RECONSTRUCTING PAST TEMPERATURE VARIATIONS: MATHEMATICAL GROUNDS AND SOME RESULTS

D.M. SONECHKIN

P.P. Shirshov Oceanology Institute,

Russian Academy of Sciences, Moscow

In collaboration with

N.M. Datsenko (HMC of Russia),

A. Moberg and H. Grudd (Stockholm University)

Methodology of past climate millennial reconstruction:

One can consider every type of proxies as a thermometer with an unknown scale.

These scales are variously complex and nonlinear.

They can be compared with each other under the only condition that their periods of observation overlaps completely.

Therefore, it is not appropriate to use some proxies to reconstruct a part of the time period of interest, and some other proxies to reconstruct another part of it.

Moreover, all proxy thermometers are more or less inertial in their responses. There are lower-resolution proxies (ice cores, lake sediments etc), and there are higher-resolution proxies (corals and tree-rings).

Therefore, it is necessary to use each data type only at timescales where they perform best.

To choose such respective scales it is necessary to develop specific models for each kind of proxy-data.

A tree-ring model

The main suppositions:

- The wood production of a mature tree must be of the same value during the years with the same climate and environmental conditions.
- The tree-ring width of a year (***dR(t)***) is a bad measure of this year wood production.
- The tree-ring area well-known as the so-called basal area increment (***BAI(t)***) is a better measure:

- Assuming a cross-section of tree stems to be circular the basal area increment of a *t*-year (in respect of such areas of adjacent years) can be estimated as

$$BAI(t) = 4\pi\left[\left(R(t)+dR(t)\right)^2 - \left(dR(t)\right)^2\right]$$

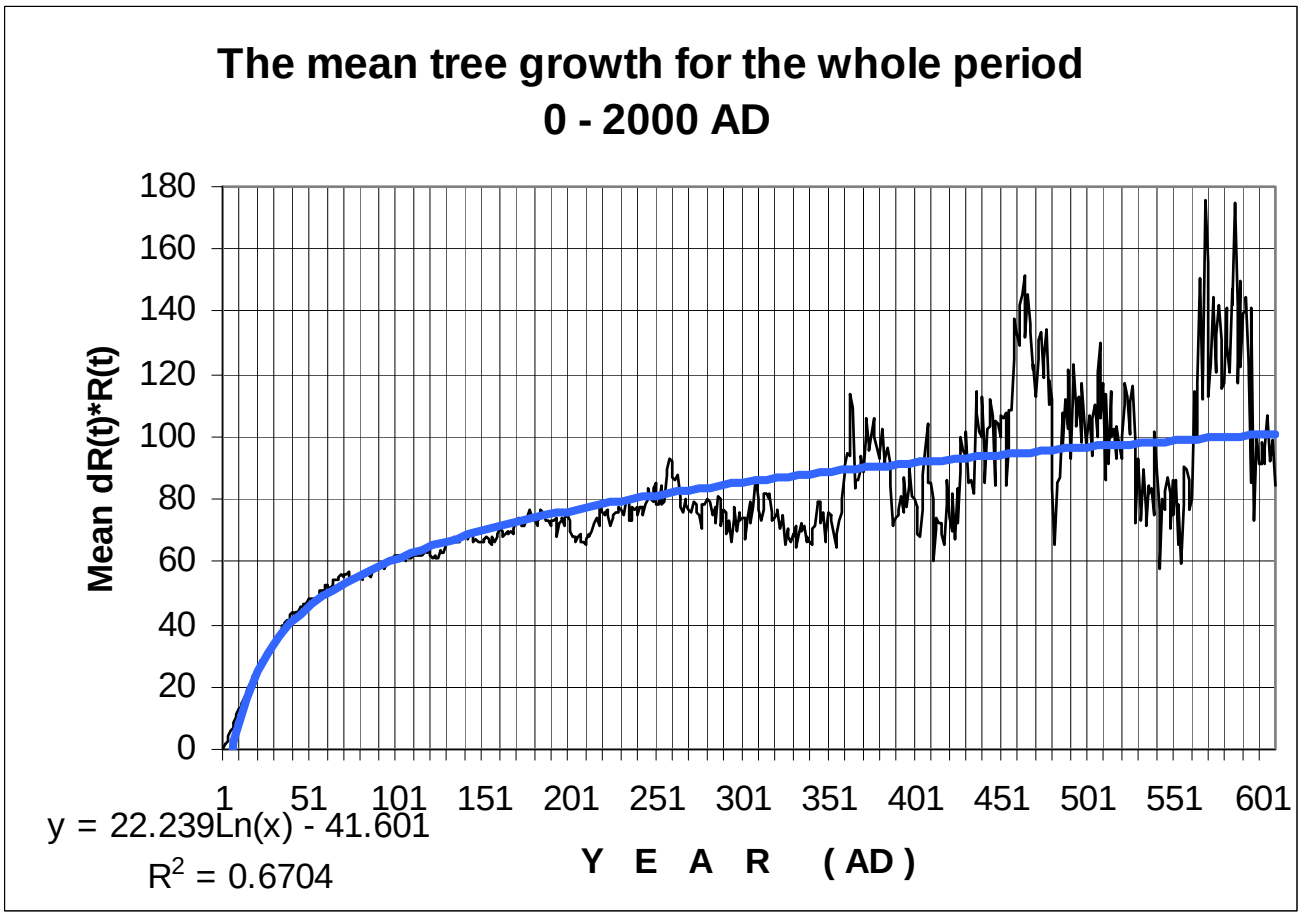
$$= 4\pi\left[2R(t)dR(t) + \left(dR(t)\right)^2\right] \approx R(t)dR(t),$$

$$because \;\; R(t) >> dR(t)$$

The same approximation is correct for other (either elliptic or polygonal) shapes if consequent rings are more or less congruent with each other.

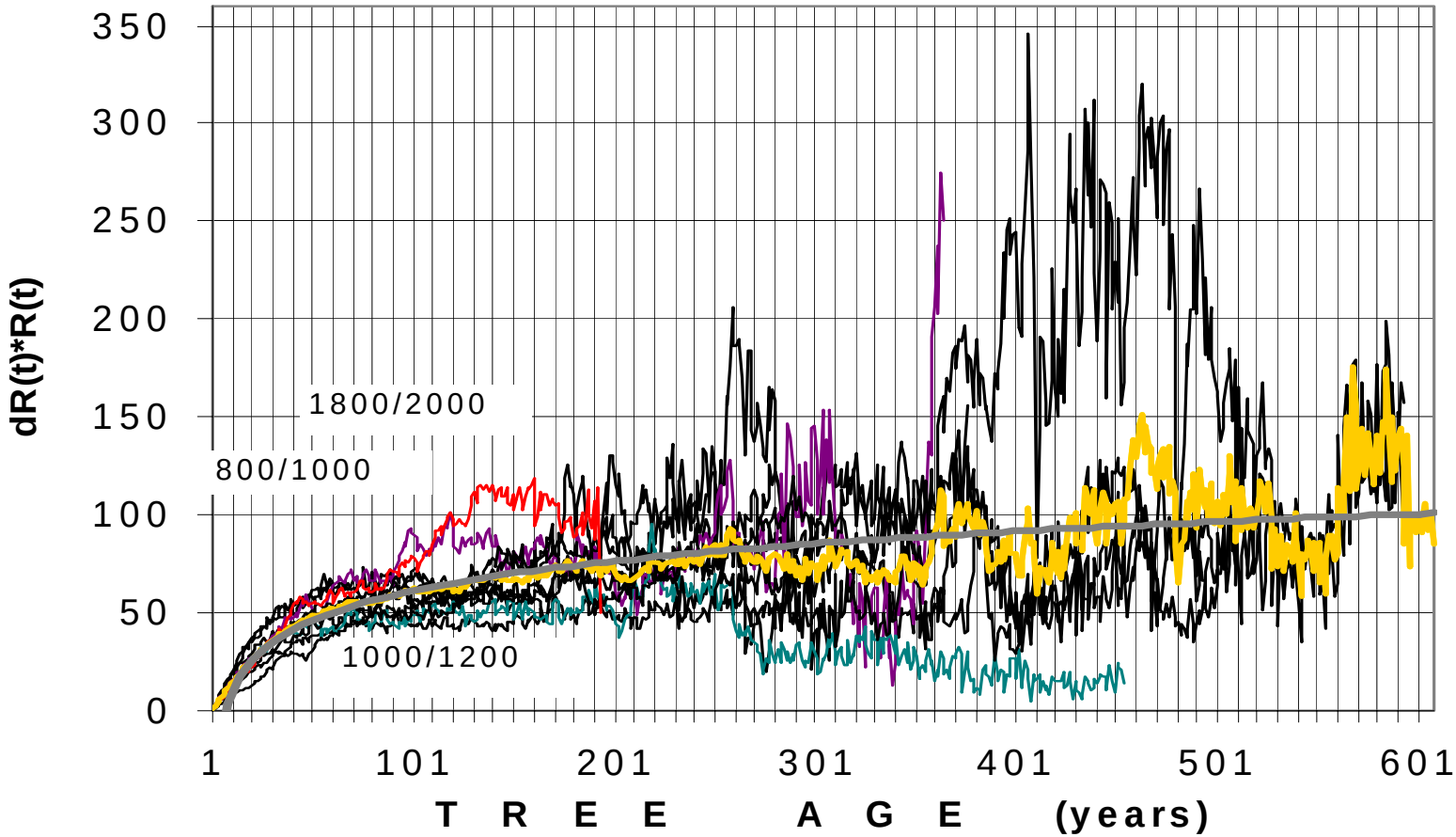
AN EXAMPLE
for the Tornetrask tree-ring set (-5500 B.D. – 2000 A.D.)

An apparent AGE-DEPENDENCE of the ***dR(t)*R(t)*** index

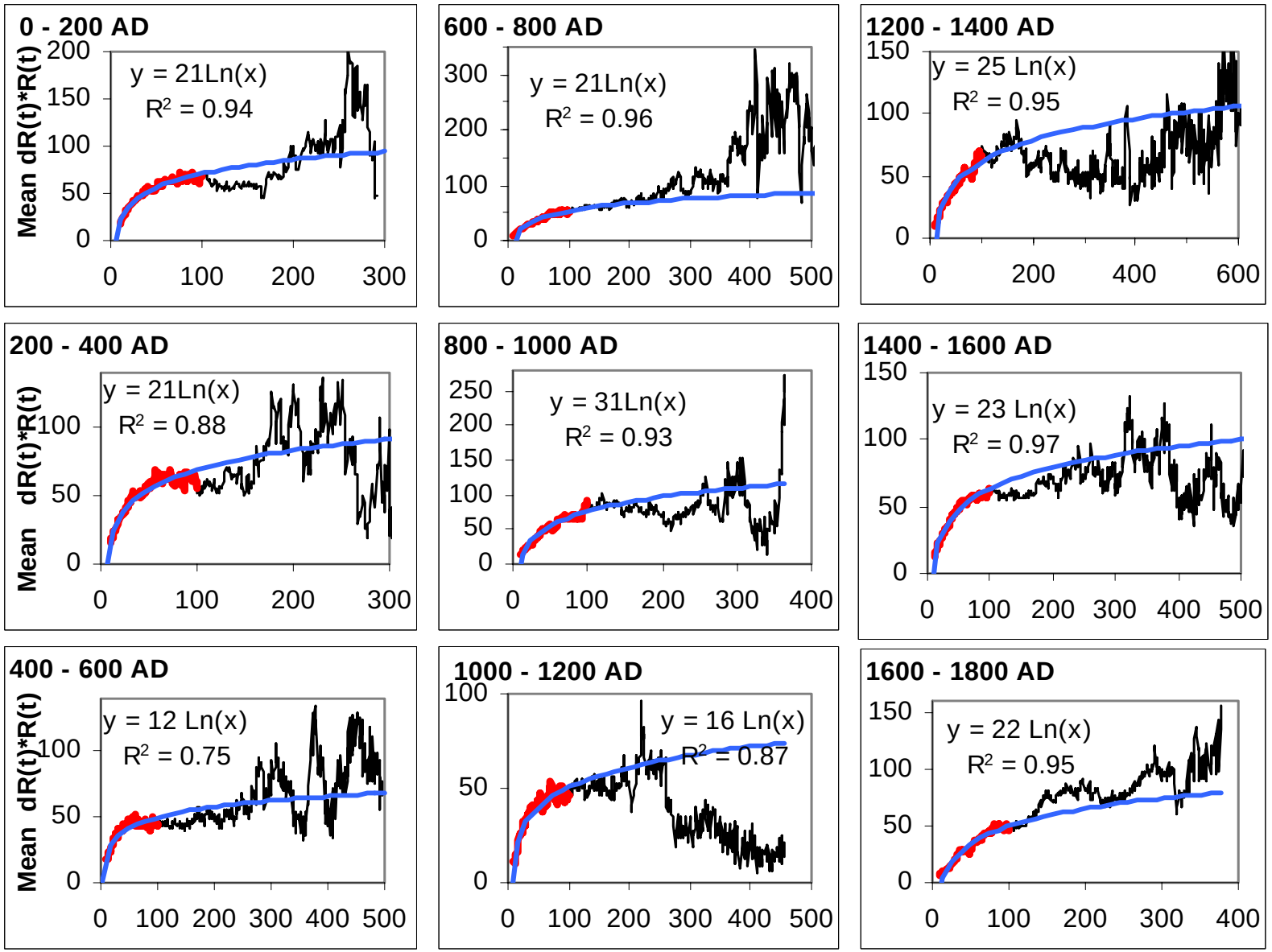


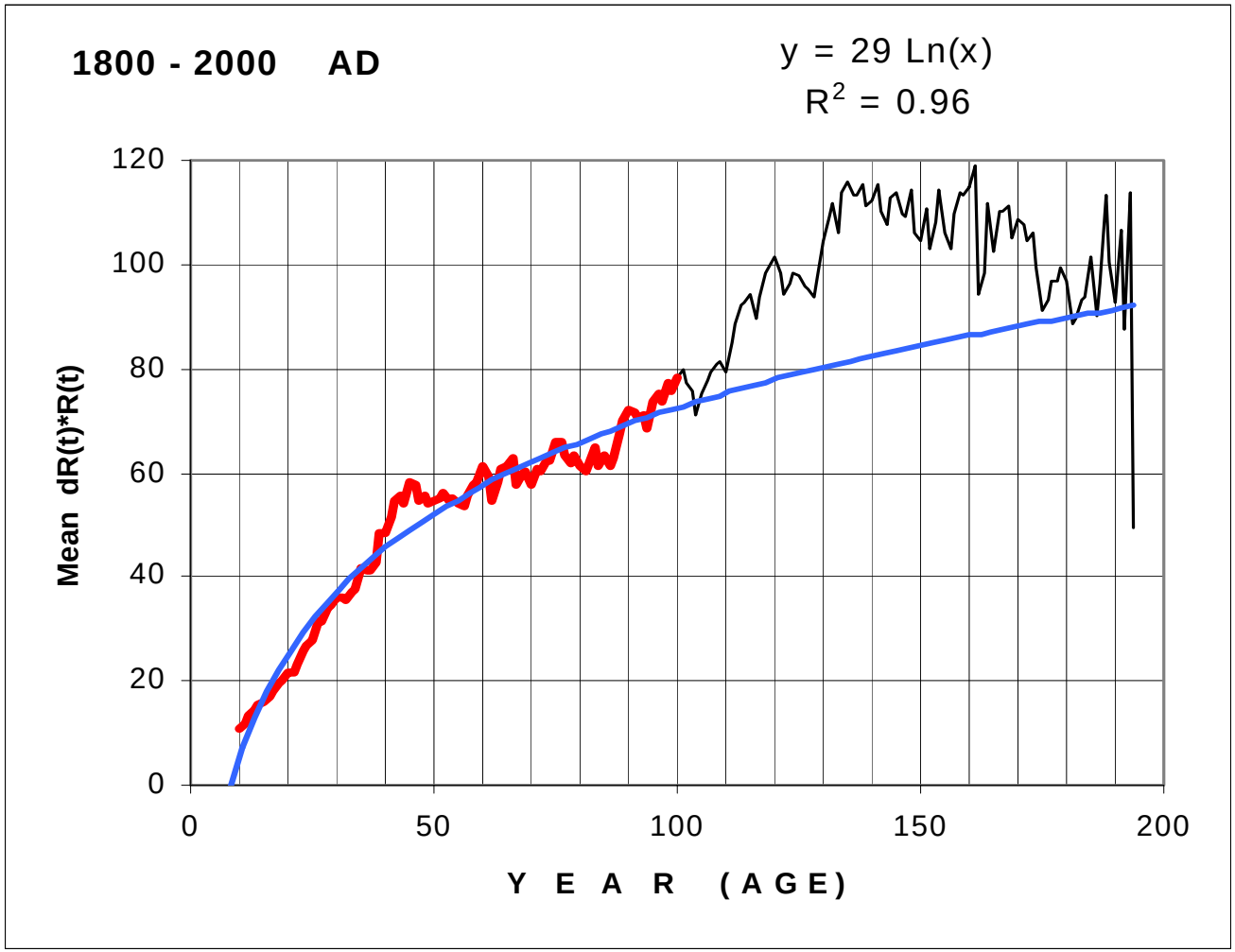
The age-dependent basal-area increment curves for the consequent 200y-long periods

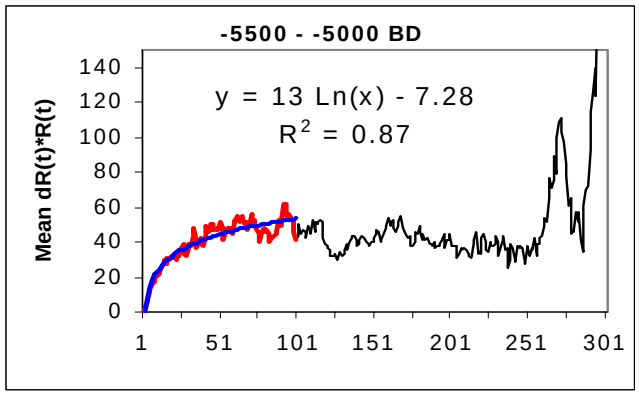
and the mean curve for the whole 0-2000AD period

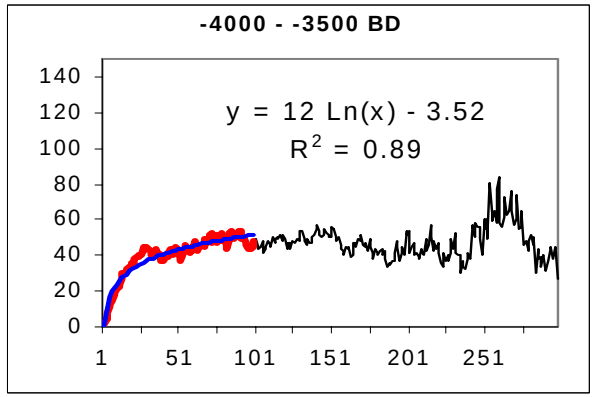


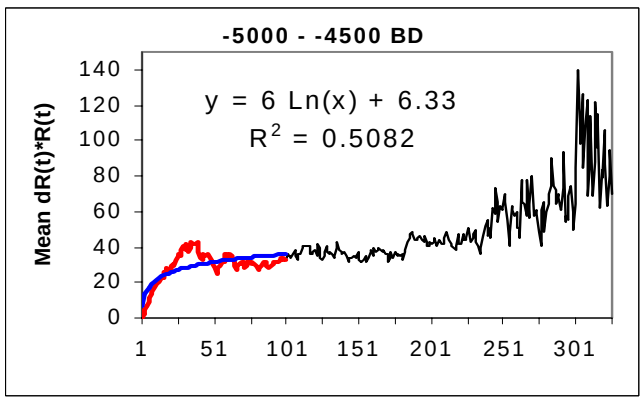
A CHRONOLOGY of the ***dR(t)*R(t)*** indices for mature trees (>100 y) with taking into consideration a lower-frequency differentiation in the wood productivity of 100-year old trees

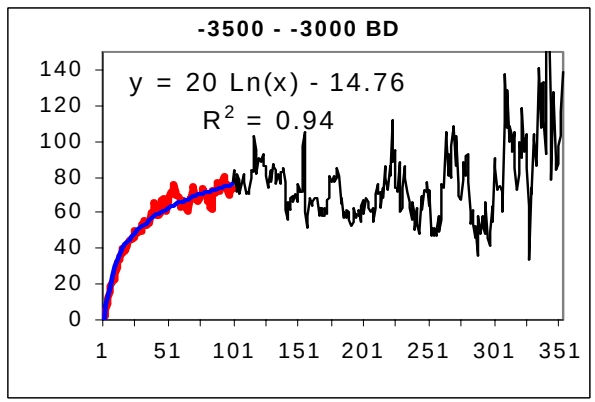

0 - 200 AD
y = 21Ln(x)
R² = 0.94
Mean dR(t)*R(t)
600 - 800 AD
y = 21Ln(x)
R² = 0.96
1200 - 1400 AD
y = 25 Ln(x)
R² = 0.95
200 - 400 AD
y = 21Ln(x)
R² = 0.88
Mean dR(t)*R(t)
800 - 1000 AD
y = 31Ln(x)
R² = 0.93
1400 - 1600 AD
y = 23 Ln(x)
R² = 0.97
400 - 600 AD
y = 12 Ln(x)
R² = 0.75
Mean dR(t)*R(t)
1000 - 1200 AD
y = 16 Ln(x)
R² = 0.87
1600 - 1800 AD
y = 22 Ln(x)
R² = 0.95

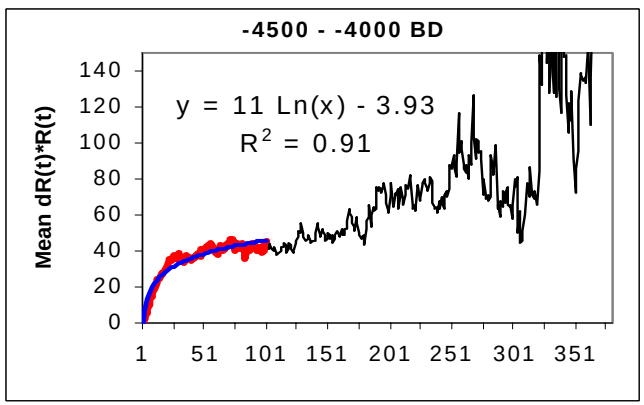

1800 - 2000 AD
y = 29 Ln(x)
R2 = 0.96
Mean dR(t)*R(t)
120
100
80
60
40
20
0
0
50
100
150
200
Y E A R (A G E)

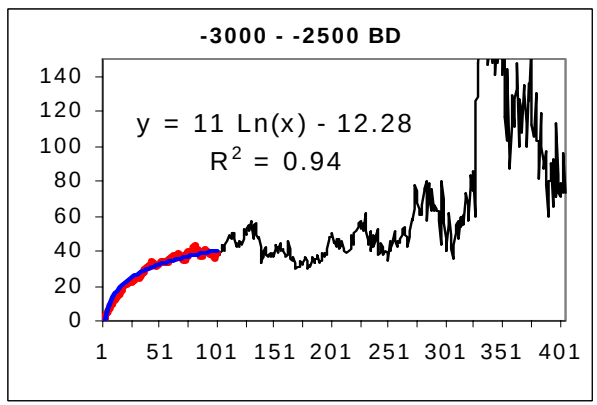

-5500 - -5000 BD
Mean dR(t)*R(t)
y = 13 Ln(x) - 7.28
R2 = 0.87
0
20
40
60
80
100
120
140
1
51
101
151
201
251
301

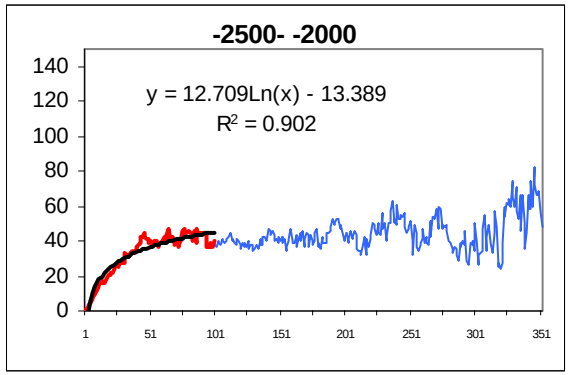

-4000 - -3500 BD
y = 12 Ln(x) - 3.52
R2 = 0.89
0
20
40
60
80
100
120
140
1
51
101
151
201
251

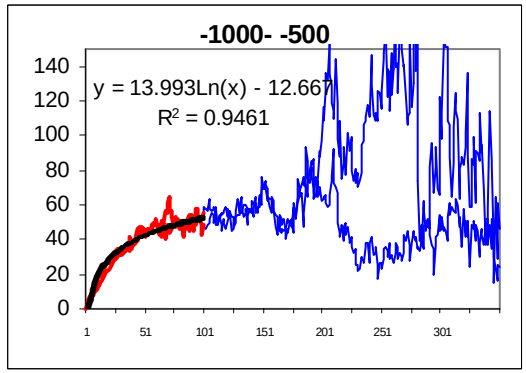

-5000 - -4500 BD
Mean dR(t)*R(t)
y = 6 Ln(x) + 6.33
R2 = 0.5082
0
20
40
60
80
100
120
140
1
51
101
151
201
251
301

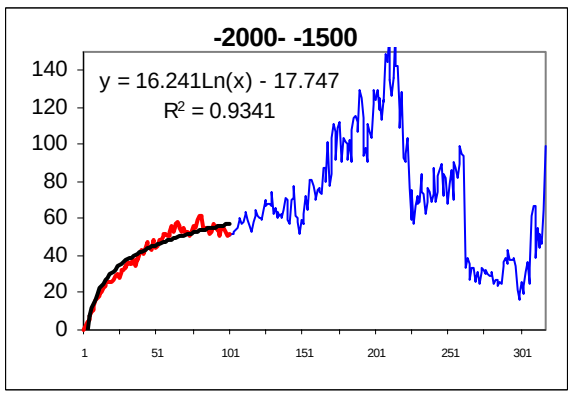

-3500 - -3000 BD
y = 20 Ln(x) - 14.76
R2 = 0.94
0
20
40
60
80
100
120
140
1
51
101
151
201
251
301
351

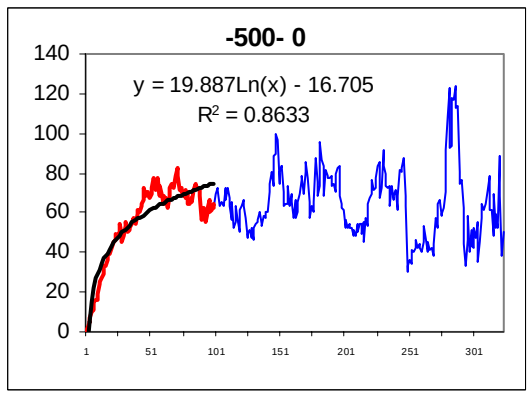

-4500 - -4000 BD
Mean dR(t)*R(t)
y = 11 Ln(x) - 3.93
R2 = 0.91
0
20
40
60
80
100
120
140
1
51
101
151
201
251
301
351

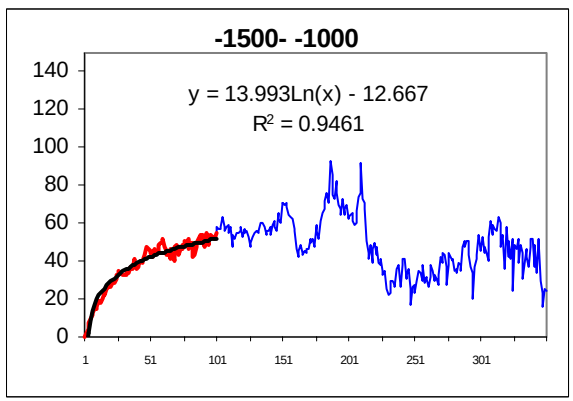

-3000 - -2500 BD
y = 11 Ln(x) - 12.28
R2 = 0.94
0
20
40
60
80
100
120
140
1
51
101
151
201
251
301
351
401


-2500- -2000
y = 12.709Ln(x) - 13.389
R2 = 0.902
140
120
100
80
60
40
20
0
1
51
101
151
201
251
301
351

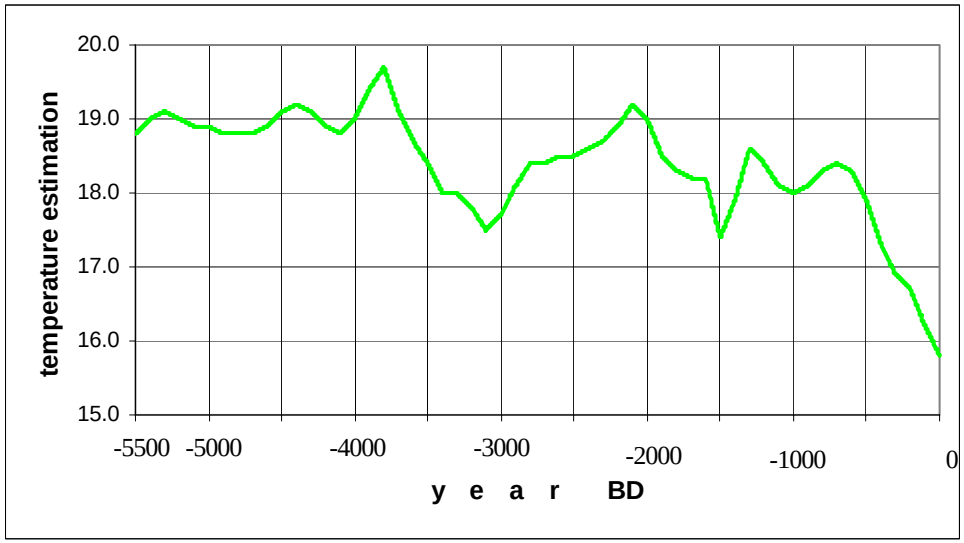

-1000- -500
y = 13.993Ln(x) - 12.667
R2 = 0.9461
140
120
100
80
60
40
20
0
1
51
101
151
201
251
301

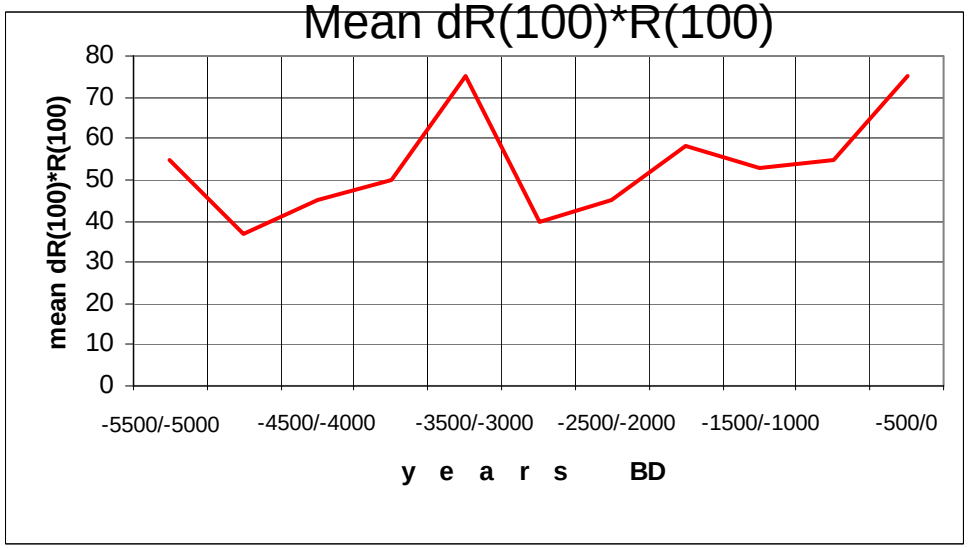

-2000- -1500
y = 16.241Ln(x) - 17.747
R2 = 0.9341
140
120
100
80
60
40
20
0
1
51
101
151
201
251
301

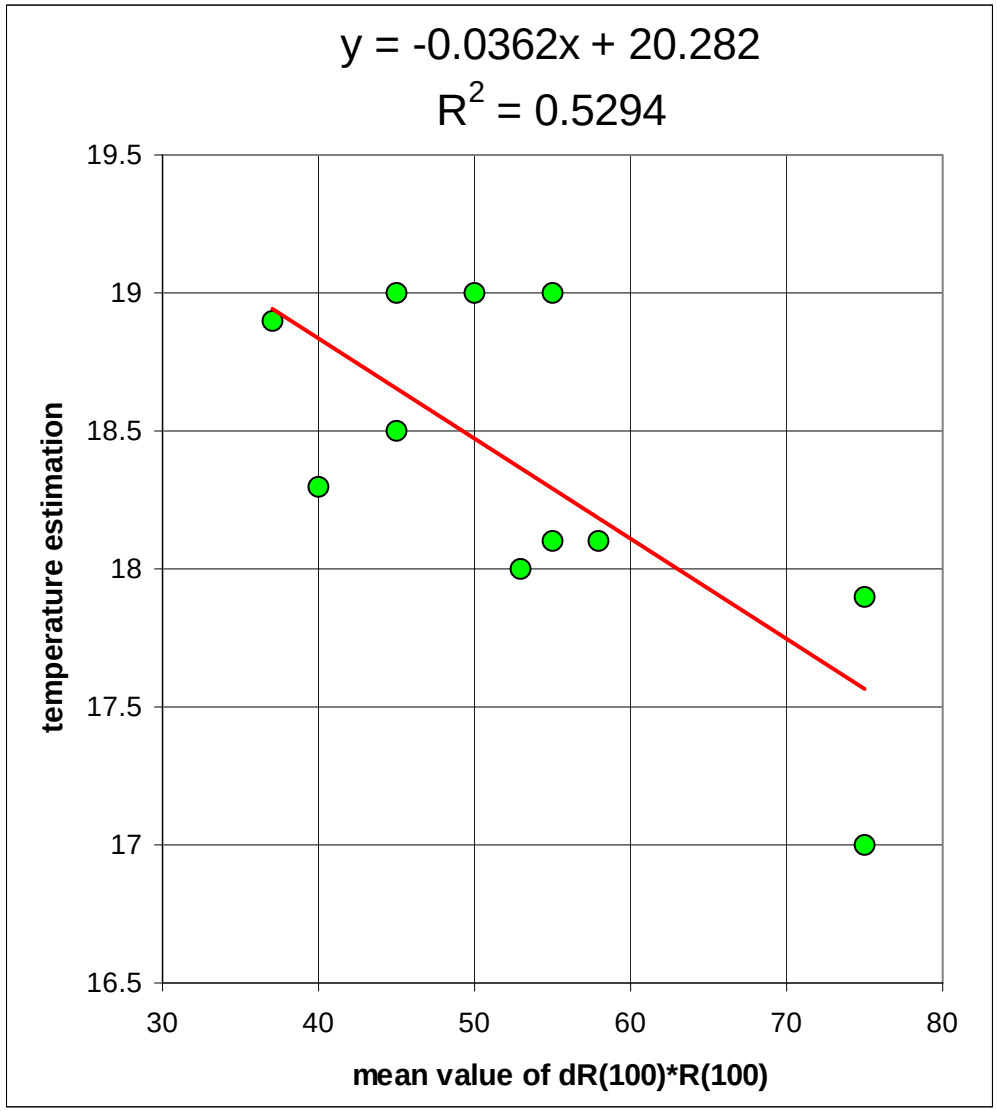

-500- 0
y = 19.887Ln(x) - 16.705
R2 = 0.8633
140
120
100
80
60
40
20
0
1
51
101
151
201
251
301


-1500- -1000
y = 13.993Ln(x) - 12.667
R2 = 0.9461
140
120
100
80
60
40
20
0
1
51
101
151
201
251
301

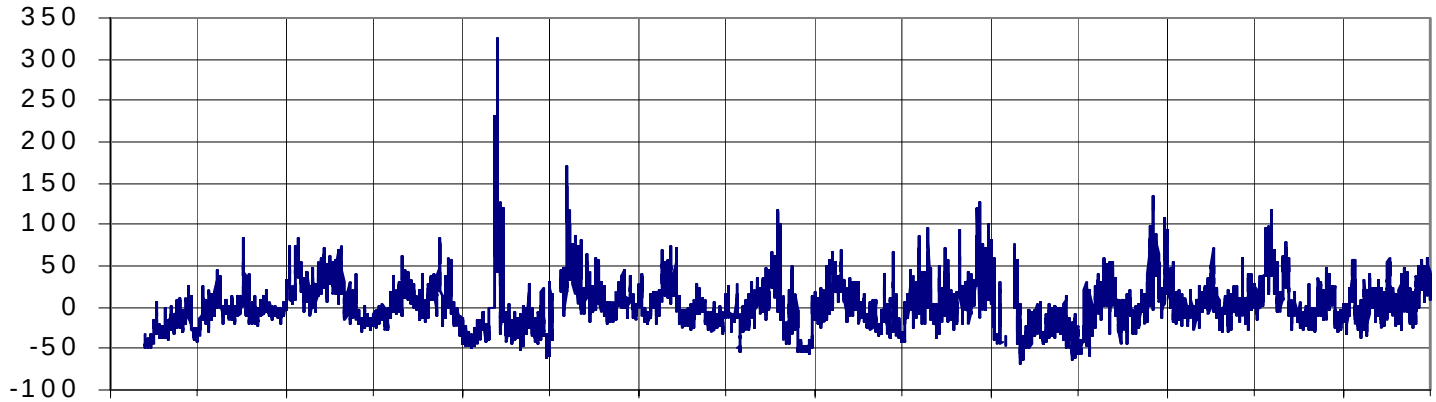
A temperature estimation (Gotland dO18, Moerner, 1976)



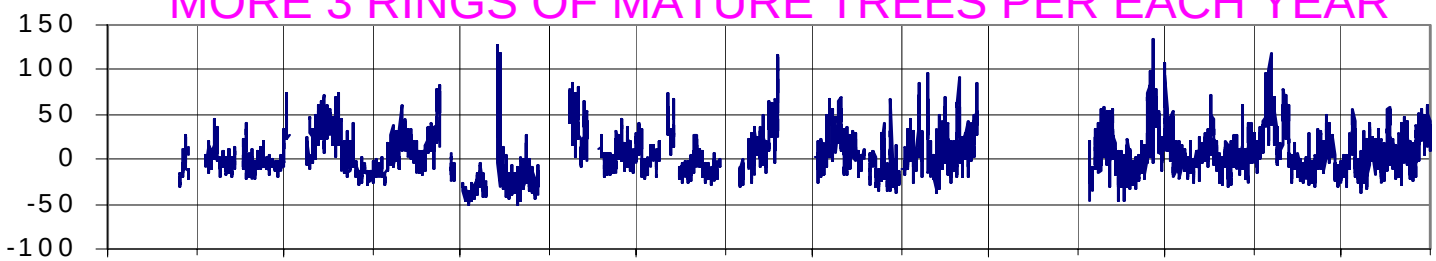



y = -0.0362x + 20.282
R2 = 0.5294
19.5
19
18.5
18
17.5
17
16.5
30
40
50
60
70
80
temperature estimation
mean value of dR(100)*R(100)

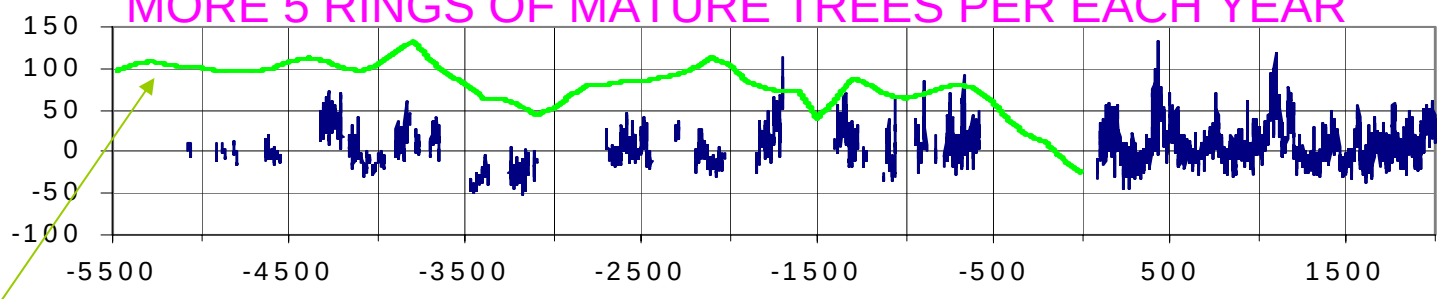
FULL SET OF MATURE TREES



MORE 3 RINGS OF MATURE TREES PER EACH YEAR



MORE 5 RINGS OF MATURE TREES PER EACH YEAR



Gotland dO18: Moerner, 1976

CONCLUSION

- The ***dR(t)*R(t)-Mean dR(100)*R(100)*** – index is insensitive to the age of mature (>100y) trees, I.e. no explicit standardization is necessary to use.
- Moreover, this index is capable to preserve lower-frequency tree-growth variability better than other known indices.
- It seems the shapes of the whole age-curves as such can be used to reconstruct multicentennial and even millennial temperature variations.