

# DENDROECOLOGY AND ENVIRONMENTAL FORENSICS

## Scientific principles, methods & Daubert criteria

Trees as proxy-recorder of environmental releases

DENDROECOLOGY

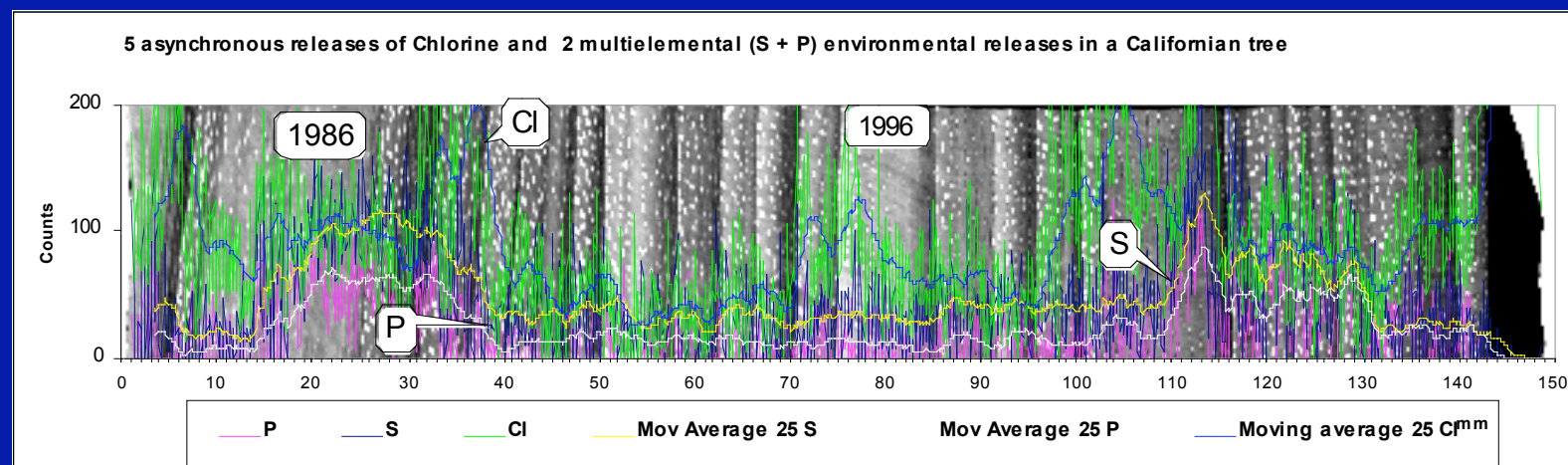
Uptake and fixation of pollutants

DENDROCHRONOLOGY

Age dating

EDXRF Line scanning

Quantifying the pollutant or its tracers, their anomalies and plume's onset (time frame)



# Daubert Criteria

## Legal Admissibility

- In 1993, the United States Supreme Court issued its landmark decision in *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579 (1993), which made significant changes in the standards for admissibility of expert opinions in federal courts. The Supreme Court established a gatekeeping requirement under which courts must screen expert opinions for reliability and exclude “junk science.” The Court also established a new, more flexible test to be used in this process. These standards have now become better defined through their application by courts over the fifteen years since *Daubert*, including a number of environmental cases.
- Rule 702 of the Federal Rules of Evidence governs the admissibility of expert opinions. The rule, in its original form, provided: If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise.

# Daubert Criteria

## Legal Admissibility

- In Daubert, the Supreme Court held that district court judges have a “gatekeeping role” to determine evidentiary reliability of scientific evidence before it is admitted and redefined the requirements for admissibility of scientific evidence under Rule 702.
- Admissibility is based on a two-step analysis in which the trial court determines (1) whether the proffered expert opinion reflects scientific knowledge, whether the findings are derived by the scientific method and whether the work amounts to good science (**reliability**), and (2) whether the proffered expert opinion is relevant to the task at hand (**relevance**).
- For the first step in this admissibility analysis, the Supreme Court provided a list of nonexclusive factors, which it characterized as “general observations,” which a court should analyze in determining the reliability of scientific evidence :

# Daubert Criteria

## Legal Admissibility

- 1. whether the scientific theory or technique "can be (and has been) tested"
- 2. whether the scientific theory or technique "has been subjected to peer review and publication";
- 3. "the known or potential rate of error"
- 4. "the existence and maintenance of standards controlling the technique's operation"
- 5. "general acceptance" in the "relevant scientific community"
- Need to distinguish phytoscreening (current uptake, outer rings) from age-dating / characterizing release in forensics (dated rings),

# Some famous forensics cases in US Courts

**Lindbergh's baby kidnapping trial (1936) : Kidnappers used an old repaired ladder. The remainder of the cleats from which the cleats were sawed were found. Annual rings and tool marks were used as evidence. Mr Bruno Hauphman was convicted and later executed.**

**Witness trees for boundary disputes (Oklohomia versus Texas, Missouri versus Iowa, Tennessee versus Virginia), Oil field in Texas versus Okloahoma as river channels moved between 1819 and 1919.**

**Land owners versus oil companies for brine to have killed trees (1941). In one case, silting was cause of tree death, in another case was the planting of grapewine.**

**Verifying the age or origin of ancient artwork.**



## THE BACK UP IN DENDROECOLOGY

Plants uptake and fix the pollutants.

Phytoremediation : <http://www.ncbi.nlm.nih.gov/entrez/pubmed/phytoremediation>

Google = 61,700 entries to phyto-remediation

Dendroecology : <http://www01.wsl.ch/dendrobiblio/>  
<http://simpleinterest.us/currentpastissues/dendro.pdf>

Google = 3100 entries to dendroecology,

Accepted in the scientific community. Over 200 chemicals documented (Elemental and organic pollutants, isotopes) ; USGS / EPA guide for using trees for assessing polluted sites ; Phytoremediation used at hundreds of sites over the planet.

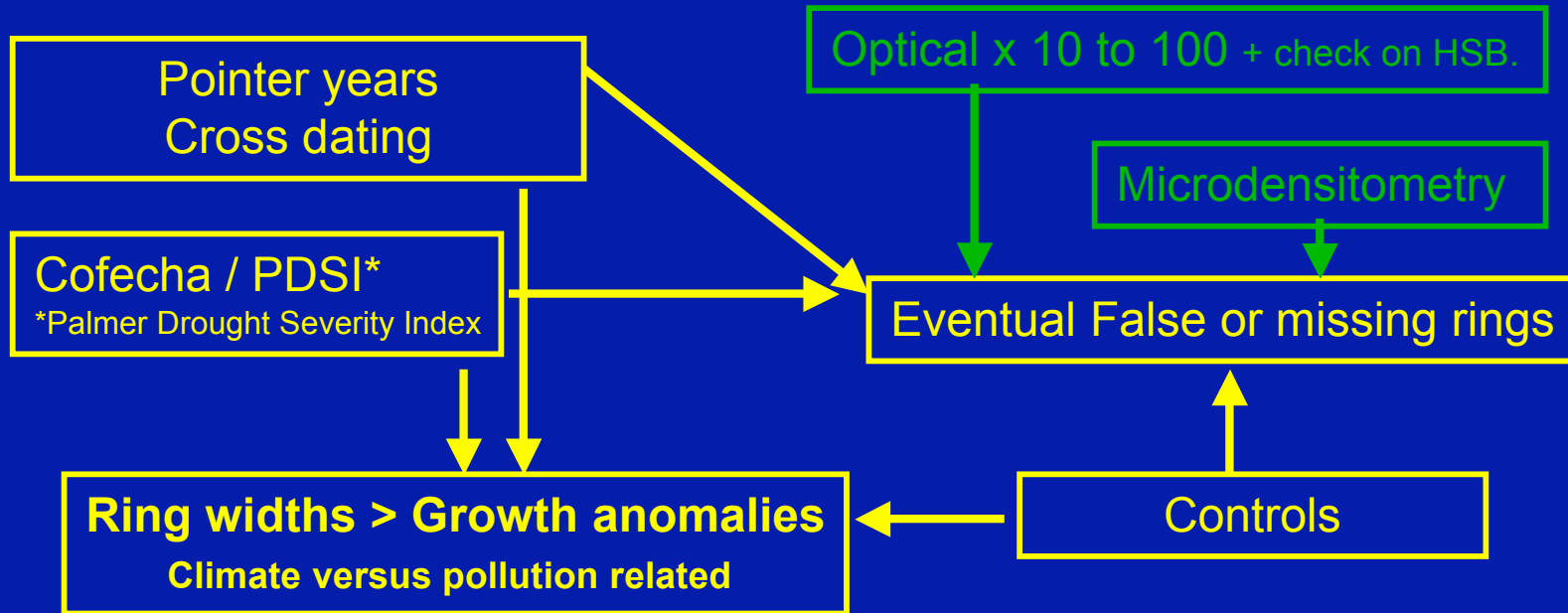
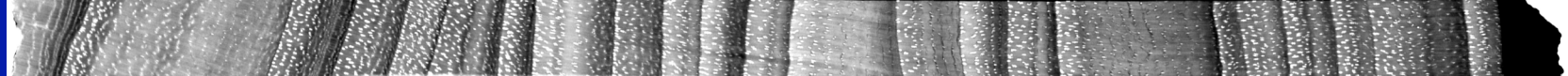
Balouet, J. C., Oudijk, G., Smith, K. T., Petrisor, I., Grudd, H., Stocklassa, B., 2007. Dendroecology and environmental forensics: From fundamentals to case studies: Environmental Forensics, 8:1–19, 2007, Taylor & Francis Group, LLC ISSN: 1527–5922

Schweingruber F. H., 1996 : Tree rings and environment dendroecology, Swiss Federal Institute for Forest, Haupt, ISBN 3-258-05458-4, 609 pp.)

USGS, US DoI, US EPA, 2008 : User's Guide to the Collection and Analysis of Tree Cores to Assess the Distribution of Subsurface Volatile Organic Compounds, Scientific Investigations Report 2008–5088.

**Over 200 environmental releases characterized and dated**

# DENDROCHRONOLOGY : AGE DATING & CROSS DATING



EDXRF calibrated to digital versus microdensitometric image with resolution image / data of 500 dpi (every 50 $\mu$ , or 3 times higher than typical numerical images)

Precision by the year, eventually up to the season (earlywood versus latewood).  
Different ages from expertise i. e. no impact before year XXXX or after year YYYY, impact at year ZZZZ...

## RELIABILITY (Daubert) : USING TREES FOR AGE DATING Dendrochronology

Principles back to Theophrastus (332 B. C.) and Da Vinci (1500)  
Most common applications : Archaeology, antiques, environment  
(Paleoclimatology, Glaciology, Fires, wounds, floods, storms, insect plagues, geomorphology...)

*"The rings in cut stems (or branches) show their number of years, as well as those years that were moister or dryer, according their larger or smaller width." Da Vinci*

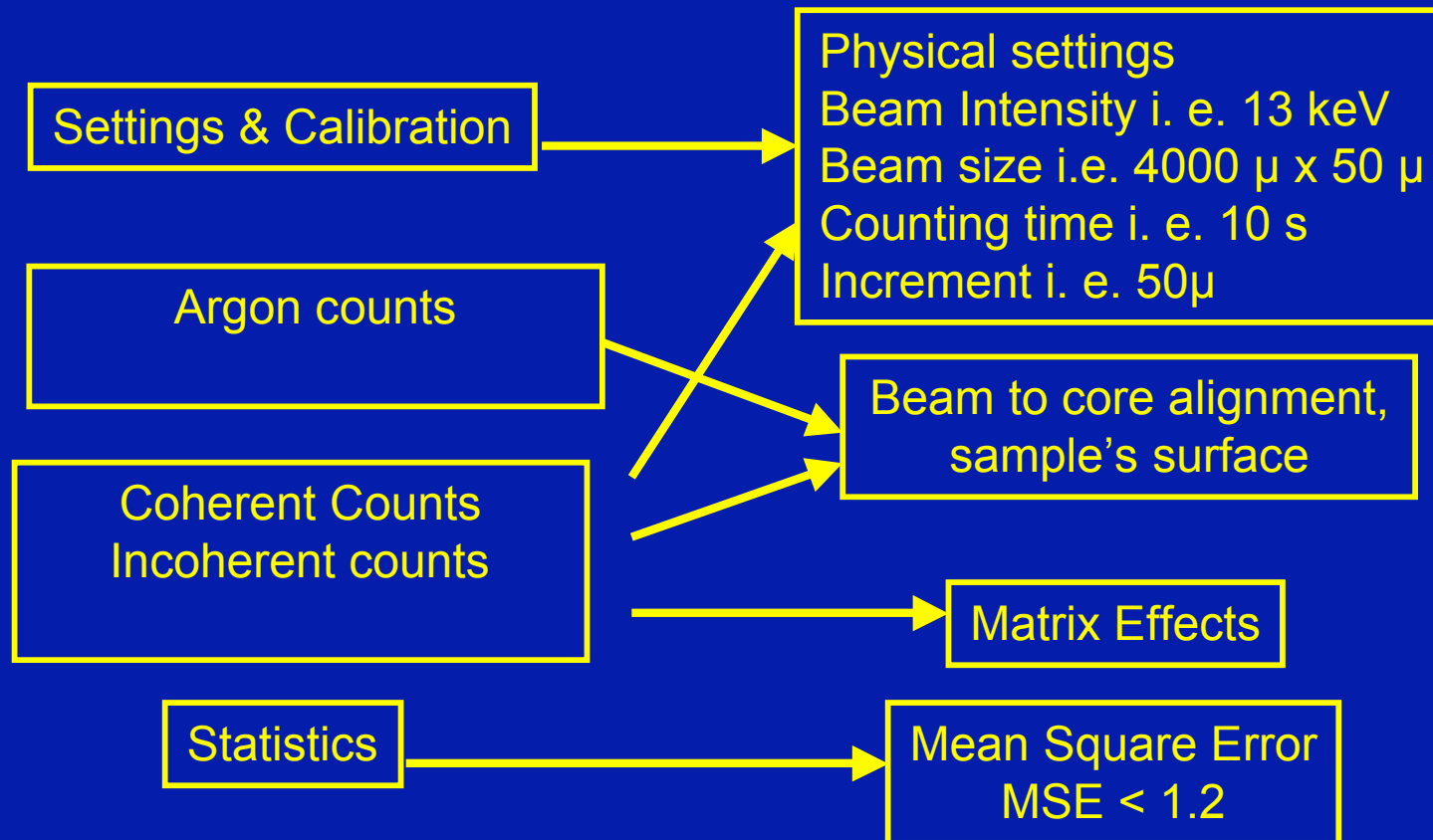
Accepted Method? Tought to pupils worldwide in primary schools.  
About 100 labs & several hundred trained scientists over the world.  
Several tens of thousands trees analysed (> 1177 plant species and genera)  
Precision by the year (i. e. NOAA paleoclimate back to 2000 BC).

Over 10,000 publications. Google : 461,000 for tree ring ; 32,900 entries for dendrochronology  
Websites : <http://www01.wsl.ch/dendrobiblio/> <http://www.ncdc.noaa.gov/paleo/treering.html>,  
<http://web.utk.edu/~grissino/contents.htm>

No other age dating method as precise or as cheap



# Energy Dispersive X-Ray Fluorescence (EDXRF) QUALITY CHECK : RELIABILITY OF ANALYTICAL RUN



Note that for a core of 20 cm, there are 4000 analytical points and 38 (35 elements + Coh + Incoh cts + MSE) data at each point. This is 152 000 data per core.

## CROSS CHECKING Energy Dispersive X-Ray Fluorescence (EDXRF)

Coherent Counts  
Incoherent counts,

Eventual False rings

Elemental counts

> Or < Detection limit (ppm level)

Cross checking with other cores  
of same species  
Elemental concentrations as  
background, natural variability

Cross checking over analysed core :  
physiology : age/size trends, HSB,  
Intraring and interring patterns, variability,  
eventual retranslocation

Raw data corrections, statistics : correction for matrix effects, Centered moving average as time series, annual means

**SIGNIFICANT ANOMALIES**  
Amplitude, Multielemental ? Progressiveness of release

## RAW DATA and searched tracers

EDXRF at 50  $\mu$  increment, for 1 cm ring width, represents 200 data points over a growth period of about 200 days (#1 day per spot). Variability potentially related to climatic factors (sun, precipitation, temperature) + matrix.

Correction for matrix effects

Data turns density free

$Y = X \times \text{Average total cts} / \text{total cts at } X$   
Reflects concentration only

Annual mean  
Based on distances to  
cambium / ring widths  
(optional)

Reflects uptake and fixation over the year  
Removes point to point variability

Time series  
(for markers)

Weighted centered average

$Y = (X_{-3} \times a + X_{-2} \times b + X_{-1} \times c + X + X_{+1} \times c + X_{+2} \times b + X_{+3} \times a) / (2a + 2b + 2c + 1)$  i. e.  $a = 0.1 < b = 0.3 < c = 0.6$

Smooths short time / climate related variability

**SIGNIFICANT ANOMALIES** Amplitude  $\gg$  over core's maxima ,  
Increase in minima & maxima, Multielemental ?

## RELIABILITY (Daubert) and EDXRF

EDXRF used in dendroecology since 1970. Many other uses since the 1960s in criminal investigations (fingerprinting drugs, explosives, liquids, glass, paint, fabrics, soil, metal, plastics,...), in industrial processes (oil, mining, paper, plastics...) and the environment.

Accepted in the scientific community with thousands of EDXRF equipment in the world, from portable units (EPA method 6200) to Synchrotrons. Thousands of publications and expertises.

Testing : Precision and repeatability by 1%, DL by the ppm  
Non destructive method : sample can be re-run.  
Statistical evaluation by MSE, Quality assessment throughout cores data,  
Comparison to controls and other trees of same species,

Also possibility to use GC/MS and basically all other analytical methods on isolated rings

## RELIABILITY (Daubert) and DENDROECOLOGY applications to forensics

Method used by governmental organizations (i. e. USGS, USFS, EPA), Europe, Universities ... for decades. Vast publication record. Parcimony principles met. Trees as proxy-recorders (*Trees can't lie*).

Works on sites with discontinued plumes, or already mitigated. Allows to distinguish comingled plumes. Allows allocation of torts (release timeframe vs ownership, fingerprinting, quantified impacts).

Testing : statistical evaluation by MSE, Quality assessment throughout cores data, Comparison to controls and other trees of same species, Non destructive. Potential rate of error : 1% in EDXRF. Natural backgrounds versus impacts.

Some limitations to applicability : presence of trees in plume. Does not work on pure HCs (if no tracers). Overwhelming backgrounds (i. e. oceanic) potentially masking minor –pollution related-enrichments such as Cl from fossil fuels. Not « Emerging » technology : decades and hundreds of applications (forensics and non forensics) worldwide.

From my own work : Collaboration with 8 environmental firms, governmental organization (Universities, USFS, States' DoEs), > dozen attorneys. 90 % of 40 cases settled out of Court, some cases still pending –however most cases confidential. Over 17 million analytical data, 31 tree species, 130 trees. Over 60 environmental releases dated. Spatio-temporal mapping.