THE UNIVERSITY of NEW MEXICO

2018 AmeriFlux PI Meeting
Wednesday, October 24, 2018
Bloomington, IN

AMERIFLUX

The effect of land-cover conversions on surface temperature in semi-arid ecosystems at the Southwestern United States

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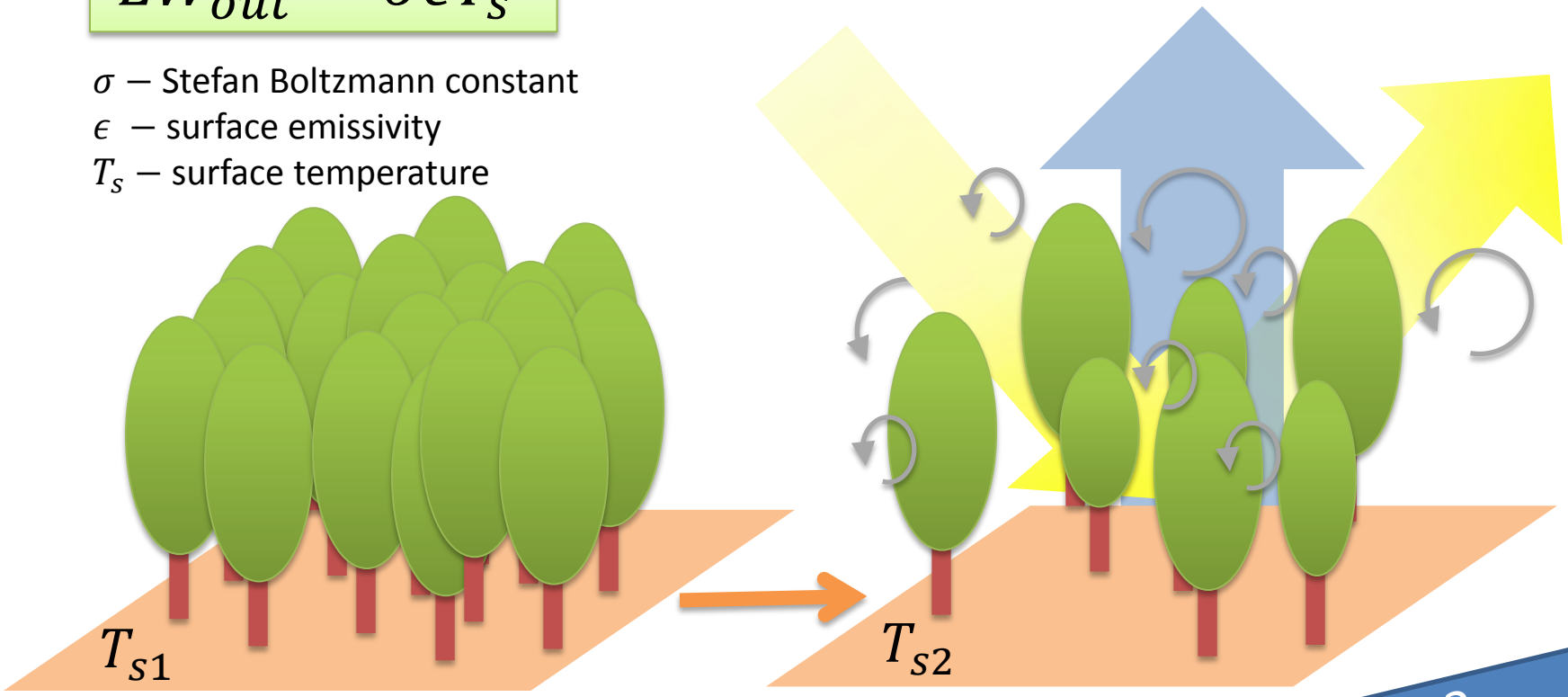
Land-cover conversion

Effects of Land-cover conversion

$$LW_{out} = \sigma \epsilon T_s^4$$

σ – Stefan Boltzmann constant
ϵ – surface emissivity
T_s – surface temperature



reflectivity , roughness , eco-physiology → changes in T_s

What is ΔT_s?
Why will it change?

Calculating the contribution of Δalbedo, Δconductance etc. to ΔT_s

$$SW_{in} - SW_{out} + LW_{in} - LW_{out} = H + LE + G_s$$ **Energy balance**

$$SW_{in}(1-\alpha) + LW_{in} - \sigma\epsilon T_s^4 = g_a c_p (T_s - T_a) + g_c L_v D/p_a + G_s$$

Albedo — Aerodynamic conductance — Canopy conductance

$$T_s = \frac{\lambda_0}{1+f}(R_n^* - LE - G_s) + T_a$$

$$\lambda_0 = (4\epsilon\sigma T_a^3)^{-1}$$
$$R_n^* = SW_{in}(1-\alpha) + LW_{in} - \epsilon\sigma T_a^4$$
$$LE = g_c L_v D/p_a$$
$$f = \lambda_0 g_a c_p$$

$$\Delta T_s = \frac{\partial T_s}{\partial \alpha}\Delta\alpha + \frac{\partial T_s}{\partial g_a}\Delta g_a + \frac{\partial T_s}{\partial g_c}\Delta g_c + \cdots$$

Contribution of $\Delta\alpha$ — Contribution of Δg_a — Contribution of Δg_c

+ contribution of interactions ($\Delta\alpha\Delta g_a$, $\Delta g_a \Delta g_c$ …)

+ contribution of higher order terms (Δg_a^2, Δg_a^3 …)

Juang, J.Y. et al., 2007. Separating the effects of albedo from eco-physiological changes on surface temperature along a successional chronosequence in the southeastern United States. *Geophysical Research Letters*, *34*(21).
Lee, X. et al., 2011. Observed increase in local cooling effect of deforestation at higher latitudes. *Nature*, *479*(7373), p.384.

The effect of land-cover conversions on T_s in the New-Mexico Elevation Gradient

Piñon-Juniper woodland (US-Mpj)

Land-cover conversion

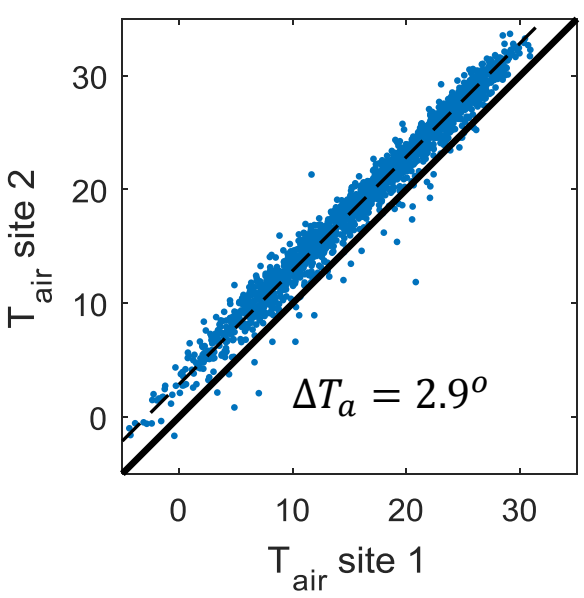
Juniper Savanna (US-Wjs)

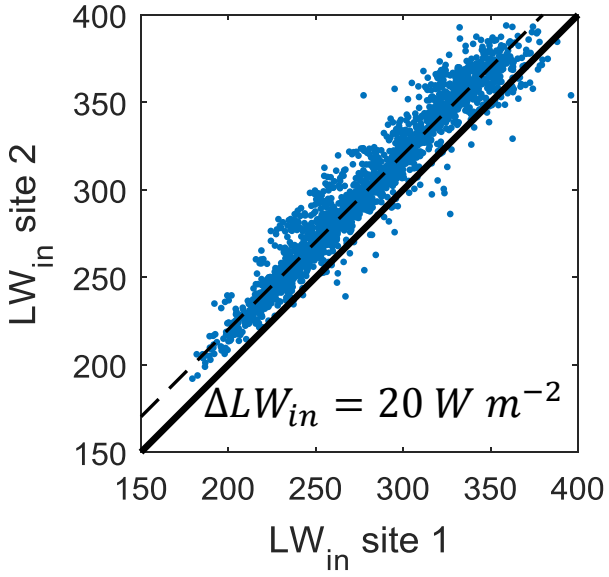
$$LW_{out} = \sigma \epsilon T_s^4 \quad \rightarrow \quad \Delta T_{s,calc} = T_{s2} - T_{s1}$$

$$\Delta T_{s,est} = \frac{\partial T_s}{\partial \alpha} \Delta \alpha + \frac{\partial T_s}{\partial g_a} \Delta g_a + \frac{\partial T_s}{\partial g_c} \Delta g_c + \cdots$$

Comparing US-Mpj and US-Wjs

(site 1) (site 2)





$$\Delta T_{s,est} = \frac{\partial T_s}{\partial \alpha}\Delta\alpha + \frac{\partial T_s}{\partial g_a}\Delta g_a + \frac{\partial T_s}{\partial g_c}\Delta g_c + \cdots + \frac{\partial T_s}{\partial T_a}\Delta T_a + \frac{\partial T_s}{\partial LW_{in}}\Delta LW_{in} + \cdots$$

The effect of land-cover conversions on T_s in the New-Mexico Elevation Gradient

Piñon-Juniper woodland (US-Mpj)

Land-cover conversion

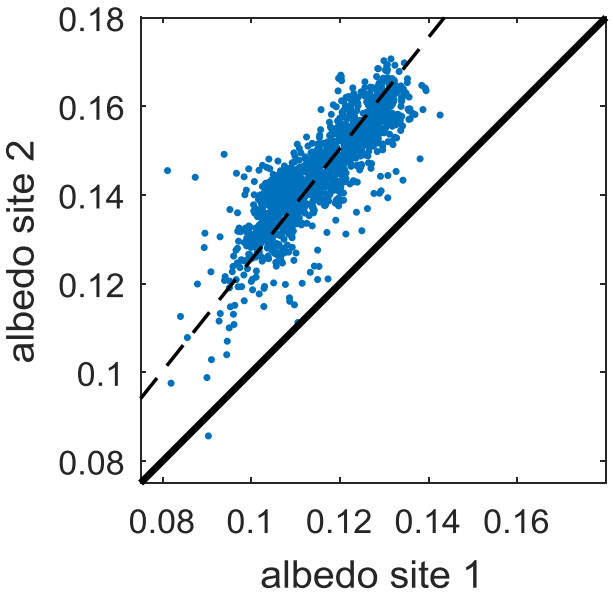
~~Juniper Savanna (US-Wjs)~~

Converted site (Mpj+Wjs hybrid)

Construct a converted site – identical to Mpj but with albedo, aerodynamic conductance and canopy conductance 'inspired' by Wjs

Constructing the converted site

Albedo



Albedo increases by 25%

Aerodynamic conductance

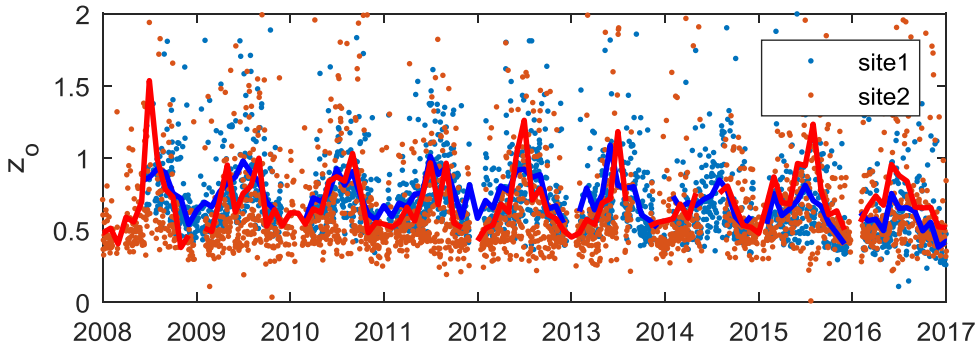
$$U = \frac{u_*}{k} \log \frac{z-d}{z_0}$$

$$T_s - T_a = \frac{H}{k\rho c_p u_*} \log \frac{z-d}{z_H}$$

$$g_a = \frac{k^2 \rho c_p U}{\log\left(\frac{z-d}{z_0}\right) \log\left(\frac{z-d}{z_H}\right)}$$

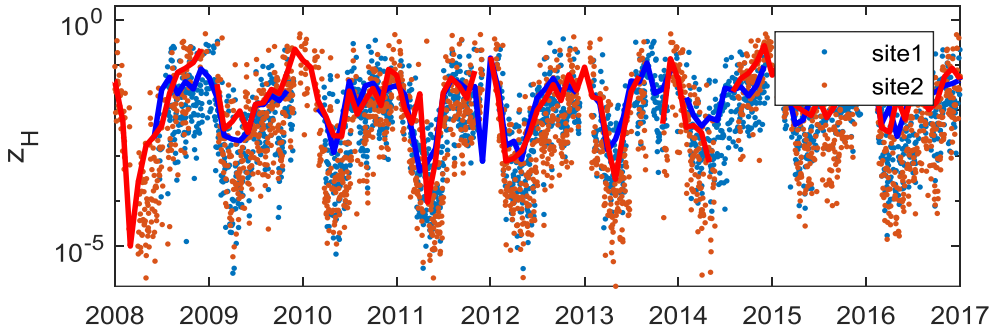
Constructing the converted site

Momentum roughness

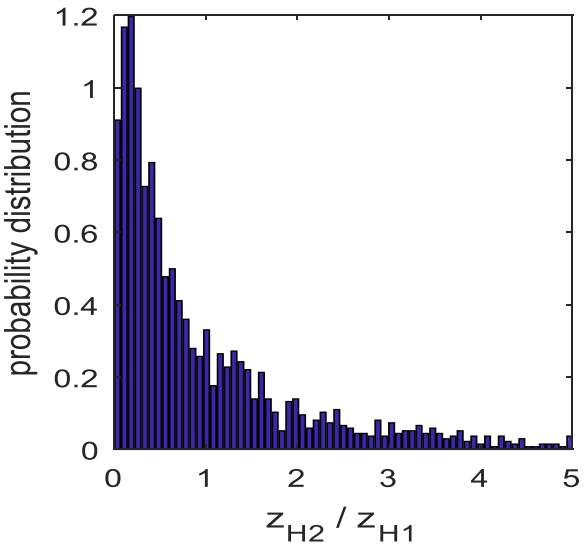


not statistically different

Temperature roughness



statistically different



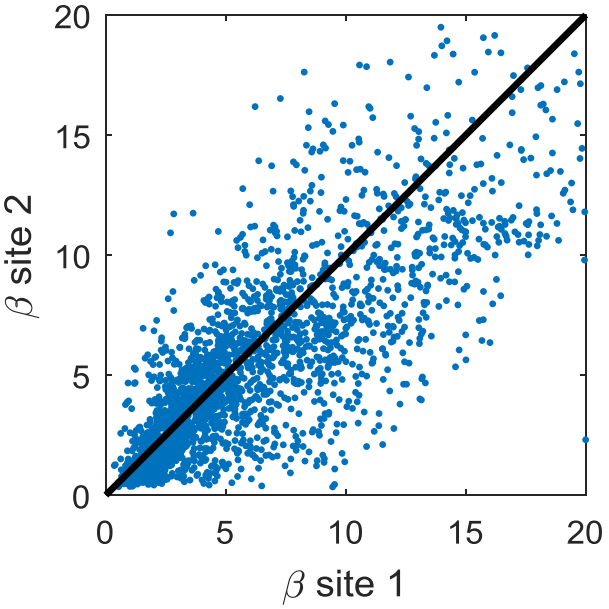
For 65% of the data $z_{H2}/z_{H1} < 1$
With a median of 0.56

Constructing the converted site

$$SW_{in}(1-\alpha) + LW_{in} - \sigma\epsilon T_s^4 = g_a c_p (T_s - T_a) + LE + G_s$$

$$SW_{in}(1-\alpha) + LW_{in} - \sigma\epsilon T_s^4 = g_a c_p (T_s - T_a)(1 + 1/\beta) + G_s$$

Bowen ratio $\beta = H/LE$



Calculate T_s for the converted site

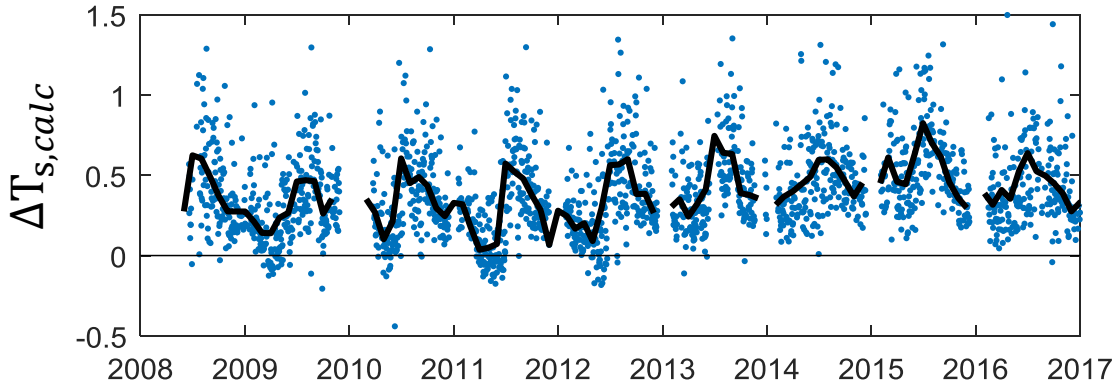
Calculate $\Delta T_{s,calc}$

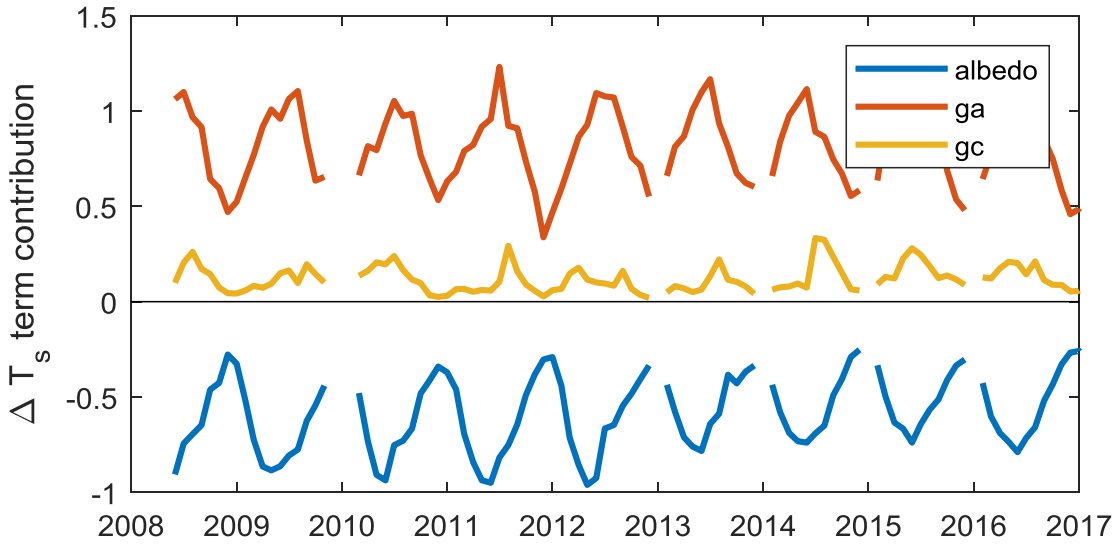
Calculate terms of contribution

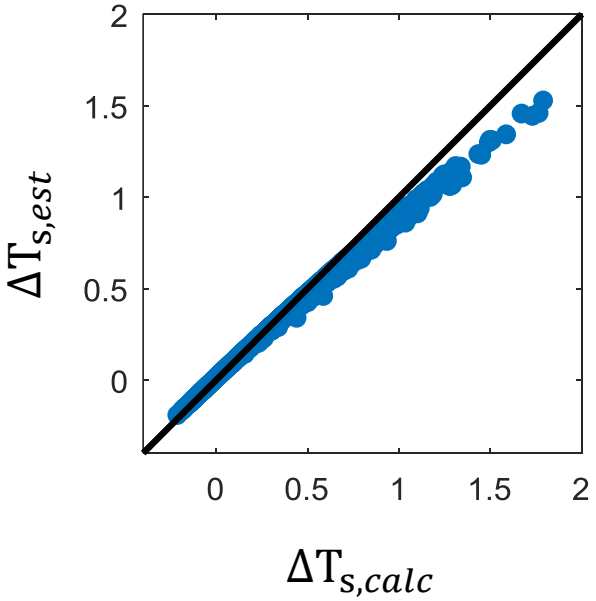
Results

$$SW_{in_c} = SW_{in_1}$$
$$LW_{in_c} = LW_{in_1}$$
$$z_{0_c} = z_{0_1}$$
$$\alpha_c = 1.25\alpha_1$$
$$z_{H_c} = 0.56 z_{H_1}$$

$\Delta T_{s,calc} = +0.4\ ^{o}C$







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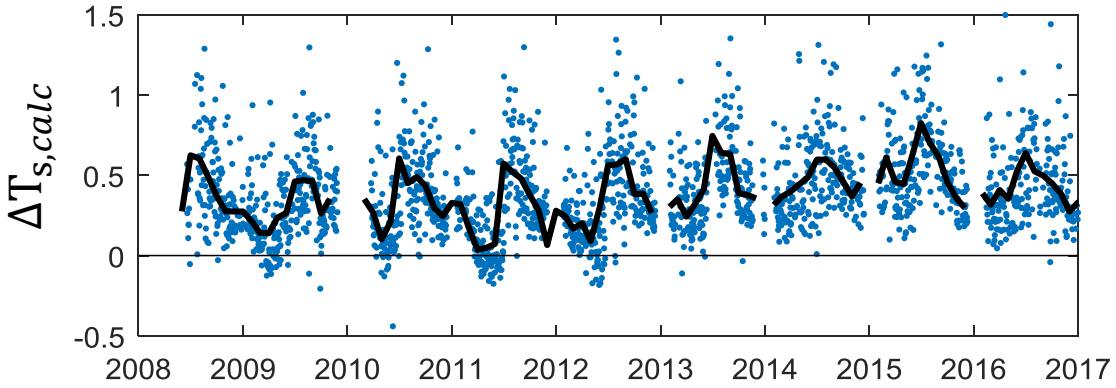
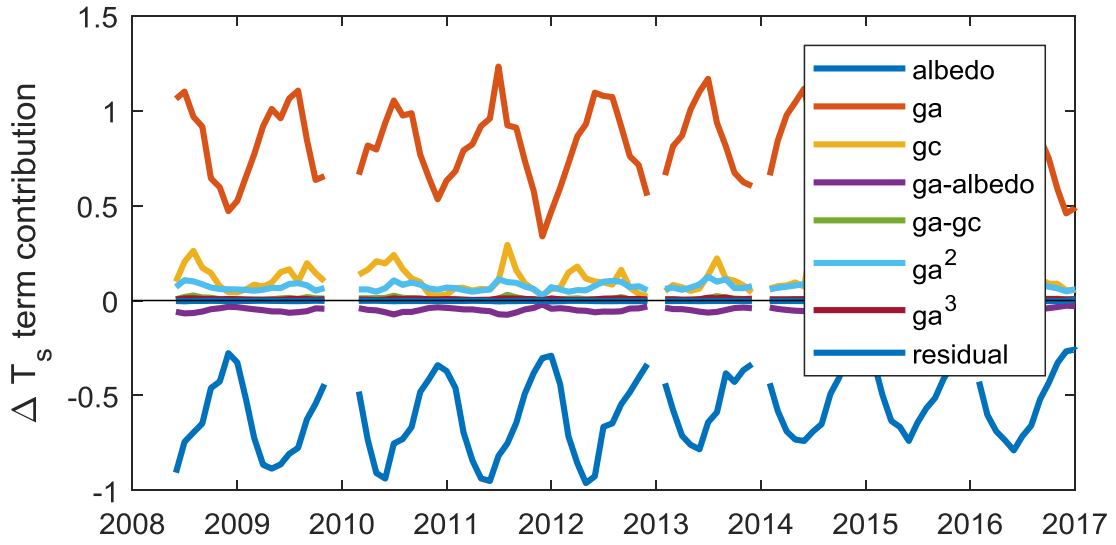
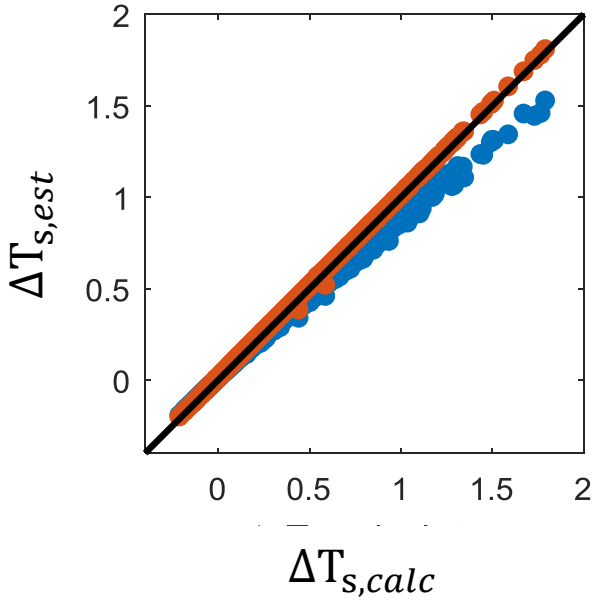
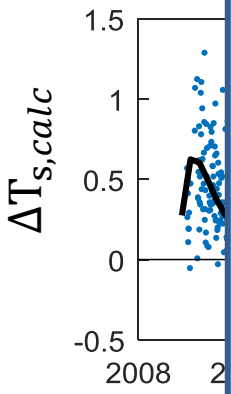


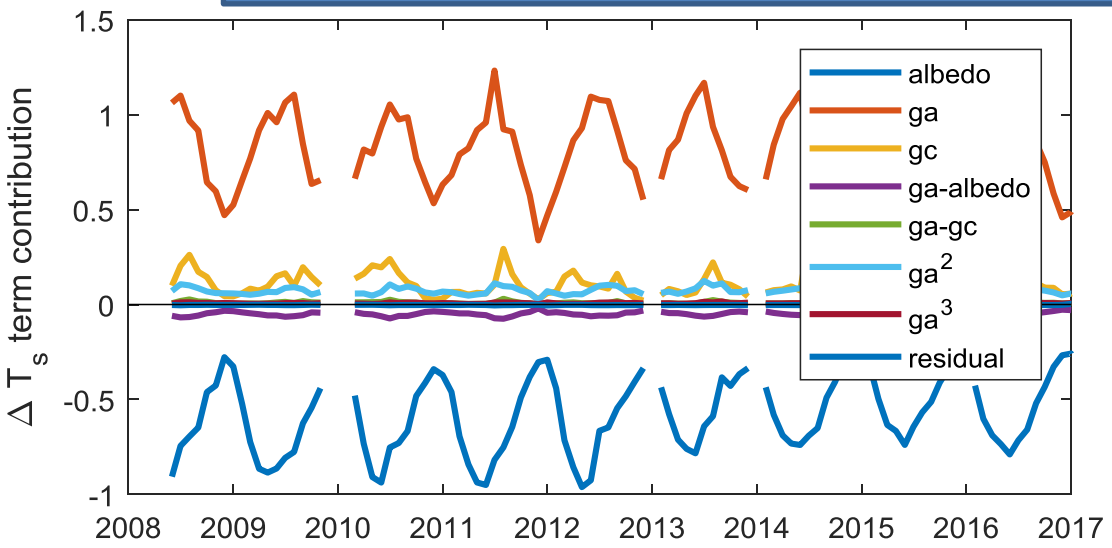


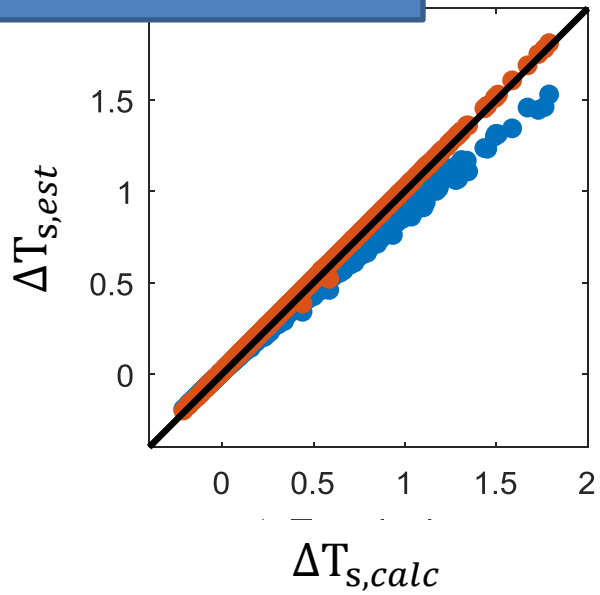


Results

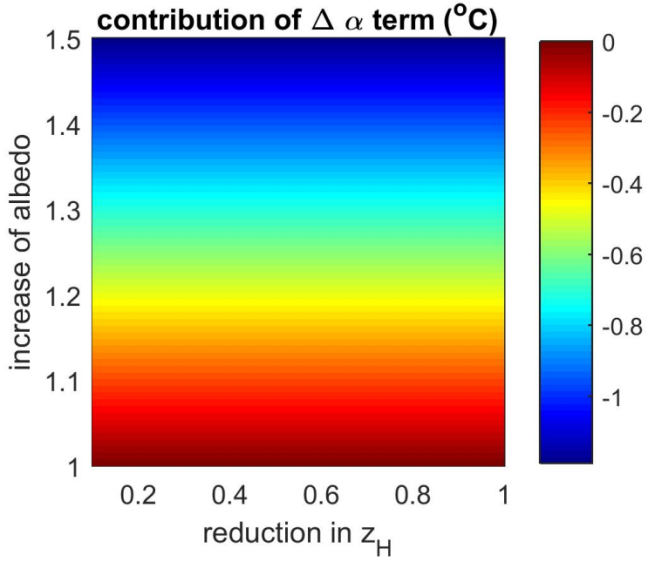
- In this system, $\Delta\alpha$ and Δg_a are the most important contributions .
- The other terms are relatively less important
- These terms may become important in high ΔT_s

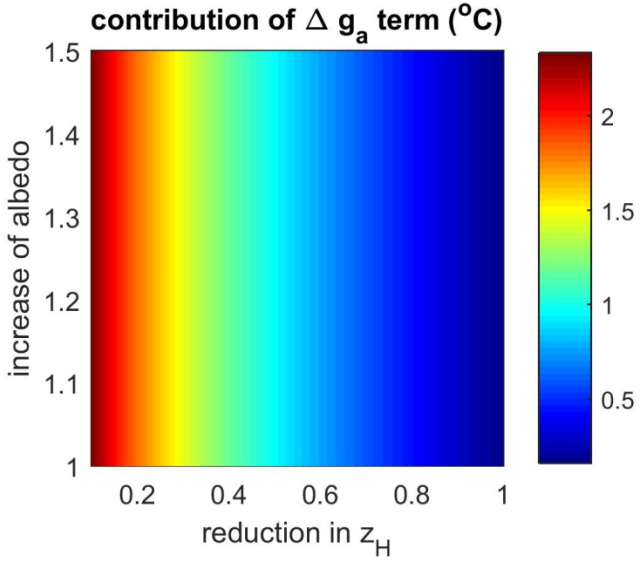






Results: sensitivity analysis

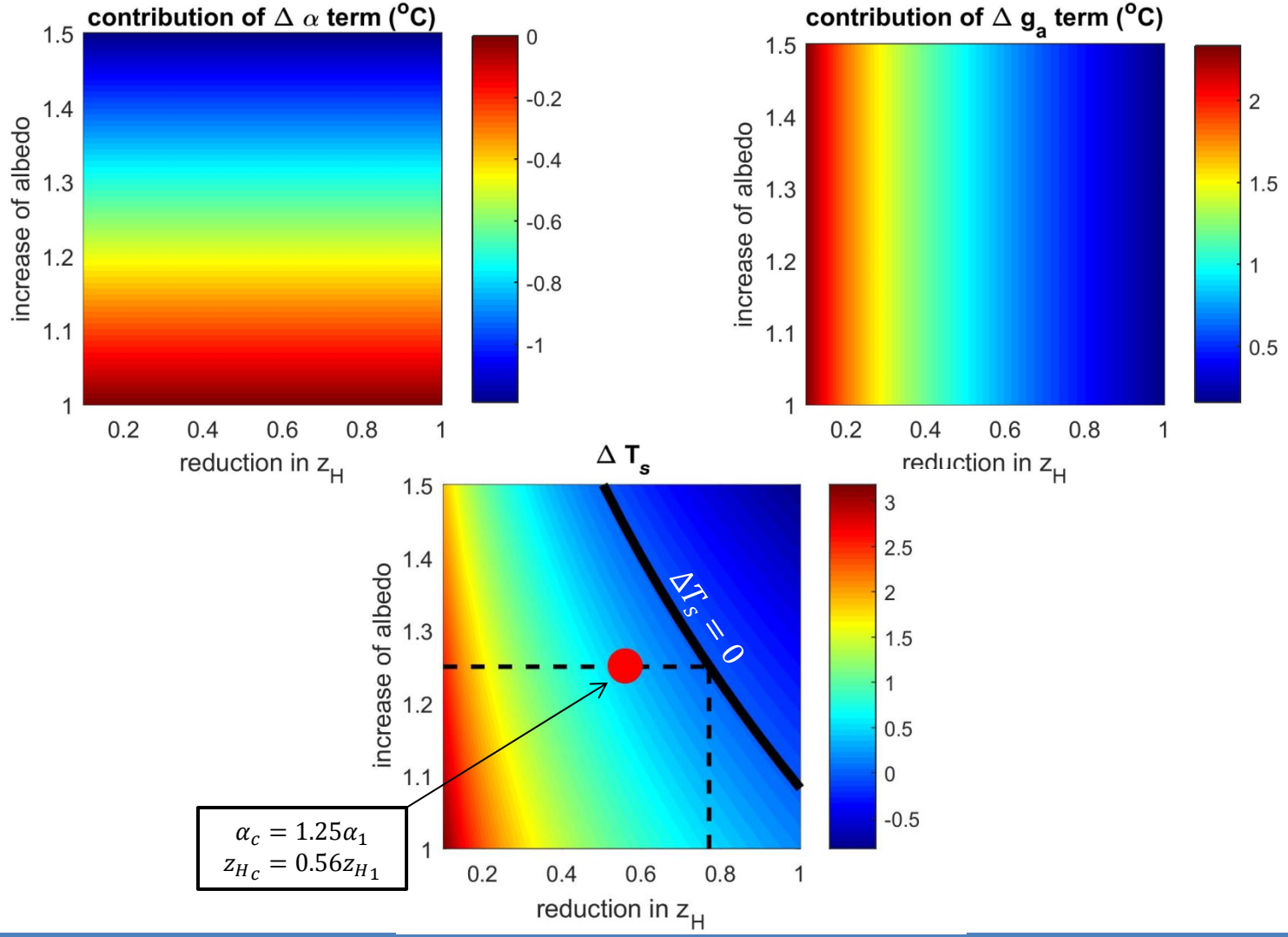




Increasing albedo lowers T_s irrespective to z_H

Reducing z_H increases T_s irrespective to albedo

Results: sensitivity analysis



Summary and conclusions

- I checked the effect of land-cover changes of surface temperature
- I imposed changes in albedo and conductance through roughness lengths
- For conversion from Piñon-Juniper woodland to Juniper savanna, first order terms $\Delta\alpha$ and Δg_a contributed the most to ΔT_s
- $\Delta\alpha$ and Δg_a had compensating effects, therefore changing T_s in only +0.4^{o}C

Future plans

- Expand the analysis to other expected land-cover conversions at the New-Mexico Elevation Gradient
- Explore the effect of additional long term trends on ΔT_s

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