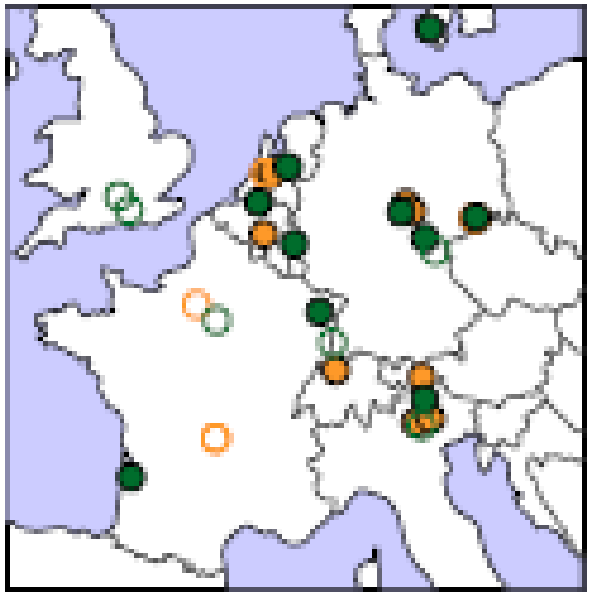
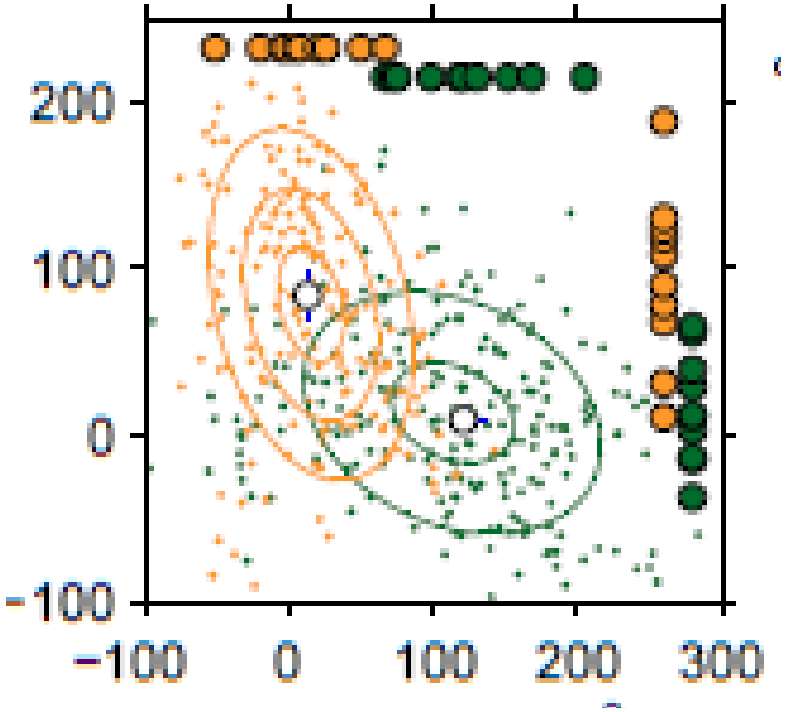




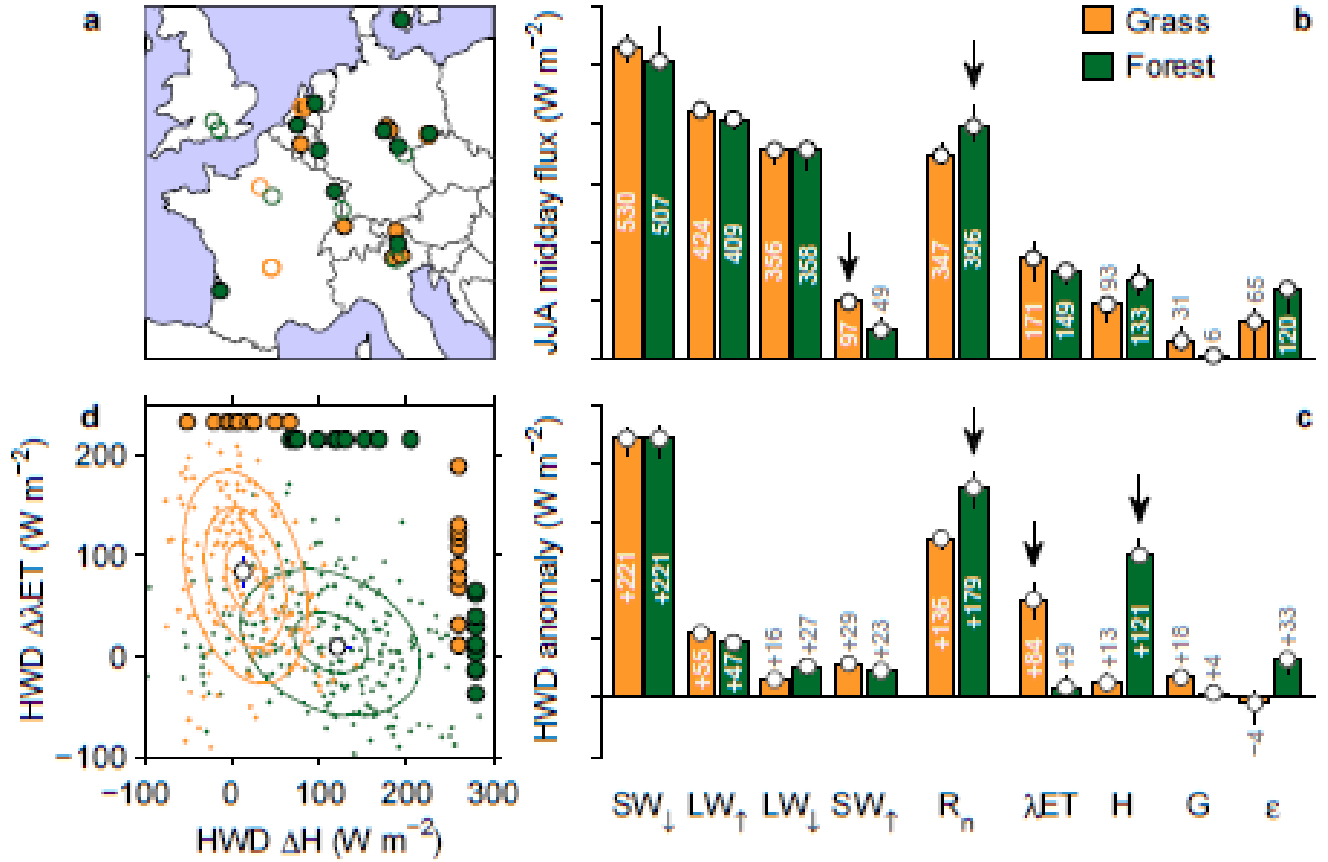
Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Milieu

Grass-Forest contrasting response to heatwave days – a feedback study

Bart van den Hurk
Lennert Stap
Chiel van Heerwaarden

FLUXNET observations

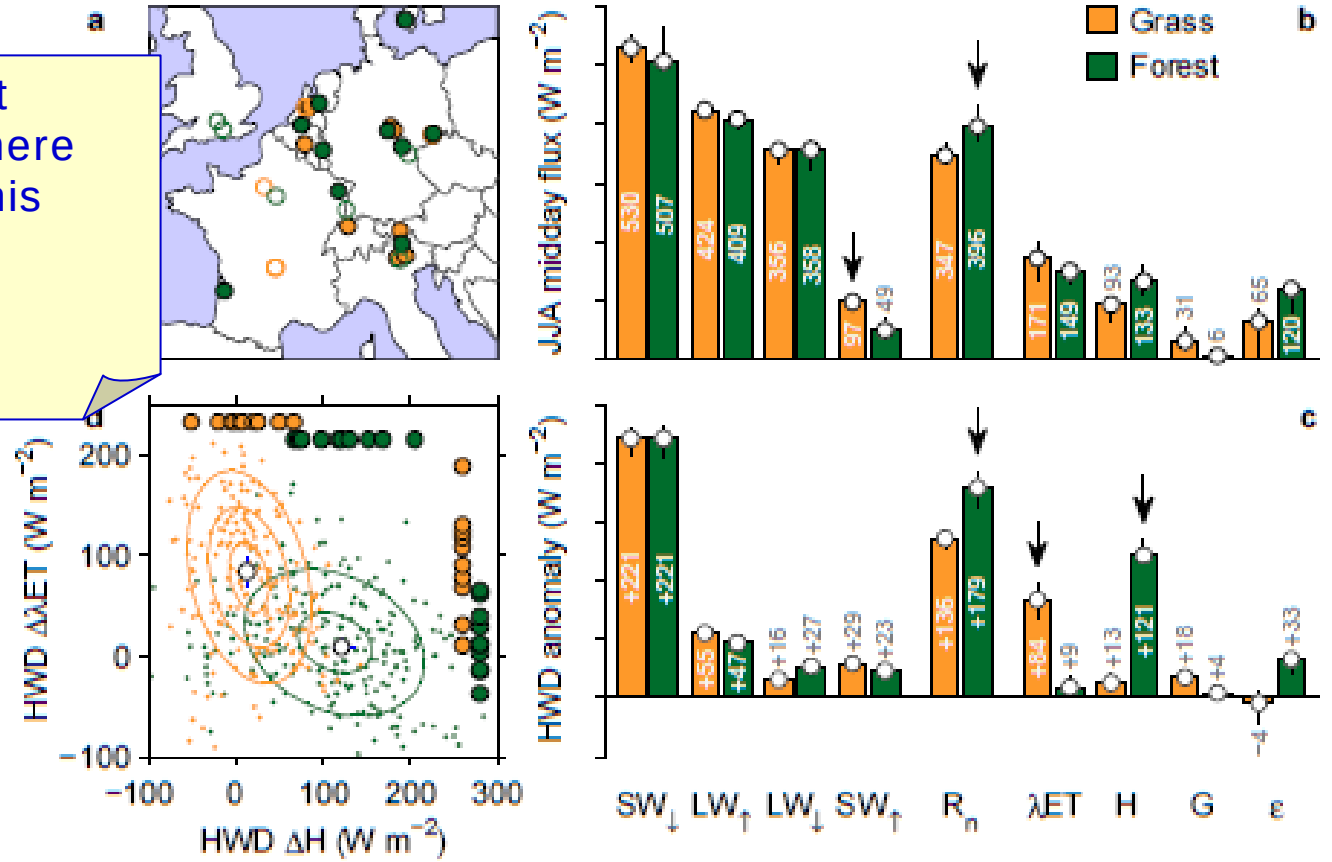
Teuling et al (2010): Forest and Grass have a different response to heatwave days



FLUXNET observations

Teuling et al (2010): Forest and Grass have a different response to heatwave days

How important are land-atmosphere feedbacks for this contrasting response?



FLUXNET observations

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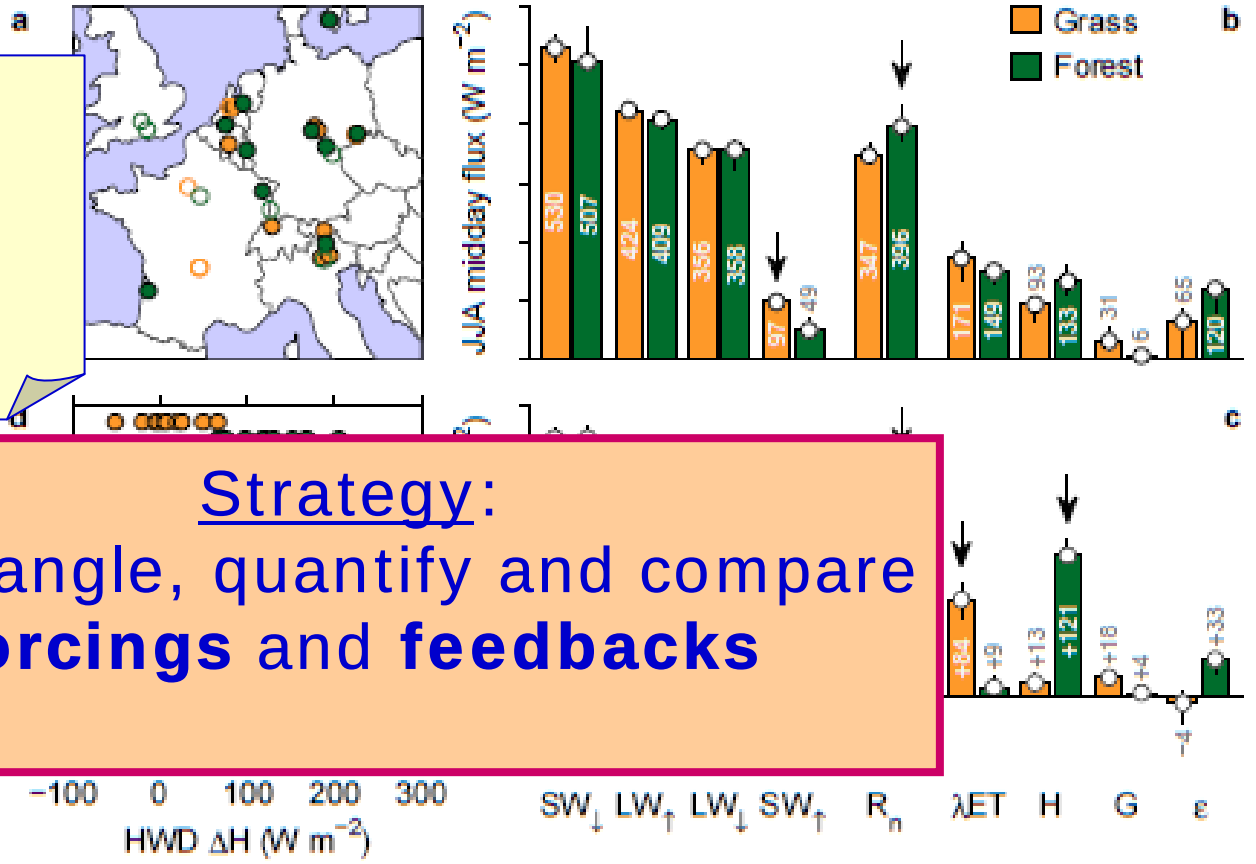
How important are land-atmosphere feedbacks for this contrasting response?



Strategy:
Disentangle, quantify and compare **forcings** and **feedbacks**

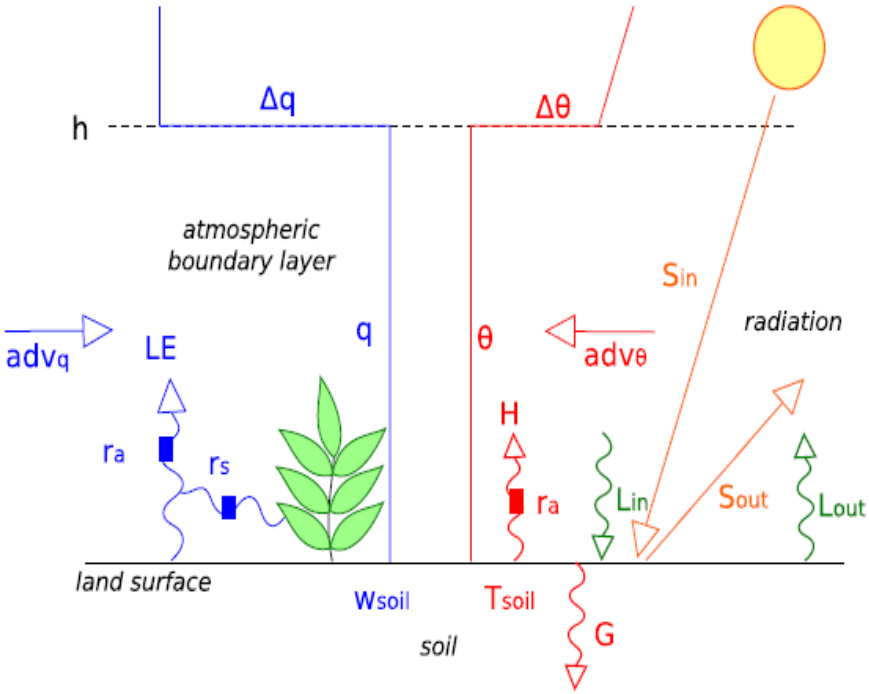
Conceptual PBL – Land surface model

Consider the following system:

$$\frac{d\theta}{dt} = \frac{1}{h}\left(\frac{H}{\rho c_p} + w_e \Delta\theta\right) + adv_\theta$$

$$\frac{dq}{dt} = \frac{1}{h}\left(\frac{LE}{\rho L_v} + w_e \Delta q\right) + adv_q$$

$$R_{net} = H + LE + G$$



And the Penman-Monteith equation:

$$LE = \frac{\Delta A + D\rho c_p / r_a}{\Delta + \frac{c_p}{L_v}\left(1 + \frac{r_s}{r_a}\right)}$$

$A = R_{net} - G = (1-\alpha)S_{in} + L_{in} - L_{out} - G$
$D = q_{sat}(T) - q$
$\Delta = dq_{sat}/d_T$

Van Heerwaarden et al, 2010

Derivative dLE/dt

$$\frac{dLE}{dt} = \overbrace{c_0 \frac{dq_{sat}}{dT}\left\{(1-\alpha)\frac{dS_{in}}{dt} + \frac{dL_{in}}{dt}\right\}}^{\text{surface radiation forcing}} + \overbrace{c_0\left(H\frac{d^2q_{sat}}{dT^2} + \frac{\rho c_p}{r_a}\frac{dq_{sat}}{dT}\right)\{adv_\theta\} - c_0\frac{\rho c_p}{r_a}\{adv_q\}}^{\text{boundary-layer forcings}}$$

$$+ \overbrace{c_0\left(H\frac{d^2q_{sat}}{dT^2} + \frac{\rho c_p}{r_a}\frac{dq_{sat}}{dT}\right)\left\{\frac{H}{\rho c_p h} + \frac{w_e\Delta\theta}{h}\right\} - c_0\frac{\rho c_p}{r_a}\left\{\frac{LE}{\rho L_v h} + \frac{w_e\Delta q}{h}\right\}}^{\text{boundary-layer feedbacks}} - \overbrace{c_0\left(\frac{\rho c_p}{r_a^2}(q_{sat}-q) - LE\frac{c_p}{L_v}\frac{r_s}{r_a^2}\right)\frac{dr_a}{dt}}^{\text{surface-layer feedback}}$$

$$- \overbrace{c_0\frac{dq_{sat}}{dT}\frac{dL_{out}}{dt} - c_0\frac{dq_{sat}}{dT}\frac{dG}{dt} - c_0 LE\frac{c_p}{L_v}\frac{1}{r_a}\frac{dr_s}{dt}}^{\text{land surface feedbacks}}, \qquad (1)$$

$$c_0 = 1\Big/\left[\frac{dq_{sat}}{dT} + \frac{c_p}{L_v}\left(1 + \frac{r_s}{r_a}\right)\right]$$

$$LE = \frac{\Delta A + D\rho c_p / r_a}{\Delta + \frac{c_p}{L_v}\left(1 + \frac{r_s}{r_a}\right)}$$

Van Heerwaarden et al, 2010

Derivative dLE/dt

Forcing

Feedback

Heating/moistening through advection

Change of radiation in time

Changes in aerodynamic coupling due to stability effects

$$\frac{dLE}{dt} = \overbrace{c_0 \frac{dq_{sat}}{dT}\left\{(1-a)\frac{dS_{in}}{dt} + \frac{dL_{in}}{dt}\right\}}^{\text{surface radiation forcing}} + \overbrace{c_0\left(H\frac{d^2q_{sat}}{dT^2} + \frac{\rho c_p}{r_a}\frac{dq_{sat}}{dT}\right)\{adv_\theta\} - c_0\frac{\rho c_p}{r_a}\{adv_q\}}^{\text{boundary-layer forcings}}$$

$$+ \overbrace{c_0\left(H\frac{d^2q_{sat}}{dT^2} + \frac{\rho c_p}{r_a}\frac{dq_{sat}}{dT}\right)\left\{\frac{H}{\rho c_p h} + \frac{w_e\Delta\theta}{h}\right\} - c_0\frac{\rho c_p}{r_a}\left\{\frac{LE}{\rho L_v h} + \frac{w_e\Delta q}{h}\right\}}^{\text{boundary-layer feedbacks}} - \overbrace{c_0\left(\frac{\rho c_p}{r_a^2}(q_{sat}-q) - LE\frac{c_p}{L_v}\frac{r_s}{r_a^2}\right)\frac{dr_a}{dt}}^{\text{surface-layer feedback}}$$

$$- \underbrace{c_0\frac{dq_{sat}}{dT}\frac{dL_{out}}{dt} - c_0\frac{dq_{sat}}{dT}\frac{dG}{dt} - c_0 LE\frac{c_p}{L_v}\frac{1}{r_a}\frac{dr_s}{dt}}_{\text{land surface feedbacks}}, \qquad (1)$$

Heating/moistening through boundary layer growth

$$c_0 = 1\Big/\left[\frac{dq_{sat}}{dT} + \frac{c_p}{L_v}\left(1 + \frac{r_s}{r_a}\right)\right]$$

Soil moisture depletion

Longwave cooling

Soil heating

$$LE = \frac{\Delta A + D\rho c_p / r_a}{\Delta + \frac{c_p}{L_v}\left(1 + \frac{r_s}{r_a}\right)}$$

Van Heerwaarden et al, 2010

Coupled Penman-Monteith equation

Consider the following system:

$$\frac{d\theta}{dt} = \frac{1}{h}\left(\frac{H}{\rho c_p} + w_e \Delta\theta\right) + adv_\theta$$

$$\frac{dq}{dt} = \frac{1}{h}\left(\frac{LE}{\rho L_v} + w_e \Delta q\right) + adv_q$$

$$R_{net} = H + LE + G$$

And the Penman-Monteith equation:

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$A = R_{net} - G = (1-\alpha)S_{in} + L_{in} - L_{out} - G$
$D = q_{sat}(T) - q$
$\Delta = dq_{sat}/d_T$

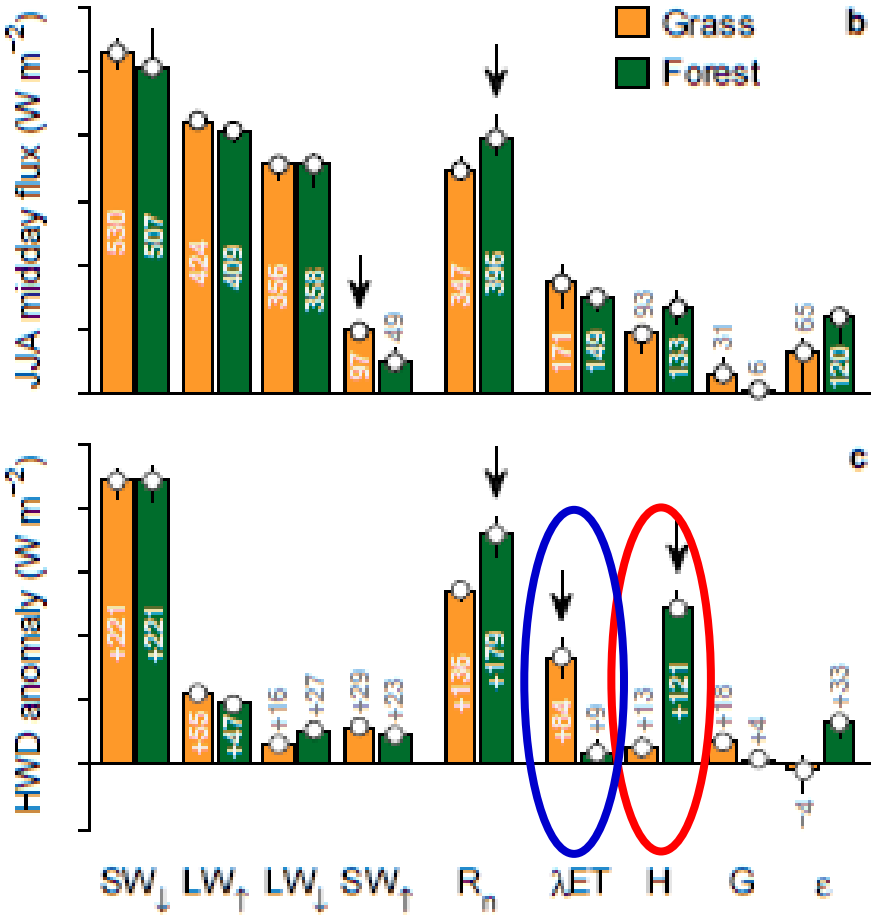
Replaced by

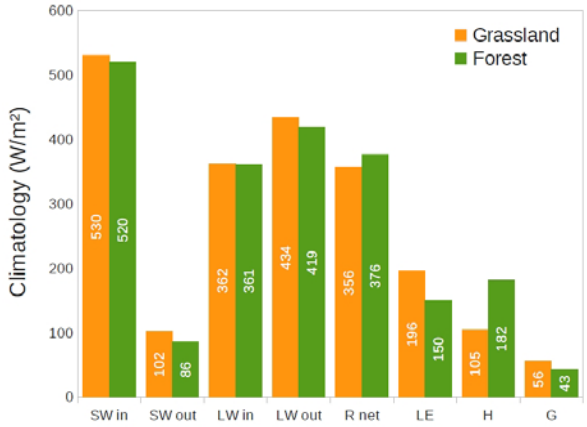
KNMI testbed:
Full Single Column Model
Forcing from RCM
7 years timeseries
Cabauw

3 runs:
Cabauw site
pure grass
pure forest

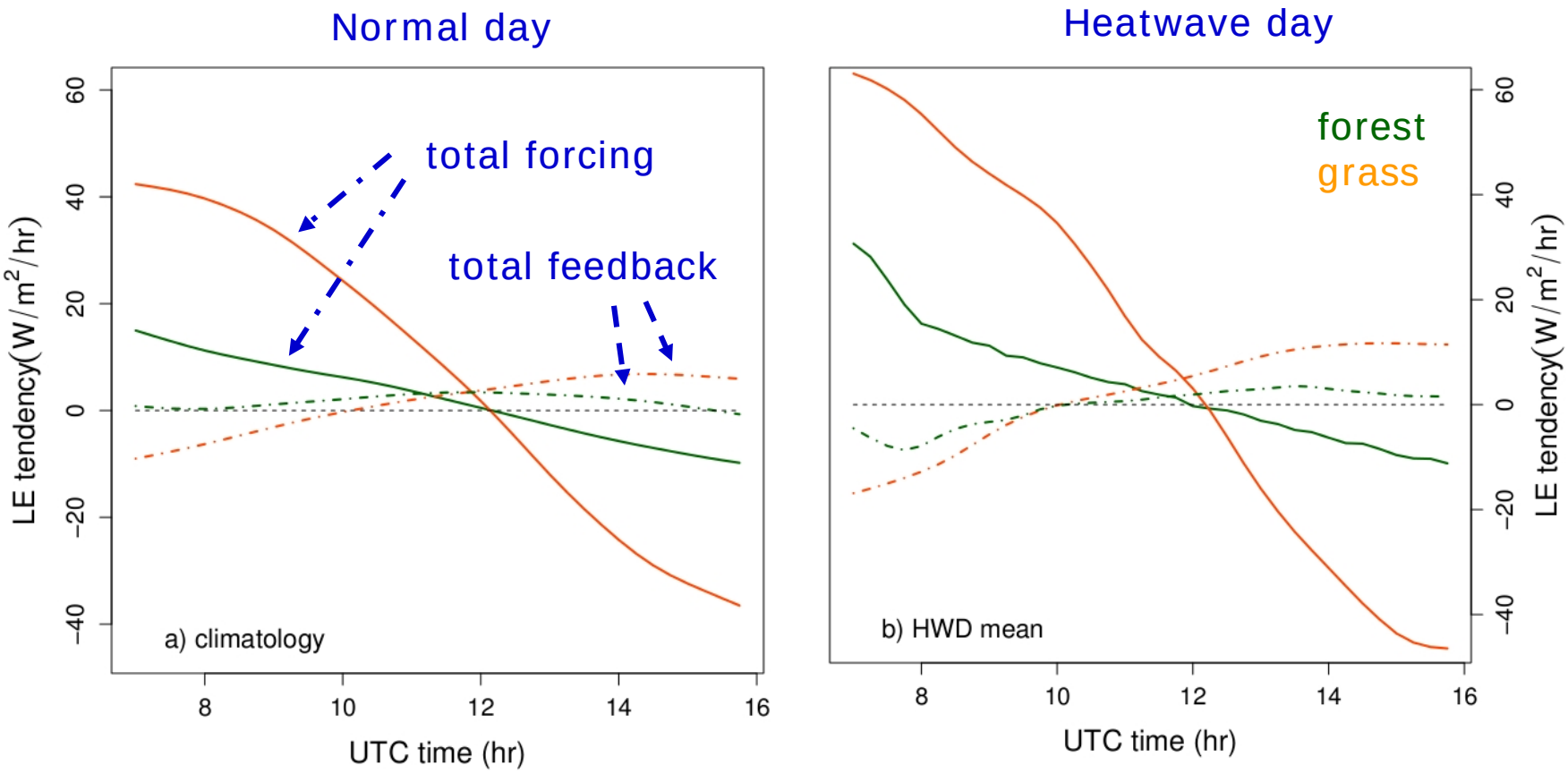
Van Heerwaarden et al, 2010

Climatology and HWD anomaly





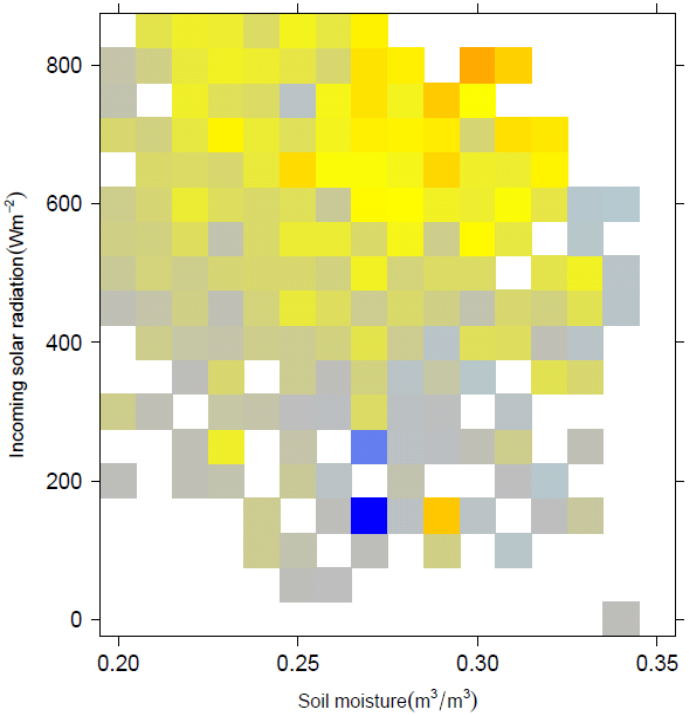
Forcings and feedbacks for forest & grass



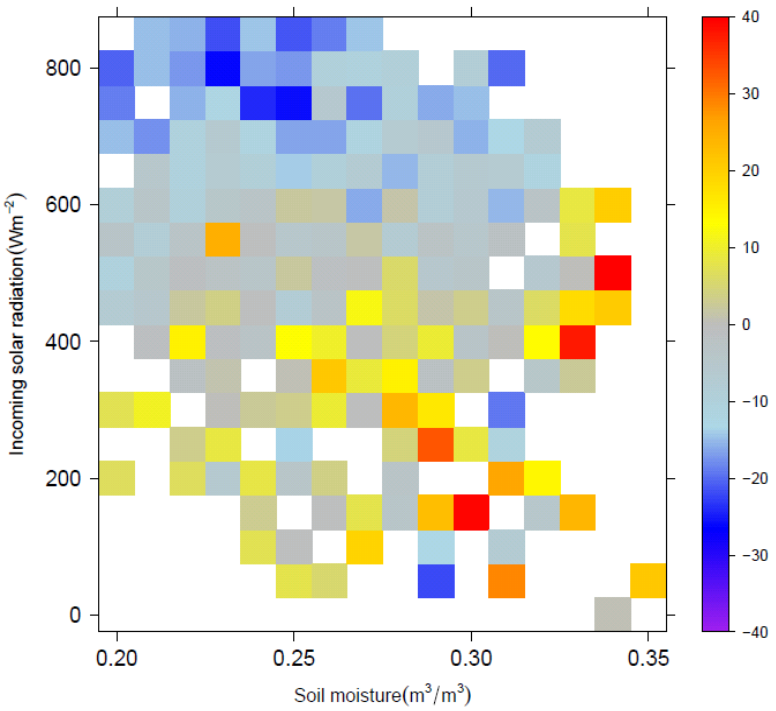
Forest-Grass contrast various feedbacks

Daily mean Evaporation difference due to feedback (W/m2)

Boundary layer feedback



Surface resistance feedback



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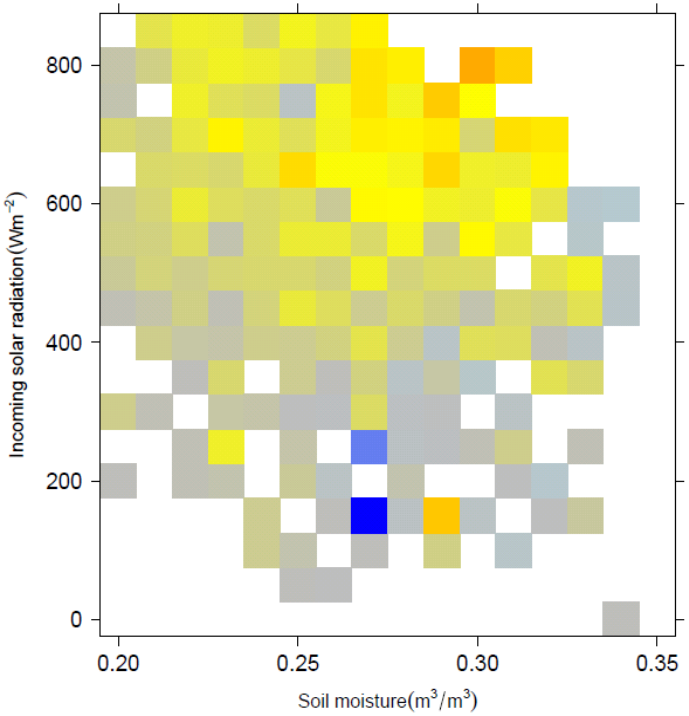
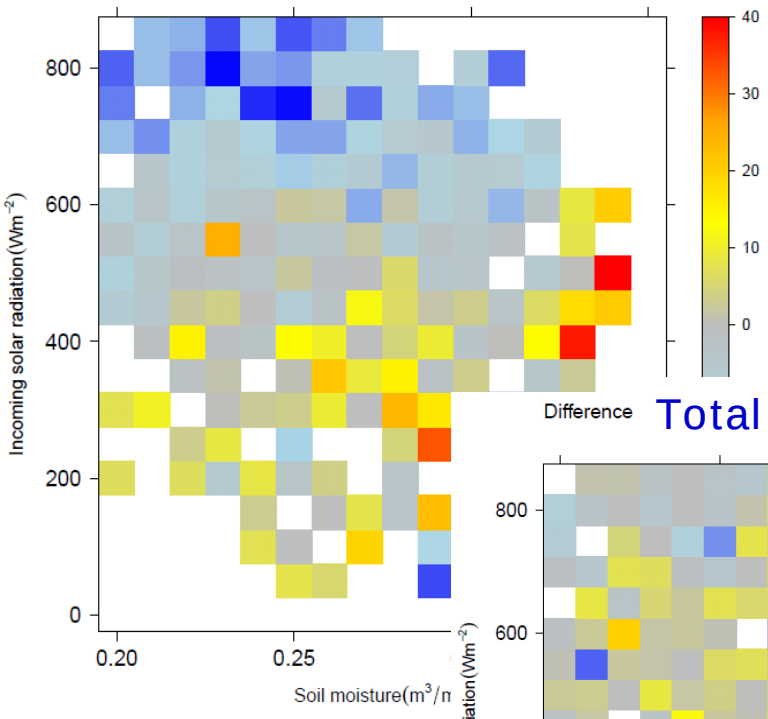
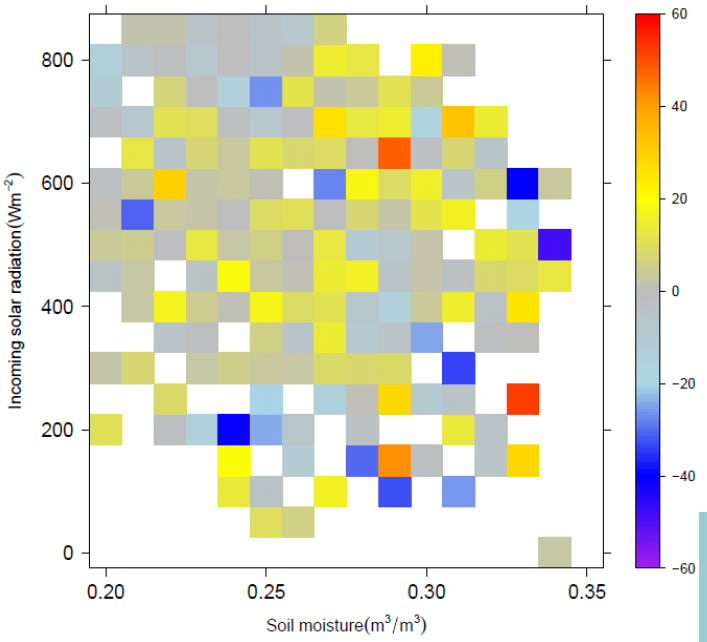


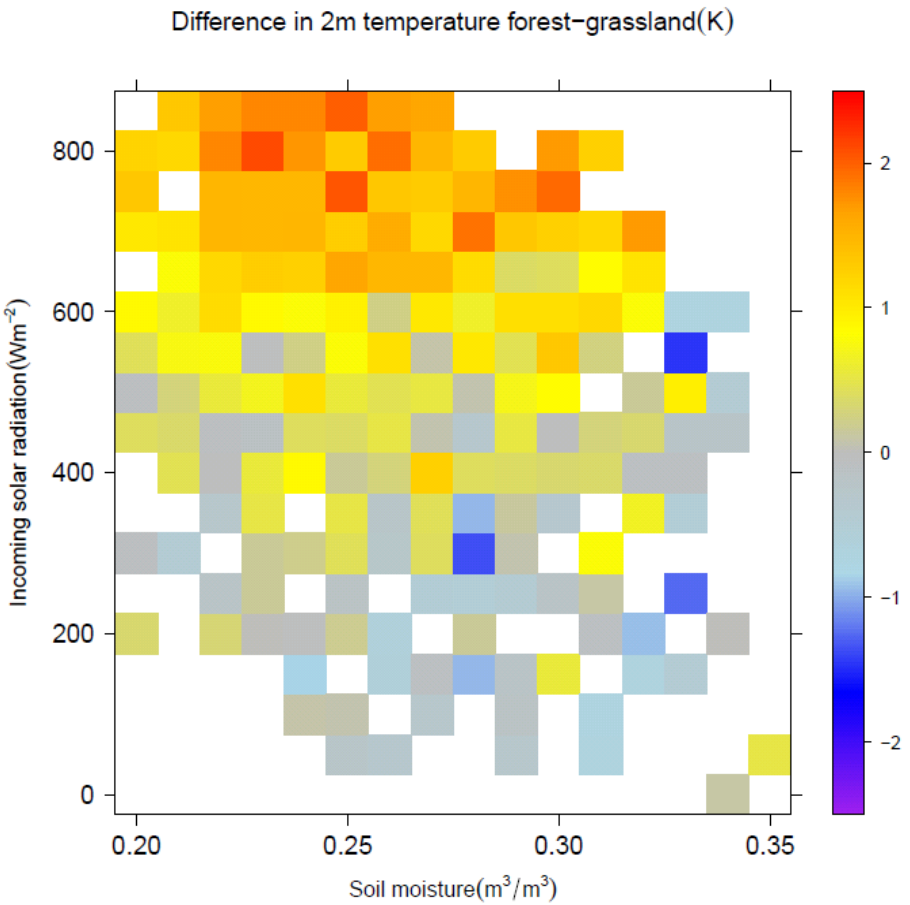
Surface resistance feedback

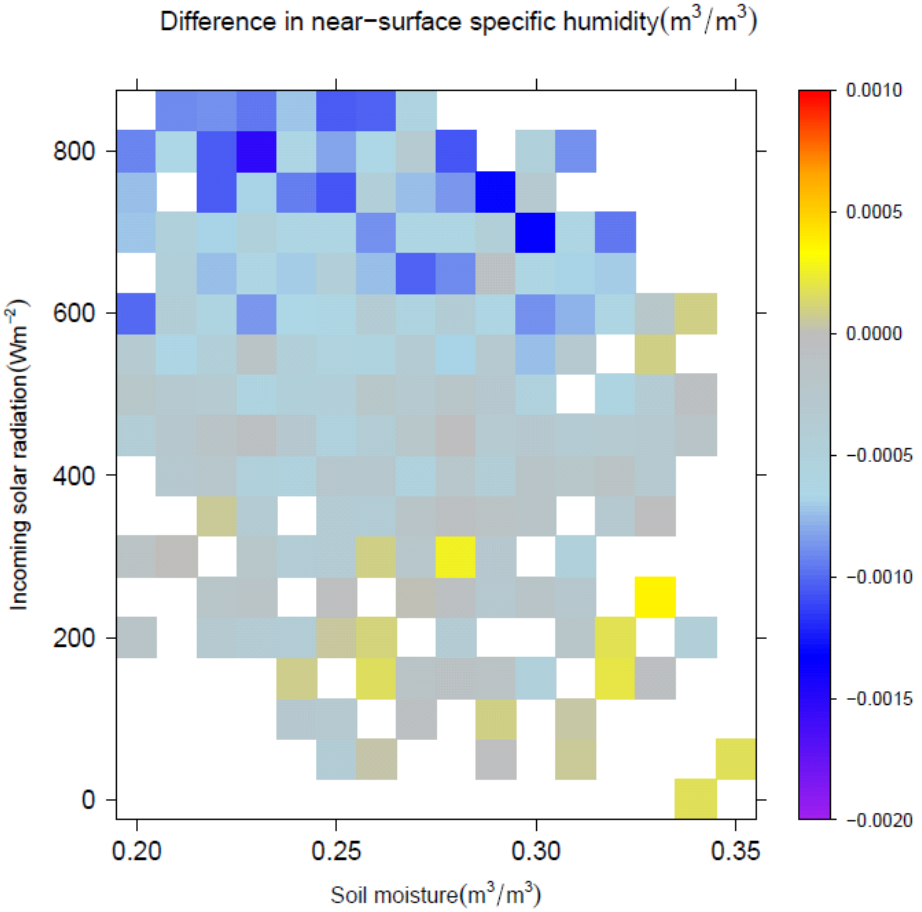


Total feedback



Temperature and humidity difference

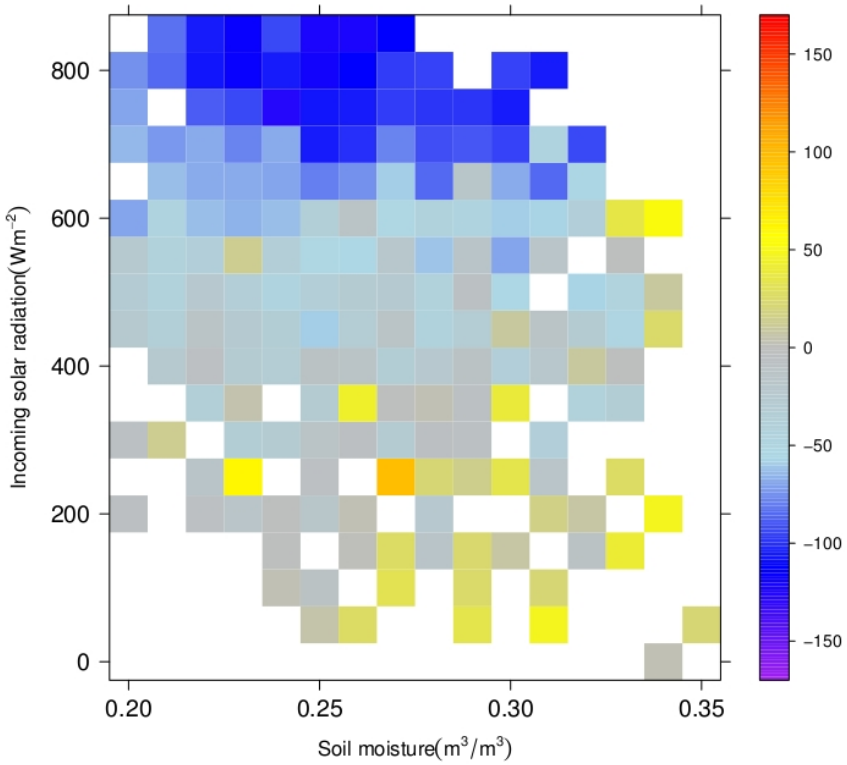




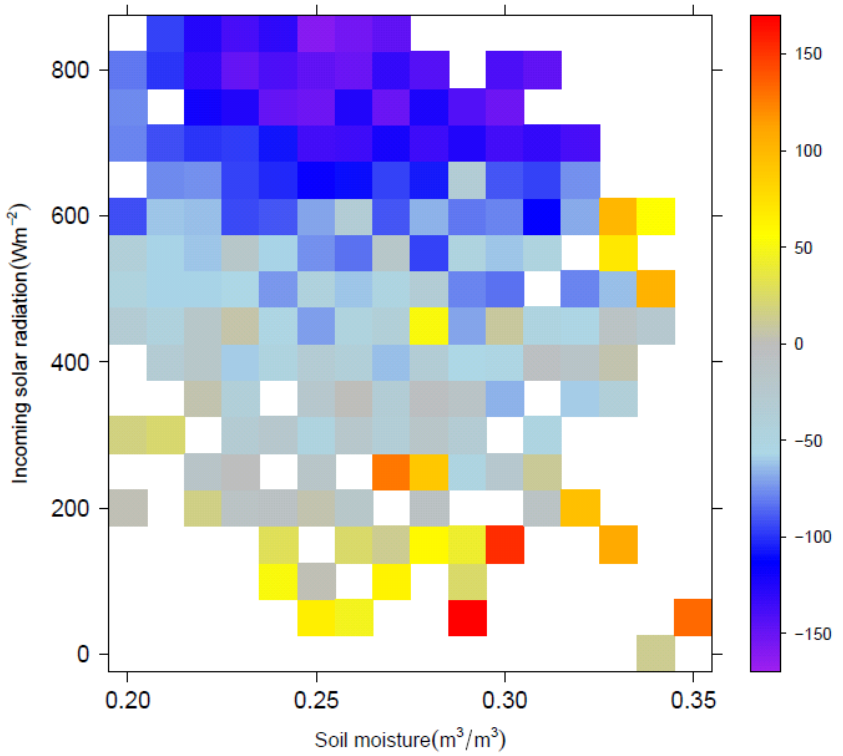
Implications for offline modelling

ΔLE forest-grassland

SCM

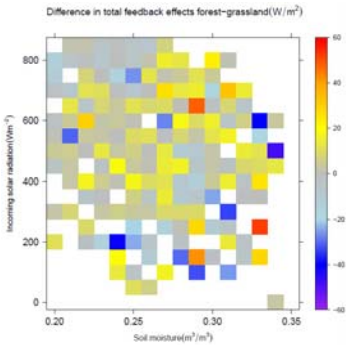


Offline model

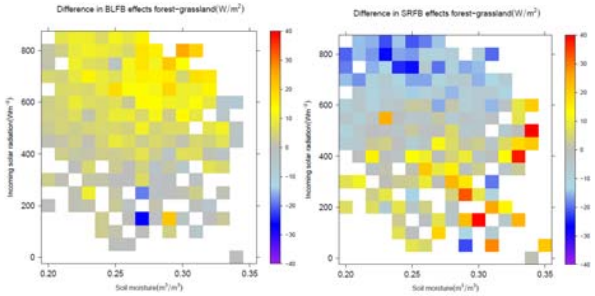


Conclusions

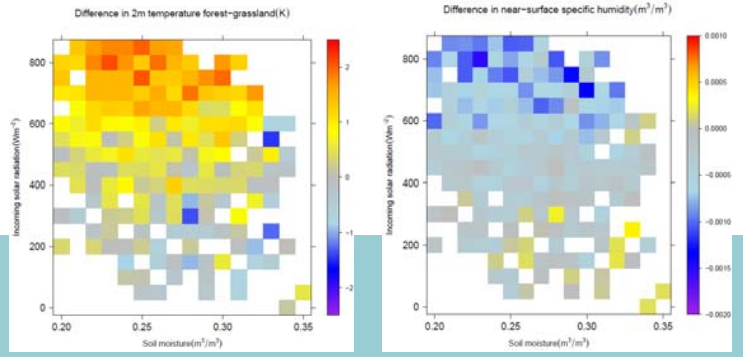
Total land-atmosphere feedback strength for forest and grass comparable...



But with a different mechanism and diurnal structure...



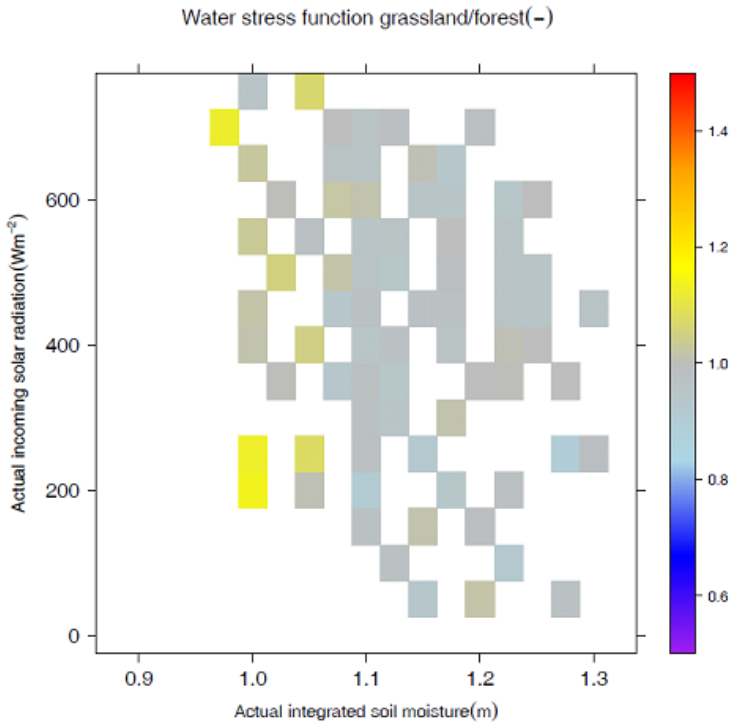
Leading to difficulty when trying to mimic this contrast with offline model

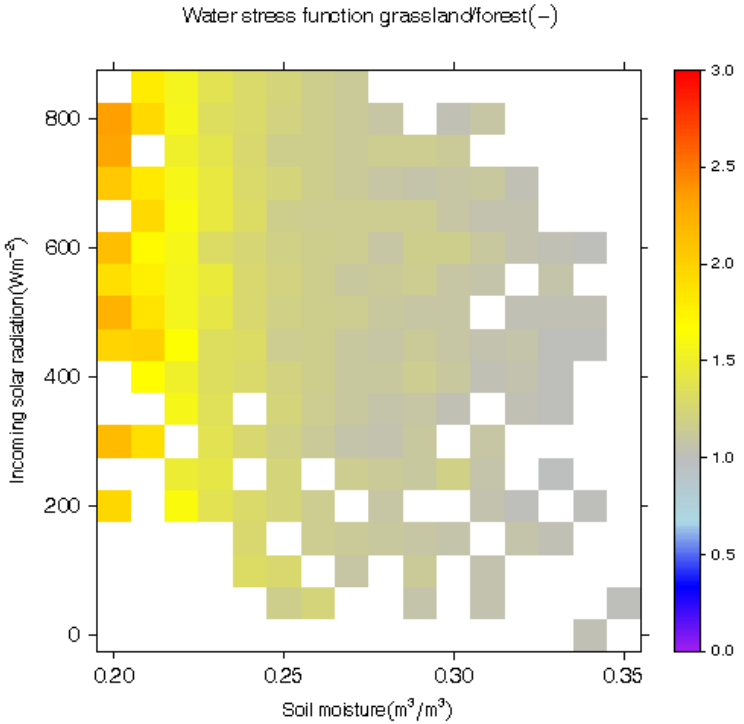


Effect of soil depletion

2 effects

- grass has roots more concentrated in upper part of the soil
- grass has depleted more soil moisture by enhanced evaporation from the past





Soil moisture grass or forest run (only overlapping regimes shown)

Soil moisture reference run