CLIMATIC CYCLES AND TREE-GROWTH; A STUDY OF THE ANNUAL RINGS OF TREES IN RELATION TO CLIMATE AND SOLAR ACTIVITY

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649550791

Climatic Cycles and Tree-Growth; A Study of the Annual Rings of Trees in Relation to Climate and Solar Activity by A. E. Douglass

Except for use in any review, the reproduction or utilisation of this work in whole or in part in any form by any electronic, mechanical or other means, now known or hereafter invented, including xerography, photocopying and recording, or in any information storage or retrieval system, is forbidden without the permission of the publisher, Trieste Publishing Pty Ltd, PO Box 1576 Collingwood, Victoria 3066 Australia.

All rights reserved.

Edited by Trieste Publishing Pty Ltd.
Cover @ 2017

This book is sold subject to the condition that it shall not, by way of trade or otherwise, be lent, re-sold, hired out, or otherwise circulated without the publisher's prior consent in any form or binding or cover other than that in which it is published and without a similar condition including this condition being imposed on the subsequent purchaser.

www.triestepublishing.com

A. E. DOUGLASS

CLIMATIC CYCLES AND TREE-GROWTH; A STUDY OF THE ANNUAL RINGS OF TREES IN RELATION TO CLIMATE AND SOLAR ACTIVITY

Trieste

CLIMATIC CYCLES AND TREE-GROWTH

A STUDY OF THE ANNUAL RINGS OF TREES IN RELATION TO CLIMATE AND SOLAR ACTIVITY

BY

A. E. DOUGLASS

Director of Steward Observatory, University of Arizona

Vol. I

15609
21/9/20

PUBLISHED BY THE CARNEGIE INSTITUTION OF WASHINGTON
WASHINGTON, 1919

QK
745
D62
v.1
cop. 2

CARNEGIE INSTITUTION OF WASHINGTON
PUBLICATION NO. 289

PRESS OF GIBSON BROTHERS, INC.,
WASHINGTON, D. C.

CONTENTS.

	PAGE.
I. INTRODUCTION	9
Trees suitable for climatic study	11
Introduction to special studies on the yellow pine	12
Location	12
Climate and seasonal conditions	13
II. PRELIMINARY STUDIES ON THE YELLOW PINE	15
Yearly identity and the dating of rings	15
Cross-identification	16
Cross-identification and climate	17
Month of beginning annual means	17
The time of year of ring formation	18
Significance of subdivisions in rings	20
Number of trees necessary for reliable results	21
Direction of maximum growth	22
Rate of growth and age	22
Growth and soil	22
III. COLLECTION OF SECTIONS	23
The first Flagstaff group of 25 sections	23
Subgroups	24
First suggestion of cross-identification	24
The Flagstaff 500-year record	24
The second Flagstaff group of 7 sections	27
The Prescott group	27
South of England group	29
Outer coast of Norway group	30
Inner coast of Norway group	32
Christiania group	35
Central Sweden group	35
South Sweden group	36
Eberswalde (Prussia) group	37
Pilsen (Austria) group	39
Southern Bavaria group	39
Old European trees	40
Windsor (Vermont) group	41
Oregon group	42
The Sequoia group	44
The Sequoia journey of 1918	49
IV. DETAILS OF CURVE PRODUCTION	54
Preparation of radial samples	54
Form of sample	54
Method of cutting	54
Preparation for measurement	55
Identification of rings	55
Fire-scars	56
Cross-identification between distant points	57
The difficult ring 1580	58
Measuring	58
Tabulating	59
Averaging	60
Smoothing	61
Standardizing	63
Plotting	64
Problems in plotting	64
V. CORRELATION WITH RAINFALL	65
Result of study of curves	65
Early tests of rainfall correlation	65
The Prescott correlation	66
Accuracy	66

	PAGE.
V. CORRELATION WITH RAINFALL—*contd.*	
The Prescott correlation—*continued.*	
Mathematical relation of rainfall and growth	67
Character of the conservation term	67
Summary	70
Sequoia correlation with rainfall	70
Future work	72
Meteorological districts	72
Meteorological districts and growth of trees	72
Arizona and California	73
Meteorological districts and solar correlation	73
VI. CORRELATION WITH SUNSPOTS	74
Dry-climate tests	74
Wet-climate reaction	74
The European groups	76
Windsor (Vermont) correlation	79
The sunspots and their possible causes	81
Appearance	81
Suggested causes of sunspots	82
Length of the sunspot period	84
Tree-growth and solar activity	84
VII. METHODS OF PERIODIC ANALYSIS	85
Need for such analysis	85
Proportional dividers	85
The optical periodograph	86
Schuster's periodogram	86
The optical periodogram	86
Application to length of sunspot period	88
Production of differential pattern	89
Theory	90
The automatic optical periodograph	92
The curve	92
Track and moving mechanism	92
Differential pattern mechanism	93
The periodogram mechanism	94
Periodograms	96
Resolving power of the periodograph	96
VIII. CYCLES	98
Significance of cycles	98
Predominant cycles	98
Locality and solar cycles	99
Illustrations of cycles	101
The 11-year cycle	101
The 11-year cycle in sequoia	102
Correlation curves	103
Double and triple cycles	103
A 2-year cycle	106
Periodograph analyses	107
Differential patterns	107
The 11-year cycle	107
Changes in the 11-year tree-cycle of Arizona	108
Sequoia pattern	109
Other solar cycles	109
The 100-year cycle	110
Illustration by the periodograph	110
Summary	111
Addendum	112
APPENDIX	113
Tables of mean tree-growth by groups	113
Bibliography	124

ILLUSTRATIONS.

PLATES.

PAGE.

PLATE 1.
A. Bottomless pits near Flagstaff, illustrating drainage through limestone 12
B. Yellow pine forest of northern Arizona 12

PLATE 2.
Cross-identification of rings of growth in yellow pine (*Pinus ponderosa*). 24

PLATE 3.
A. Section of Scotch pine from Southern England 30
B. Section of Scotch pine from coast of Norway 30

PLATE 4.
A. Section of Scotch pine from Ös, Norway 36
B. Section of Scotch pine from Dalarne, Sweden 36

PLATE 5.
A. Upland contours, above Camp 6 in Sequoia Grove: D–19 46
B. Basin contours, Indian Basin, looking S. E.: D–12 and 13 in center. 46

PLATE 6.
A. Cutting radial sample from end of log, Converse Hoist, D–20, age 2800 years 50
B. Site of oldest tree, Converse Hoist, D–21, age 3200 years 50

PLATE 7.
A. Cutting sample from stump, Enterprise: D–22, age 3000 years 52
B. Centennial stump, Enterprise; cut in 1874, D–23, age 3075 years 52

PLATE 8.
A. Section of Scotch pine from Eberswalde, Prussia, showing solar rhythm 74
B. Another section from the same forest, showing same rhythm 74

PLATE 9.
A. Periodogram of the sunspot numbers, 1755–1911. Corrugations show periods. The numbers give length of period in years. The white line is the year 1830 and shows phase 88

PAGE.

PLATE 9—*continued.*
B. Differential pattern used in making the periodogram, consisting of the sunspot curve mounted in multiple 88
C. Same pattern photographed out of focus to show discontinuities in the vertical lines 88
D. Sweep of sunspot numbers, 1755–1911 88
E. Differential pattern of sunspot numbers made by the periodograph process 88

PLATE 10.
A. The automatic optical periodograph. 94
B. Differential patterns of Sequoia record, 3200 years at 11.4 94

PLATE 11.
A. Periodogram of standard 5-year period 96
B. Periodogram of mixed periods 96
C. Periodogram of sunspot numbers 1610–1910 96
D. Periodogram of Flagstaff 500-year record to show cycles between 4 and 15 years of length 96
E. Periodogram of same continued to 25 years 96

PLATE 12. Differential patterns:
a. Sunspot numbers, 1610–1910 at 11.4. 108
b. 57 European trees, 1830–1910 at 11.4. 108
c. 80 European trees, 1800–1910 at 11.4. 108
d. South Sweden, 1830–1910 at 12.0 ... 108
e. Vermont group, 1650–1910, at 11.3. 108
f. Flagstaff group, 500 years, at 11.4 ... 108
g. Flagstaff group at 23.5 years 108
h. Norway, 1740–1910, at 23.8 years ... 108
i. Austria, 1830–1910, at 22.0 years ... 108
j. Norway, N–2 400 years, at 33.0 108
k. Vermont, 250 years, at 32.5 108
l. Sweden, 1740–1910, at 37.0 108
m. Sequoia, 1300–250 B. C., at 33.0 108
n. Flagstaff, 500 years, at 33.0 108
o. Sequoia, 3200 years at 101 108
p. Flagstaff, 500 years at 120 108
q. Standard 5-year period at 5.0 years. 108
r. 5 to 10 year logarithmic variable period at 8.0 108

TEXT-FIGURES.

PAGE.

1. Effect of monthly distribution of precipitation on thickness of rings of growth; Prescott, Arizona 19
2. Monthly and yearly precipitation at Prescott, and size and character of rings 21
3. Annual growth of trees at Flagstaff from 1385 to 1906, A. D. 25
4. Comparison of two Flagstaff groups. Variations in annual rainfall according to month of beginning annual means. 26
5. Growth of individual trees compared with precipitation at Flagstaff 27
6. Annual growth of trees near Prescott, Arizona 28
7. Annual rainfall and growth of trees (Group V) at Prescott. Dotted line = rainfall. Solid line = growth 29
8. The nine European groups 31
9. Sunspots and growth of trees at Eberswalde, Germany 38
10. Growth of old European trees. A. Six Norwegian trees, mostly from inner fjords. B. Eight trees from Dalarne, Sweden 40
11. Oregon group. Curve No. 1, actual tree growth; No. 2, trees growth departures, smoothed; No. 3, sunspot numbers displaced 2 years to left 43
12. Cross-identification in first five sequoias and gross rings in No. 1 48
13. Correlation between tree growth and rainfall in smoothed curves; Flagstaff. 65
14. Early test of correlation between tree growth and rainfall by years; Flagstaff 66
15. Relation of tree growth and rainfall at Prescott. Tree growth and rainfall uncorrected 68
16. Five-year smoothed curves of growth and rainfall 68
17. Accumulated rain and smoothed tree growth 68
18. Actual tree growth and growth calculated from rain 68
19. Actual rain and rain calculated from tree growth 68
20. Huntington's early curves of sequoia growth and rainfall compared with growth calculated by a conservation formula 71
21. Comparison of Fresno rainfall (after Huntington) and sequoias D-1 to 5.. 71
22. Sunspot numbers and annual rings in spruce tree from south Sweden 75

PAGE.

23. Six European groups, standardized and smoothed 75
24. Three European groups, standardized and smoothed 77
25. Comparison between 57 north Europe trees (smoothed) and sunspot numbers. The trees are from England, Norway, Sweden, and north Germany 77
26. Dates of large rings in 80 European trees compared with sunspot curves. Ordinates give number of trees in total of 80 showing maxima in respective years 78
27. Tree growth at Windsor, Vermont, showing measures uncorrected; same standardized and smoothed, and sunspot numbers displaced 3 years to left 78
28. Smoothed quarterly rainfall (upper curve), sunspot numbers (center), and tree growth (lower) at Windsor, Vermont, 1835 to 1912 79
29. Correlation curves of solar cycle, rainfall, and tree growth at Windsor, Vermont, 1835 to 1912 80
30. Schuster's periodogram of the sunspot numbers 86
31. Diagram of theory of differential pattern in periodograph analysis 91
32. Smoothed curve of Arizona pines showing the half-sunspot period for 120 years 102
33. Changes in the 11-year period in 500 years. Solid line, Arizona pine; dotted line, sequoia 103
34. Correlation curves in the 11-year cycle 104
35. Early curve of Arizona pines from 1700 to 1900 A. D. (No. 4) compared with double and triple sunspot cycles combined (No. 3) 105
36. Double sunspot period in tree growth at inner fjords of Norway; lower curve a 22.8-year cycle 105
37. Double sunspot rhythm in sequoia, D-12 about 300 A. D. 105
38. Triple sunspot cycle in a single tree from northern Norway. Lower curve, a 34-year cycle 106
39. D-22 at 750 to 660 B. C., showing a 2-year period 106
40. Two differential patterns of Huntington's preliminary 2000 year sequoia record. The most prominent cycle is about 105 years in length, shown in the upper diagram 109

CLIMATIC CYCLES AND TREE-GROWTH

A STUDY OF THE ANNUAL RINGS OF TREES IN RELATION TO CLIMATE AND SOLAR ACTIVITY

By A. E. Douglass

Director of Steward Observatory, University of Arizona