

Weather reanalysis on an urban scale using WRF

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Motivation

- Traditional weather forecasts no longer good enough
- Weather forecasts can be strongly influenced by the local environment
- General demand for high resolution forecasts and archives of (extremes in) temperature, thermal comfort, precipitation, ...

AIM: 15 year fine scale (100m) urban climatology reanalysis archive for Amsterdam



Traditional weather forecast

DutchNews.nl

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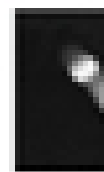
Heavy rain, thunderstorms lead to flooding, Schiphol airport delays

Society     July 28, 2014

Very heavy showers and some thunder is set to hit much of the Netherlands on Monday, the **KNMI** weather bureau says.

In some south-western parts, up to four centimetres of rain may fall in some places, leading to localised flooding. Flooding has already been reported in Zeeland, Zuid-Holland and western parts of Brabant, news agency **ANP** says.

Fe



Het Parool

HOME | AMSTERDAM | STADSGIDS | OPINIE

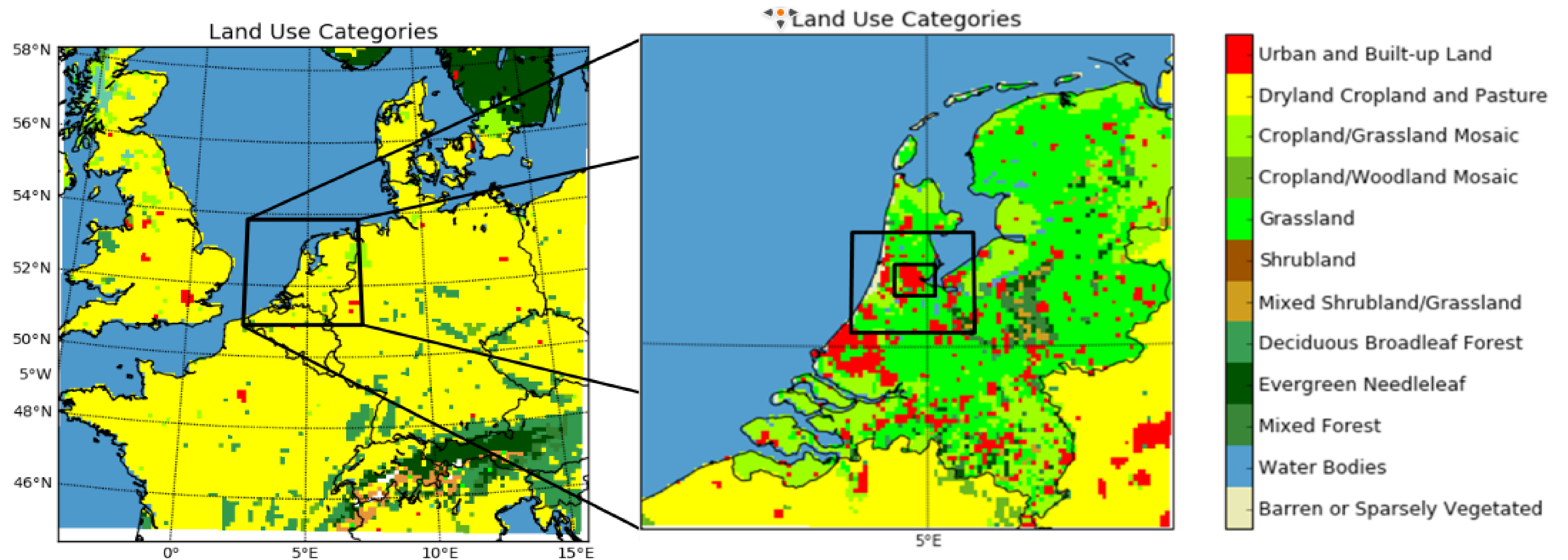
Veel wateroverlast in Amsterdam



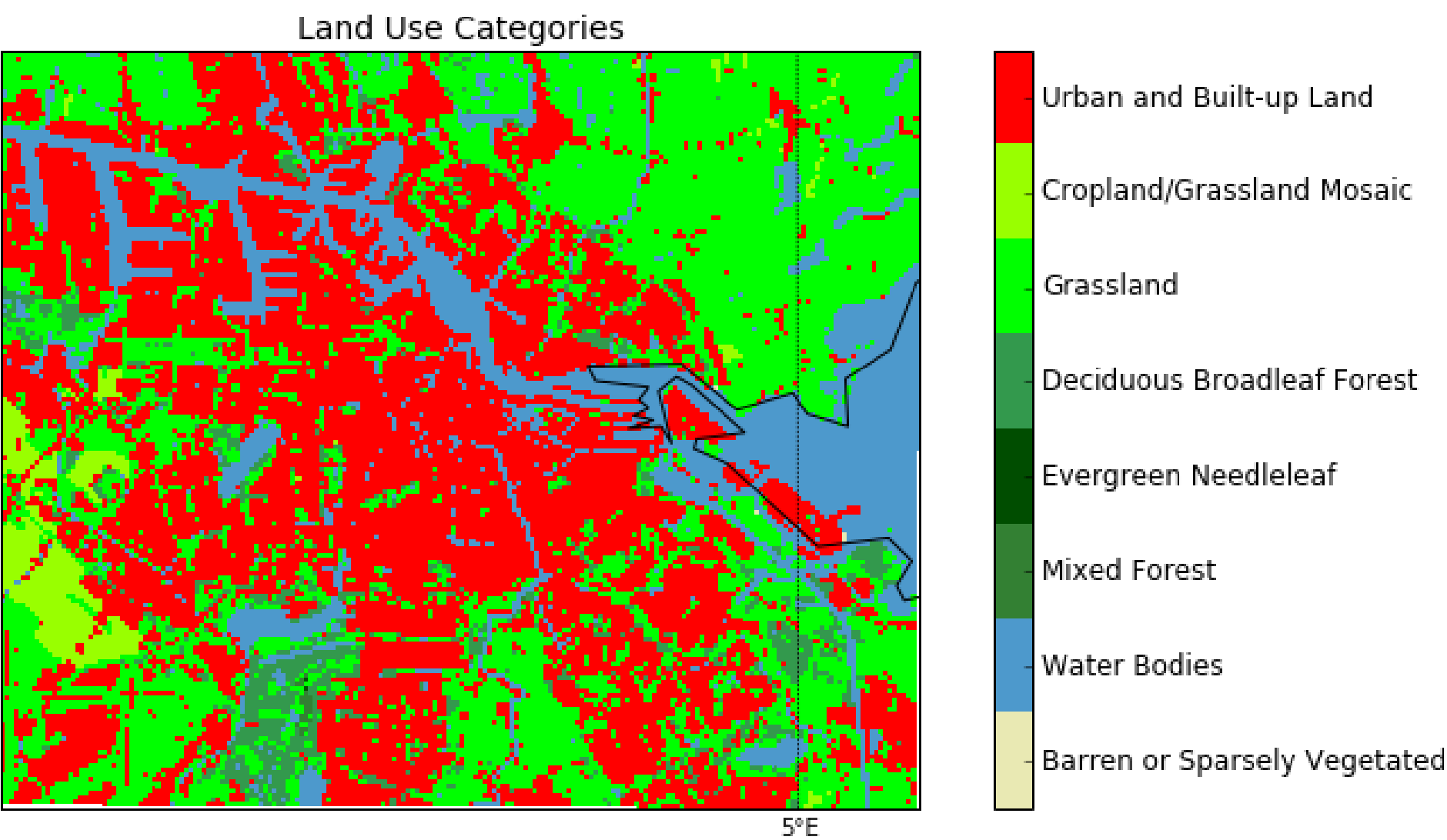
Station Amsterdam-Zuid staat onder water © Robin Kok

Model domains

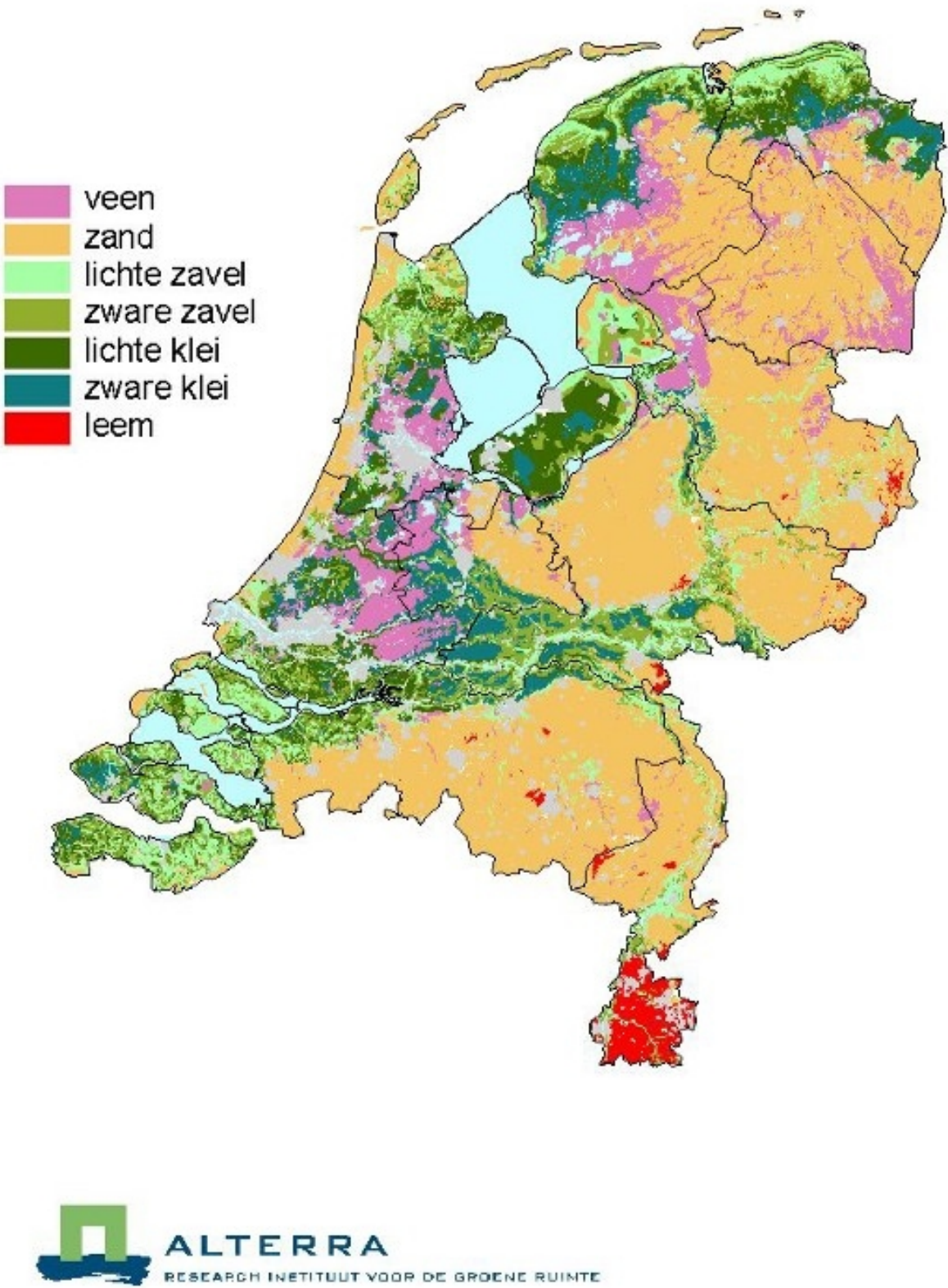
- 4 domains with 12500, 2500, 500, 100m resolution
- ECMWF boundaries every 6 hours, 0.5x0.5deg



Detailed urban morphology data



Detailed soil map
Grondsoortenkaart Nederland



Detailed elevation data (AHN2)



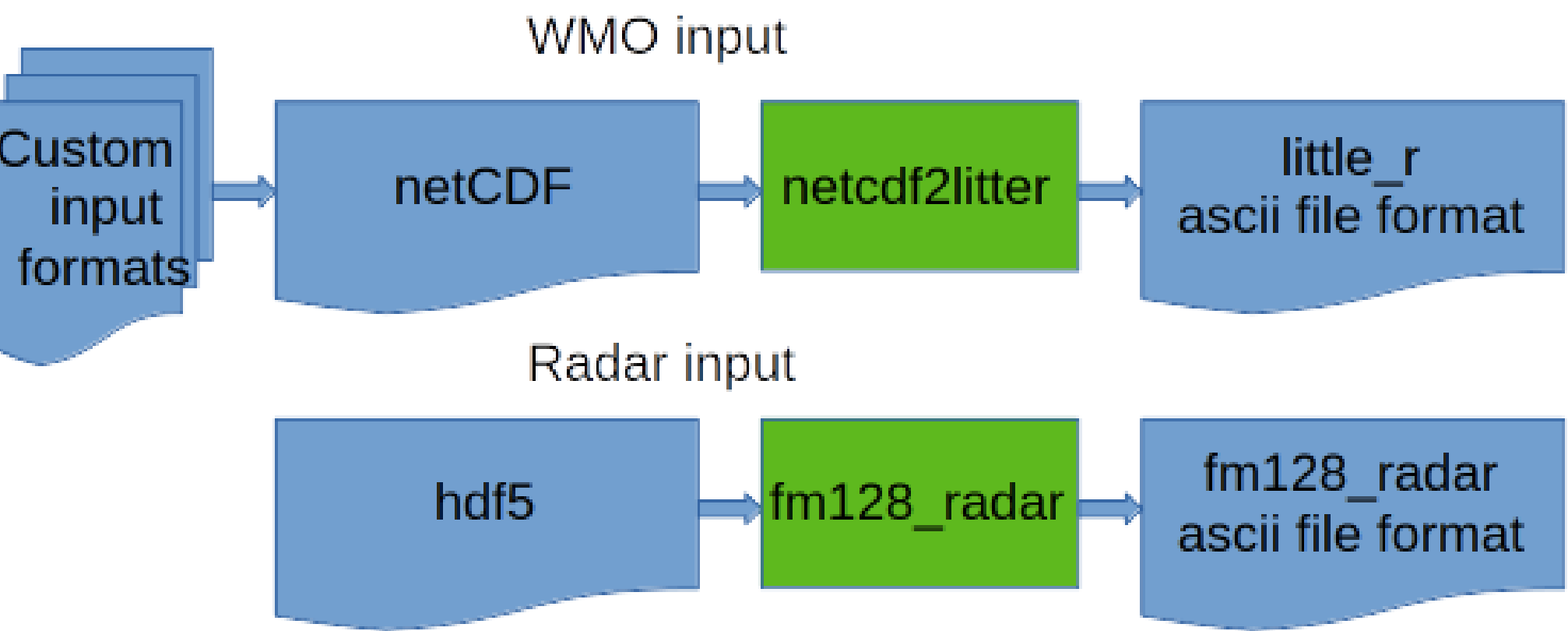
Ronda, R.J., G.J. Steeneveld, B.G. Heusinkveld, J.J. Attema, and A.A. Holtslag, 2017: doi:10.1175/BAMS-D-16-0297.1"Urban Finescale Forecasting Reveals Weather Conditions with Unprecedented Detail. Bull. Amer. Meteor. Soc., 98, 2675-2688

Conversion of large scale input data

- Tooling to convert upstream data format into

WRFDA accepted data format:

- WMO input data from KNMI, DWD and UKMO
- Radar data from KNMI



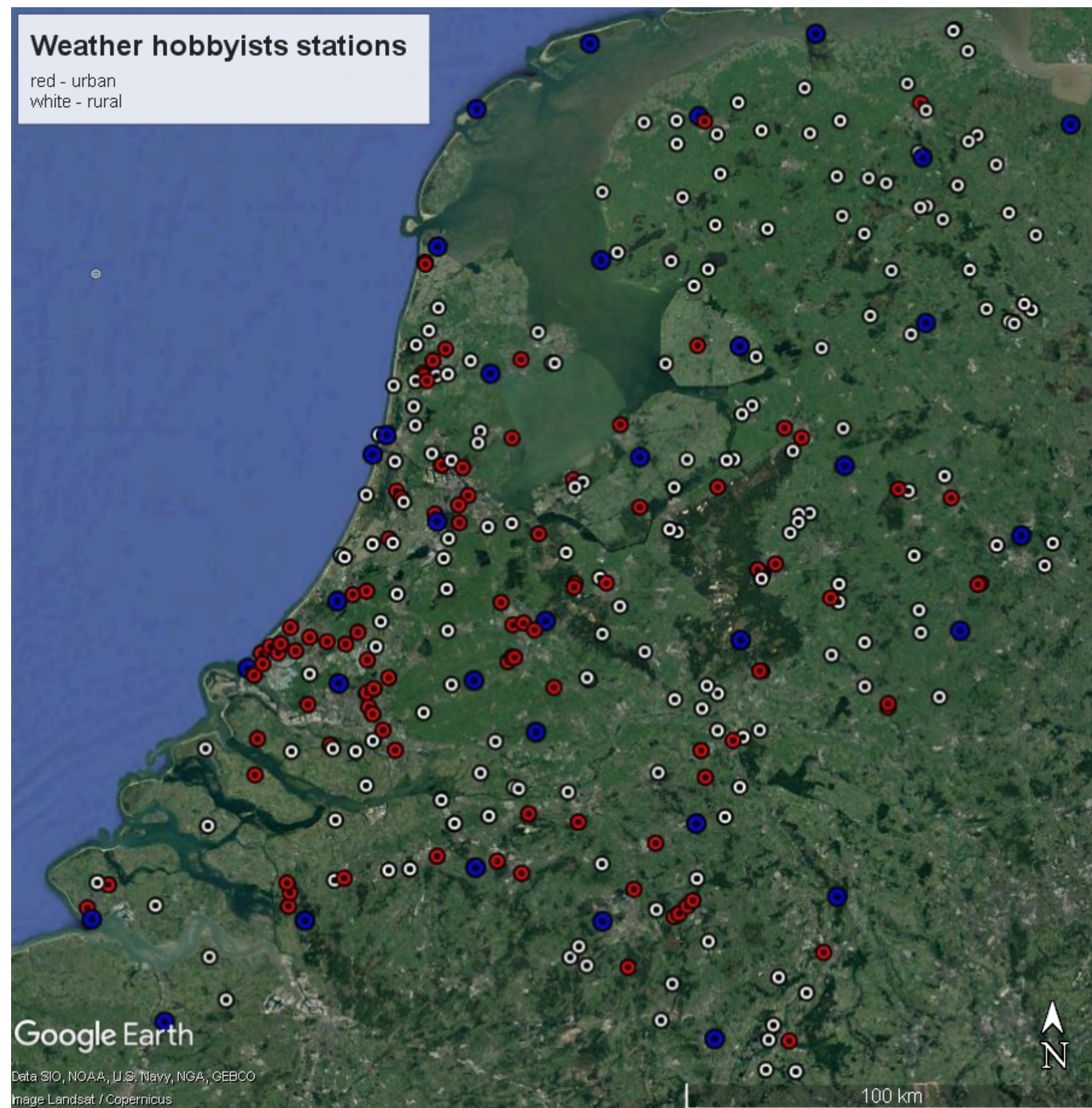
13.48000	2.1600061052				NIAMEY-AERO / NIGER				FM-35 TEMP				GTS (ROHK) USNR20 DRRN 242300			
227.00000	1	-888888	-888888	55	-888888	T	F	F	-888888	-888888	20100824230000-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000		
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98600.00000	0	227.00000	0	300.75000	0	293.75000	0	4.11556	0	240.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000		
100000.00000	0	97.00000	0	-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0		
92500.00000	0	788.00000	0	299.94998	0	290.94998	0	6.68778	0	255.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000		
85000.00000	0	1530.00000	0	295.94998	0	284.94998	0	1.54333	0	225.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000		
70000.00000	0	3187.00000	0	283.35001	0	278.75000	0	7.71667	0	75.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000		
50000.00000	0	5900.00000	0	267.04999	0	256.04999	0	12.86111	0	85.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000		
40000.00000	0	7610.00000	0	256.64999	0	240.64999	0	6.68778	0	75.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000		
30000.00000	0	9720.00000	0	242.64999	0	239.04999	0	6.68778	0	165.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000		
25000.00000	0	10990.00000	0	232.64999	0-888888.00000	0	6.17333	0	145.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0		
20000.00000	0	12470.00000	0	220.25000	0-888888.00000	0	3.60111	0	135.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0		
15000.00000	0	14260.00000	0	205.84999	0-888888.00000	0	18.00556	0	100.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0		
10000.00000	0	16640.00000	0	194.04999	0-888888.00000	0	9.77444	0	70.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0		
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-777777.00000	0-777777.00000	0	13.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0-888888.00000	0		
58	0	0														
Header record				Data record				Ending record				3 tail integer				

TOTAL NUMBER = 16														
#-----#														
RADAR KCYS														
#-----#														
FM-128 RADAR 2015-07-07_21:00:00										41.165	-107.189	1887.0	3	
3735.9 -888888.000 -88 -888888.000										10.288	0	0.576		
5128.9 -888888.000 -88 -888888.000										13.029	0	0.944		
6870.5 -888888.000 -88 -888888.000										8.192	0	1.229		
FM-128 RADAR 2015-07-07_21:00:00										41.192	-107.189	1887.0	3	
3737.3 -888888.000 -88 -888888.000										10.262	0	0.746		
5130.6 -7.381 0 1.692										13.338	0	0.473		
6872.5 -888888.000 -88 -888888.000										8.373	0	0.626		
FM-128 RADAR 2015-07-07_21:00:00										41.219	-107.189	1887.0	3	
3740.0 -888888.000 -88 -888888.000										9.447	0	1.072		
5133.9 -8.476 0 1.632										12.828	0	0.833		
6876.7 -888888.000 -88 -888888.000										8.969	0	0.991		
FM-128 RADAR 2015-07-07_21:00:00										41.246	-107.189	1887.0	3	
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R. van Haren. (2018, September 17). fm128 radar (Version 1.2.0). doi:10.5281/zenodo.1420223

R. van Haren. (2018, June 13). netcdf2littler (Version 1.0.0). doi:10.5281/zenodo.1288465

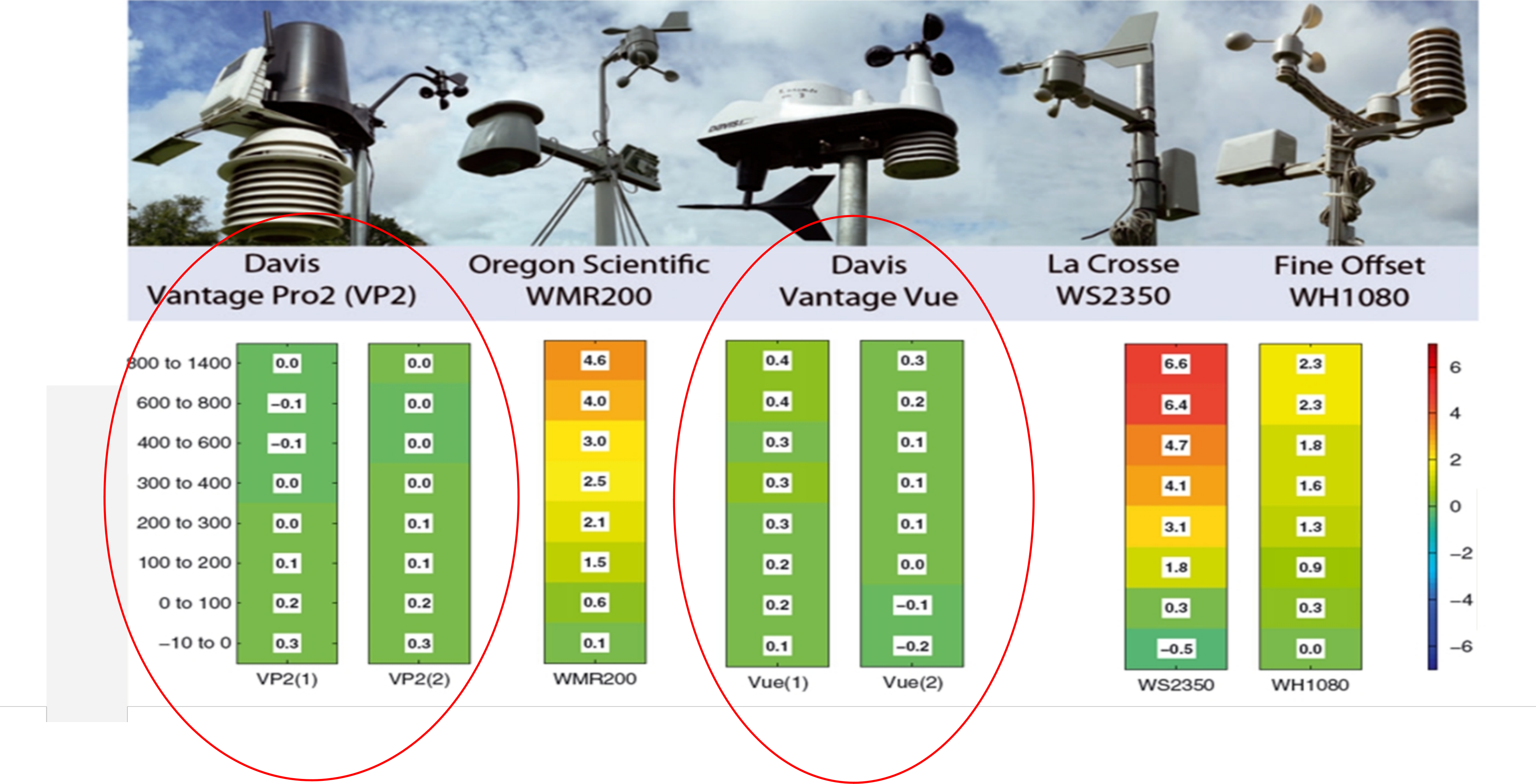
Urban weather data



About 300 stations in the Netherlands, variable quality and availability, direct transfer to Weather Underground website

Urban weather data from Weather Underground: <https://www.wunderground.com/>

Urban weather data



Variable quality hobby stations

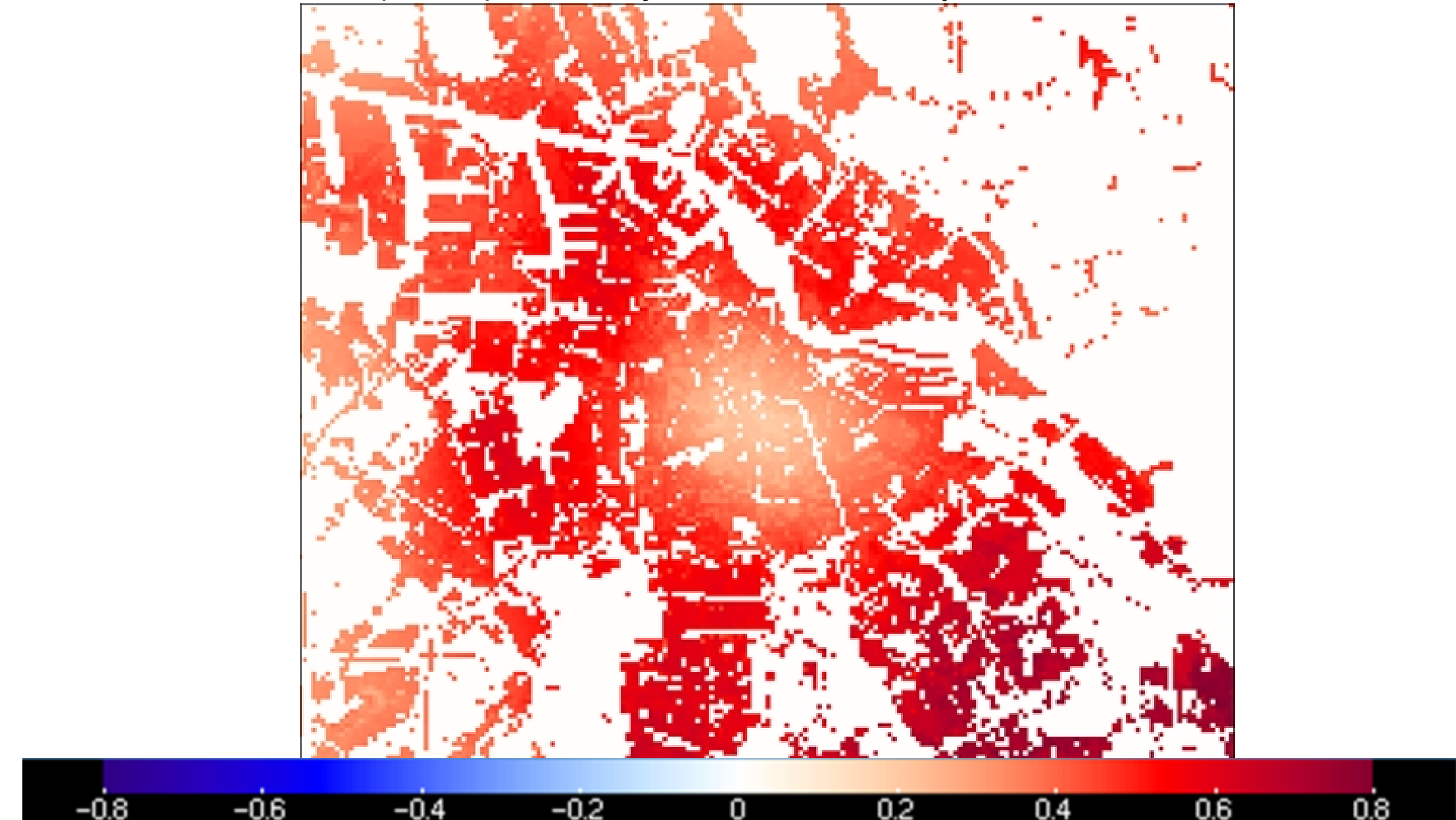
Nudging of urban fabric temperatures

- Urban temperatures are nudged by applying corrections on urban fabric (walls and roads). Urban fabric has storage to preserve the effect of nudging between 2 cycles.
- Single urban stations are not representative for neighborhood and city scale due to local variability
- Instead we apply corrections to the temperatures of walls and roads based on downward longwave radiation and 10-m wind:

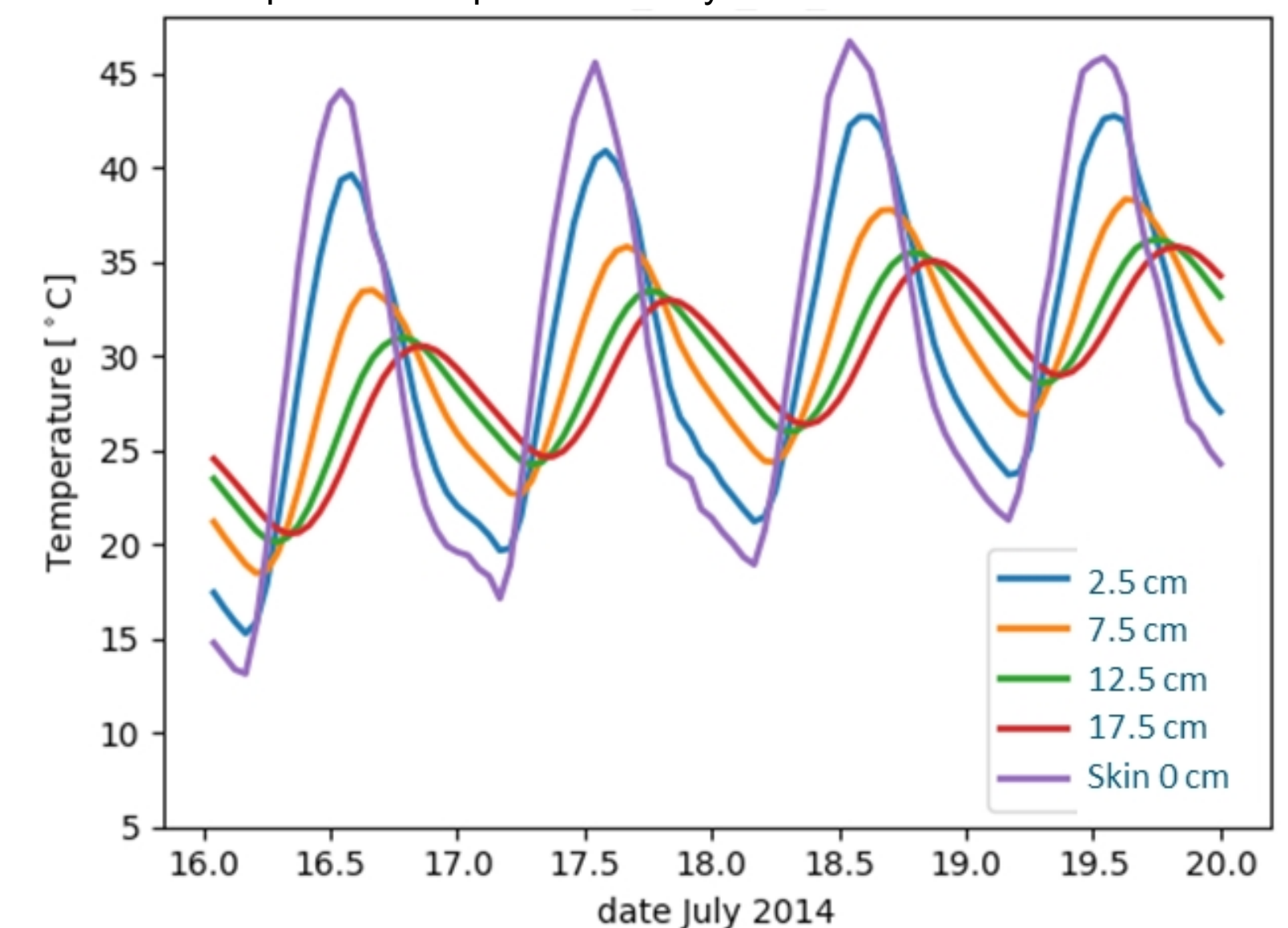
$$\Delta T = \alpha * GLW + \beta * U + \gamma$$

- Actual applied correction depends on material properties and urban morphology of the gridcell. Deeper layers have a smaller correction as it is more difficult for them to lose heat.

Example temperature adjustment outer wall layer

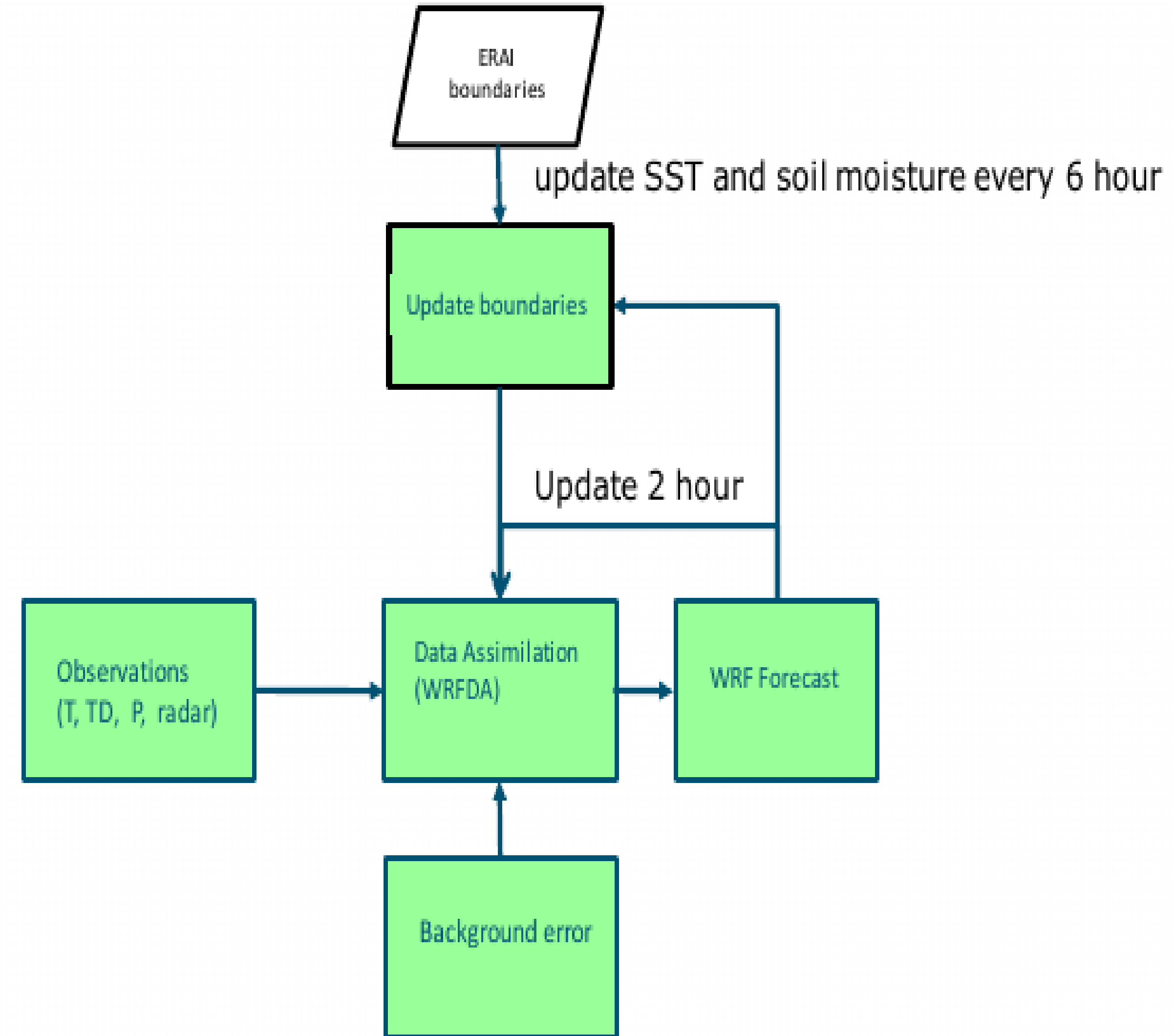


Temperature amplitude wall layers

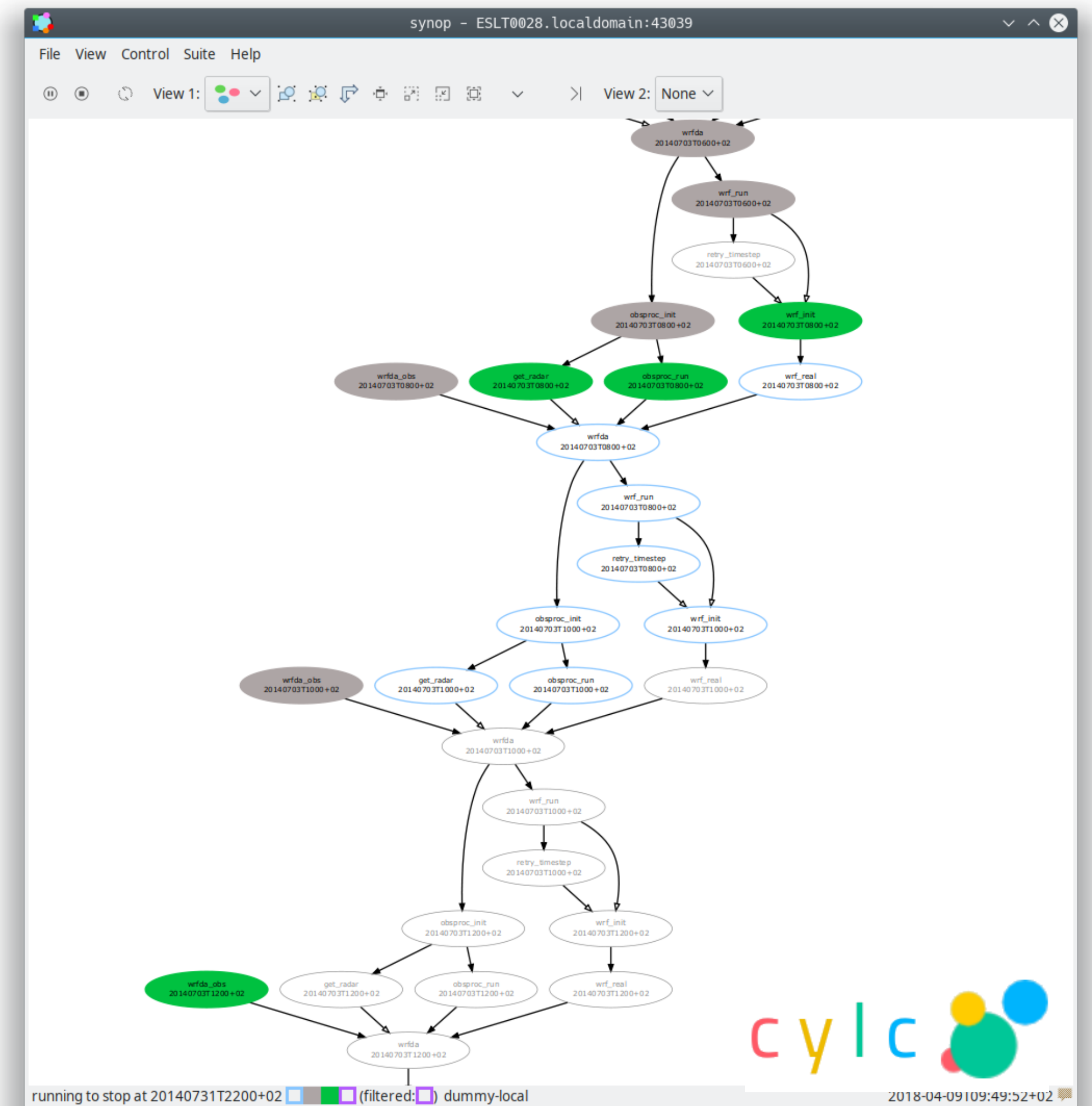
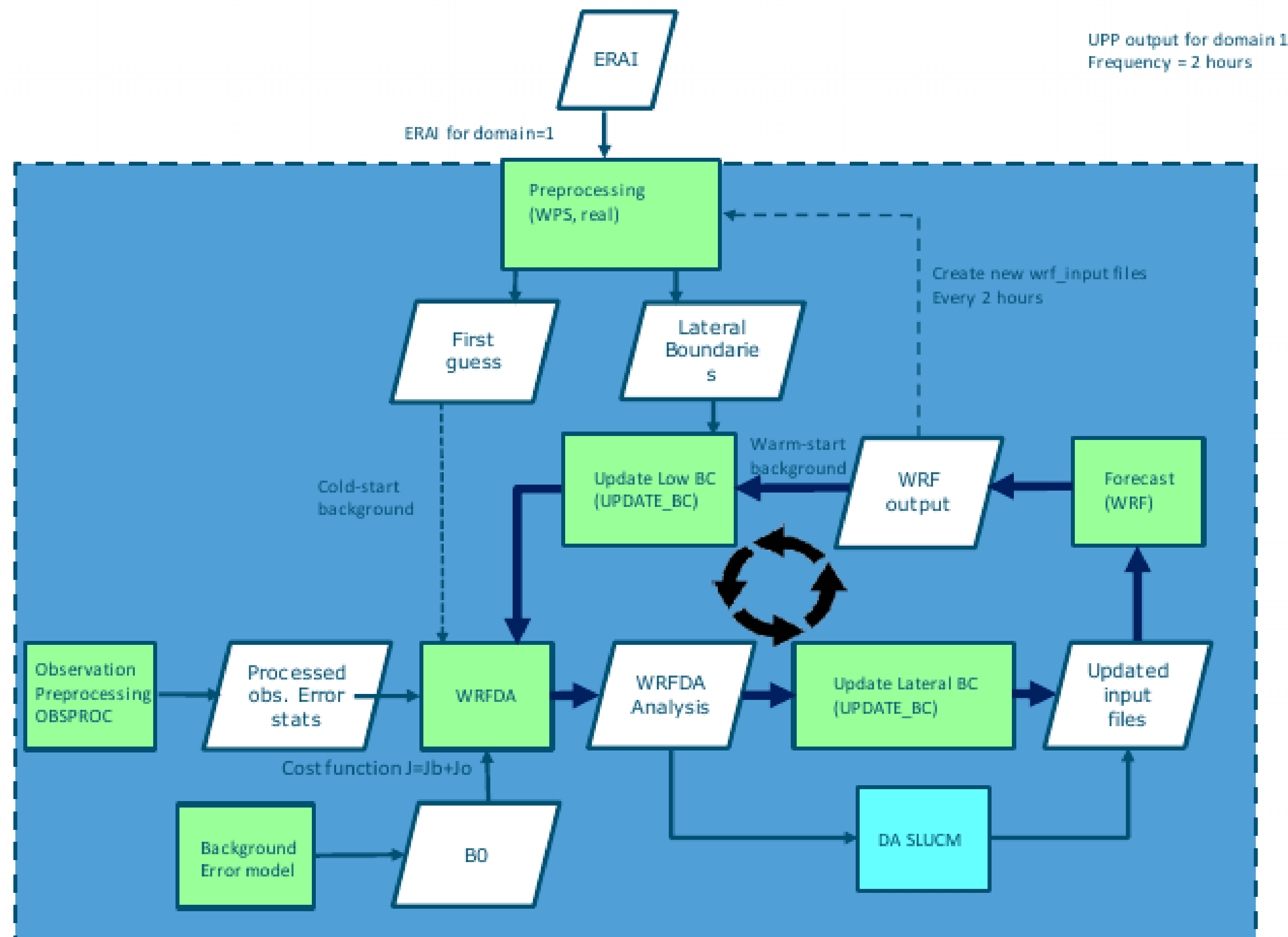


Data assimilation and nudging

- Data assimilation (3DVAR) for WMO and radar data
- For assimilation of radar data, volumetric radar reflectivity and radial wind velocity is used. Clutter removal from reflectivity and interpolated to domain grid.
- Nudging of urban fabric temperatures using data from weather hobbyists.



Integration with workflow engine

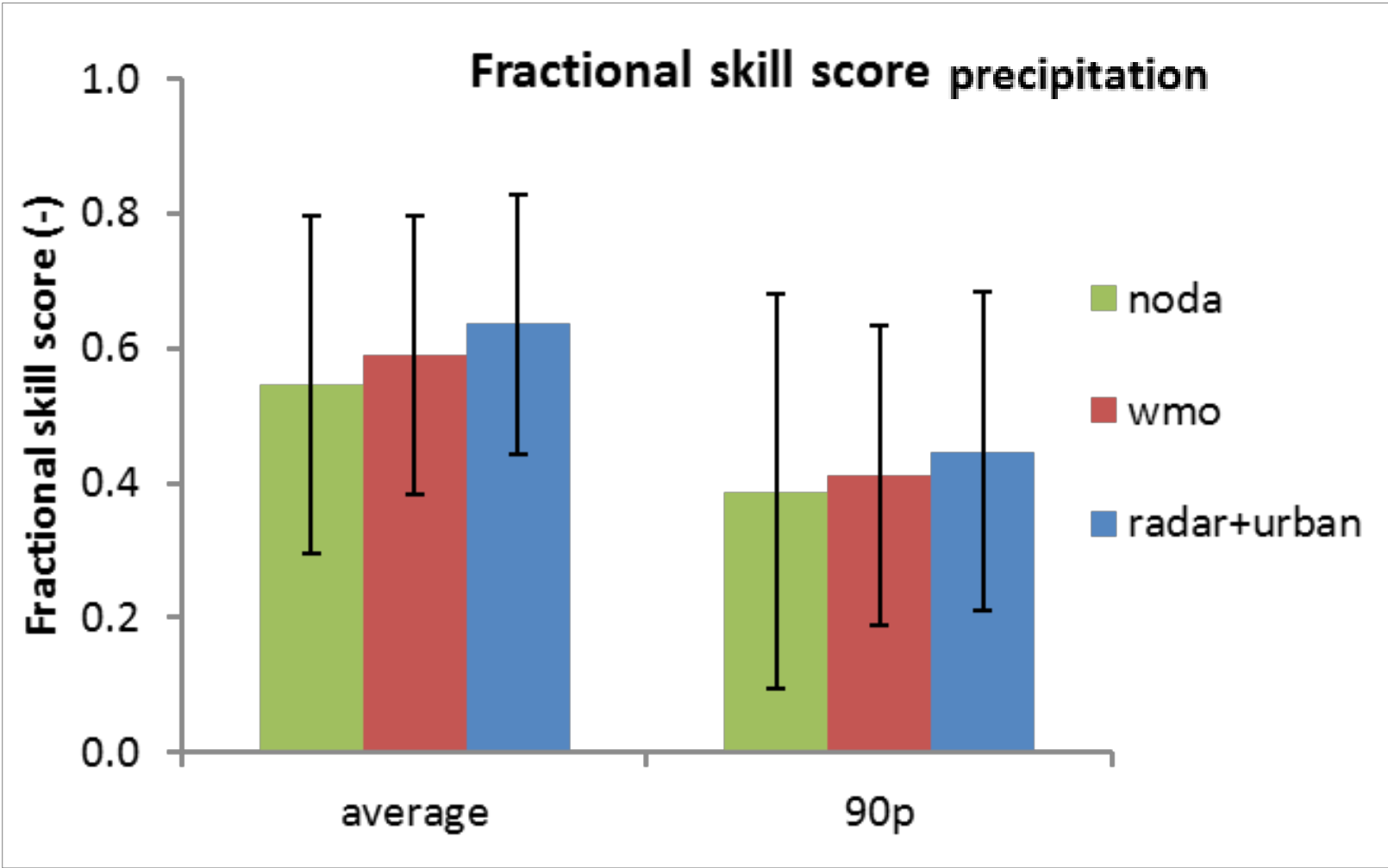
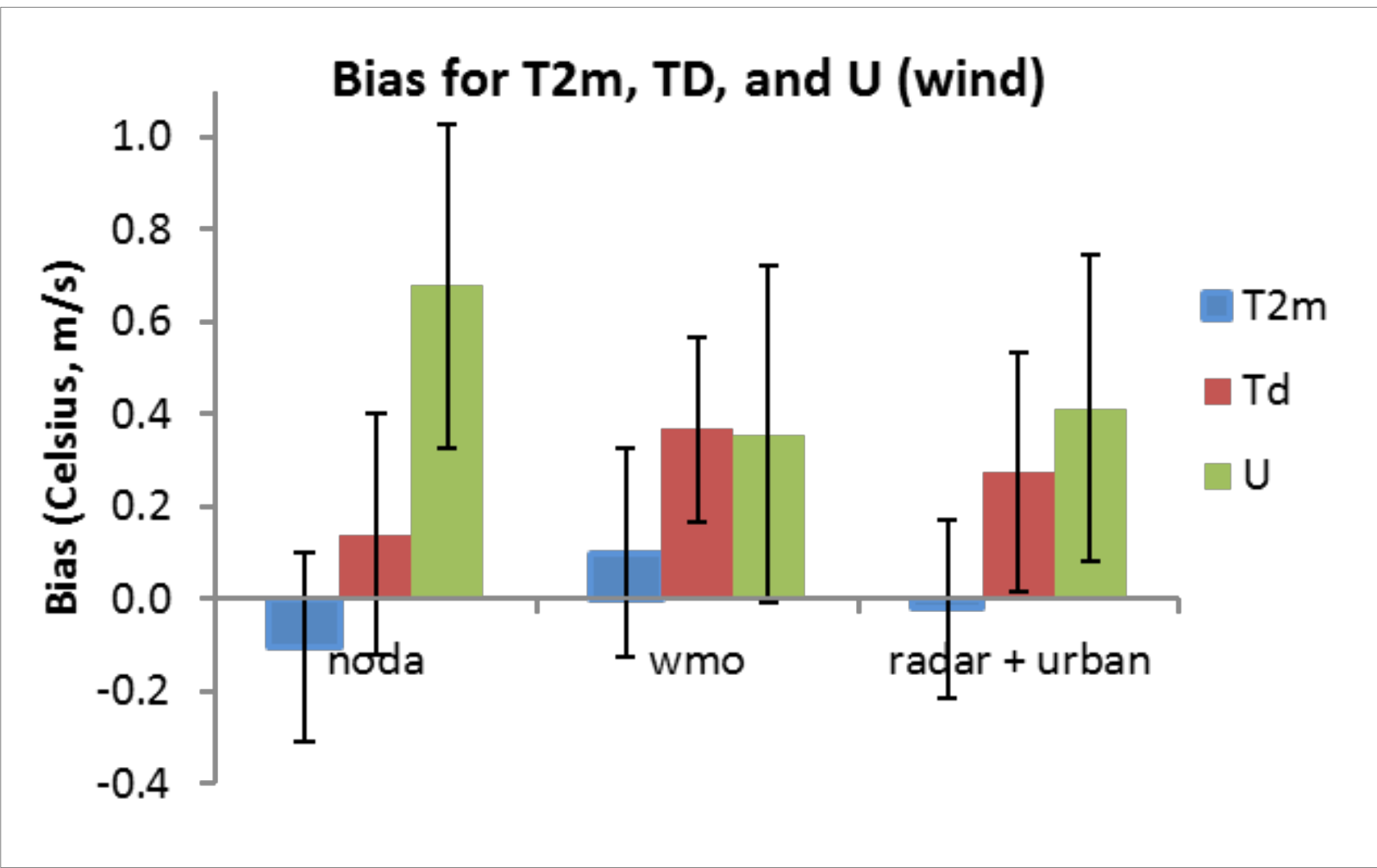
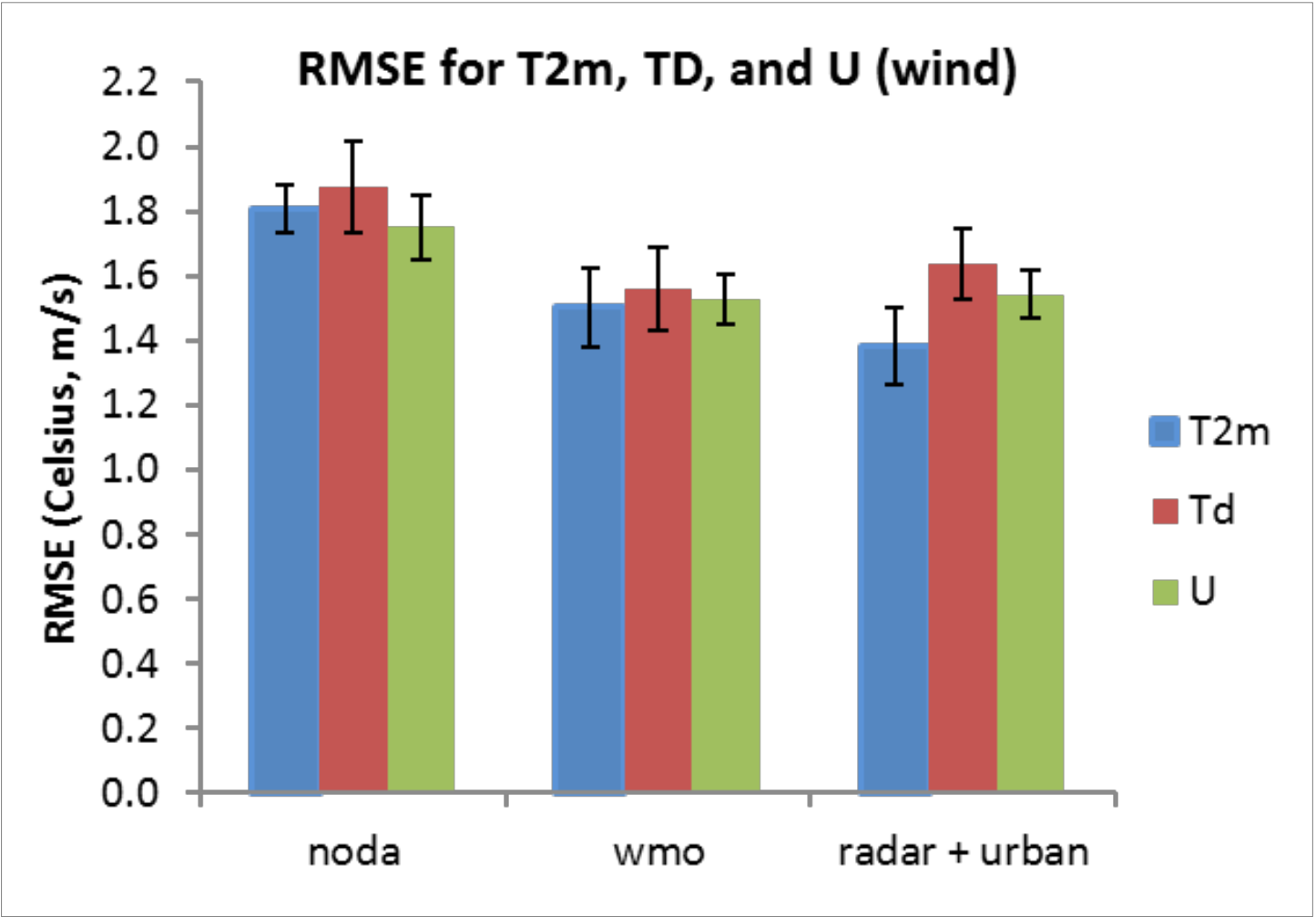
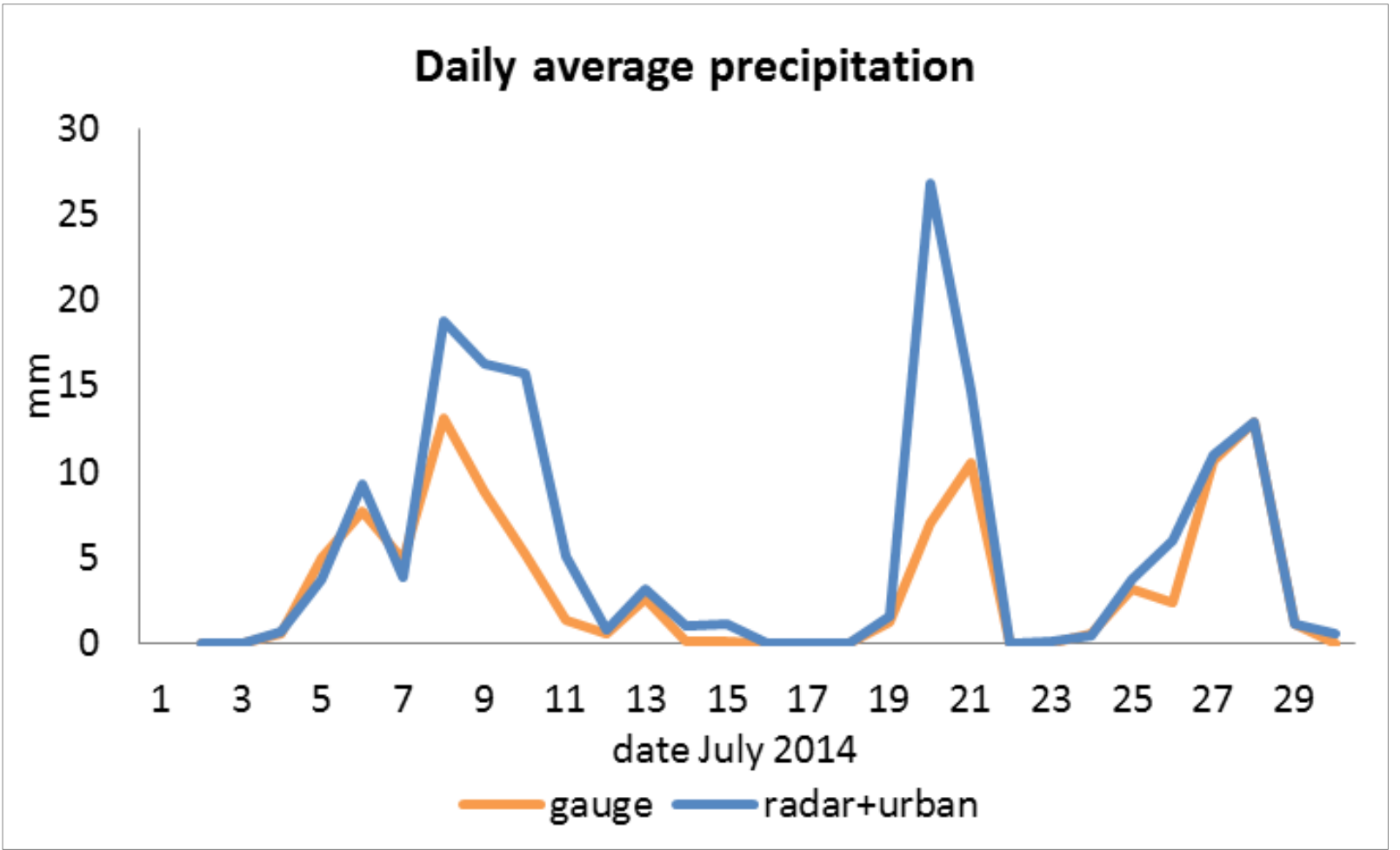


R. van Haren. (2018, September 18). WRFpy (Version 0.2.1). doi:10.5281/zenodo.1420918

H.J. Oliver et al., (2018, May 22). CYLC (Version 7.7.0). doi: 10.5281/zenodo.1251084

General results

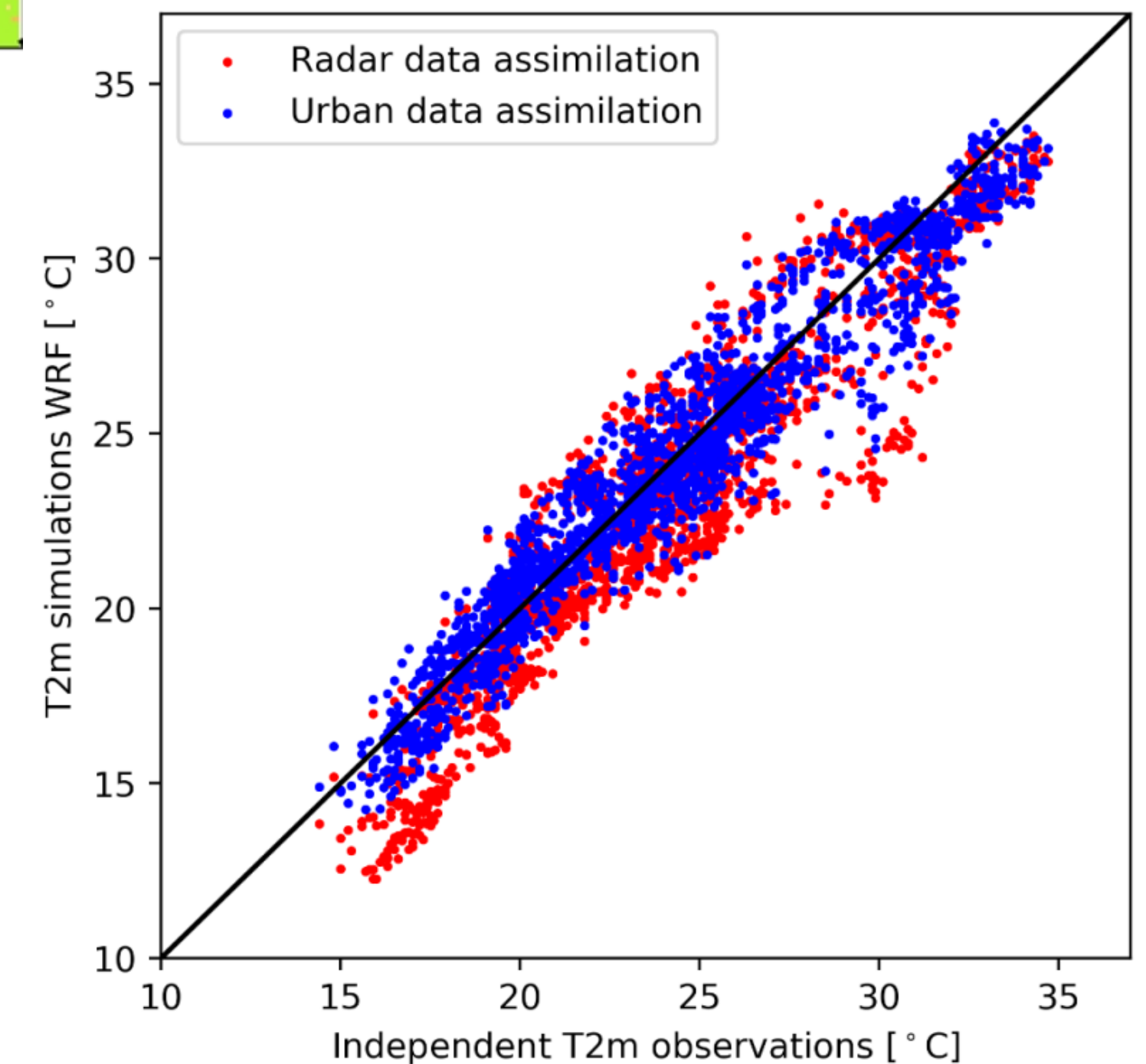
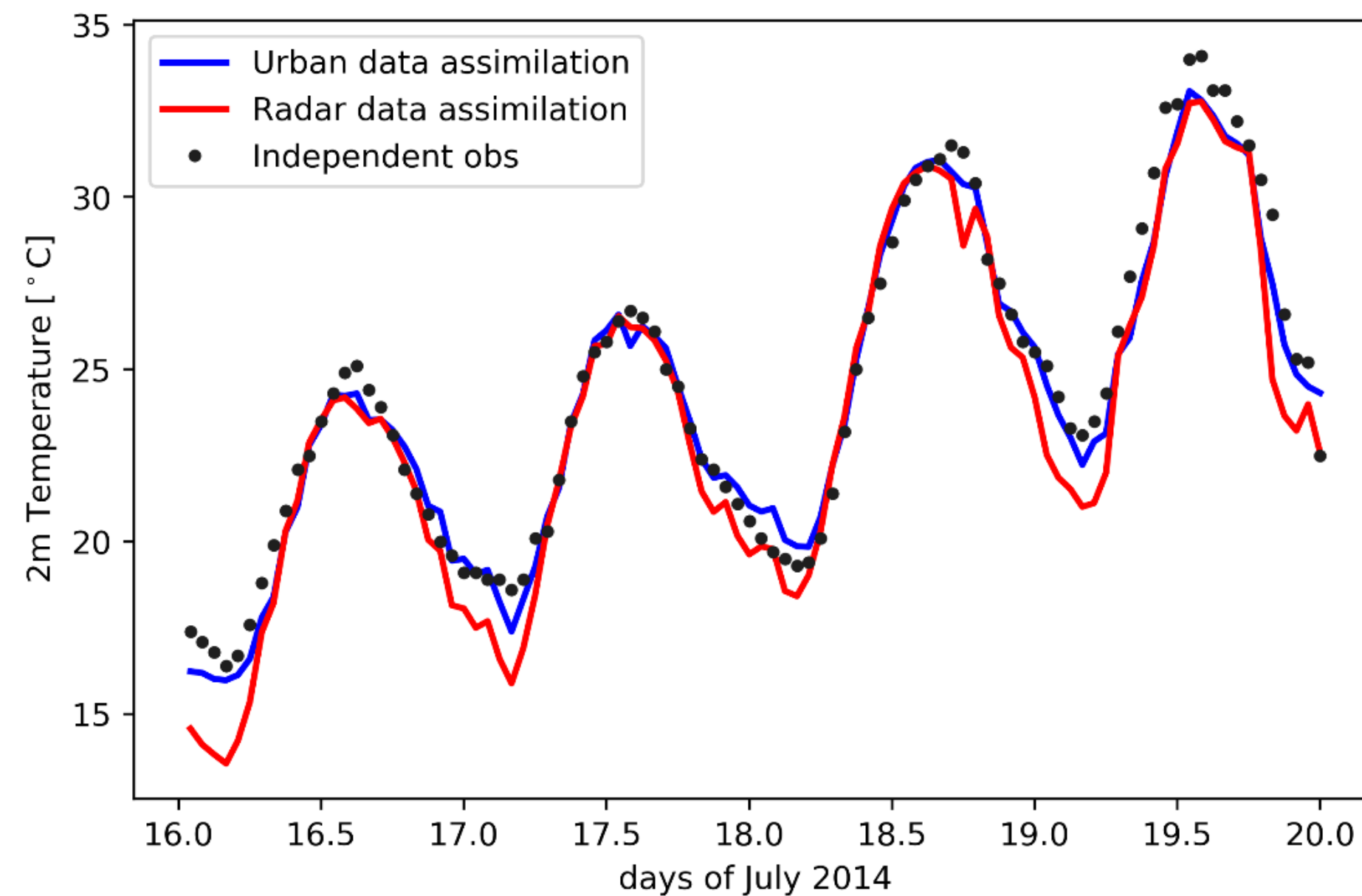
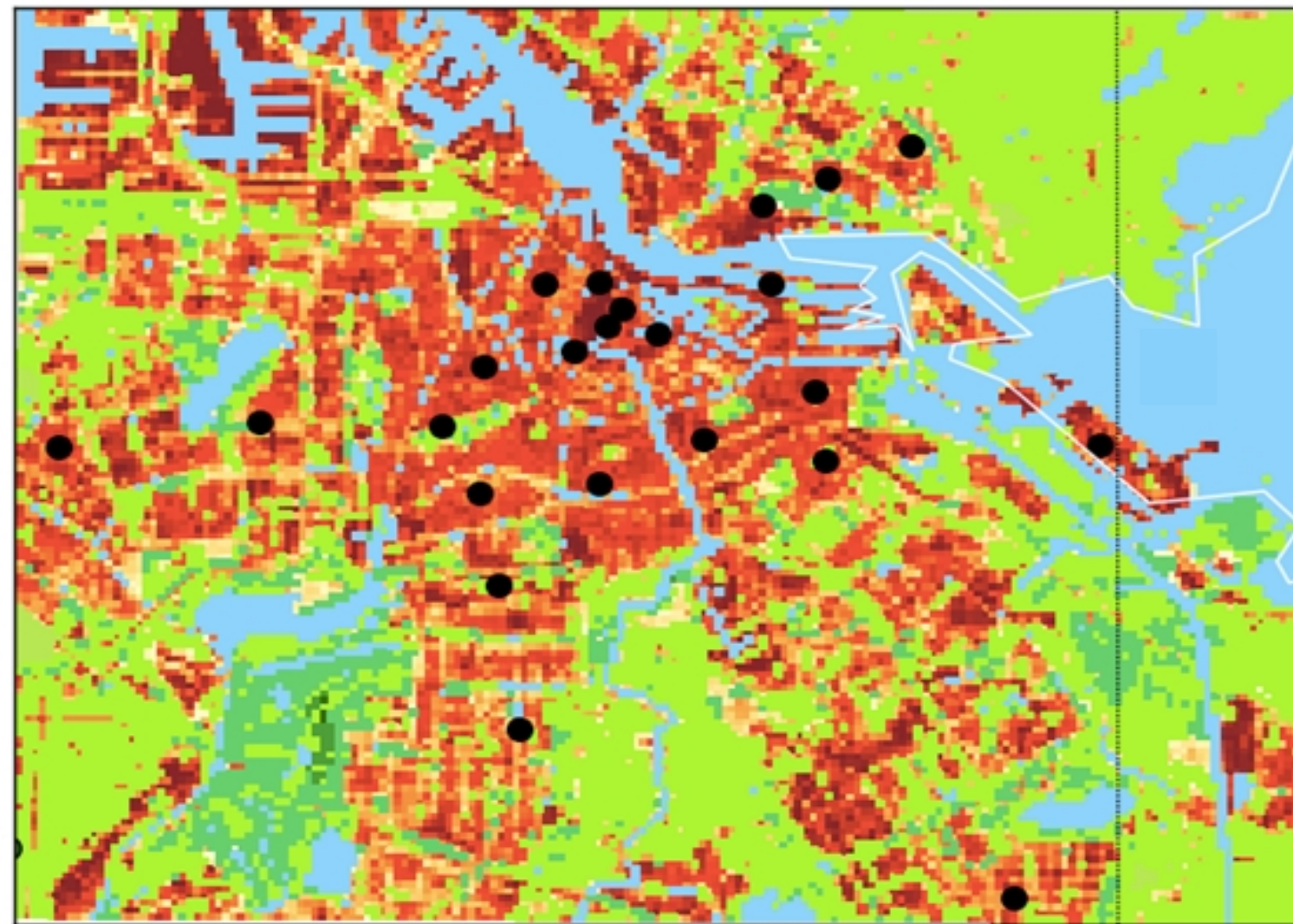
- Verification on subset of WMO stations**
1 and 2 hours after data assimilation



Urban results - comparison with independent urban stations

- **WMO + radar:**
 - RMSE = 1.84 °C
 - Bias = -0.84 °C
- **WMO + radar + urban:**
 - RMSE = 1.25 °C
 - Bias = -0.18 °C

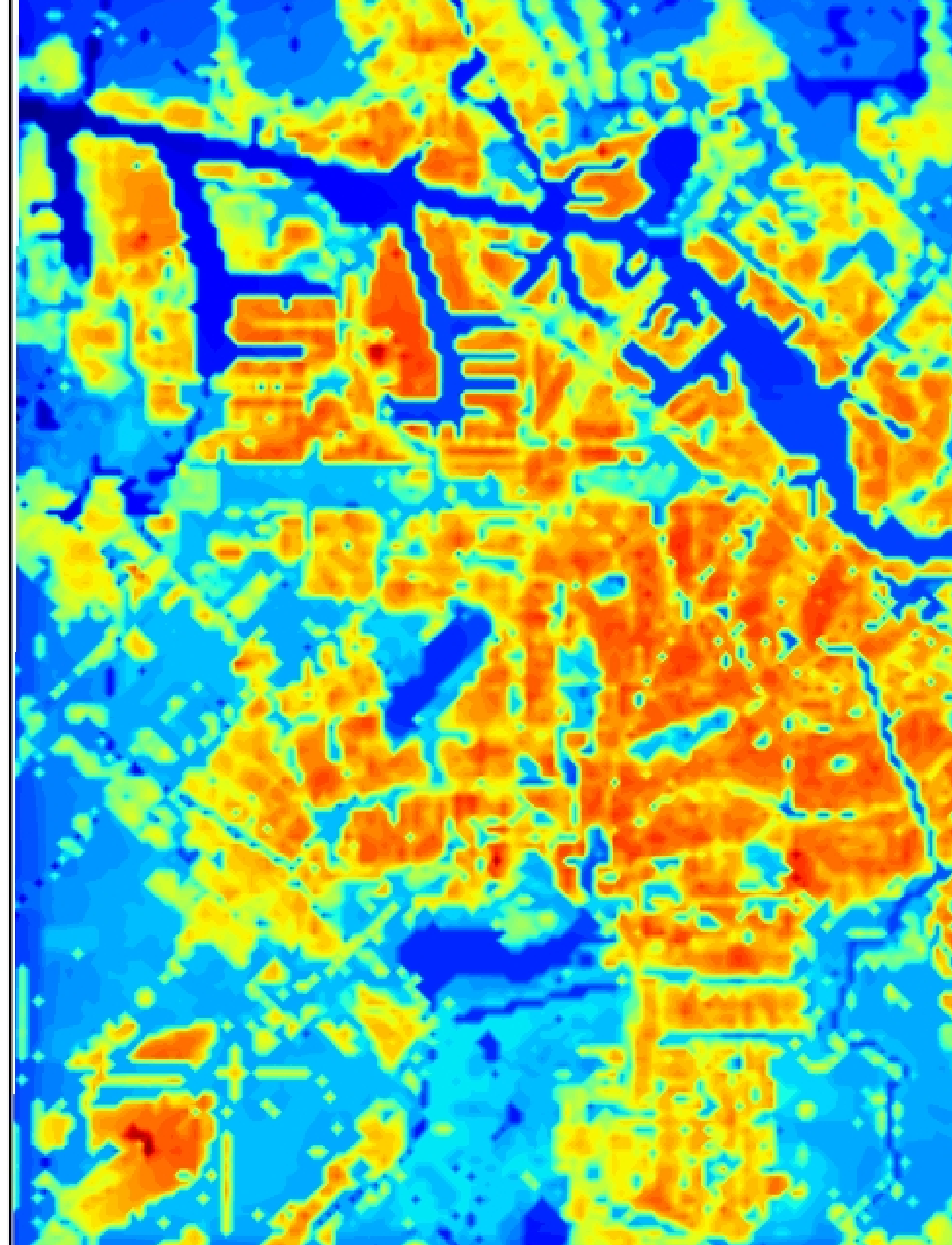
Location independent stations



Results

Tooling around WRF ecosystem to facilitate setting-up and running (long) WRF simulations with (optional) data assimilation

- Novel approach to nudge modeled urban canyon temperatures with quality controlled urban weather observations
- WMO data assimilation improves forecasts substantially in various meteorological metrics
- Radar data assimilation is challenging, slightly/moderately better in prediction location of precipitation
- Nudging urban fabric temperatures with citizen weather data reduces the cold biases present in WRF





Thank you!

Project github: <https://github.com/era-urban>

Presentation: [doi://10.5281/zenodo.1475377](https://doi.org/10.5281/zenodo.1475377)

Conference proceeding: [doi://10.1109/eScience.2018.00049](https://doi.org/10.1109/eScience.2018.00049)