Temperature decomposition of paired site observations reveals new insight in climate models' capability to simulate the impact of land use change

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Motivation

- Geophysical impact of land use changes (LUC) between natural vegetation types (e.g. deforestation) has been proven to be important, especially on a local/regional scale
- Ability of current climate models in simulating the impact of LUC should be evaluated

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  - No distinction between daytime and nighttime climate

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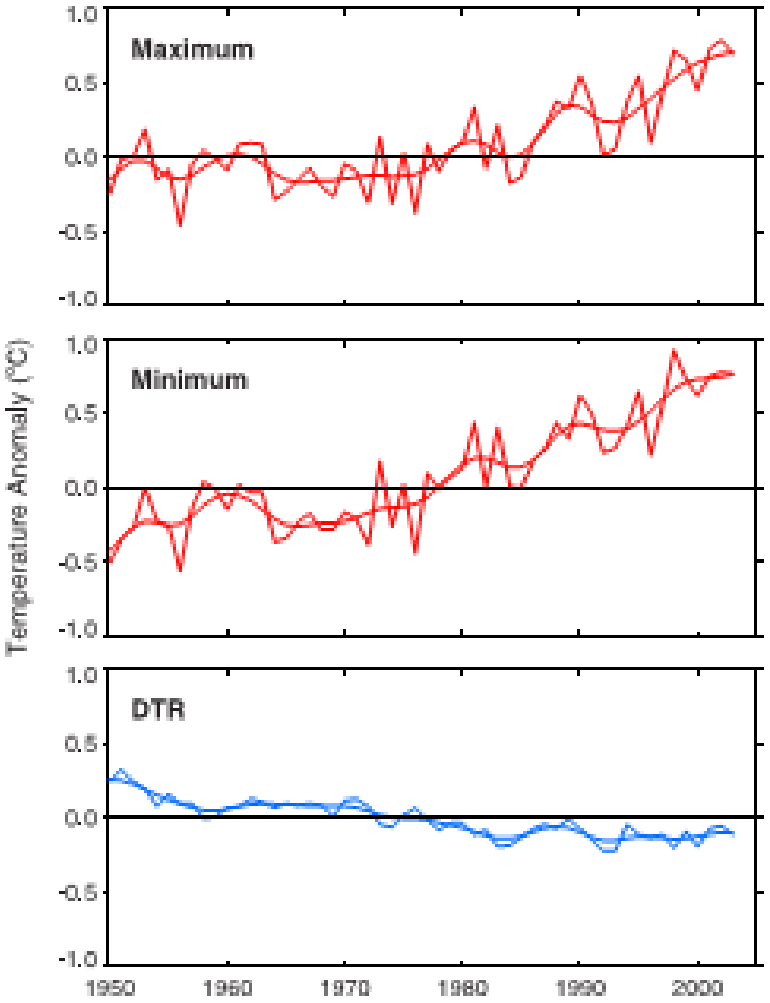

Figure 1. Time series of annual maximum temperature, minimum temperature, and DTR anomalies for global land areas over the period 1950–2004.

[*Vose et al.*, 2005]

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  - Offline mode only
  - Focus on only one element of the surface energy budget
  - No distinction between daytime and nighttime climate
- Simulated impact of LUC differs strongly in current generation models (**LUCID** project, *Land-Use and Climate, Identification of Robust Impacts*)

New methodology

1. **Direct** evaluation of differences in surface climate

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2. **Online** model simulations which account for atmospheric feedbacks
3. A separate analysis of **daytime** and **nighttime** climate
4. A simultaneous evaluation of **all SEB components** (SEB **=** surface energy budget)

Data

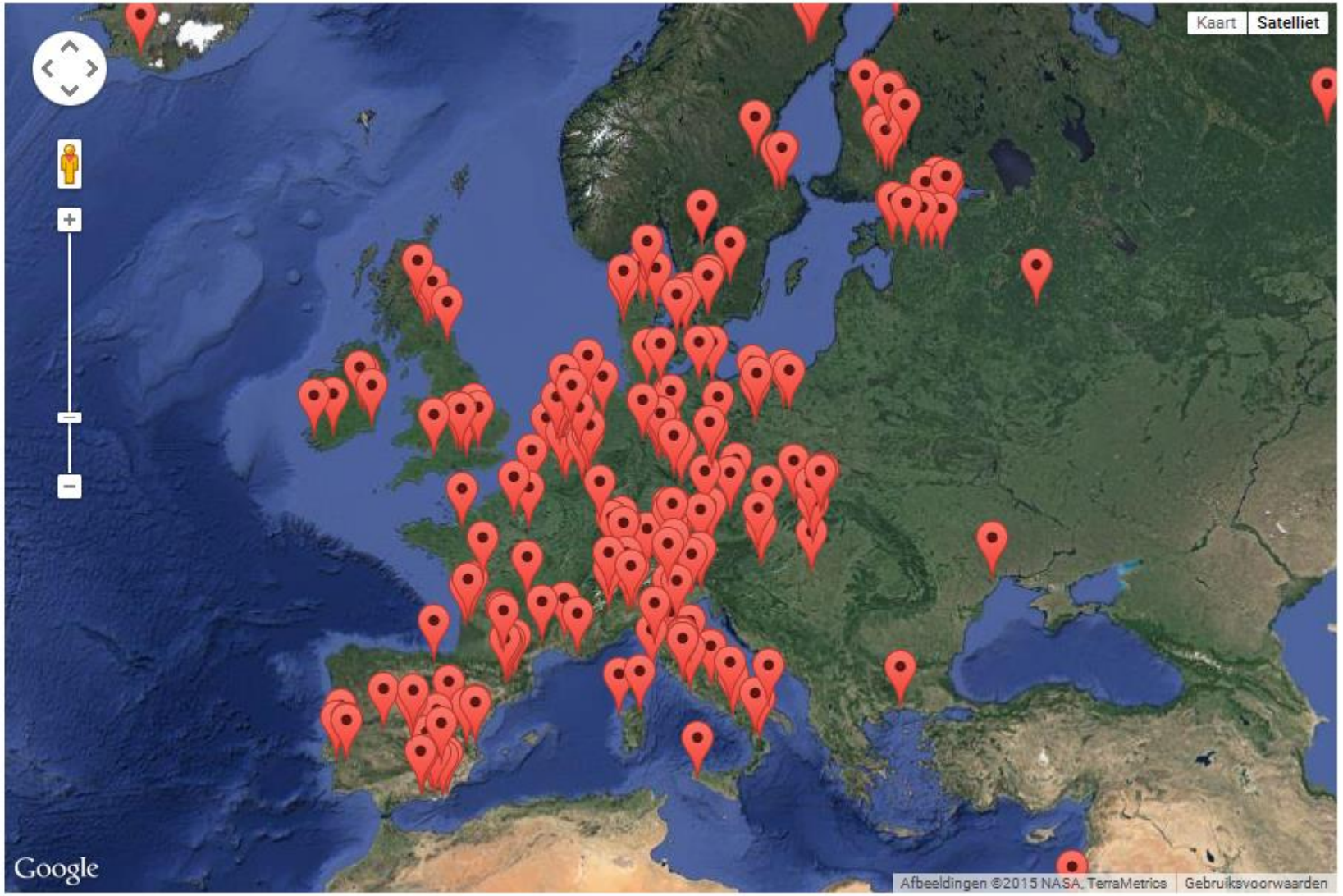
- Observational data

Data

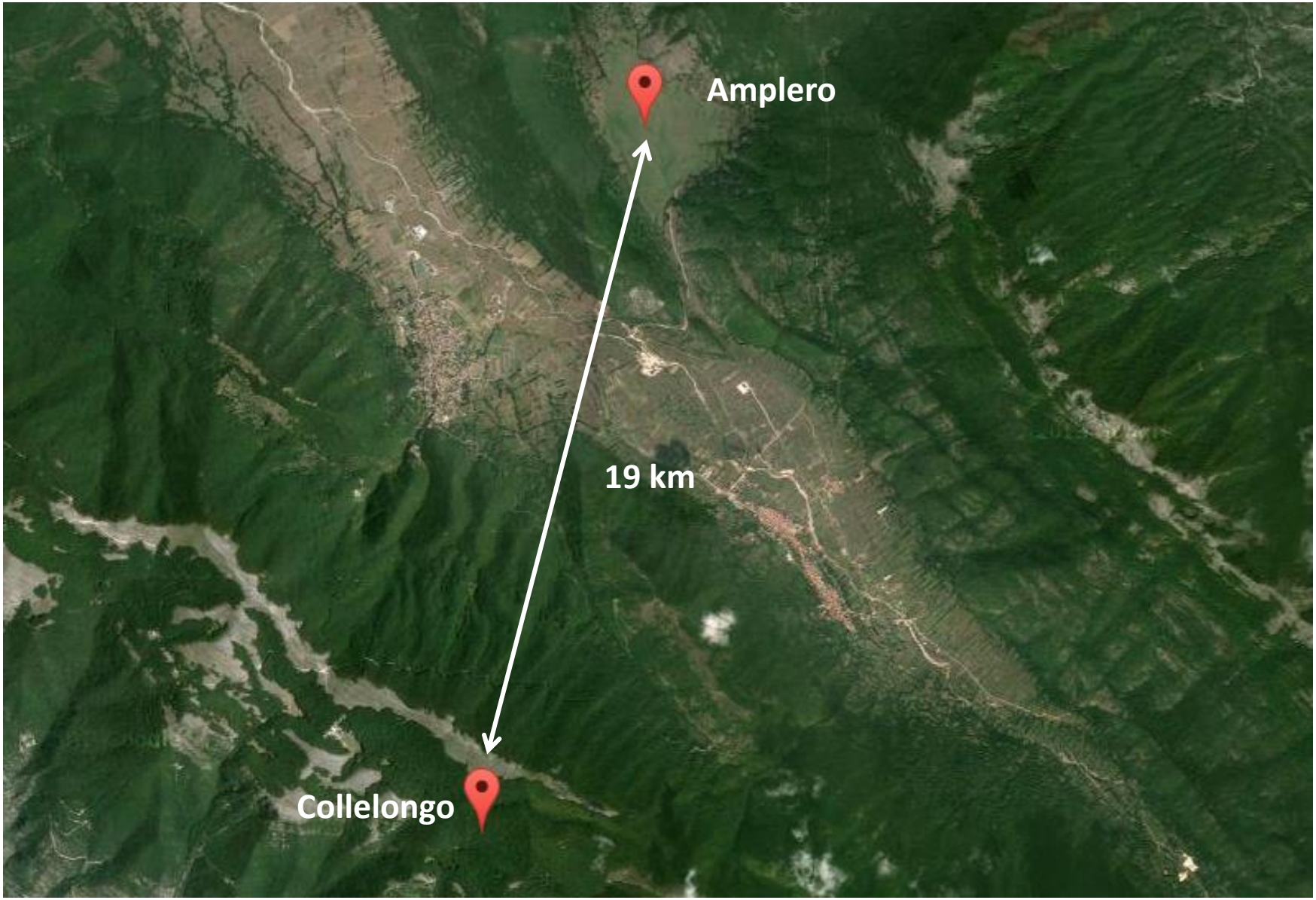
- Observational data
  - Paired eddy covariance flux measurements representing a LU change from forest to open land (= **deforestation**)

FLUXNET

Sites list



Example



Selected site pairs

Cluster name	Lat	Lon	Site name	Elevation (m)	Distance (km)	Data availability	Land use	IGBP class	Climate group
DK1	55,49	11,65	Soroe-LilleBogeskov	40	28,8	2004:2008	Mixed forest	DBF	Temperate
DK1	55,53	12,10	Risbyholm	10	28,8	2004:2008	Cropland	CRO	Temperate
DE1	50,96	13,57	Tharandt	380	8,5	2004:2008	Mixed forest (87% evergreen)	ENF	Temperate
DE1	50,89	13,52	Klingenberg	480	8,5	2004:2008	Cropland	CRO	Temperate
CZ1	49,50	18,54	Bily Kriz Beskidy	908	0,9	2004:2006	Young Norway spruce plantation	ENF	Temperate-Continental
CZ1	49,50	18,54	Bily Kriz Grassland	855	0,9	2004:2006	Grassland (managed as meadow)	GRA	Temperate-Continental
IT2	45,96	11,28	Lavarone	1343	19,3	2003:2008	Mixed coniferous forest	ENF	Temperate
IT2	46,02	11,05	Monte Bondone	1550	19,3	2003:2008	Grassland (managed as meadow)	GRA	Temperate
IT1	41,85	13,59	Collelongo	1550	6,2	2003:2008	Irregularly structured beech forest	DBF	SubTropical-Mediterranean
IT1	41,90	13,61	Amplero	884	6,2	2003:2008	Pasture	GRA	SubTropical-Mediterranean
ES1	39,35	-0,32	El Saler	10	7,8	2004:2006	Pine forest	ENF	SubTropical-Mediterranean
ES1	39,28	-0,32	El Saler-Sueca	41	7,8	2004:2006	Cropland	CRO	SubTropical-Mediterranean
PT1	38,54	-8,00	Mitra Tojal	250	7,4	2004:2005	Cork and holm oak	EBF	SubTropical-Mediterranean
PT1	38,48	-8,02	Mitra Evora	190	7,4	2004:2005	Grassland	GRA	SubTropical-Mediterranean

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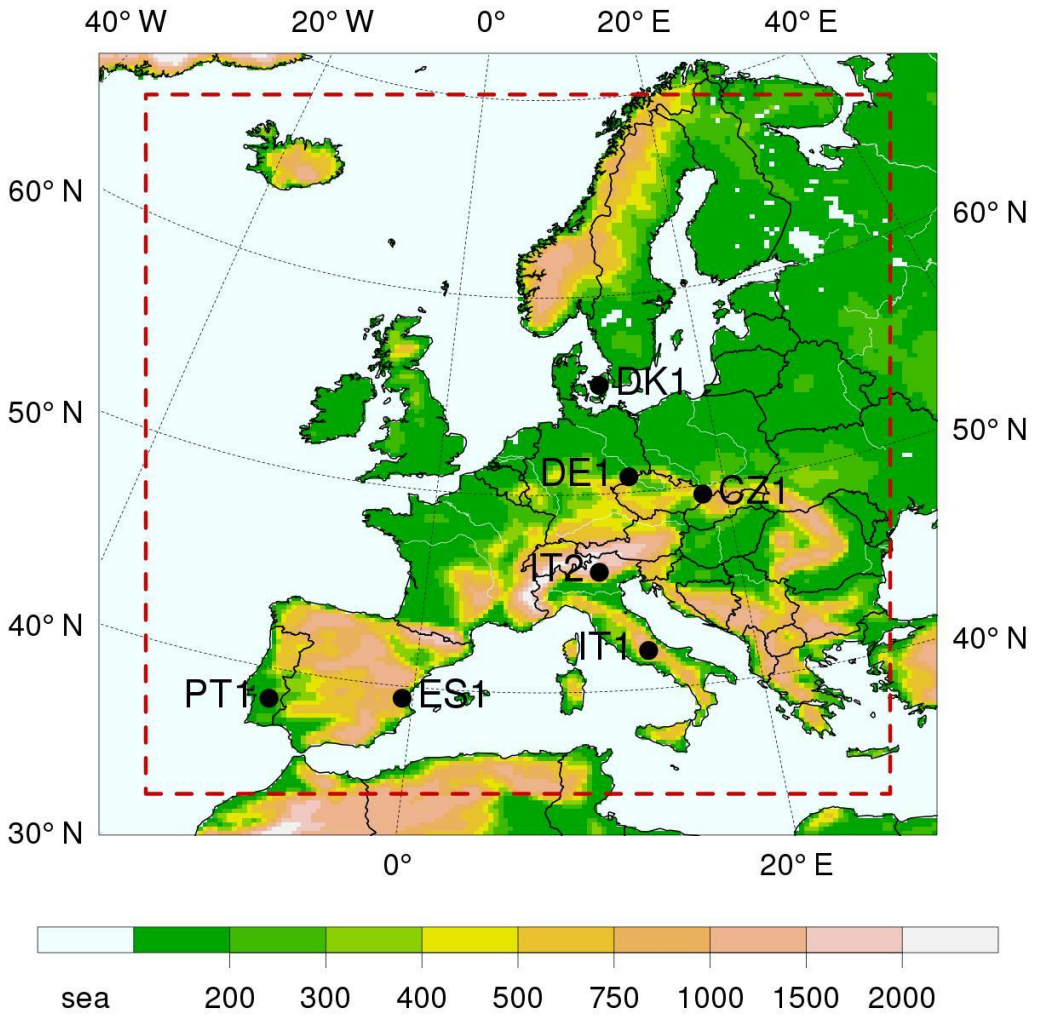
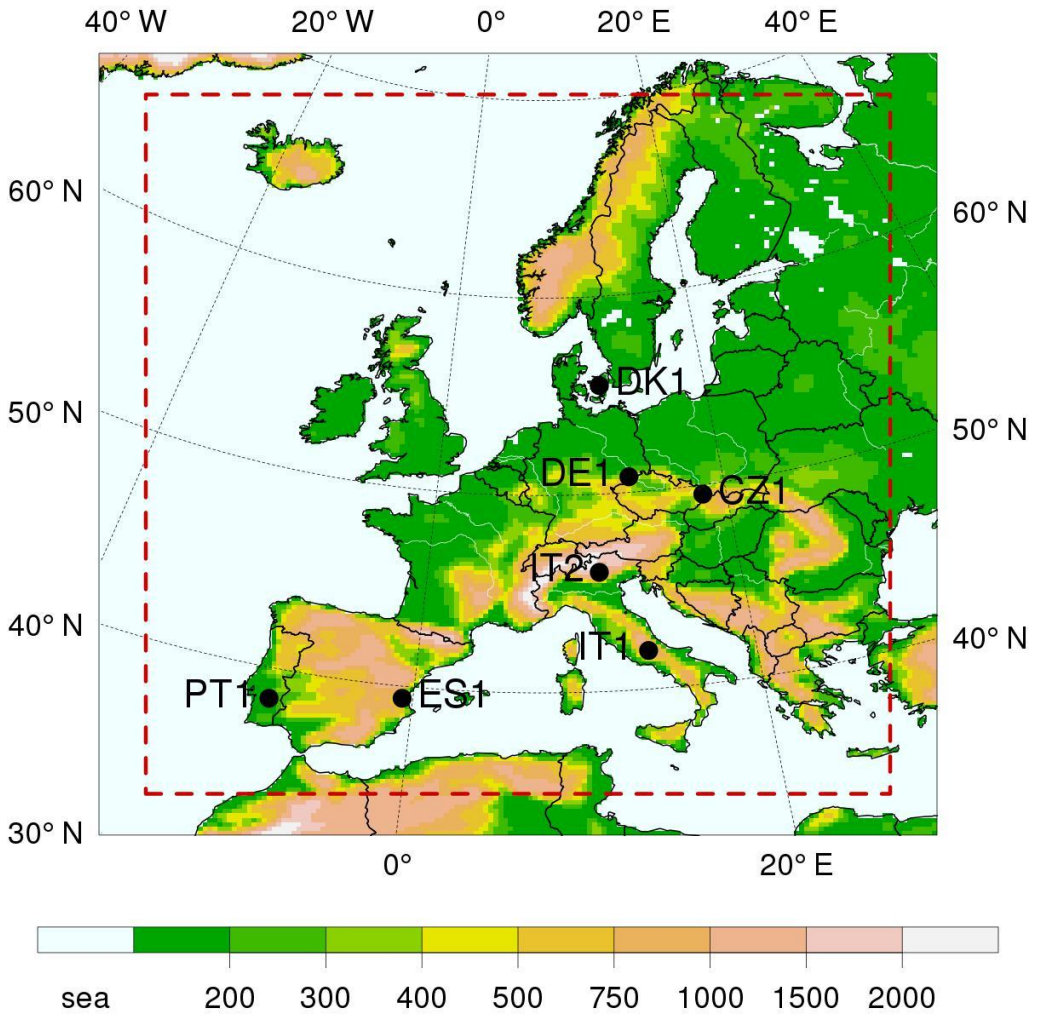
Model simulations

- COSMO-CLM^2 : COSMO-CLM 4.8 coupled to Community Land Model version 3.5 (CLM3.5)



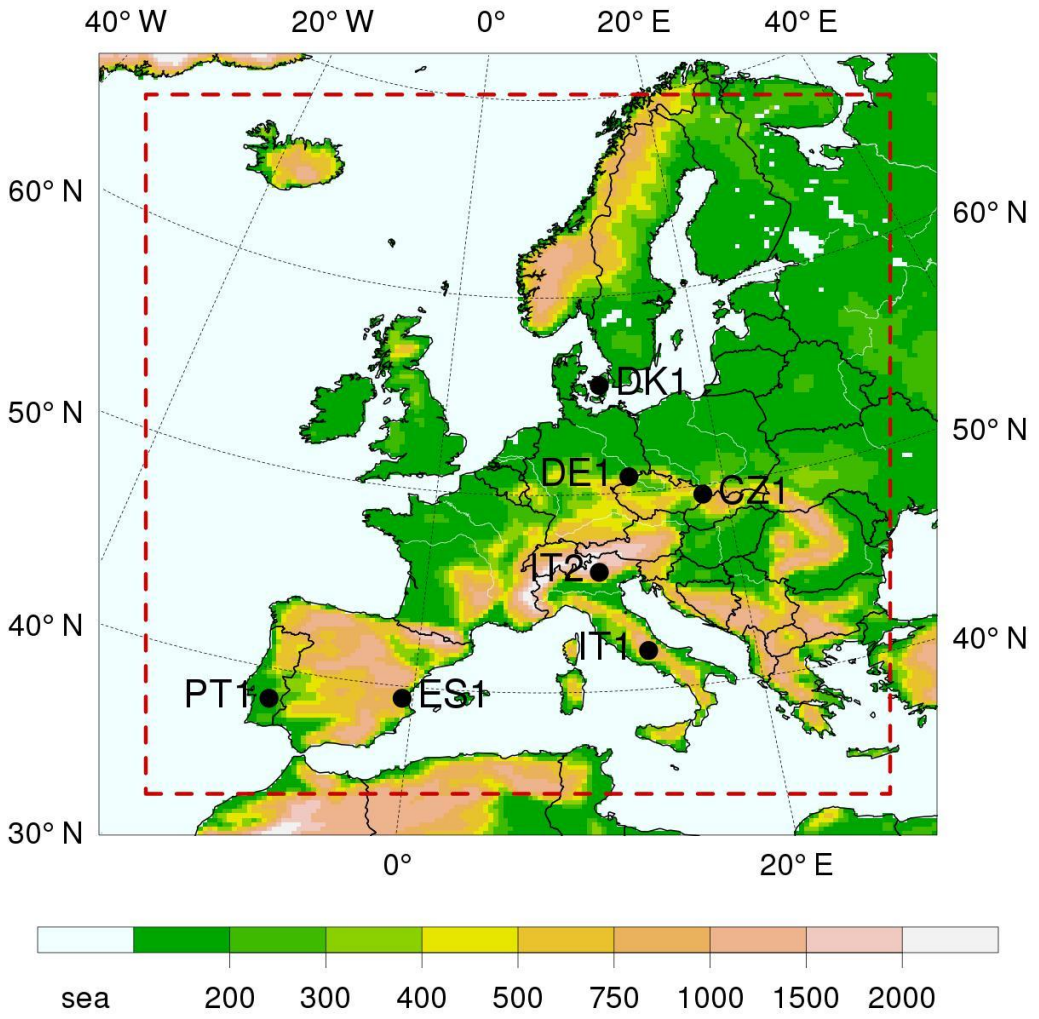
Model simulations

- COSMO-CLM^2 : COSMO-CLM 4.8 coupled to Community Land Model version 3.5 (CLM3.5)
- 0.22 degrees grid resolution (25 km)



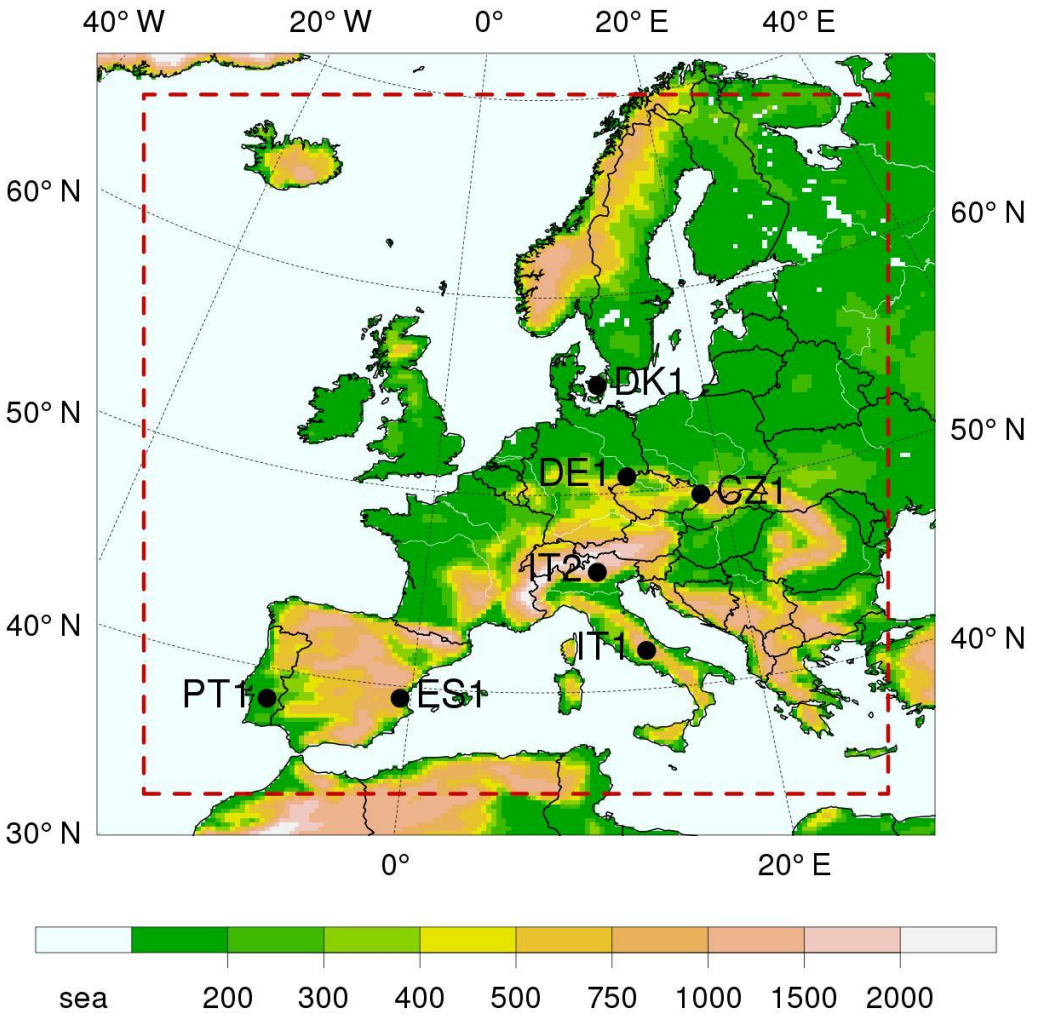
Model simulations

- COSMO-CLM^2 : COSMO-CLM 4.8 coupled to Community Land Model version 3.5 (CLM3.5)
- 0.22 degrees grid resolution (25 km)
- Two simulations, which adjust LU in pixels with observational site pair to
  1. Forest
  2. Open land



Model simulations

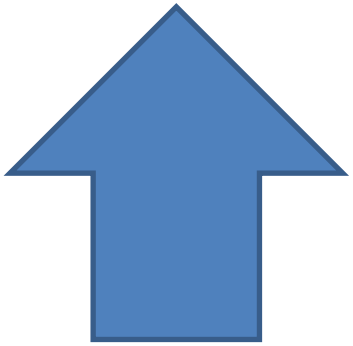
Cluster name	Site name	PFT	CTH	LAImax
DK1	Soroe-LilleBogeskov	BDT-T	20	4,8
DK1	Risbyholm	Crop	0,5	1,4
DE1	Tharandt	NET-T	26,5	7
DE1	Klingenberg	Crop	0,5	2,4
CZ1	Bily Kriz Beskidy	NET-T	12,5	6,7
CZ1	Bily Kriz Grassland	C3 Grass	0,5	2,2
IT2	Lavarone	NET-T	30	8
IT2	Monte Bondone	C3 Grass	0,5	3,2
IT1	Collelongo	BDT-T	21,2	5
IT1	Amplero	C3 Grass	0,5	2,4
ES1	El Saler	NET-T	12	3,1
ES1	El Saler-Sueca	Crop	0,5	1,1
PT1	Mitra Evora	BDT-T	7	2,2
PT1	Mitra Tojal	C3 Grass	0,5	1,7



Methodology

- Surface temperature change decomposition equation

$$\delta T_s = \frac{1}{4\varepsilon\sigma T_s^3}[-SW_{in}\delta\alpha_s + (1-\alpha_s)\delta SW_{in} + \delta LW_{in} - \delta LE - \delta H - \delta G - \delta I - \sigma T_s^4 \delta\varepsilon_s] \quad (2)$$



$$\epsilon_s\sigma T_s^4 = [1-\alpha_s]SW_{in} + LW_{in} - LE - H - G - I \quad (1)$$

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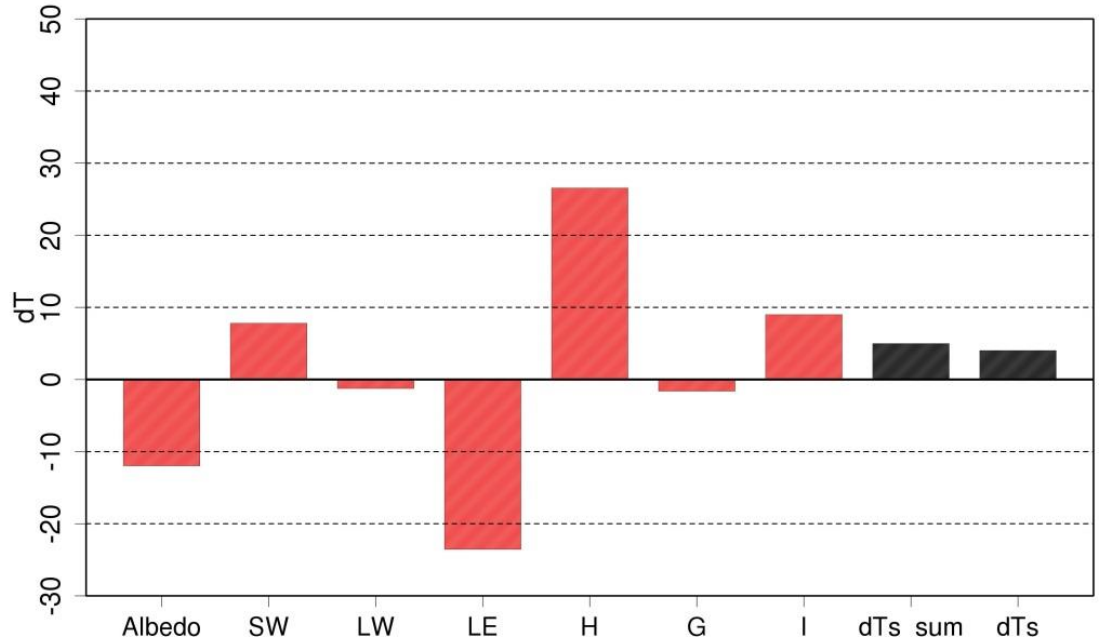
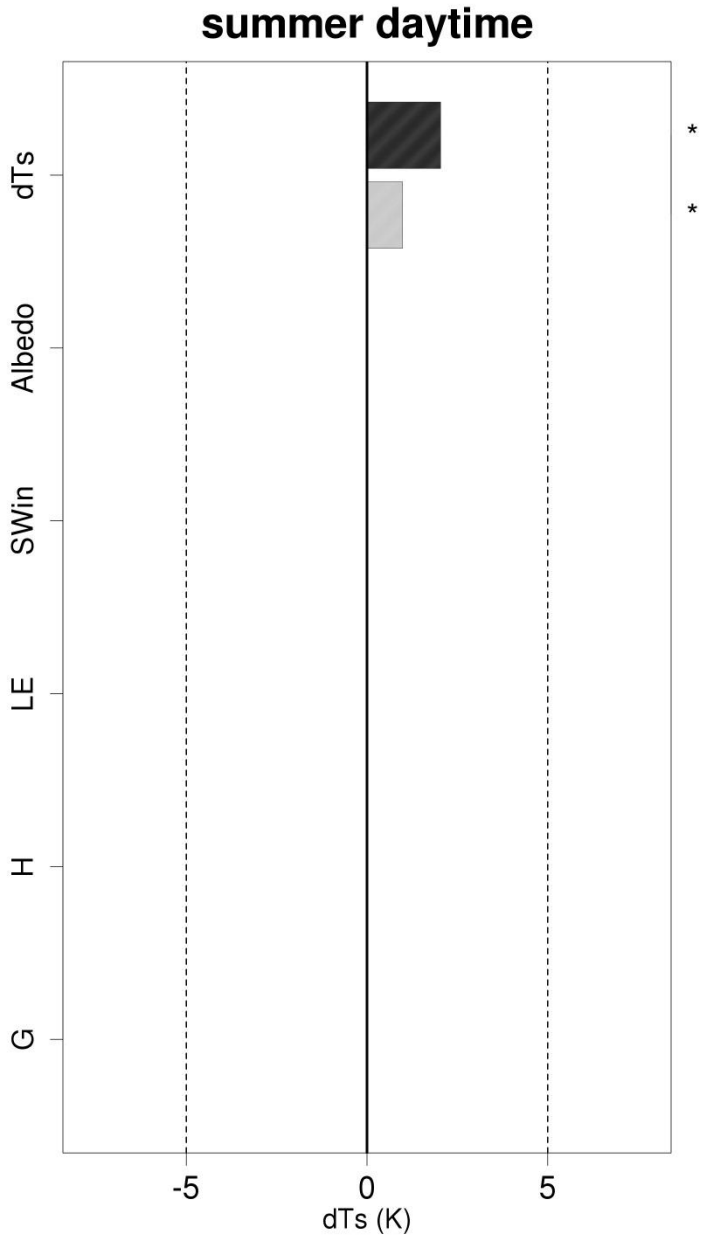


dTs decomposition – JJA 15



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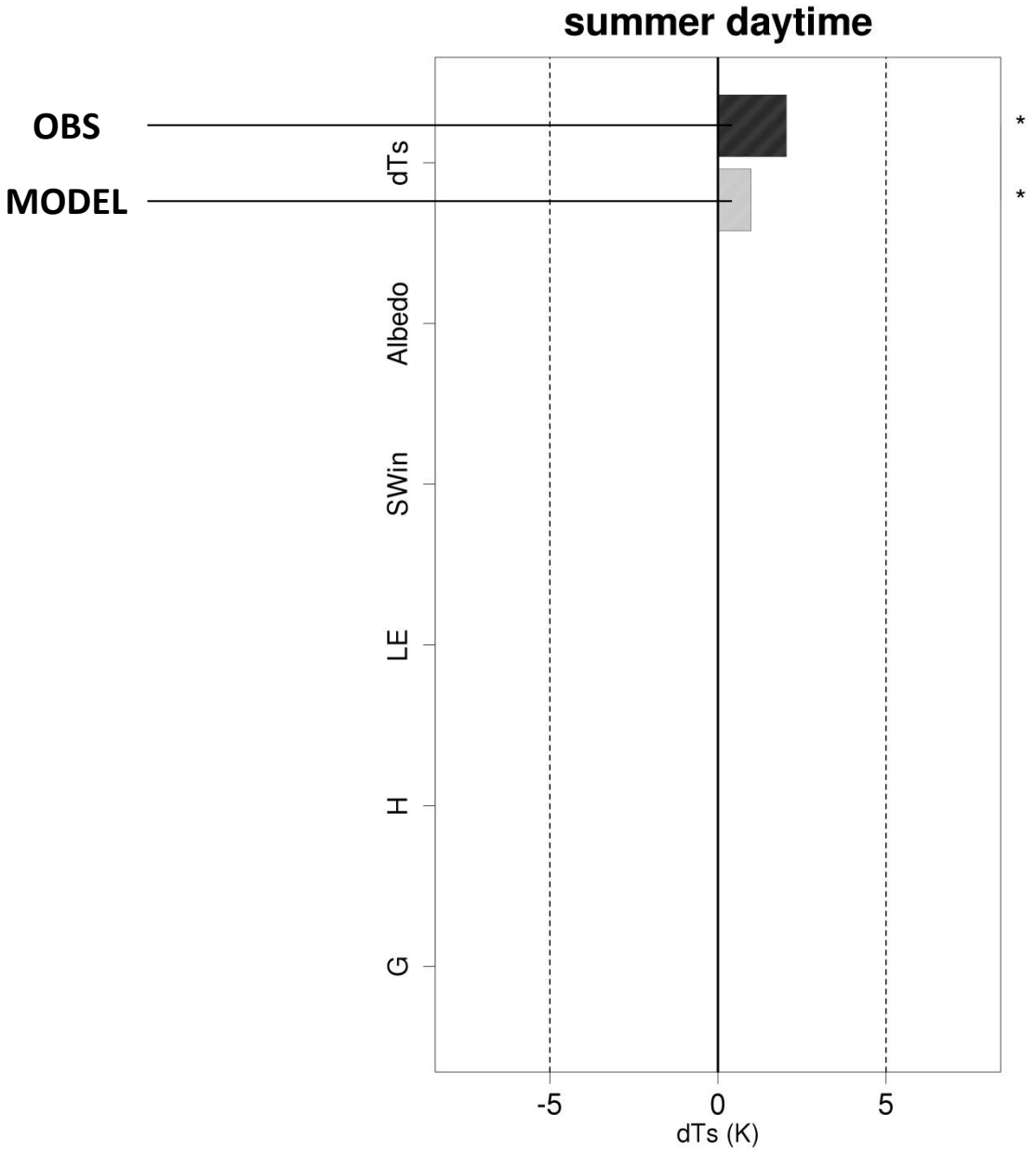

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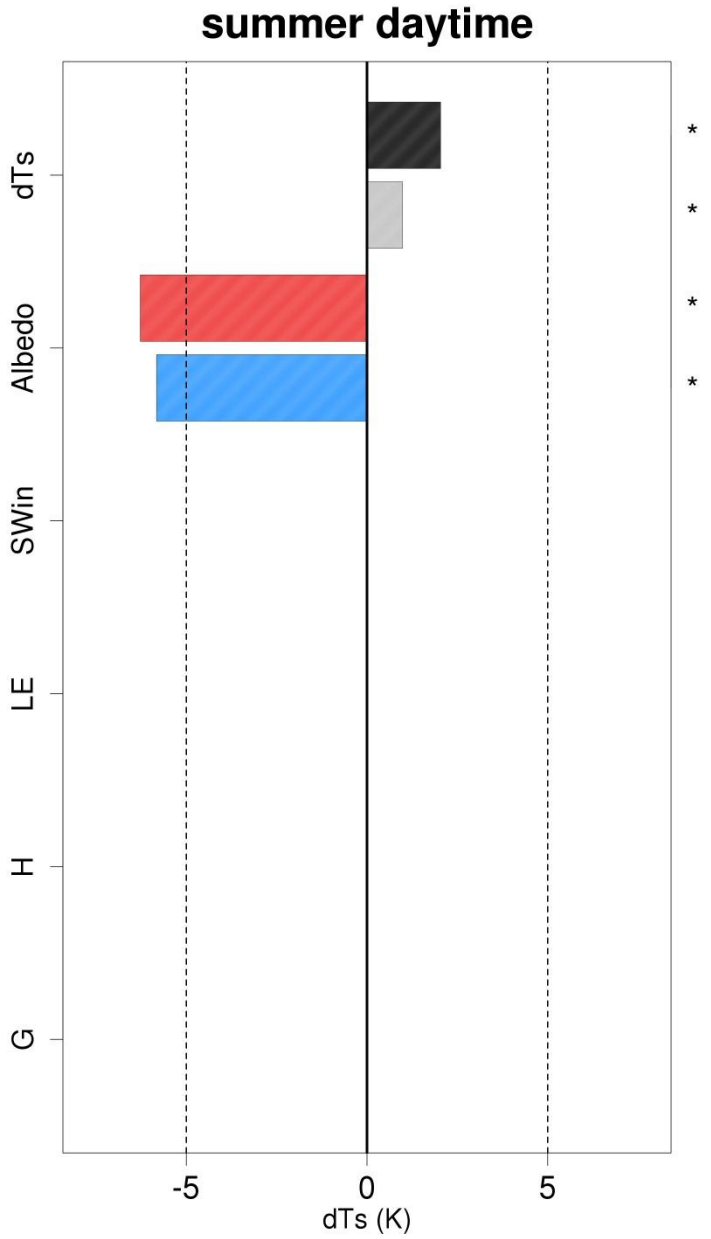

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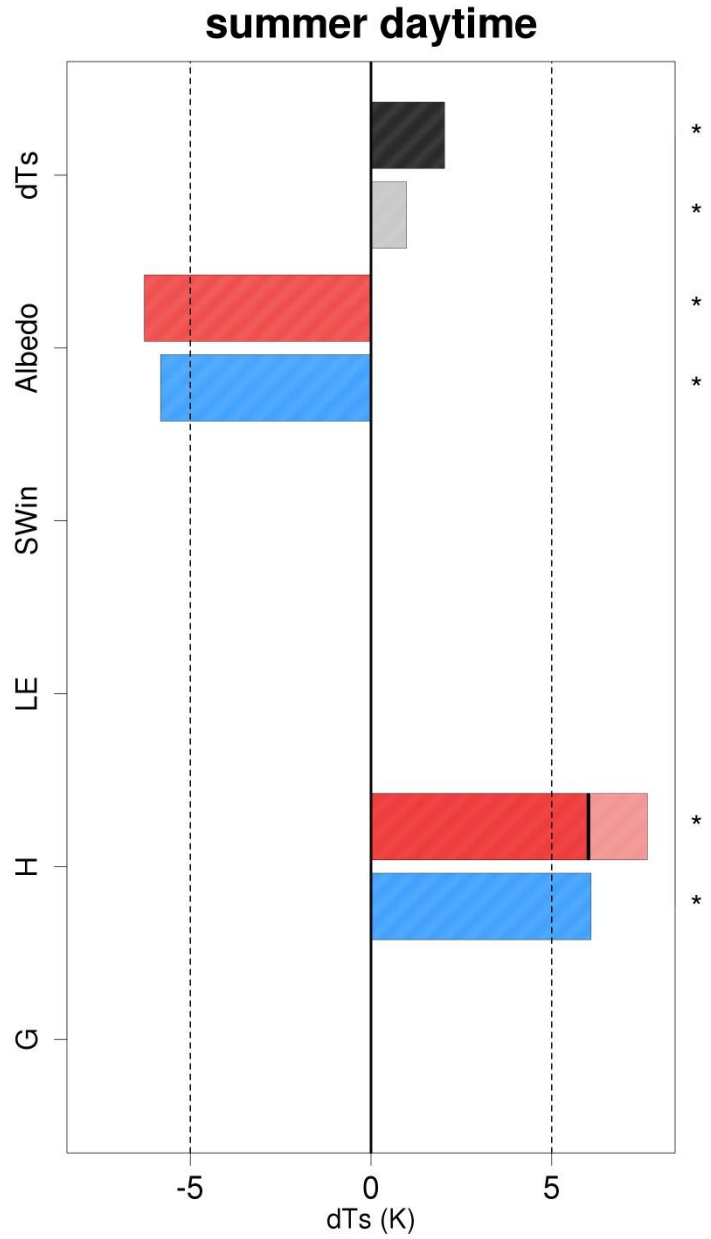
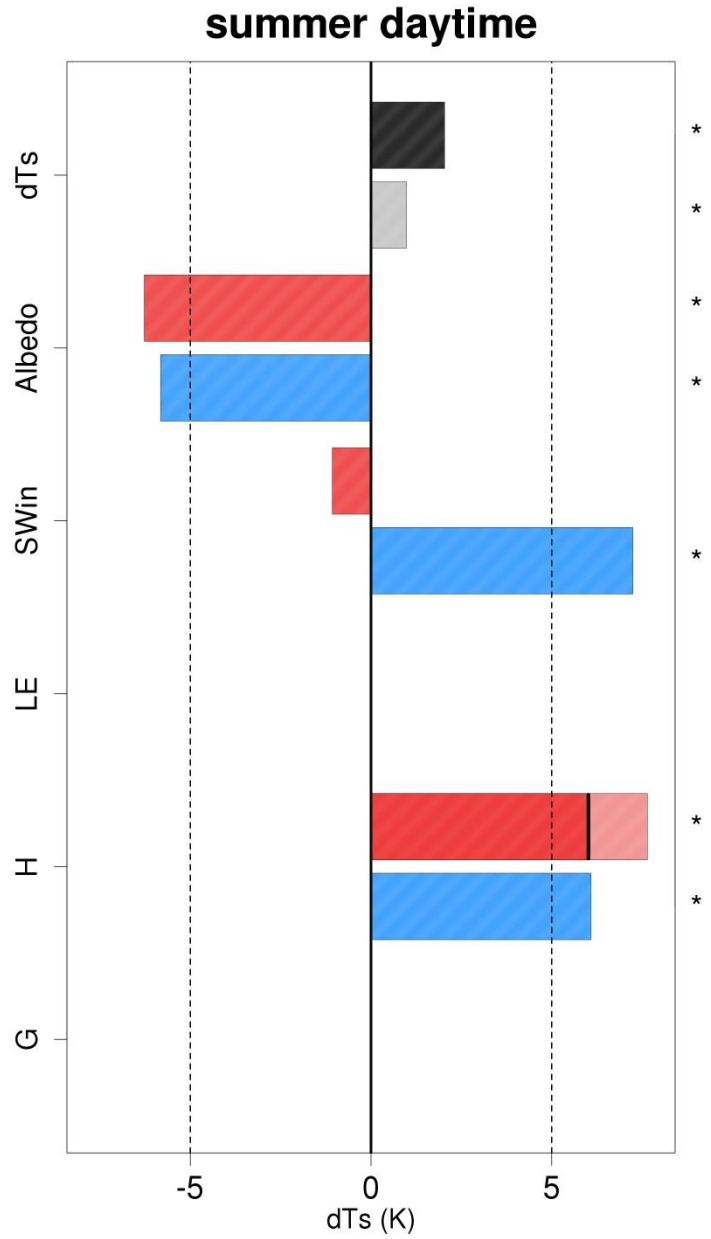
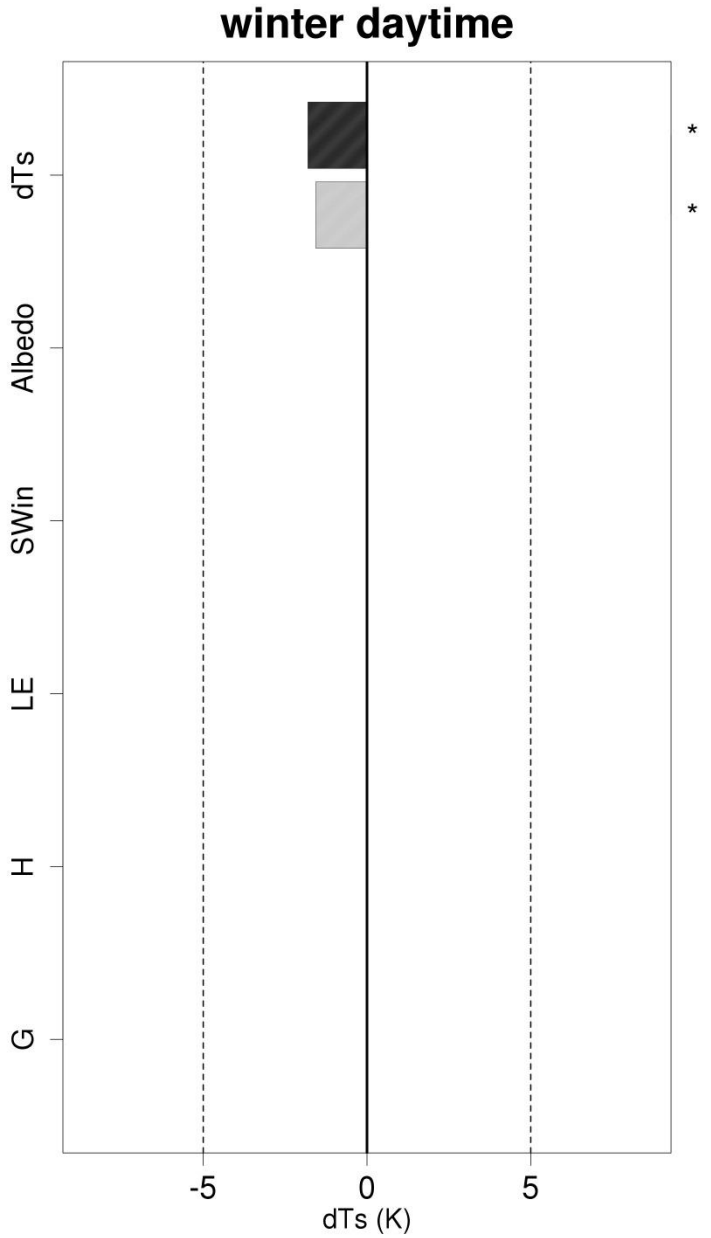


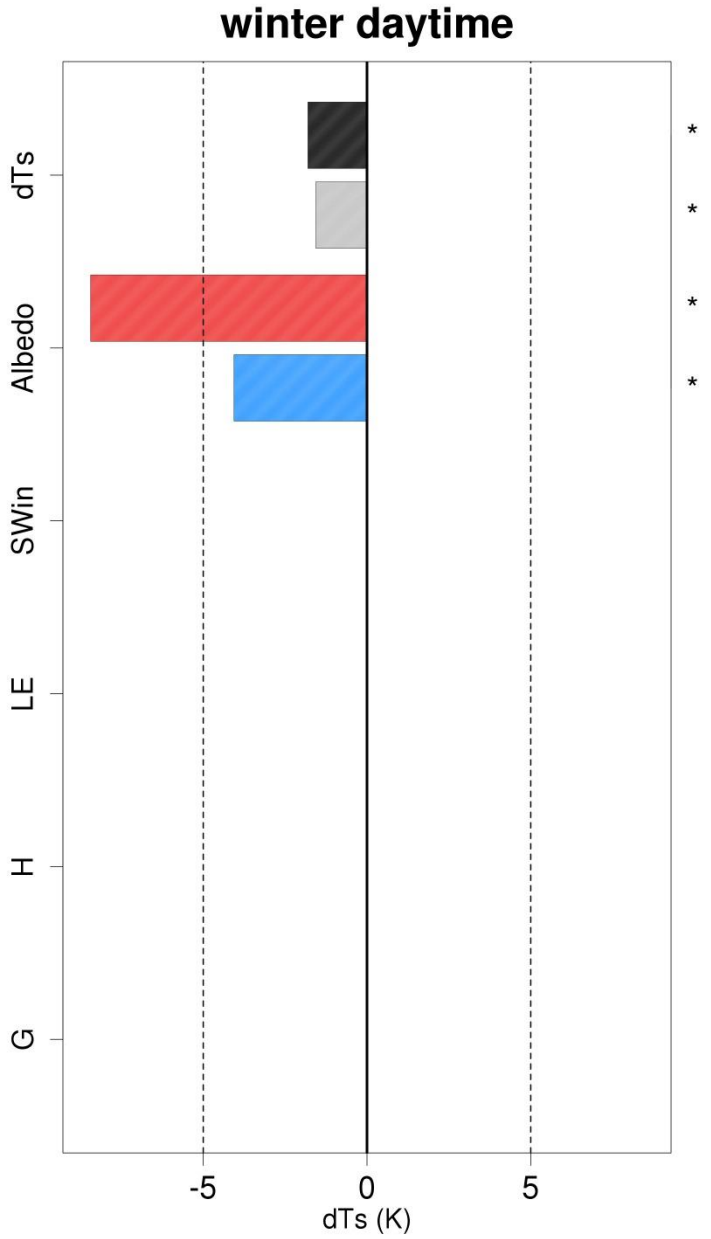
dTs decomposition – JJA 15



dTs decomposition – DJF 15

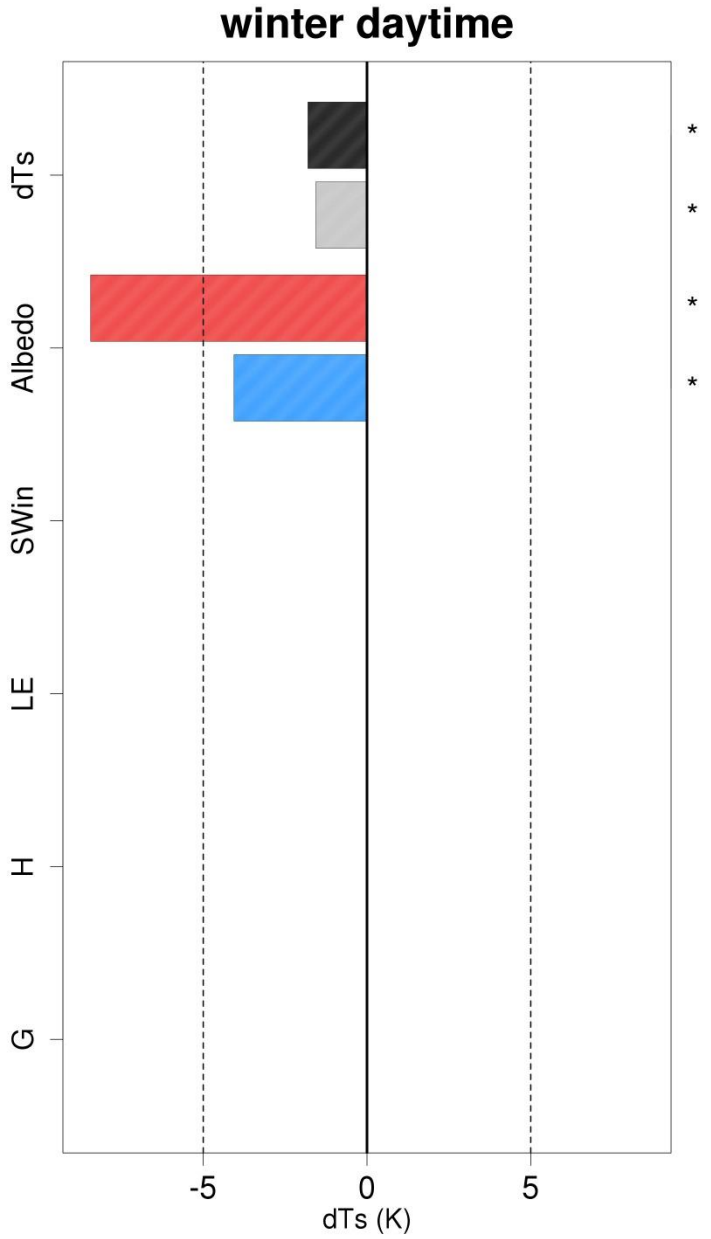


dTs decomposition – DJF 15



dTs decomposition – DJF 15

Obs.: 25% snow days
Model: 5% snow days



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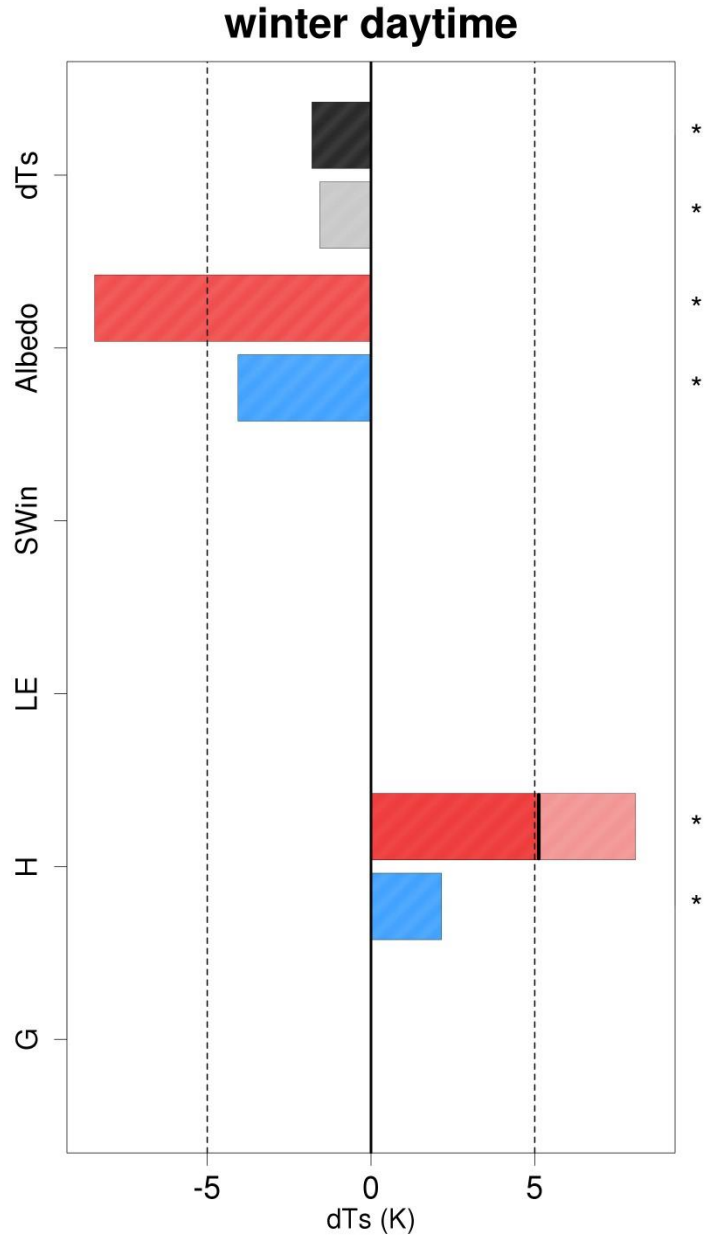

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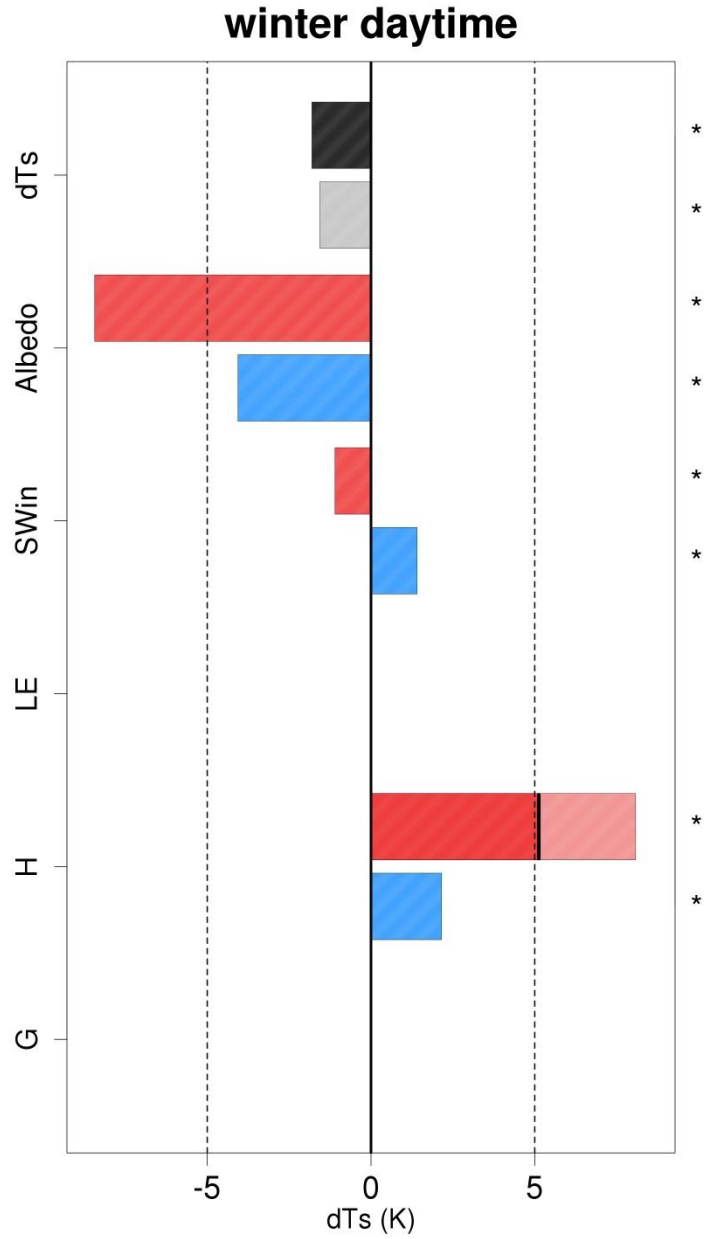
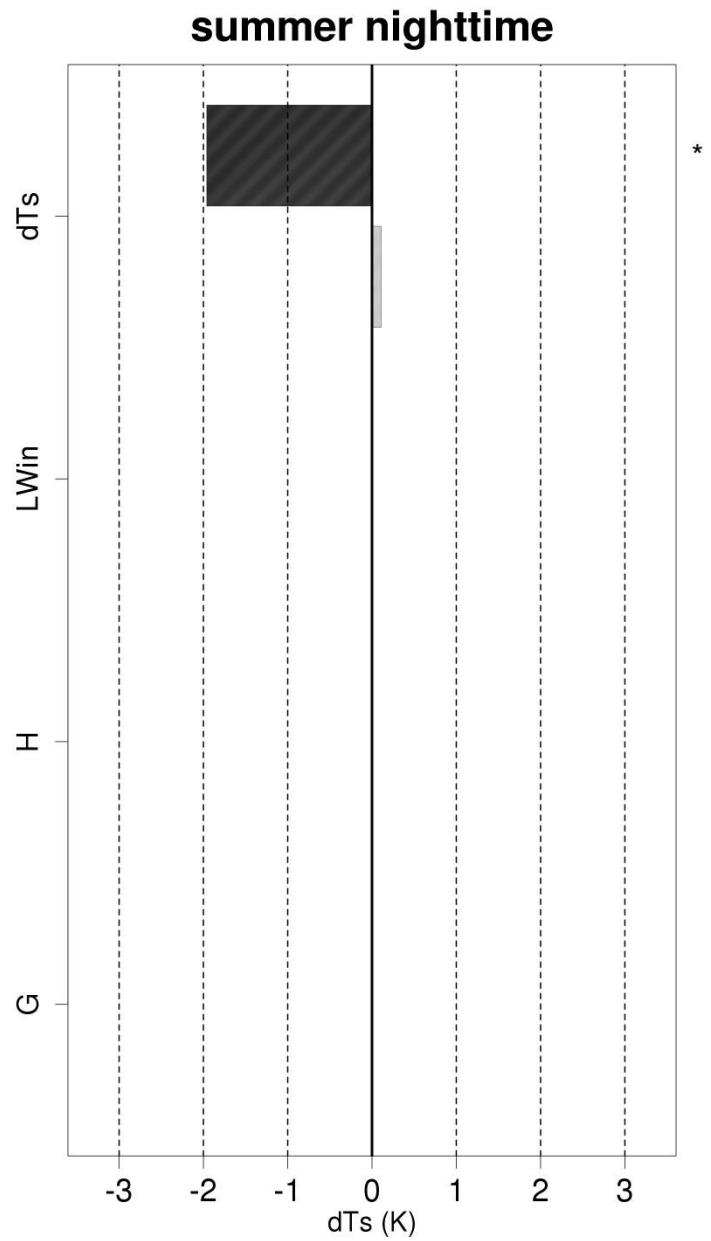
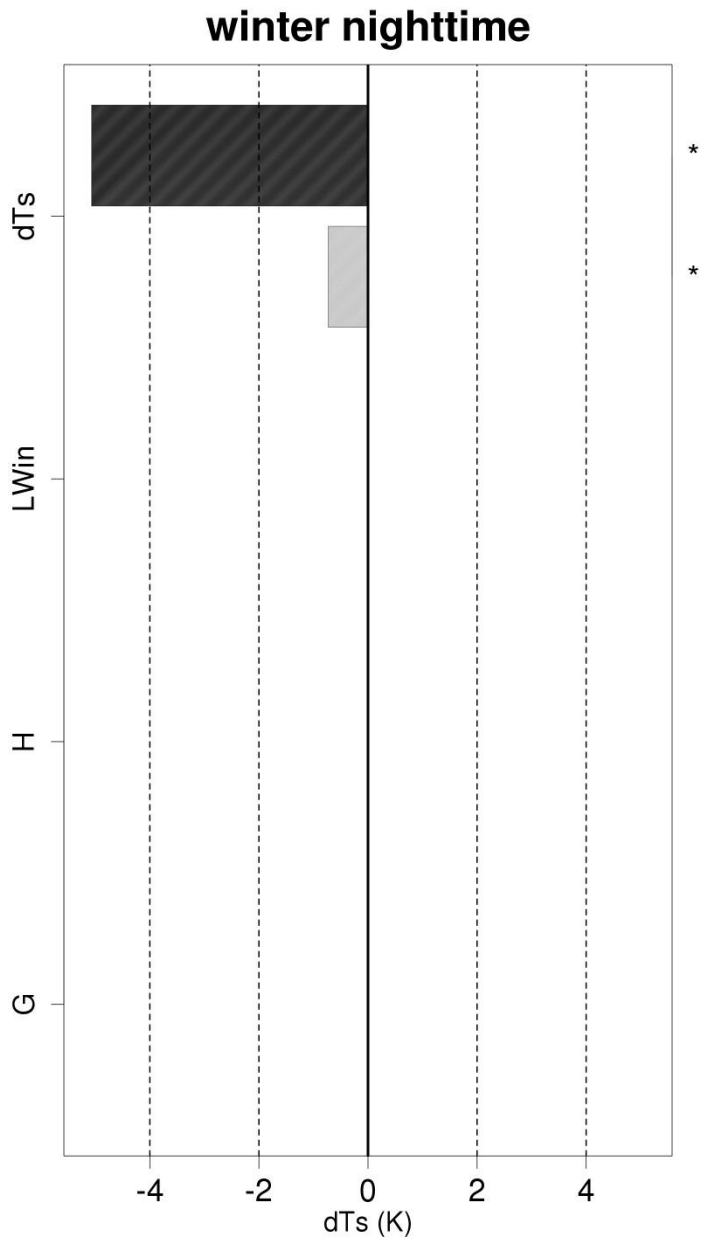


dTs decomposition – 03





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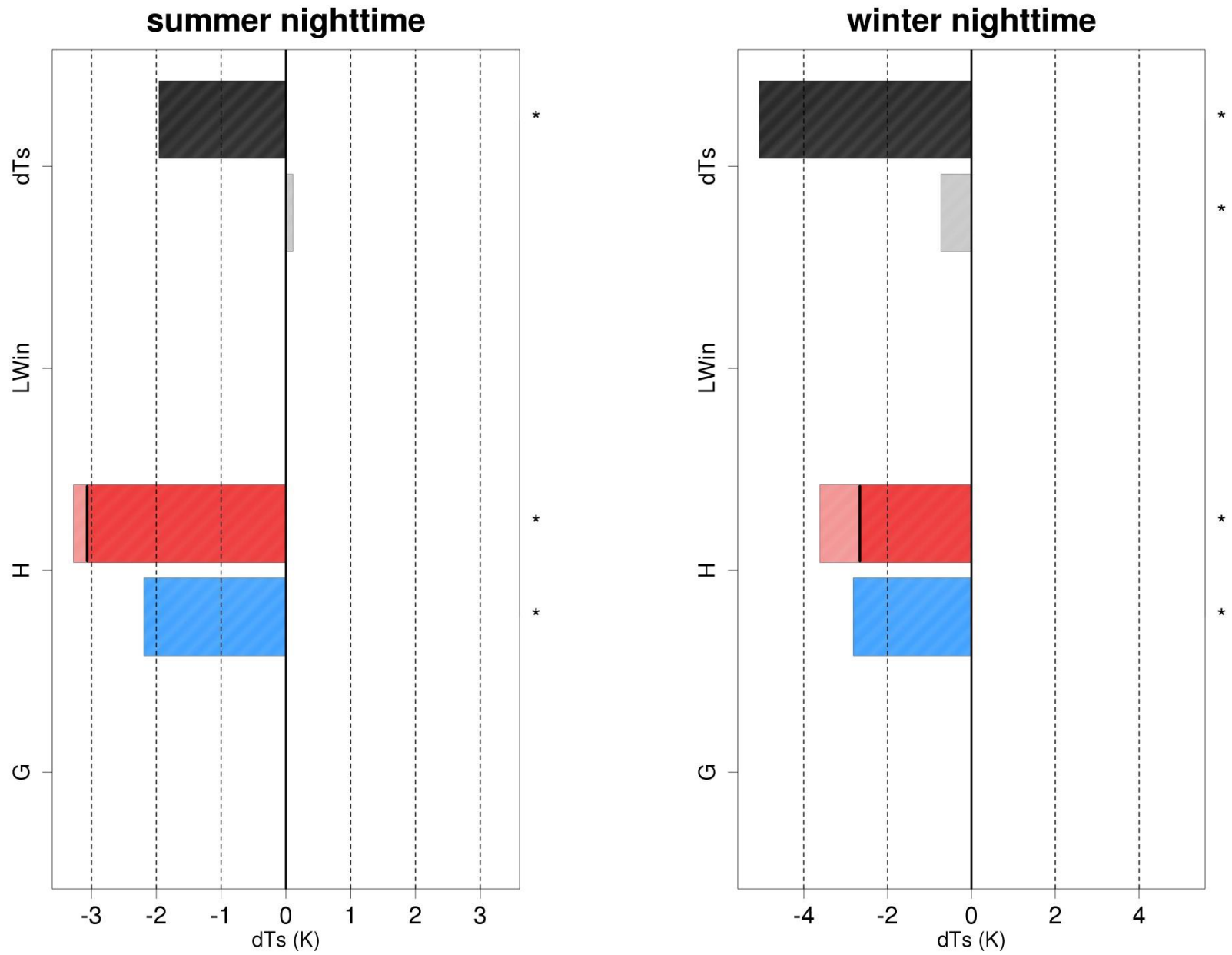
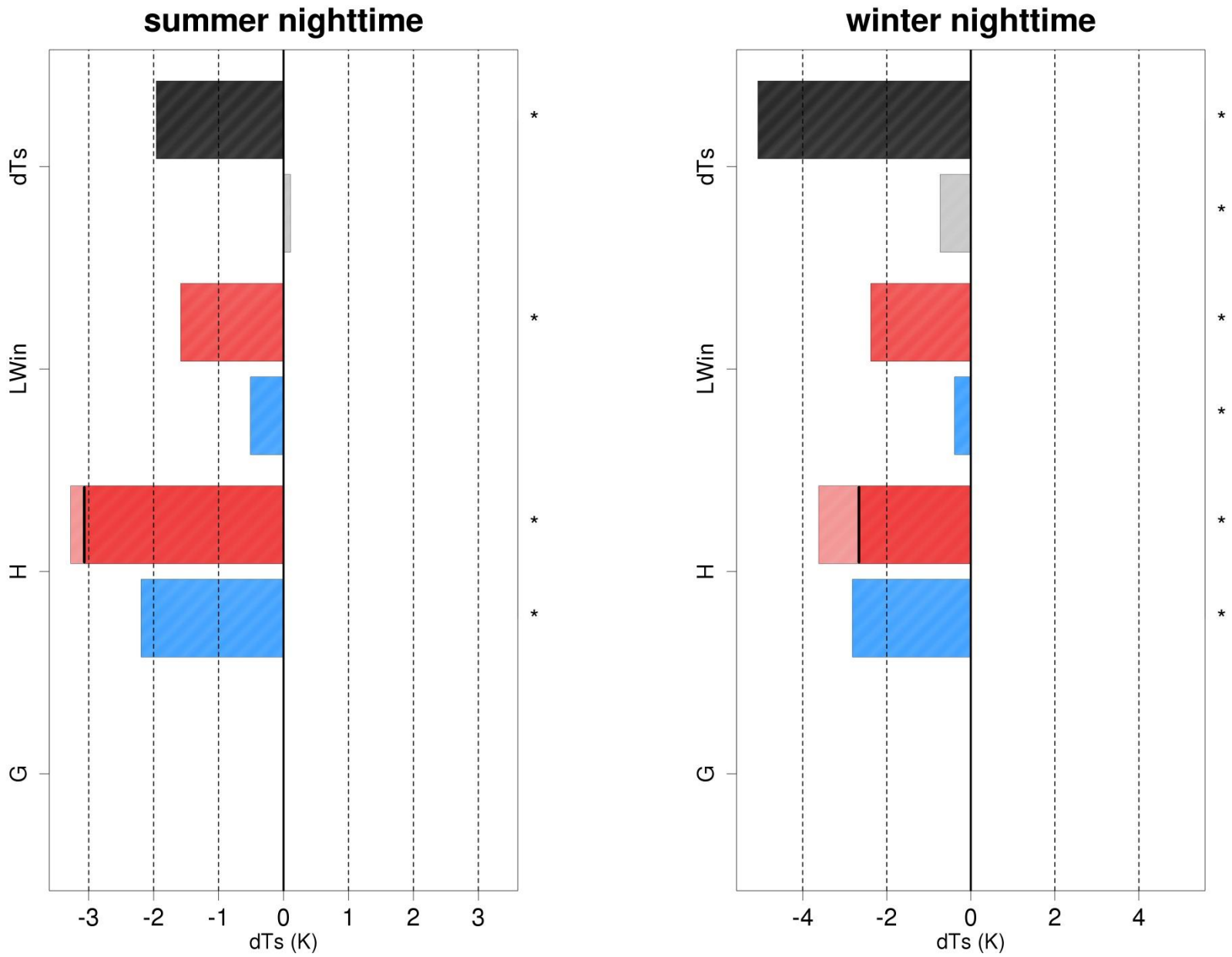
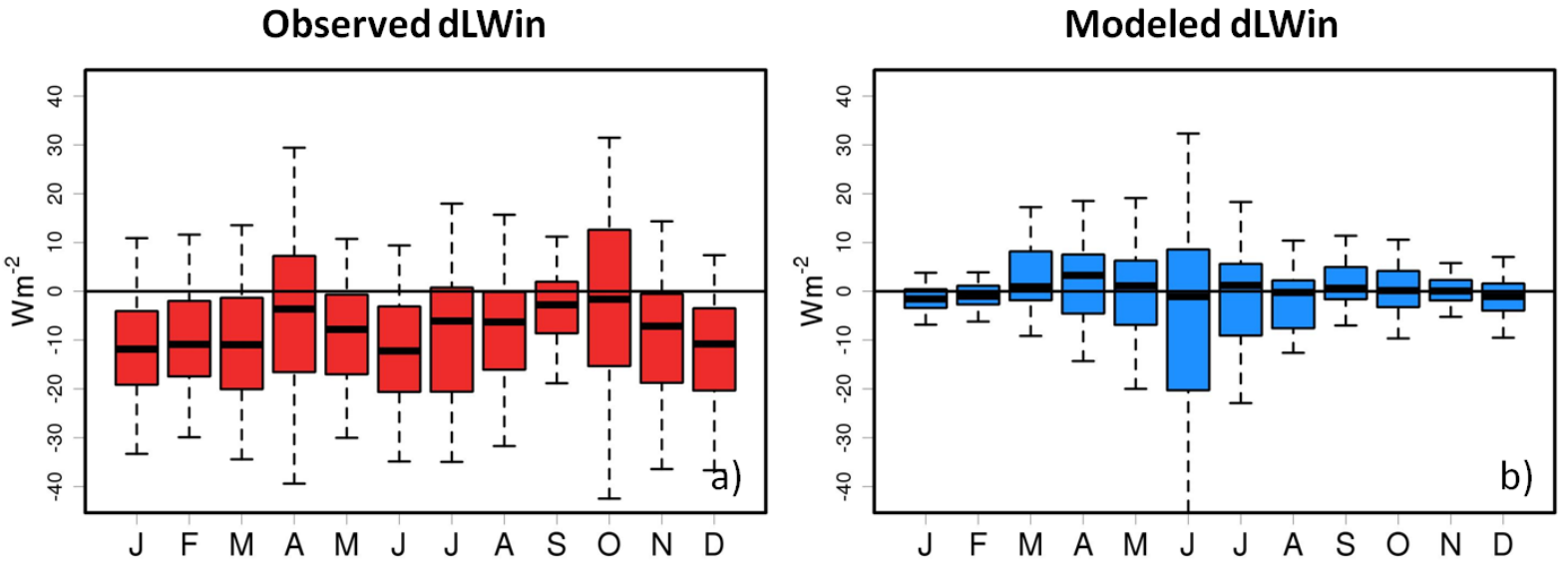


dTs decomposition – 03

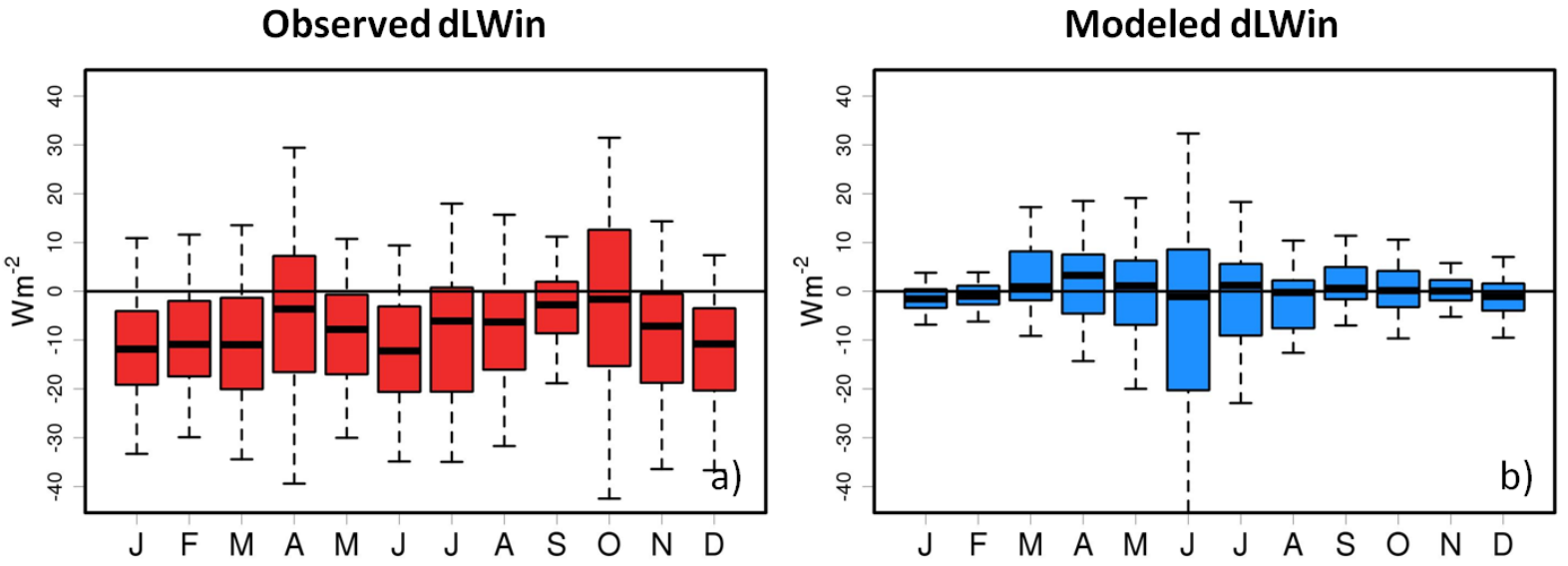


Difference in LWin



- 3 Hypotheses
  1. Decrease in atmospheric humidity

Difference in LWin



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  2. Forest BVOC emissions

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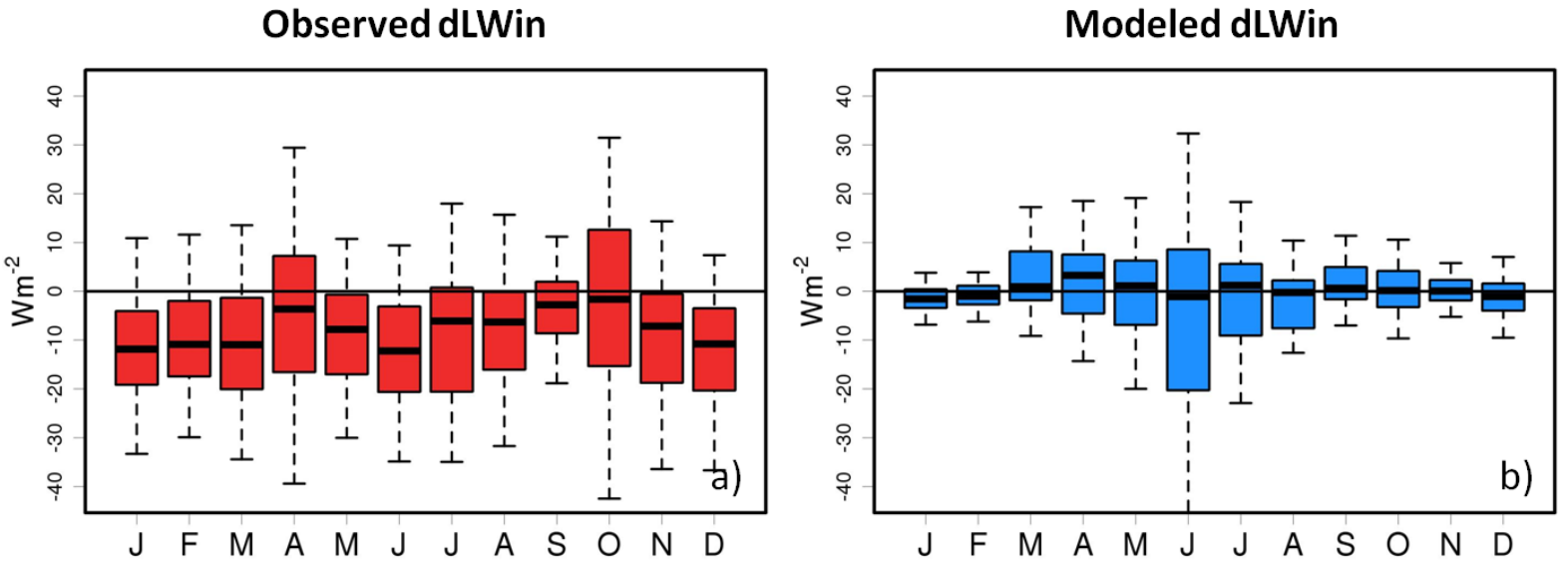

- 3 Hypotheses
  1. Decrease in atmospheric humidity
  2. Forest BVOC emissions
  3. More stable temperature profile due to decreased turbulence

Conclusions

Effect of deforestation on **daytime** climate	
Reality	*COSMO-CLM²*
Cooling due to lower surface albedo (**αs**), which is offset by warming due to reduced surface roughness (**Rs**)	✓
?	Reduced **Rs** -> reduced convective uplift –> reduced **CLC** -> increase in **SWin** -> surface warming (most prominent in JJA)
Effect of deforestation on nighttime climate	
Reality	*COSMO-CLM²*
reduced **Rs** -> reduced turbulent mixing -> surface cooling	✓
Lower **LWin** and associated surface cooling	×
Surface warming due to more heat storage (**G**) release (JJA)	Surface warming due to more heat storage release (**G**) (JJA & DJF)

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