"Environmental Services of forests and terrestrial and aquatic interactions"

Forest Shelter as an Environmental Service

Alexander Robertson *M.Sc., D. Phil (Oxon)*

Öngulsstaðir, Eyjafirði, Íslandi

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The *Wind Reader* is a nine chapter series of PPT’s was developed for a course at the Agricultural University of Iceland and is available in Icelandic and English. The *Wind Reader* explores the influence of wind in the landscape in rural and urban settings pertaining mostly to:-

Iceland

Newfoundland

Scotland

Forestry

Soil Conservation

Landscape Architecture

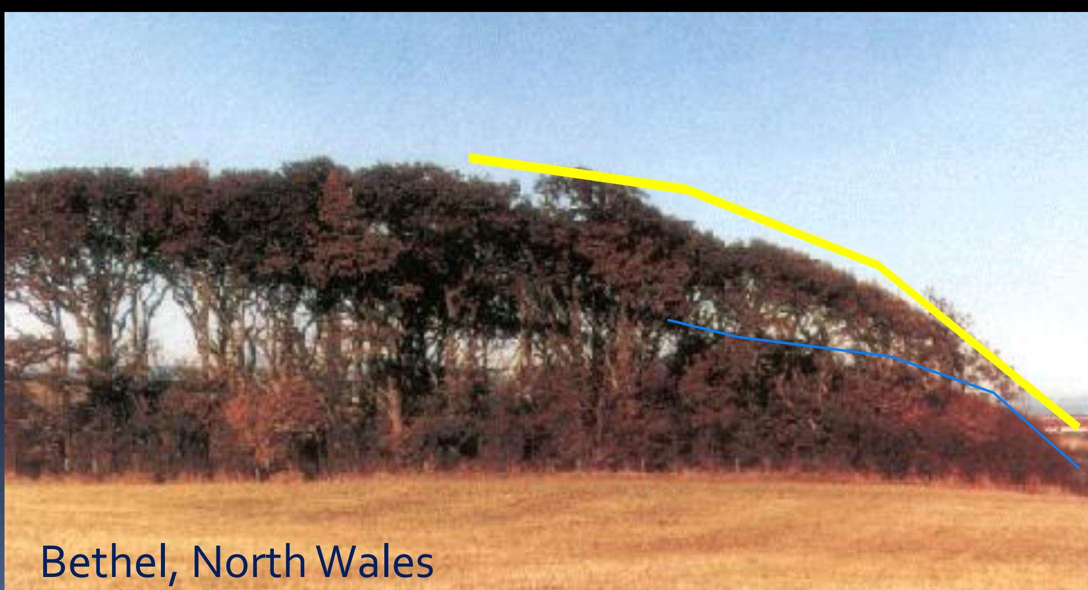
Landscape Heritage

Assessing Wind

This is what I used to dream of creating

These 300 + year-old tall, straight, symmetrically boled trees in this plantation forest in Karelia, Russia are an obviously indication of an area with very low average wind speeds, apart from an occasionally storm.

Mostly, windiness is often a persistent feature of maritime countries which is often manifest in by a persistent wind shear of spinneys in the temperate climates of Turnberry, Scotland (bottom left) and Bethel, N. Wales.



Note that in both examples even the understory is shaped by a wind shear.

Two graphical versions of a universally accepted wind profile for extolling the shelter effect of wind breaks and what actually happens in Nature.

Alistair MacLeod,
Source: Farm Shelter Assessment
Forest Research, Newton. Scotland

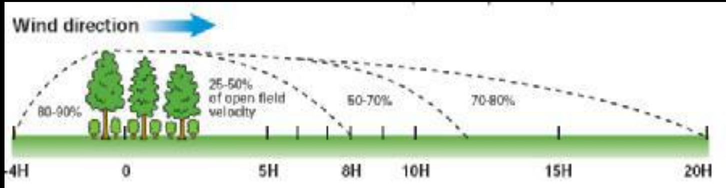
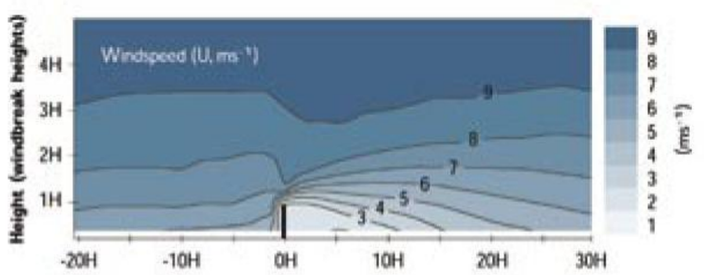


Figure 1. Zones of reduced wind velocity downwind of barrier as percentage of open field velocity. Vertical scale exaggerated.

Trees for Shelter Windbreaks for Australian Farms
A report for the Joint Venture Agro forestry Program by Helen Cleugh edited by Bob Lehane



Contours of windspeds as a result of wind shelter provided by a medium porosity model windbreak placed in the wind tunnel.

Sveinn Runólfsson's photo of sand blown through the bottom of a shelterbelt at Gunnarsholt illustrates one of the many deficiencies in these models.

Examples of larch deformation as a biological indicator of wind speed

Low wind
< 5 m^{s-1}

Occasionally windy
5-10 m^{s-1}

Moderate,
persistent wind
10-15 m^{s-1}

Brisk persistent wind
15-20 m^{s-1}

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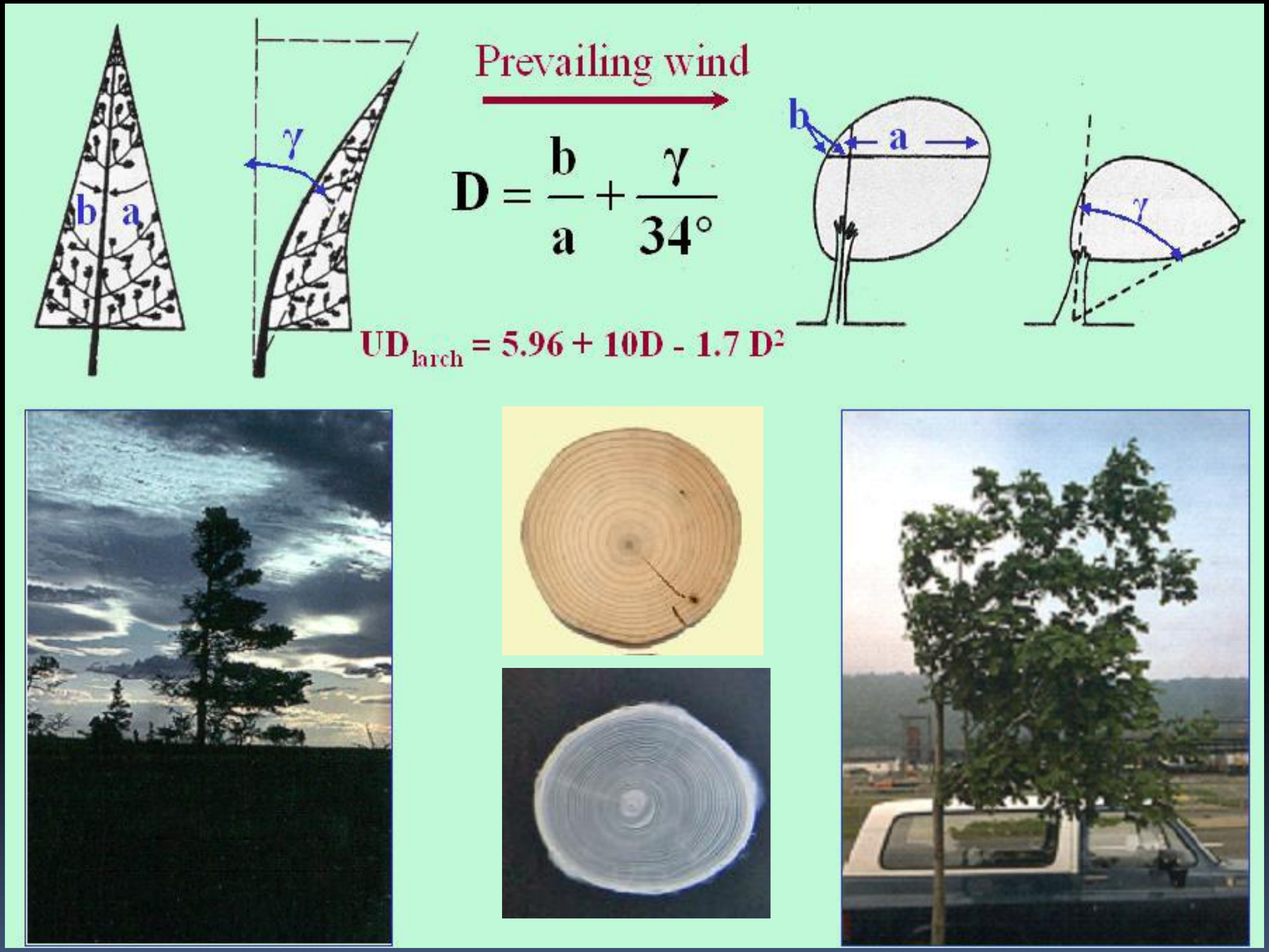
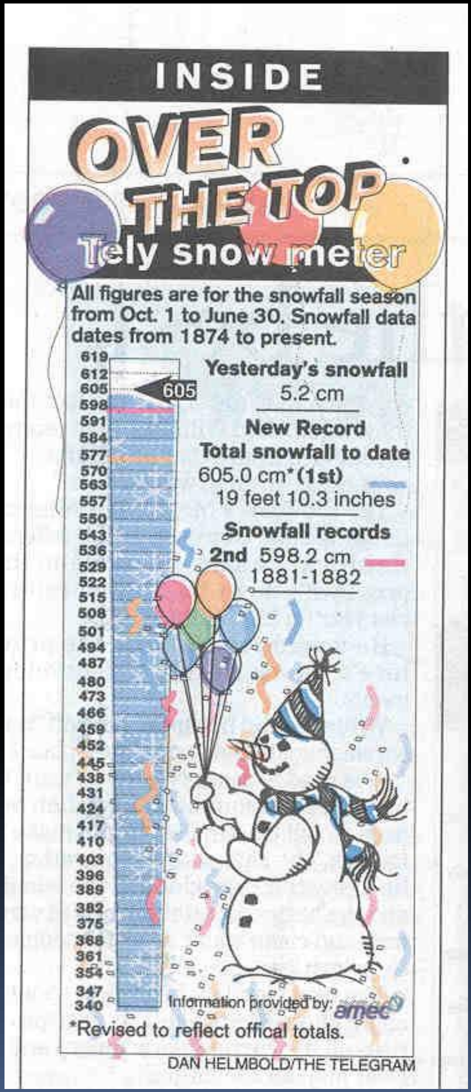
A tree deformation index for calculatiing mean wind speed.

The equations were derived by correlating the deformation of larch with wind data from nearby meteorological stations at several airports across Newfoundland.



A venacular assessment of wind directions

The primary purpose of the garden is to eliminate bothersome snow drifting with a 'snow-trap' shelterwood that is attractive year-round. The total amount of snowfall for the winter of 2002- 2001 in St. John's was a record-breaking 6.48 m



INSIDE

OVER THE TOP

Tely snow meter

All figures are for the snowfall season from Oct. 1 to June 30. Snowfall data dates from 1874 to present.

619 612 605 598 591 584 577 570 563 557 550 543 536 529 522 515 508 501 494 487 480 473 466 459 452 445 438 431 424 417 410 403 396 389 382 375 368 361 354 347 340

605

Yesterday's snowfall
5.2 cm

New Record
Total snowfall to date
605.0 cm* **(1st)**
19 feet 10.3 inches

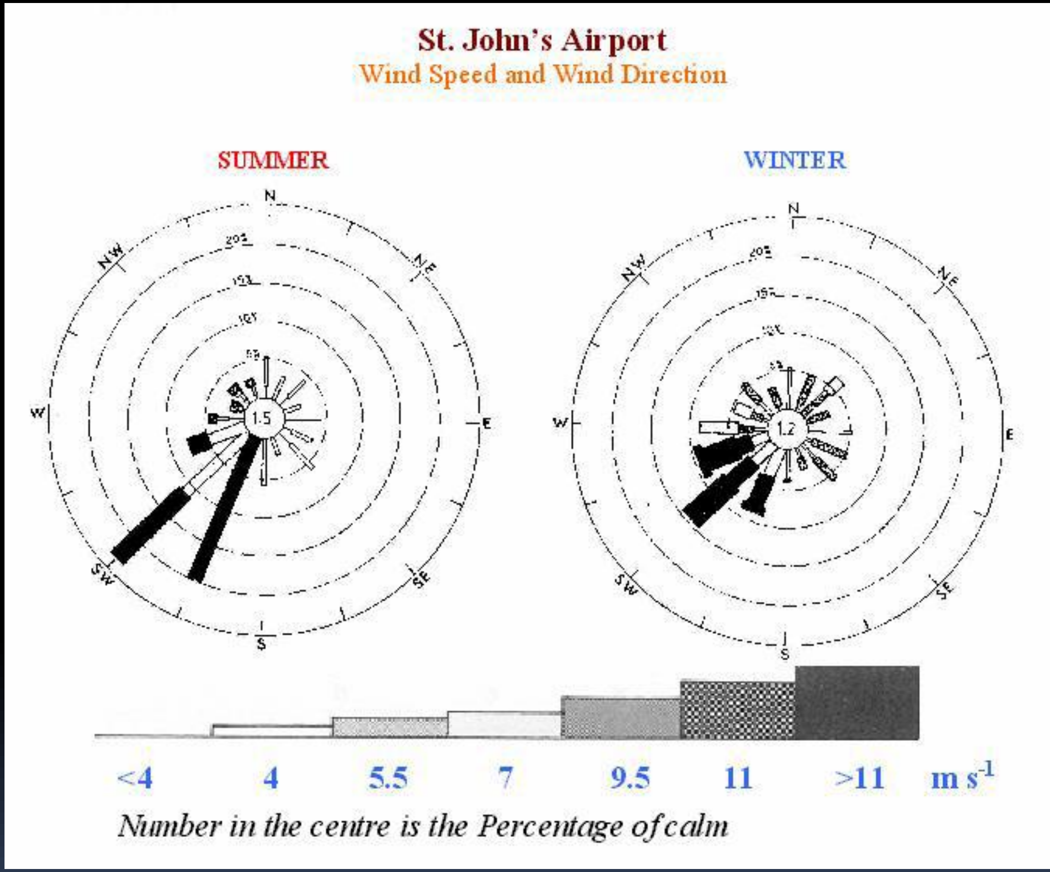
Snowfall records
2nd 598.2 cm
1881-1882

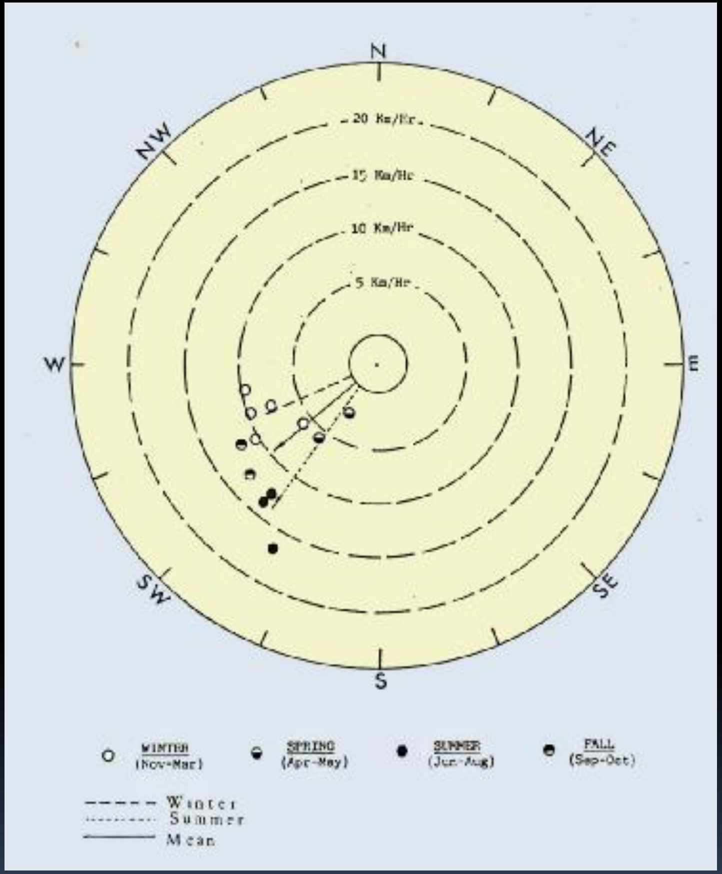
Information provided by: amec

*Revised to reflect offical totals.

DAN HELMBOLD/THE TELEGRAM

An example of a common wind rose showing the difference between summer and winter winds while a centroid graph (left) shows a distinctive mean monthly directional shift in wind regimes in St. John's, Newfoundland



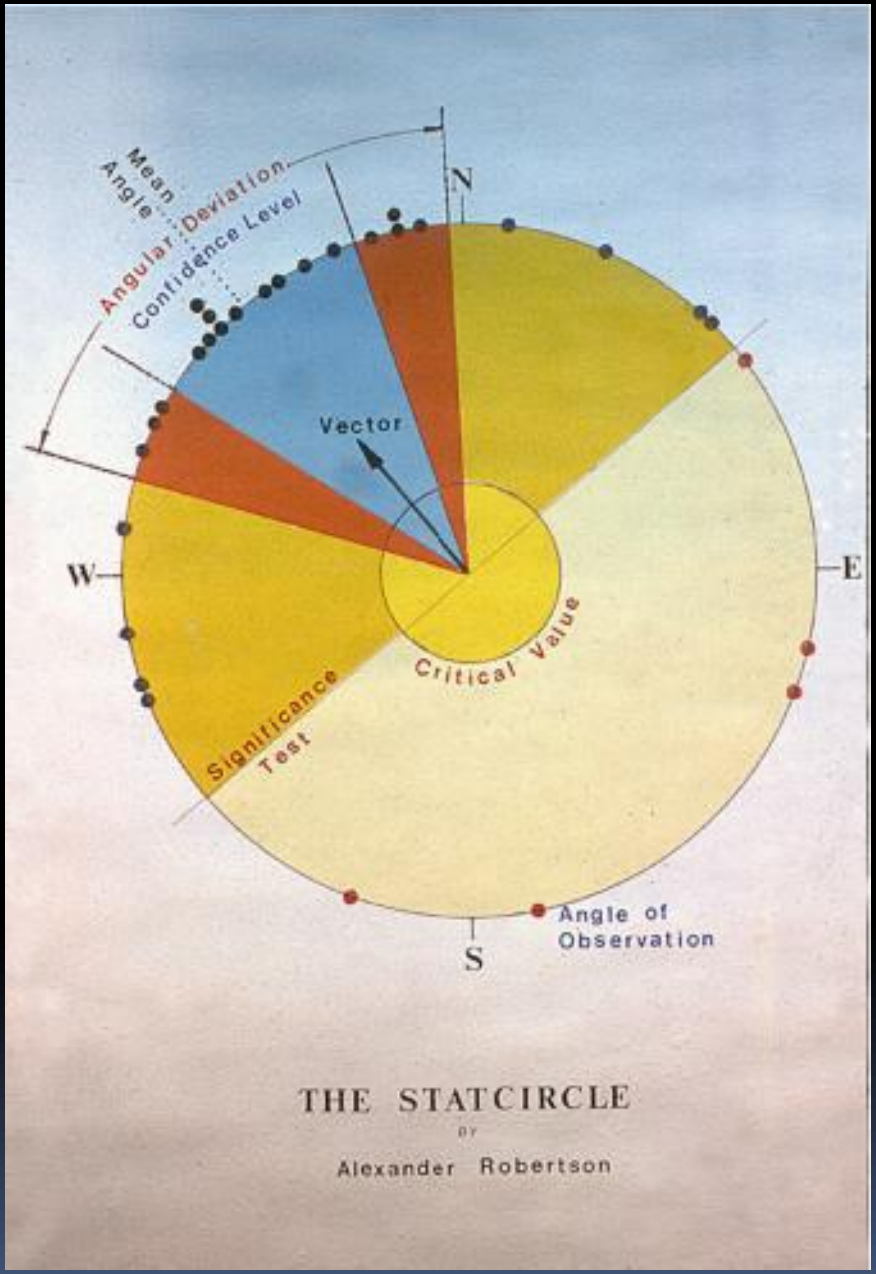


CIRCULAR STATISTICS

Analysis of Directional Influences

Circular statistics *(right)* are an ideal and relatively simple statistical approach to formally describing and testing the correlations between directional phenomena - such as effects of wind on various aspects of tree growth, wood density variation within a tree, dispersion of seed and effects of weather on vegetation.

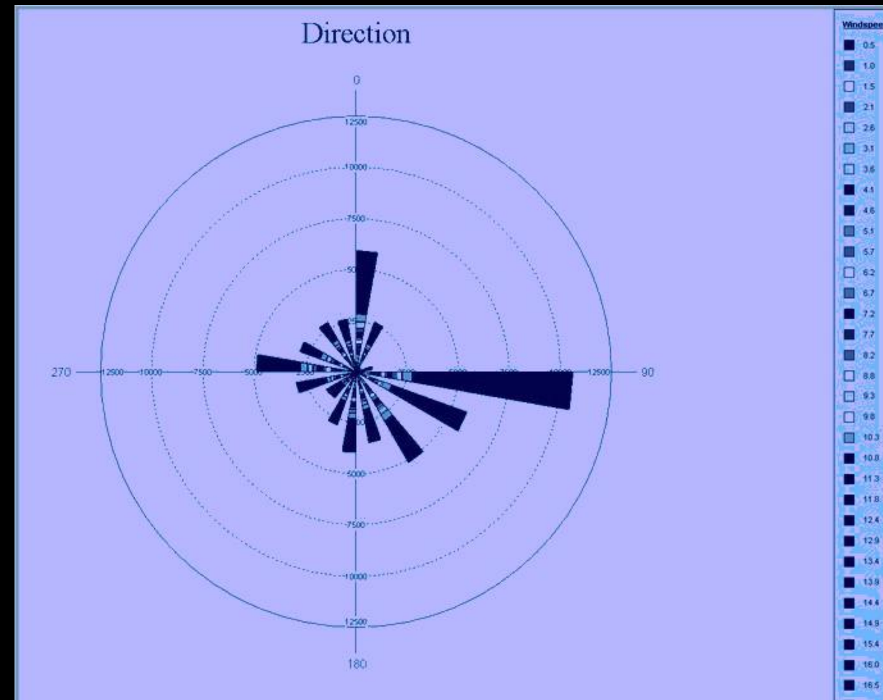
- Angle of observation
- Length of mean vector
- Mean angle
- Angular deviation
- Confidence level
- Critical value
- Significance test



C:\Program Files\ORIANA\Oriana_Data\.STORHOFDI WIND DIR.ori

BASIC STATISTICS

Analysis begun: May 28, 2008 3:22:28 PM
Variable **Direction**
Data Type Angles
Number of Observations **61,725**
Data Grouped? Yes
Group Width (& Number of Groups) 10° (36)
Mean Vector (μ) 1.3E+2°
Length of Mean Vector (r) 0.1
Median 1.1E+2°
Concentration 0.3
Circular Variance 0.9
Circular Standard Deviation 1.2E+2°
Standard Error of Mean 1.3°
95% Confidence Interval (-/+) for μ 1.2E+2°
1.3E+2°
99% Confidence Interval (-/+) for μ 1.2E+2°
1.3E+2°



Software Provided by
Kovach Computing Services

Oriana

http://www.kovcomp.co.uk/oriana

KCS

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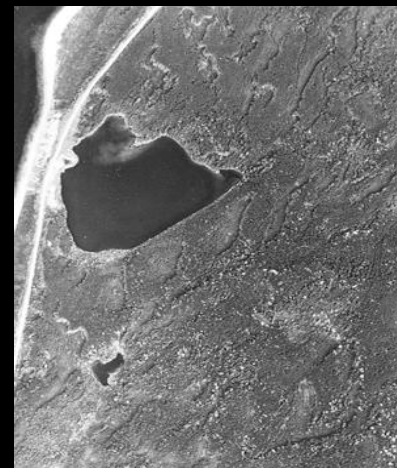
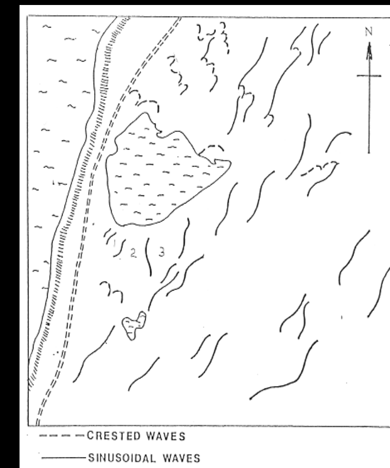
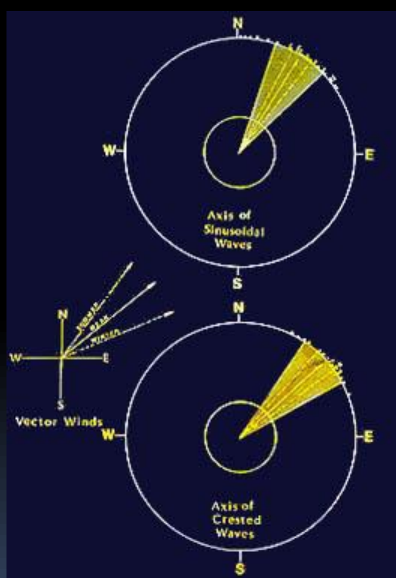
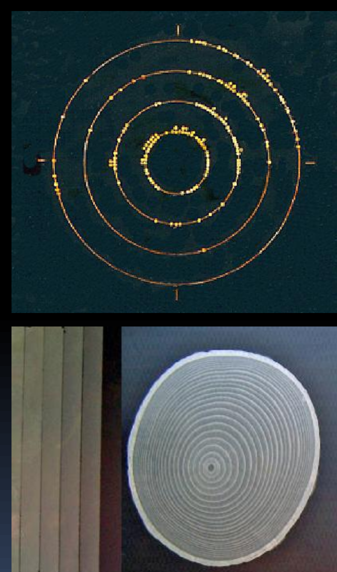
The Spirity Cove balsam fir wave forest is a unique wind-shaped ecosystem that is ideal for the study of many long-term weather effects on many temporal and spatial scales



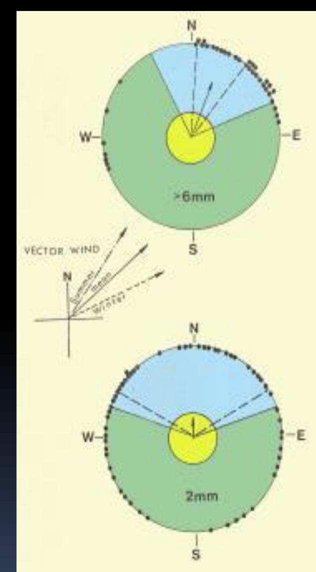




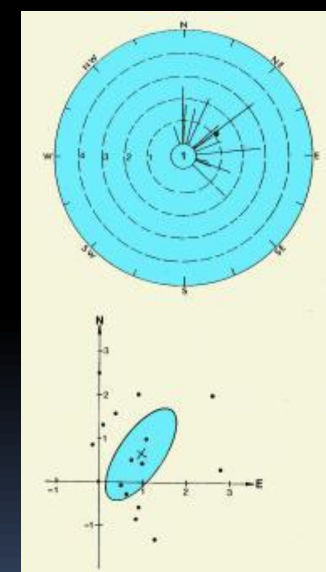
Dead-tree strips



Compression wood



Angular distribution of compression wood



Vector ring width and confidence elipse

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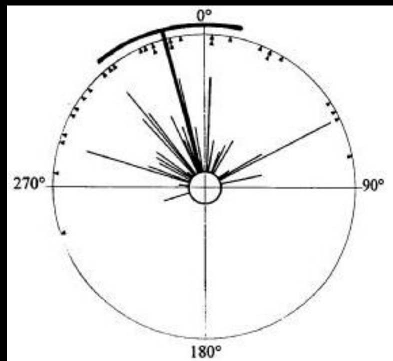
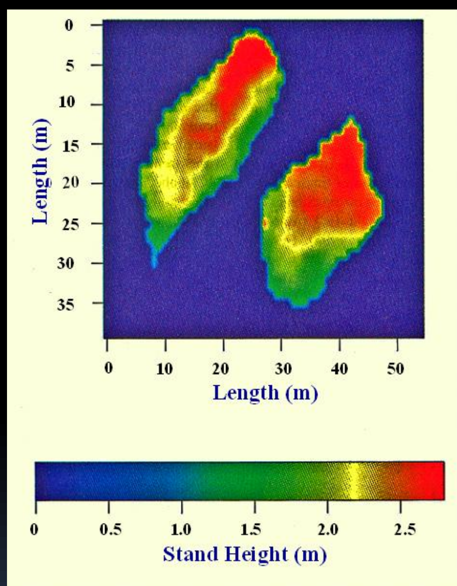
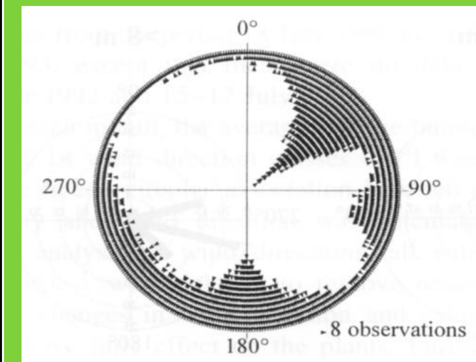
Circular statistical analysis of birch colonization and the directional growth response of birch and black cottonwood in south Iceland

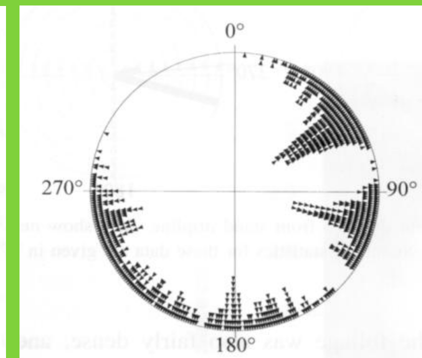
Ása L. Aradóttir[1], Alexander Robertson[2] and Edward Moore[3]



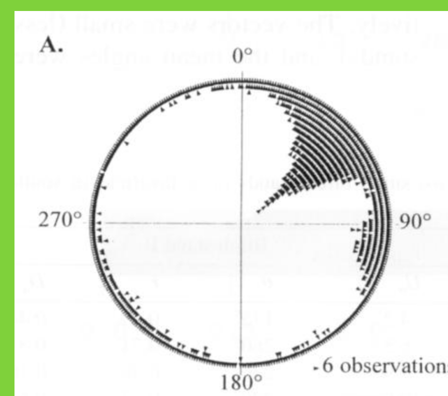




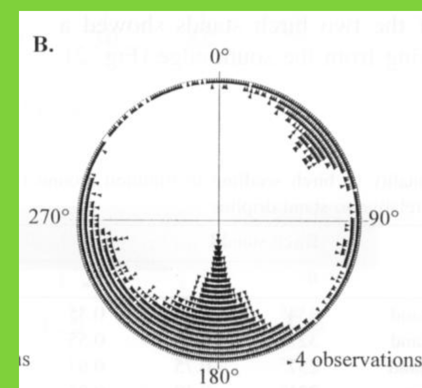
$> 2\ m\ s^{-1}$



$>10\ m\ s^{-1}$



'dry' winds
(Rh<75%)



'wet' winds
(Rh>85%)

Crown asymmetry of black cottonwood saplings and strong curvature of the isolated birch stands indicated a growth response to stress caused by southerly winds, but regeneration of birch seedlings was strongly directional as a response to seed dispersal by strong, dry easterly and northeasterly winds.

FRACTAL GEOMETRY

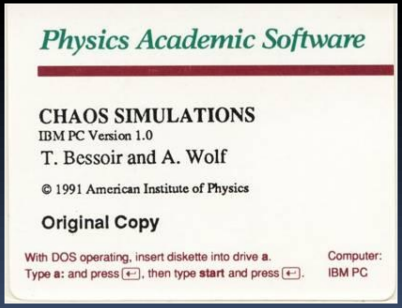
THE CALCULUS OF HETEROGENEITY

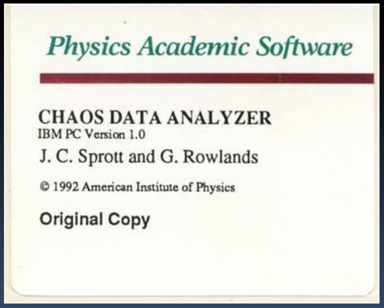
&

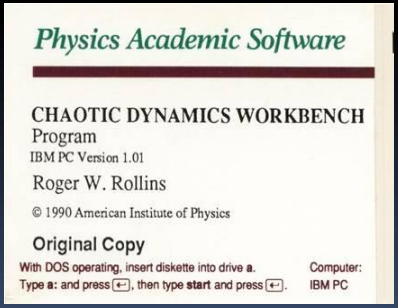
CHAOTIC DYNAMICS

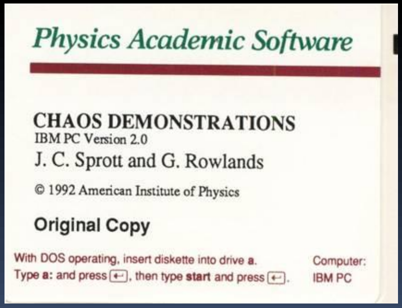
THE CALCULUS OF INSTABILITY

Or, simply put, a measure of roughness evolving from the process of change

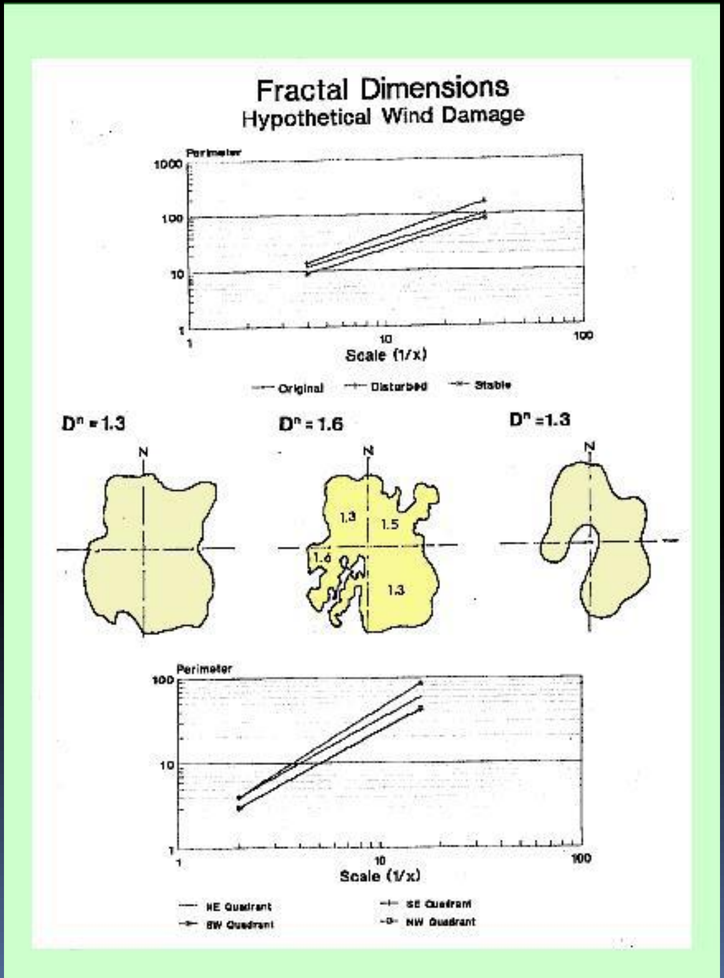








Complexity is the most frequently-used word associated with this new-age way of describing and analysing the impact of environmental disturbance on landscape patterning and their influence on forest growth.



First principles of complexity

- *fractal geometry*, the calculus of heterogeneity

- *dynamical systems*, the power spectrum of change

-*chaos*, origin of patterns,

- *percolation*, drift of diversity

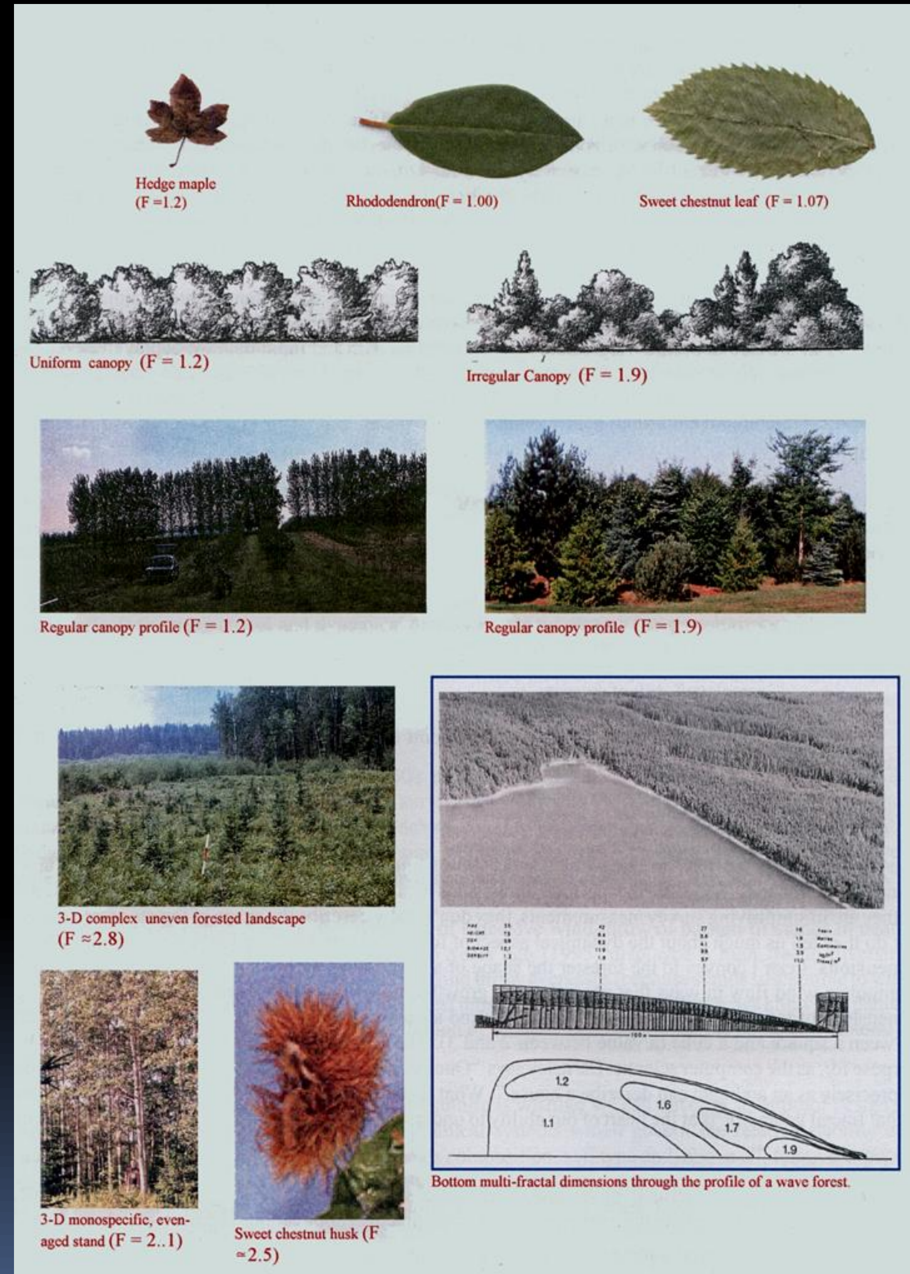
- *directionality*, madly off in all directions

DiSPENSING WITH EUCLID

In forest surveys we rely on three dimensions, line (dimension 1) square (dimension 2) and cubical (dimension 3) shapes. These are the ‘perfect’ dimensions handed down to us from the ancient Greeks.

Using ‘perfect’ dimensions, one cannot convey the roughness of a shelterwood.

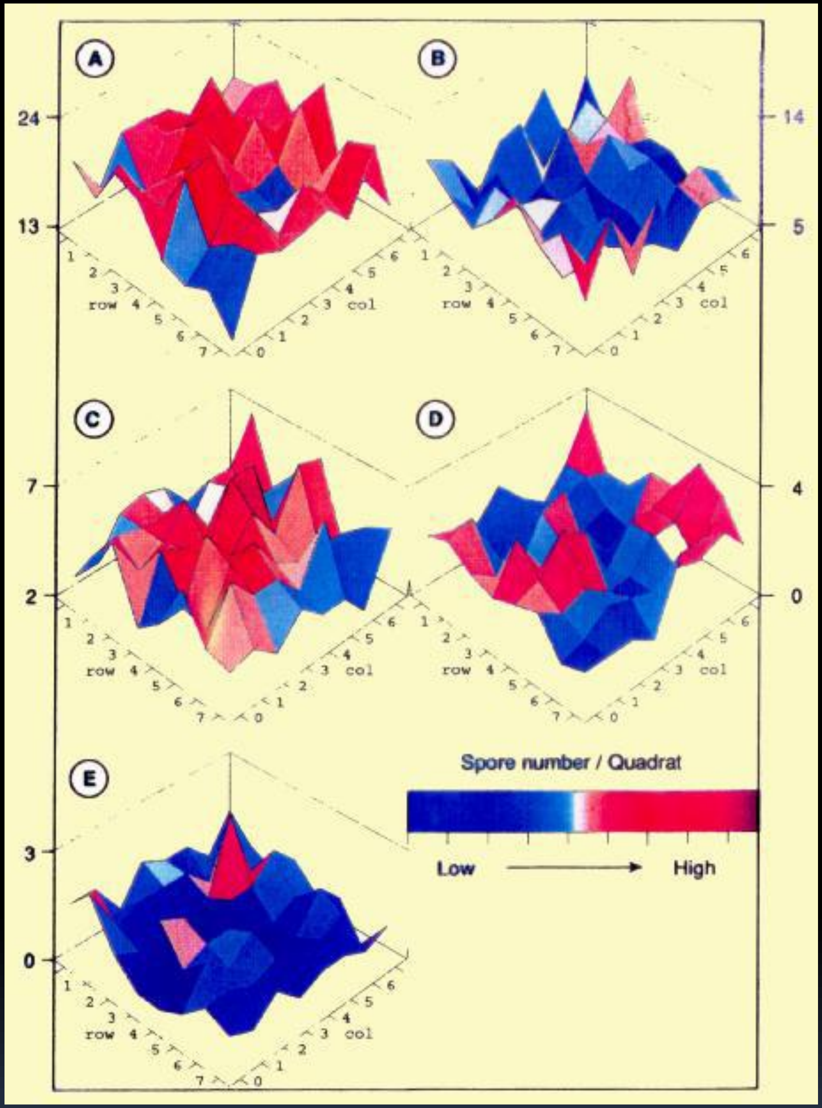
For that we need a new measure, i.e., the fractal dimension of ‘imperfect’ dimensions of roughness which lie between a line and a square (i.e., having a value between 1 and 2), and between a square and a cube (a value between 2 and 3).



FRACTAL DIVERSITY

i.e., combined measures of roughness (fractal dimension) and diversity (number of quadrates with different spore counts adjacent to a patch) was used to explain the role of micro scale Taylor vortices on the distribution of fungal spores onto a membrane filter

Spore ranges

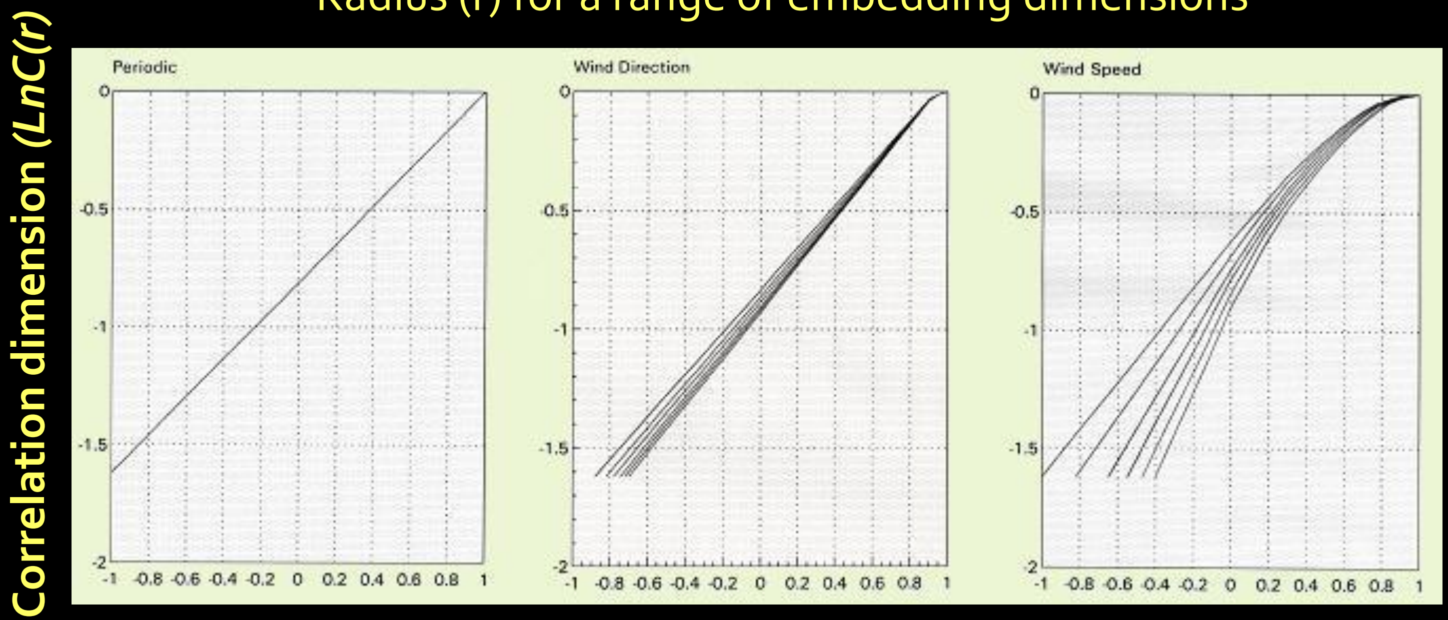


Rows & columns of gridded membrane filters

Source: M. C. Hampson & A. Robertson *Distribution of Fungal Spores and Fractal Diversity of Quadrats on membrane Filters* J. Food Protection 58:1038-1047 (1995)

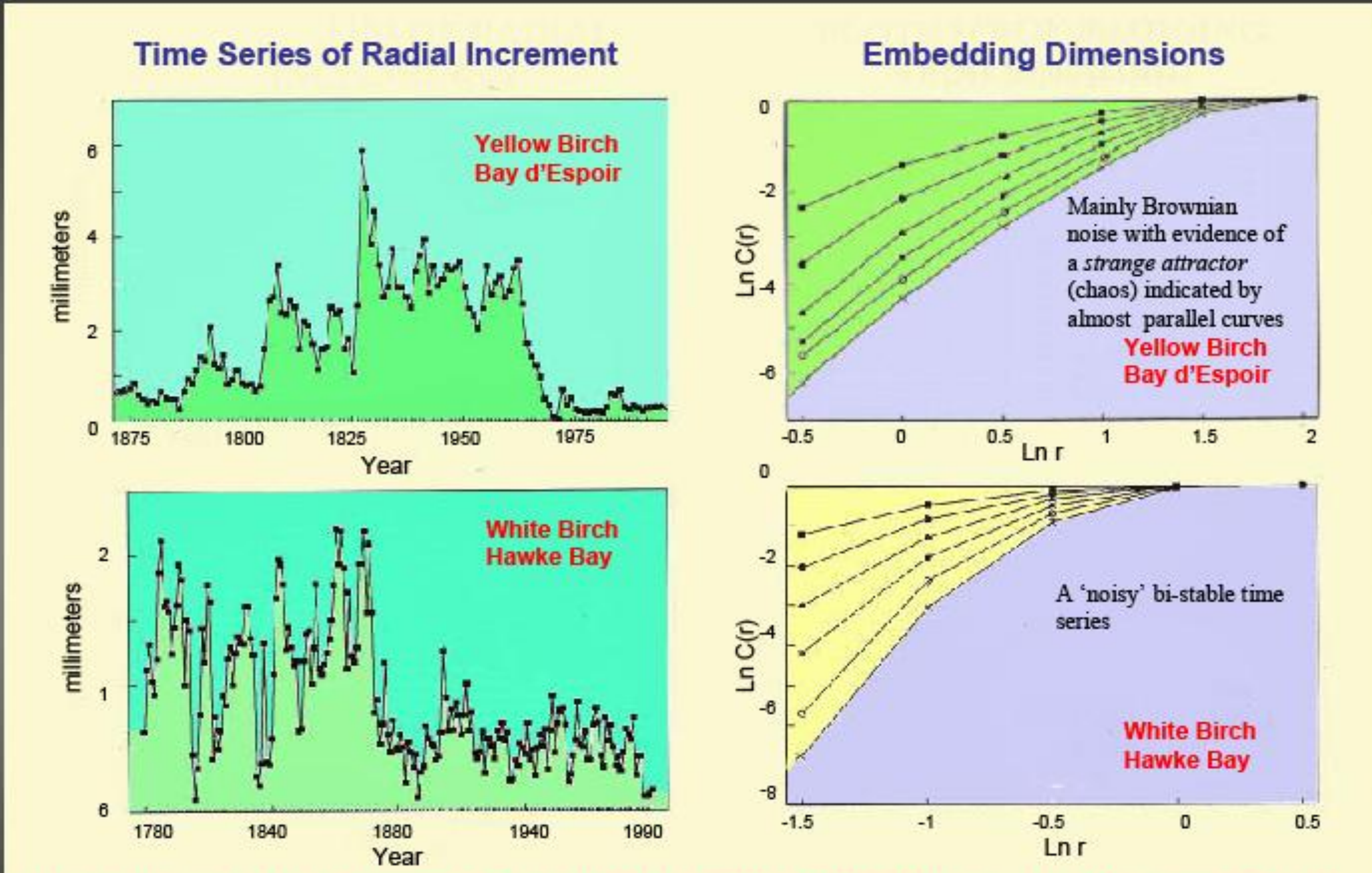
Turbulent Time Series 1

Log-Log plots of Correlation Integral /C(r) versus Hyersphere of Radius (r) for a range of embedding dimensions



The slopes of the periodic case are coincidental. Veering of wind direction, associated with frontal passages, produces a time series with well-defined patterns as indicated by the slightly divergent curves. The wind speed time series by comparison, is characteristically noisy; but still has some pattern *(if it were truly random the last curve on the right would be vertical).* Graphs pertaining to wind were derived from analysis of averages at 3 minute intervals over an 18 months period measured at the Gunnarsholt experimental site.

Source: Alexander Robertson. *Directionality, fractals and chaos in wind-shaped forests*. Agric. For. Meteorology 72:133-166 (1994)

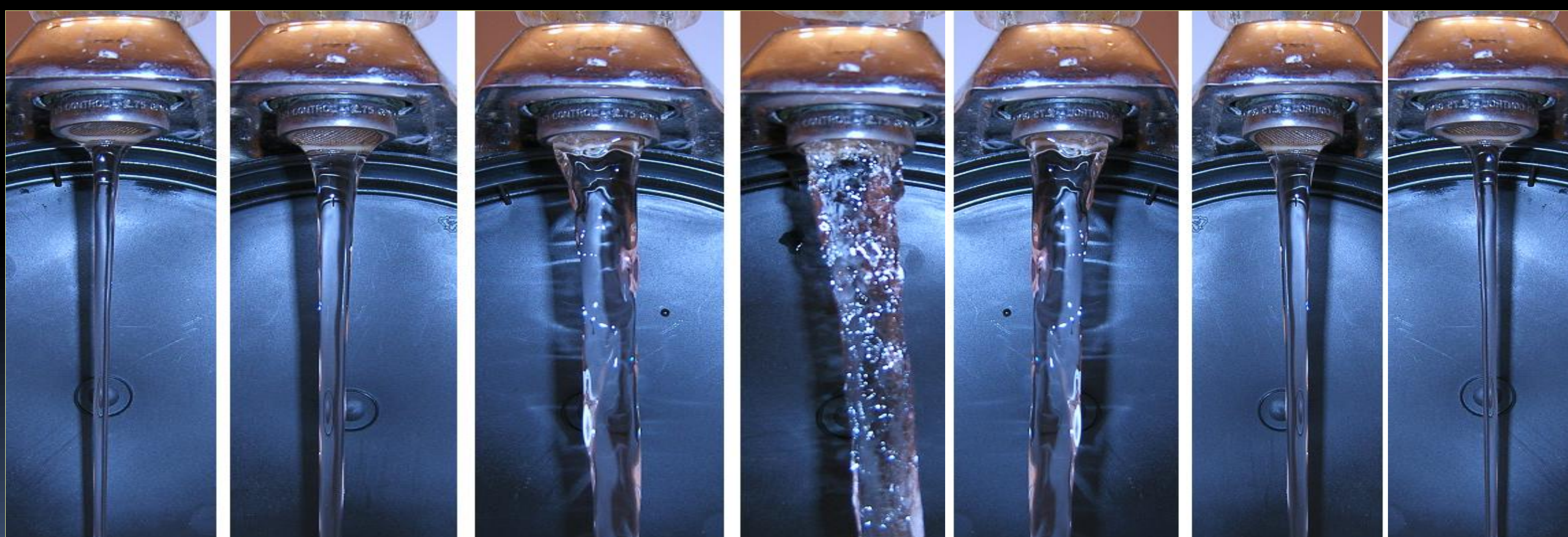


Source: Alexander Robertson. *Directionality, fractals and chaos in wind-shaped forests*. Agric. For. Meteorology 72:133-166 (1994)

Biodiversity is fundamentally a process of chaotic dynamics

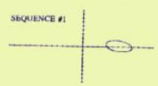
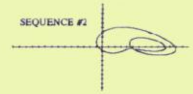
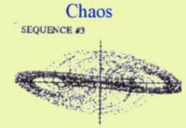
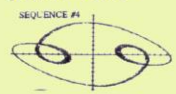
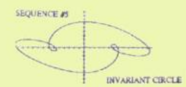
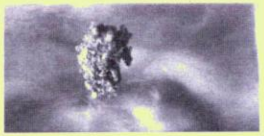
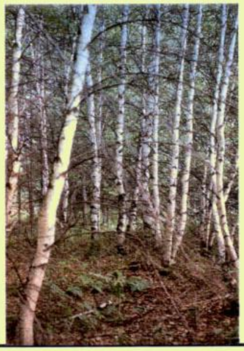
Opening and closing a tap slowly illustrates the principle of a forcing parameter which evokes phase changes from one dynamic state to another. At low pressure the flow is more or less featureless (laminar). A slight increase produces a steady, well-defined helix (stable). Another slight increase produces an unsteady double helix (stable + chaotic). At full pressure, the helix persists, but they are disjunct and short-lived (chaotic). Releasing the pressure gradually we go back through these states to (laminar). When we turn on a tap in normal use, the transition through these dynamical states is so rapid that we only see the chaotic state. If a poll was taken to find out which pattern is the most interesting, it would probably be the partially-recognizable stable + chaotic state.

Weather – especially its influence of wind on biodiversity in the landscape - is a lot like that; insofar as it evolves through many dynamical states, such that it often generates too much complexity for our minds to absorb



laminar Stable Stable+chaotic Chaotic Stable+chaotic Stable laminar

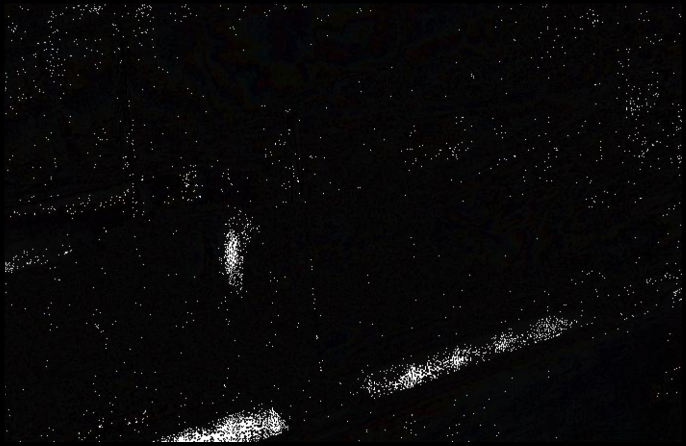
Analogies of Chaotic Dynamics in Mathematical, Ecological and Dynamical Systems

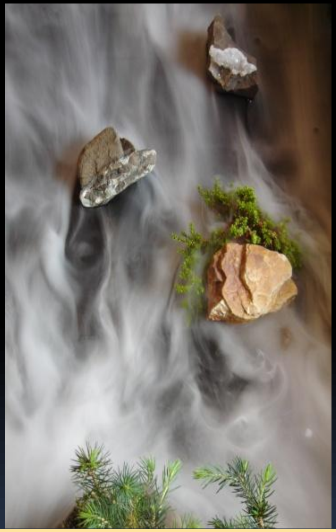
TOPIC	ORIGINAL ATTRACTOR		FORCING PARAMETER	NEW ATTRACTOR	
	STABLE	LIMIT CYCLE	CHAOS	CHAOS+STABLE	STABLE
Value of forcing parameter	C = 0.22	C = 0.3	C = 0.376	C = 0.39	C = 0.4
PHASE PORTRAIT	Invariant Circle 	Limit Cycle 	Chaos 	Chaos + Stable 	Stable 
Reynolds number for ind flow Patterns around Trees	$\Re = 10^{-2}$	$\Re = 20$	$\Re = 100$	$\Re = 10^4$	$\Re = 10^6$
Corresponding wind flow patterns around a tree	Homogeneous 	Vortex 	Chaos 	Strong-oscillations 	Weak-oscillation 
Birch Forest	Pure birch 	High + understorey 	New high forest 	Disturbance response 	Birch + planted 

C = A forcing parameter in a difference equation such $x_3 = Cx_2 - 1x_1^3 + 1\,x_3$; slight changes in C produces dramatically different phase portraits of time series

$\Re$ = Rayleigh number is dimension less and expresses a forcing parameter where at certain values $\Re$ the fluid becomes unstable to for new patterns.

Dry-ice visualization models illustrating the importance of adding roughness elements to the landscape and on buildings

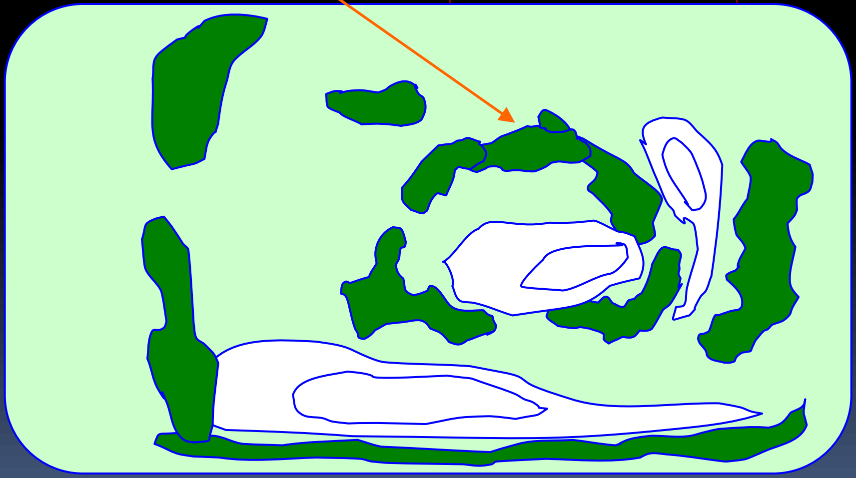




It is partially predictable due to chaotic dynamics of convective acceleration . In other words, the flow patterns are an inherently non-linear system; such that replication of flow patterns can only be approximated – but sufficiently so for practical demonstrations.

DIRECTIONALITY, ROUGHNESS (FRACTAL) AND CHAOTIC DYNAMICS
are important variables to consider as environmental services for forestry

The concepts of directionality, roughness (fractal dimensions) and the chaotic dynamics, inherent in seasonal changes, were applied in the design of this planting scheme



It is the rich fractal diversity, seasonal chaotic dynamics of the landscape and somewhat unpredictable directionality of weather systems that makes Mt. Esja so attractive.

Jón Geir Pétersson

Environmental Services for Forestry

Circular Statistics – the calculus of directionality

Circular and spherical statistics have been applied in biology and geostatistics but rarely in forestry. Which is rather odd, given that there are many internal and external directional influences affecting virtually every aspect of forestry.

Fractal Geometry – the calculus of heterogeneity

The time-honored Euclidean geometry is inadequate for describing the myriad of scaling factors, lacunarity and heterogeneity of forests which, in many regions, is influenced greatly by the interactions between wind and forests. Dynamically speaking, such interactions are basically non-linear systems; whereby, short-term prediction is possible but long-term is only partially predictable at best.

Combining circular (and spherical) statistics with measures of roughness and chaotic data analyses provides a valuable environmental service for forestry.