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Ecological memory effects in Norway spruce ring-width chronologies across managed forests in Central-East Germany: Implications for modelling and planning

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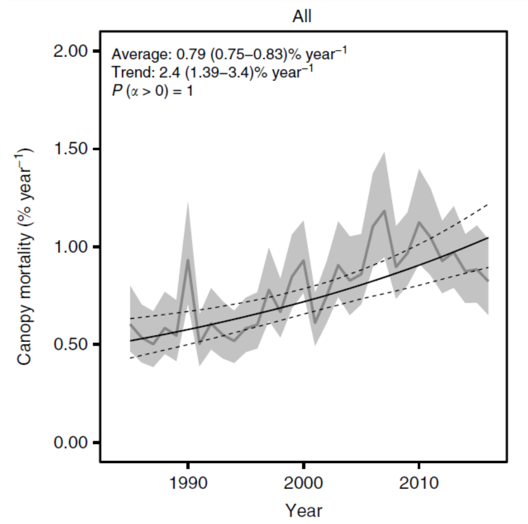
Objectives

Senf et al. (2018)



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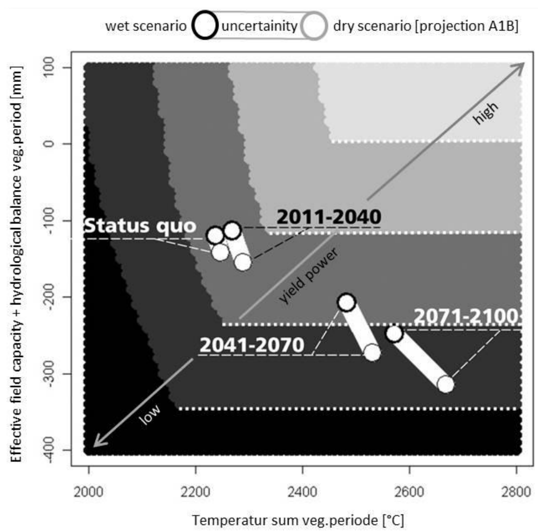
Canopy mortality has doubled in Europe's temperate forests over the last three decades

Cornelius Senf [1,2], Dirk Pflugmacher[1], Yang Zhiqiang[3], Julius Sebald[2], Jan Knorn[1], Mathias Neumann [2], Patrick Hostert [1,4] & Rupert Seidl [2]

- Canopy mortality Germany: 1.47 (−0.58 to 3.53)% year^{-1}
- Temperature increase distinctly drives canopy mortality
- Canopy degradation encompasses tree harvesting (planned and salvage logging due to secondary pests)

Albert & Schmidt (2012)

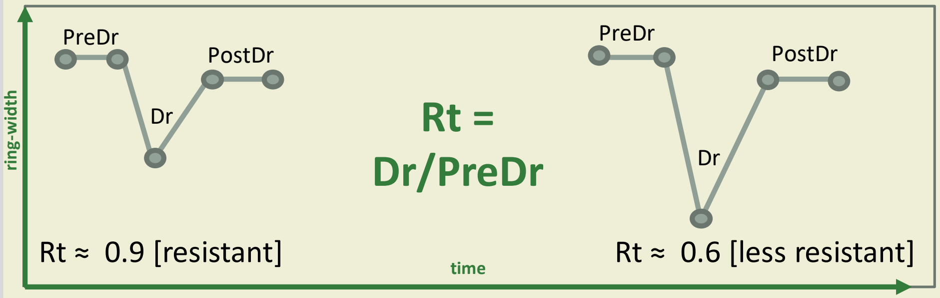


- Norway spruce (*Picea abies [L.] H. KARST*) covers 30% of Central Europe's forest area (14x10^6 ha, Pretzsch 2012)
- Site requirements Norway spruce:
  - rainfall > 850 mm yr^{-1}
  - particularly sensitive to droughts during boreal summer
- Climate scenarios imply hotter droughts leading to increased mortality & reduction of yield power (see graphic)

Hypothesis & Data

Hypothesis: The *drought tolerance* of Norway spruce depends on the *memory of trees*

„Drought tolerance“ [Resistance index (Rt)]



Lloret et al. (2011)

[**PreDr**] Pre-drought (mean ring-width 3 years **prior** to the event)
[**PostDr**] Post-drought (mean ring-width 3 years **after** the event)
[**Dr**] ring-width of the event-year

„Tree‘s memory“


Contents lists available at ScienceDirect

Dendrochronologia

journal homepage: www.elsevier.com/locate/dendro

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Signals and memory in tree-ring width and density data

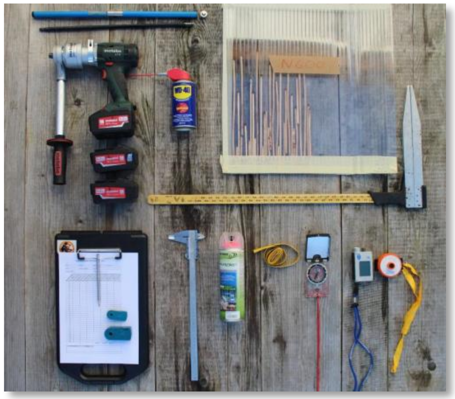
Jan Esper[a,*], Lea Schneider[a], Jason E. Smerdon[b], Bernd R. Schöne[c], Ulf Büntgen[d,e,f]

Memory effects in trees are e.g. related to:

- needle generations (see example on the right)
- previous year bud development
- storage starch+sugars in parenchym ray tissue

Four needle generations on twig from Norway spruce of Thrunigia (Germany, photo: R. Wenzel)

How to measure tree‘s Rt and memory?



Tree-ring widt sampling equipment (Möller 2019)

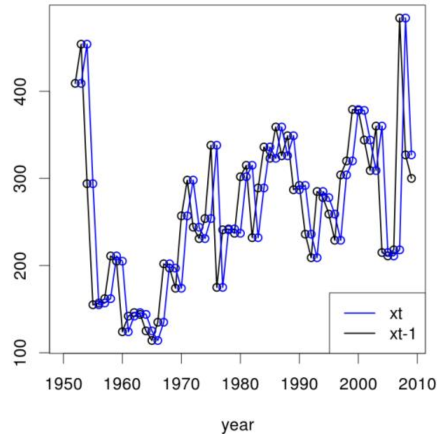
Tree-ring width time series record Rt and tree‘s memory.

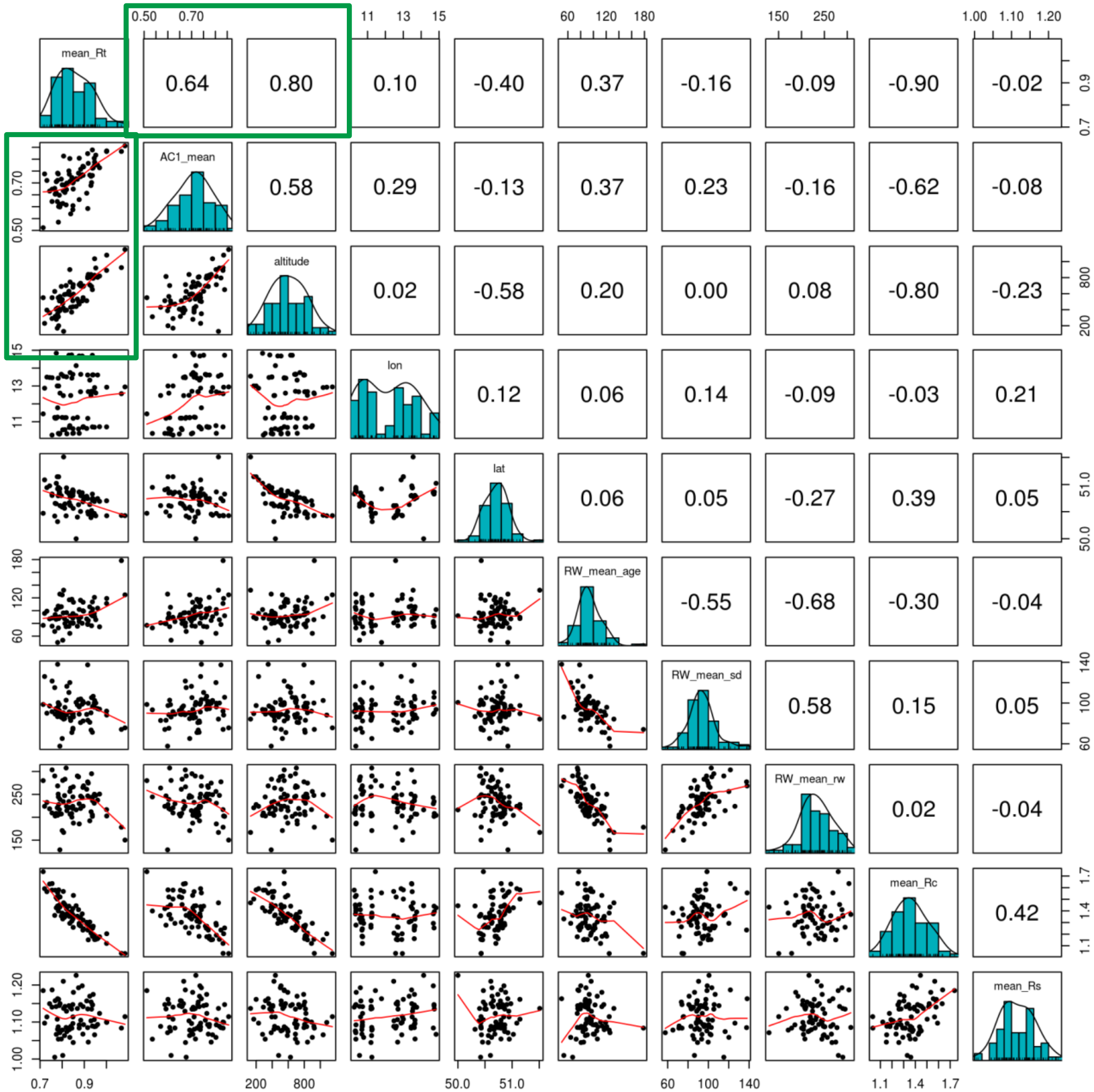
- one-layered spruce stands (similar ages) from central Germany (Thuringia+Saxony)
- dominant trees of 76 sites
- 2 radii of max. 20 trees per site
- altitude: 130-1150m asl
- lon: 10-15°E / lat: 50-51.5°N

Tree‘s memory = AC1!

AC is the correlation of a signal with a delayed copy of itself as a function of delay (wikipedia 2020):

Cov (Xt,Xt-τ)
[τ = lag]





We suppose that the average drought resistance (mean_Rt) of spruce along vertical and zonal transects in Central Germany depends on:

- Tree stands mean AC (lag1): AC1_mean
- Tree stands altitude
- Tree stands lon, lat
- Tree stands average tree age: RW_mean_age
- Tree stands average standard deviation (=„sensitivity“): RW_mean_sd
- Tree stands average ring-width (dimension of trees): RW_mean_rw
- mean recovery (mean_Rc) and mean resilience (mean_Rs) were not examined

➢ Signif. relations to AC1 and altitude

Results- *temporal stability AC1*

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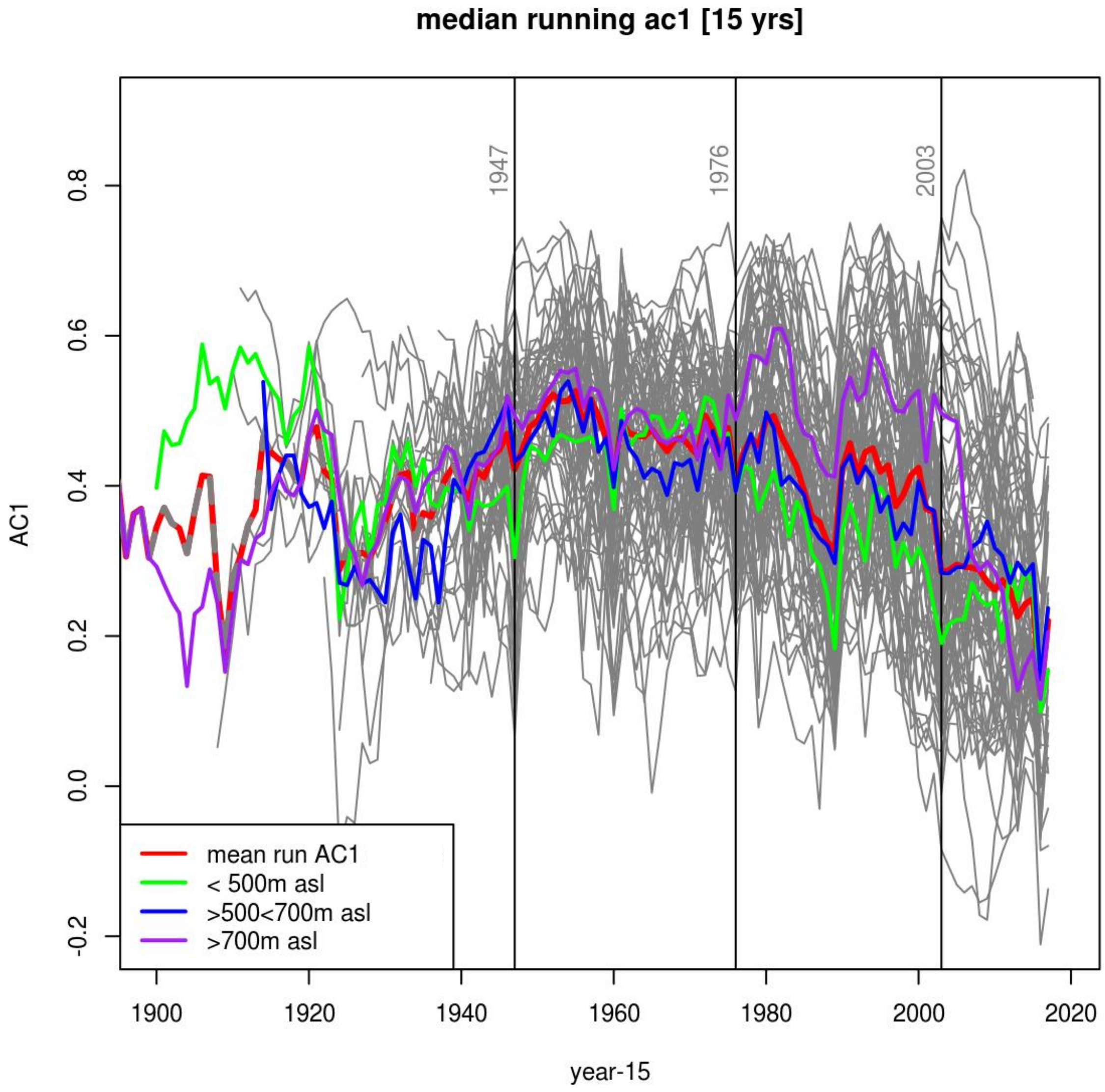

Moving AC1 along vertical transects (window length: 15yr, window motion: recent to past):

- AC1 not stable over time and with altitude
  - ➢ a matter of age, photo-assimilate allocation, forest structure?
- Distinct AC1 diff. during 1990s and homogeneity during 1960s
  - ➢ impact of massive air pollution?
- Pan-European droughts (1947,1976,2003)- no direct impact
  - ➢ a methodological issue?
- Common AC1 decline since ~2000s
  - ➢ changed forest management? If so, implications for recent forest management? <u>We don‘t know yet!</u>

Results- *some details*

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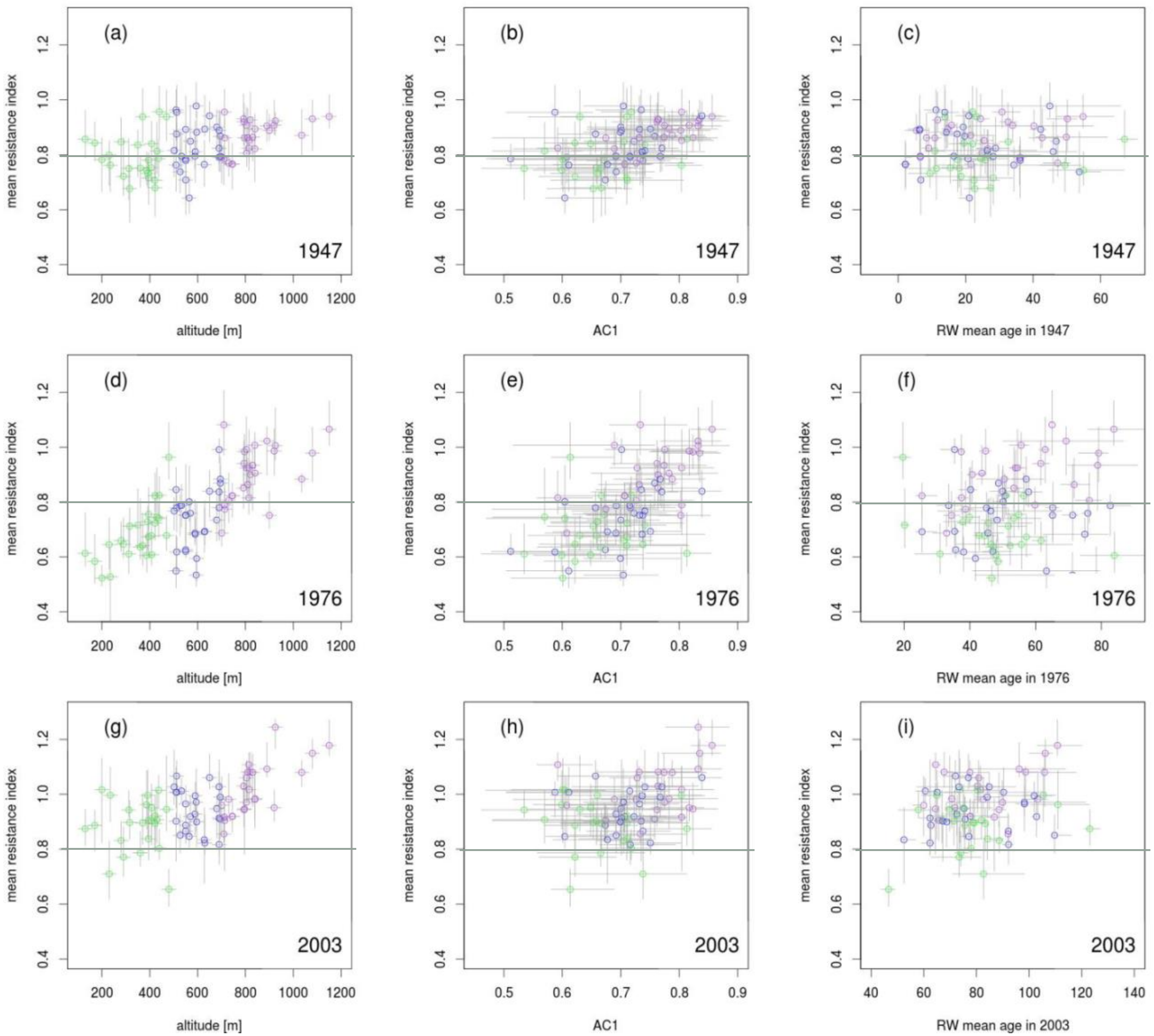


Rt during drought events and relations to altitude, AC1 and tree stand age during the event (colors display altitude):

- Rt responded positively to altitude during all event years
- Rt positively responded to AC1 (most distinctly in 1976)
- No influence of tree stand age on Rt
- Rt differed among droughts due to:

- drought characteristics (time, space and intensity)
- trees suffered already before the event (PreDr period)
- Adaptation of trees (trees have learned)

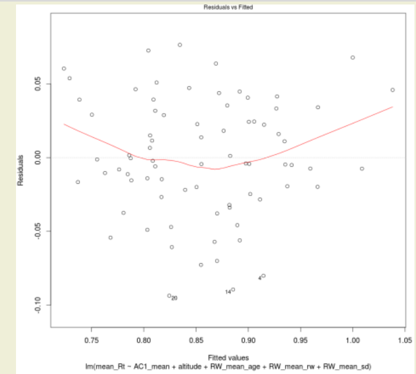
Results- *modelling*

Hypothesis: The *drought tolerance* of Norway spruce depends on the *memory of trees*

1st multiple linear model with all predictors and interactions, focusing on AC1 => best model explained [adj-R^2] = 73.4%:

mean_Rt ~ AC1_mean + altitude + RW_mean_age + RW_mean_rw + RW_mean_sd

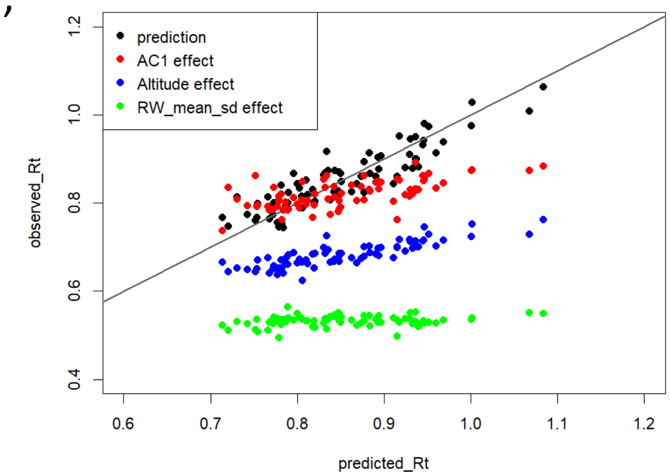
Problem: Homogeneity assumption violated!



2nd generalized linear mixed model (Gamma-distribution, spatial clustering related site distances)

Fixed effects:

	Estimate	Std. Error	t value	Pr(>|z|)	
(Intercept)	1.619e+00	7.519e-02	21.539	< 2e-16	***
AC1_mean	-5.639e-01	9.727e-02	-5.797	6.75e-09	***
altitude	-2.623e-04	2.938e-05	-8.927	< 2e-16	***
RW_mean_sd	2.730e-03	5.059e-04	5.395	6.85e-08	***
RW_mean_rw	-6.339e-04	1.944e-04	-3.260	0.00111	**



Result: AC1 exlained the highest portion of Rt!

Conclusions

- Norway spruce ring-width chronologies from 76 tree stands of Central Germany were characterized by significant lag 1 autocorrelations (AC1)
- The mean drought tolerance (Rt) showed significant associations to sampling site altitudes
- The drought tolerance (Rt) was significantly positively related to tree‘s memory (AC1)
- Generalized linear mixed model results underlined the importance of AC1 for the drought tolerance of Norway spruce
- Open questions:
  - What determines AC1 (genetics, previous year(s) tree „decisions “)?
  - Do we have a management strategy to control AC1 (interventions: more frequent and intense?)

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