DynaRoot - Dynamic Root Evaluation

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TREE INSPECTION INSTRUMENTS Seminar
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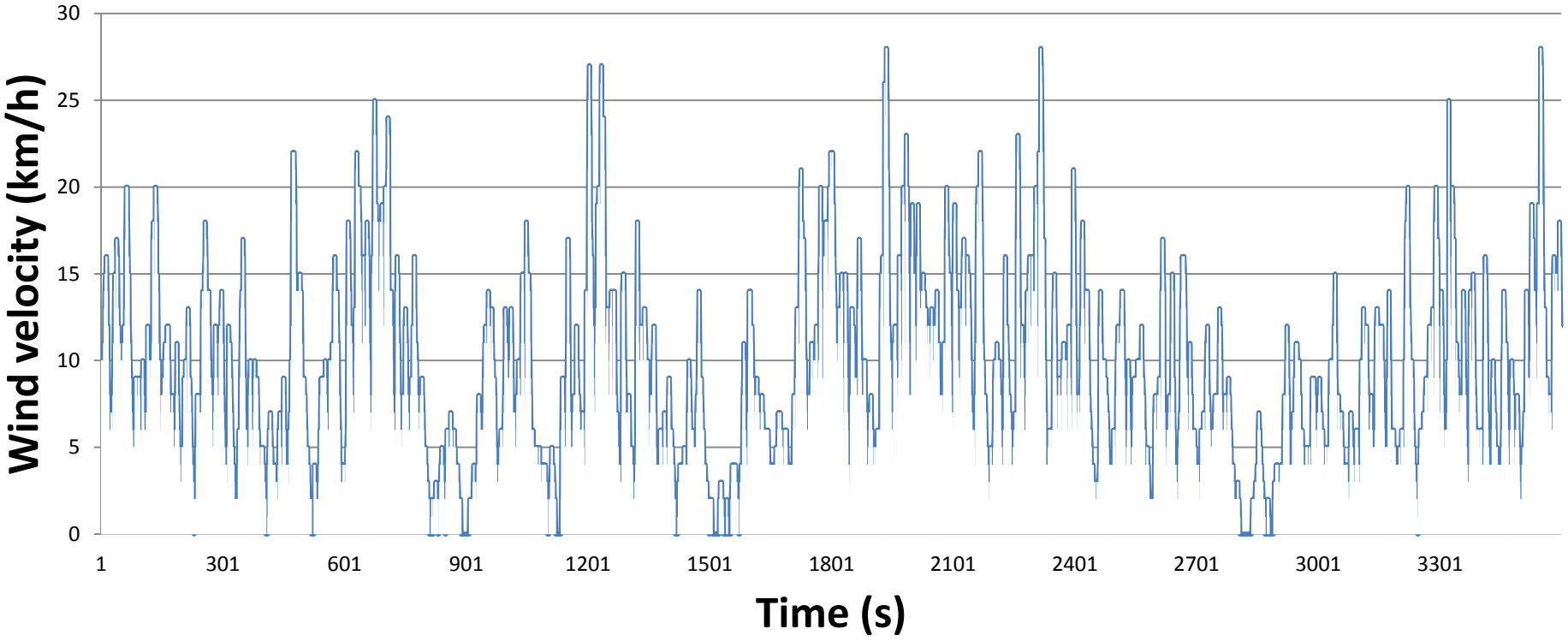
Dynamic Root Evaluation -DynaRoot

A new technique
First demonstartion was at University of Pisa, 2016

The wind load is dynamic load



IDEA

The Dynamic Root Evaluation method is based on inclination measurements at root collar, correlated with wind gust velocity measurements.

The evaluation technique is similar to the pulling test method. Instead of applying a static force (pulling by rope), we rely on natural wind pressure.

Idea:

- instead of pulling by rope we are using wind
- instead of force we are using wind pressure: p_{wind}

$$p_{wind} = \rho/2\ V^2$$

- where: ρ is air density, V is wind gust velocity

consequence

- in normal wind condition wind velocity is relative low, so high sensitivity sensors are necessary: resolution is 0,001 degree.
- If the 56m tall leaning tower in Pisa would change the inclination by 0,001 degree, the top horizontal movement would be only 1 mm.

wind velocity (km/h)	10	20	40	60	90	120
wind pressure (Pa)	5	19	74	167	375	667

Instruments are:

- Inclinometer(s)
- Anemometer

Root Collar Inclination Recorder

High sensitivity, dual axes inclination sensor. Resolution is 0,001 degree. Working range is +/- 2 degree.

The mounting device and the house including GPS, data logger and sensor

Root Collar Inclination Sensor

Technical data:

- Dual axes inclinometer
- Measuring range +/- 2 degree
- Resolution: 0,001 degree
- Temperature compensated
- Sampling rate is 10 Hz
- Integrated GPS
- Data stored on 8 GB SD card
- File name is the exact date and time, provided by GPS
- Fixing by a single screw
- Operating voltage: 12V, current: 20 mA

Anemometer

Sampling rate 1/sec

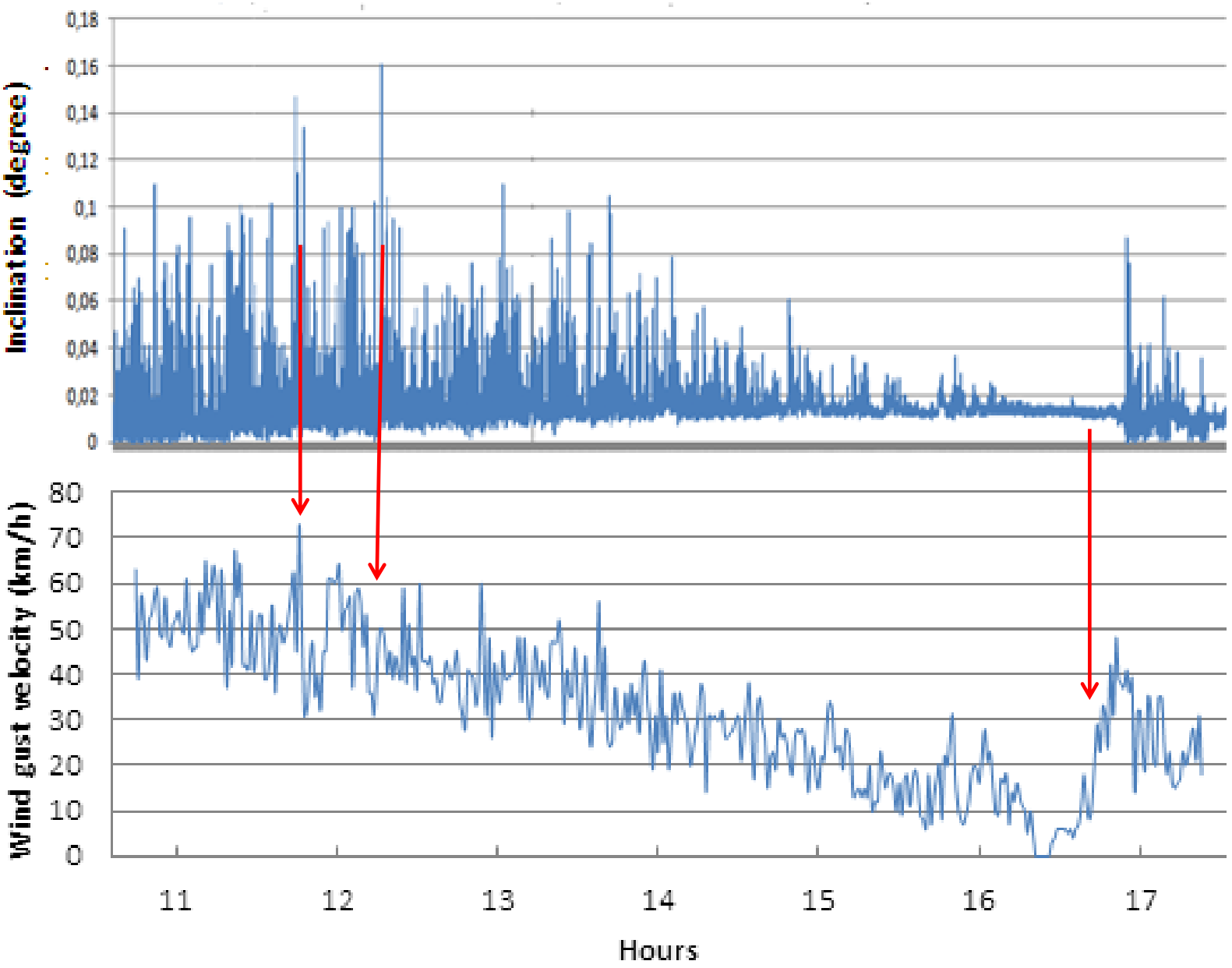
Need to measure the real wind velocity.

Best location: open field 10 height

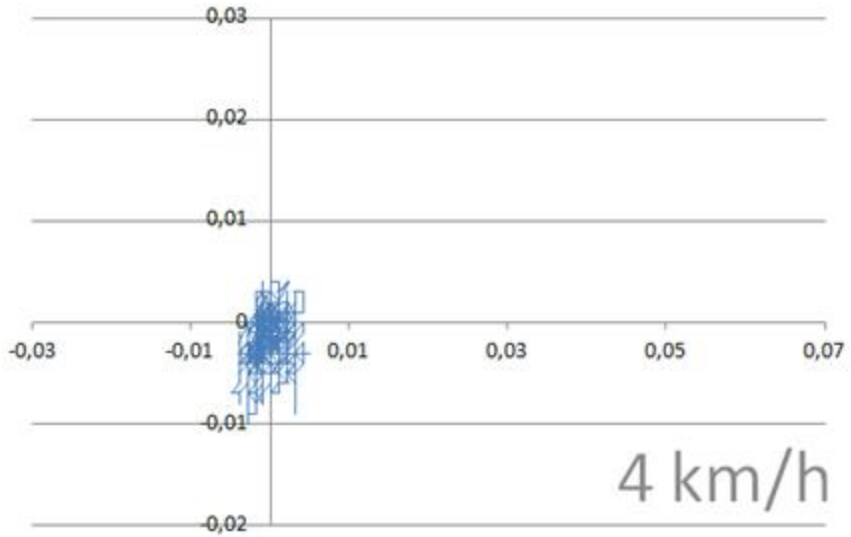
Disturbation by buildings is not allowed

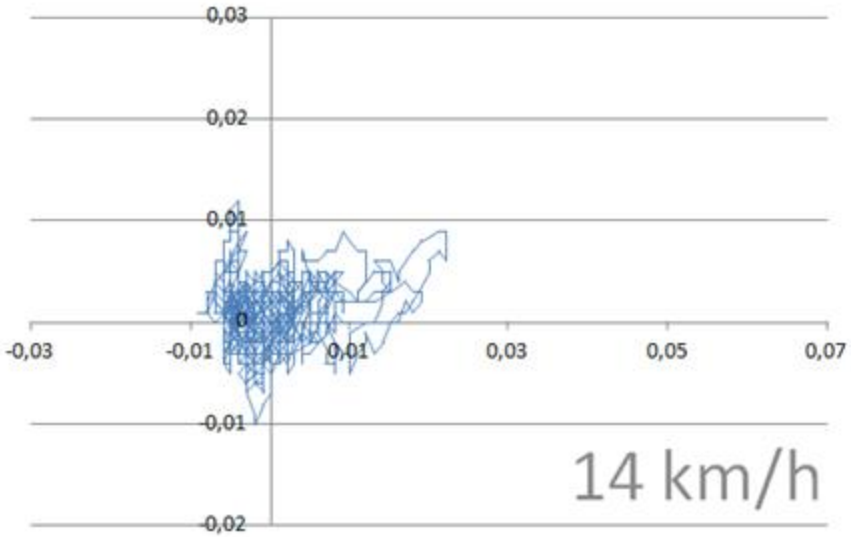
10m tall mobile pole with ultrasonic anemometer and data logger

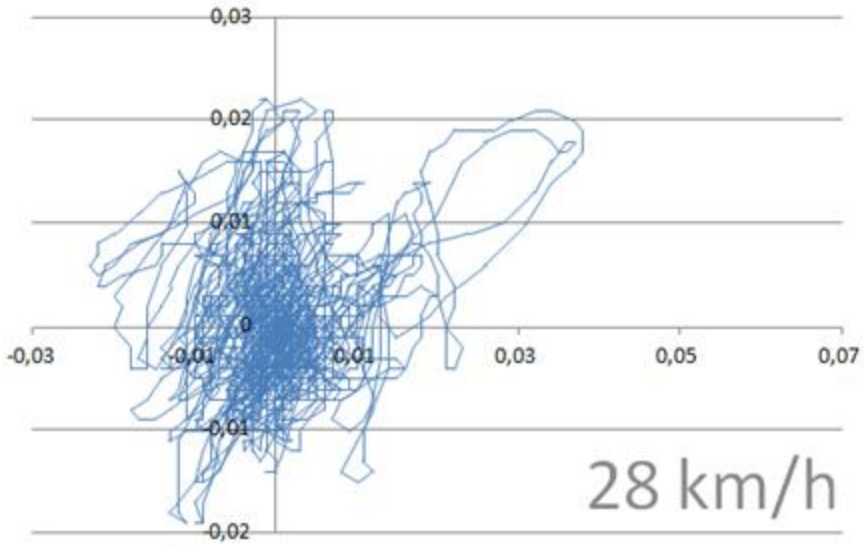
No **direct** correlation between wind and inclination!

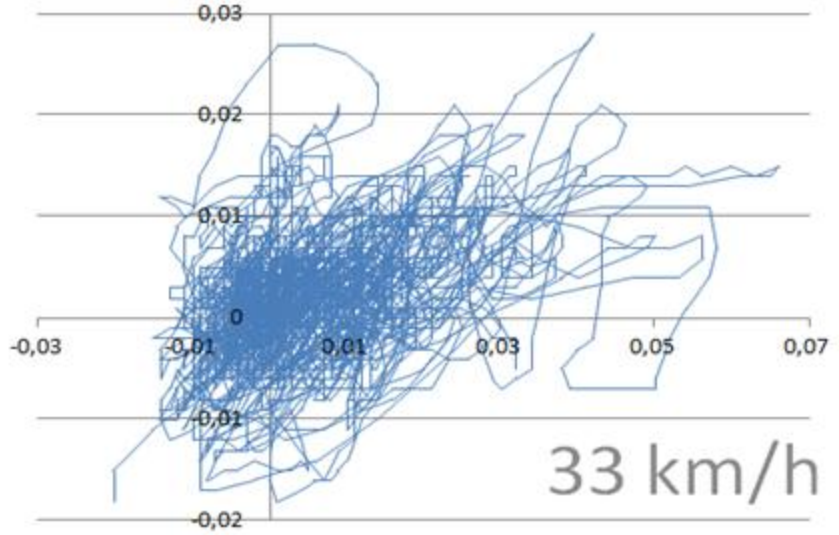


Tree trunk inclination in different wind velocity

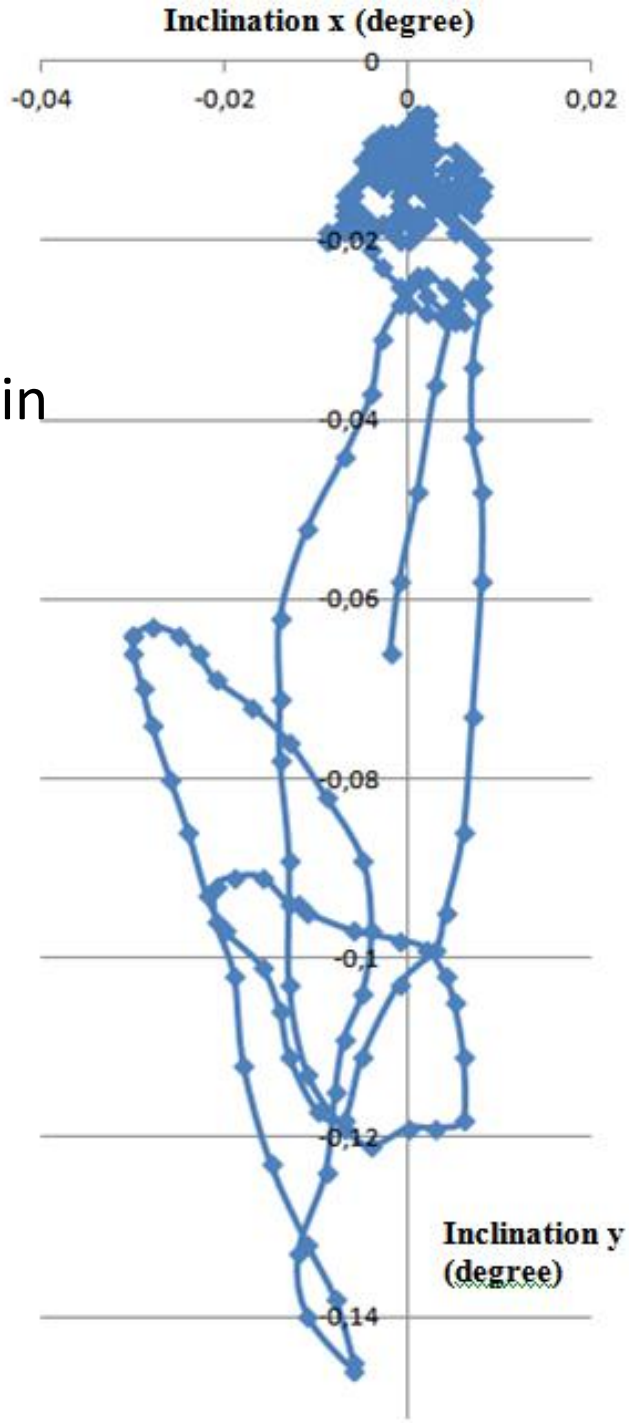








The movement of the root collar in a balance loss scenario.



Dynamic model of a tree

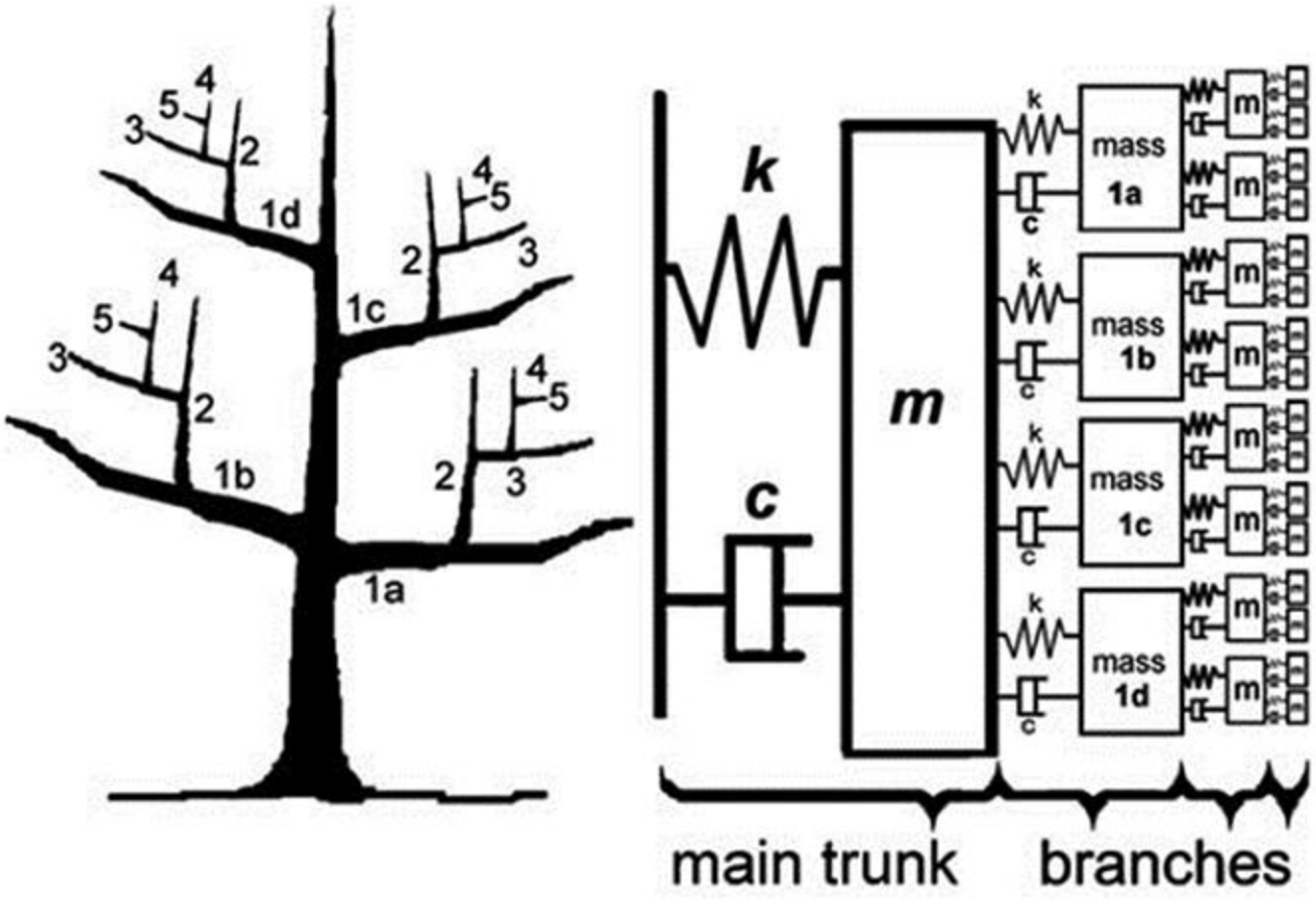
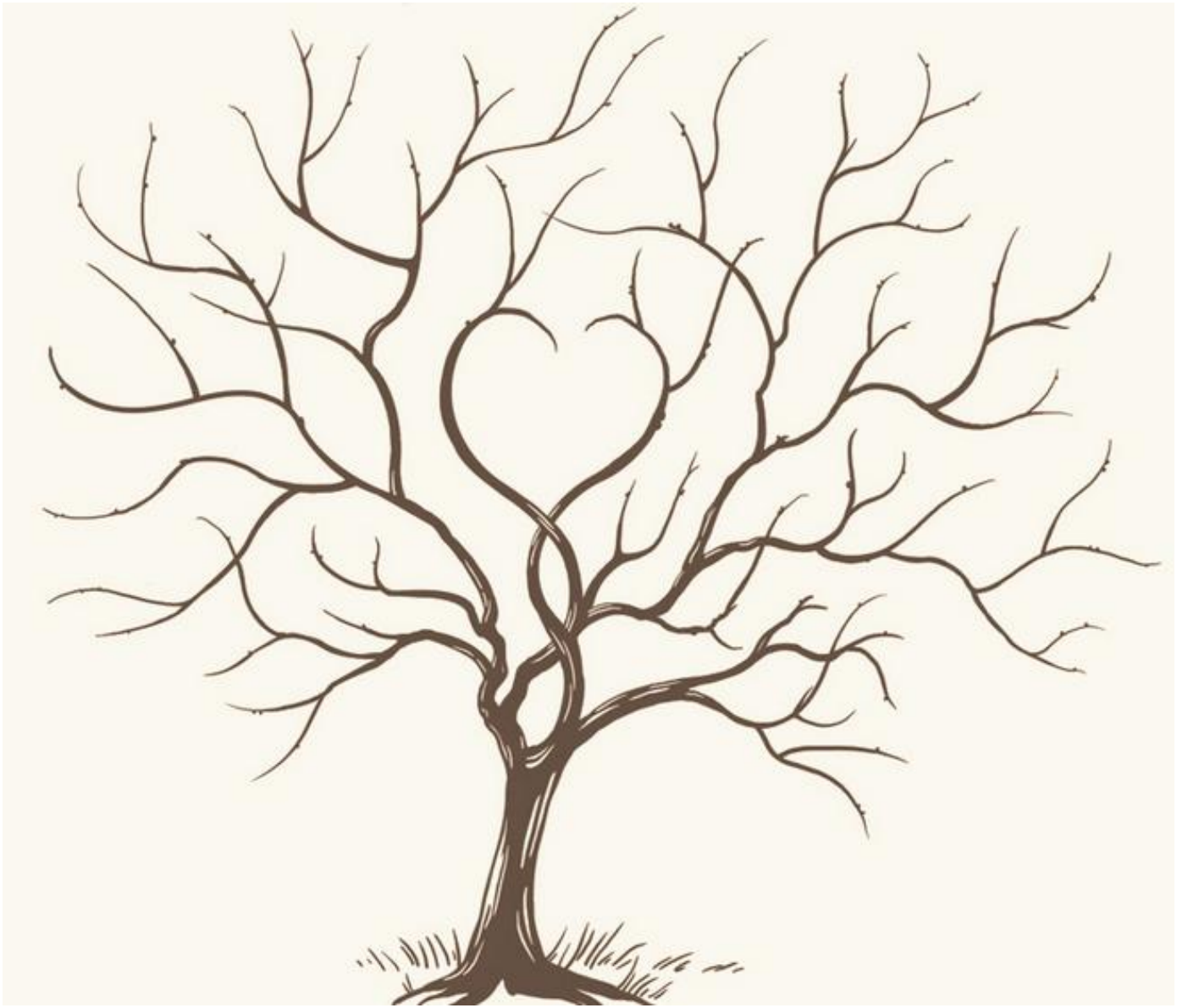


Figure from: James, Kent.R., N. Haritos, and P.K. Addes. 2006. Mechanical stability of trees under dynamic loads. American Journal of Botany 93(10):1361–1369.

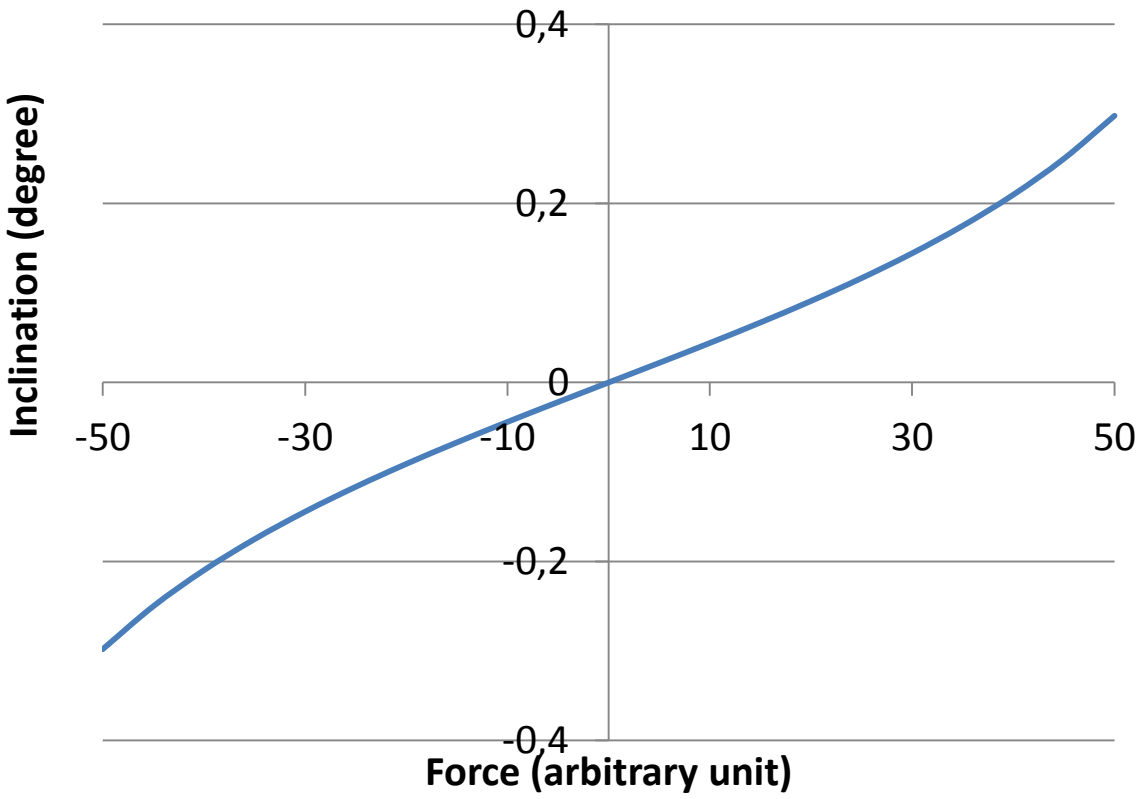
Double Pendulum Displays Chaotic Motion



Double Pendulum Displays Chaotic Motion.mp4

Chaos theory is the field of study in mathematics that studies the behavior and condition of **nonlinear dynamical system**s that are **highly sensitive to initial conditions**—a response popularly referred to as the butterfly effect. Small differences in initial conditions yield widely diverging outcomes for such dynamical systems, rendering long-term prediction impossible in general. This happens even though these systems are deterministic, meaning that their future behavior is fully determined by their initial conditions, with no random elements involved. In other words, the deterministic nature of these systems does not make them predictable. This behavior is known as **deterministic chaos**, or simply **chaos**.

Non-linearity in tree trunk inclination – force relation



Experimental background is pullingtest: inclino

Literature speaks about chaos phenomena

- A mass damping system described by Den Hartog (1956) has been defined for trees (James et al. 2006), and occurs when the **branches sway together (in phase) or against each other (out of phase) in a complex manner.**

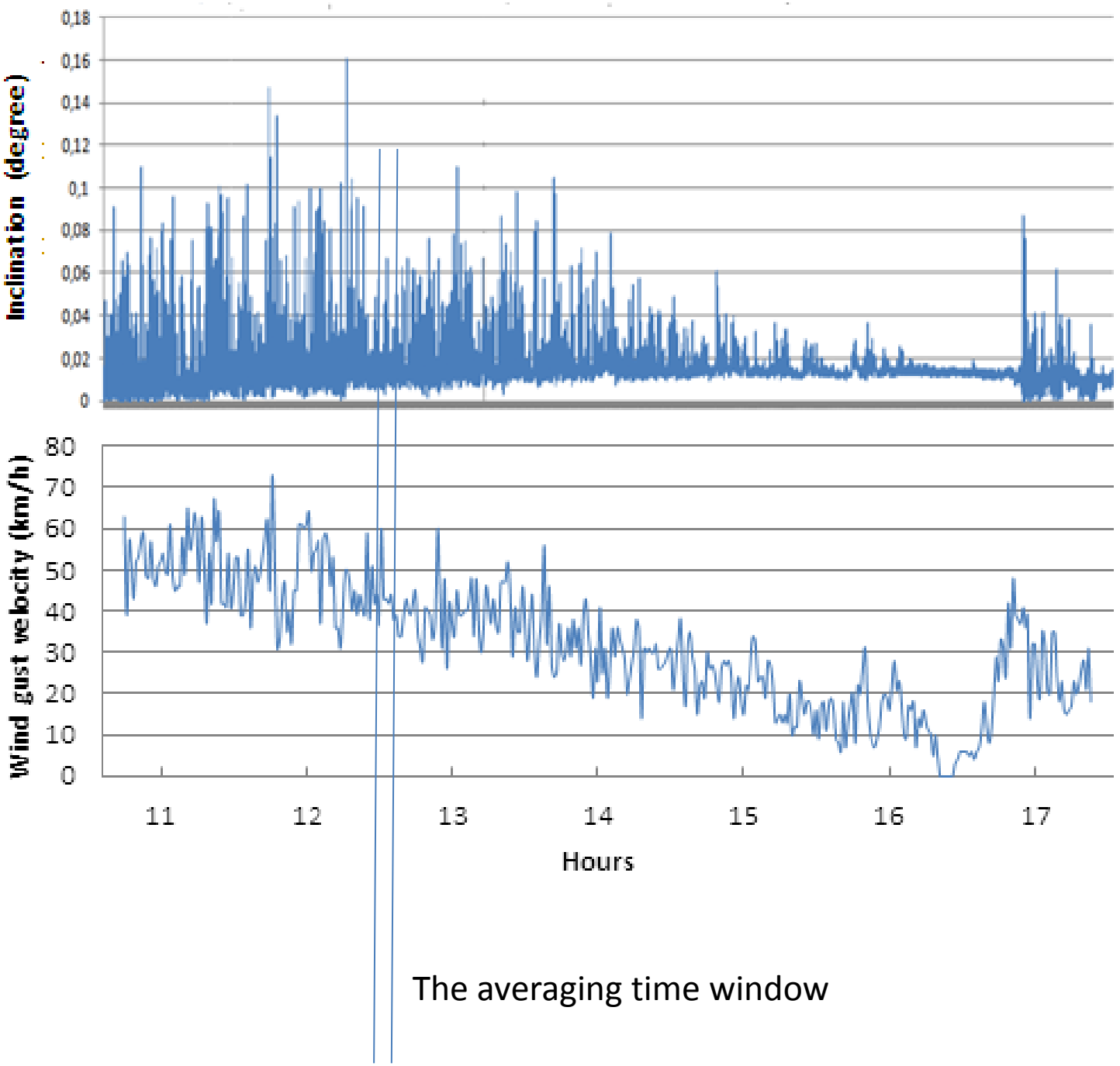
- Studies indicating that the **form of the tree has a greater influence** than the material properties (Sellier and Fourcaud 2009) – importance of initial conditions.

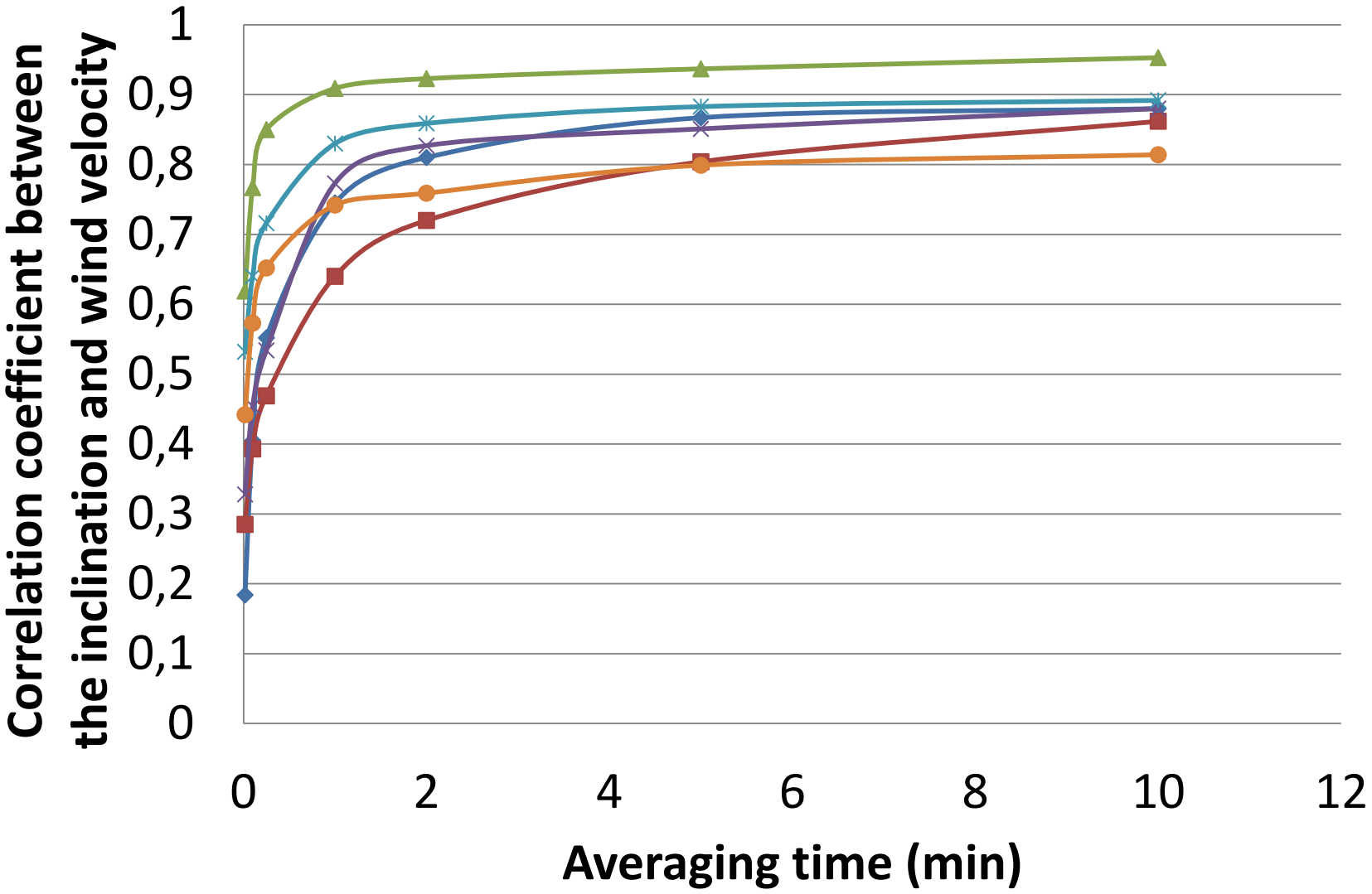
CHAOS

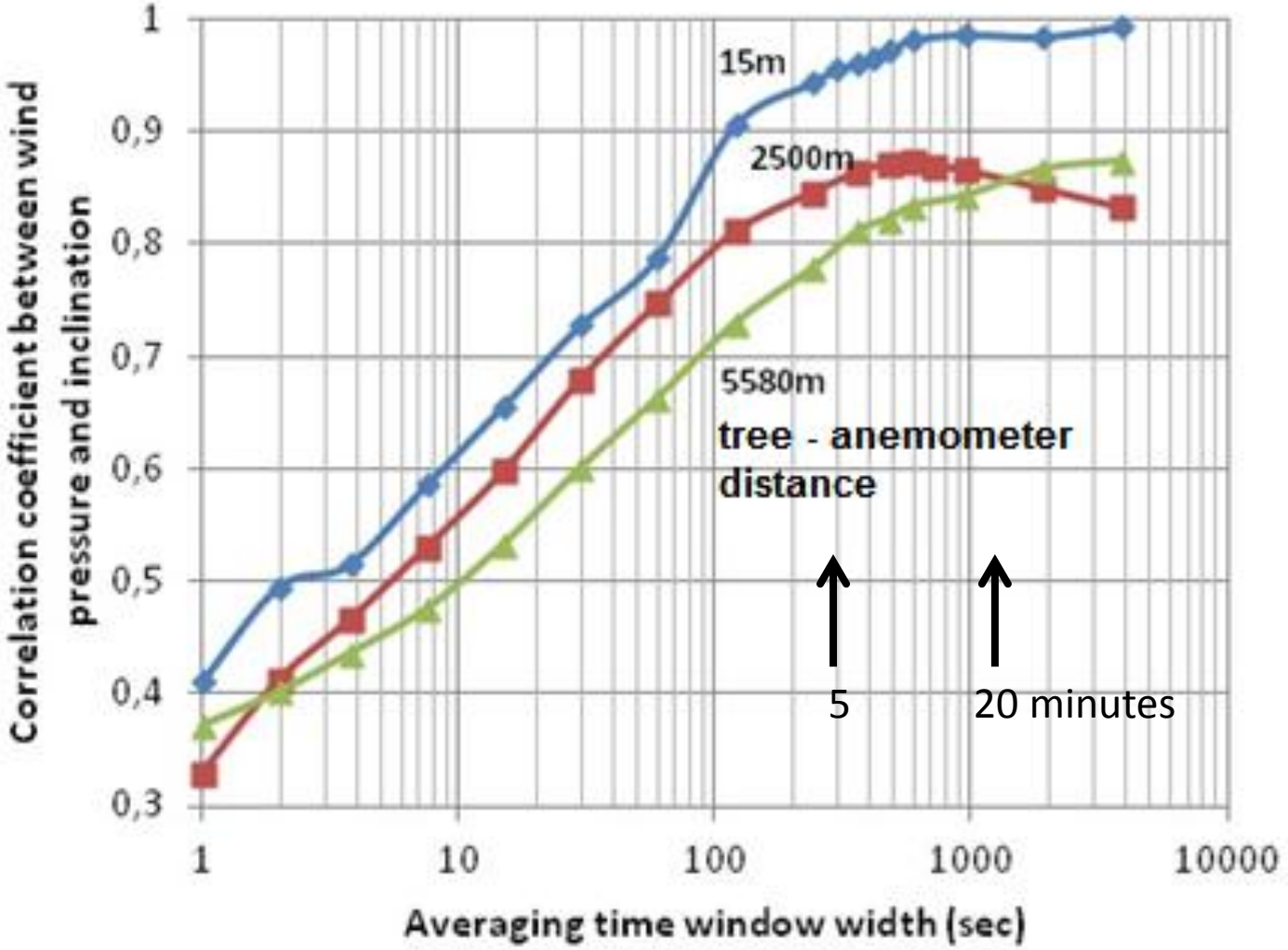
Tree dynamics – the relation between wind and tree trunk inclination is described by chaos.

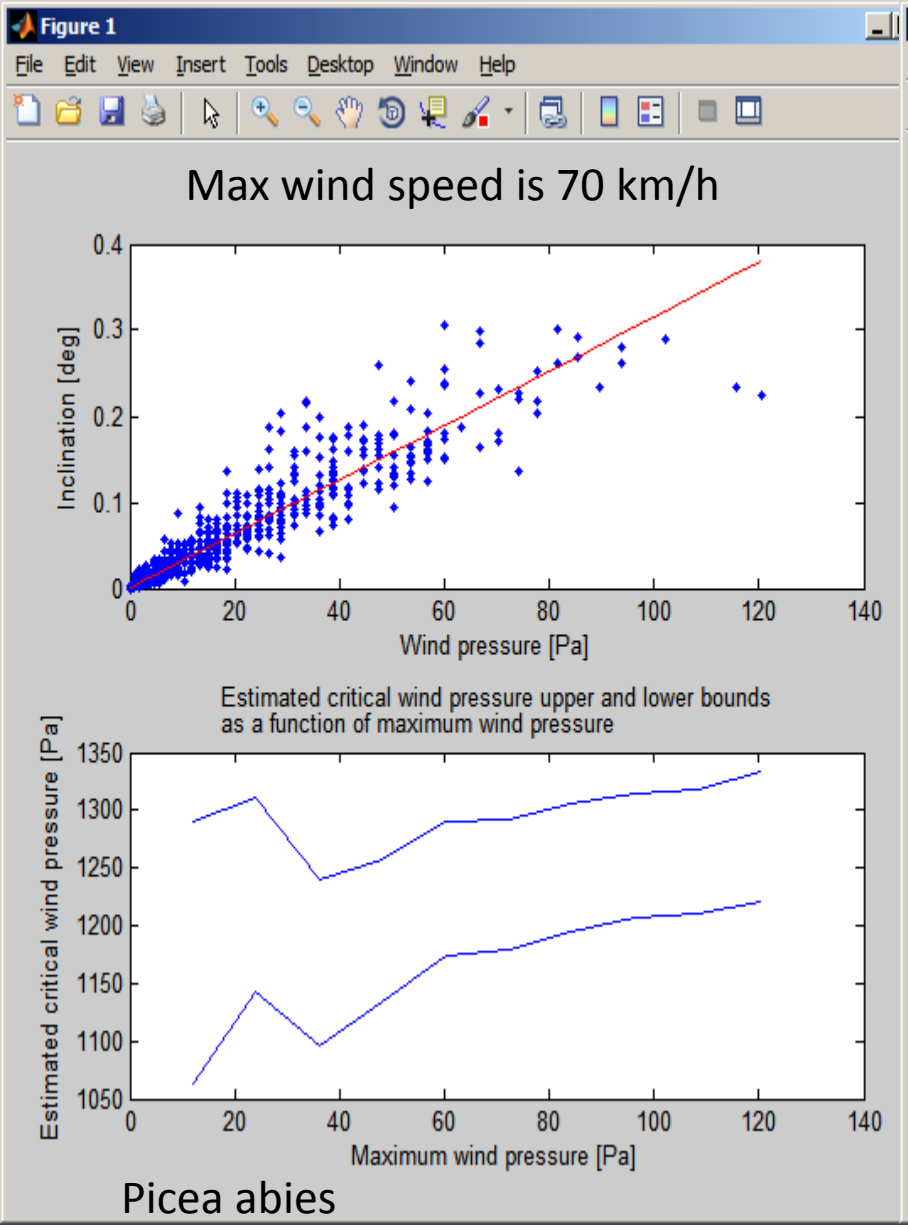
We need to learn from chaos:
-Characterization of a chaotic system is possible by statistical methods:

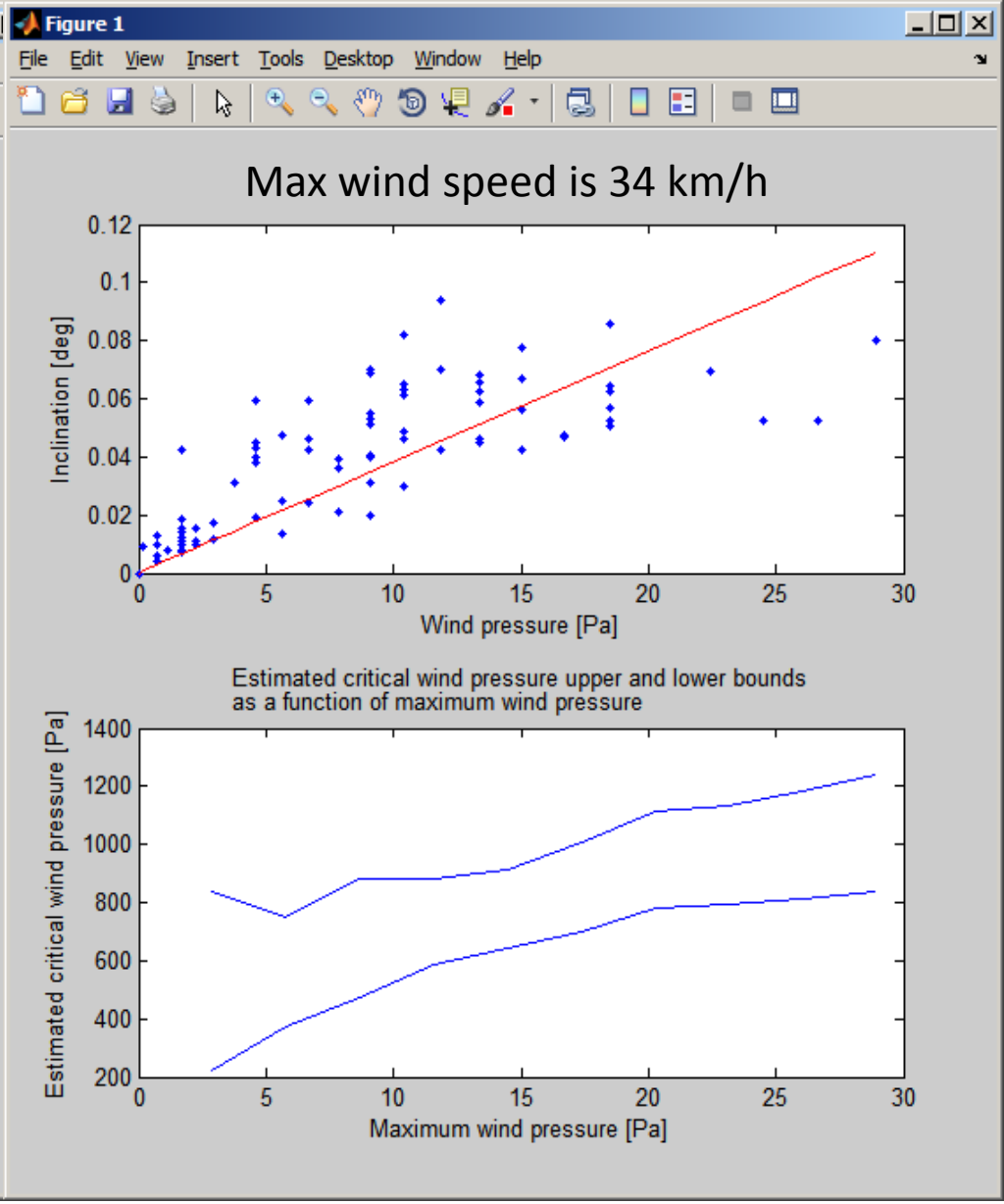
- „averaging” data over certain time, typical 5 minutes.


Inclination (degree)
0,18
0,16
0,14
0,12
0,1
0,08
0,06
0,04
0,02
0
Wind gust velocity (km/h)
80
70
60
50
40
30
20
10
0
11
12
13
14
15
16
17
Hours
The averaging time window


Correlation coefficient between the inclination and wind velocity
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
0
2
4
6
8
10
12
Averaging time (min)


Correlation coefficient between wind pressure and inclination
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
15m
2500m
5580m
tree - anemometer distance
5
20 minutes
1
10
100
1000
10000
Averaging time window width (sec)

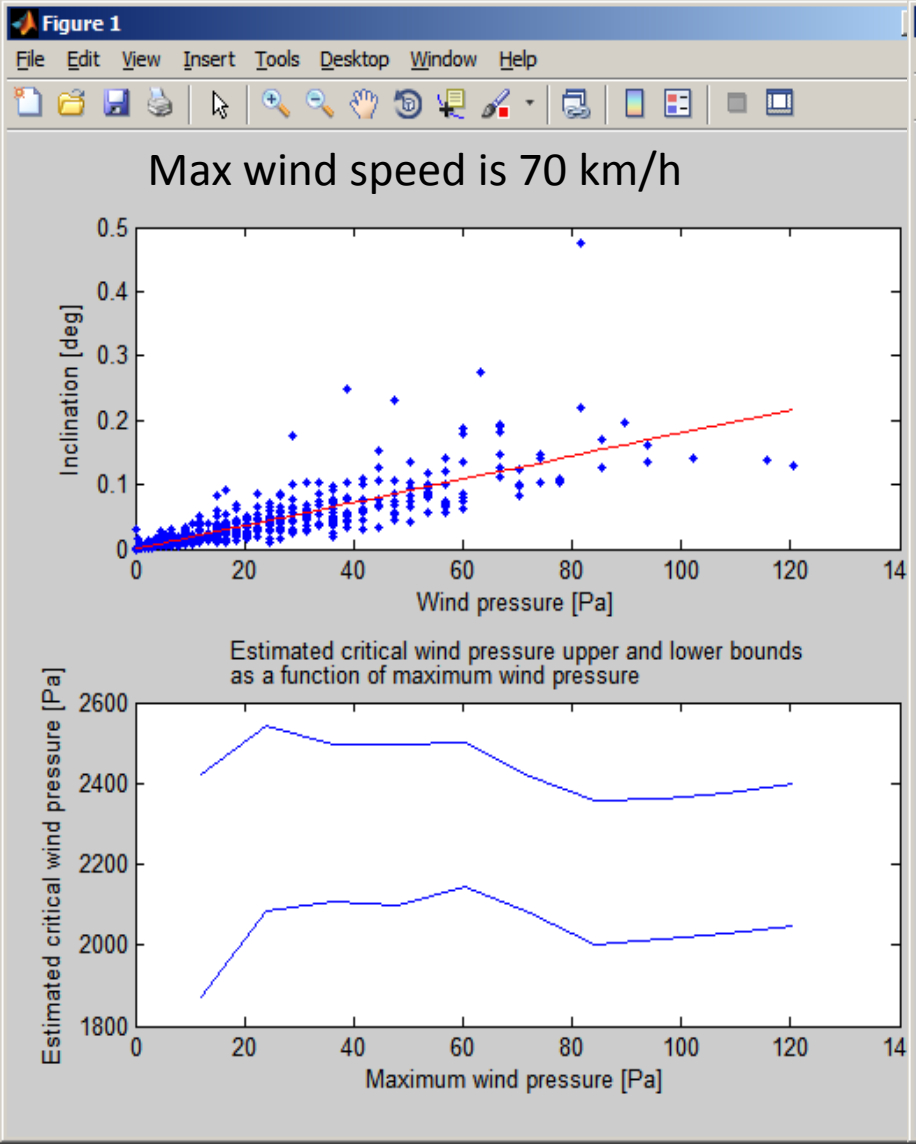


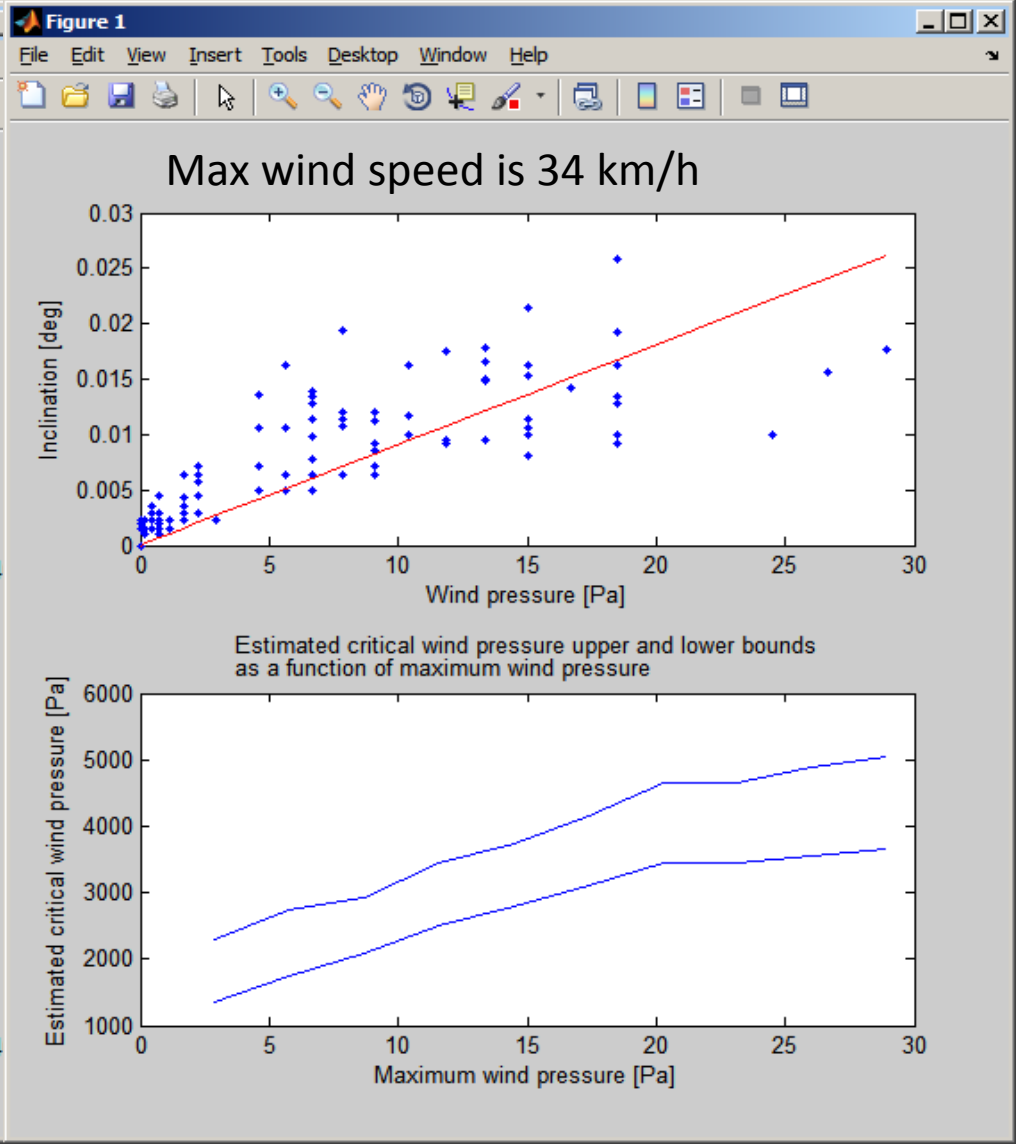


Picea abies

Date : March 2, SF= 1,9+/-0,1
Critical wind pressure =1293 +/-58
Correlation coeff. =0,924

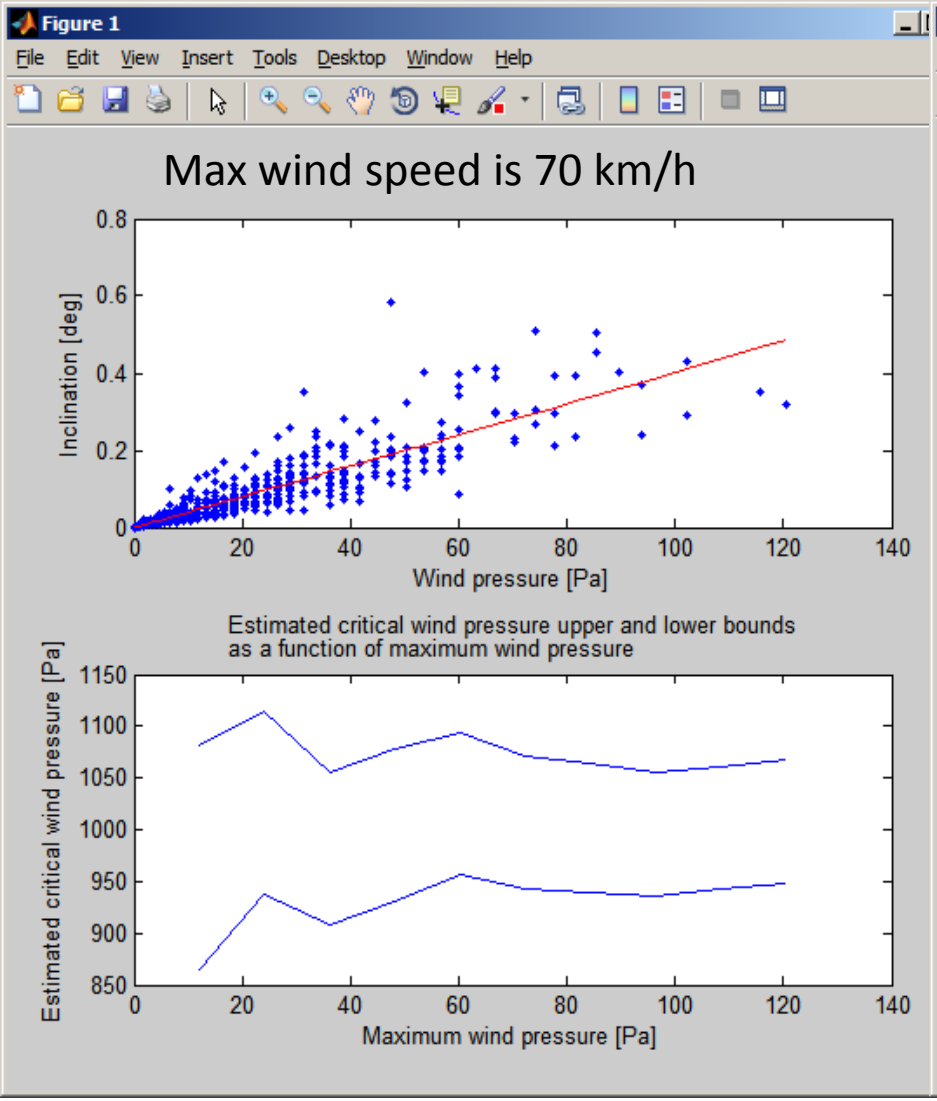
Date : March 26, SF= 1,6 +/- 0,3
Critical wind pressure = 1063 +/- 202 Pa
Correlation coeff. = 0,754

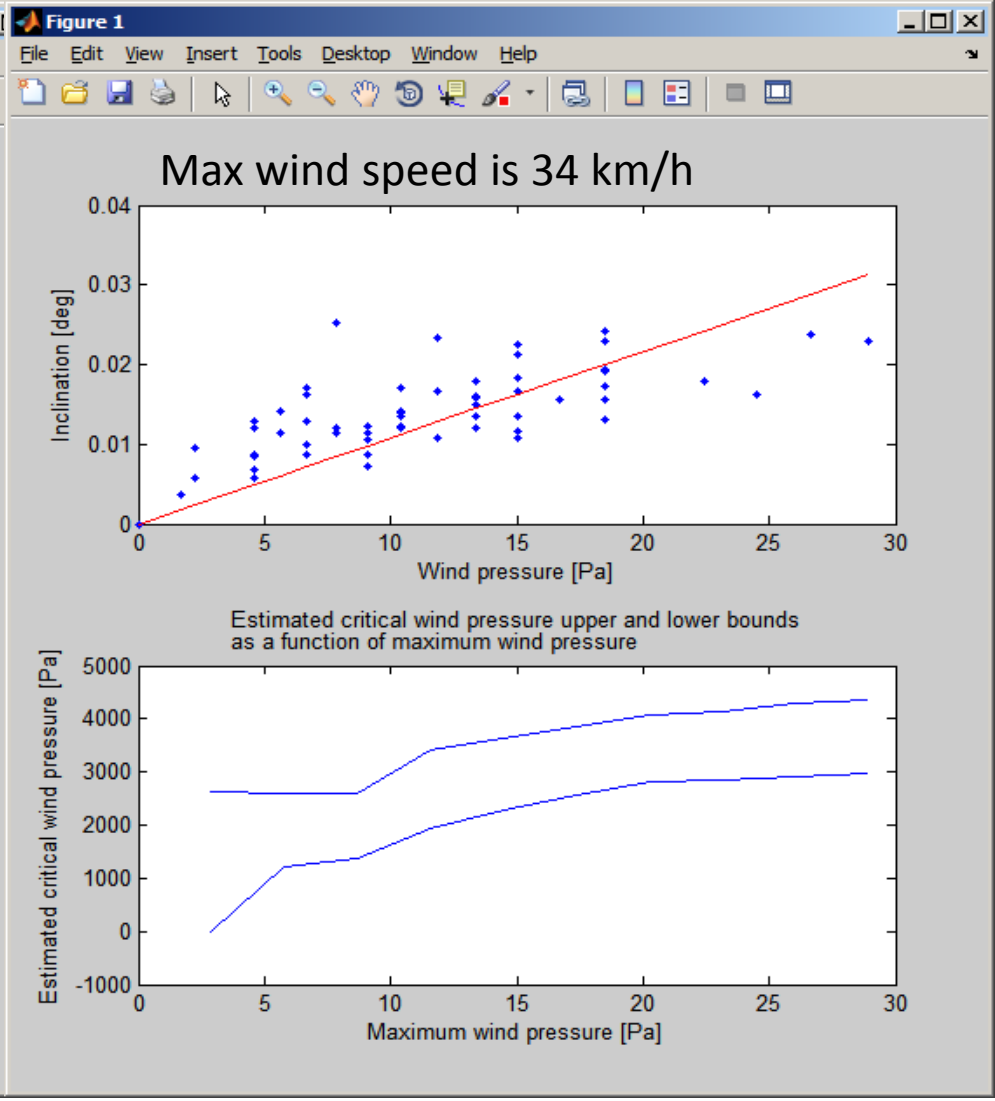




Prunus armeniaca, before pruning
Date : March 2, SF= 3,4+/-0,3
Critical wind pressure = 2252 +/- 178
Correlation coeff. =0,818

Prunus armeniaca, after massive pruning
Date : March 26, SF= 6,7 +/- 1,1
Critical wind pressure = 4489 +/- 718 Pa
Correlation coeff. = 0,831

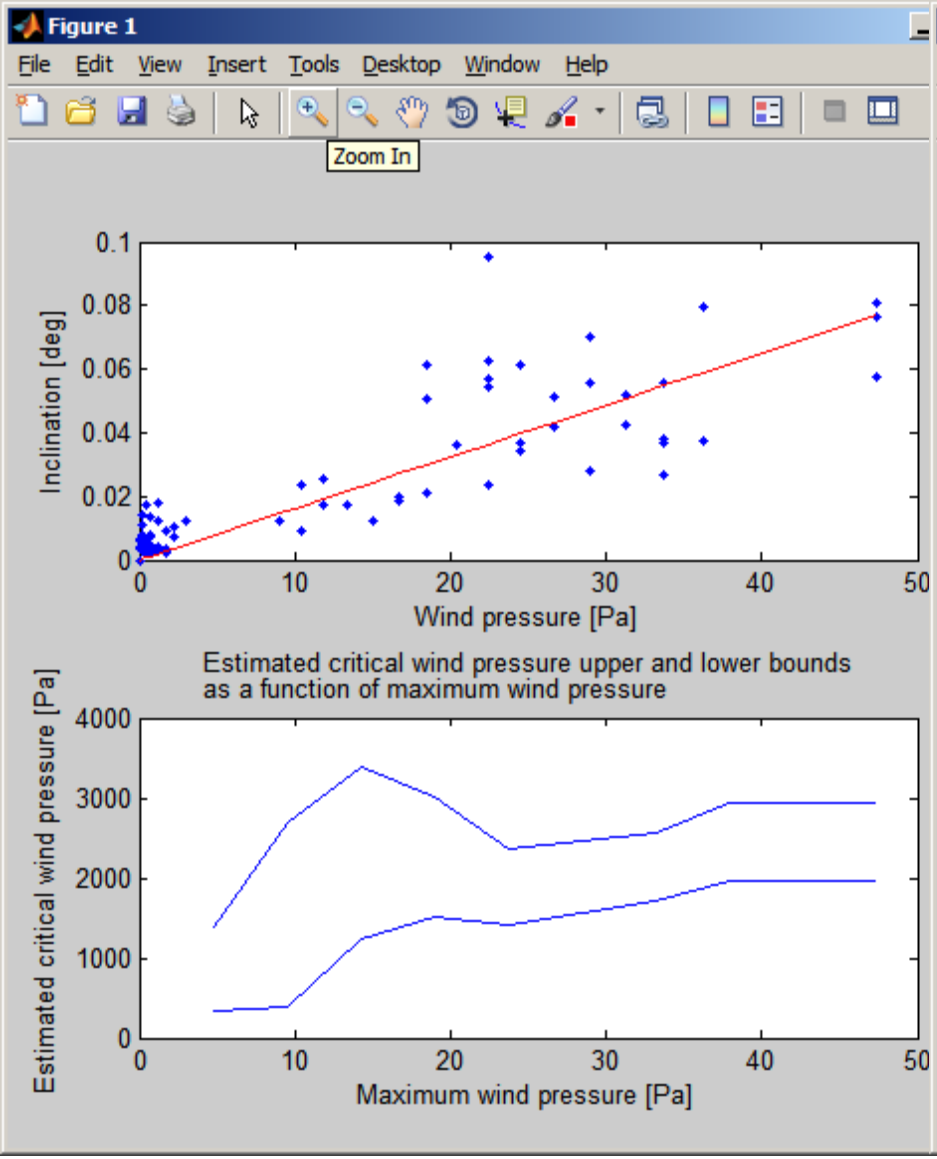


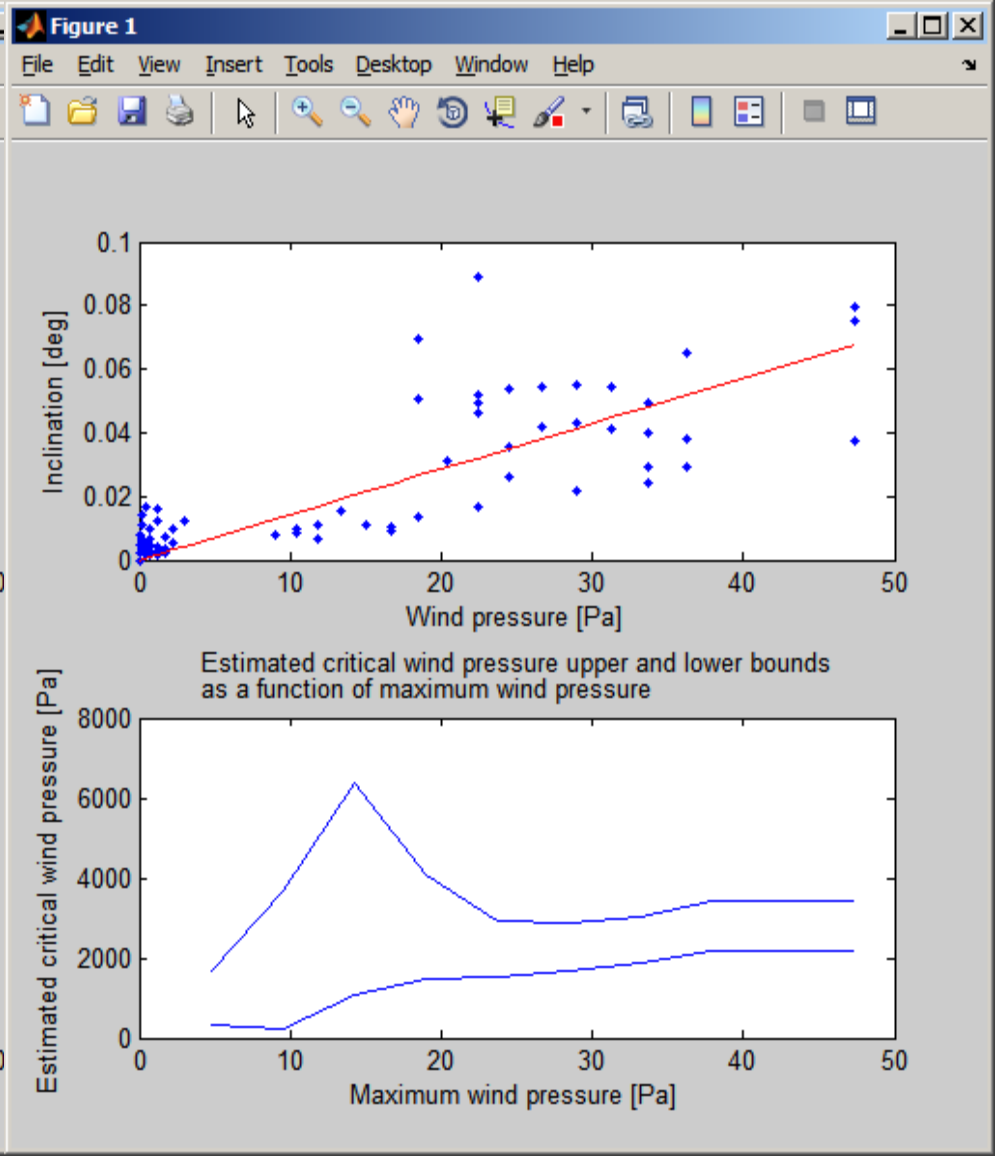


Prunus domestica, before pruning
Date : March 2, SF= 1,5+/-0,1
Critical wind pressure = 1018 +/- 60
Correlation coeff. =0,883

Prunus domestica, after massive pruning
Date : March 26, SF= 5,6 +/- 1,1
Critical wind pressure = 3756 +/- 699 Pa
Correlation coeff. = 0,700


Intact picea abies
picea abies with root decay





Picea abies, intact
Date : April 6, SF= 3,8+/-0,7
Critical wind pressure = 2502 +/- 448
Correlation coeff. =0,865

Picea abies, intact with root decay
Date : April 6, SF= 4,3 +/- 0,9
Critical wind pressure = 2842 +/- 580 Pa
Correlation coeff. = 0,834

Procedure of DynRoot Evaluation technique

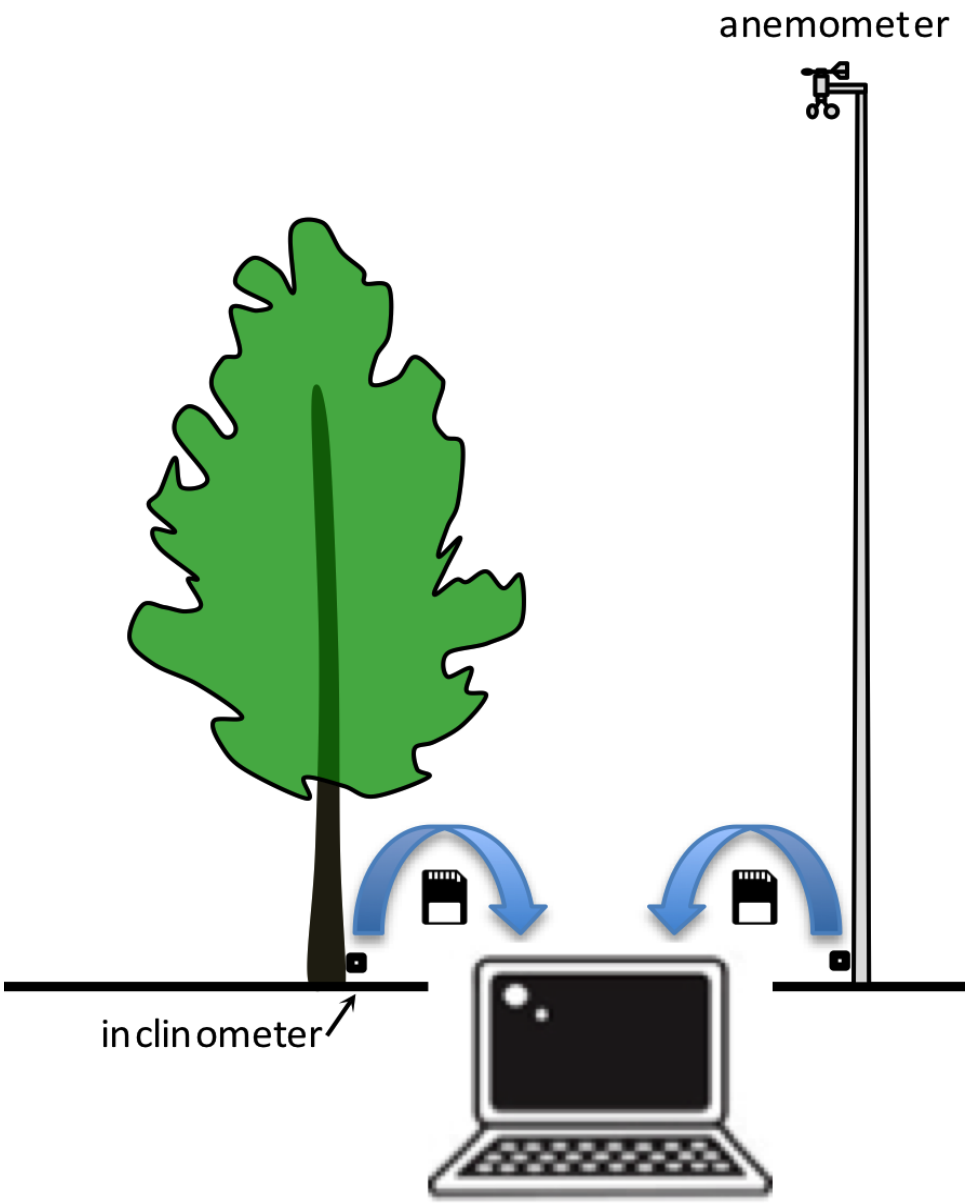
0.) selecting a day when wind gust velocity is higher than 25 km/h.

1.) installation of anemometer on the top of 10m tall pole or receiving wind data of the area (maximum 1 -5 km distance between tree and anemometer. Sampling rate is 1/sec. or faster. Starting data capture.

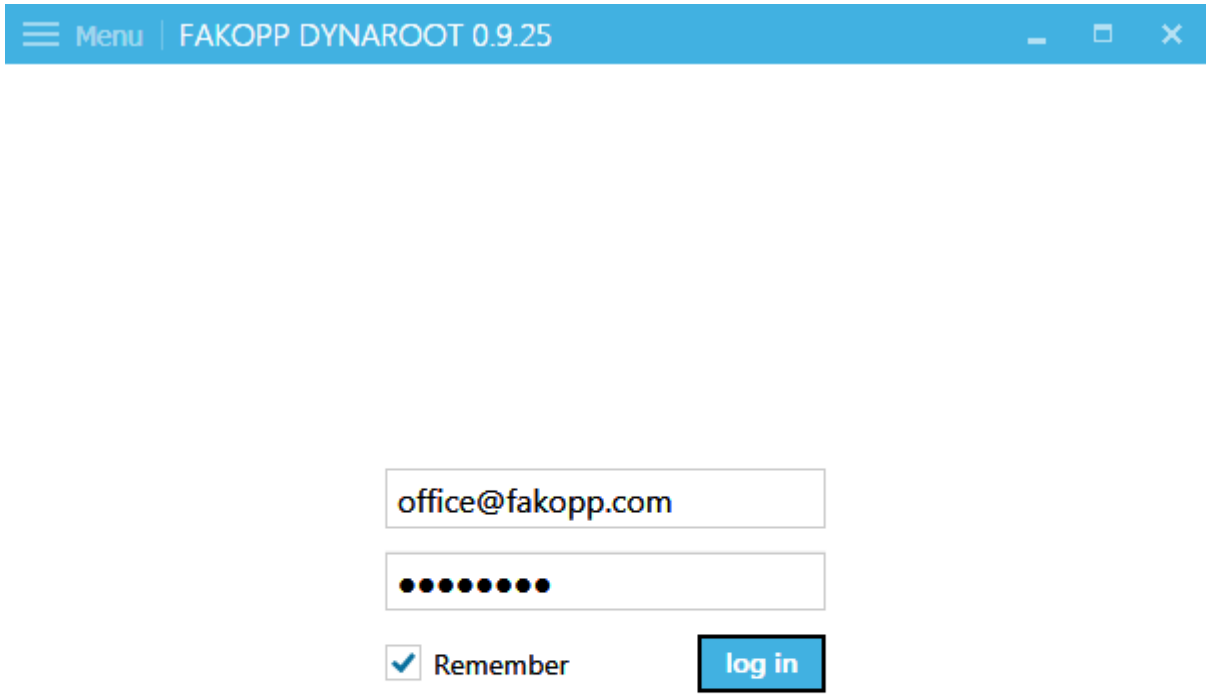
2.) installation of inclination recorders on tree trunk, at ground level. Starting data capture.

3.) Waiting 1-3 hours, than copying data from recorders to PC and evaluation.

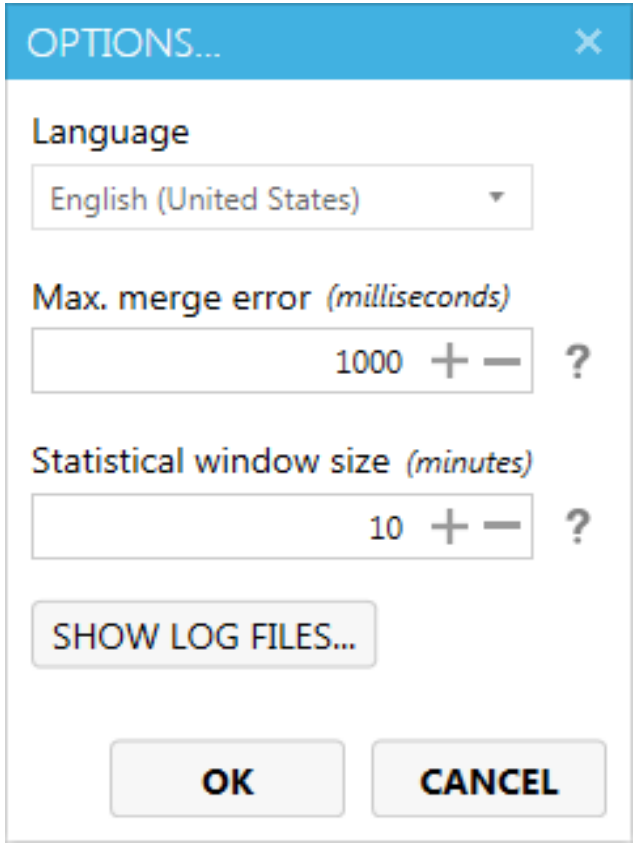
DynaRoot - setup

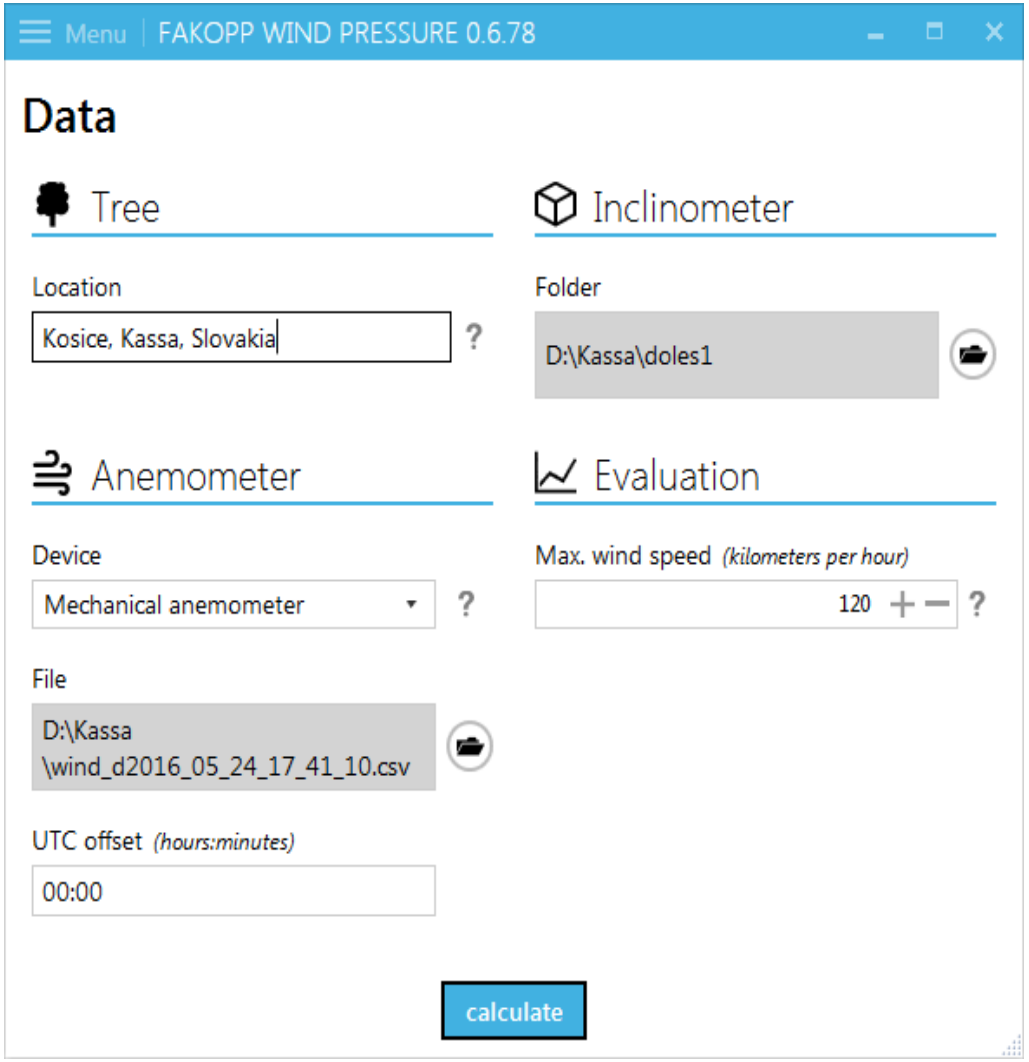


The DynaRoot evaluation software



The DynaRoot evaluation software





Menu | FAKOPP DYNAROOT 0.9.25

Data

Tree

Location

?

Inclinometer

Folder

Anemometer

Device

High-speed TX20

?

Mechanical anemometer

Ultrasound anemometer

Lutron AM-4257SD

High-speed TX20

UTC offset *(hours:minutes)*

00:00

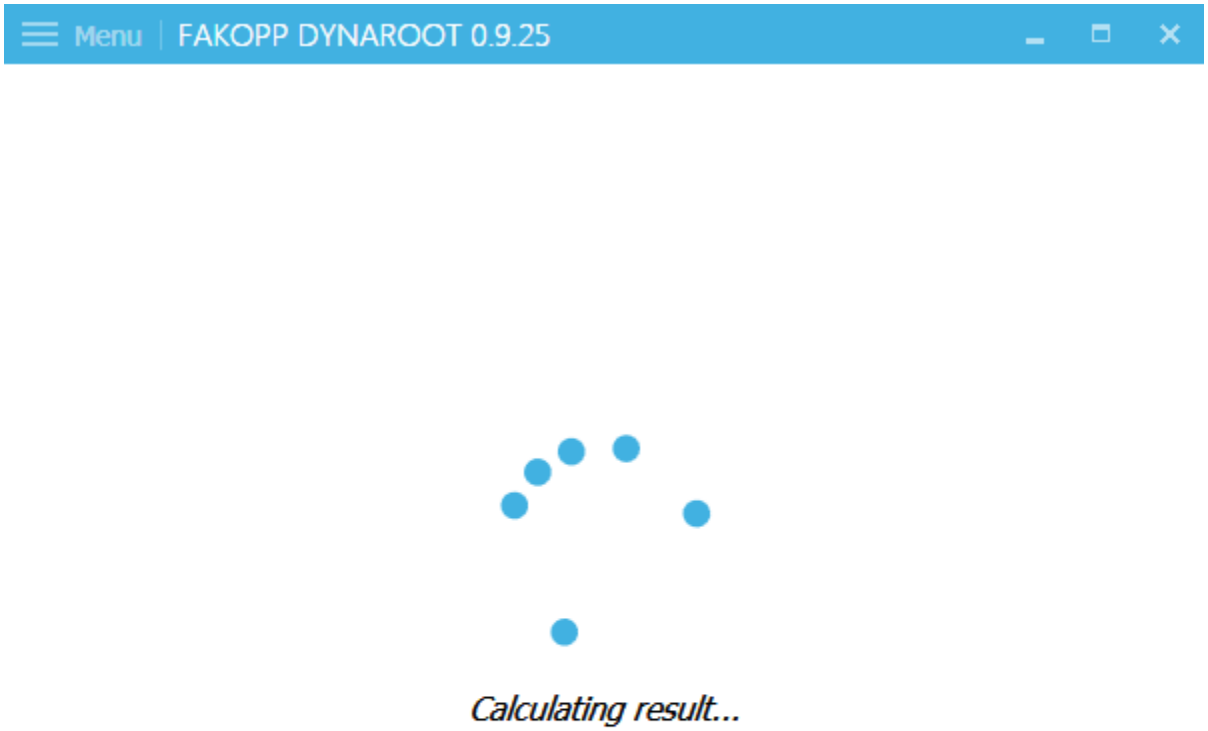
Evaluation

Ref. wind speed *(kilometers per hour)*

120

?

calculate



Uploading wind and inclination data to Fakopp server and evaluation takes around 10-20 seconds.

Fakopp DynaRoot

Menu | FAKOPP DYNAROOT 0.9.25

Evaluation

Tree

Location

Inclinometer

GPS

Show in browser...

Anemometer

Average direction

210 °

Combined data

Measurement start

2016. 11. 18. 22:28

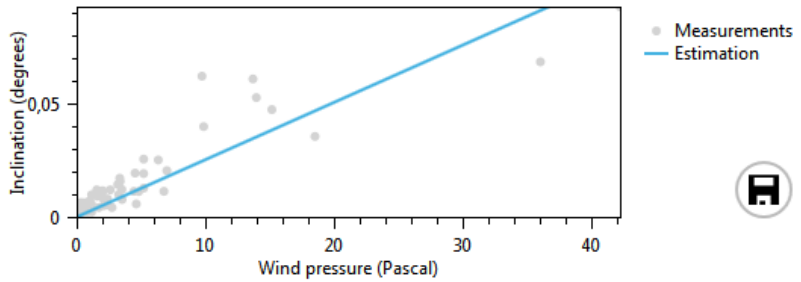
Measurement duration *(hours:minutes)*

10:52

Statistical window length *(minutes)*

5

Chart



Critical wind pressure *(Pascal)*

644 ± 90

Ref. wind speed *(kilometers per hour)*

120

Correlation coefficient

0.9225

Safety factor

0.83
high risk

Fakopp Enterprise
2016. 11. 22.

Fakopp
DynaRoot

Menu | FAKOPP WIND PRESSURE 0.6.78

Evaluation

Tree

Location

Kosice, Kassa, Slovakia

Inclinometer

GPS

Show in browser... ?

Anemometer

Average direction

82 ° ?

Combined data

Measurement start

2016.05.24. 17:41

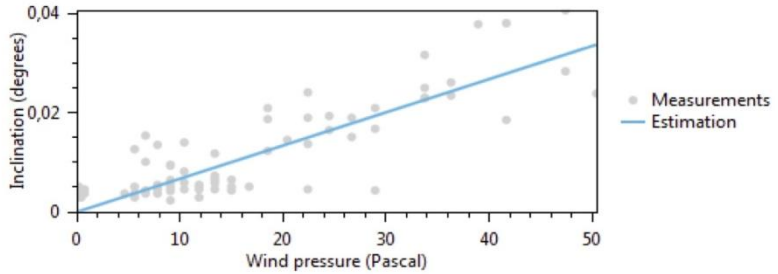
Measurement duration *(hours:minutes)*

17:05

Statistical window length *(minutes)*

10

Chart



Critical wind pressure *(Pascal)*

2434

Crit. wind pressure error

352

Correlation coefficient

0.8562

Safety factor

3.65
low risk ?

Fakopp Enterprise
2016.07.15.

Conclusions

-Root stability evaluation is possible by normal wind load, it is a realistic dynamic test.

- A correlation has been found between inclination and wind pressure after averaging the data.

- Minimum wind gust velocity for tree evaluation is 25 km/h

- Evaluation of tree root safety by the tree trunk inclination at normal wind condition is possible.

Conclusion

Wind is our friend:

- let us the dynamic tree root evaluation
- give us work to do….
-


Grazie per l'attenzione!