EGU2017-1930: Climatic and landscape controls on travel time distributions across Europe

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1. Introduction

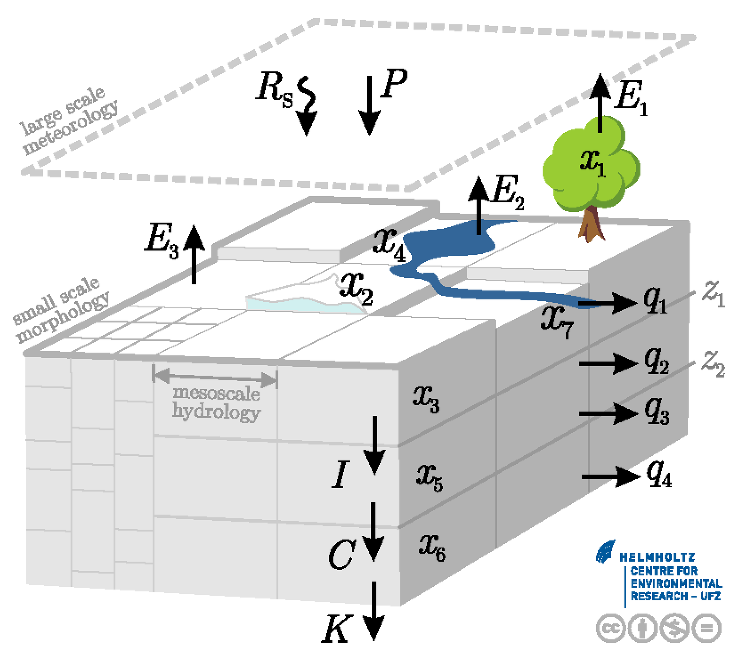
Travel time distributions (TTDs) are fundamental descriptors to characterize the functioning of storage, mixing and release of water and solutes in a river basin. Identifying the relative importance (and controls) of climate and landscape attributes on TDDs is fundamental to improve our understanding of the underlying mechanism controlling the spatial heterogeneity of TTDs, and their moments (e.g., mean TT). Studies aimed at elucidating such controls have focused on either theoretical developments to gain (physical) insights using mostly synthetic datasets or empirical relationships using limited datasets from experimental sites. A study painting a general picture of emerging controls at a continental scale is still lacking.

2. Research Objectives

- To characterize the spatio-temporal variability of TTDs in the vadose zone across the European region.
- To identify the dominant controls of climate and landscape attributes on the spatial heterogeneity of the mean travel time.

3. Modeling Framework

- We used a well-constrained grid-based mesoscale Hydrologic Model (mHM) [1, 2, 3] to generate the spatially resolved daily water fluxes and states (e.g., infiltration I, evapotranspiration E, soil moisture S) across Europe at 25 km spatial resolution for the period 1950-2015.
- mHM uses a Multiscale Parameter Regionalization (MPR) technique [1, 2] that accounts for the sub-grid variability of landscape features like terrain, soil and vegetation characteristics (at 500 m) across Europe.



Hydrologic components of mHM [1, 2]
(http://www.ufz.de/mhm/)

State equations: cell i, time t:

$$\dot{\mathbf{x}}_i(t) = \mathbf{f}(\mathbf{x}_i, \mathbf{u}_i, \boldsymbol{\beta}_i) + \boldsymbol{\eta}_i(t) \quad \forall i \in \Omega$$

Output (e.g., runoff):

$$\mathbf{q}(t) = \mathbf{g}(\mathbf{x}, \mathbf{u}, \boldsymbol{\beta}) + \boldsymbol{\epsilon}(t)$$

Multiscale parameterization:

$$\beta_i = \mathrm{O}\left\langle \beta_j \quad \forall j \in i \right\rangle_i$$

$$\beta_j = \mathrm{w}(\mathbf{u}_j, \boldsymbol{\gamma})$$

$\mathbf{f}, \mathbf{g}$ system and output functional relationships
$\mathbf{x}$ state variables
$\mathbf{q}$ l-dimensional output vector
$\mathbf{u}$ fields of physiographical and meteorological variables
η unmeasurable stochastic inputs
ϵ system's uncertainty due to measurements defects

β distributed model parameter field
γ global (or calibration) parameters
w transfer or regionalization function
O upscaling operators
i, j cell location indexes at model grid and sub-grid levels

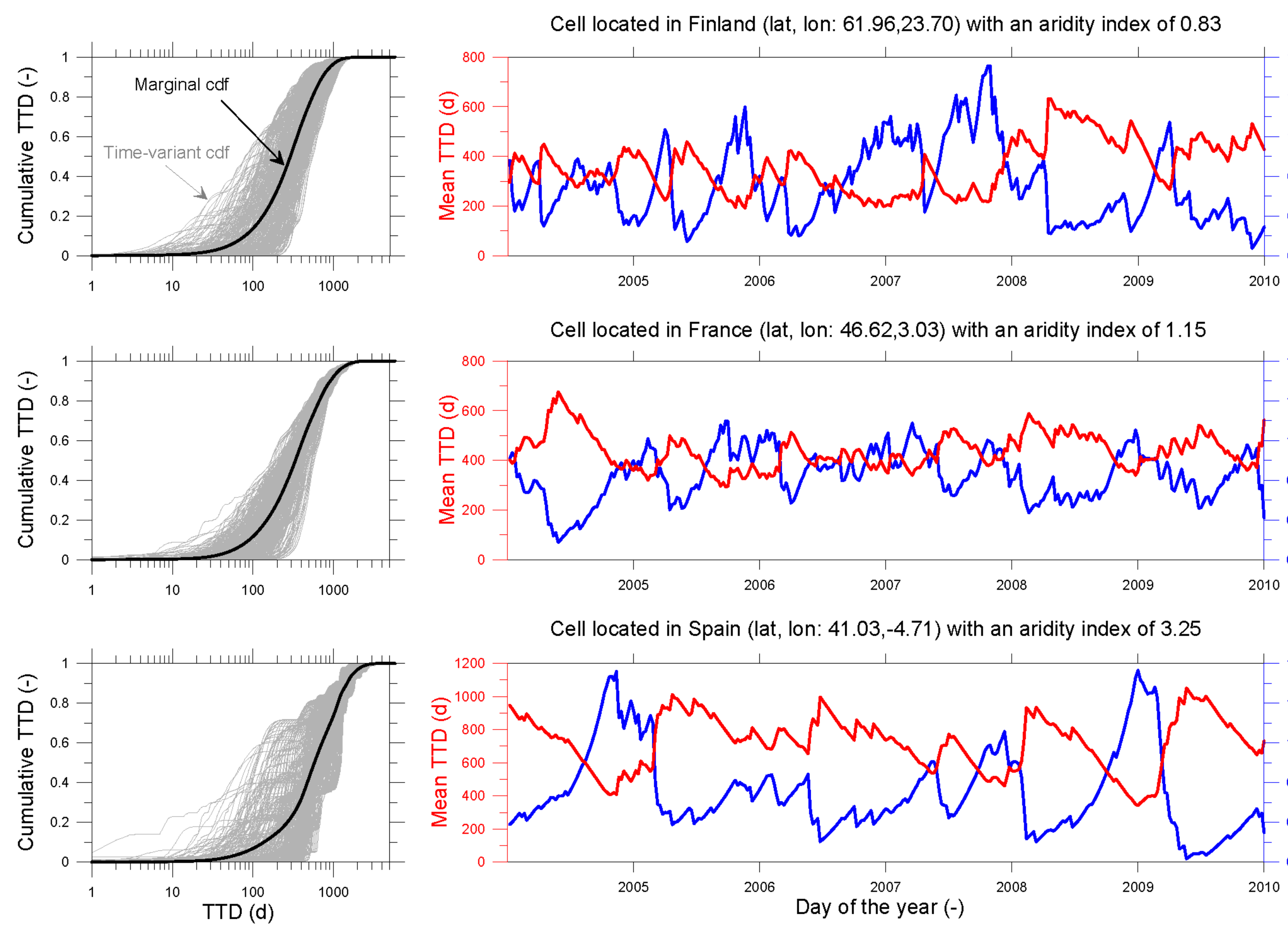
4. Formulation of Travel Time Distributions (TTDs)

We used the analytical derivation given by *Botter et al., (2010)* [4] to calculate the time-variant forward TTD ($\overrightarrow{p}_{I_{out}}$) to infer the life expectancy of the water parcel entering at the time t_{in}. Under the assumption of random sampling, the $\overrightarrow{p}_{I_{out}}$ for a given soil layer can be estimated as

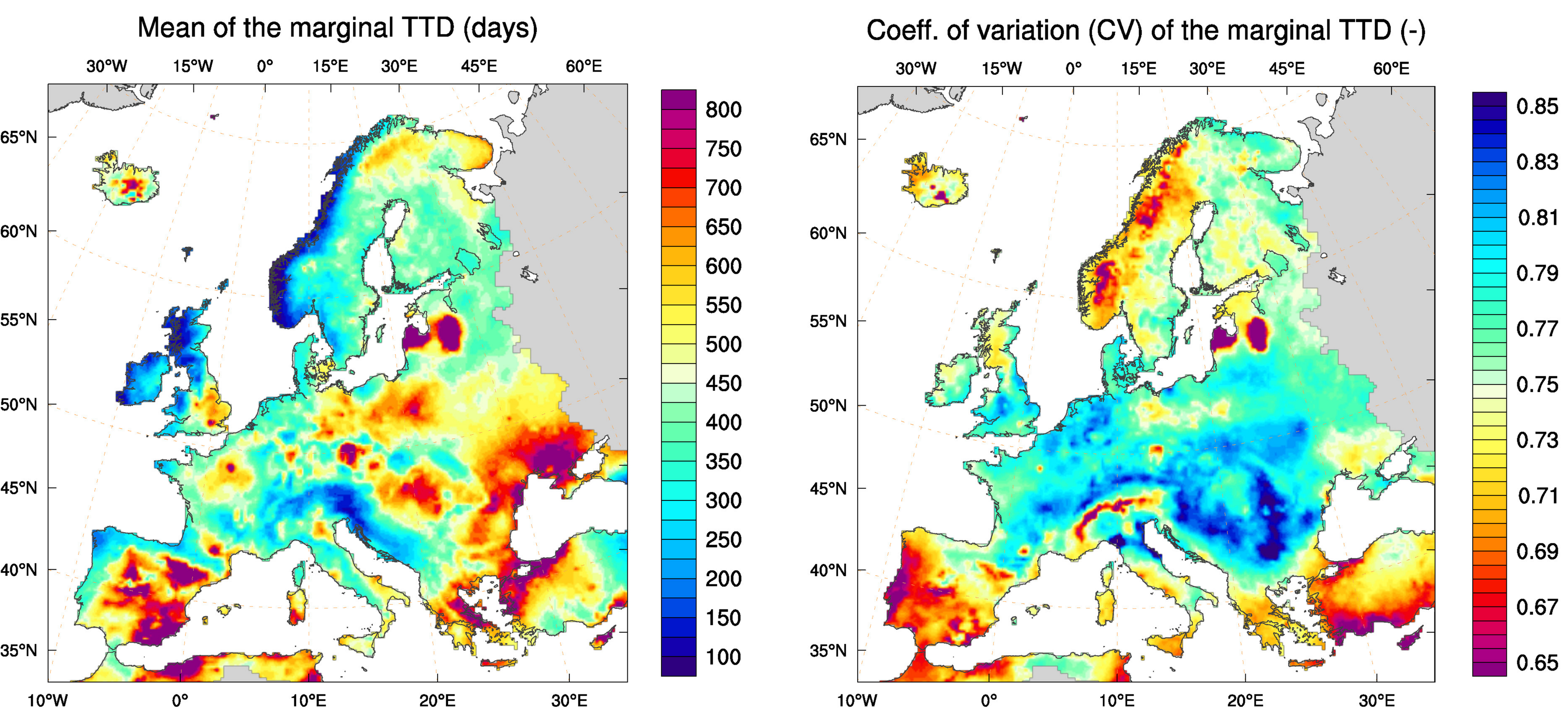
$$\overrightarrow{p}_{I_{out}}(t-t_{in}, t_{in}) = \frac{I_{out}(t)}{\theta(t_{in})\, S(t)} \exp\left(-\int_{t_{in}}^{t} \frac{I_{out}(t') + \mathrm{ET}(t')}{S(t')} \mathrm{d}t'\right)$$

with t being the chronological time ($t > t_{in}$) and the function $\theta(t_{in})$ describes the portion of the water parcel entering at t_{in} that leaves as I_o.

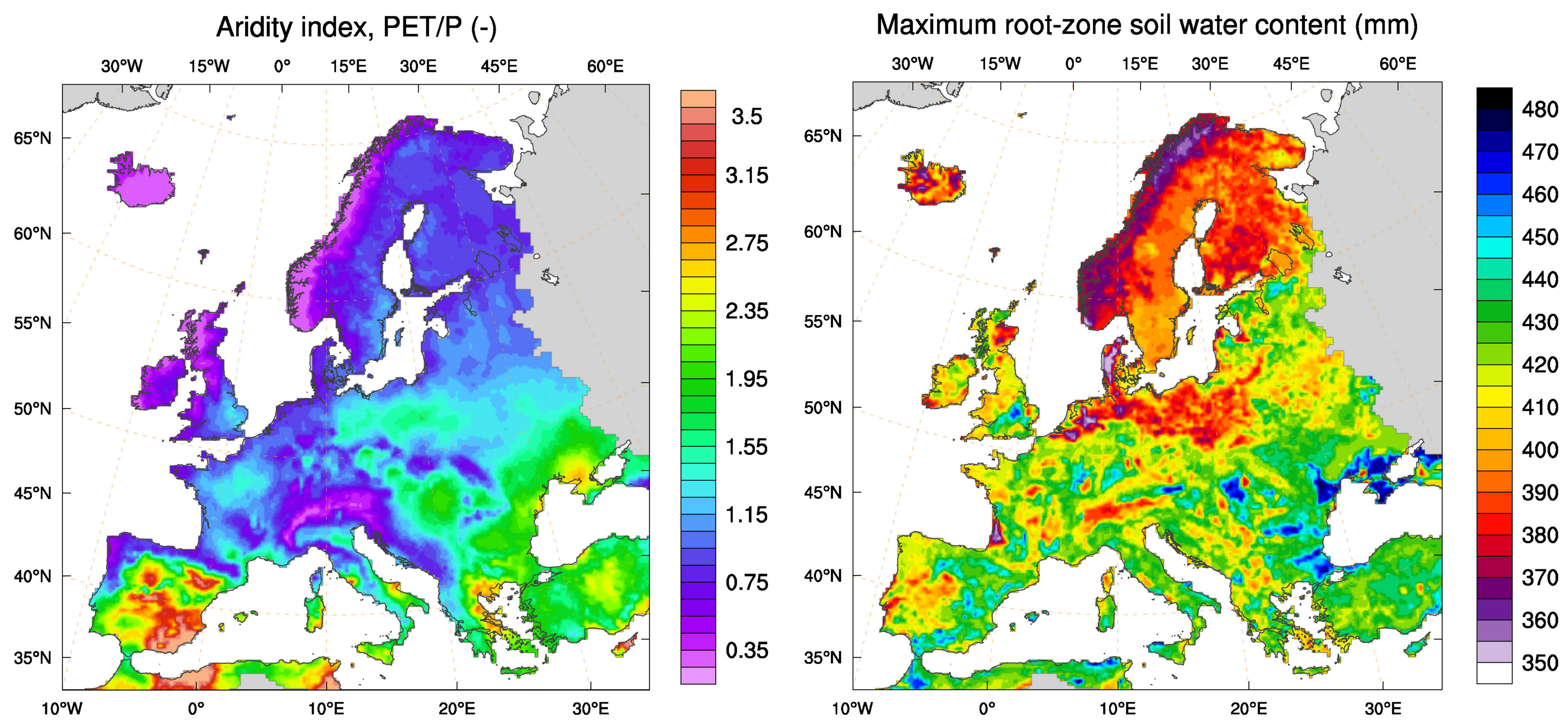
5. Spatio-temporal Variations of TTDs across Europe

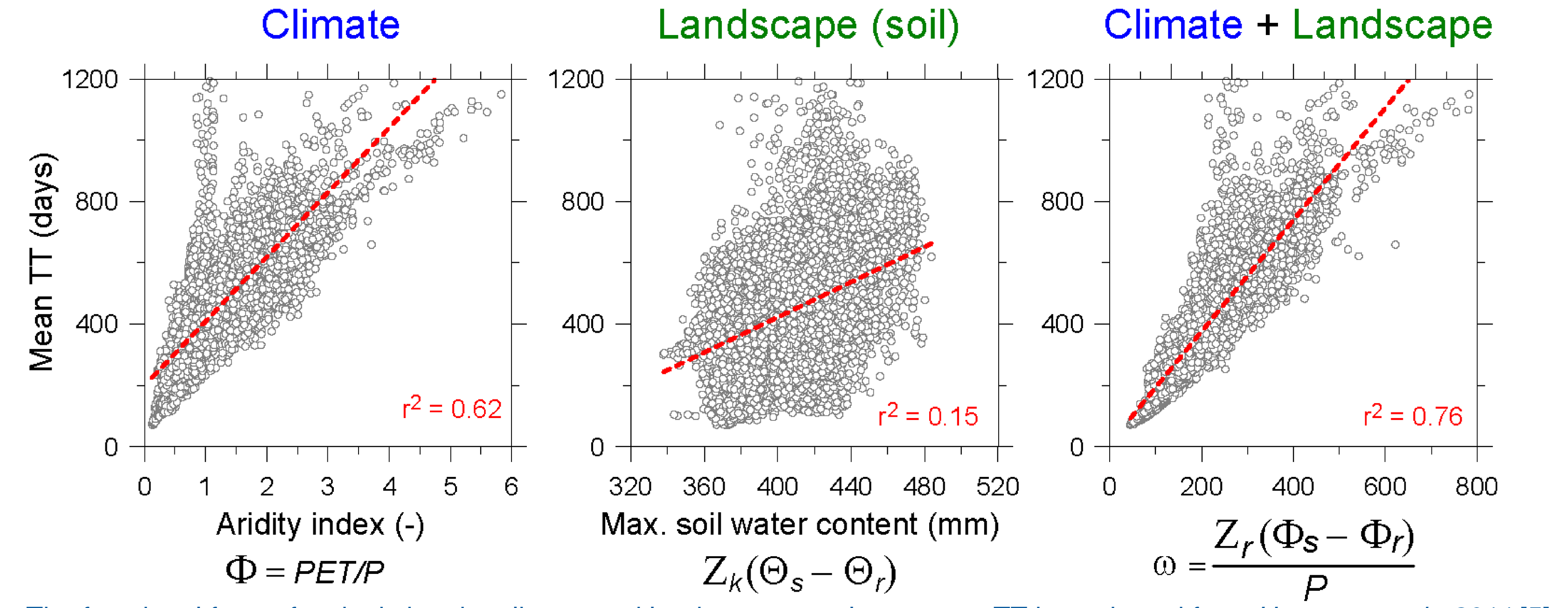


Left: CDFs of the time-variant and marginal (time averaged) TTDs. Right: Mean and CV of the time-variant TTDs.

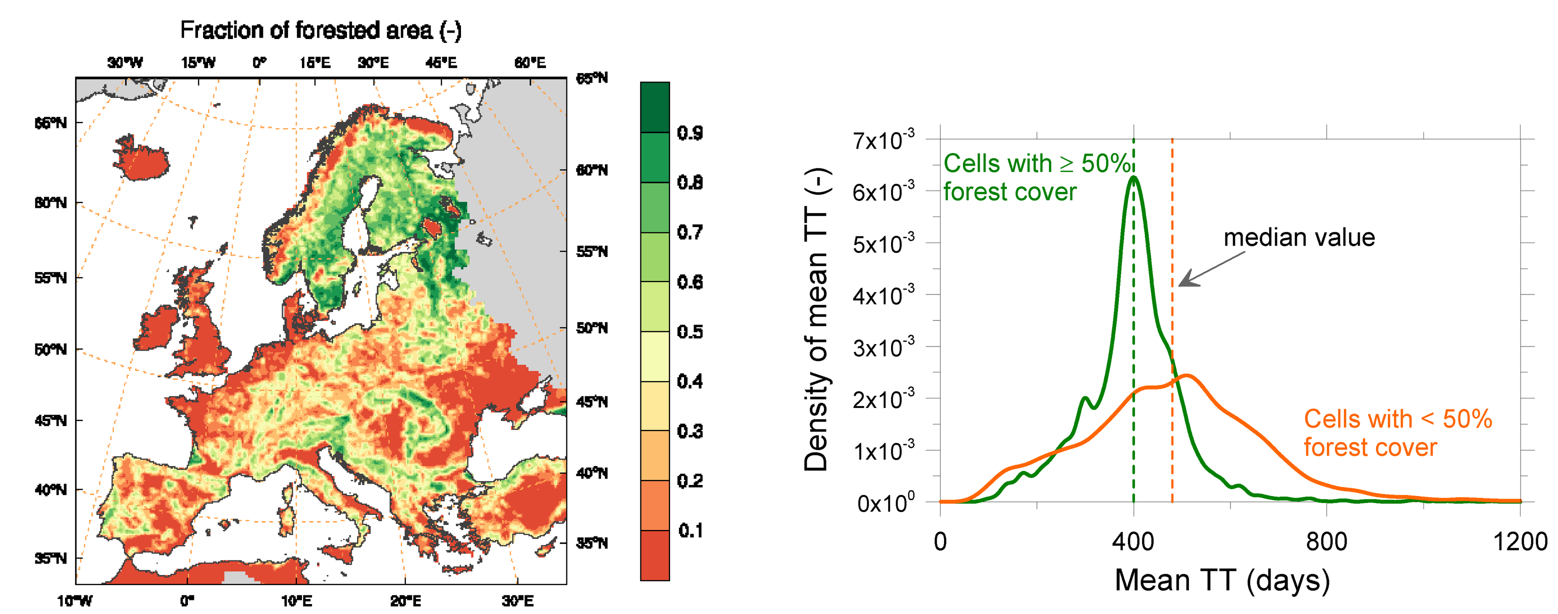


6. Climate/Landscape Controls on Mean TT





The functional form of ω depicting the climate and landcape controls on mean TT is motivated from *Harman et. al., 2011* [5]



7. Conclusions

- The TTDs in the vadose zone exhibited a considerable variability in space and time across the European region.
- While the climatic gradient across the Pan-EU provided the primary control on the spatial variability of the mean TT, accounting for heterogeneity of landscape attributes significantly strengthen such control.

[1] Samaniego, L., et al. (2010), http://dx.doi.org/10.1029/2008WR007327
[2] Kumar, R., et al. (2013), http://dx.doi.org/10.1029/2012WR012195
[3] Rakovec, O., et al. (2016), http://dx.doi.org/10.1175/JHM-D-15-0054.1
[4] Botter, G., et al., (2010), http://dx.doi.org/10.1029/2009WR008371
[5] Harman, C. J., et al., (2011), http://dx.doi.org/10.1029/2010WR010194

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