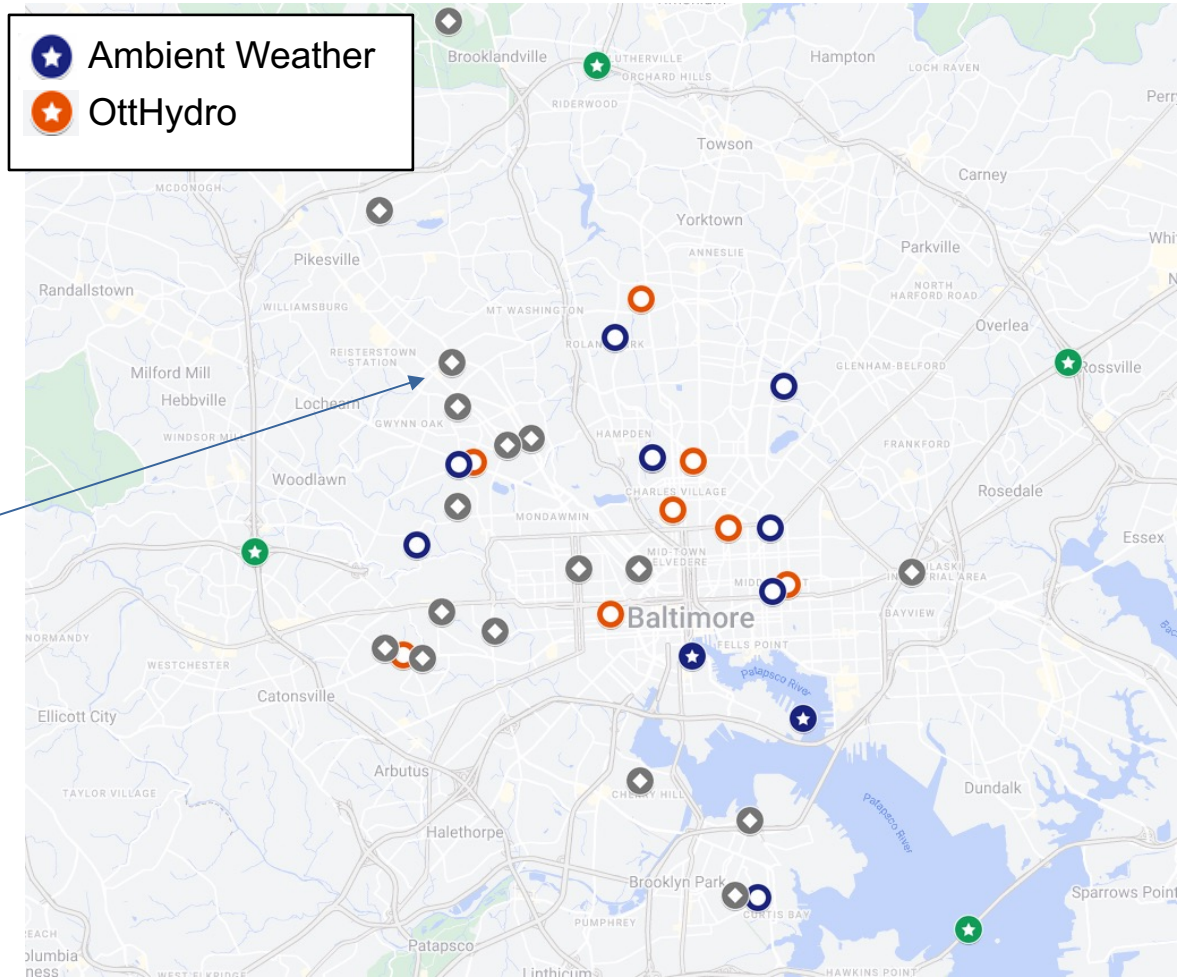
Future Plans



Planned sites

Community partners to lead expansion (doubling) of the network.