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Understanding differences in modelled and measured urban heat fluxes:

An intercomparison between HARMONIE and eddy-covariance data

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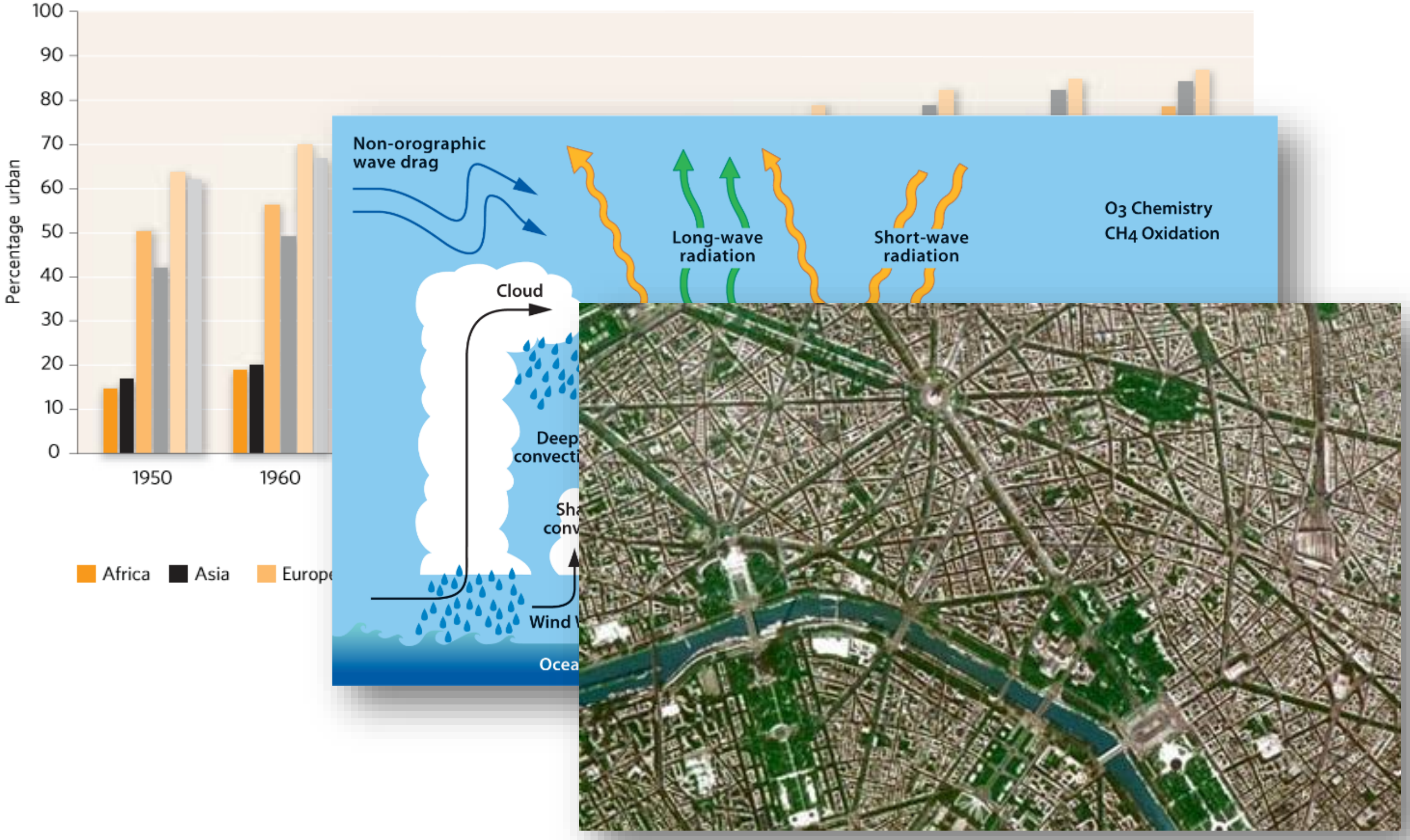
Introduction

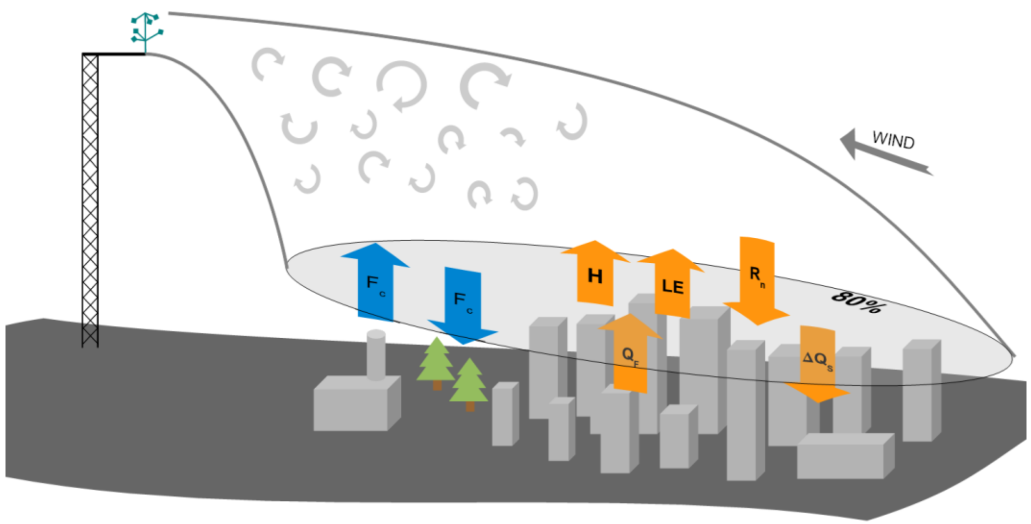


Sources: UN, 2006; ECMWF; ETH Basel

Energy balance in an urban area

$$Q^* + Q_F = Q_H + Q_E + \Delta Q_S + Q_A \quad (1)$$

$$Q^* = (SW_{in} - SW_{out}) + (LW_{in} - LW_{out}) \quad (2)$$



Nordbo et al. 2012

Objective

Karsisto et al. (2015): Seasonal surface urban energy balance and wintertime stability simulated using three land-surface models in the high-latitude city Helsinki.

- Understand the spatial and temporal differences in net radiation, sensible and latent heat fluxes between the HARMONIE model and observational data for two measurement sites in the Helsinki urban region.

Methodology

- Study sites and measurements
- Study period: winter and summer 2013
- HARMONIE model runs

Study sites and measurements

- Torni/Elisa (urban)
- Kumpula (semi-urban)

- EC set-ups and weather stations

Turbulent fluxes — Meteorology

Figure 1. Satellite image of the Helsinki city center, with the measurement sites Torni (red) and Kumpula (yellow). The Elisa tower is located right next to Torni.

Study sites and measurements

Kumpula (semi-urban)

Torni (urban)

Meteorology

- Cold and snowy winter
- Normal summer
- Large variations in *SWin*

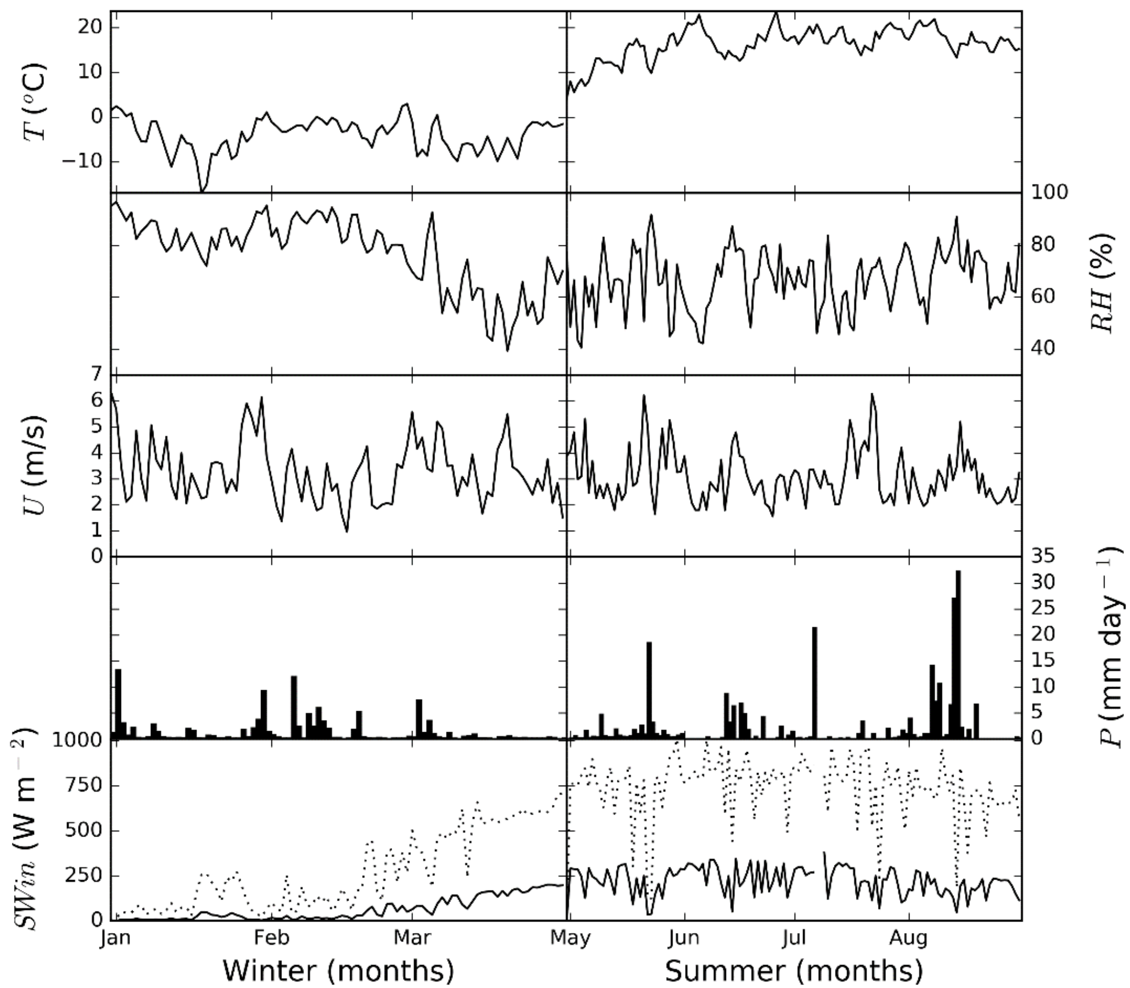


Figure 2. Time series of several meteorological variables from the Kumpula measurement site for winter (left) and summer (right) 2013.

Model runs

- Operational HARMONIE (cy38h1.2)
- 300 x 300 domain with 2.5 km grid spacing
- 65 vertical levels
- Boundary conditions from IFS forecasts
- Data assimilation for surface variables

- 1-year period starting 31-10-2012
- 6-hourly forecast cycling

Model runs

- 16 grid boxes
- 3-hourly data

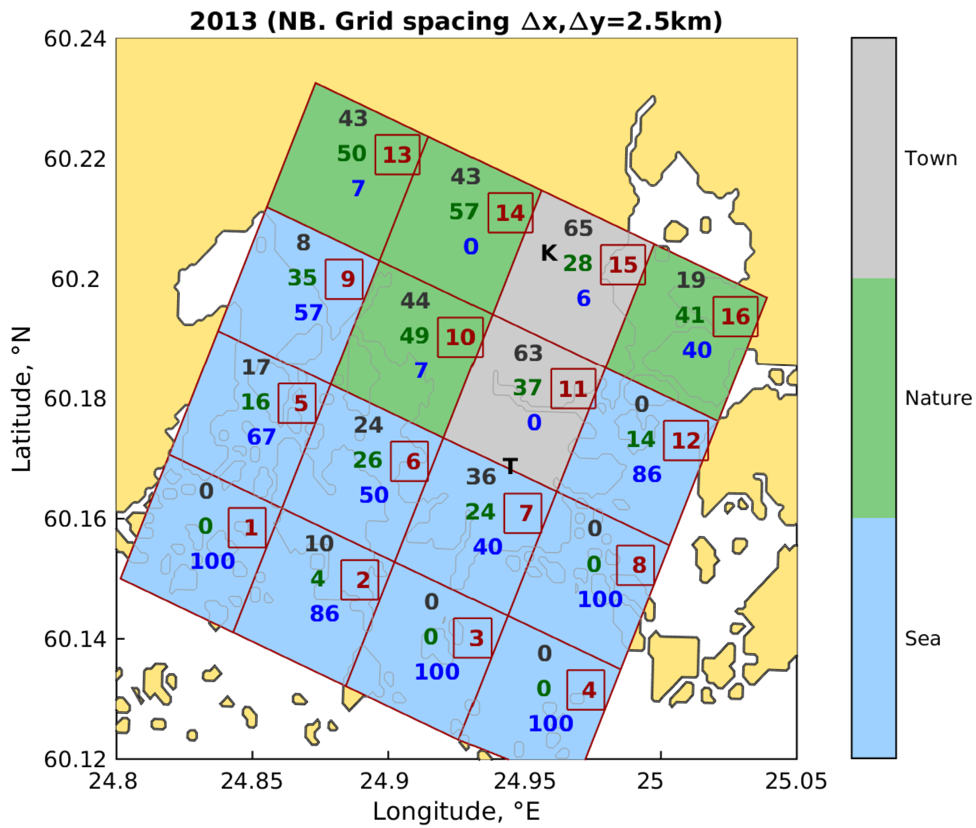


Figure 3. Map of 2.5 km grid boxes covering some of the Helsinki urban region (Curtis Wood, 2016).

Results: Net radiation (Q*)

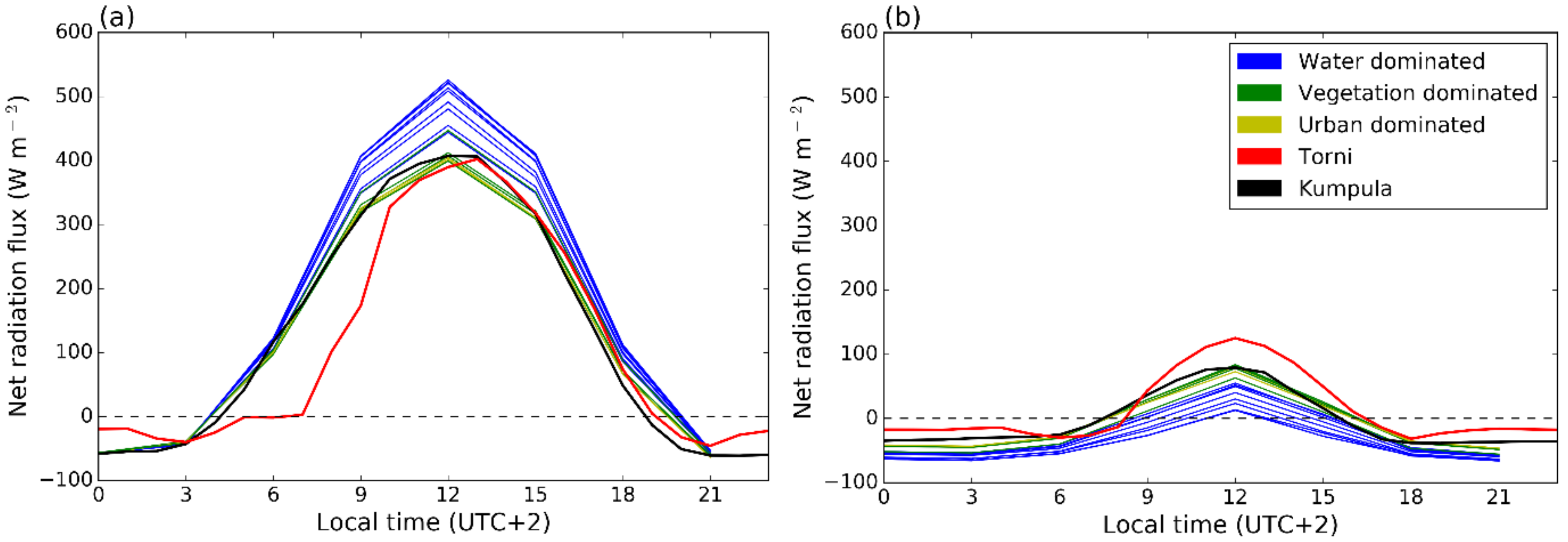
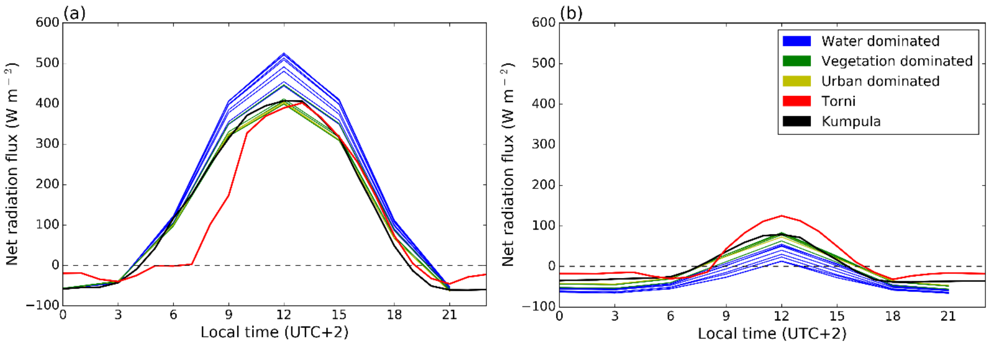


Figure 4. Mean diurnal cycles of modelled (3-hr averages) and observed (1-hr averages) net radiation (Q*) for (a) summer and (b) winter. Blue, green and yellow lines indicate the 16 model grid boxes, which are water-, vegetation- and urban dominated, respectively.

Results: Net radiation

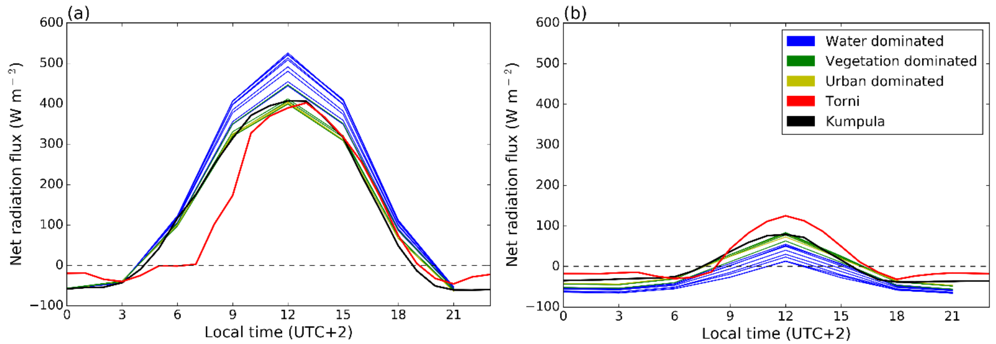


- Model captures Q* for Kumpula
- Underestimated Q* in winter for Torni
- Overestimated *SWout* for Torni

Table 1. Model statistics

		Kumpula				Torni			
		Mean	r	RMSE	MBE	Mean	r	RMSE	MBE
a) Q*									
HARMONIE	Summer	129.3	0.96	60.1	15.1	144.0	0.89	90.0	25.2
	Winter	-4.2	0.92	25.0	-5.6	21.0	0.91	39.6	-15.6

Results: Net radiation



- Urban albedo: 0.10-0.20
- Model albedo: 0.41-0.52 for urban grid boxes

- No snowploughing in the model

Table 2. Albedo

	Kumpula	Torni	Model urban	Model water
Summer	0.14	0.10	0.10-0.14	0.05-0.09
Winter	0.46	0.17	0.41-0.52	0.52-0.75

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Results: Sensible heat flux (H)

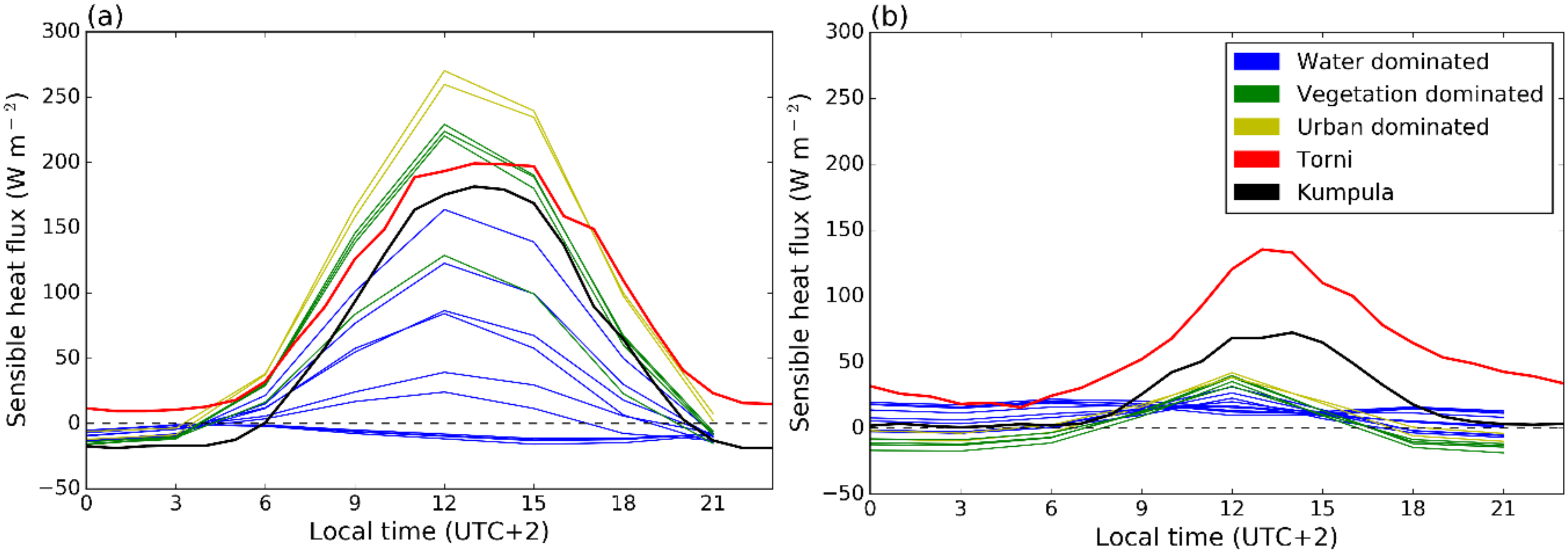

Figure 5. As Figure 4, but for the sensible heat flux H for summer (left) and winter (right).

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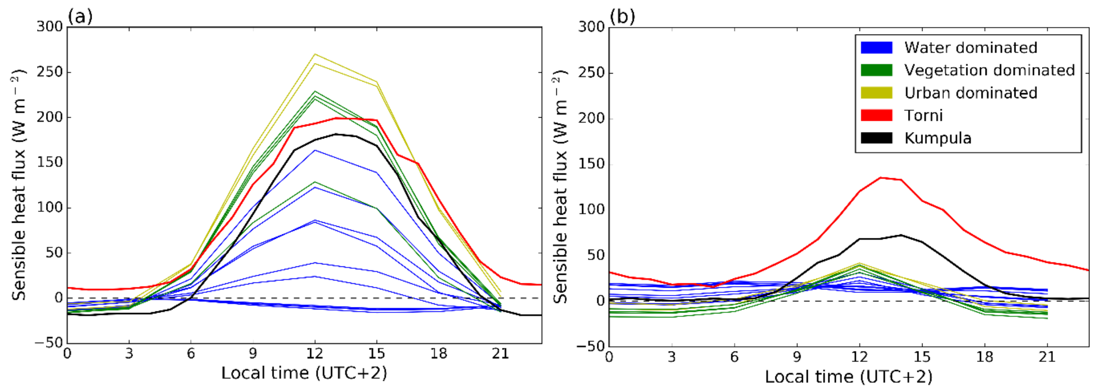
Results: Heat fluxes



- Model underestimates H in winter
- Bigger importance of Q_F and ΔQ_S in winter

Table 3. Model statistics for H

		Kumpula				Torni			
		mean	r	RMSE	MBE	mean	r	RMSE	MBE
a) H									
	Summer	61.1	0.87	84.0	54.3	87.9	0.81	64.5	1.9
	Winter	25.0	0.77	32.6	-13.5	60.5	0.65	79.5	-59.7

Results: Latent heat flux (LE)

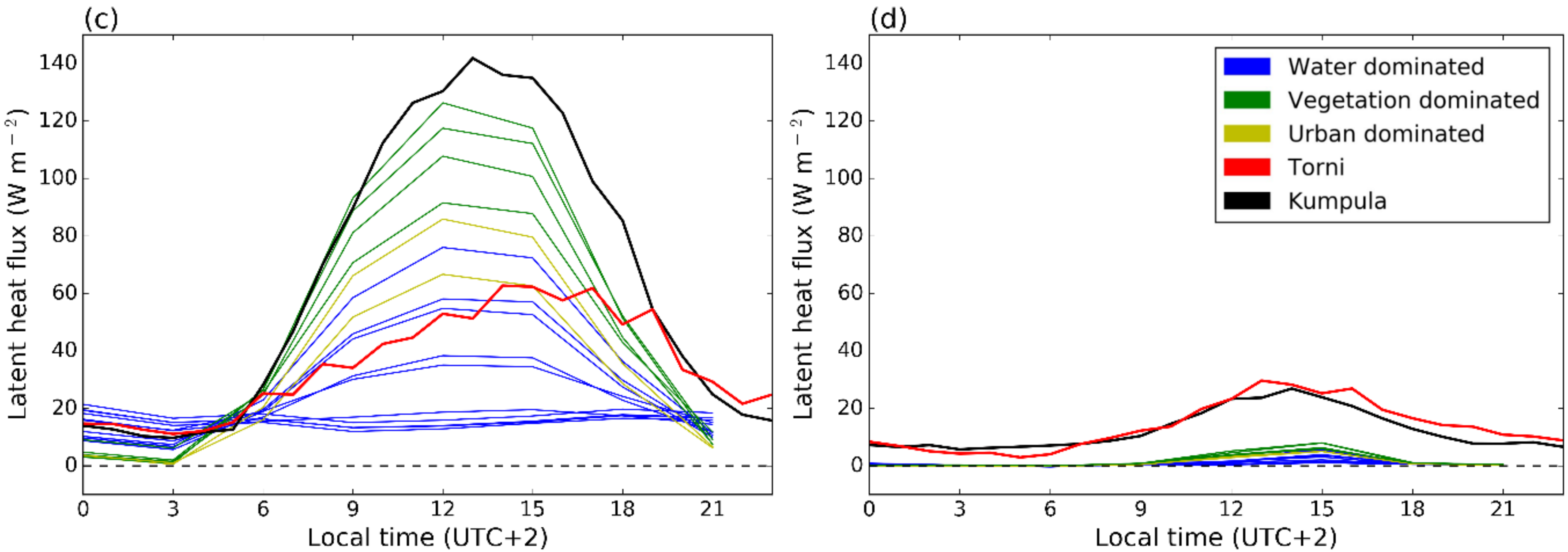
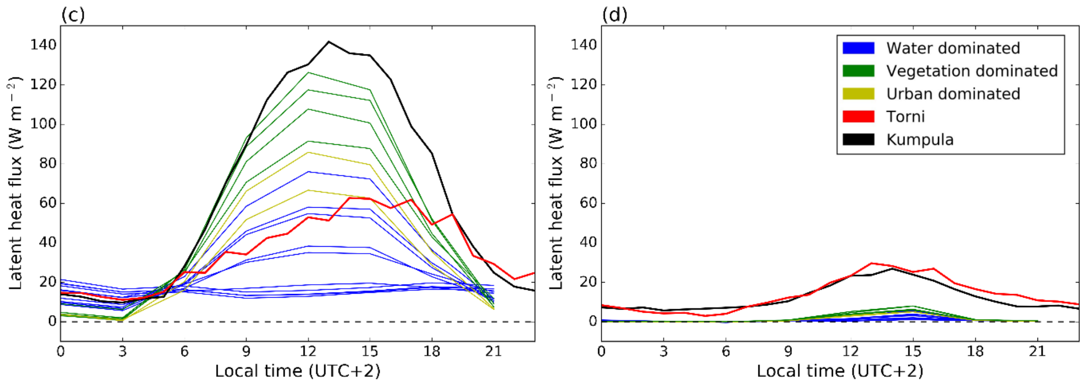


Figure 6. As Figure 4, but for the latent heat flux H for summer (left) and winter (right).

Results: Heat fluxes



- Model underestimates LE in winter
- Anthropogenic source of water is ignored

Table 4. Model statistics for LE

		Kumpula				Torni			
		mean	r	RMSE	MBE	mean	r	RMSE	MBE
a) LE									
	Summer	68.5	0.62	59.7	-38.2	37.0	0.29	59.6	9.8
	Winter	13.1	0.49	15.6	-10.7	14.1	0.34	20.6	-12.9

Conclusions

- Radiation components are well modelled by HARMONIE
- Troubles in periods with snow

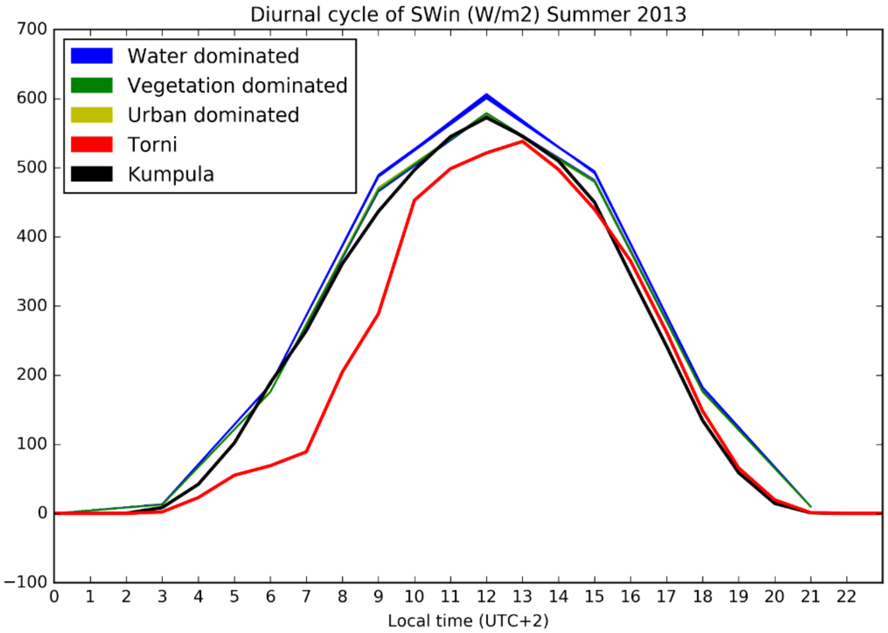
- Winter turbulent fluxes hard to capture by HARMONIE
- Anthropogenic fluxes of bigger importance

Recommendations

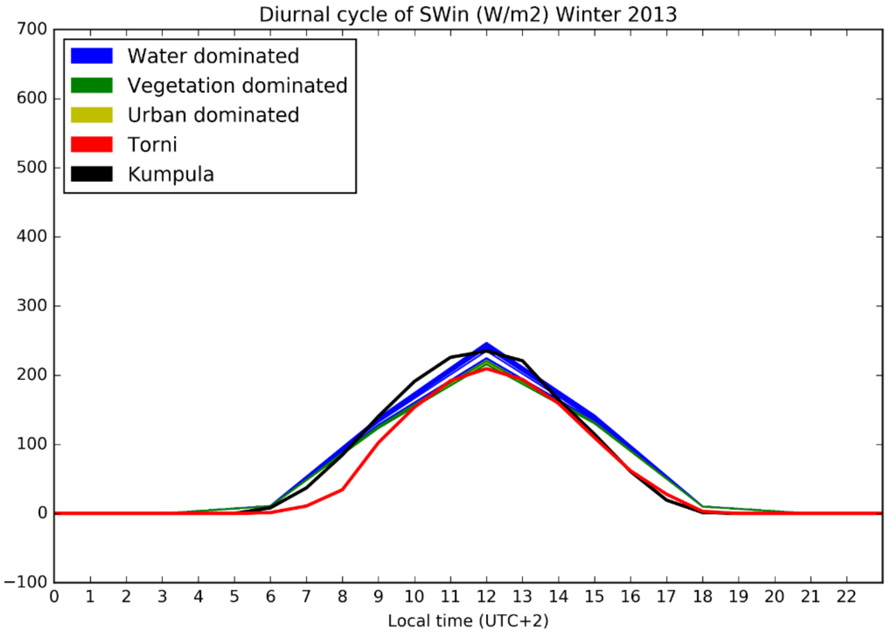
- Looking at individual tiles in HARMONIE
- Revisit snow parameterizations
- Implement better information on anthropogenic fluxes
- More specific studies to environmental factors

Thank you for your attention, any questions?

Additional slides – SW incoming

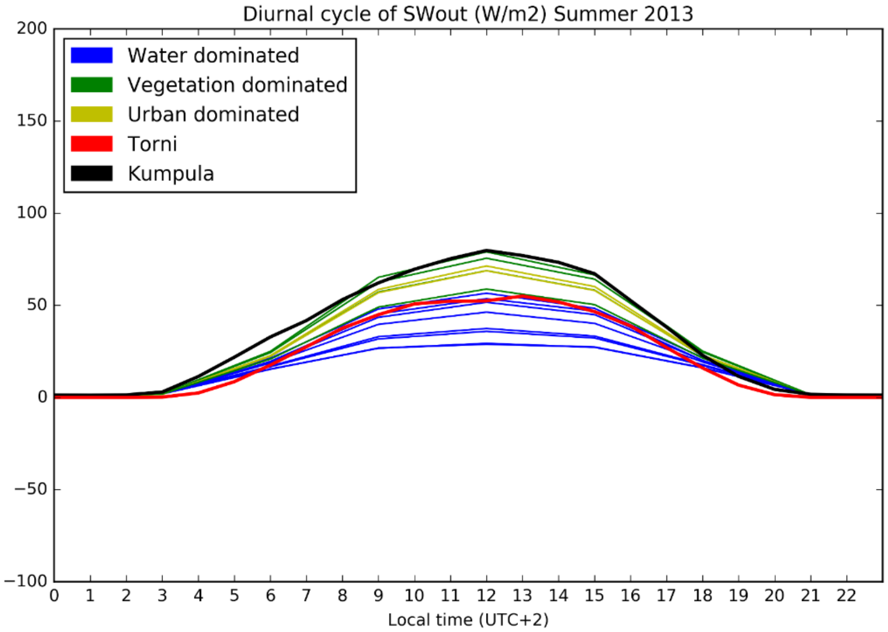


Summer

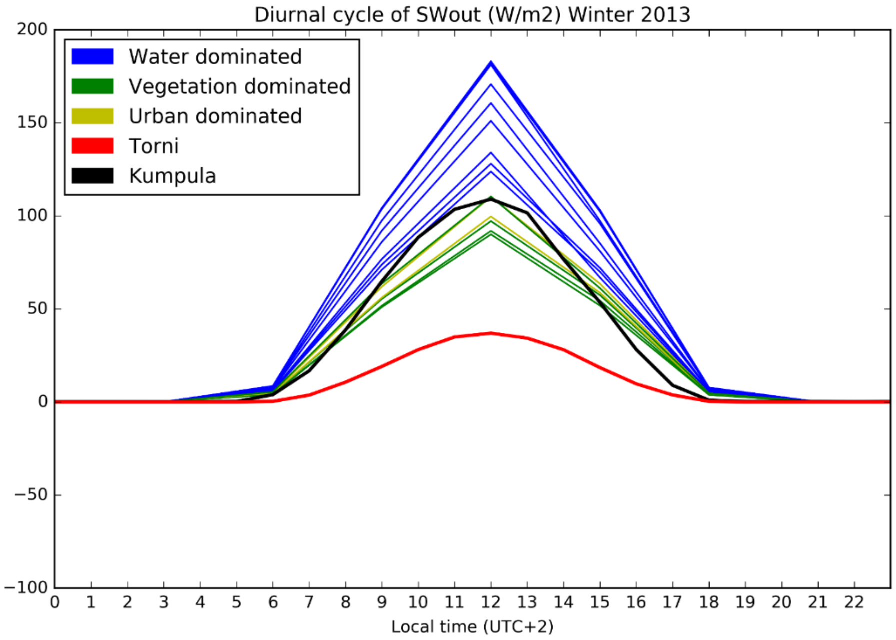


Winter

Additional slides – SW outgoing

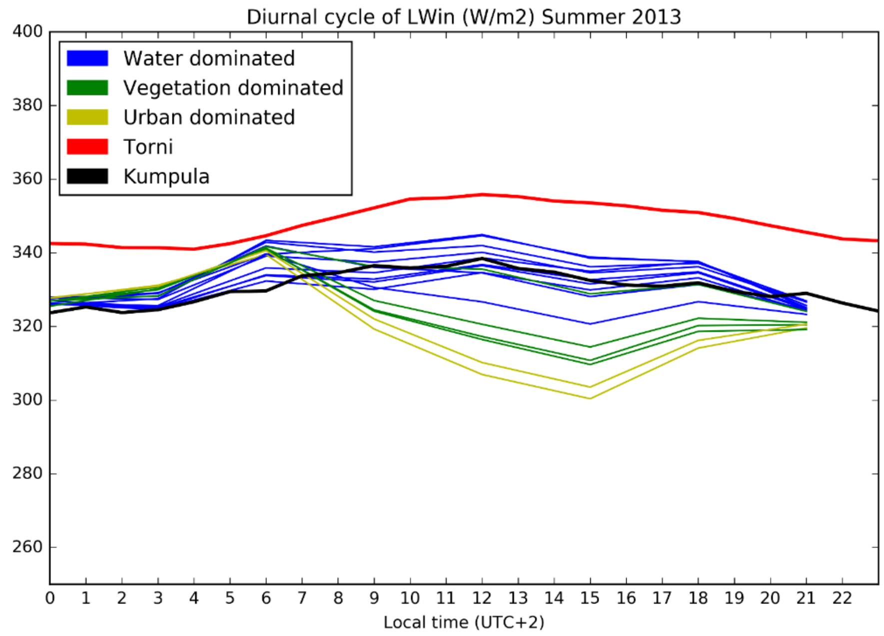


Summer

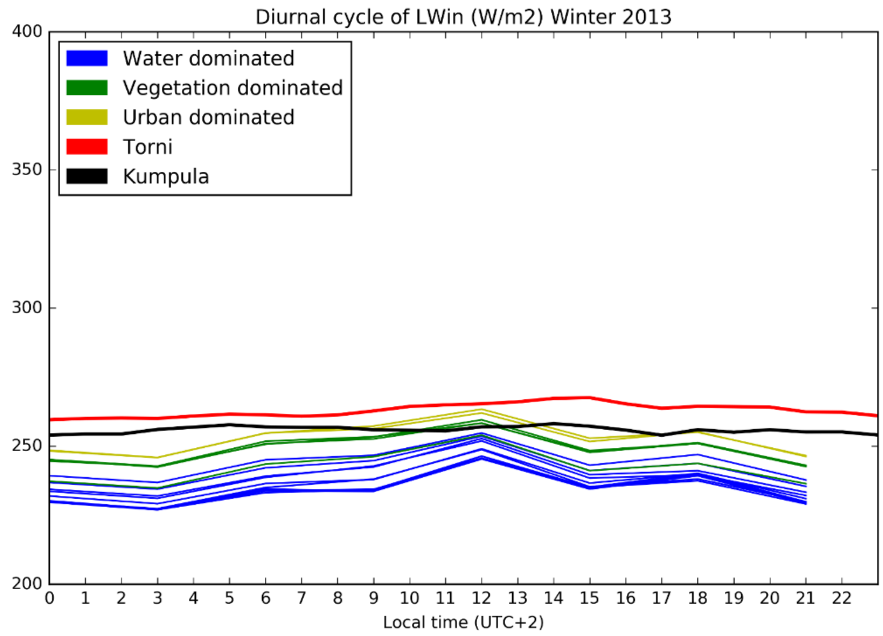


Winter

Additional slides – LW incoming

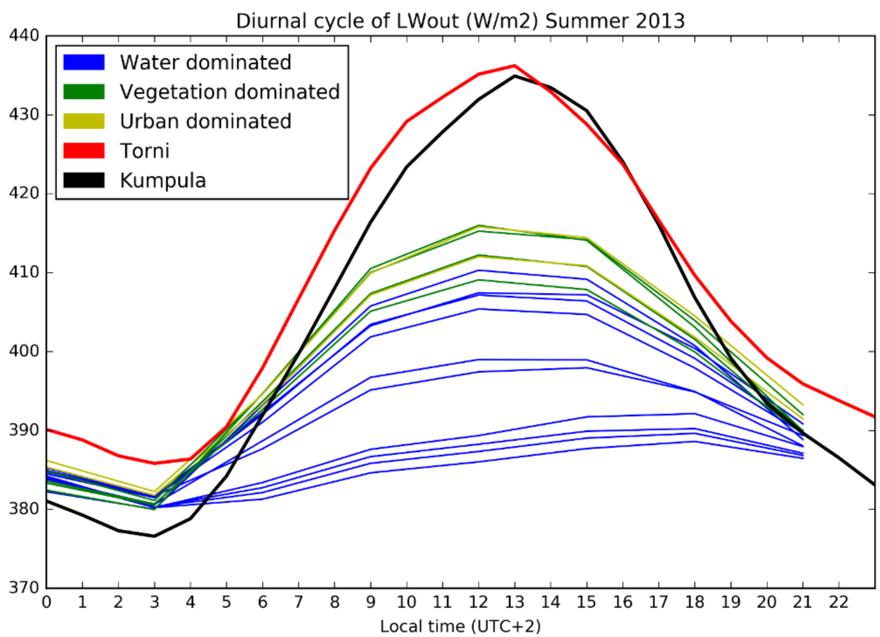


Summer

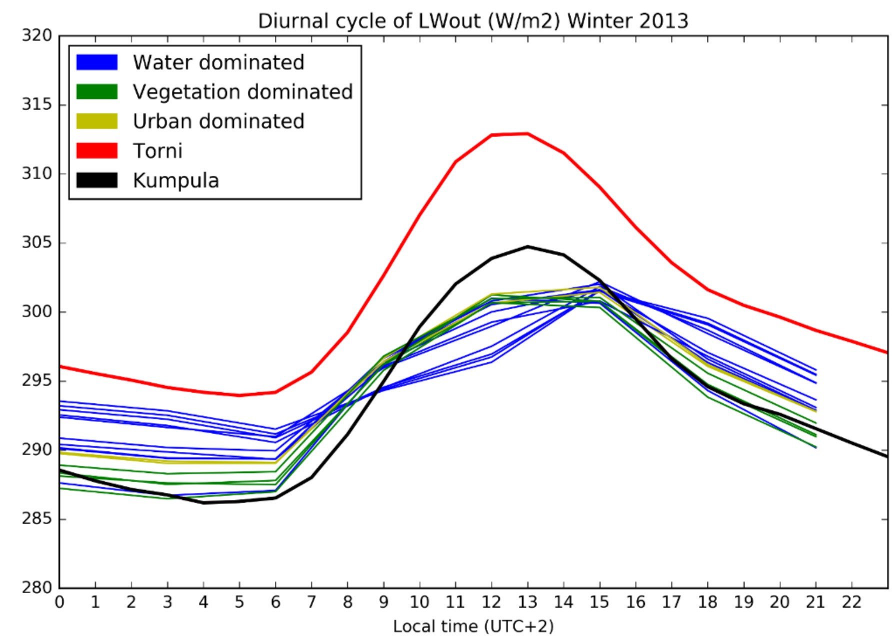


Winter

Additional slides – LW outgoing



Summer



Winter

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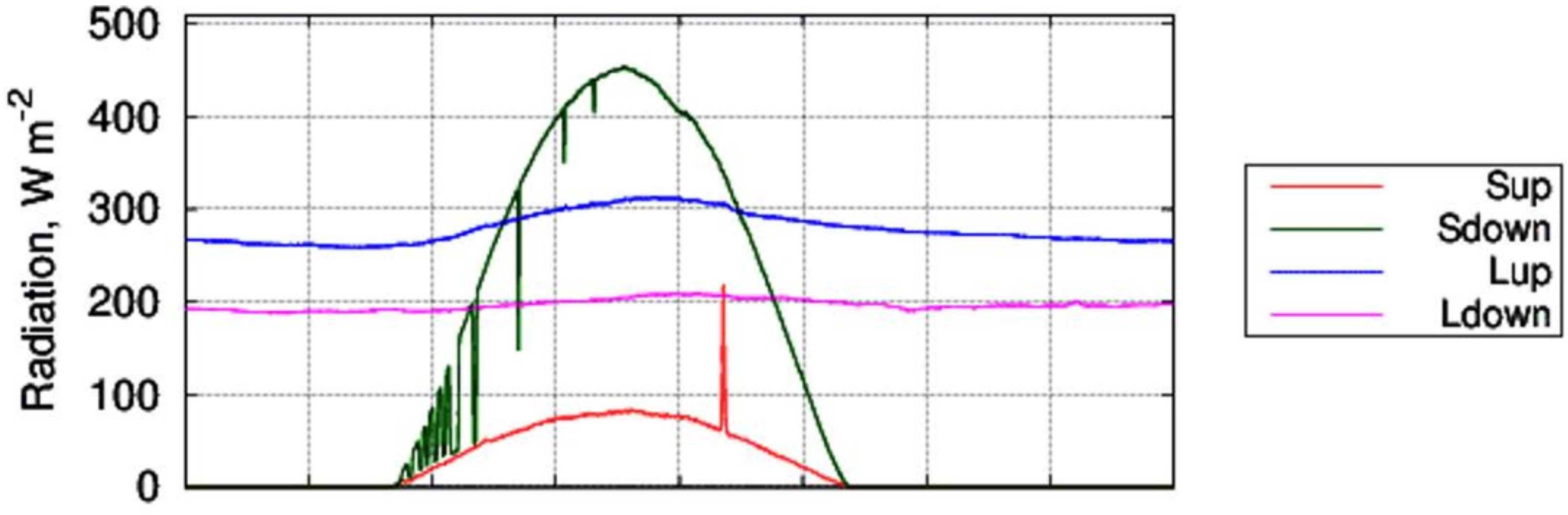
Additional slides – SW shading error



Results

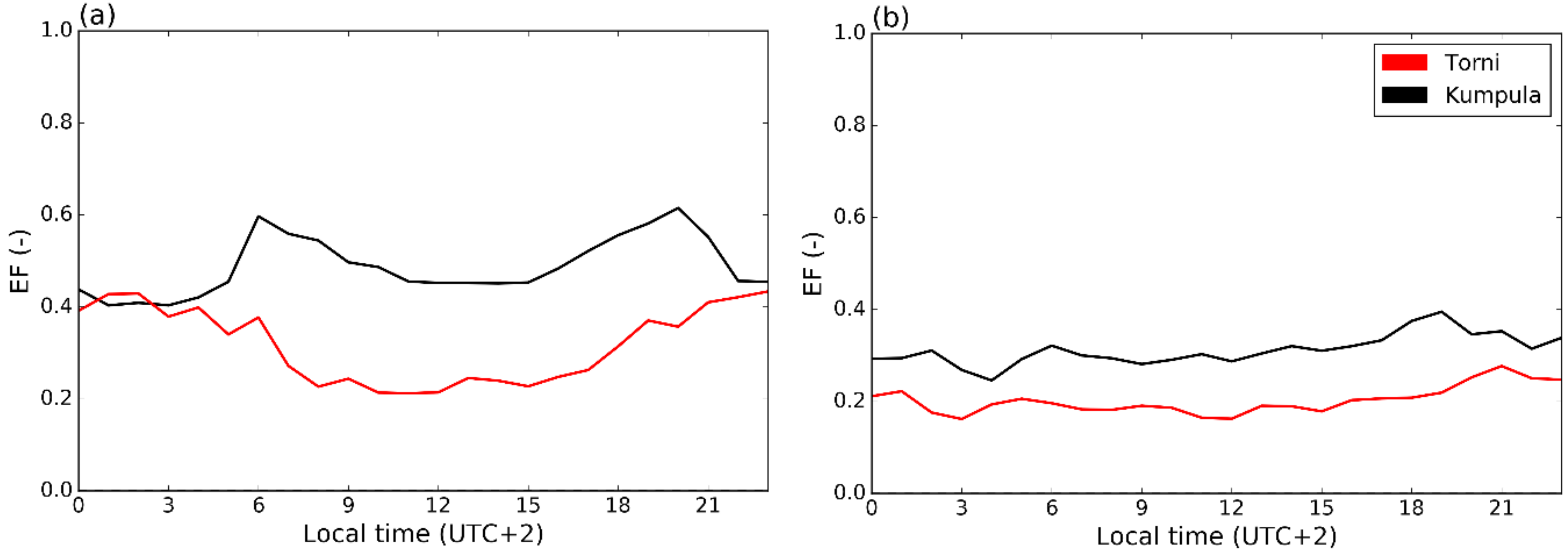


Figure 5. Diurnal mean cycles of observed (1-hr averages) evaporative fraction EF for (a) summer and (b) winter.