

Crowdsourcing Crowd (Citizen) Weather Station Data

Focus: Air temperature

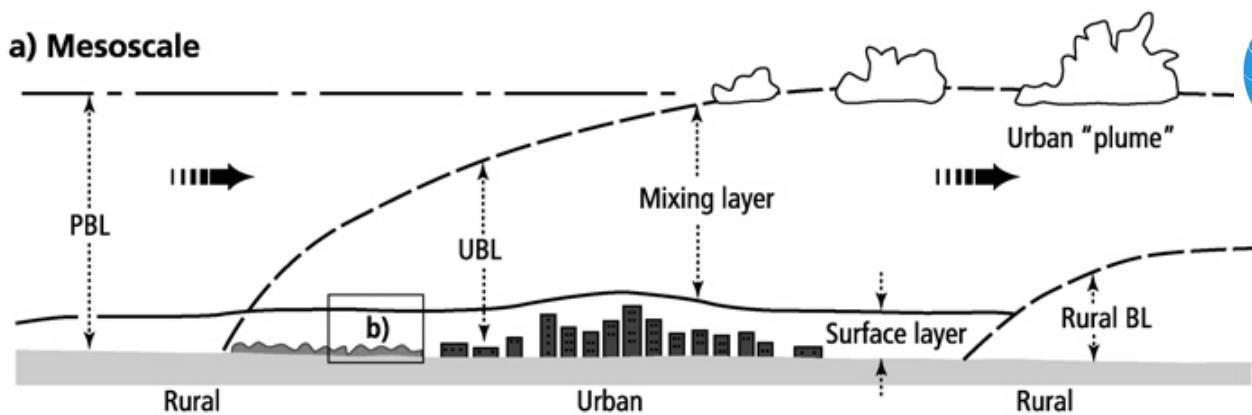


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Chair of Environmental Meteorology, University of Freiburg

BUCSS22 | 27-09-2022



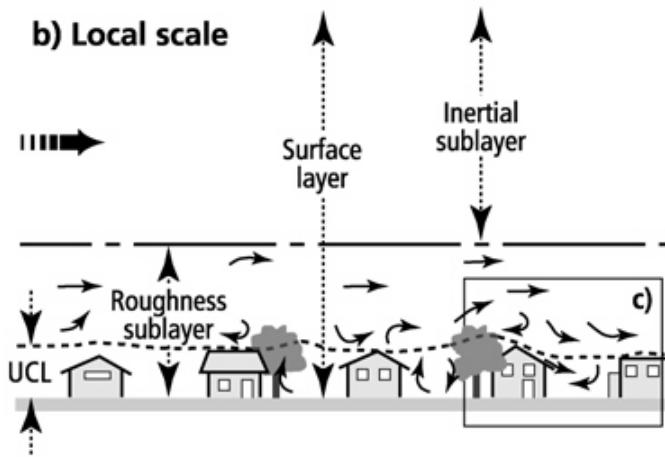
a) Mesoscale



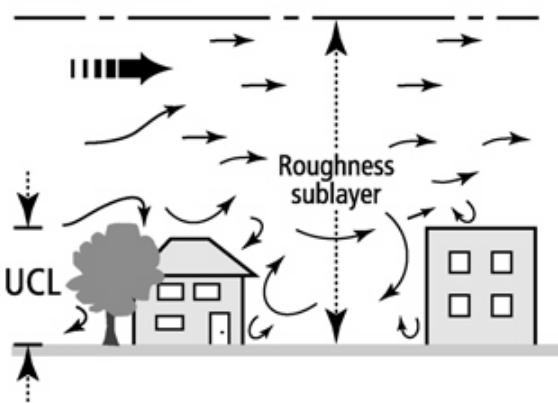
urbisphere
coupling dynamic cities and climate

UNI
FREIBURG

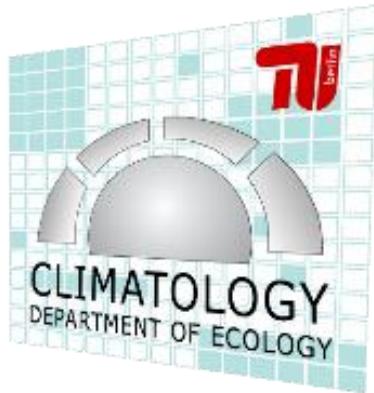
b) Local scale



c) Microscale



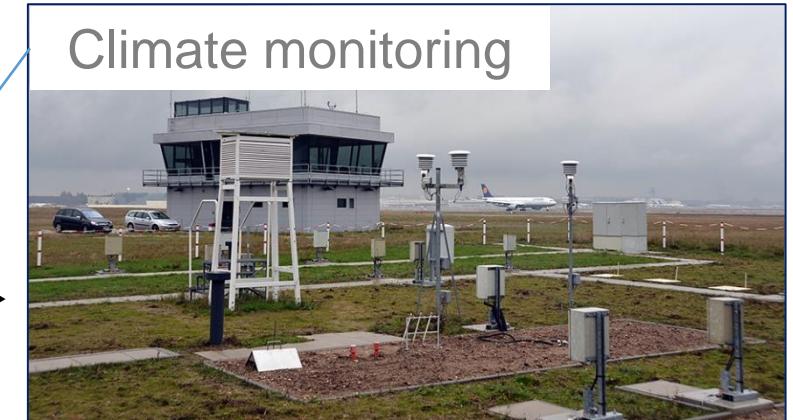
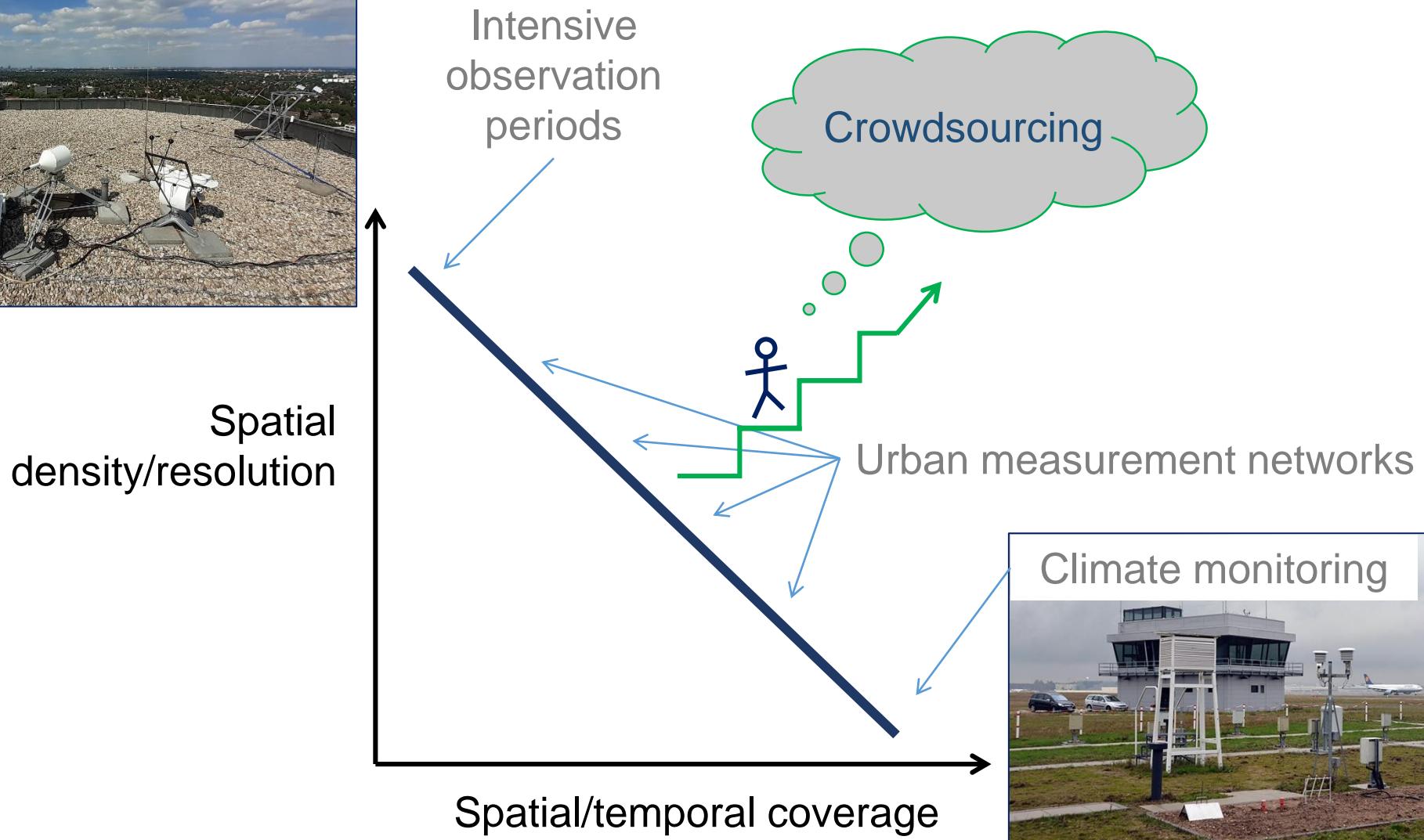
Grimmond (2006)



ENLIGHT
RUB

RUHR
UNIVERSITÄT
BOCHUM

Observational networks (in cities)



What is crowdsourcing?
(and examples)

Definitions

“Simply defined, crowdsourcing represents the act of a company or institution taking a function once performed by employees and outsourcing it to an undefined (and generally large) network of people in the form of an open call.”

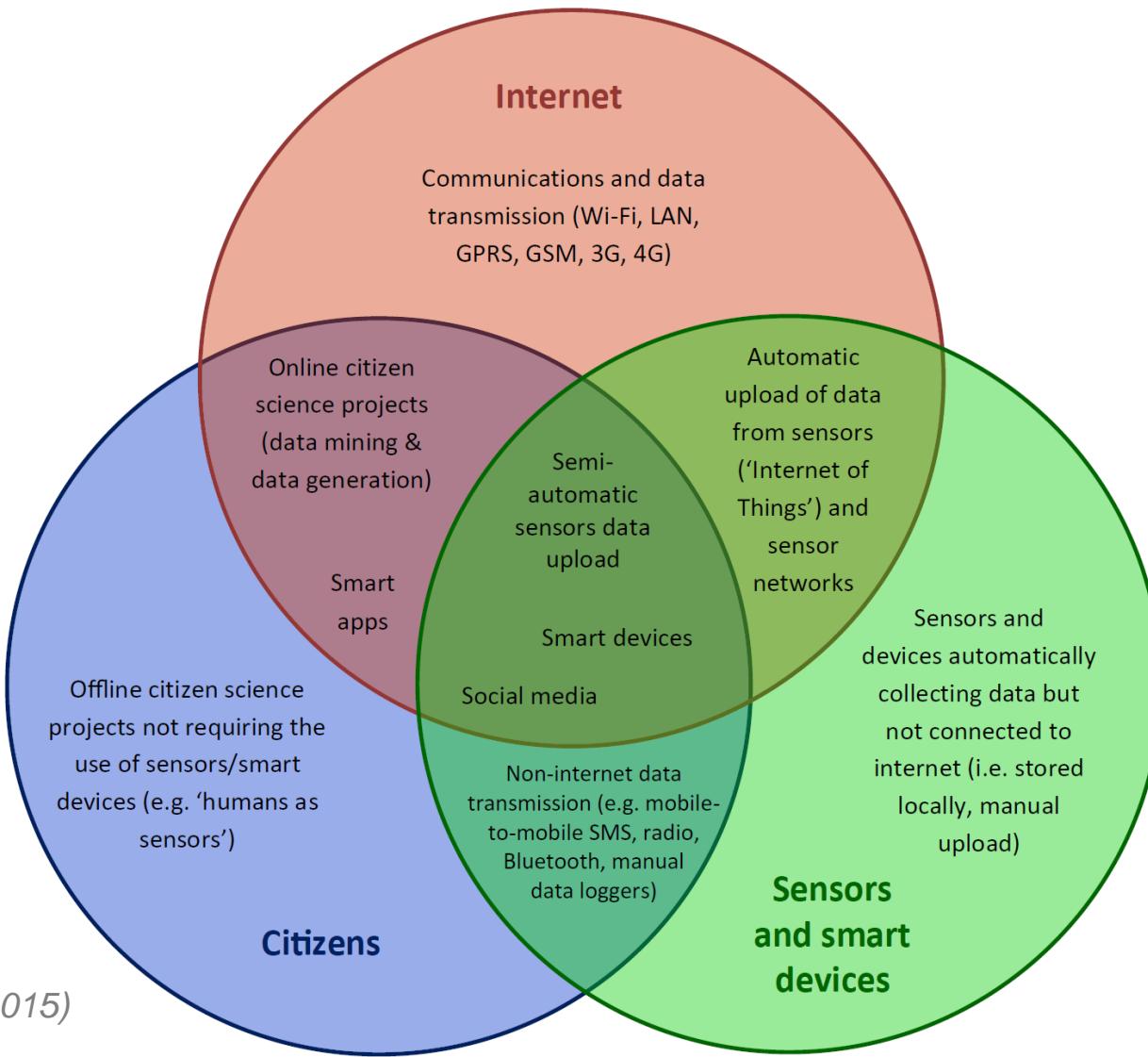
(Howe, 2006)

For atmospheric sciences:

Crowdsourcing = collecting non-traditional data from a large number of sources at high resolutions, notable from a range of public sensors, typically connected via the Internet

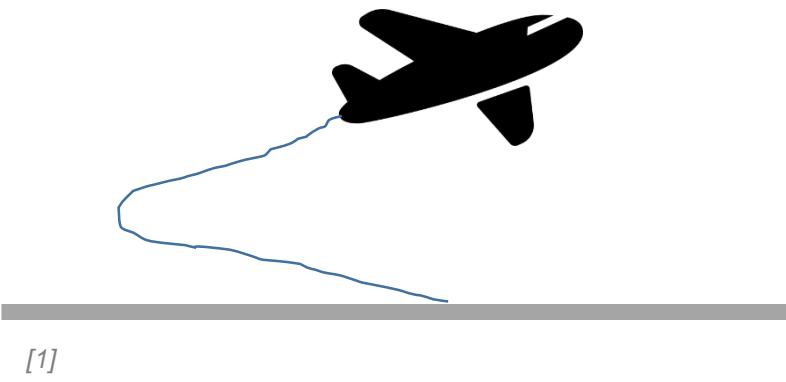
(Muller et al., 2015)

Aspects of crowdsourcing



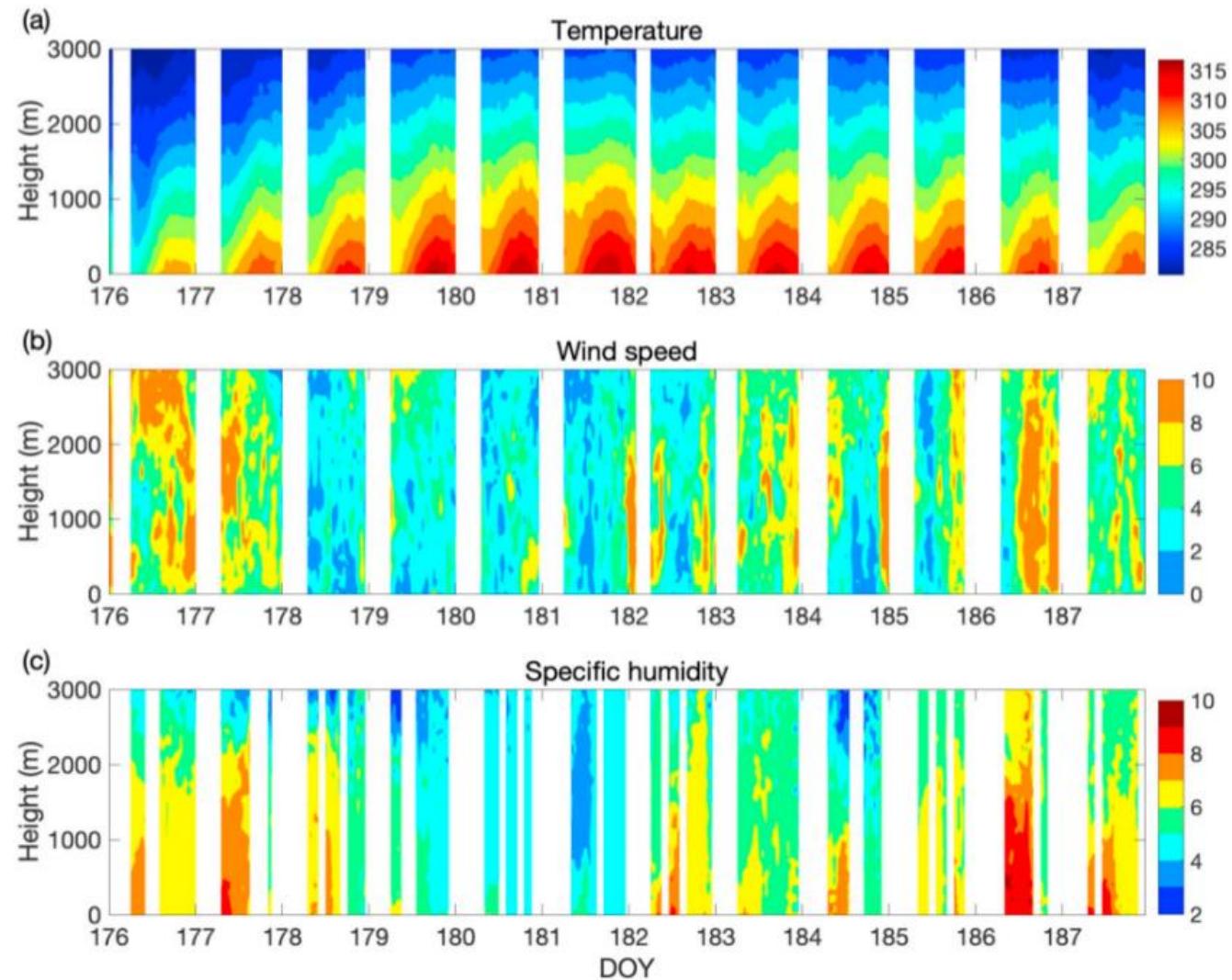
Muller et al. (2015)

Air planes...



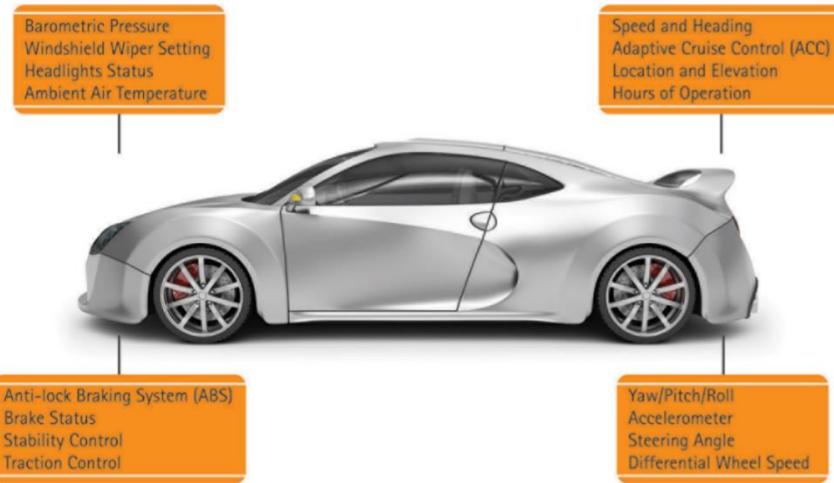
Data provided by the WMO:

<https://public.wmo.int/en/our-mandate/what-we-do/observations/Aircraft-based-observations>



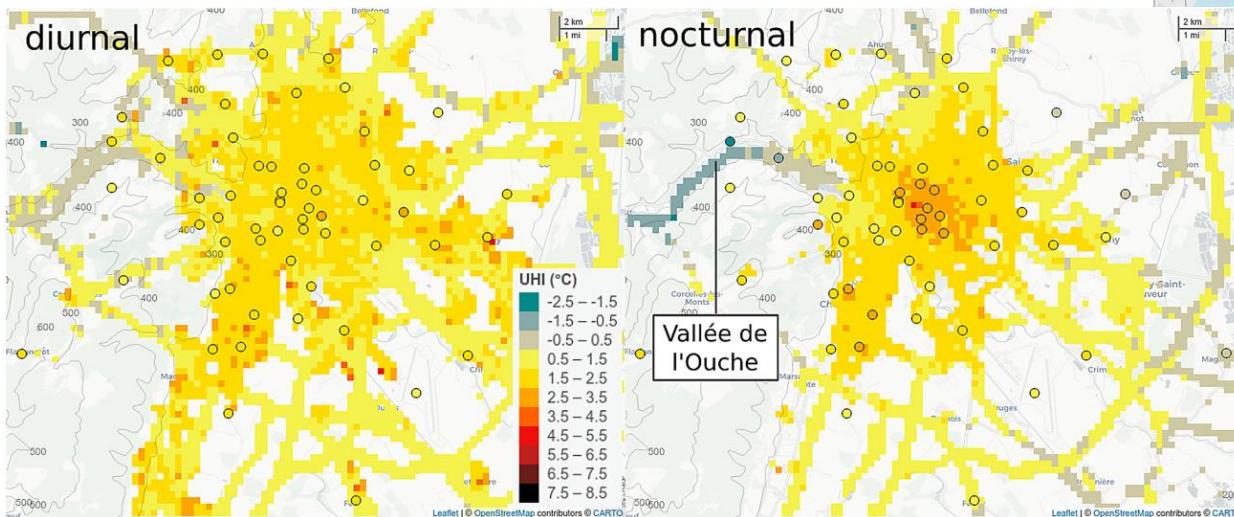
Zhang et al. (2020)

Cars...

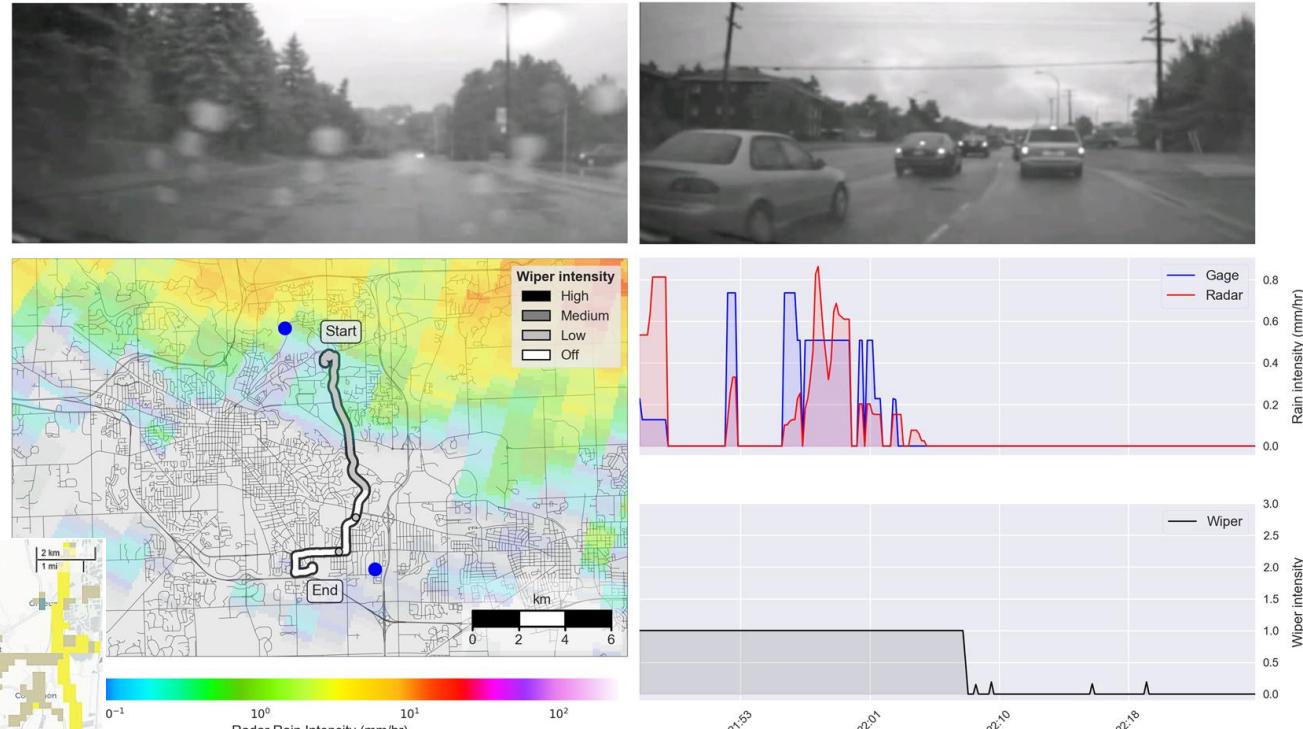


Mahoney & O'Sullivan (2013)

Air temperature



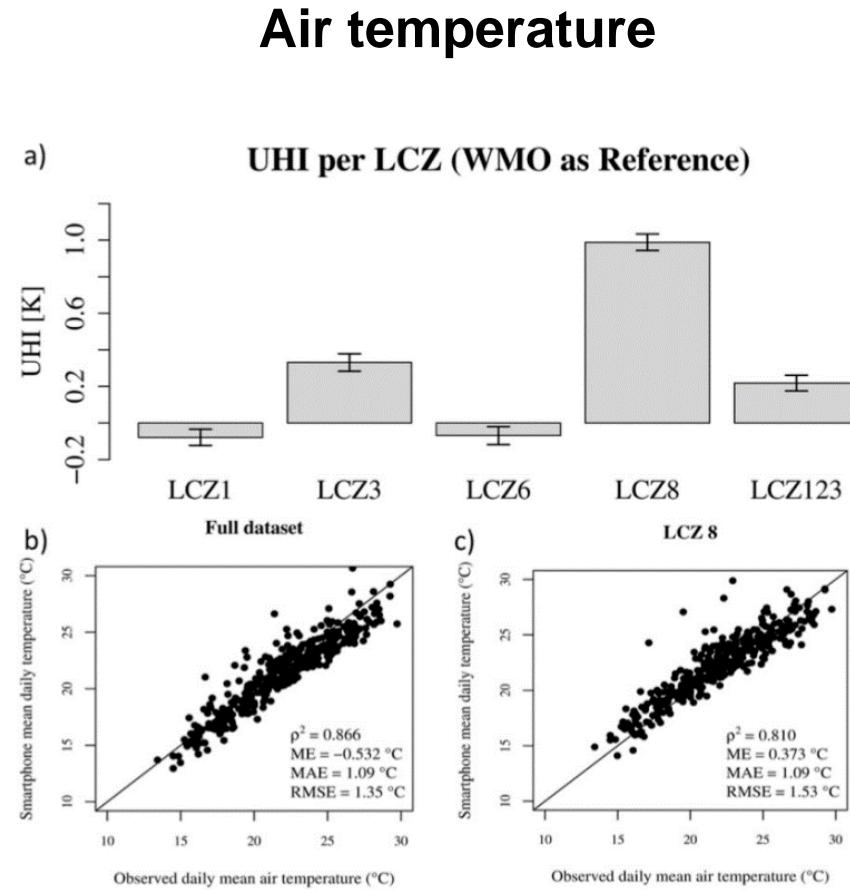
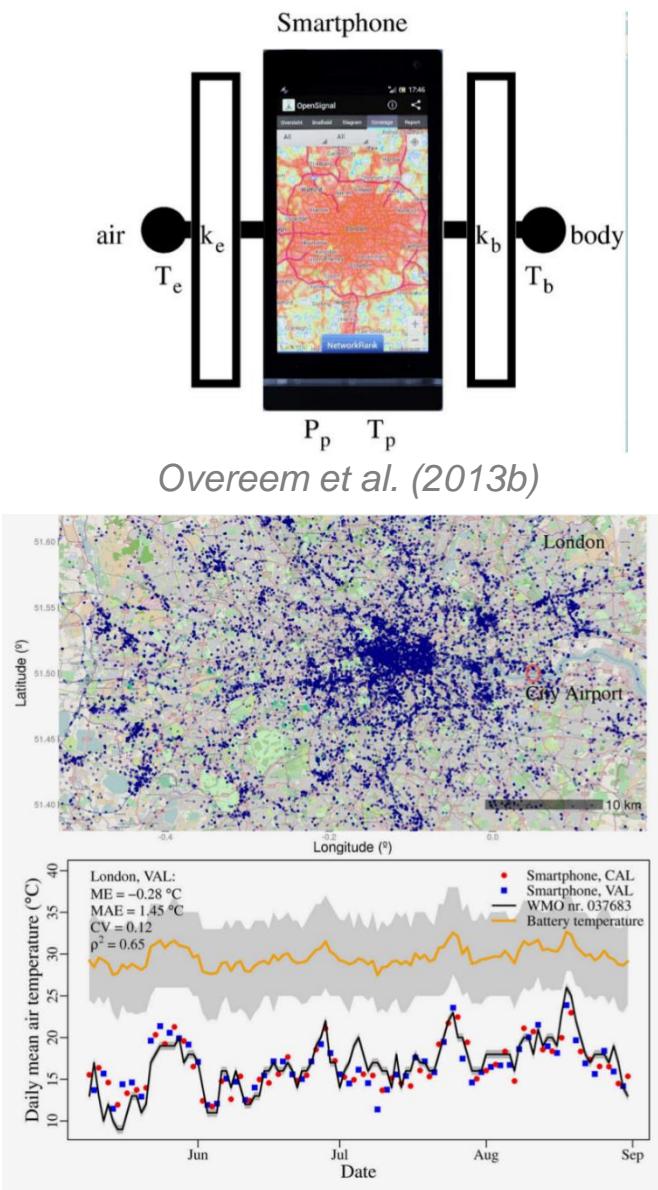
Rainfall



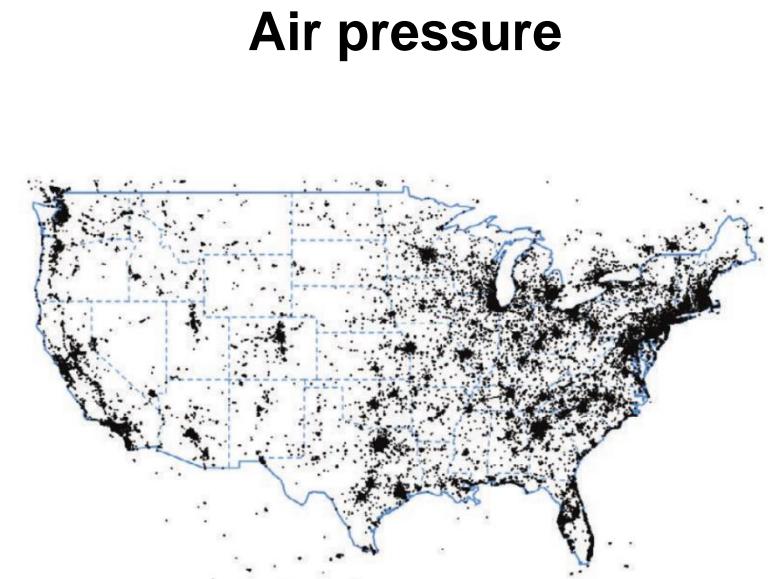
Bartos et al. (2019)

Marquès et al. (2022)

Smartphones...

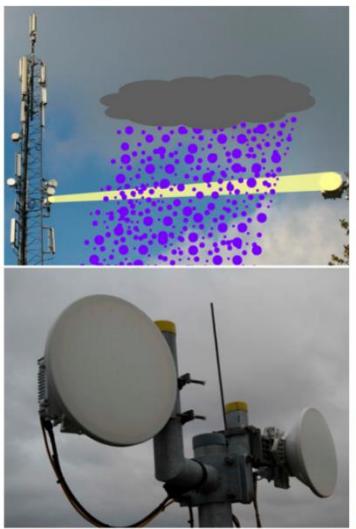


Droste et al. (2017)

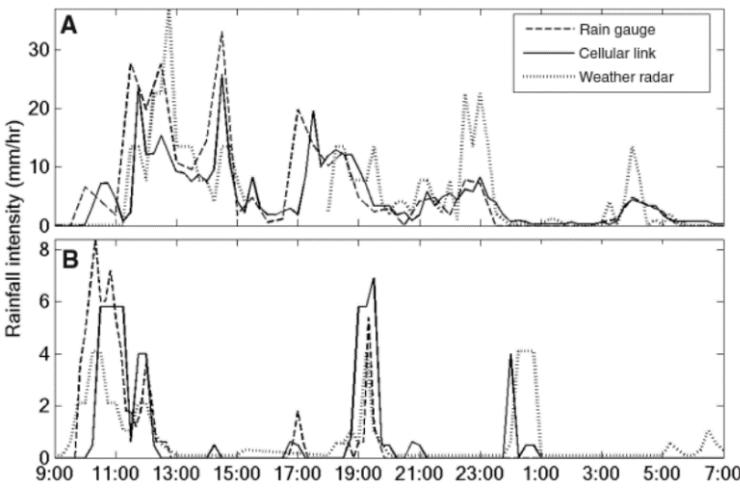


Mass & Madaus (2014)
also: Madaus & Mass (2017),
McNicholas & Mass (2018a, 2018b)

... and the networks behind them (cellular communication networks)

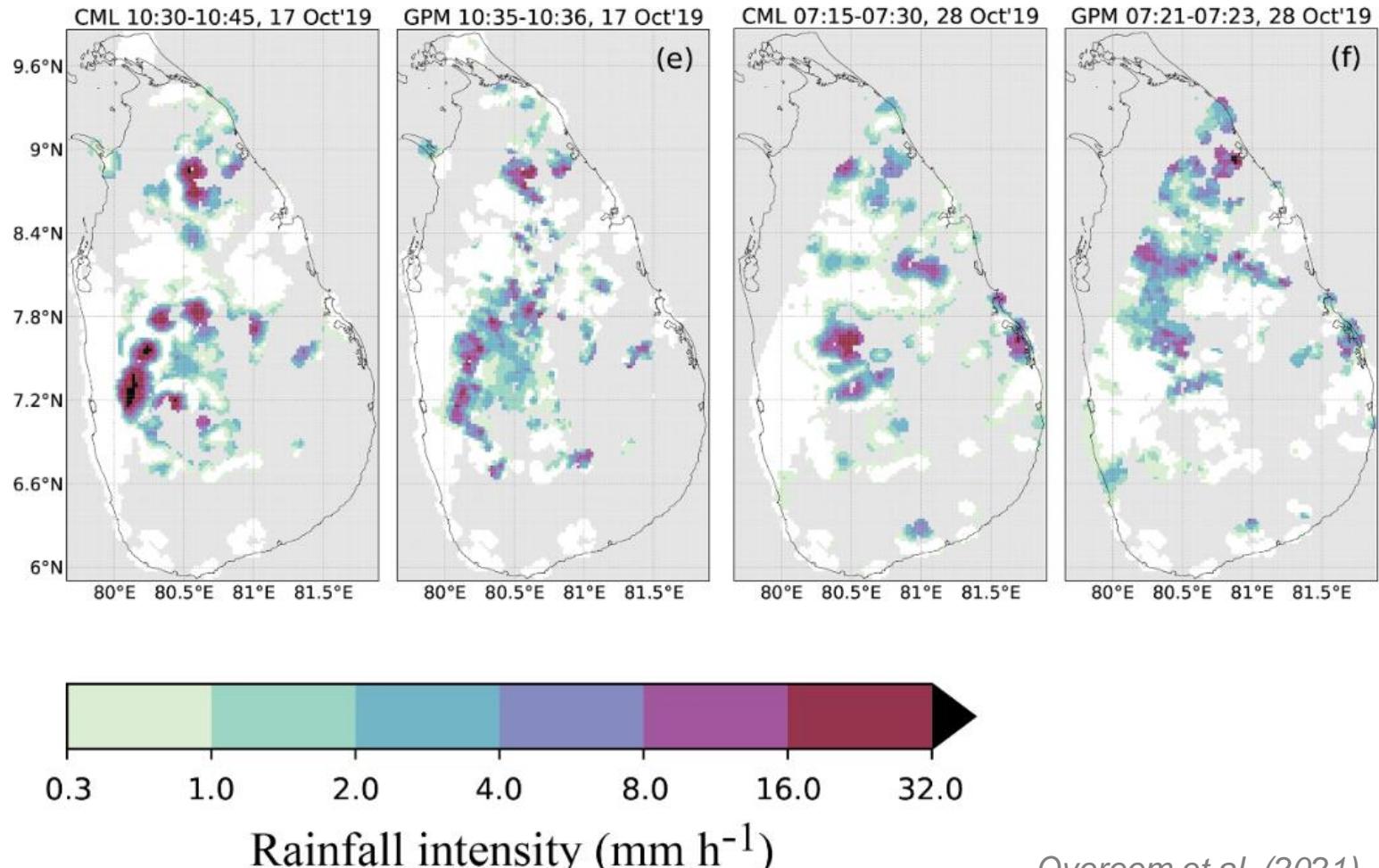


Overeem et al. (2013a)



Messer et al. (2006)

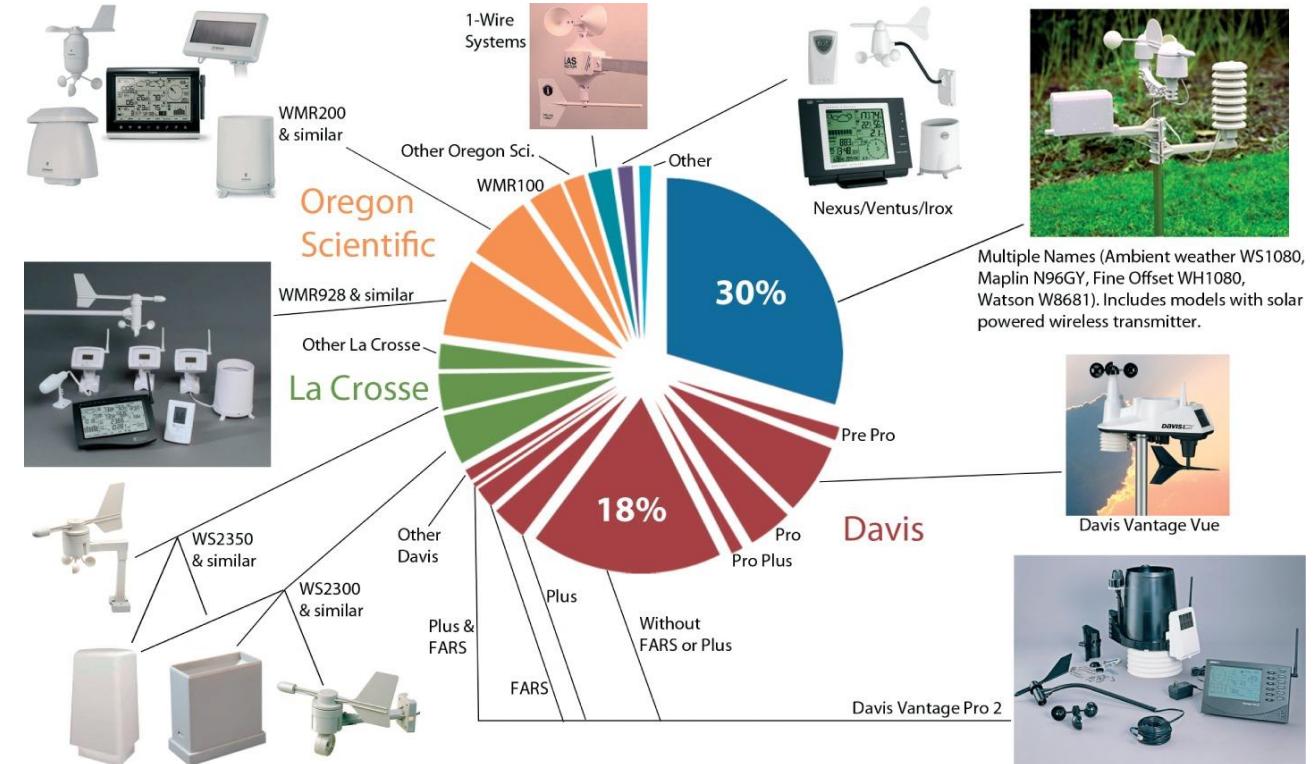
Rainfall



Overeem et al. (2021)

Citizen Weather Stations (CWS) – Crowd Weather Stations

- CWS = PWS = amateur station = amateur observation
- a meteorological station set up and maintained by individuals
- e.g. Steeneveld et al. (2011), Wolters und Brandsma (2012), Bell et al. (2013, 2015), Chapman et al. (2017), Meier et al. (2017), Fenner et al. (2017, 2019, 2021), de Vos et al. (2017, 2019a), Clark et al. (2018), Hammerberg et al. (2018), Bárdossy et al. (2021), Cornes et al. (2020), Feichtinger et al. (2020), Mandement & Caumont (2020), Nipen et al. (2020), Venter et al. (2020, 2021), Vulova et al. (2020), Chen et al. (2021), Potgieter et al. (2021), Varentsov et al. (2021), Alerskans et al. (2022), Brousse et al. (2022), Chakraborty et al. (2022), Coney et al. (2022), ...

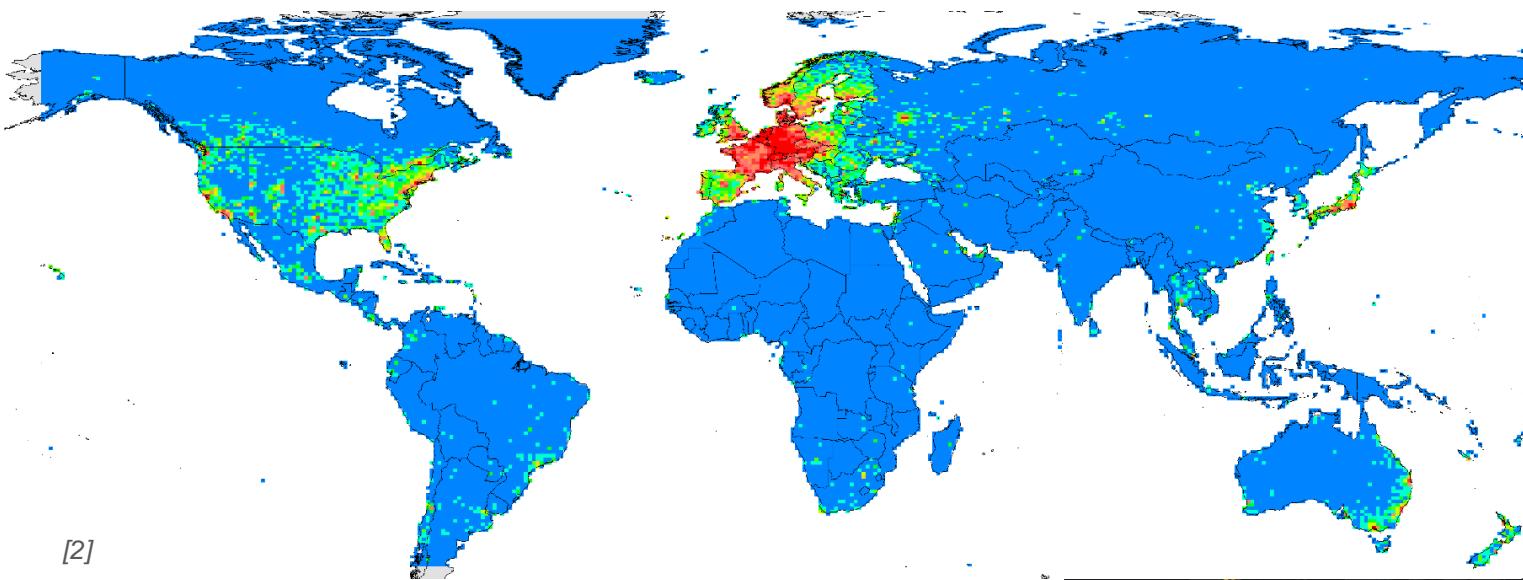


Bell et al. (2013)

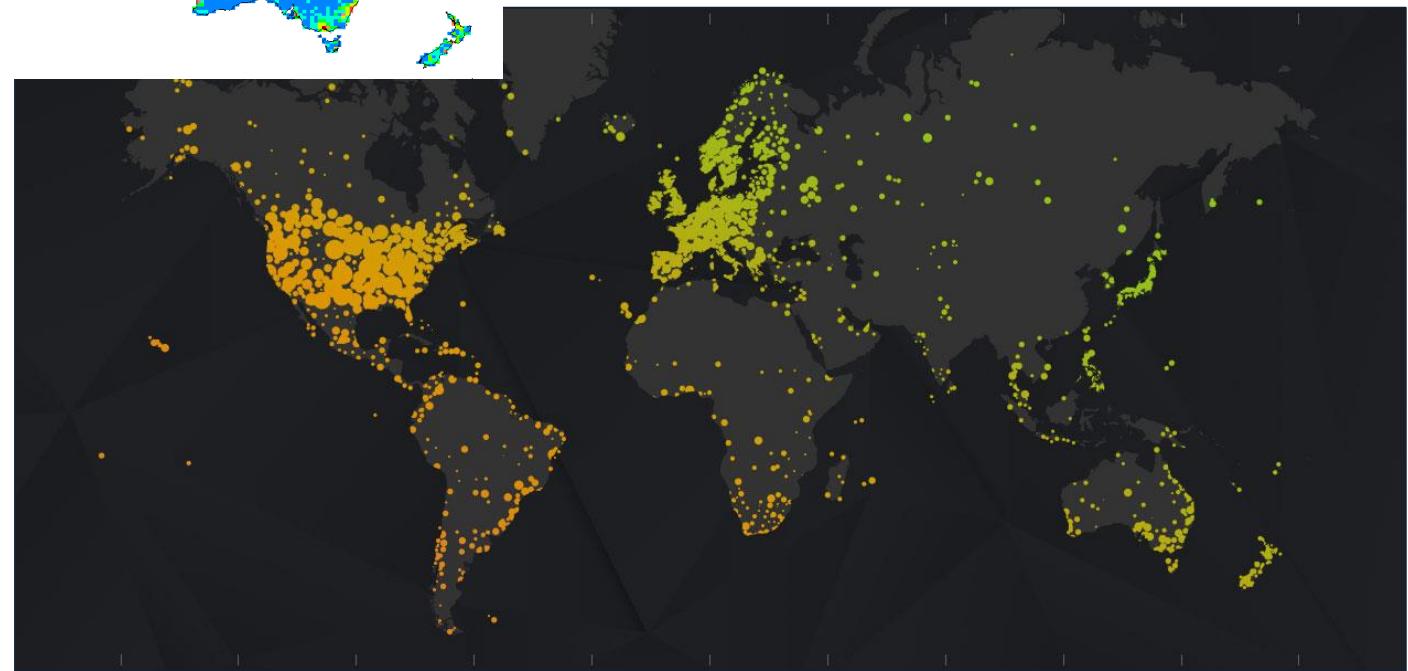
Step 1

Data sources & collection

Where to find CWS?

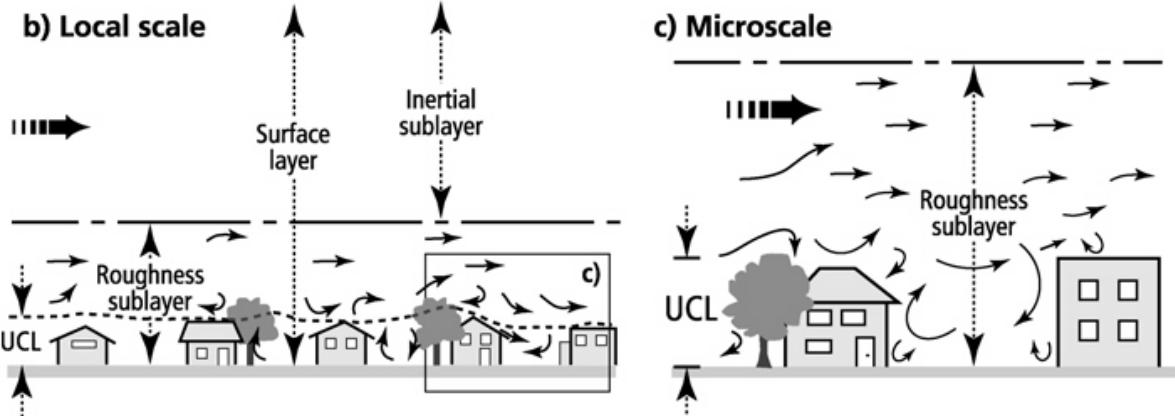
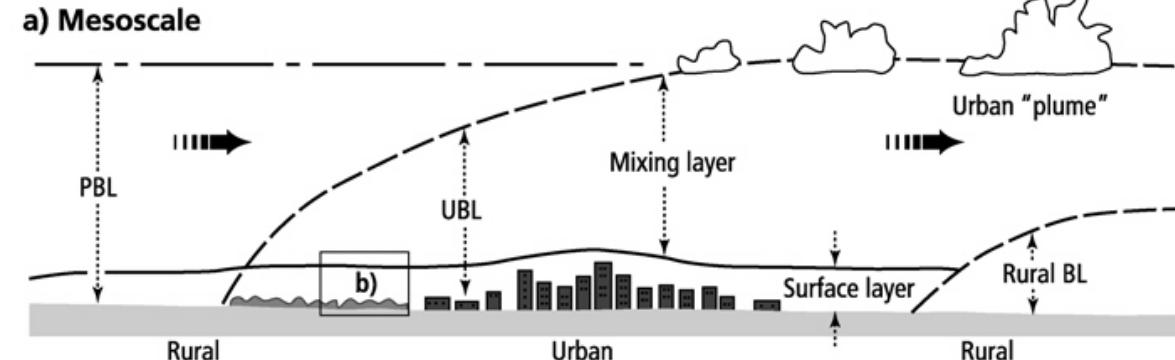


[2]



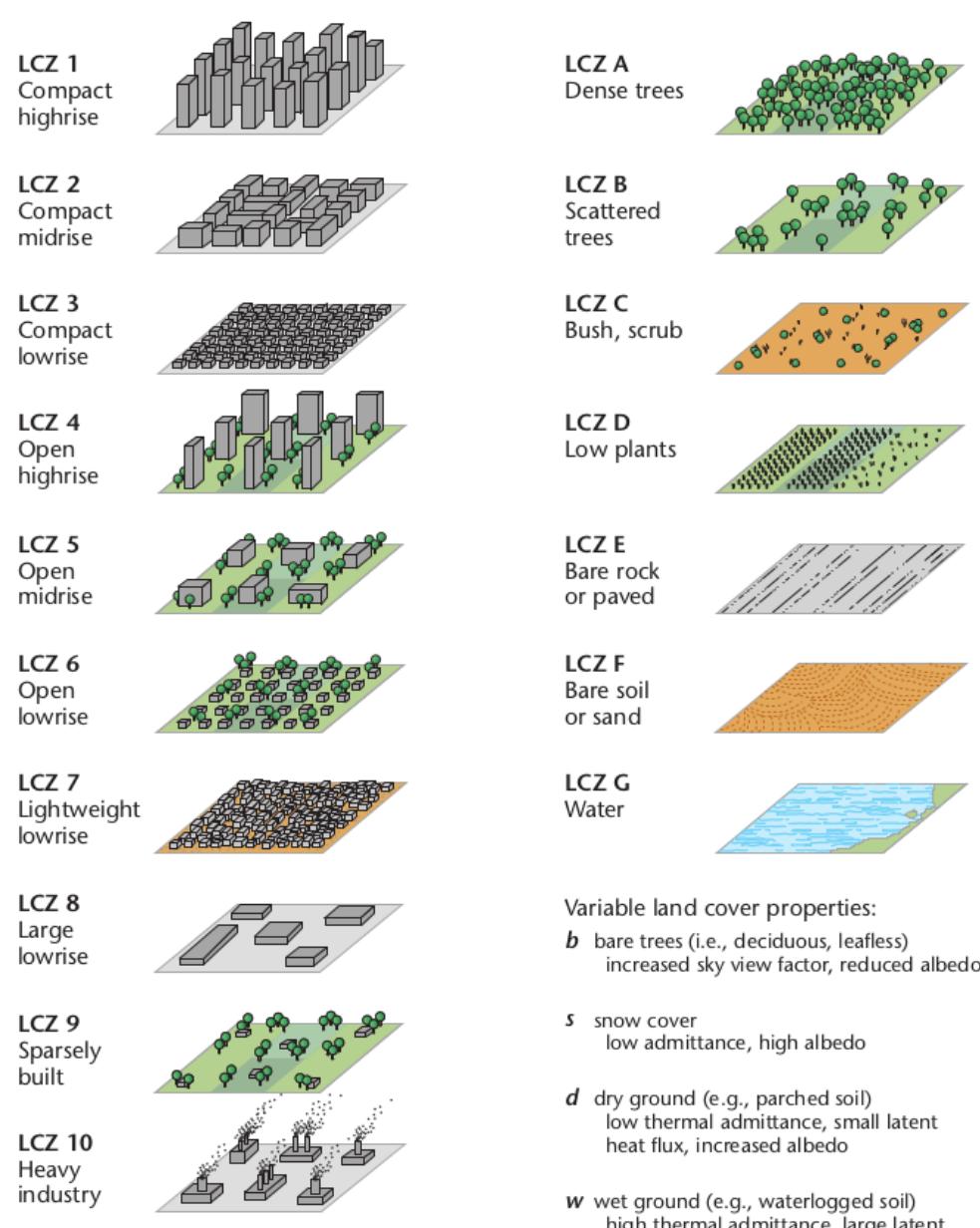
[3]

Where to find CWS in urban areas?



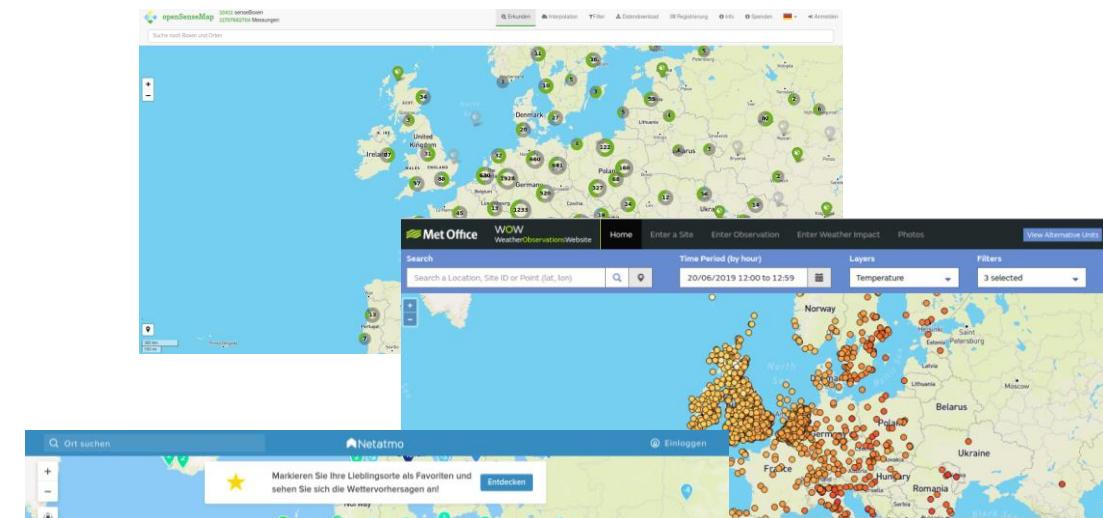
Grimmond (2006)

Stewart & Oke (2012)
Oke et al. (2017)



Platforms / data sources

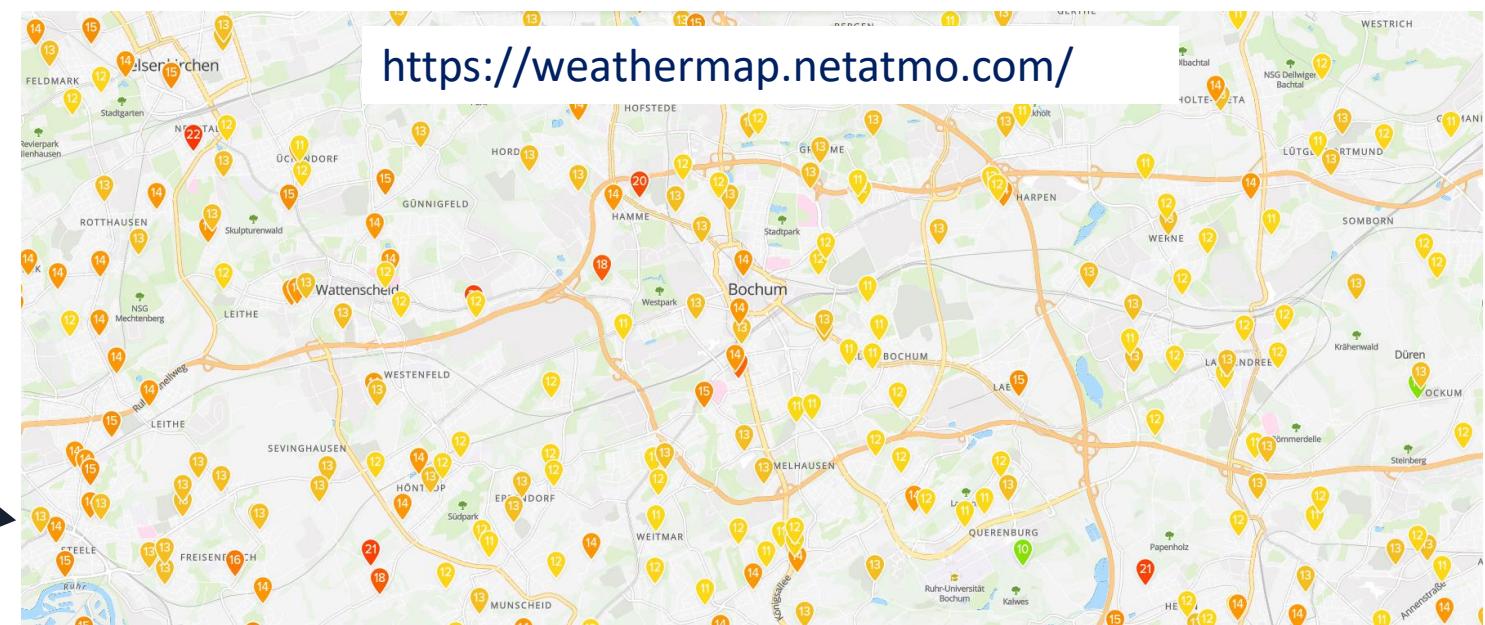
- Citizen Weather Observer Program (<http://wxqa.com/index.html>)
- Weather Observations Website (<https://wow.metoffice.gov.uk/>)
- Weather Underground/Wundermap (<https://www.wunderground.com/wundermap>)
- Netatmo/Netatmo Weathermap (<https://weathermap.netatmo.com/>)
- OpenSenseMap (<https://opensensemaps.org/>)
- PWS Weather (<https://www.pwsweather.com/>)
- Tempest WX (<https://tempestwx.com/map>)
- Ambient Weather (<https://ambientweather.net/>)
- WeatherLink (<https://www.weatherlink.com/map/>)
- FieldSense (<https://fieldsense.dk/en/>)
- ...



Netatmo CWS



<https://www.netatmo.com/>



Netatmo CWS components

Air temperature, relative
humidity, air pressure,
CO₂ concentration noise
level



Air temperature,
relative humidity

Precipitation



[9]

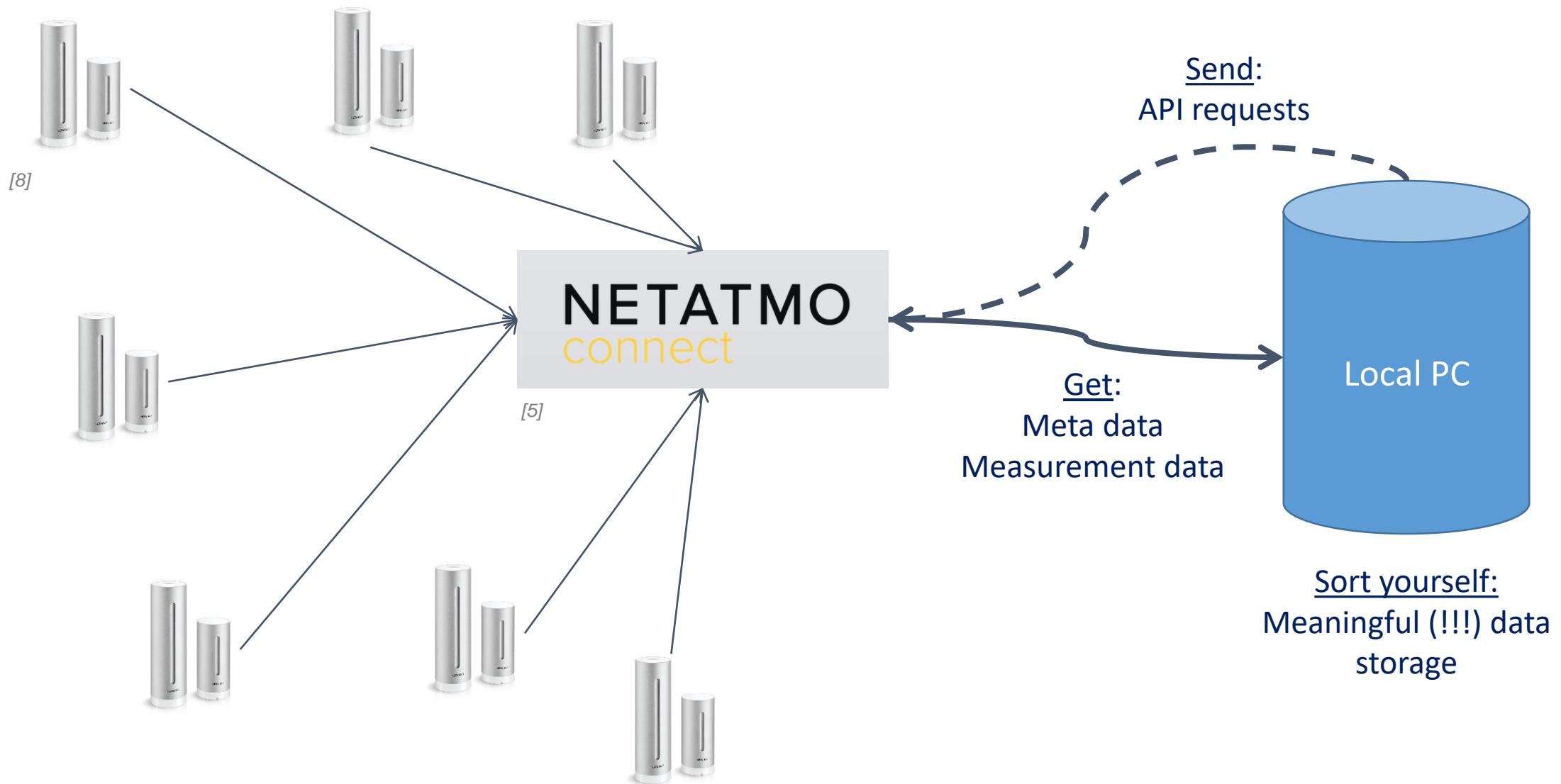
[11]



[10]

Wind speed,
direction

Data collection



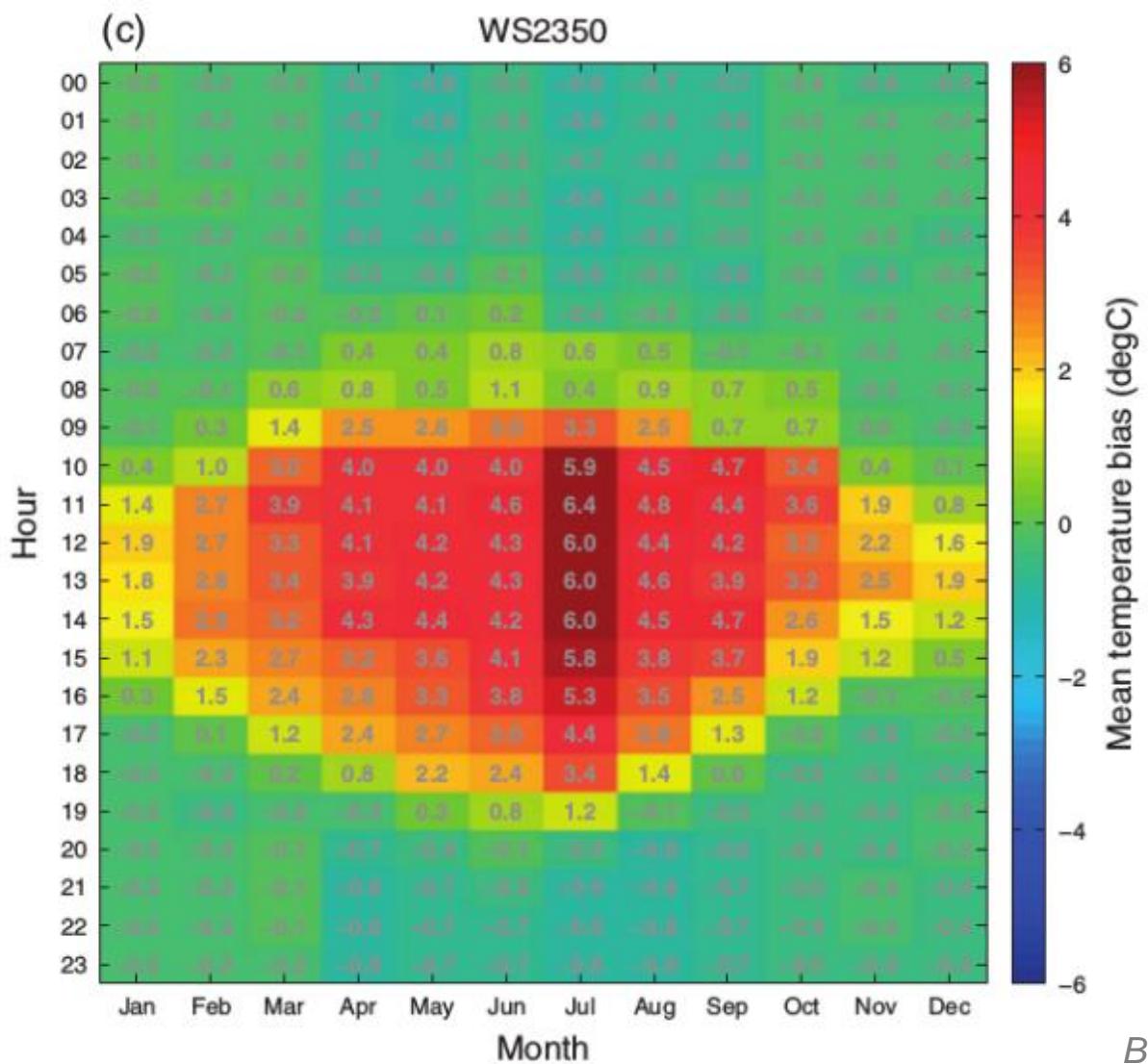
Step 2

Data quality

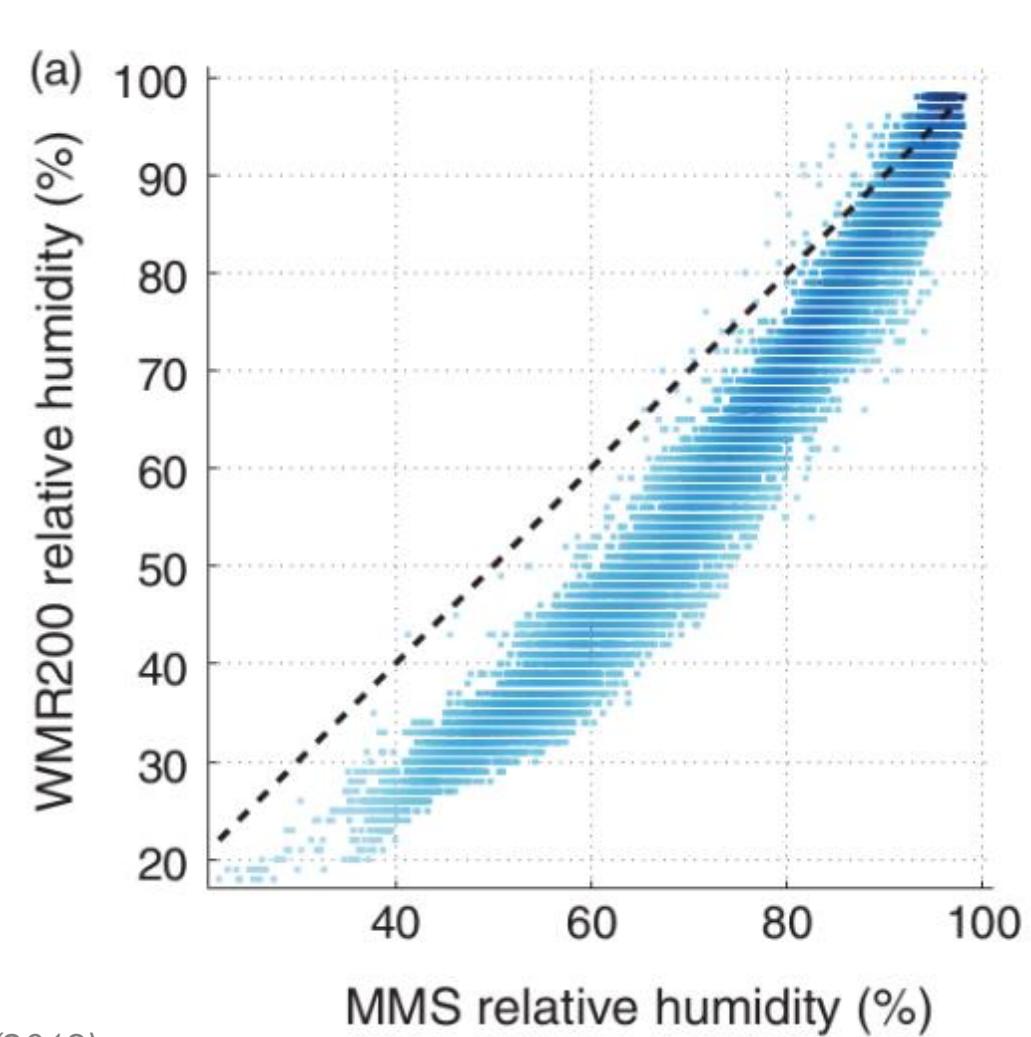
assessment & control

QA/QC of CWS

Air temperature



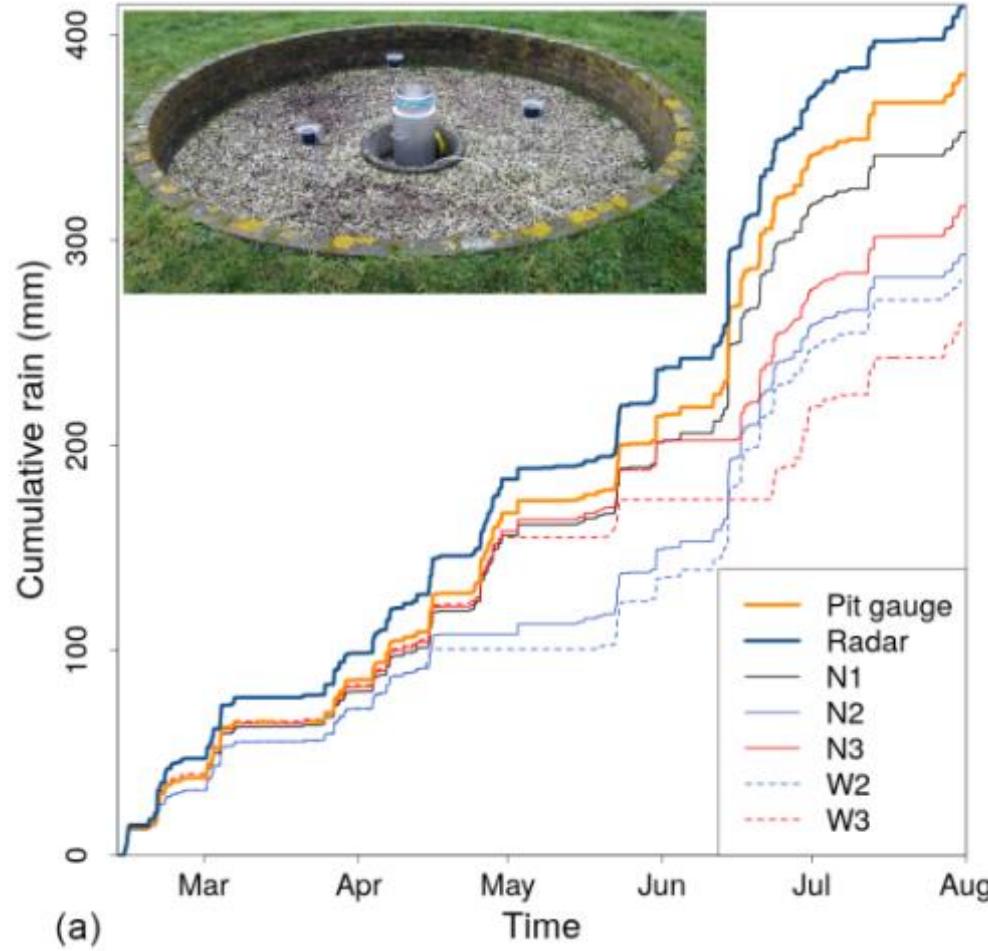
Relative humidity



Bell et al. (2013)

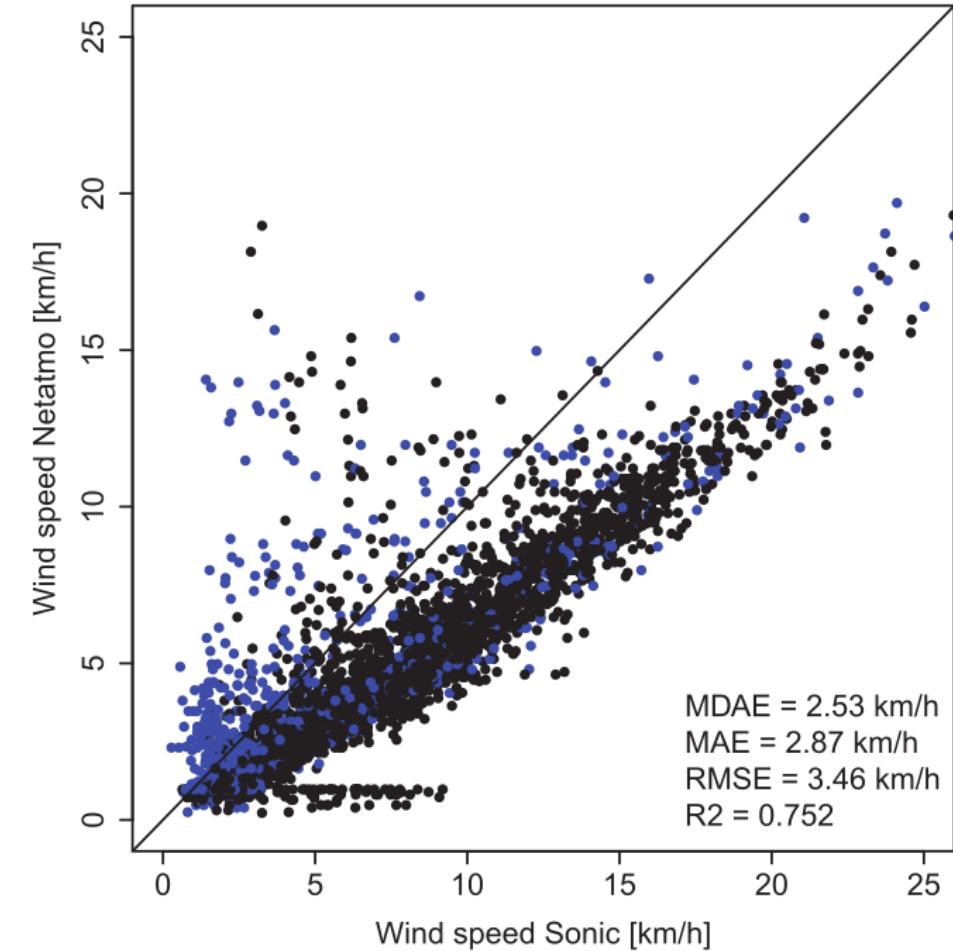
QA/QC of CWS

Rainfall



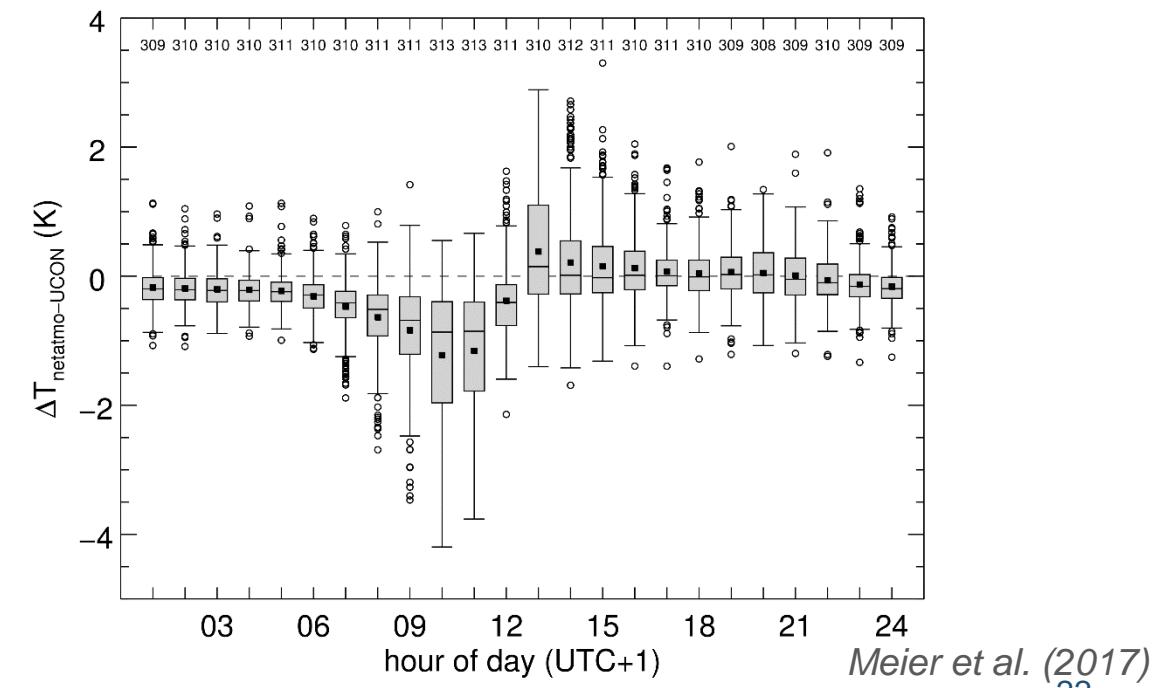
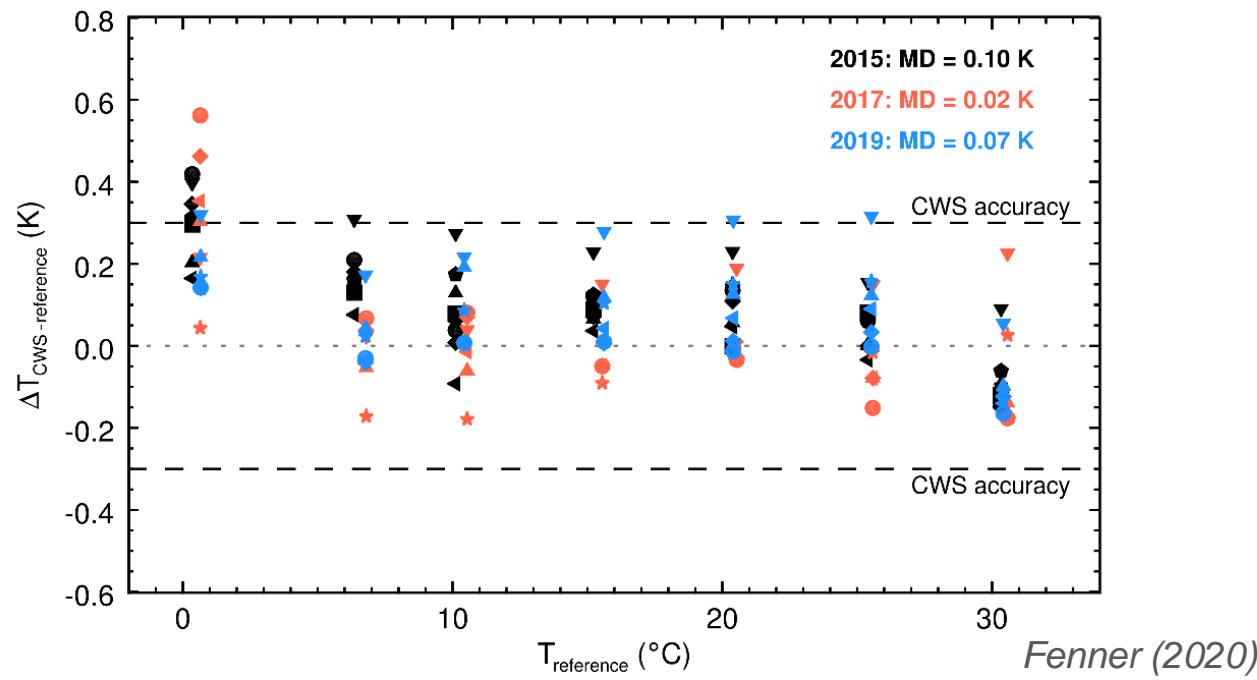
de Vos et al. (2017)

Wind speed



Droste et al. (2020)

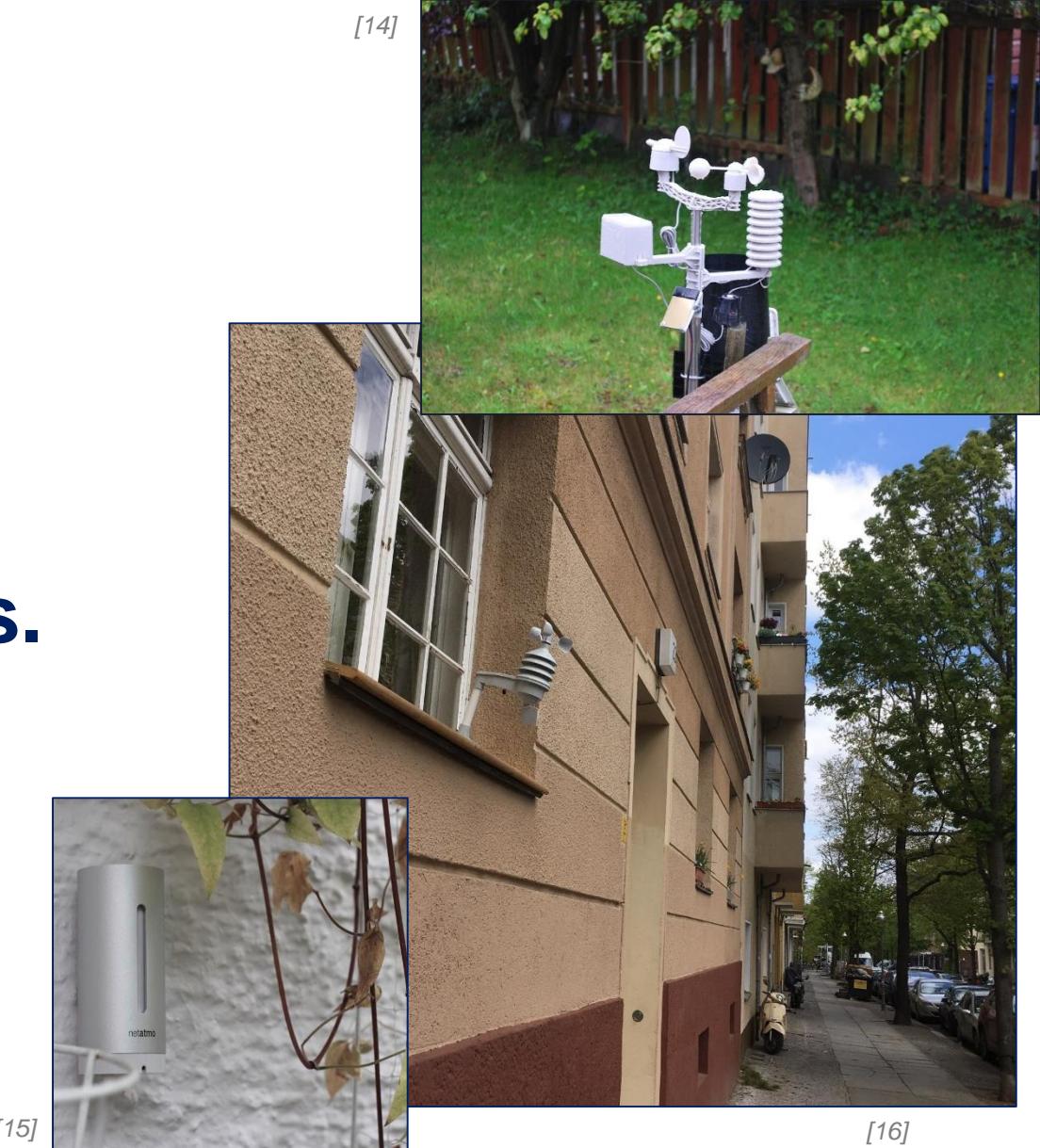
QA of Netatmo CWS



Instrumentation & siting



VS.

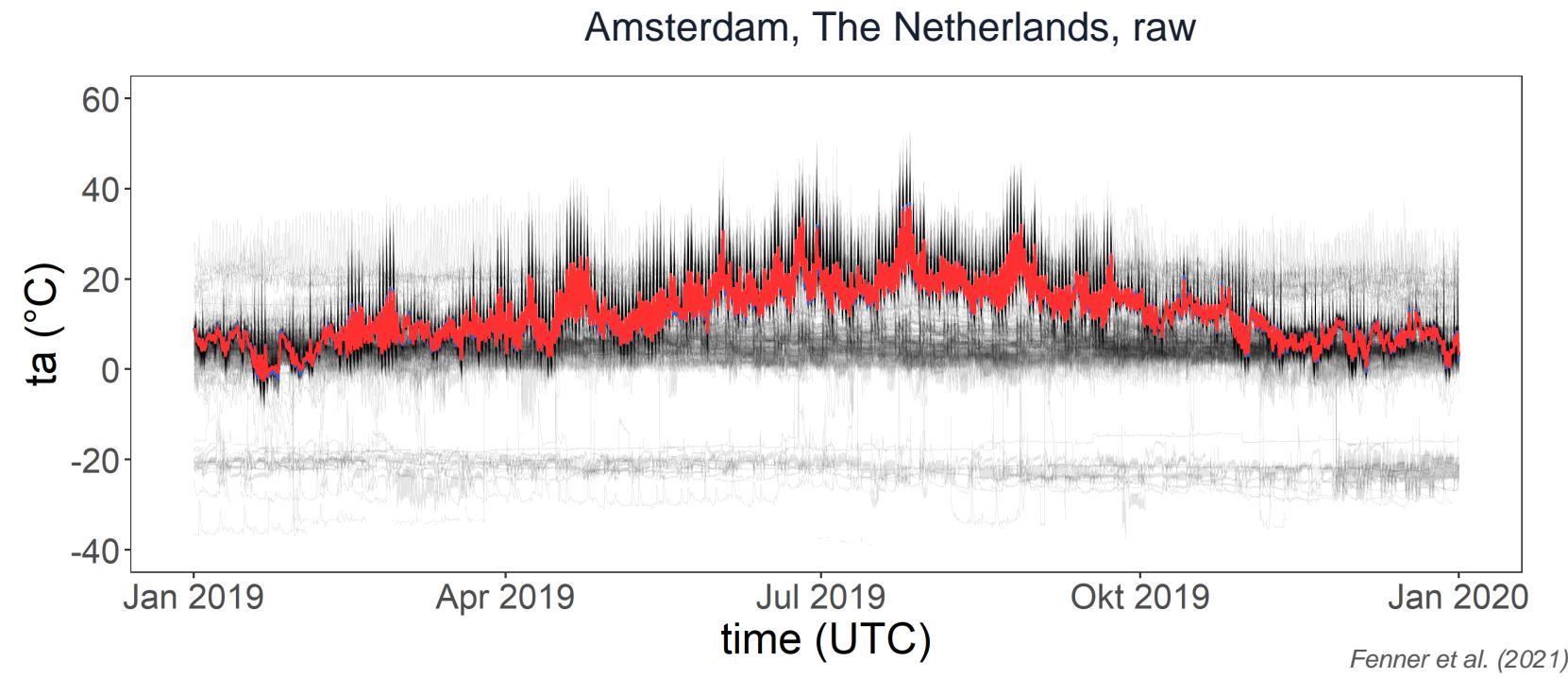


Issues with crowdsourced data sets

Main issues:

- Sensor design
- Meta data
- Representativeness
- Siting of sensors
- Calibration
- Variable-specific errors (e.g., radiative errors, high/null precipitation, high windspeed, ...)
- Intermittent data connection
- Others (temporarily moved, battery change, ...)

cf. Bell (2015), Meier et al. (2017), de Vos et al. (2017, 2019), Droste et al. (2020)



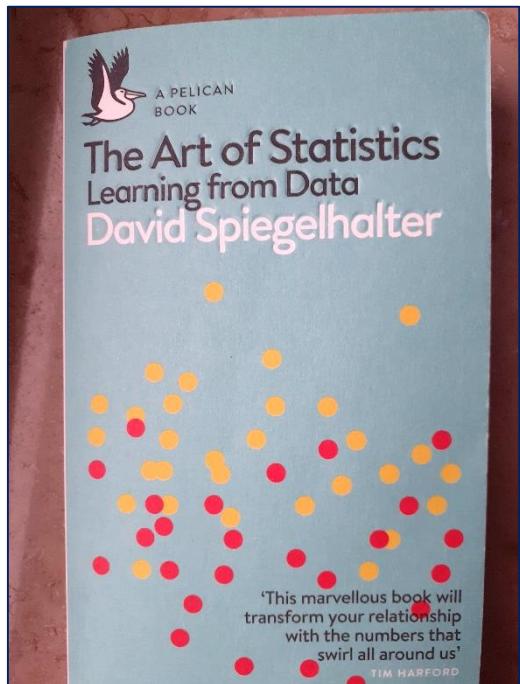
CWS quality control !!!

(I) Reference data

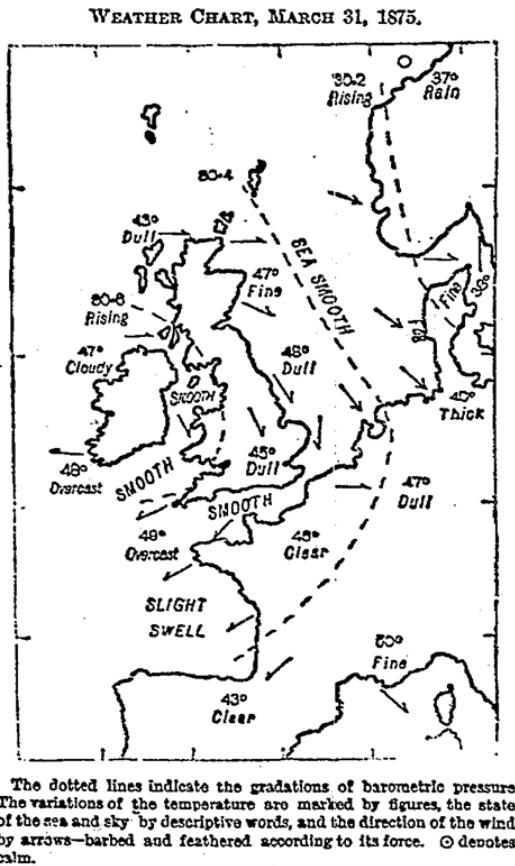
(II) “Wisdom of the crowd”

Overview of QC procedures (different variables)

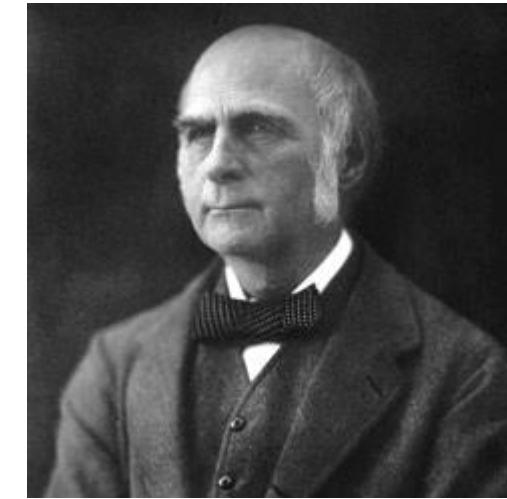
(II) “Wisdom of the crowd”



[17]



[20]



[19]

Francis Dalton (1822-1911)

Overview of QC procedures (different variables)

(I) Reference data

- *Bell (2015)*
- *Meier et al. (2017)*
- *Clark et al. (2018)*
- *Hammerberg et al. (2018)*
- *Båserud et al. (2020)*
- *Cornes et al. (2020)*
- *Droste et al. (2020)*
- *Mandement & Caumont (2020)*
- *Bárdossy et al. (2021)*
- *Chen et al. (2021)*
- *Varentsov et al. (2021)*
- ...

(II) “Wisdom of the crowd”

- *Chapman et al. (2015)*
- *Napoly et al. (2018)/Grassmann et al. (2018)*
- *de Vos et al. (2019)*
- *Båserud et al. (2020)*
- *Fenner et al. (2021)*
- ...

I have a dream ...

... to have a QC for crowdsourced CWS data that is:

- applicable without reference data
- applicable to “any” region
- applicable in near-real time
- user-friendly
- open source
- fast
- removes ALL errors but leaves as much data as possible
- is applicable to all variables



CrowdQC+

(works only with near-normally distributed data)

?

??

X

CrowdQC+ : QC levels

CrowdQC+ is a further development of CrowdQC (*Grassmann et al. 2018, Napolys et al. 2018*)

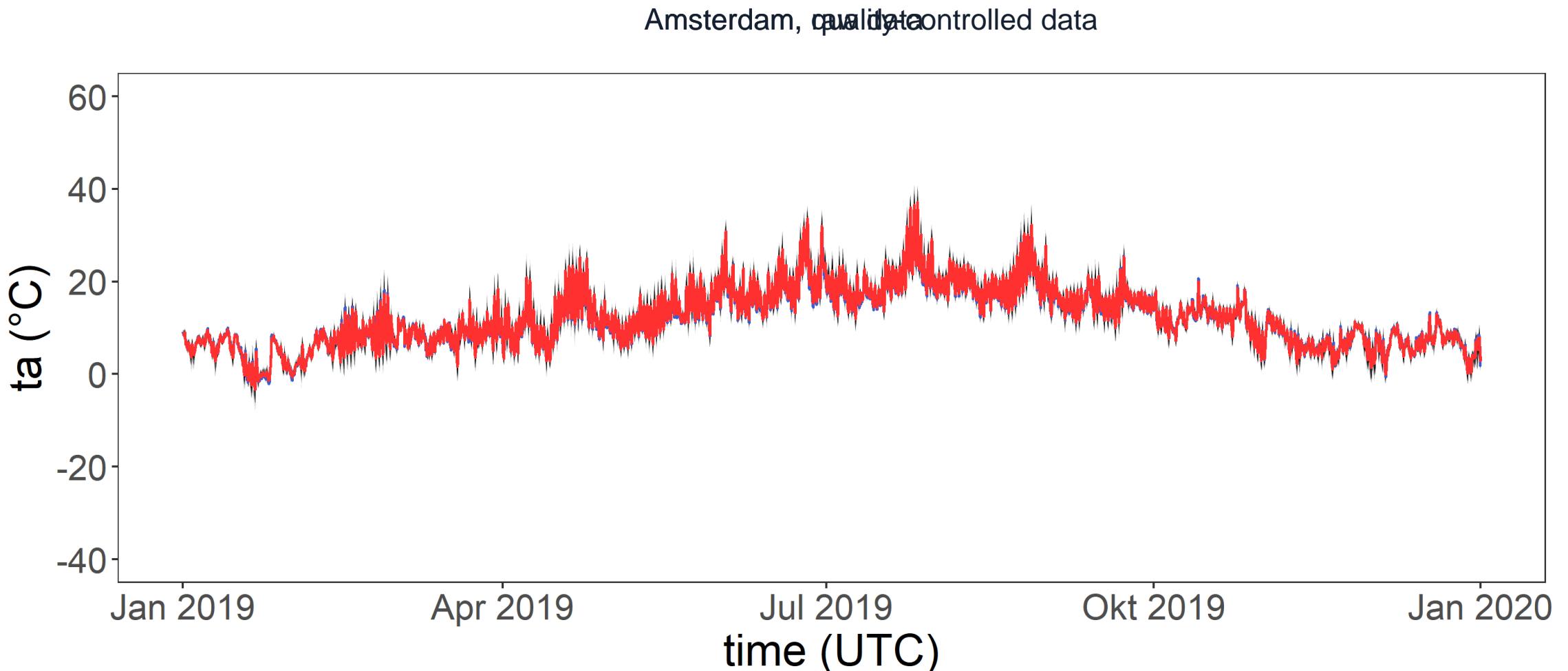
Level	Details	Comments
Main QC levels		
m1	Meta-data check	Removal of identical locations
m2	Distribution check	Outlier detection, lapse-rate adjustment, distribution assumption
m3	Duration validity	Data availability, user-defined duration
m4	Temporal correlation	Correlation with median of all CWS, user-defined duration
m5	Spatial buddy check	Spatial check with neighbouring CWS, lapse-rate adjustment, height check
Optional QC levels		
o1	Temporal interpolation	Filling of gaps
o2	Daily validity	Data availability, daily
o3	Duration validity	Data availability, user-defined duration
o4	Sensor-lag correction	Correction of data regarding known time-constant of sensor

Additional functions for enhanced user-friendliness:

Fenner et al. (2021)

- input data check, data preparation, adding of DEM information, output statistics

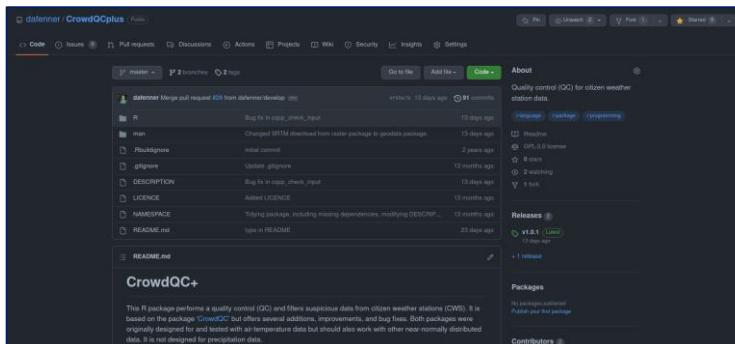
Let the magic happen



Fenner et al. (2021)

Explore CrowdQC+ yourself during the

hands-on exercise in the afternoon!



<https://github.com/dafenner/CrowdQCplus>

TECHNOLOGY AND CODE article

Front. Environ. Sci., 03 December 2021
Sec. Interdisciplinary Climate Studies
<https://doi.org/10.3389/fenvs.2021.720747>

This article is part of the Research Topic
Urban Climate Informatics
[View all 12 Articles >](#)

CrowdQC+—A Quality-Control for Crowdsourced Air-Temperature Observations Enabling World-Wide Urban Climate Applications

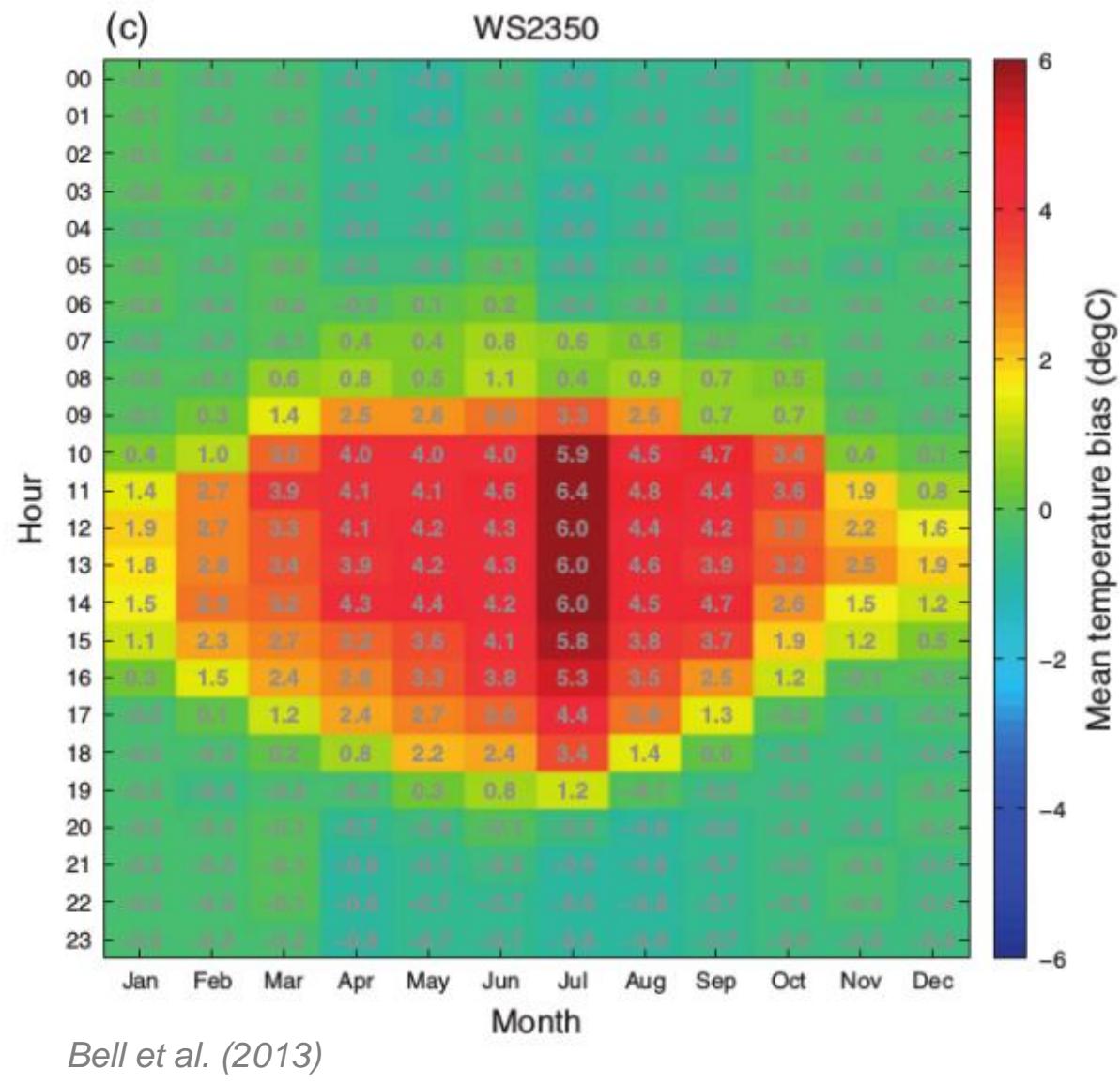
Daniel Fenner^{1,2*}, Benjamin Bechtel¹, Matthias Demuzere¹, Jonas Kittner¹ and Fred Meier³

<https://doi.org/10.3389/fenvs.2021.720747>

The need for QA & QC !

QA/QC are essential for crowdsourced (CWS) data!

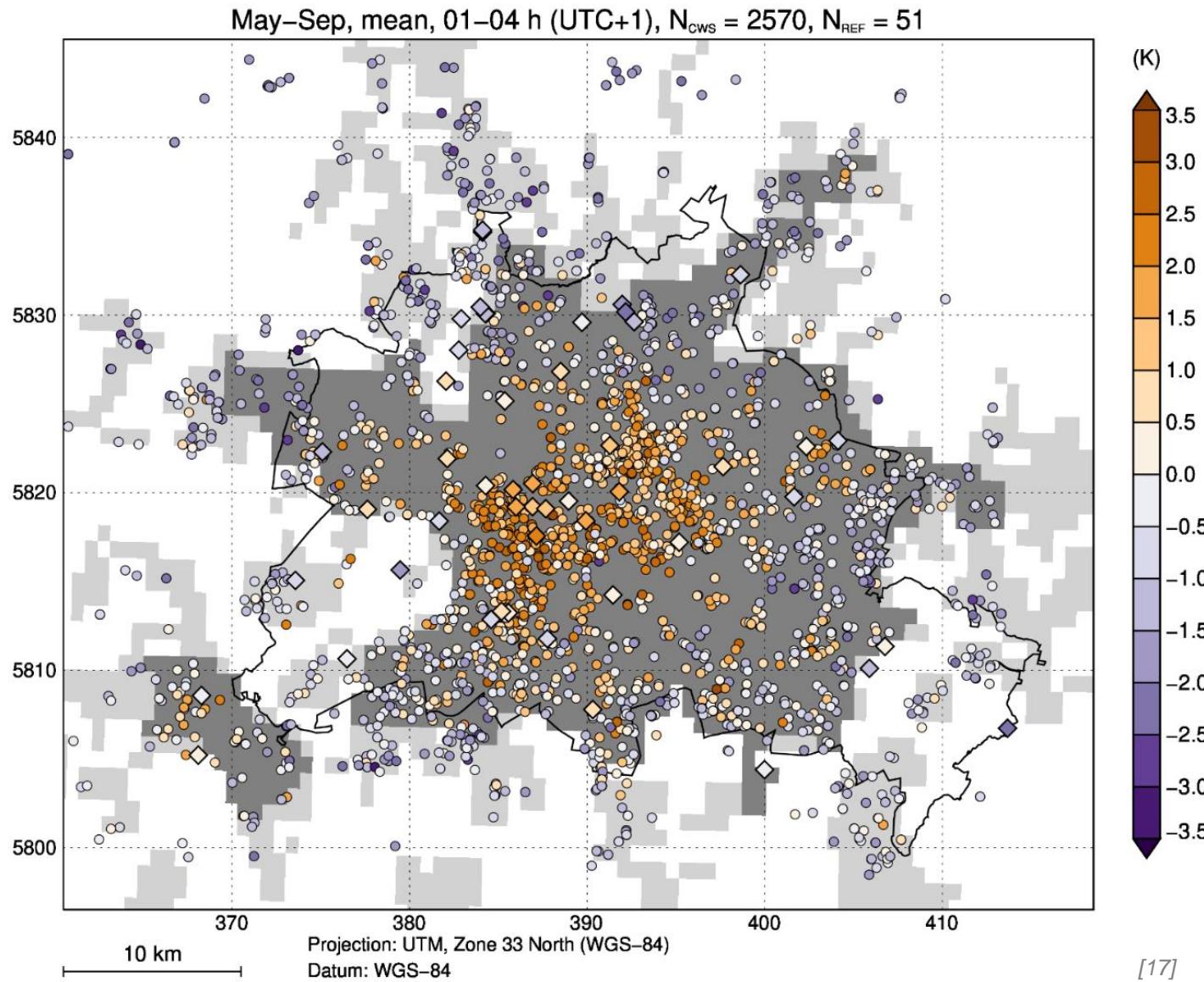
QA/QC are essential for any kind of data!!!



Step 3

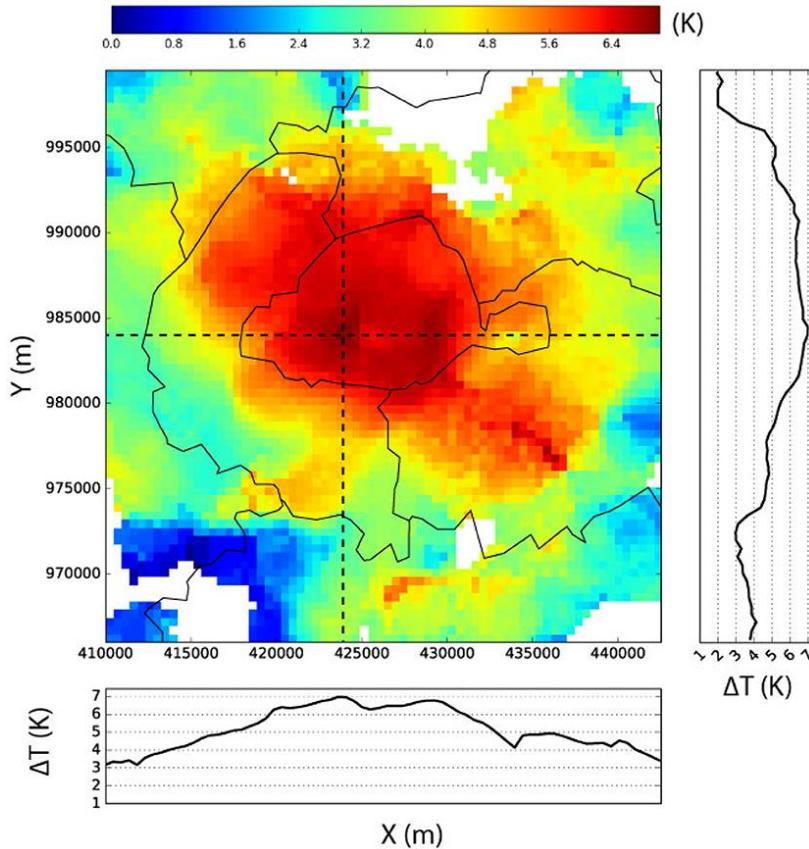
Data analyses

Air temperature distribution



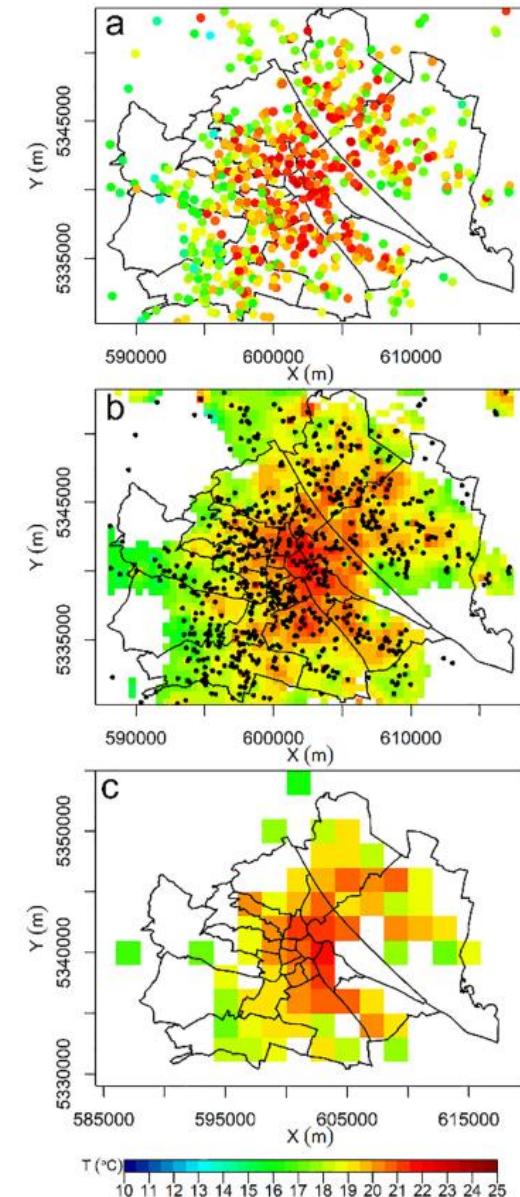
Air-temperature mapping (CWS only)

Paris, France



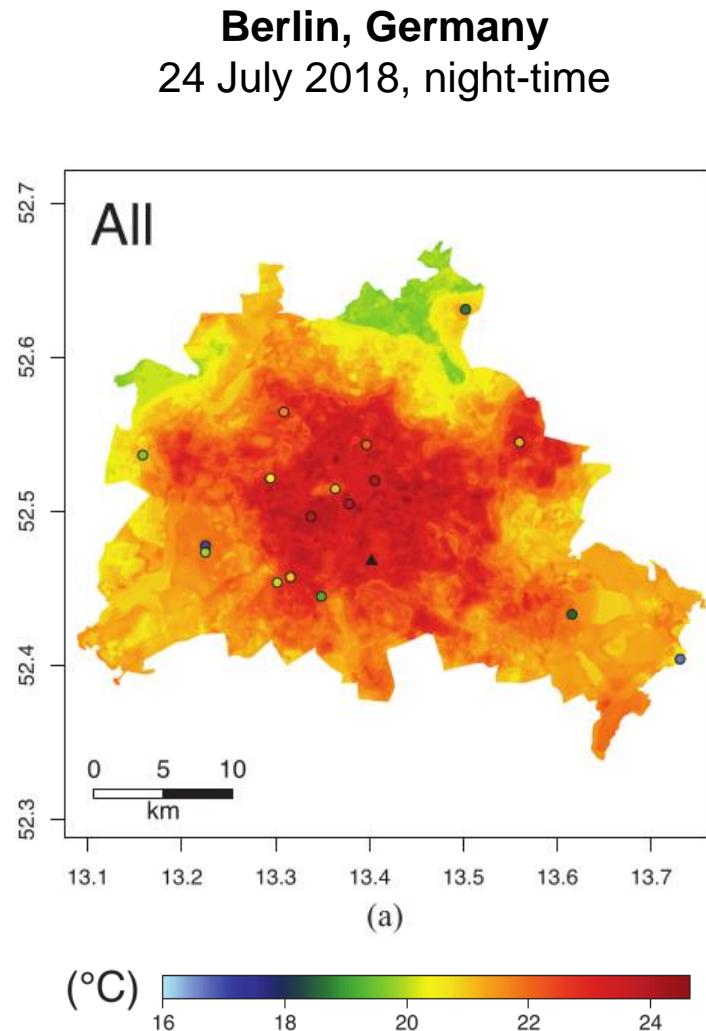
Napoly et al. (2018)

Vienna, Austria

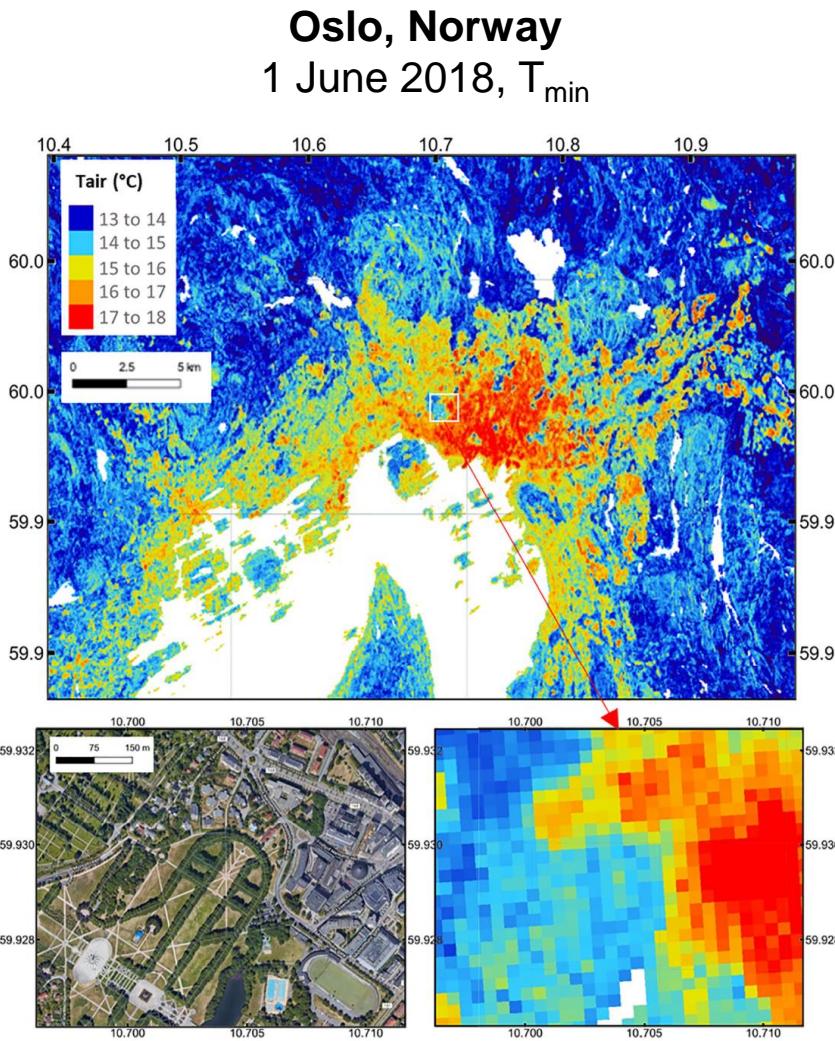


Feichtinger et al. (2020)

Air-temperature mapping (CWS+RS+ML)

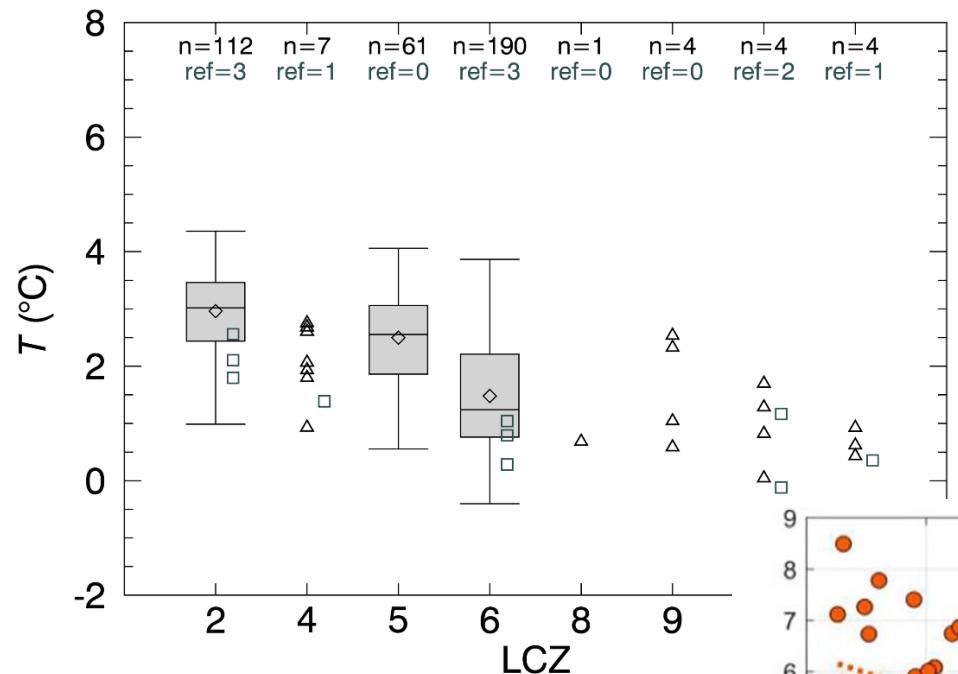


Vulova et al. (2020)



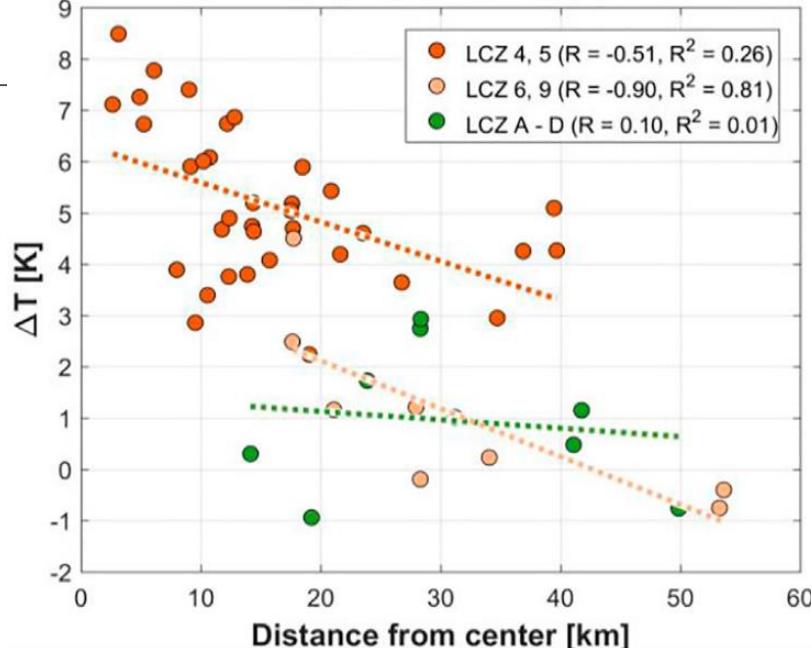
Venter et al. (2020)

(Intra-)urban analyses

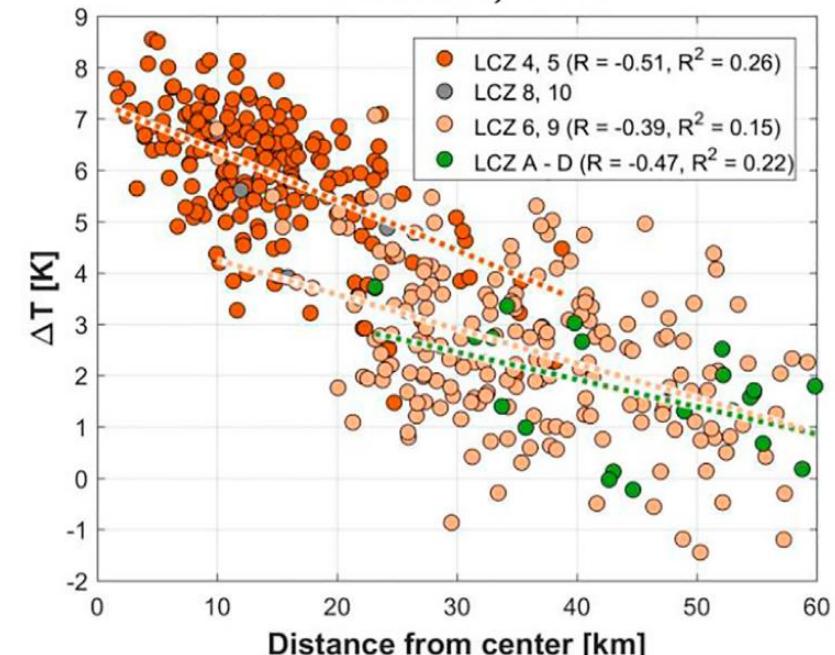


Fenner et al. (2017)

Berlin, Germany
February 2015, nighttime



Moscow, Russia
May-June 2019

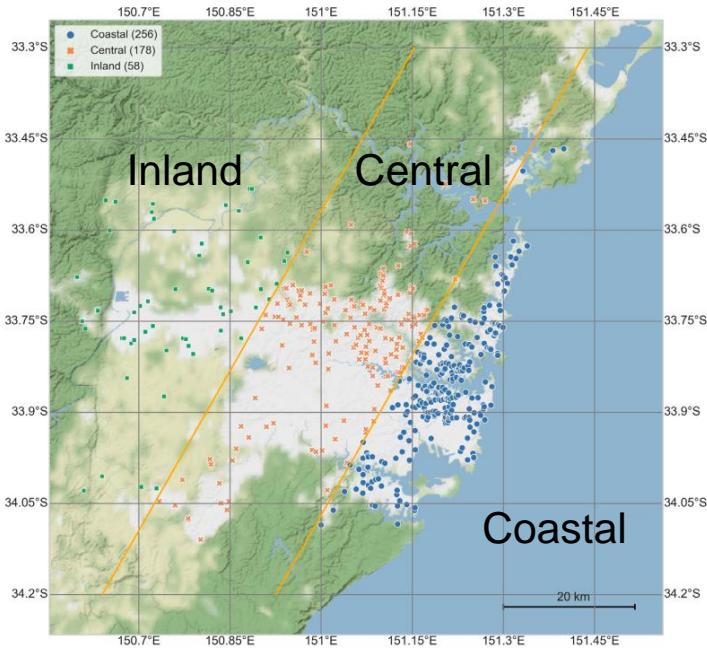


Varentsov et al. (2021)

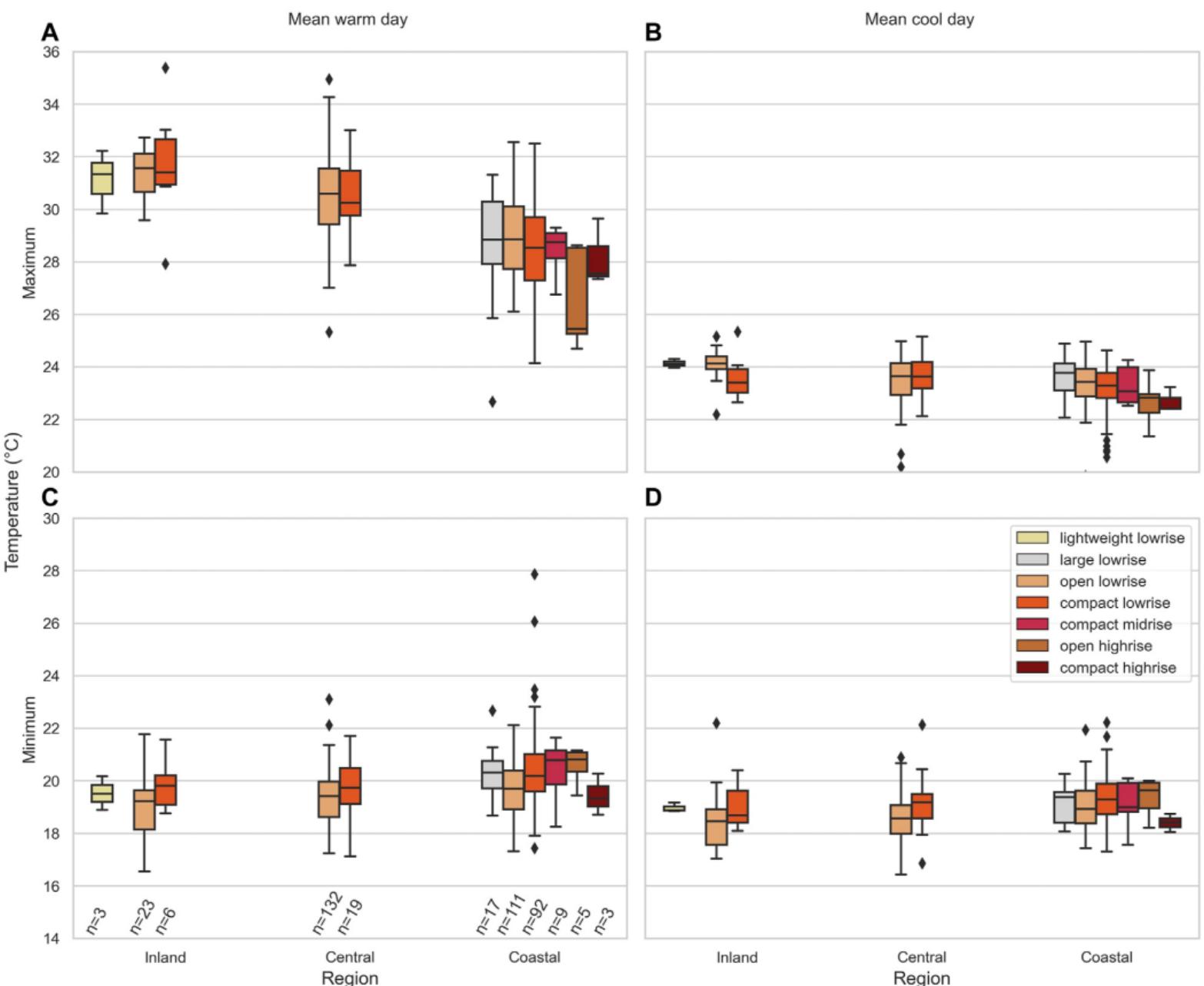
(Intra-)urban analyses

Sydney, Australia

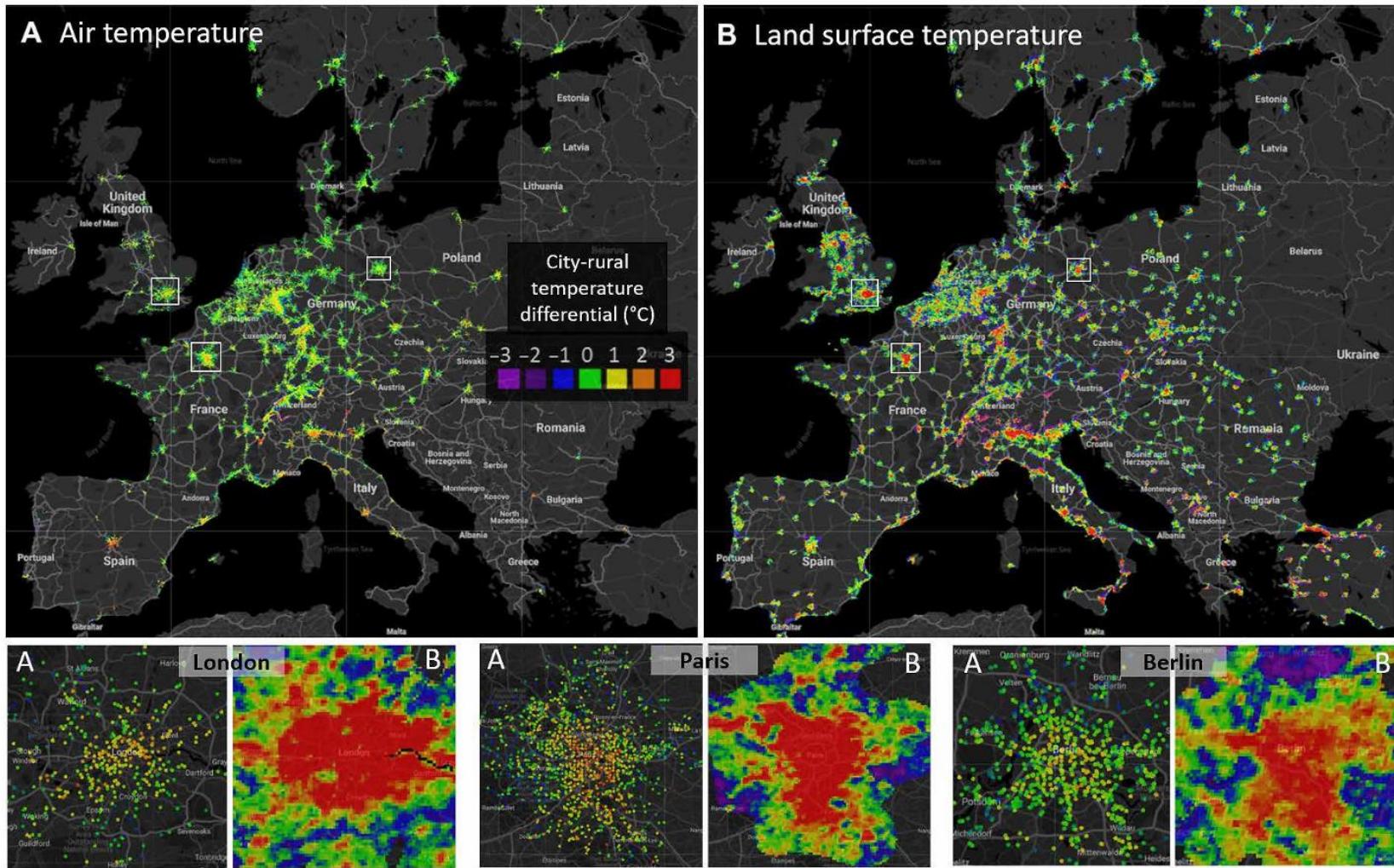
December 2020 – February 2021



Potgieter et al. (2021)

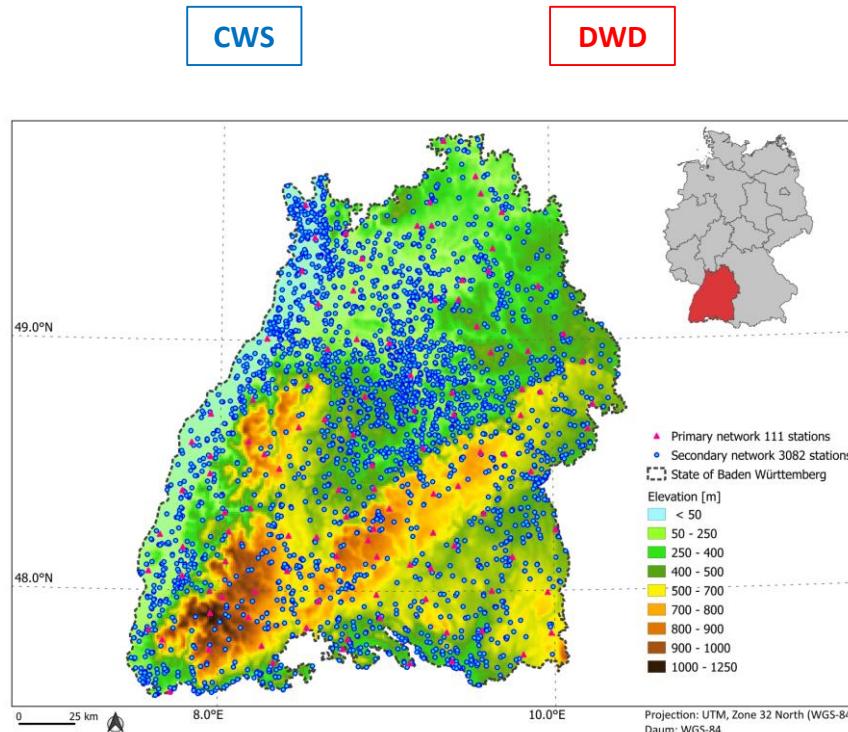


UHI comparison



Venter et al. (2021)

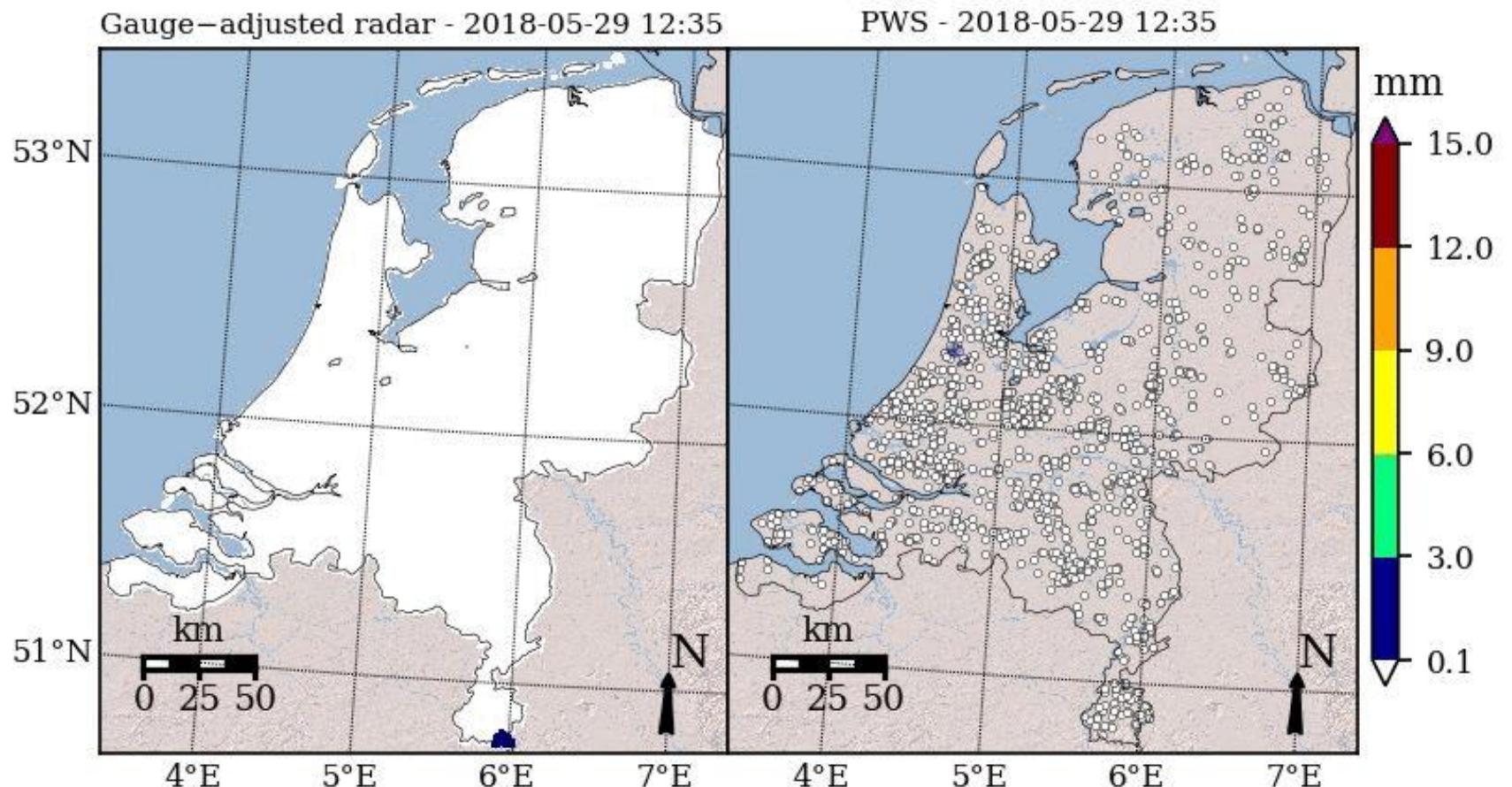
Precipitation - Interpolation



Bárdossy et al. (2020)

Precipitation – (Operational) weather monitoring

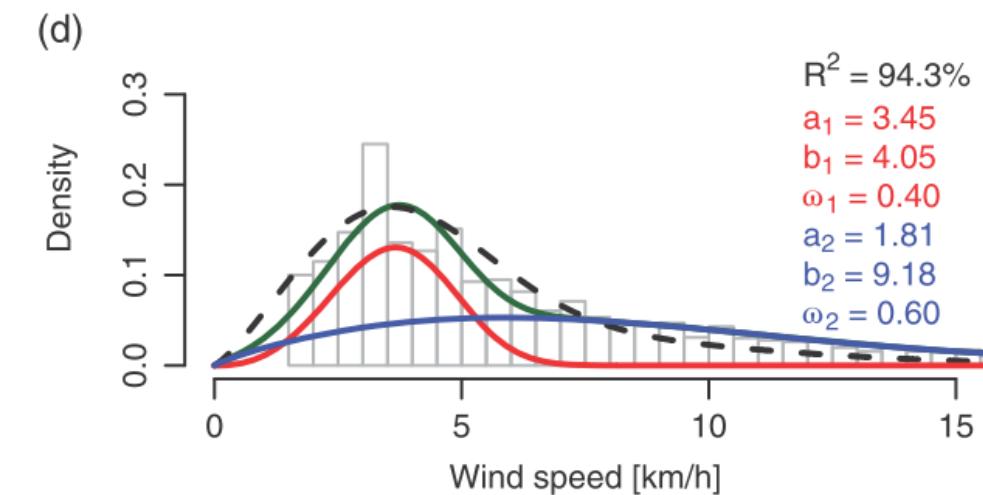
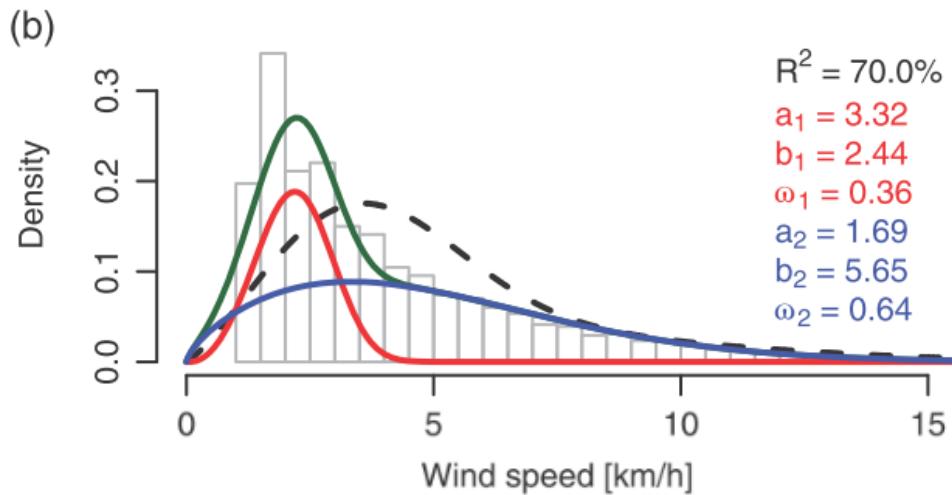
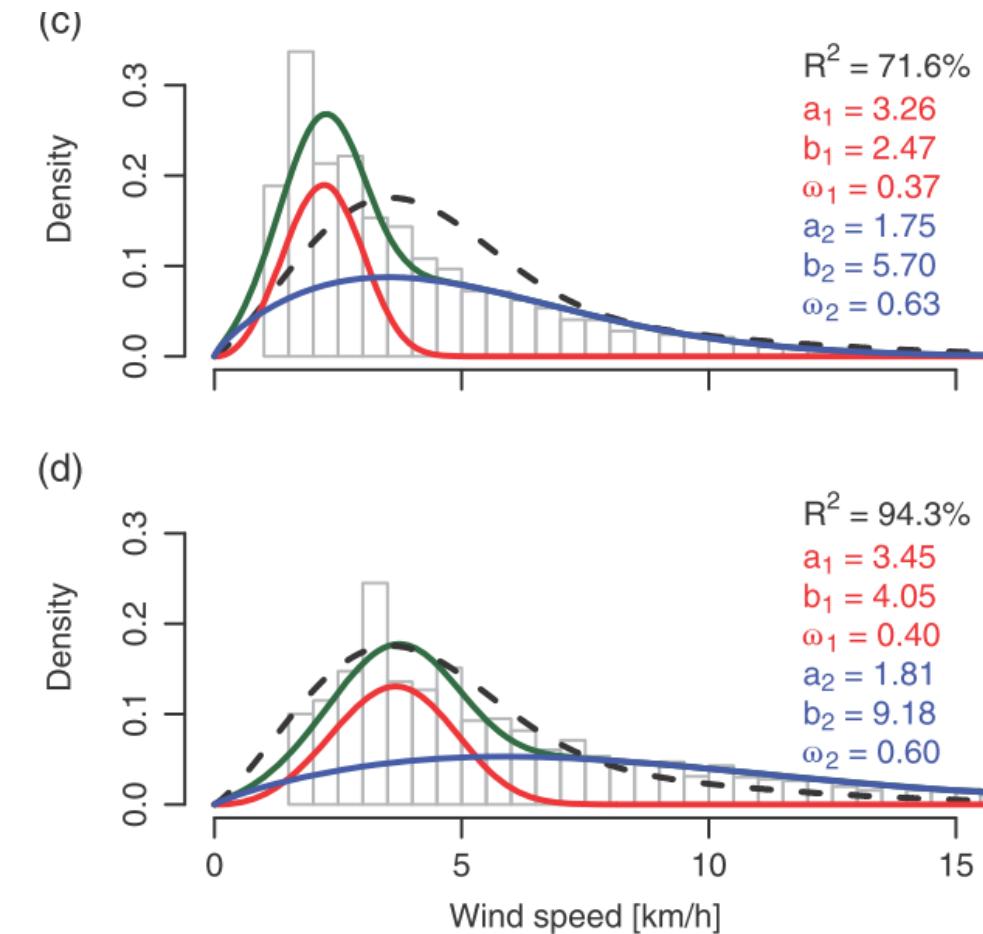
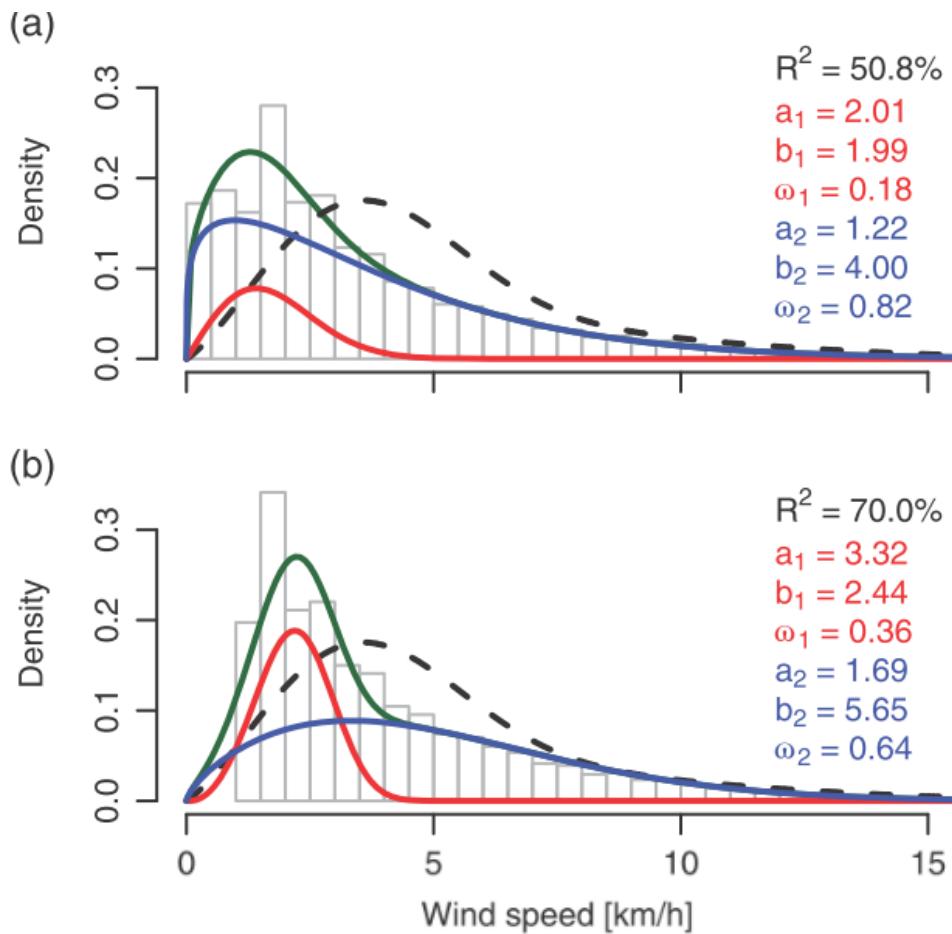
The Netherlands
29 May 2018



de Vos et al. (2019)

Wind speed

Amsterdam, The Netherlands, LCZ 2 February - April 2018

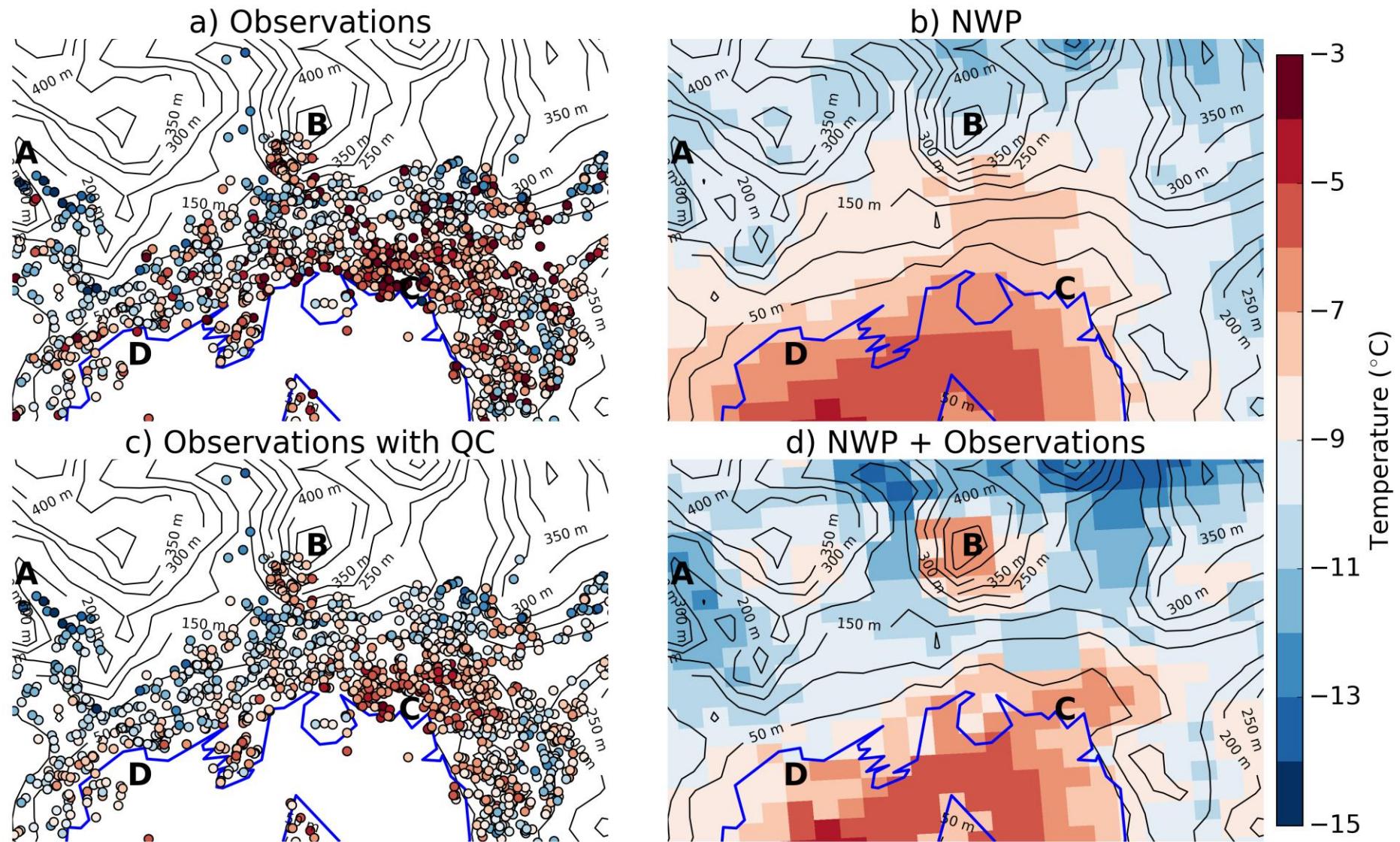


CWS

Reference

Operational weather forecast

Oslo, Norway
28 March 2018, 5 h UTC

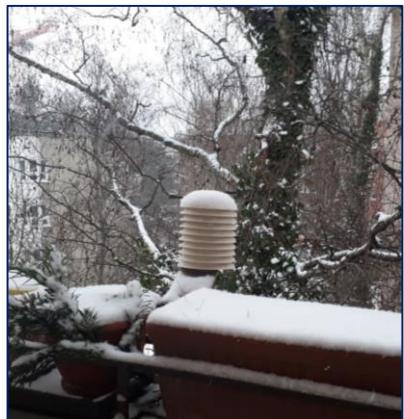


Nipen et al. (2020)

Let's wrap it up

Challenges

- Design
- Siting
- Meta data
- Spatial representativeness
- Erroneous data



[17]

Benefits

- Global coverage (theoretically)
- High density, especially in cities
- Sites in areas without professional measurements
- Cost-efficient

**Endless possibilities to use the data,
maybe also in your research?!**



[7]



Thank you!

Daniel Fenner

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Chair of Environmental Meteorology, University of Freiburg

References |

- Alerskans, E., Lussana, C., Nipen, T. N. and Seierstad, I. A. (2022): Optimizing Spatial Quality Control for a Dense Network of Meteorological Stations. *J. Atmos. Ocean. Tech.* 39 (7): 973-984. DOI: 10.1175/jtech-d-21-0184.1
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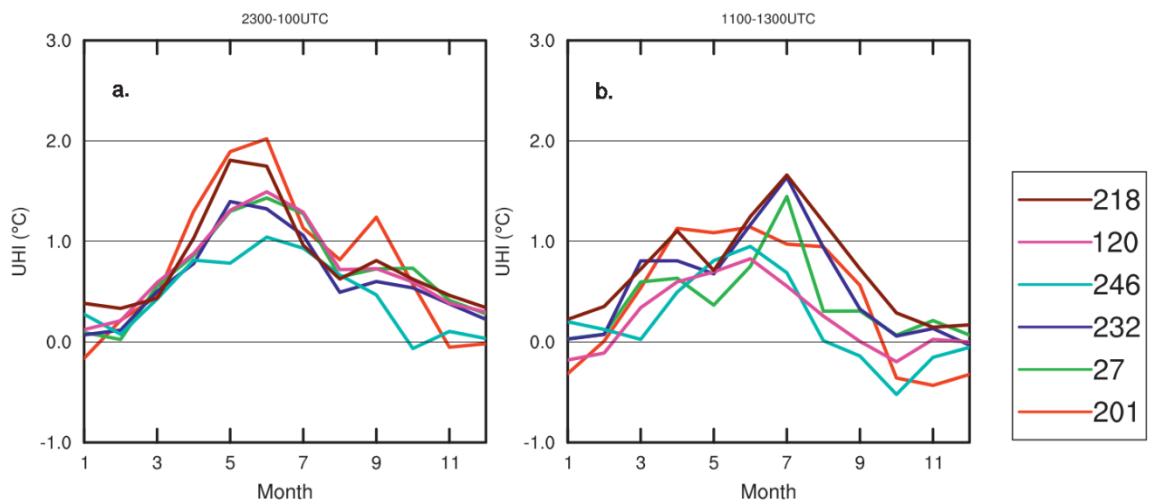
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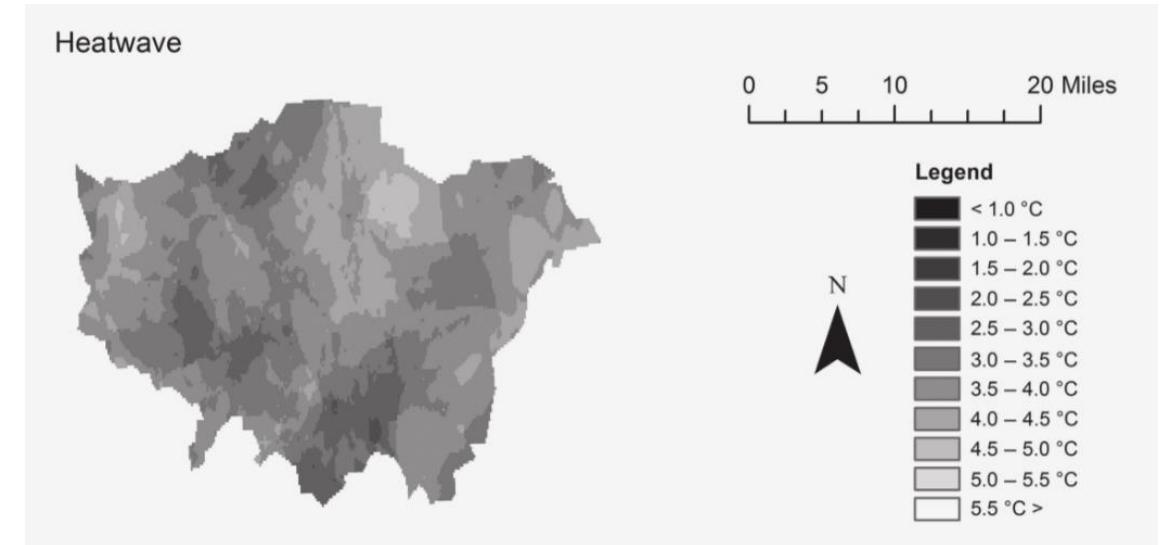
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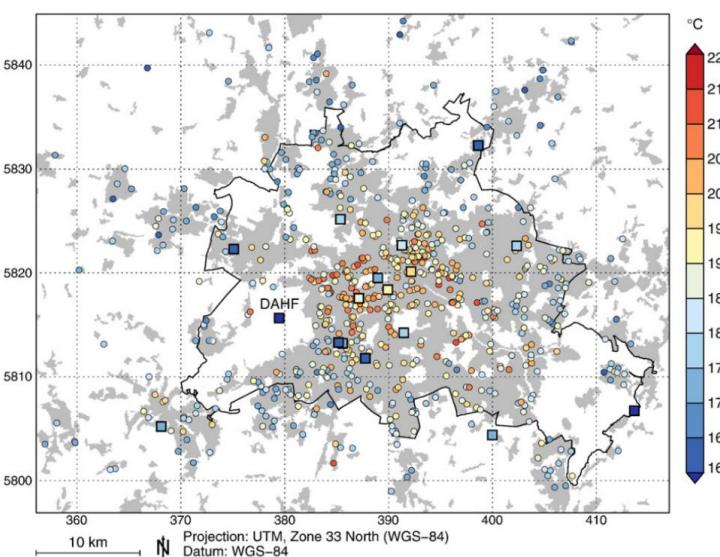
Example – Air temperature



Wolters & Brandsma (2012)

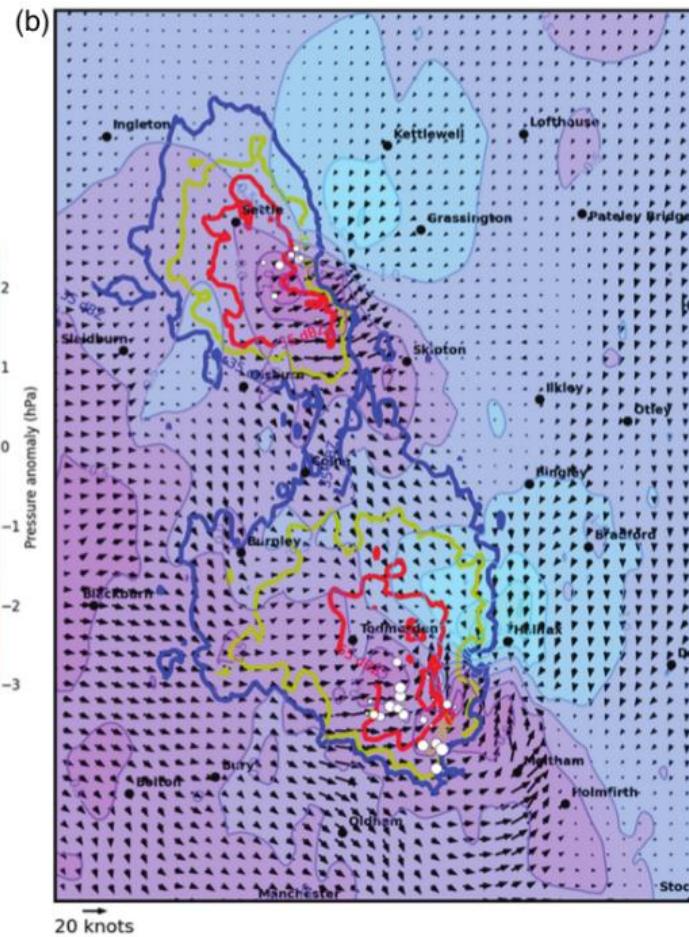
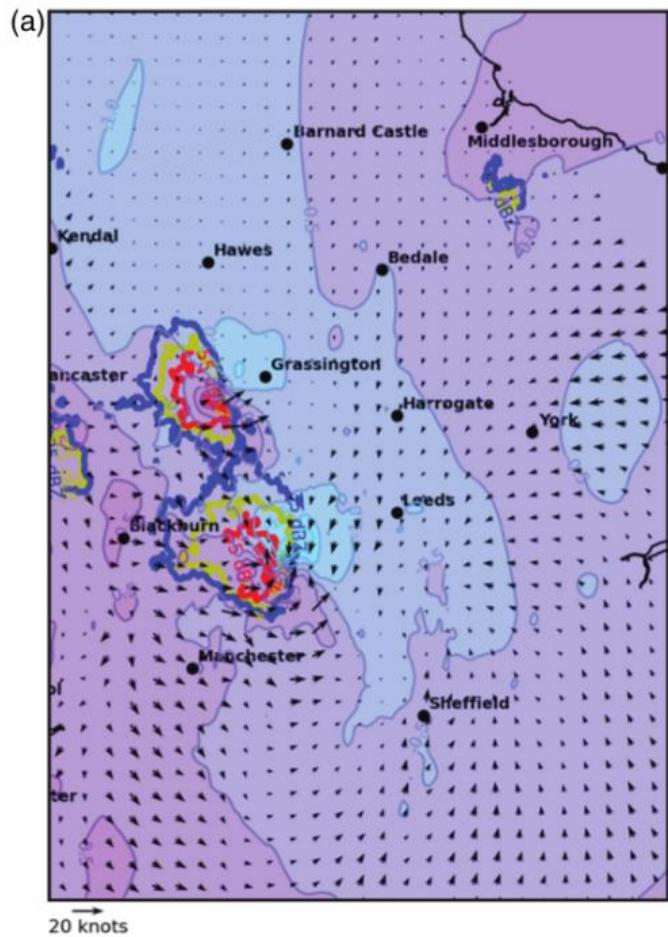


Chapman et al. (2017)

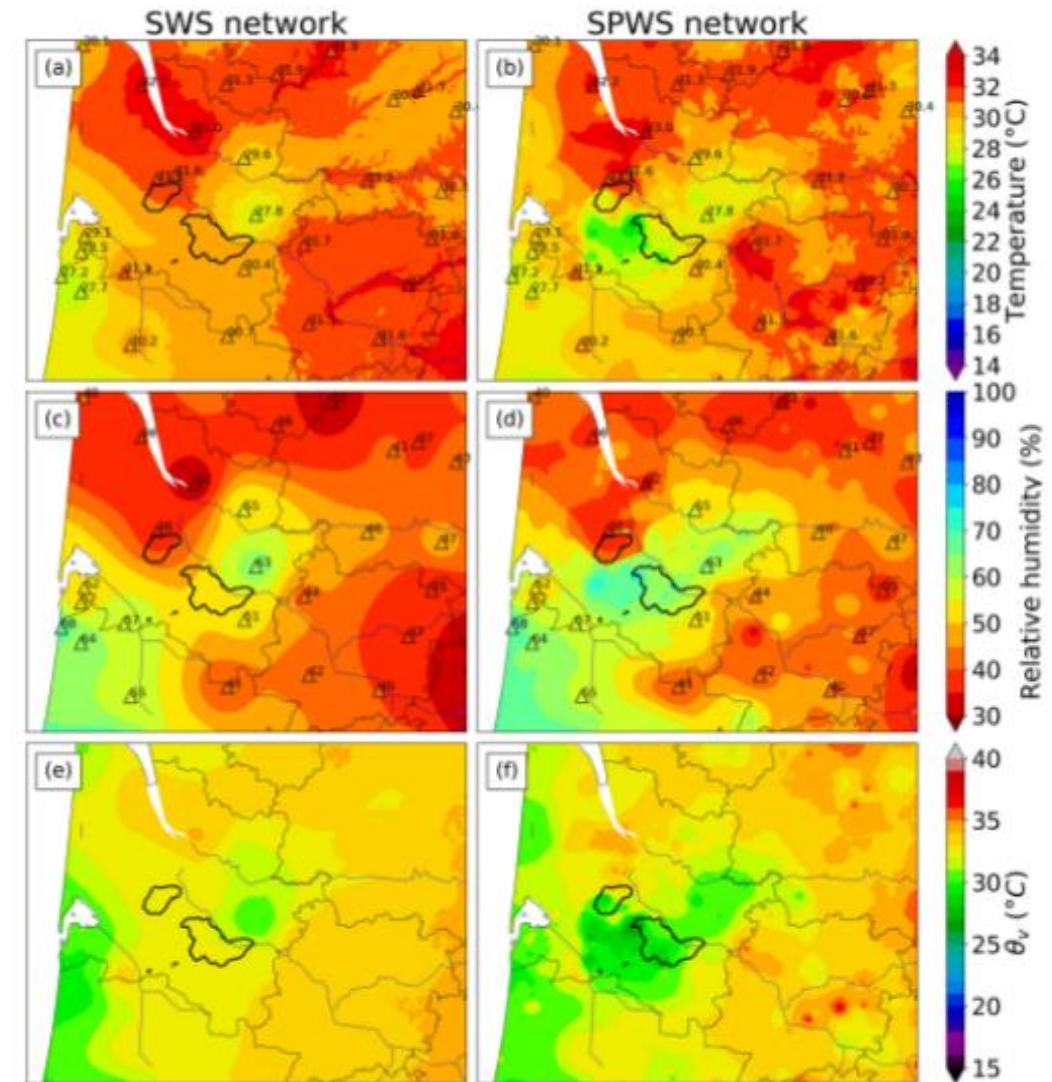


Meier et al. (2017)

Example – combination of data



Clark et al. (2018)



Mandement & Caumont (2020)