Luise Wanner, Marc Calaf, Sreenath Paleri, Hawwa Kadum, Brian Butterworth, Ankur Desai, and Matthias Mauder

A Model of the Energy Balance Gap Based on Atmospheric Stability and Surface Heterogeneity

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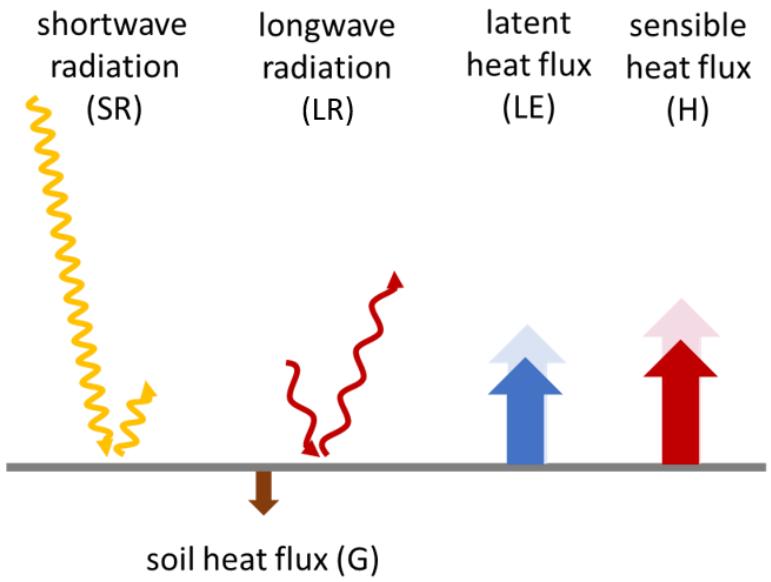
Background

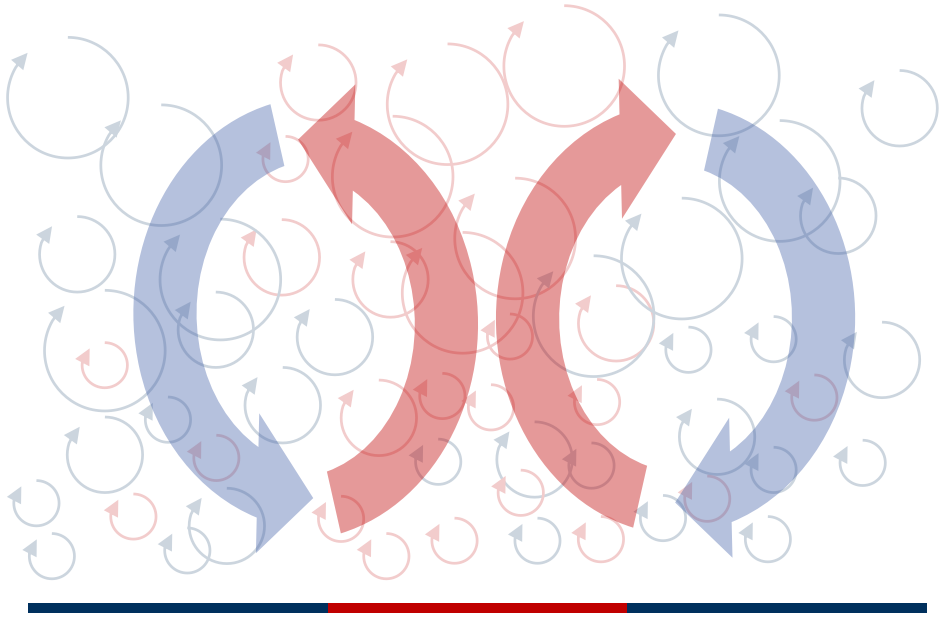
Energy balance gap

Eddy covariance (EC) method

— commonly used to measure latent & sensible heat fluxes

— systematically underestimates fluxes



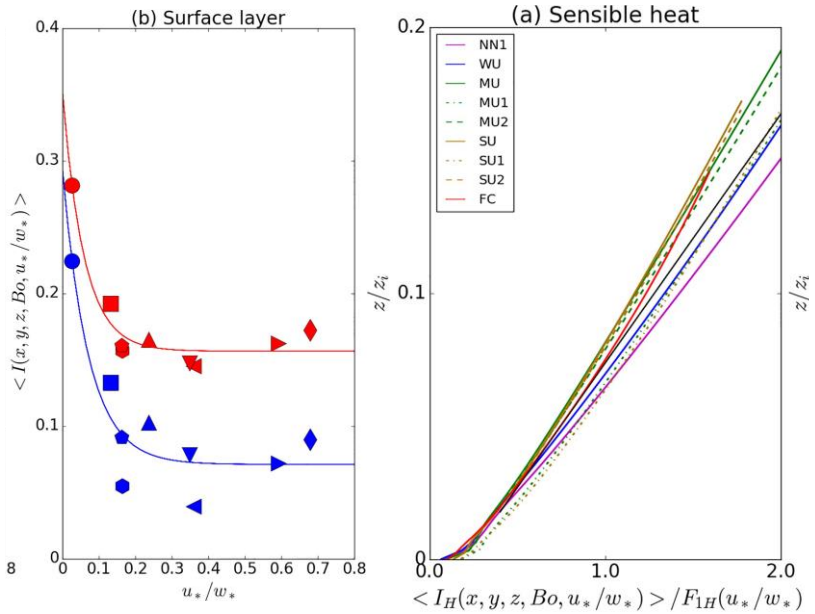


Imbalance Model

De Roo et al. 2018 (PLOS One):

Model for homogeneous surface
— Imbalance as a function of atmospheric stability (u_*/w_*) and measurement height (z/z_i)

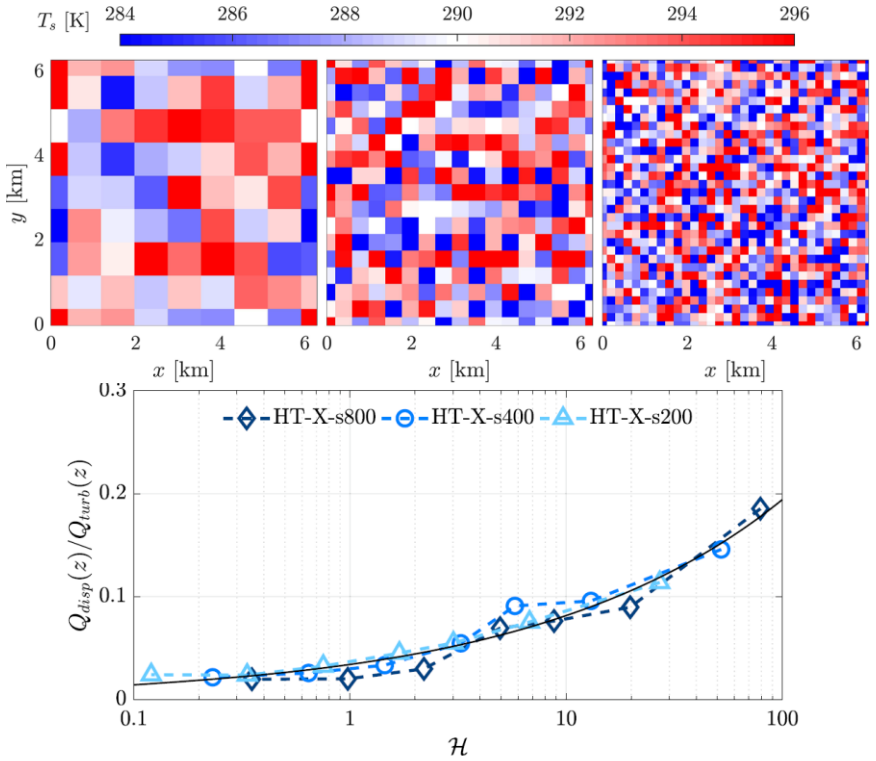
$$I\left(z, \frac{u_*}{w_*}\right) = F_1\left(\frac{u_*}{w_*}\right) F_2\left(\frac{z}{z_i}\right)$$



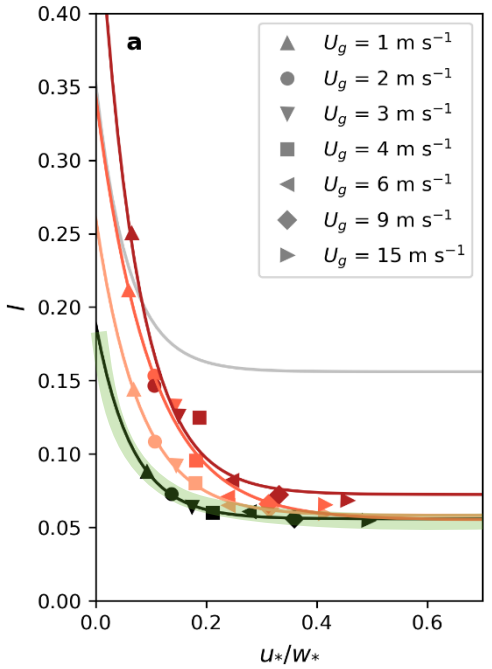
Margairaz et al. 2020 (Bound-Layer Meteorol):

Developed heterogeneity parameter

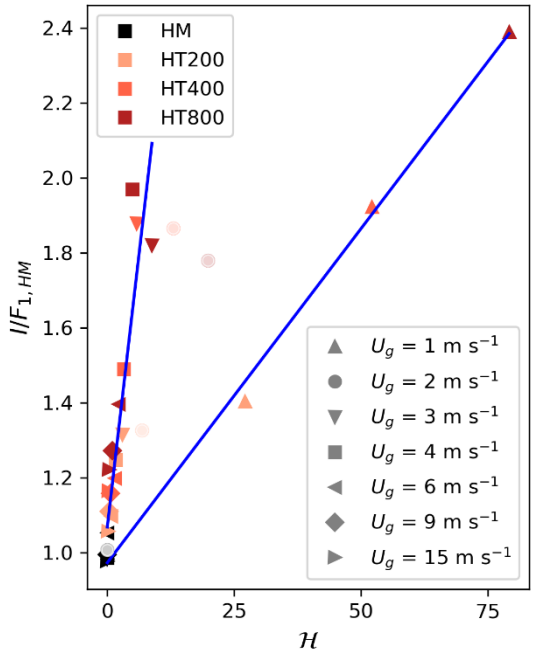
$$\mathcal{H} = \frac{g\, l_h}{{U_g}^2} \frac{\Delta T}{\bar{T}}$$



Imbalance Model

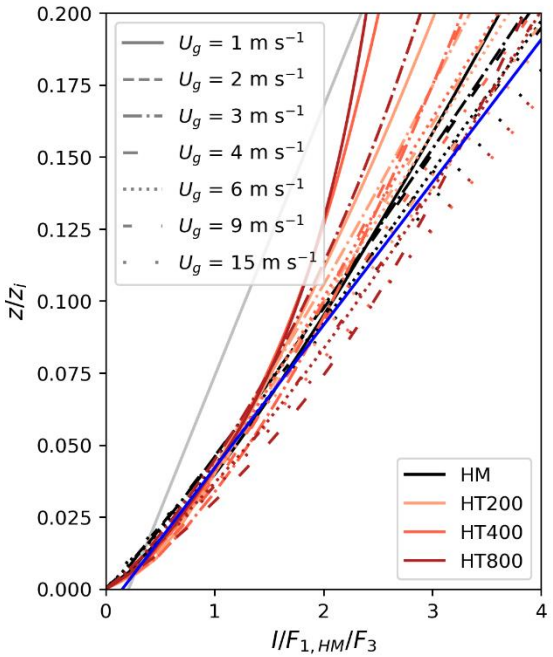


$$F_{1,\mathrm{HM}} = 0.133 \exp\left(-15.3 \frac{u_*}{w_*}\right) + 0.056$$



$$F_{3,c} = 0.018\,\mathcal{H} + 0.973$$

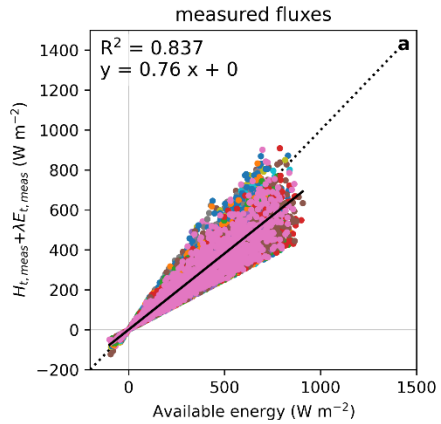
$$F_{3,r} = 0.116\,\mathcal{H} + 1.07$$

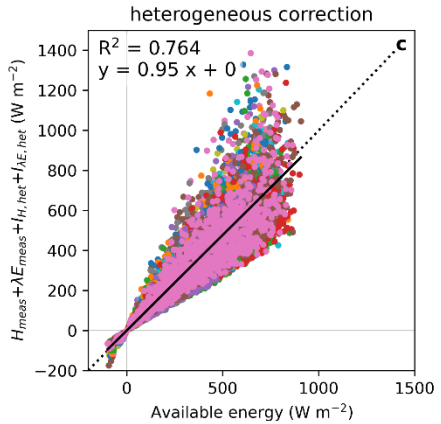


$$F_2 = 20.2 \left(\frac{z}{z_i}\right) + 0.153$$

Wanner *et al.* Incorporating the effect of heterogeneous surface heating into a semi-empirical model of the surface energy balance closure. *PLOS One.* accepted

Application to field data





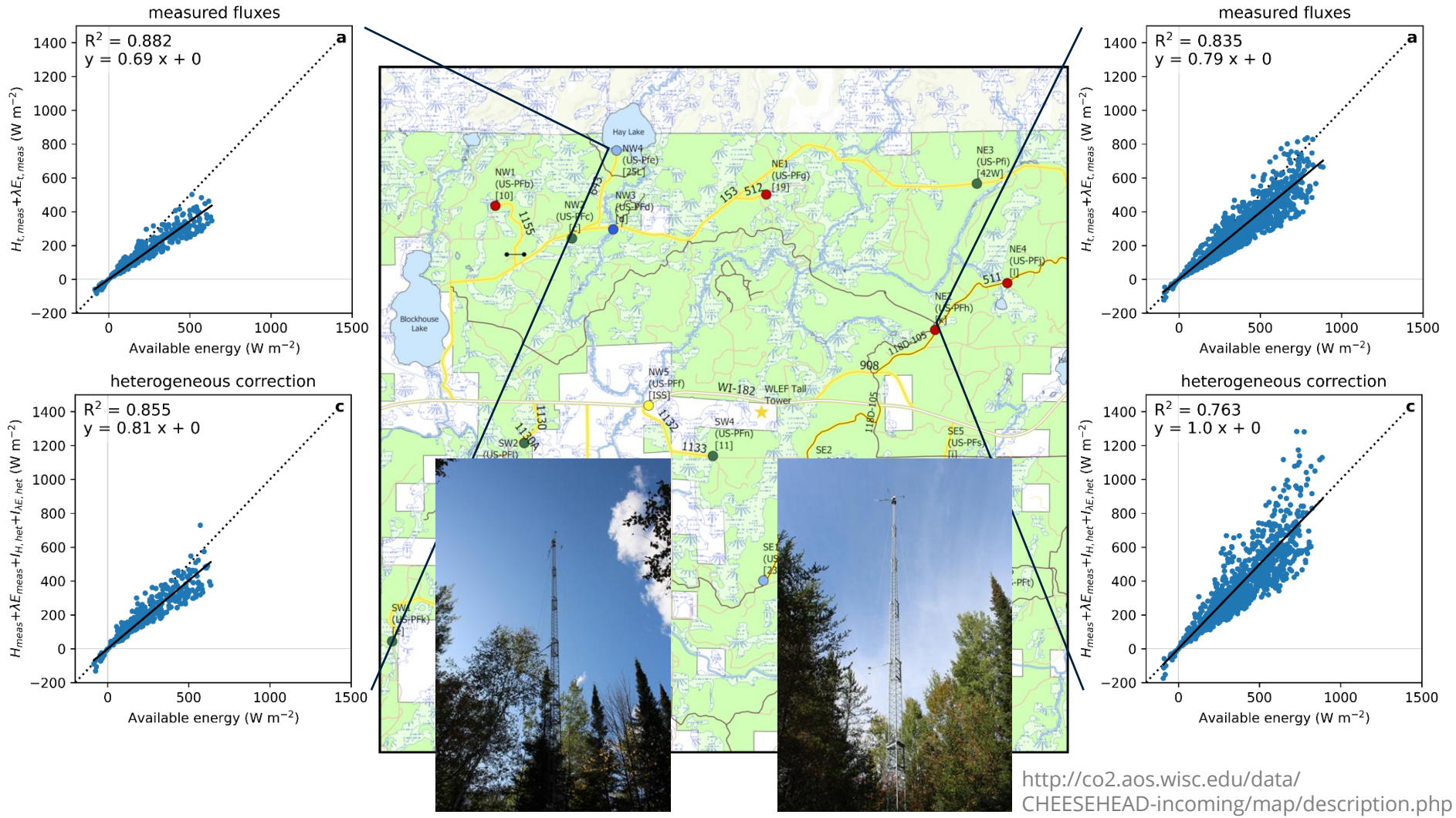
$$I_H = \frac{F_1\left(\frac{u_*}{w_*}\right) F_2\left(\frac{z}{z_i}\right) F_3(\mathcal{H})}{1 - F_1\left(\frac{u_*}{w_*}\right) F_2\left(\frac{z}{z_i}\right) F_3(\mathcal{H})} H$$

$$I_{\lambda E} = \frac{F_1\left(\frac{u_*}{w_*}\right) F_2\left(\frac{z}{z_i}\right) F_3(\mathcal{H})}{1 - F_1\left(\frac{u_*}{w_*}\right) F_2\left(\frac{z}{z_i}\right) F_3(\mathcal{H})} \lambda E$$

→ Butterworth et al. 2019, Connecting Land-Atmosphere Interactions to Surface Heterogeneity in CHEESEHEAD19, BAMS, doi: 10.1175/BAMS-D-19-0346.1

Station	measured		corrected	
	slope	R^2	slope	R^2
NW1	0.75	0.84	0.97	0.75
NW2	0.68	0.78	0.96	0.69
NW3	0.66	0.91	0.81	0.78
NW4	0.69	0.88	0.81	0.85
NE1	0.79	0.91	1.04	0.85
NE2	0.79	0.84	1.00	0.76
NE3	0.80	0.82	1.05	0.76
NE4	0.82	0.80	1.04	0.74
SW1	0.77	0.84	0.92	0.79
SW2	0.76	0.85	0.92	0.79
SW3	0.83	0.80	1.02	0.76
SW4	0.76	0.81	0.93	0.73
SE2	0.70	0.85	0.87	0.79
SE3	0.73	0.85	0.89	0.78
SE4	0.73	0.91	0.88	0.76
SE5	0.71	0.85	0.95	0.79
SE6	0.76	0.83	0.96	0.75

Application to field data



http://co2.aos.wisc.edu/data/CHEESEHEAD-incoming/map/description.php

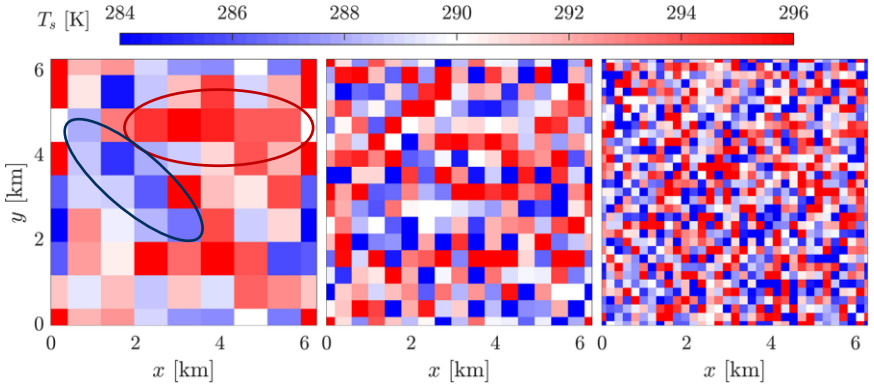
Outlook

Lacunarity

Heterogeneity scale in model ≠ heterogeneity scale in landscape

— Update scaling functions with lacunarity instead of patch size

— See talk of Hawwa Kadum (next)



Latent heat flux

— New idealized LES to derive scaling function for latent heat flux

— „energy balance“ correction for CO_2?

Thank you!

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