Land-atmosphere coupling during compound extreme heat events in the LUCAS experiment with extreme land use changes: a new coupling metric for climate extremes

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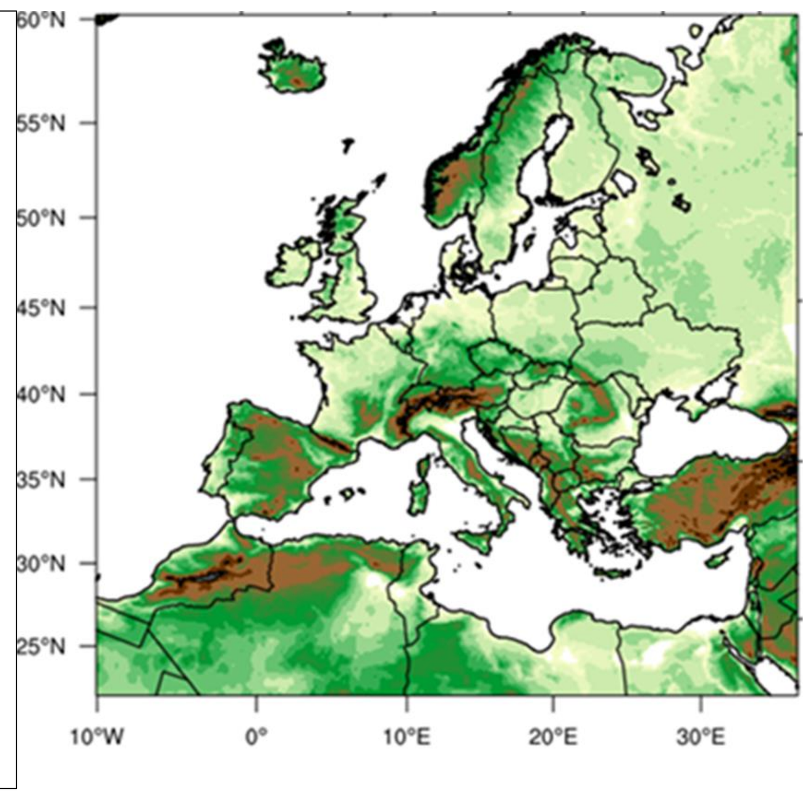
Abstract

Land use/land cover changes (LUC) modify local land surface properties that control the land-atmosphere mass, energy, and momentum exchanges. The impact of these changes depends on the scale and nature of land cover modifications and is very difficult to quantify. The Flagship Pilot Study LUCAS (Land Use & Climate Across Scales) provides a coordinated effort to study LUC using an ensemble of regional climate models (RCMs).
Heatwaves can be defined as extreme hot consecutive days and have a variety of direct, indirect, immediate, and delayed impacts, including higher water loss via evapotranspiration, lower yields of agricultural products, severe health problems, increased energy consumption and increase in the duration, size, and intensity of wildfires, causing economic losses and catastrophic environmental impacts.

Data

RCM Simulations

- EURO-CORDEX domain at 0.44º resolution
- ERA-Interim forcing
- 3 Land Use experiments
  - Current vegetation (CORINE)
  - Trees replaced by grassland (GRASS)
  - Grasses and shrubs replaced by trees (FOREST)
- 11 European research institutes



Methods:

- **Daily Maximum Temperature magnitude (MT):**

$$MT(Tx_d) = \begin{cases} \frac{Tx_d - P_{25}}{P_{75} - P_{25}} & if\ Tx_d > P_{25} \\ 0 & if\ Tx_d \leq P_{25} \end{cases}$$

- **Daily Latent Heat Flux Magnitude (MH):**

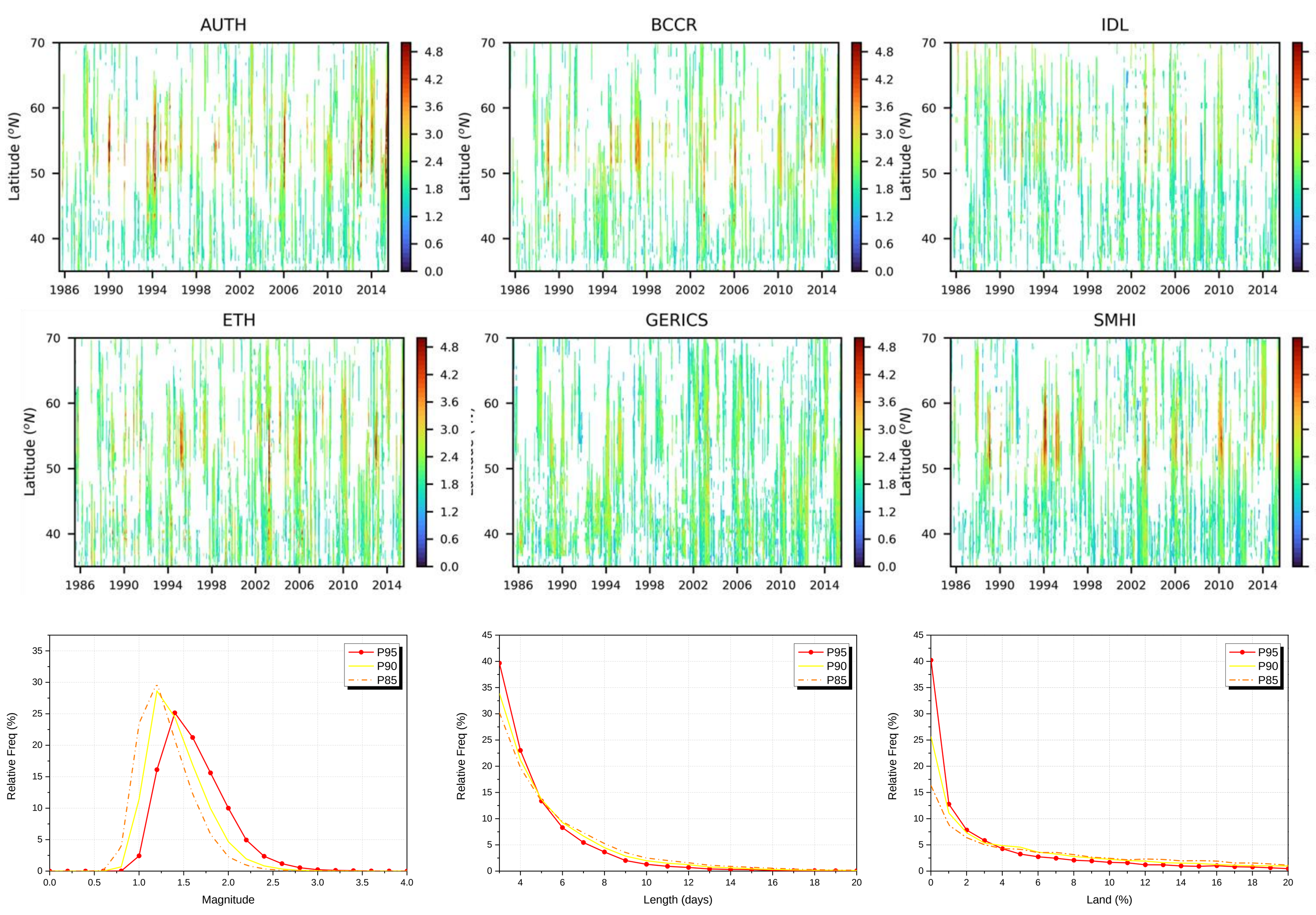
$$MH(hfls_d) = \begin{cases} \frac{hfls_d - P_{h75}}{P_{h75} - P_{h25}} & if\ hfls_d < P_{h75} \\ 0 & if\ hfls_d \geq P_{h75} \end{cases}$$

- **Latent Heat Flux-Temperature Coupling Magnitude (LETCM):**

$$LETCM = \sum MT(Tx_d) * MH(hfls_d)$$

P_{75} and P_{25} daily percentiles centred on a 91 day window
$Tasmax > P_d$ daily percentile centred on a 31 day window
Heat Wave: Tasmax > P85, P90, P95 for at least 3 consecutive days

Heat Wave Events 1986-2015

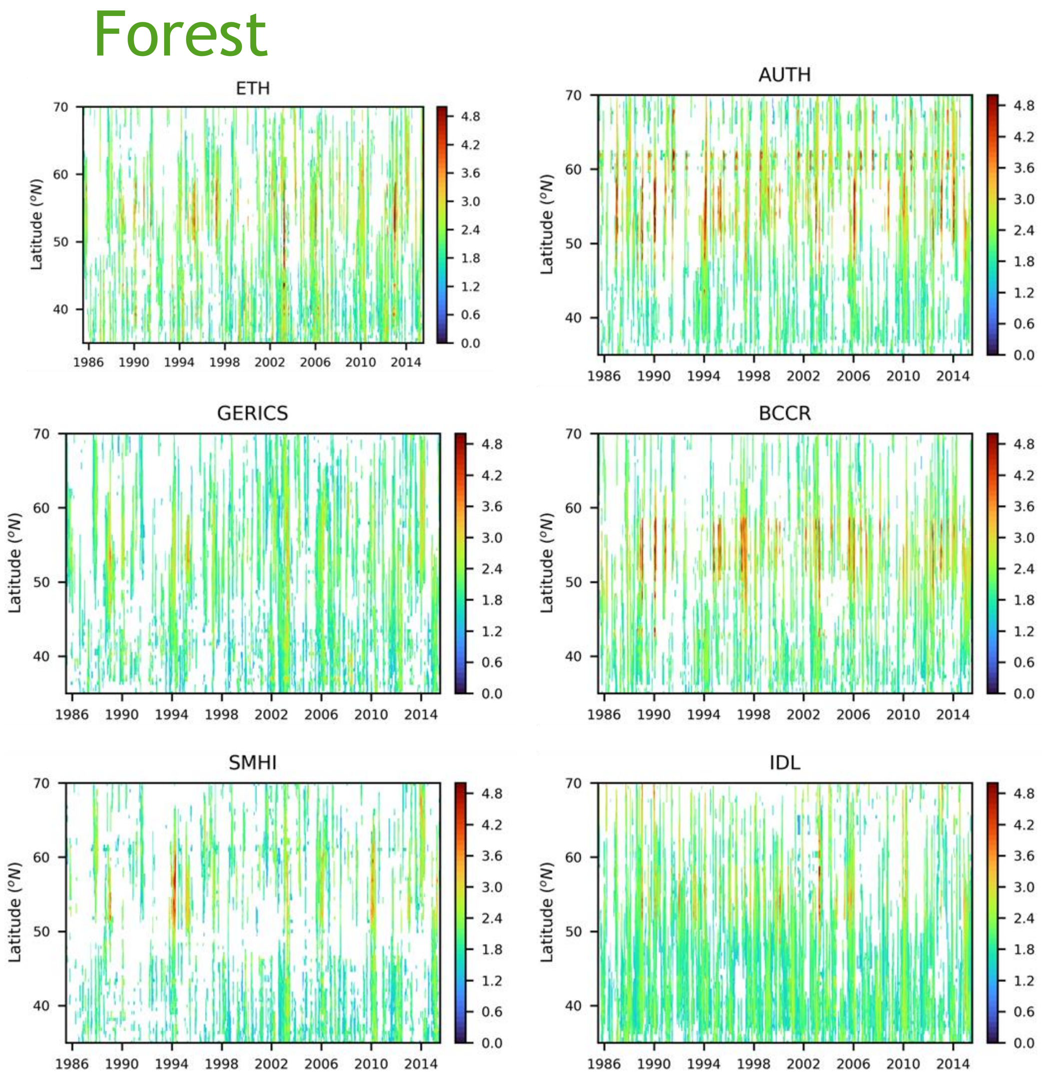


Corine

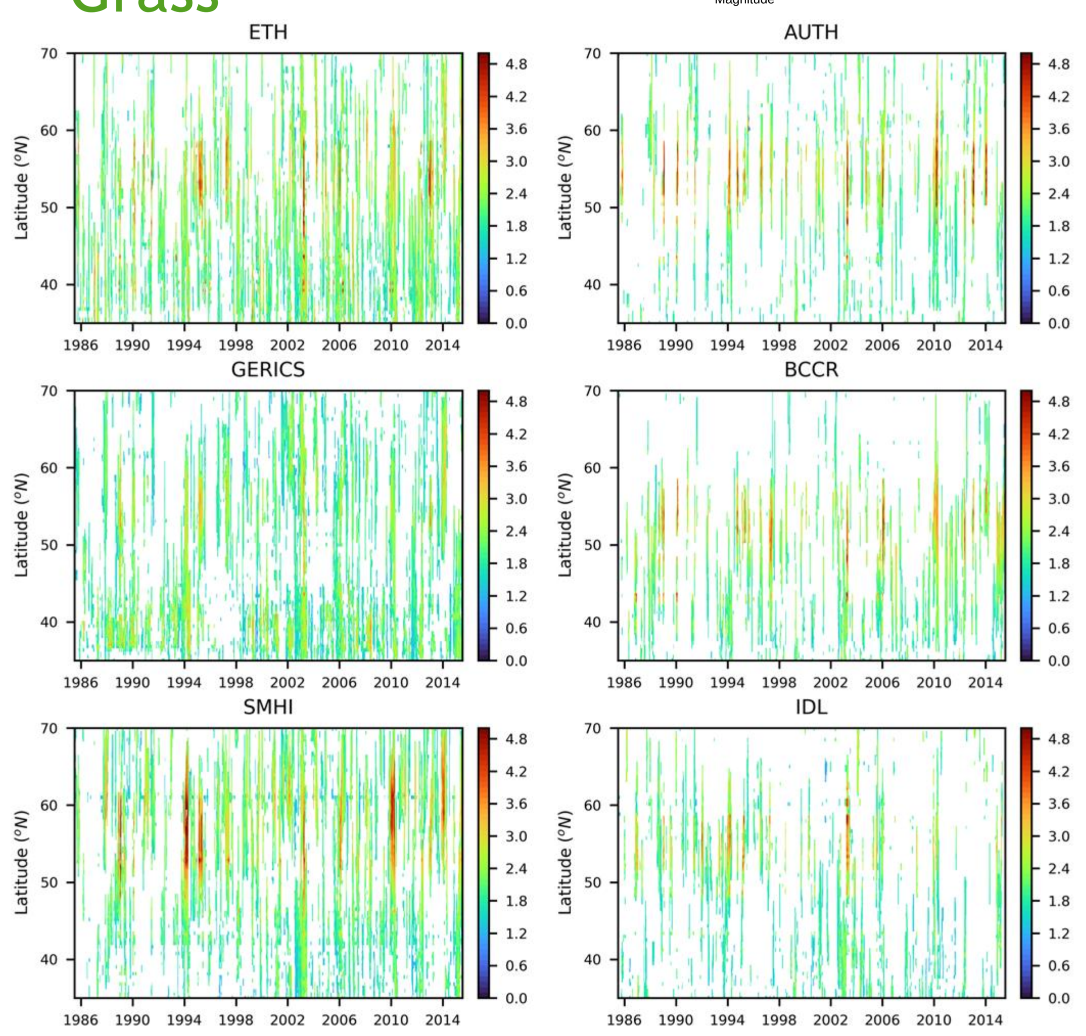
Although with some differences in magnitude, the models can represent the major European heat waves, e.g. 1994, 2003,2006, 2010, 2015.

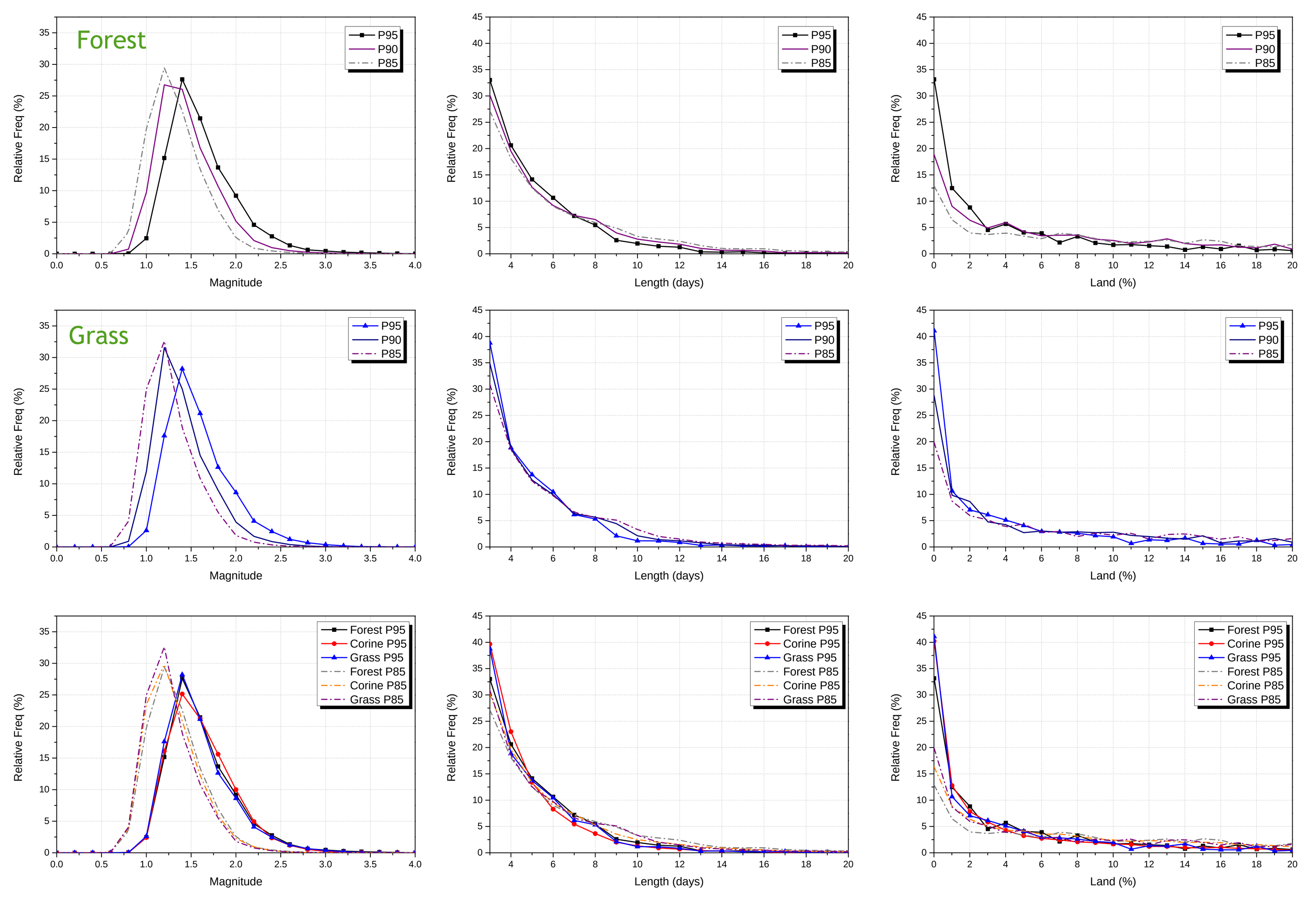
Larger percentiles are associated to shorter, but more intense heat waves. 95% of extreme heat waves have a maximum range of only 2% of the European continent

Forest



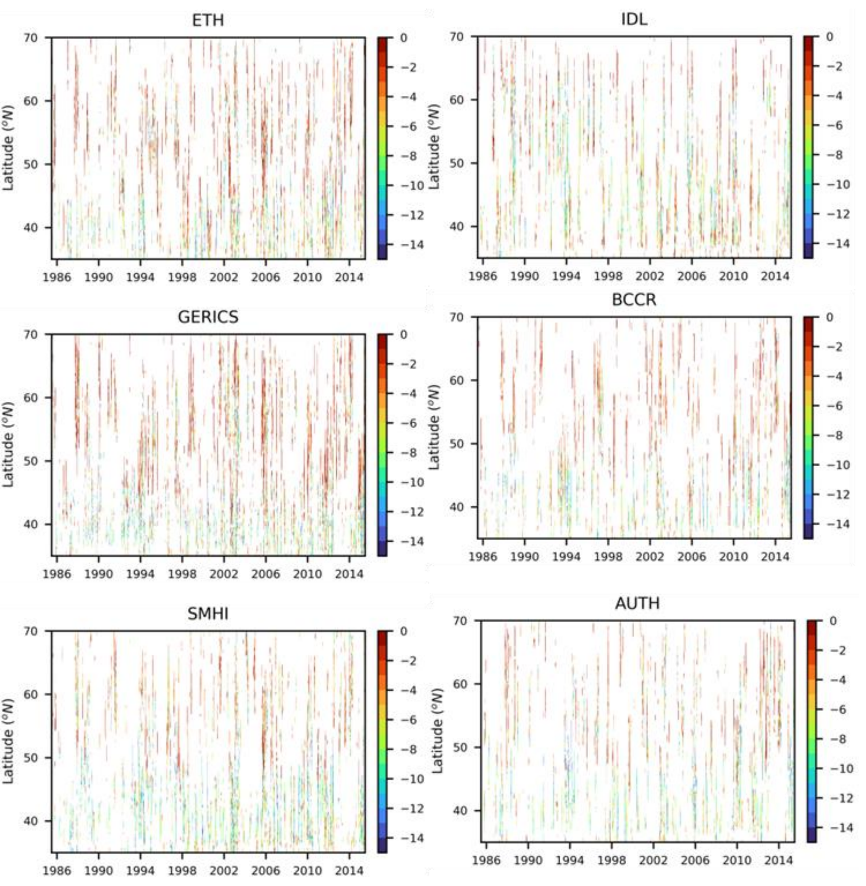
Grass





LETCM

Corine



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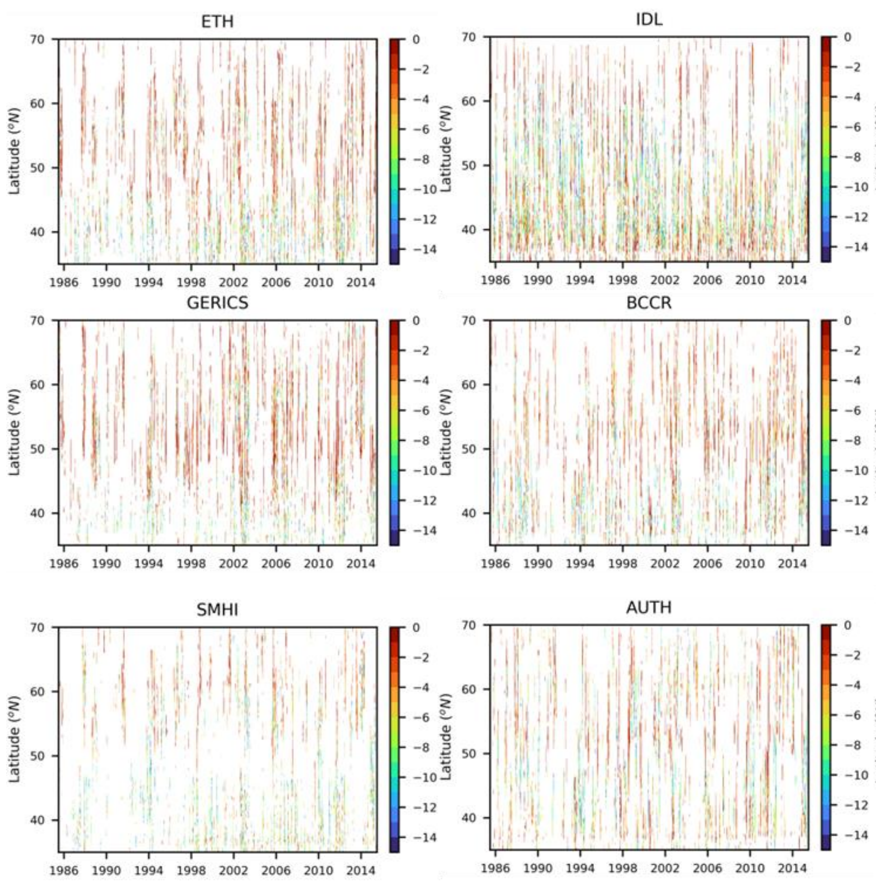

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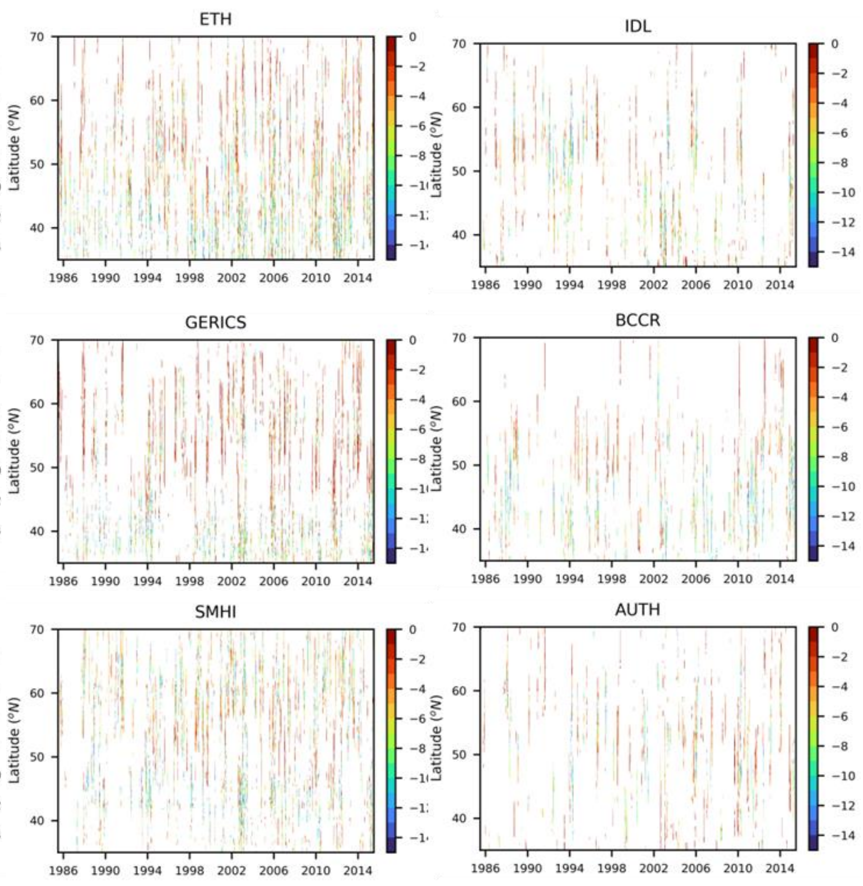

Conclusions

- Afforestation induces an increase in the number of heat waves
- The new extreme heat and latent heat metric emphasises positive temperature extremes associated to reduced evapotranspiration.
- High LETCM values in afforestation show that the increased evapotranspiration in forests during spring, induces low soil moisture during summer which enhances heat waves
- The number, amplitude and spatial distribution of compound extreme heat and evaporation is highly model dependant
- The impact of afforestation or deforestation is not consistent across models

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