Drivers of droughts and heatwave intensification mechanisms

Ryan Teuling

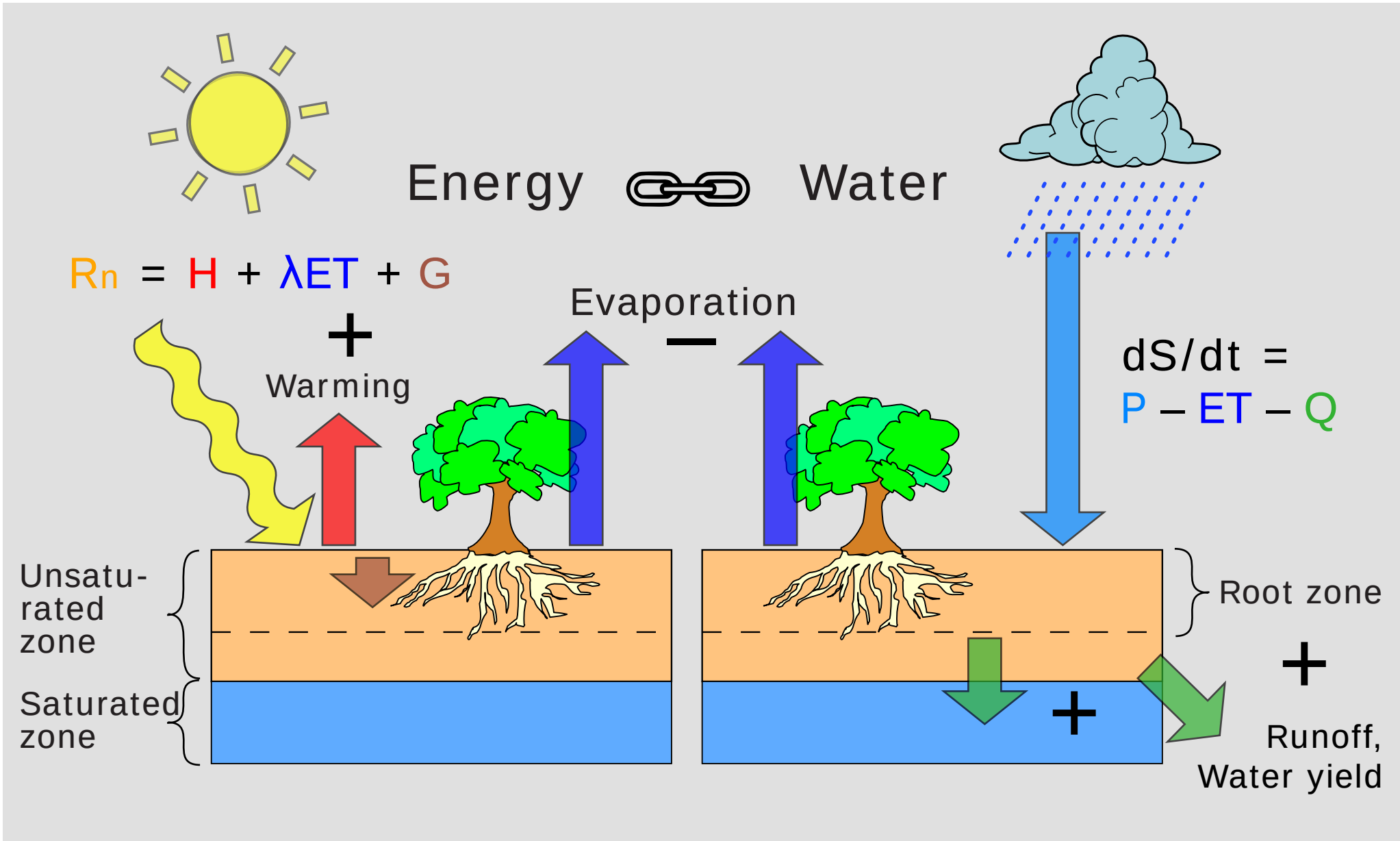
Sonia Seneviratne, Diego Miralles, Jasper Denissen, Chiel van Heerwaarden, ...

EUMETRAIN Event Week on Heatwaves and Droughts
online seminar, 29 May 2023

100years

WAGENINGEN
UNIVERSITY & RESEARCH

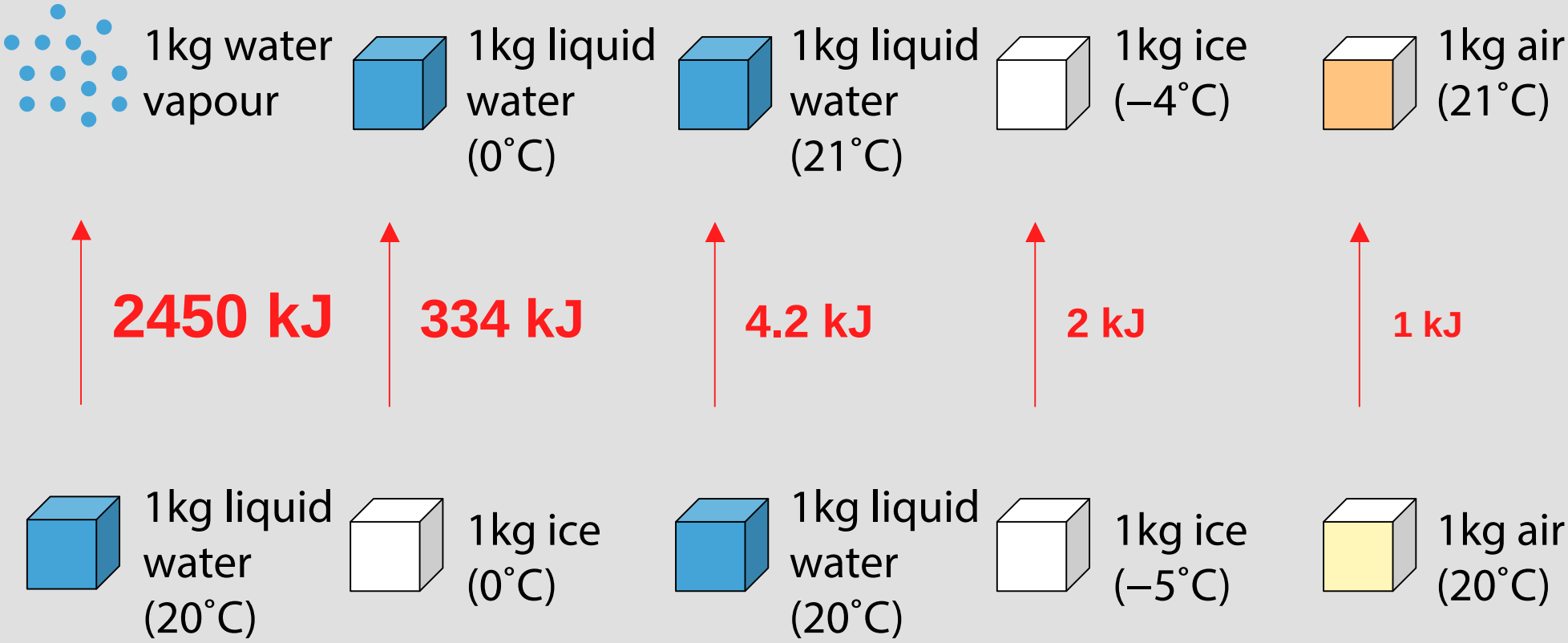
Evaporation, climate and the water cycle



Modified after Seneviratne et al. (2010), *Earth-Science Reviews* **99**

WAGENINGEN
UNIVERSITY & RESEARCH

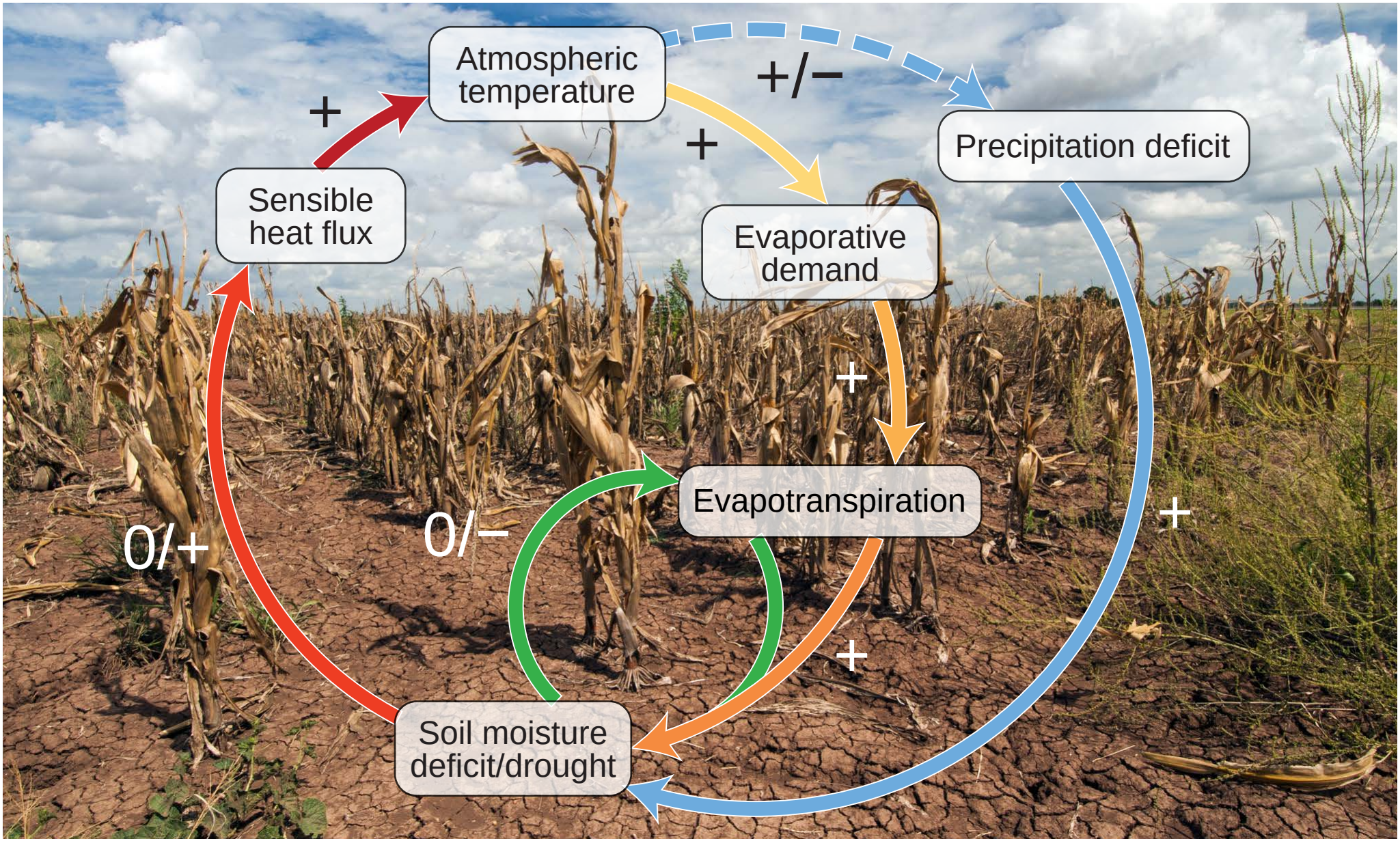
Energy and land-atmosphere exchange



Seneviratne et al. (2010), *Earth-Science Reviews* **99**

WAGENINGEN
UNIVERSITY & RESEARCH

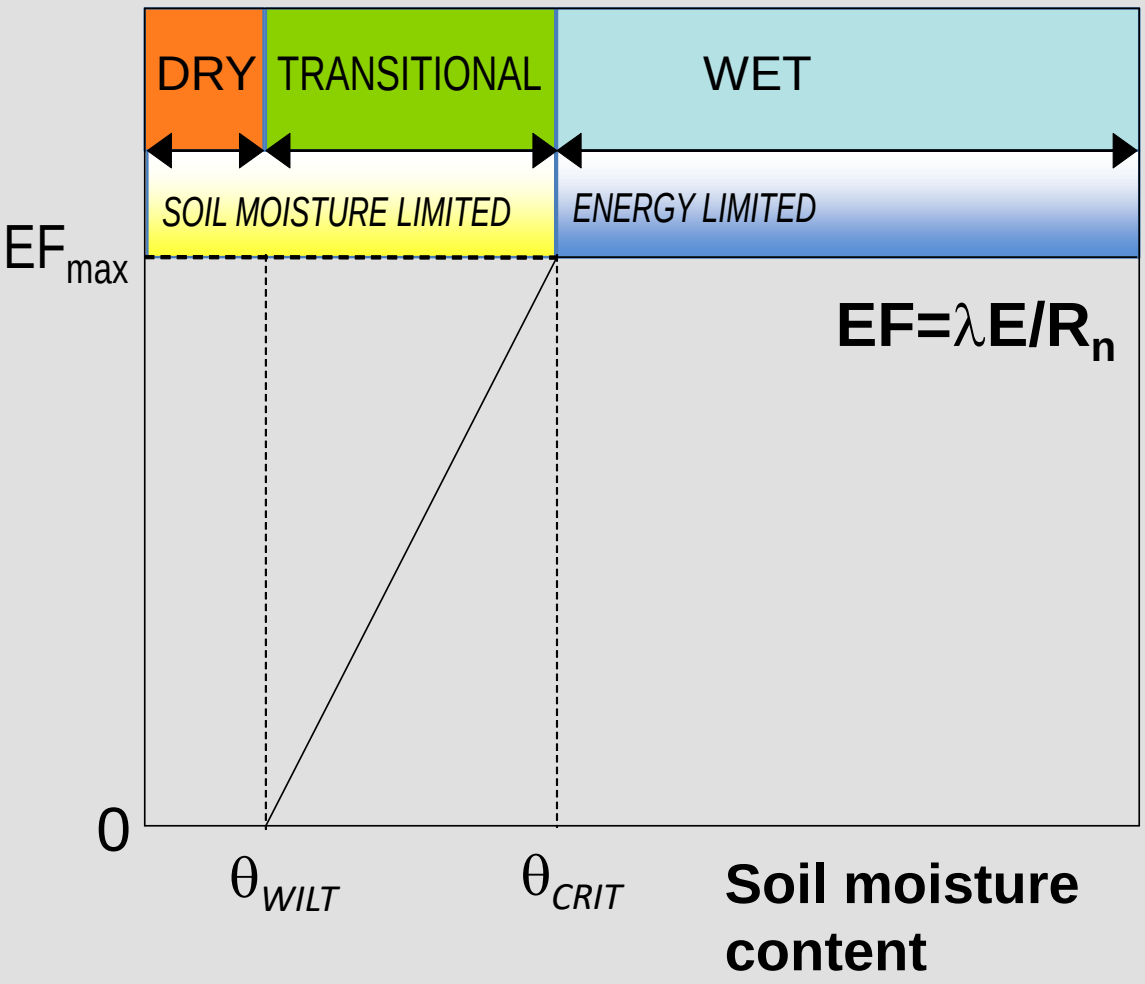
Main pathways of the drought-heat link



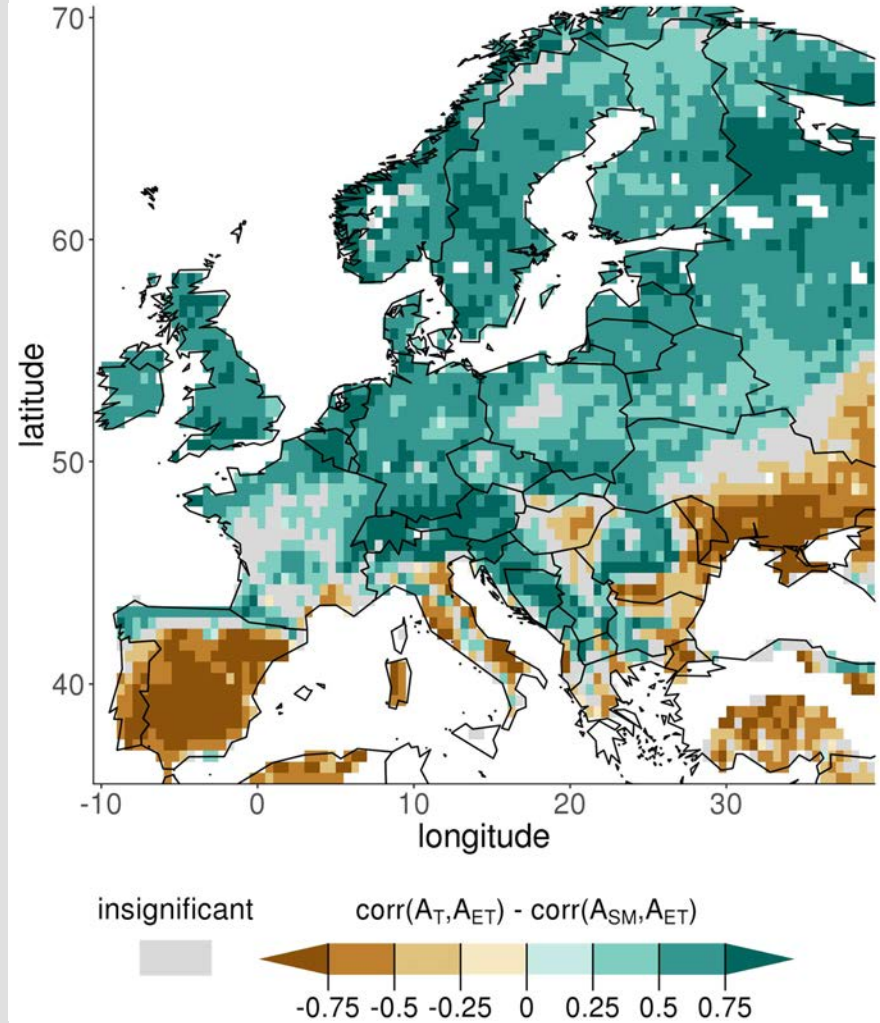
Teuling (2018), *Nature Climate Change* **8**

WAGENINGEN
UNIVERSITY & RESEARCH

Evaporation and soil moisture regimes



- Nonlinear relation, critical moisture content reflect threshold value

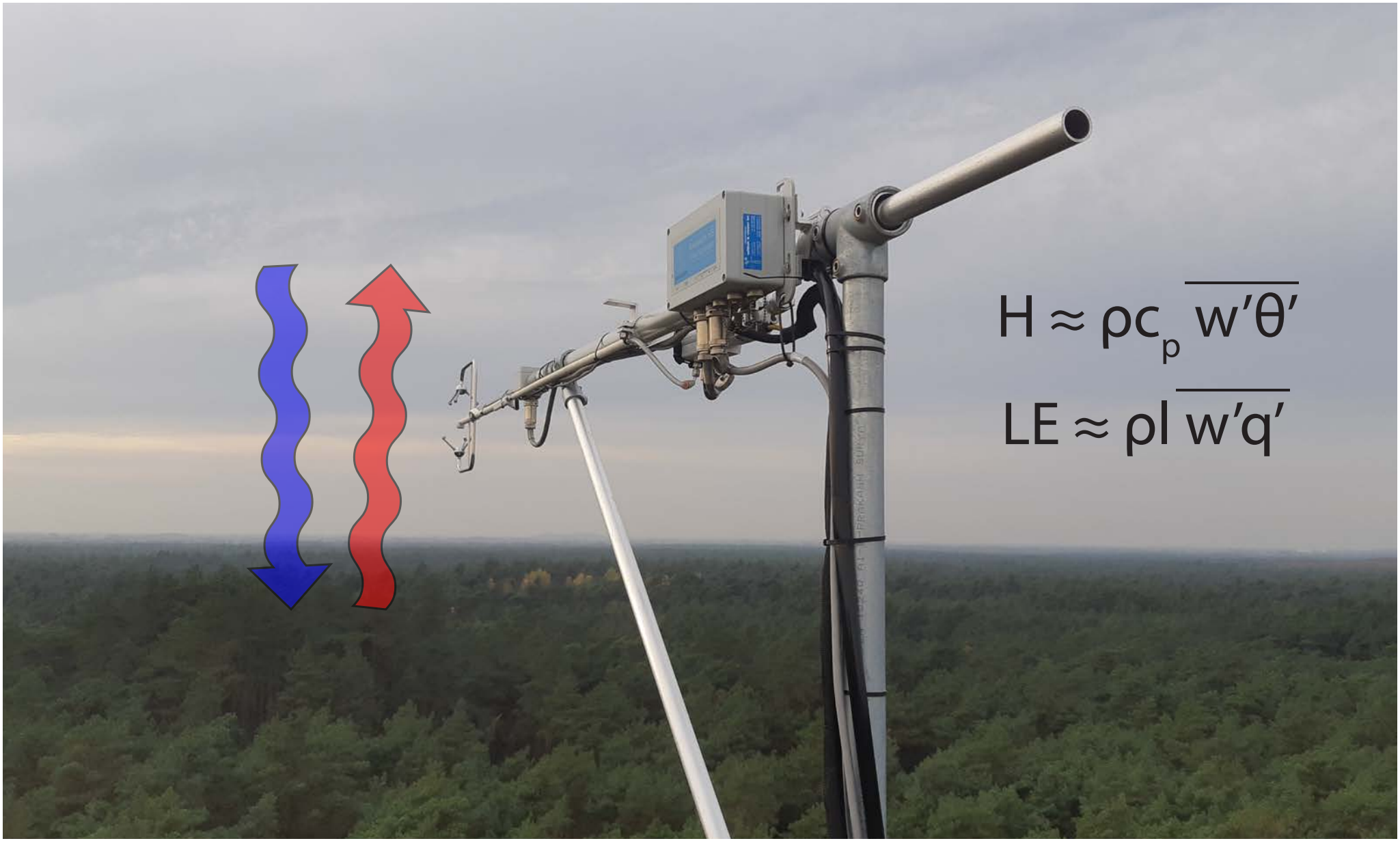


- Reflected in distinct energy and water limited regions

Seneviratne et al. (2010), *Earth-Science Reviews* **99**
Denissen et al. (2020), *JGR Atmospheres* **125**

WAGENINGEN
UNIVERSITY & RESEARCH

FLUXNET: eddy covariance flux towers



picture taken from Loobos tower, Nov. 2021

WAGENINGEN
UNIVERSITY & RESEARCH

Drought monitoring using Sentinel 1

image: ESA

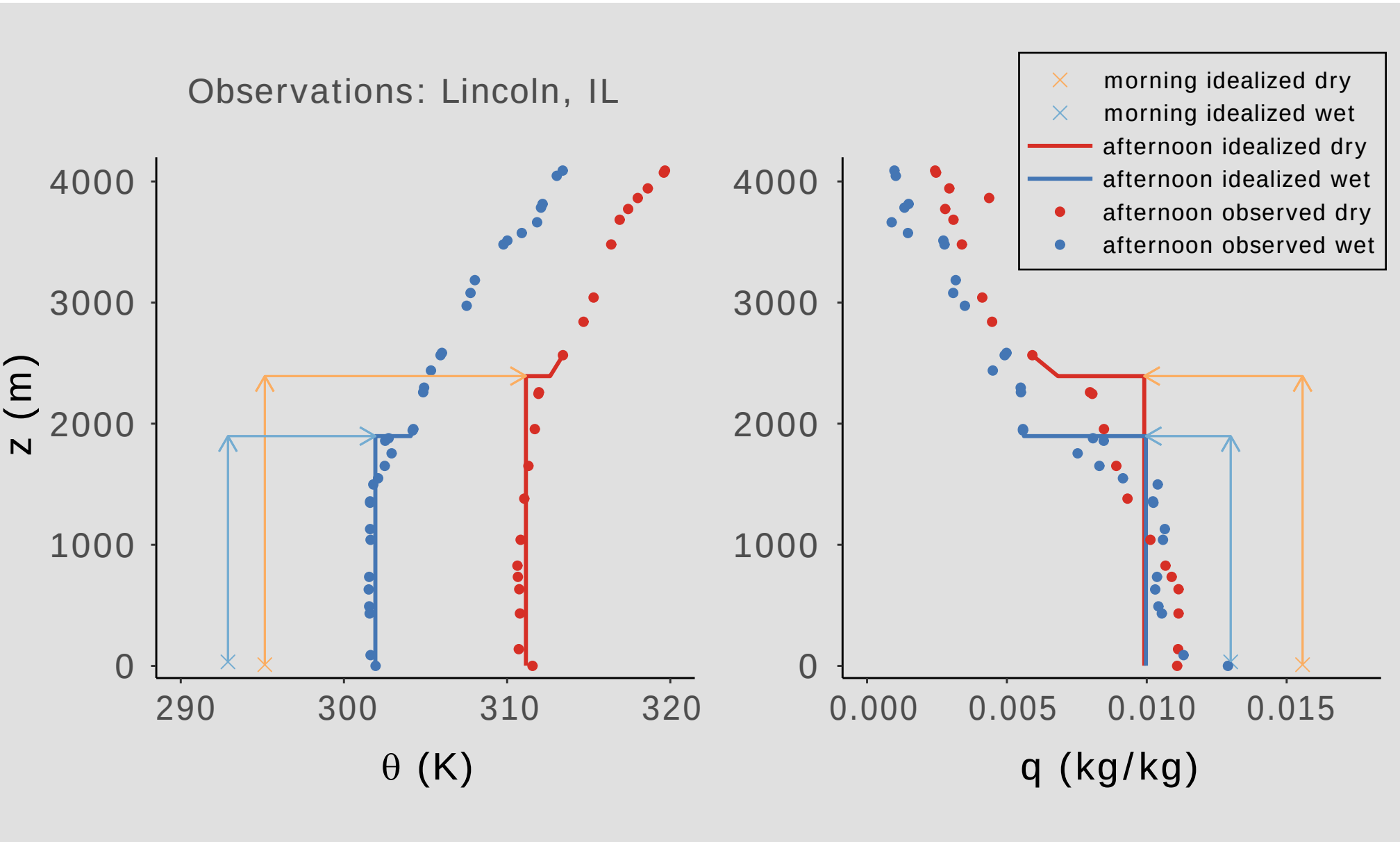
WAGENINGEN
UNIVERSITY & RESEARCH

Weather balloons

photo from 2008 IAC photo contest

WAGENINGEN
UNIVERSITY & RESEARCH

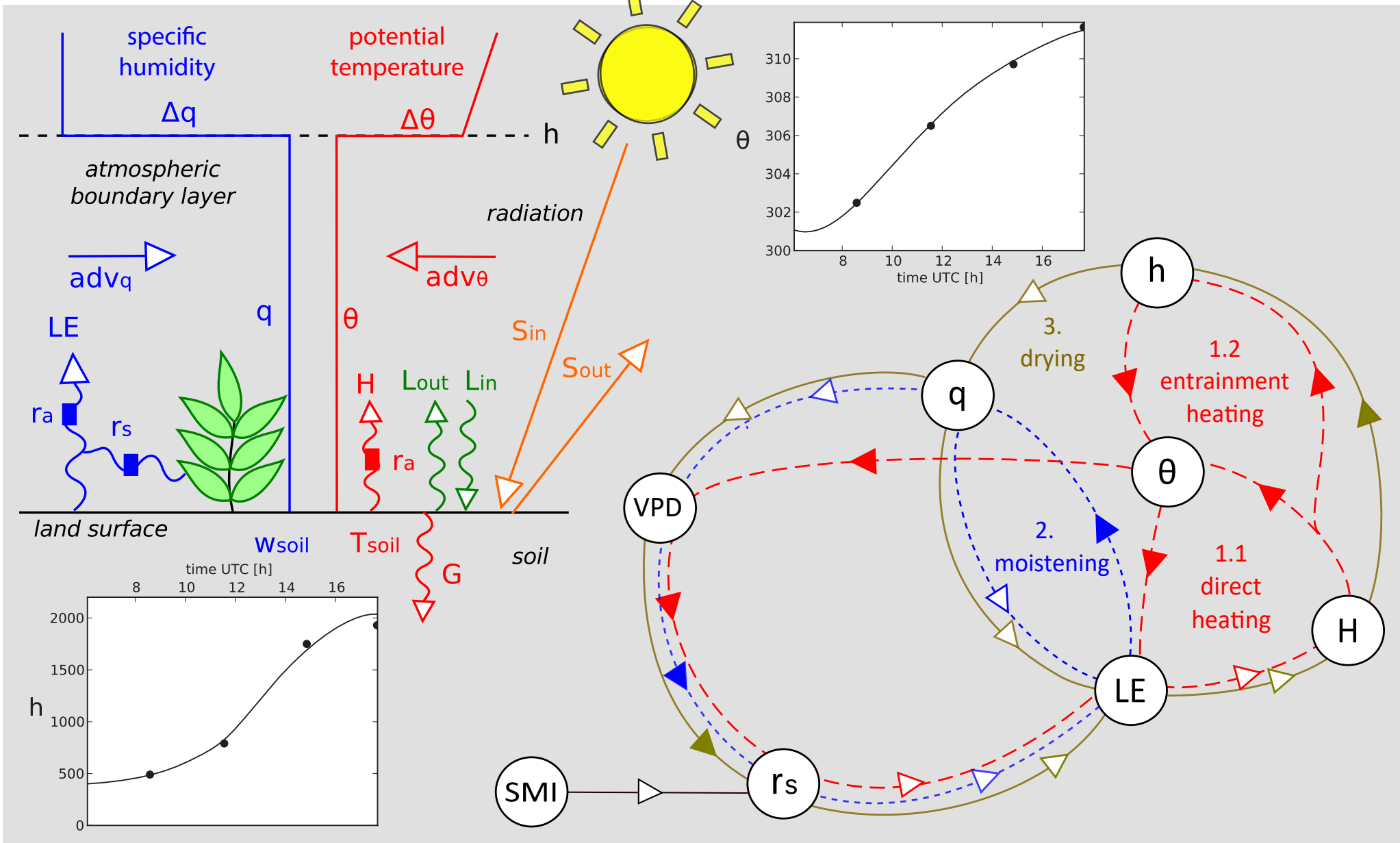
Wet vs. dry soils: Diurnal ABL evolution



Denissen et al. (2021), *npj Climate and Atmospheric Science* **4**

WAGENINGEN
UNIVERSITY & RESEARCH

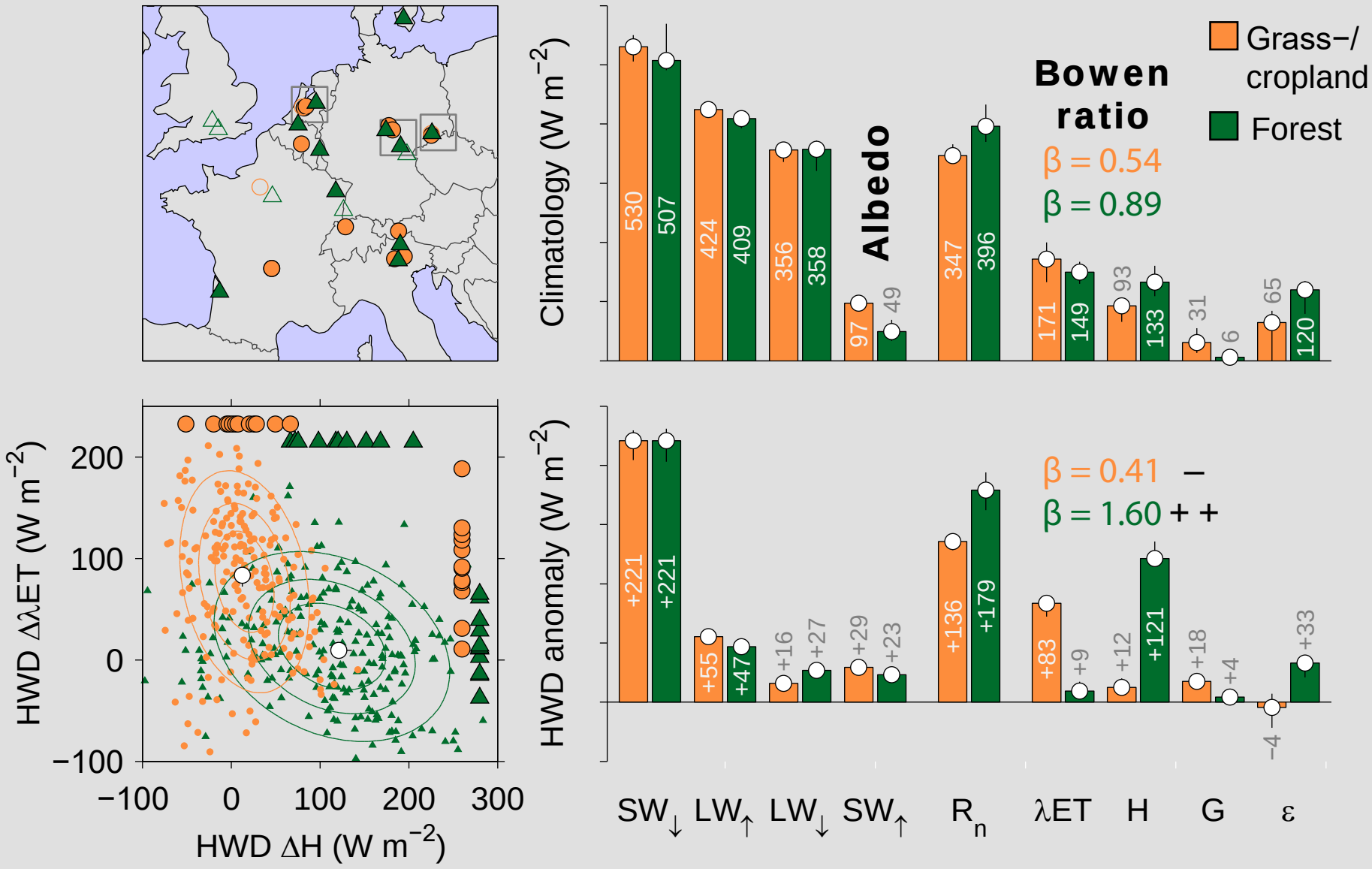
The CLASS boundary layer model



Van Heerwaarden et al. (2010), *Journal of Hydrometeorology* **11**
Lansu et al. (2020), *Geophysical Research Letters* **47**

WAGENINGEN
UNIVERSITY & RESEARCH

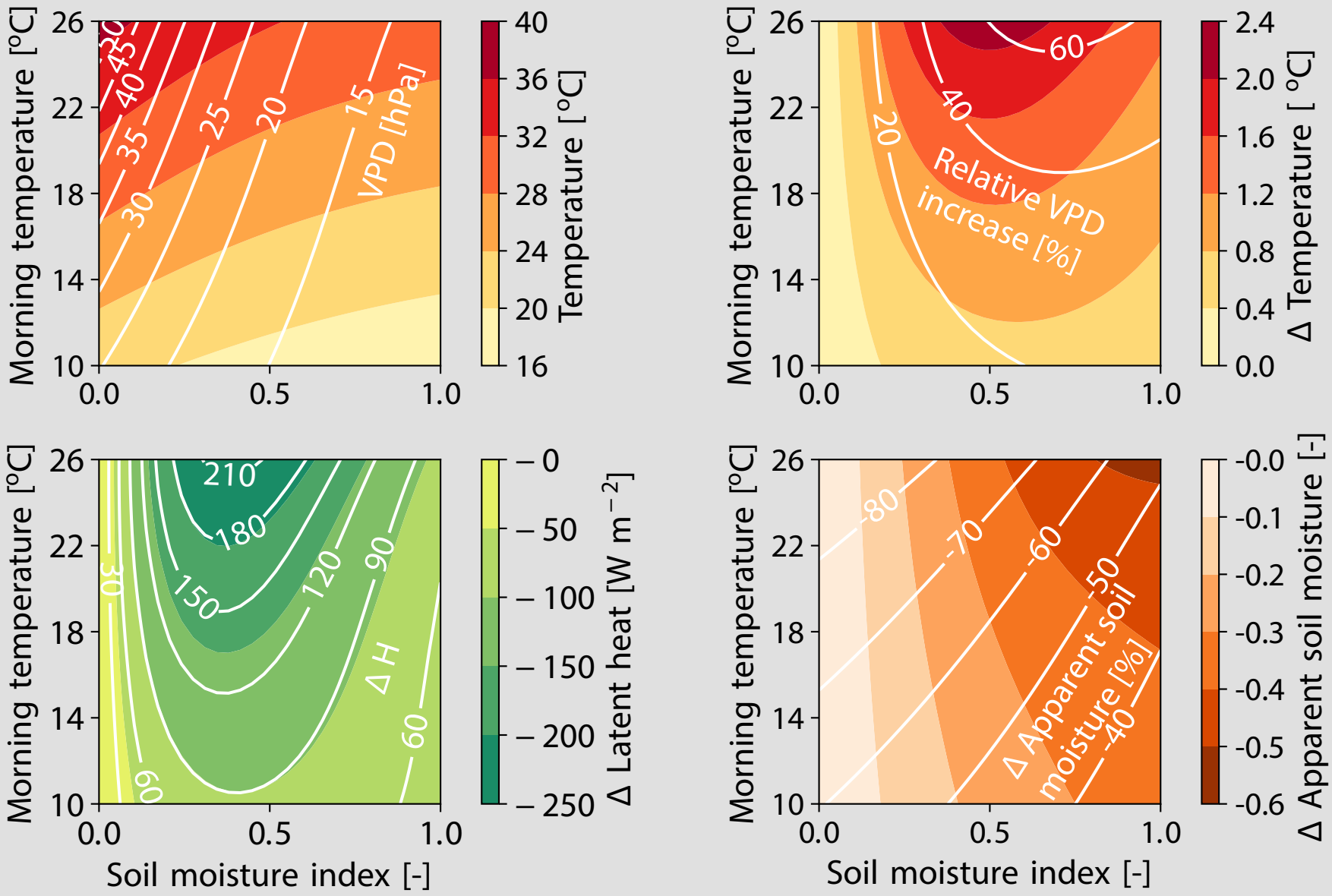
Heatwave day (HWD) heating over forest



Teuling et al. (2010), *Nature Geoscience* **3**

WAGENINGEN
UNIVERSITY & RESEARCH

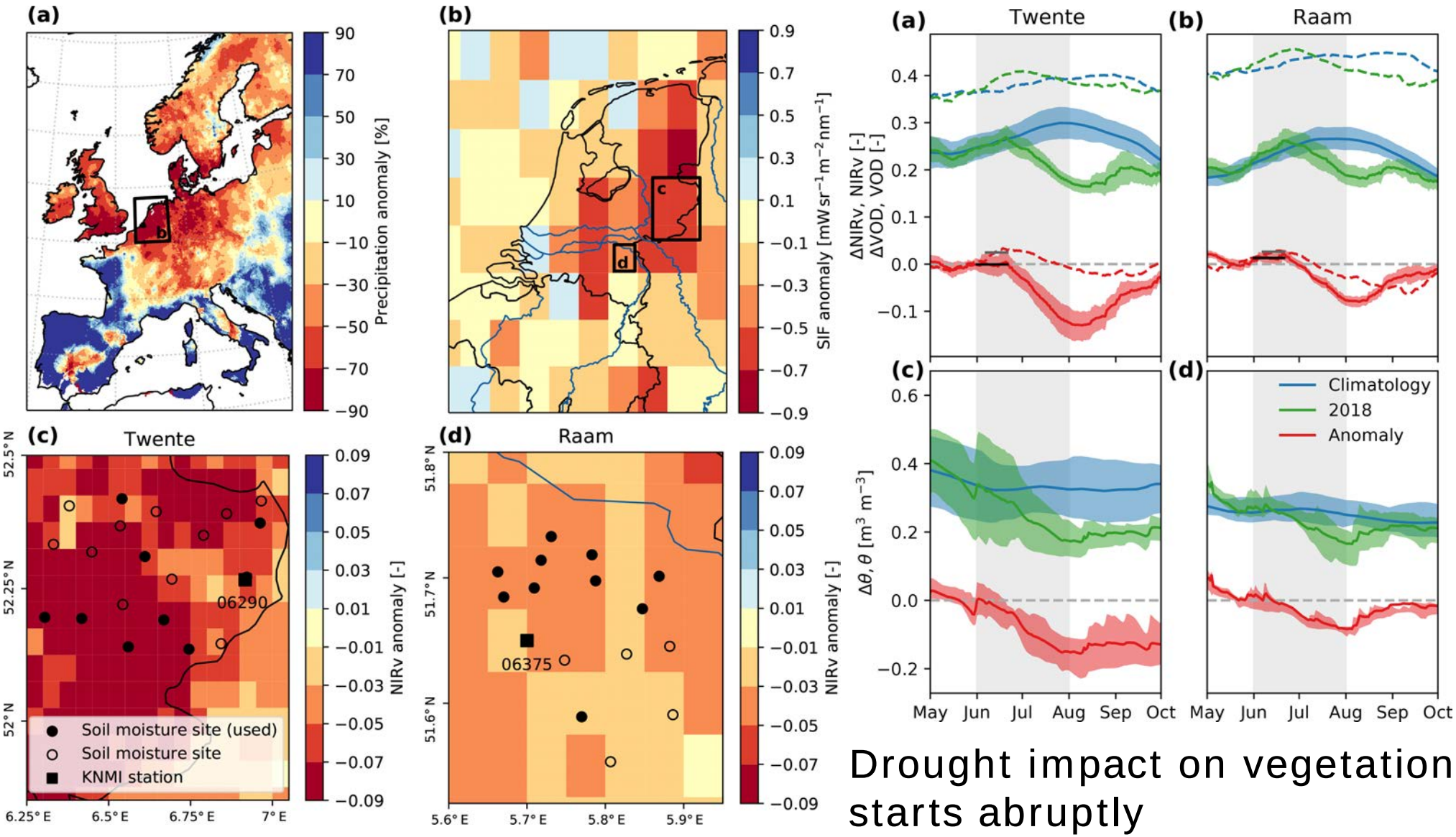
VPD impact and apparent soil dryness



Lansu et al. (2020), *Geophysical Research Letters* **47**

WAGENINGEN
UNIVERSITY & RESEARCH

Vegetation response during 2018 drought



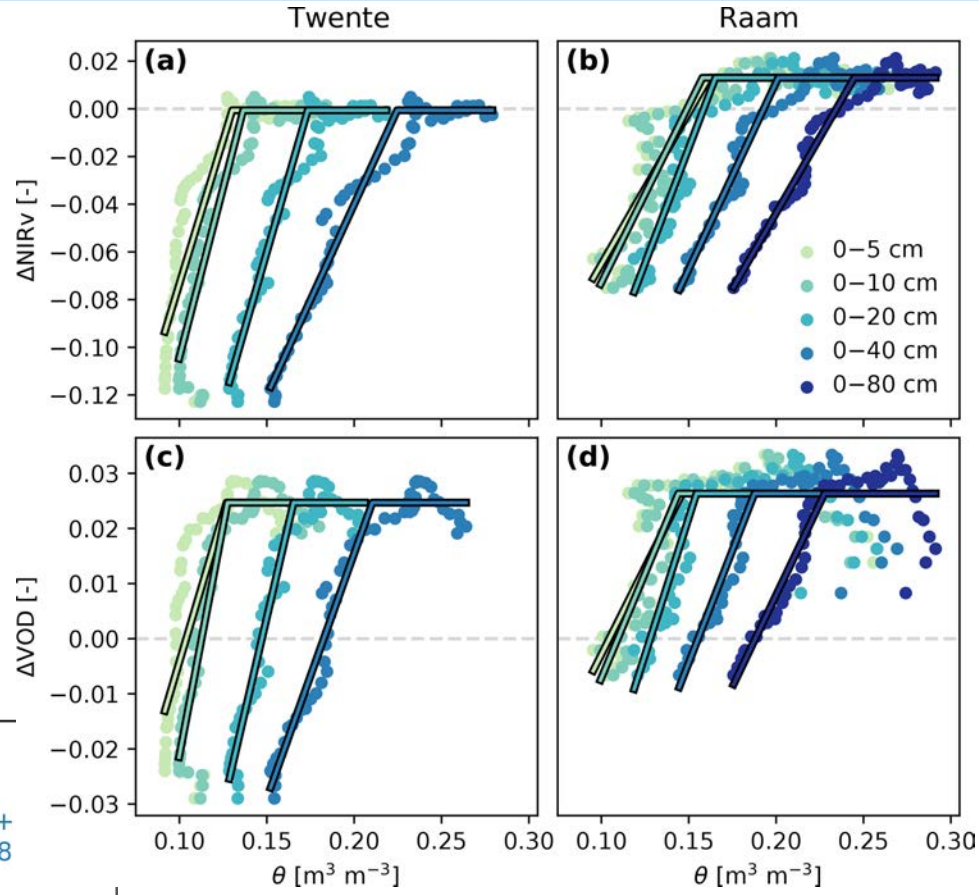
Drought impact on vegetation starts abruptly

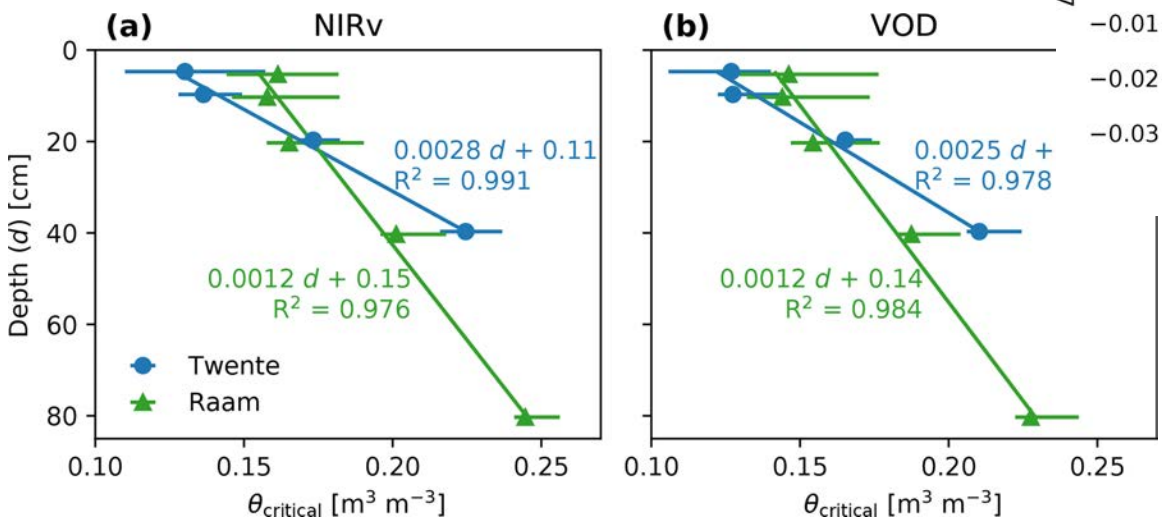
Buitink et al. (2020), *Hydrology and Earth System Sciences* **24**

WAGENINGEN
UNIVERSITY & RESEARCH

Vegetation response during 2018 drought

Nonlinear relation is found between soil moisture and vegetation indices. However this relation is different for different depths, reflecting a delayed a weakened signal deeper in the profile due to shifting root water uptake.

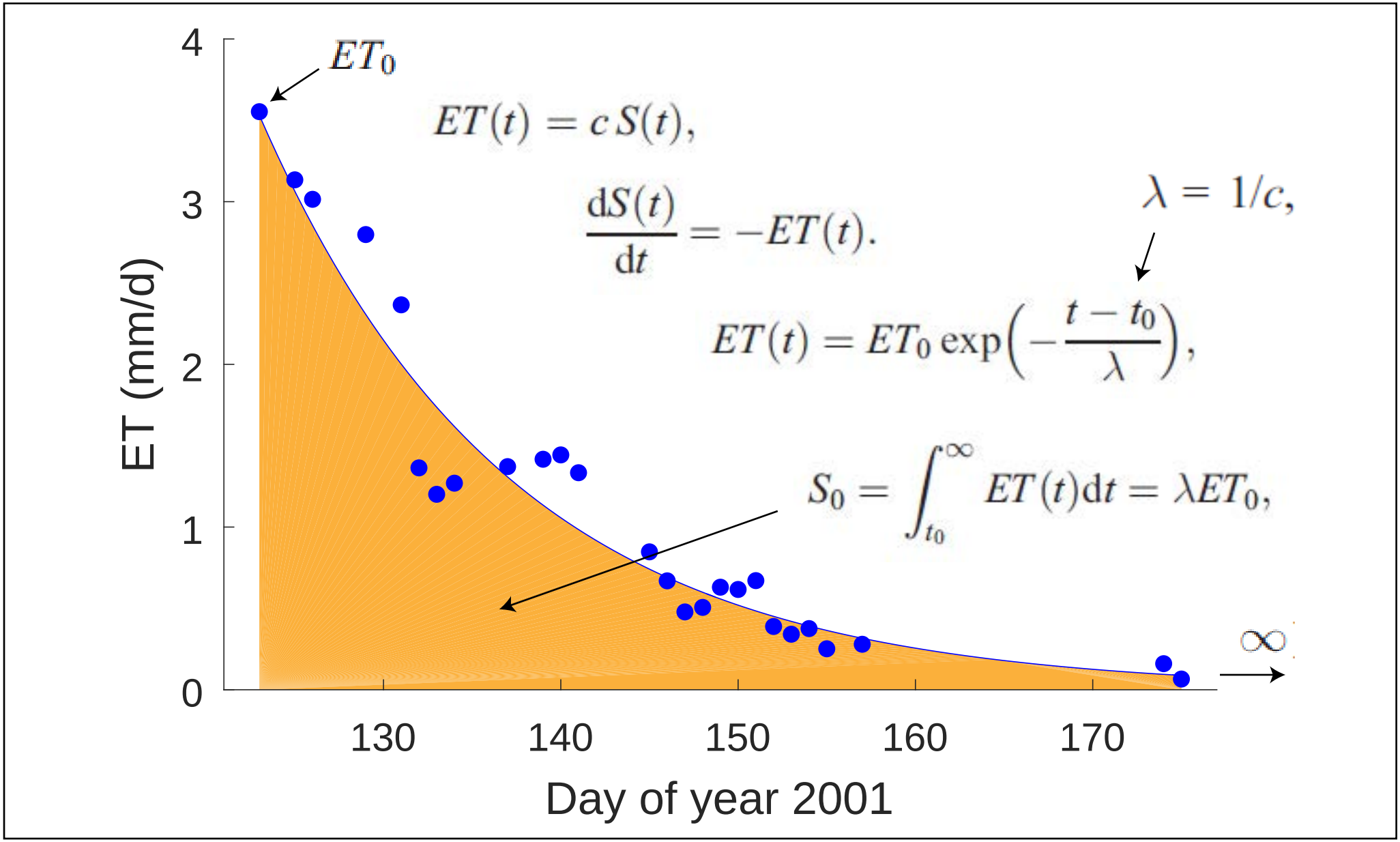




Buitink et al. (2020), *Hydrology and Earth System Sciences* **24**

WAGENINGEN
UNIVERSITY & RESEARCH

Soil moisture limitation: ET recession

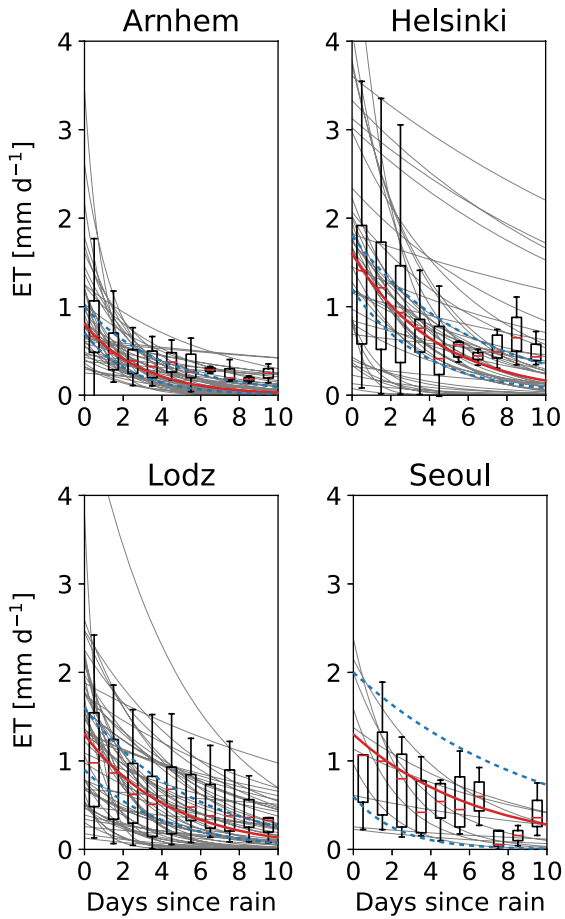


Teuling et al. (2006), *Geophys. Res. Lett.* **33**

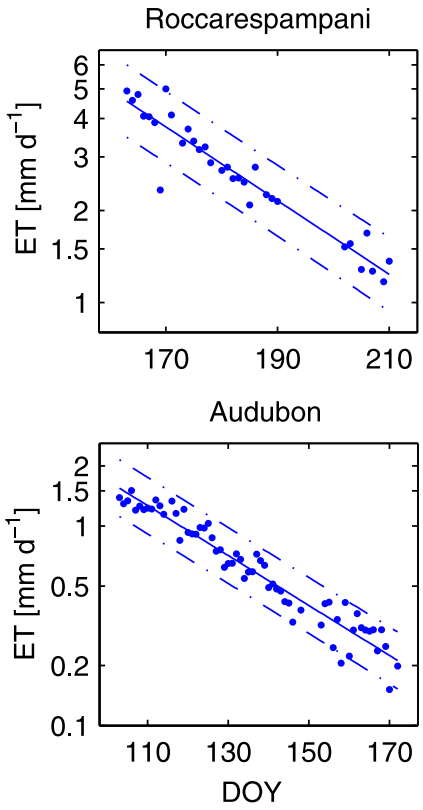
WAGENINGEN
UNIVERSITY & RESEARCH

Timescales of ET recession during drought

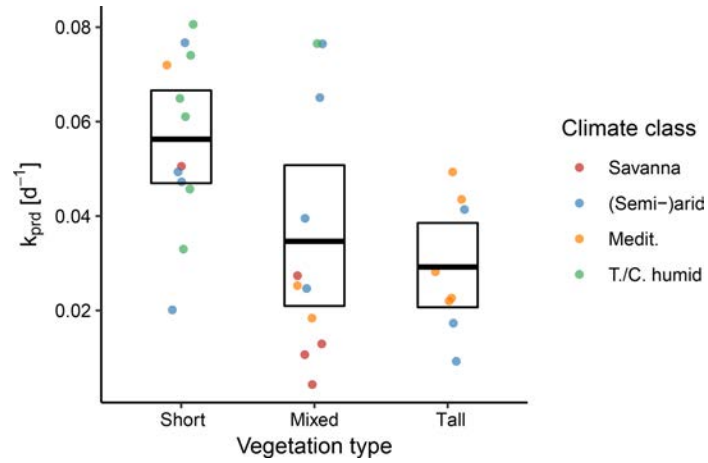
Quick recession in urban areas (k~5 d)



Natural landscapes take weeks to dry out (k~20 d)



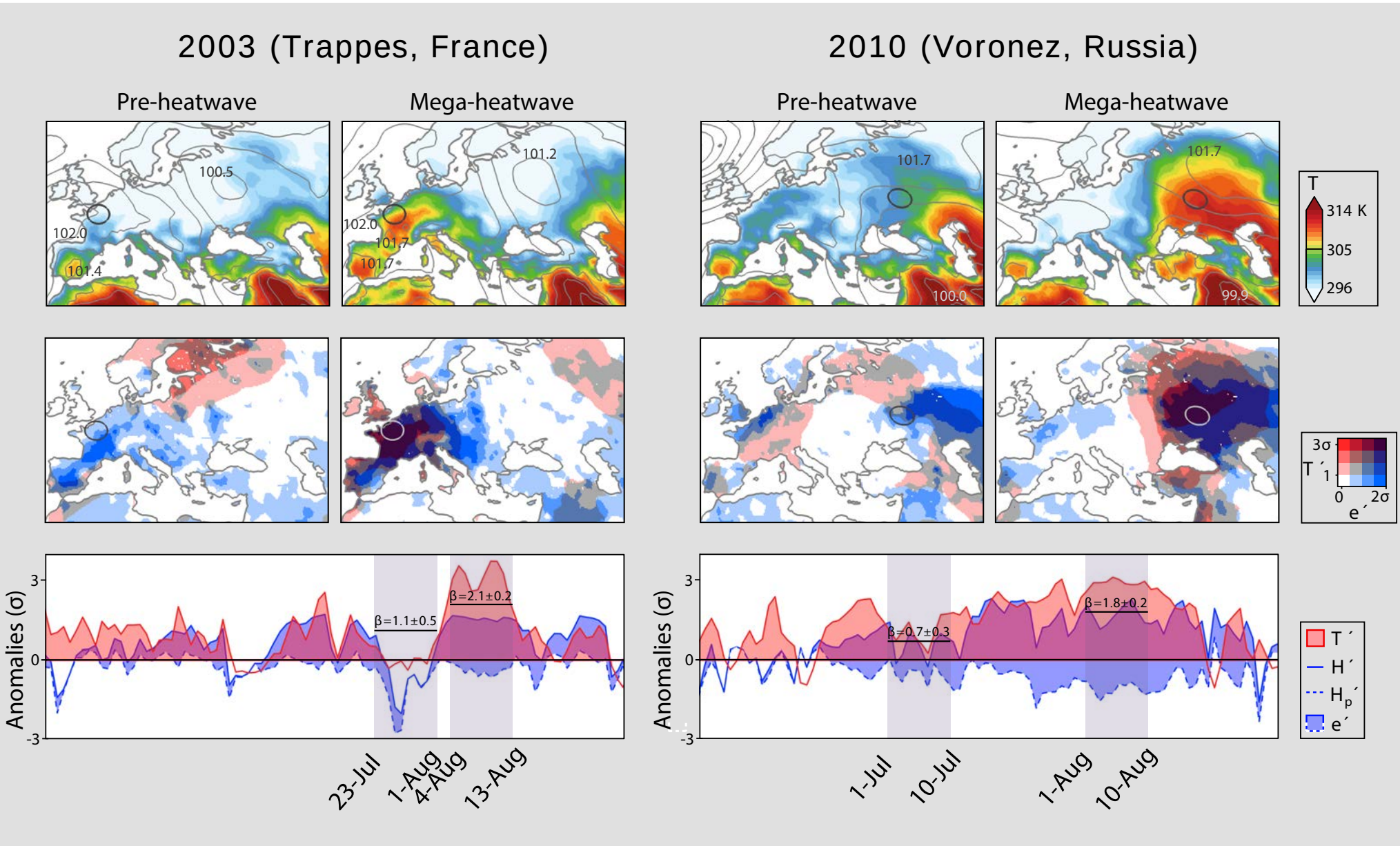
Short vegetation dries out faster (k~14 d) than forests (k~30 d)



Teuling et al. (2006), *Geophysical Research Letters* **33**
Boese et al. (2019), *Biogeosciences* **16**
Jongen et al. (2022), *Geophysical Research Letters* **49**

WAGENINGEN
UNIVERSITY & RESEARCH

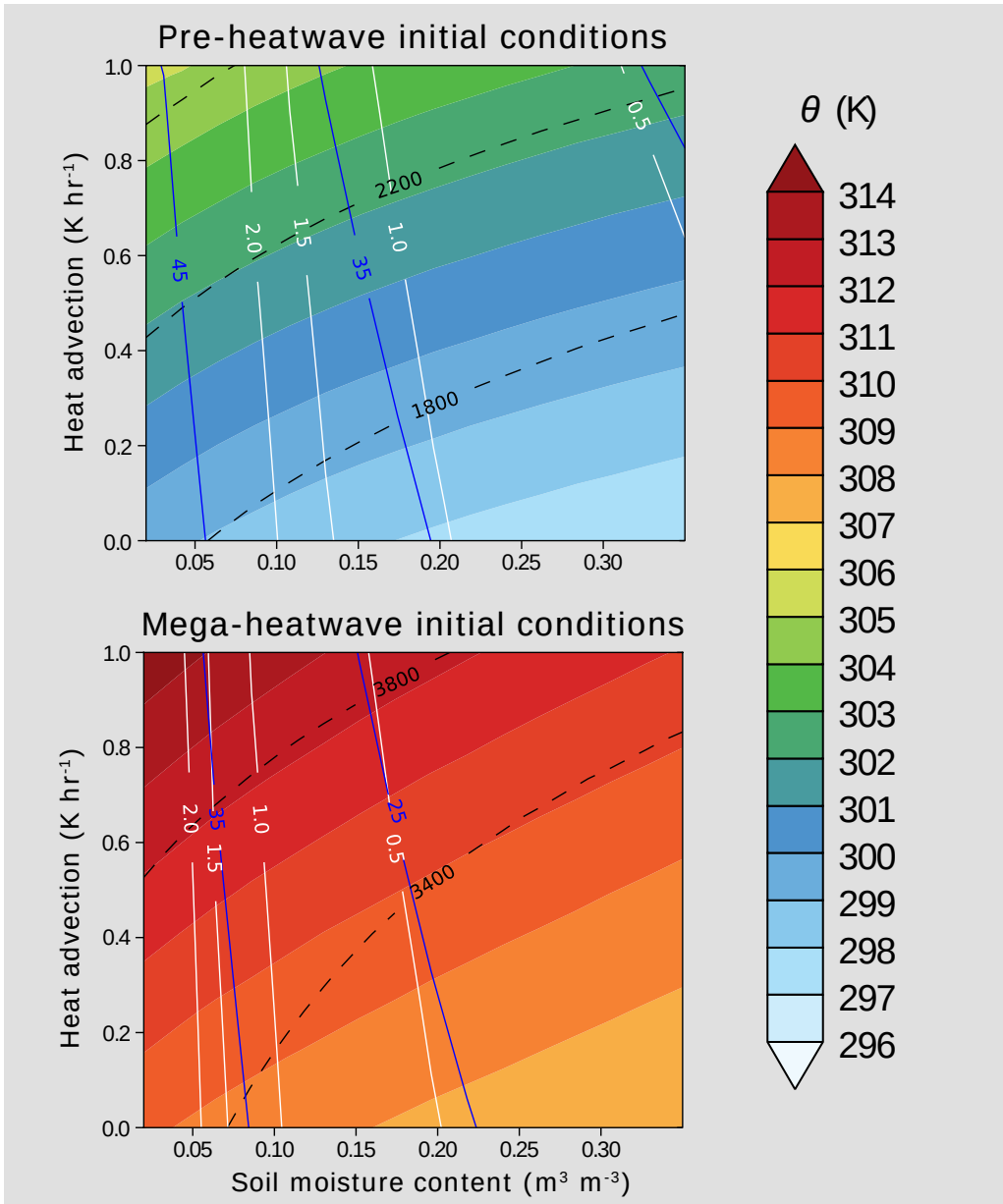
Drought-heat link during mega-heatwaves

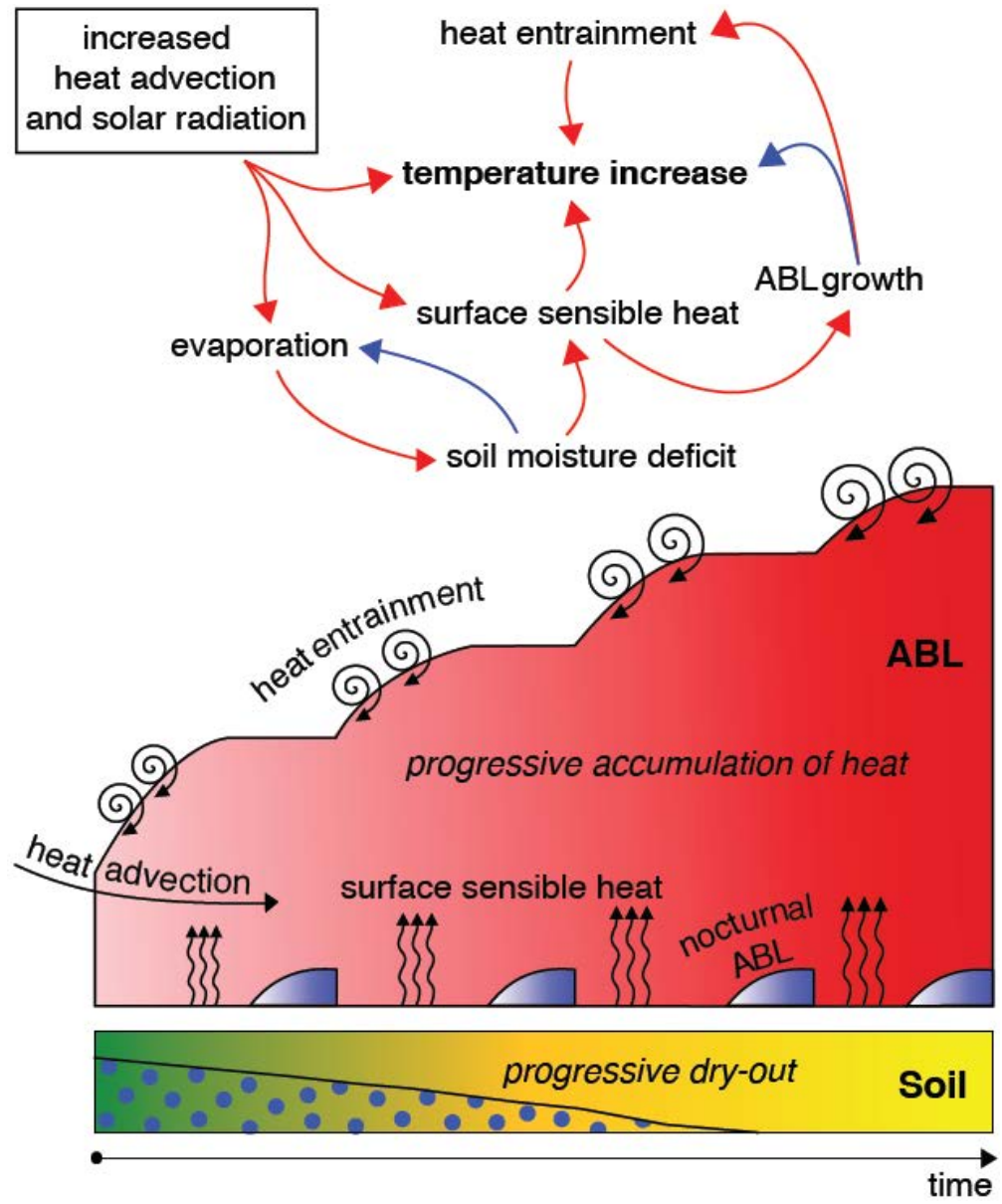


Miralles et al. (2014), *Nature Geoscience* **7**

WAGENINGEN
UNIVERSITY & RESEARCH

Mega-heatwave temperatures explained

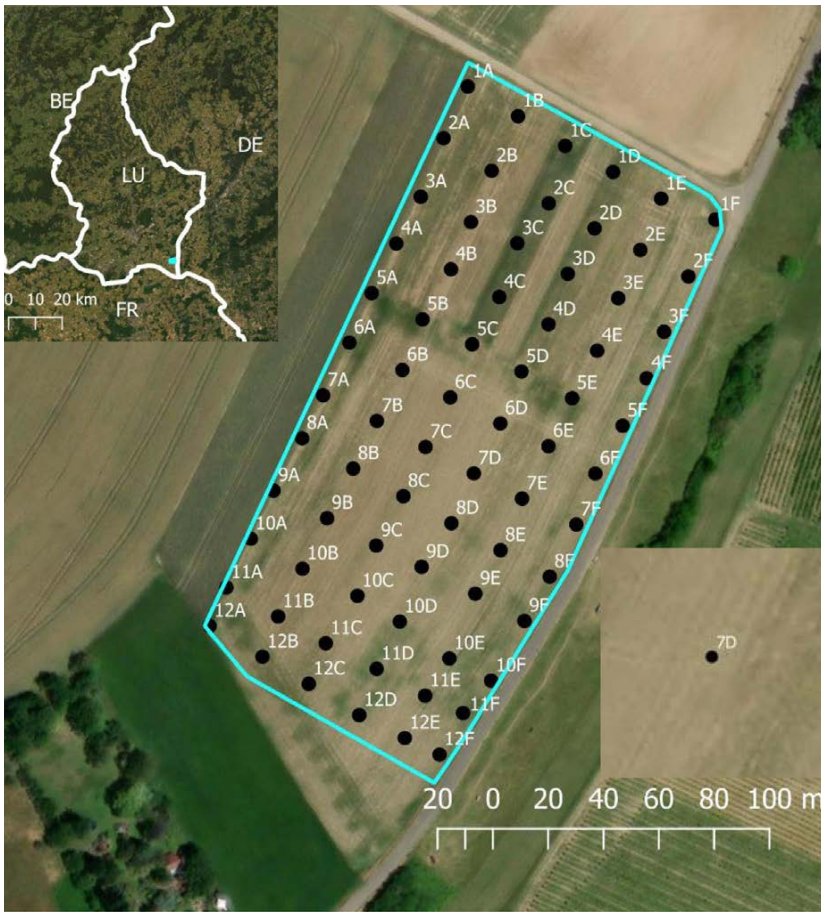


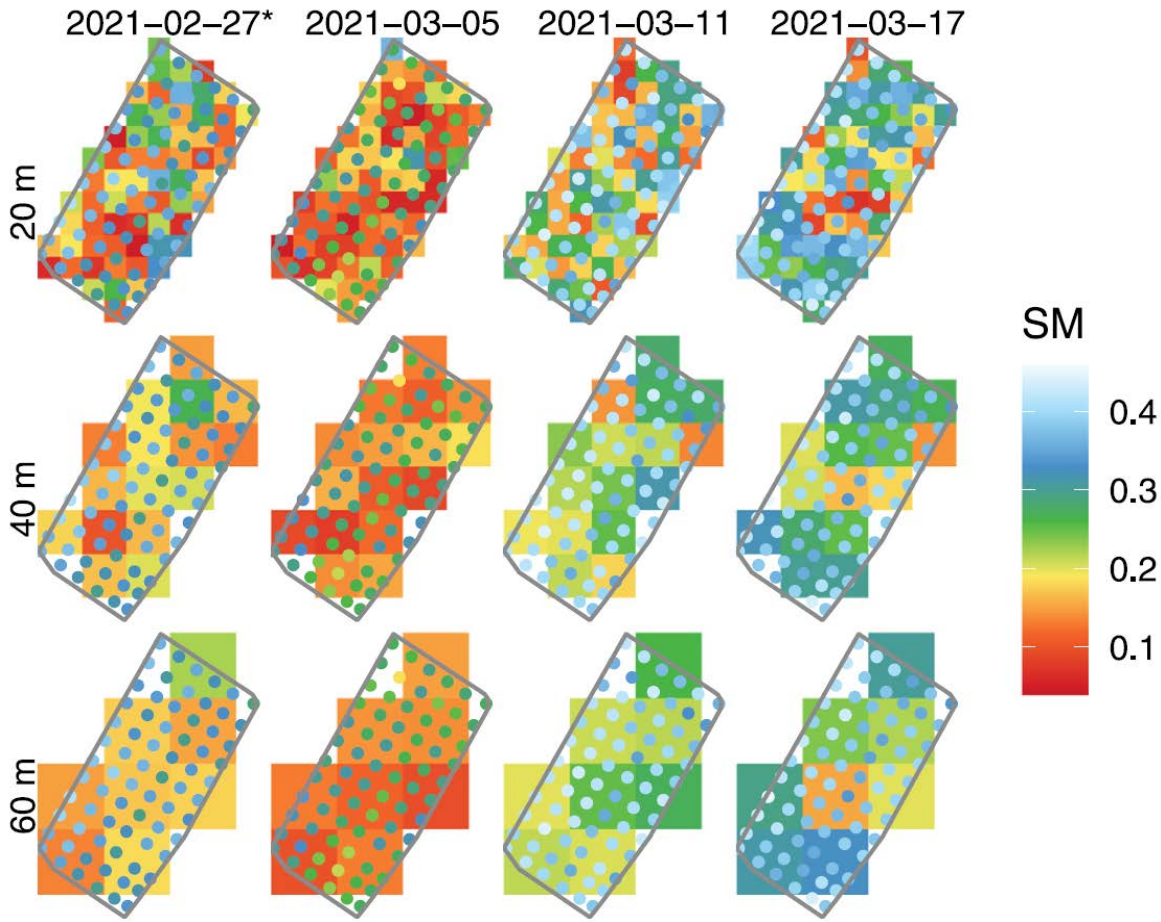


Miralles et al. (2014), *Nature Geoscience* **7**

WAGENINGEN
UNIVERSITY & RESEARCH

High-resolution soil moisture from space?

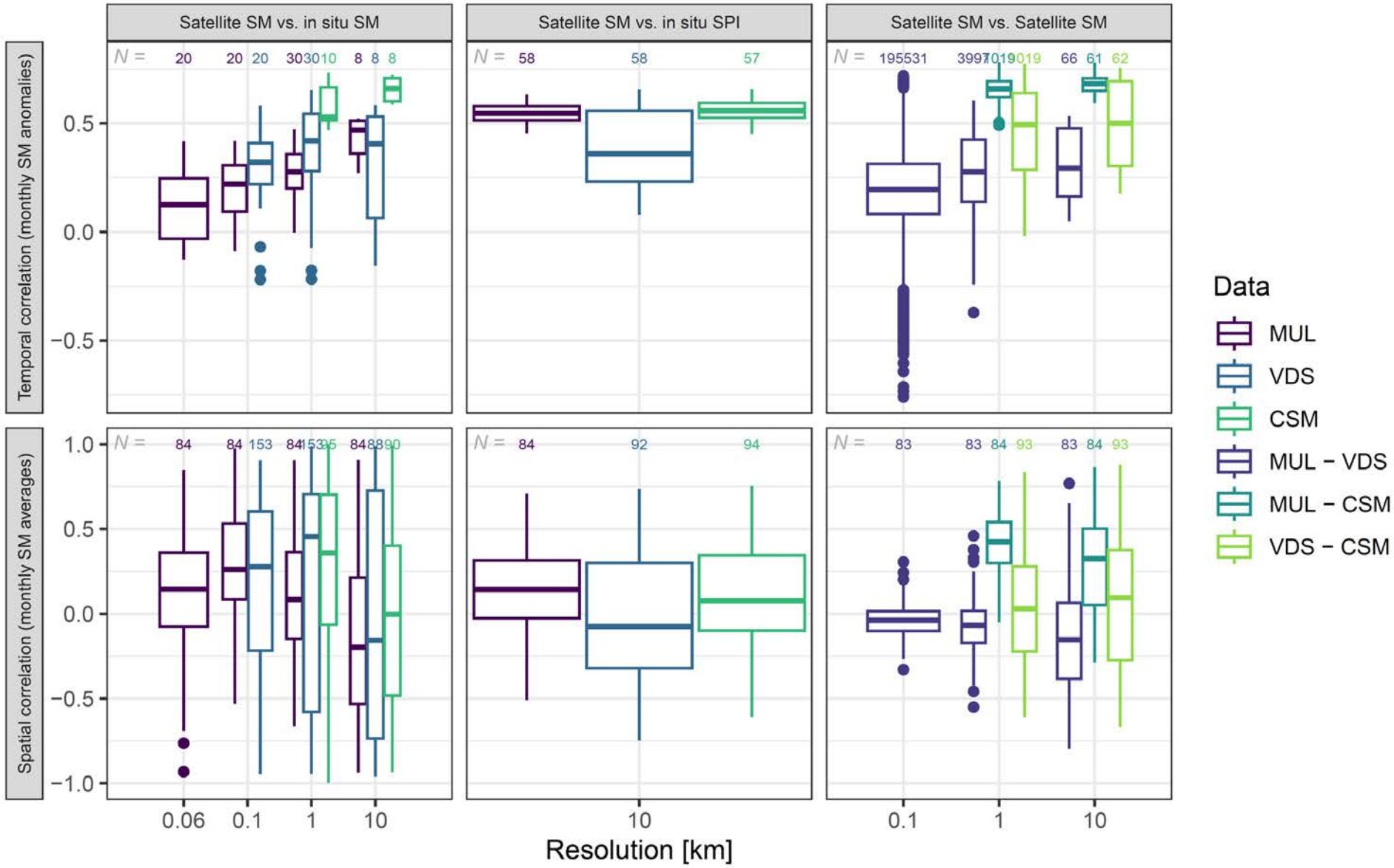




van Hateren et al. (2023), *International Journal of Applied Earth Observation and Geoinformation* **120**

WAGENINGEN
UNIVERSITY & RESEARCH

Accuracy of current soil moisture products



van Hateren et al. (2023), *in preparation*

WAGENINGEN
UNIVERSITY & RESEARCH

Take home messages

- Nonlinear and slow response of fluxes to soil moisture
- Strong land cover impact on warming during heatwaves
- ABL warming important mechanism in mega-heatwaves
- High-resolution soil moisture remote sensing promising