

Image analysis techniques for monitoring ozone damage on plants

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Tropospheric ozone and plants

- Joint project with the Dept. of Biology, University of Oslo
- We focus on imaging techniques and identification of ozone damage
- Dept. of Biology focuses on biological issues (repair processes, photoreceptors, plant ozone sensitivity etc)
- Aims
 - Identification of ozone damaged leaves from RGB images
 - Quantification of ozone damage on leaves from RGB images
 - Characterization of damage to leaf function using infrared images



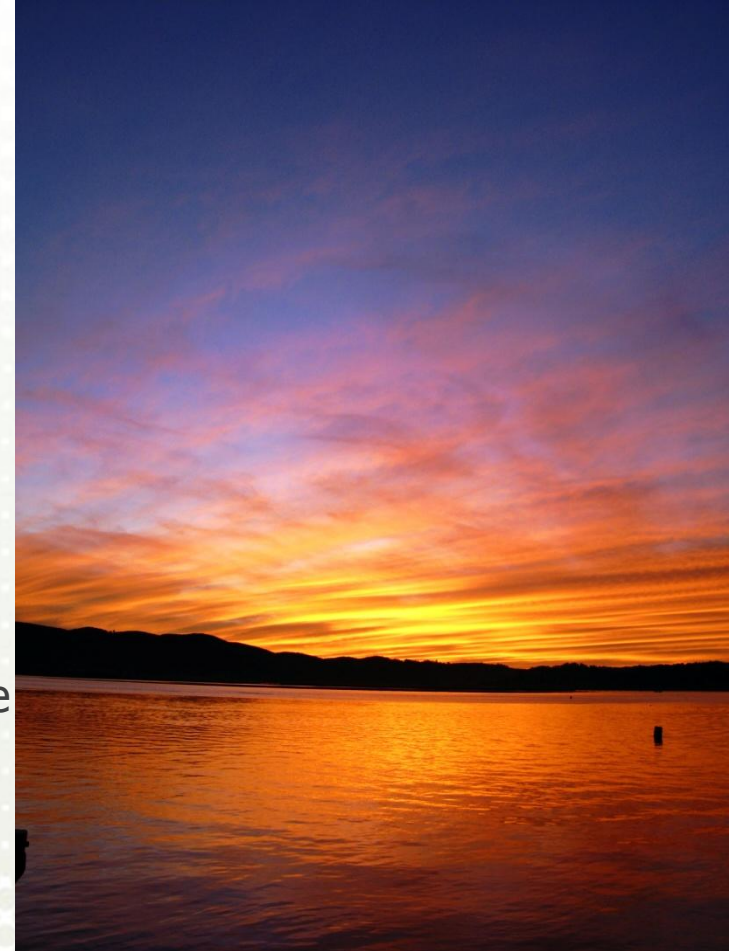
Tropospheric ozone and plants

- Tropospheric O₃: most important air pollutant affecting plants worldwide
- Reduces crop yield and plant diversity
- Background levels: 10 ppb → 30-40 ppb during the last century
- Episodes > 100 ppb are common
- Ozone enters leaves resulting in
 - Necrotic spots and lesions on leaves, earlier leaf aging
 - Reduced photosynthesis and biomass



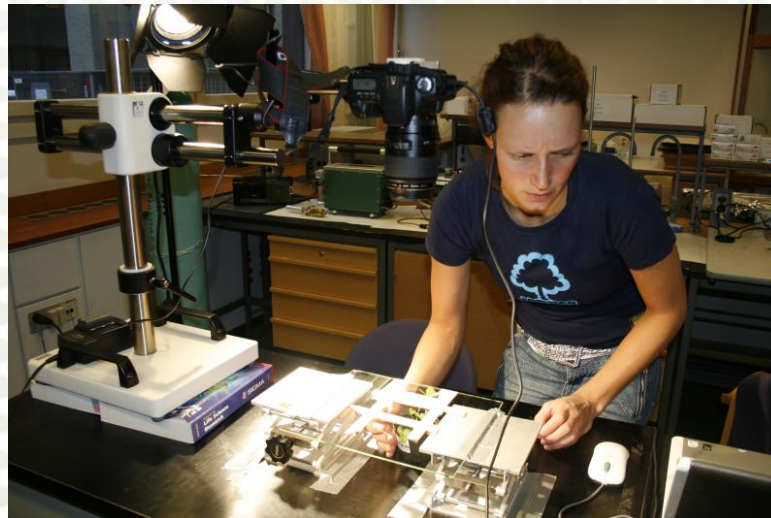
Plants in northern regions

- Plants in Scandinavia often show more ozone damage for the same ozone concentration than plants in southern/central Europe
- Climatic factors?
- Do light conditions during the northern summer night increase ozone damage?
- Examine clover species
 - Indigenous to southern and northern Europe
 - Ozone sensitive
 - Bioindicators for ozone



Identification of ozone injury

- Quantifying degree of injury by human estimate is
 - Inaccurate and dependent upon the observer
 - Time consuming
- Automated analysis gives us
 - Same degree of injury every time (no human estimate)
 - Less time consuming
- Images are captured using a high resolution (8.2 MP) SLR camera

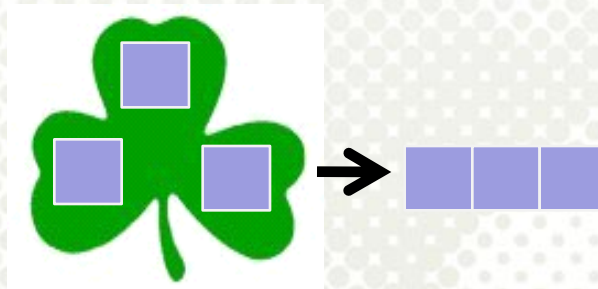


Preprocessing images

- Removing of background, two methods
 - Remove the background

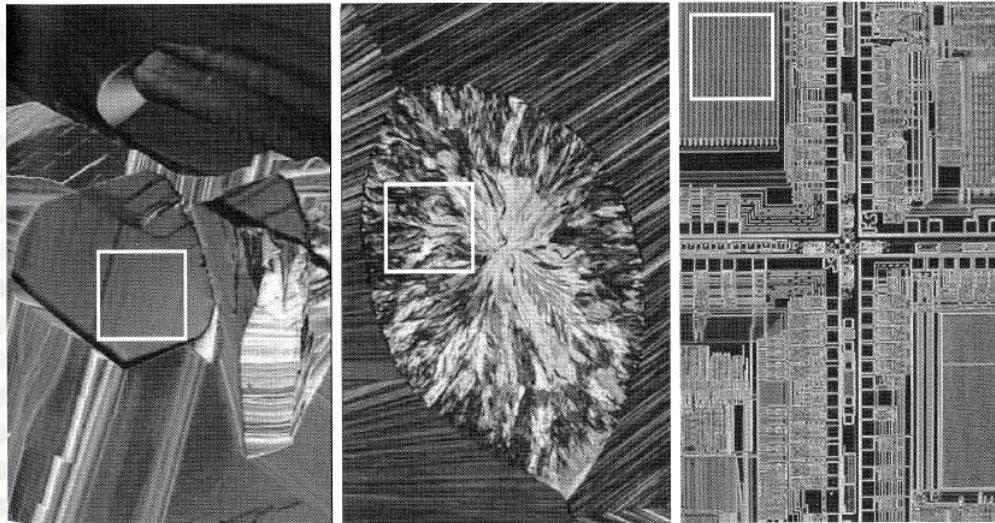


- Extract a square from each leaflet



Texture analysis

- Traditional image analysis searches for special patterns, colours or objects in the images
- Instead we analyse the texture in the image
 - Distribution and spatial covariance of gray-scales in the *entire* image
- A complicated dataset with many variables → multivariate statistics



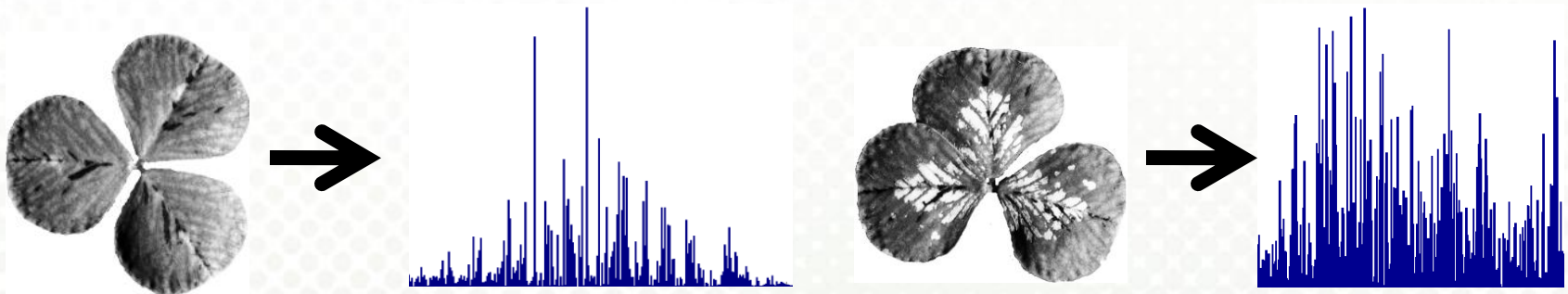
Smooth

Coarse

Periodic

Histogram statistics

- The intensity distribution of an image is plotted in a histogram

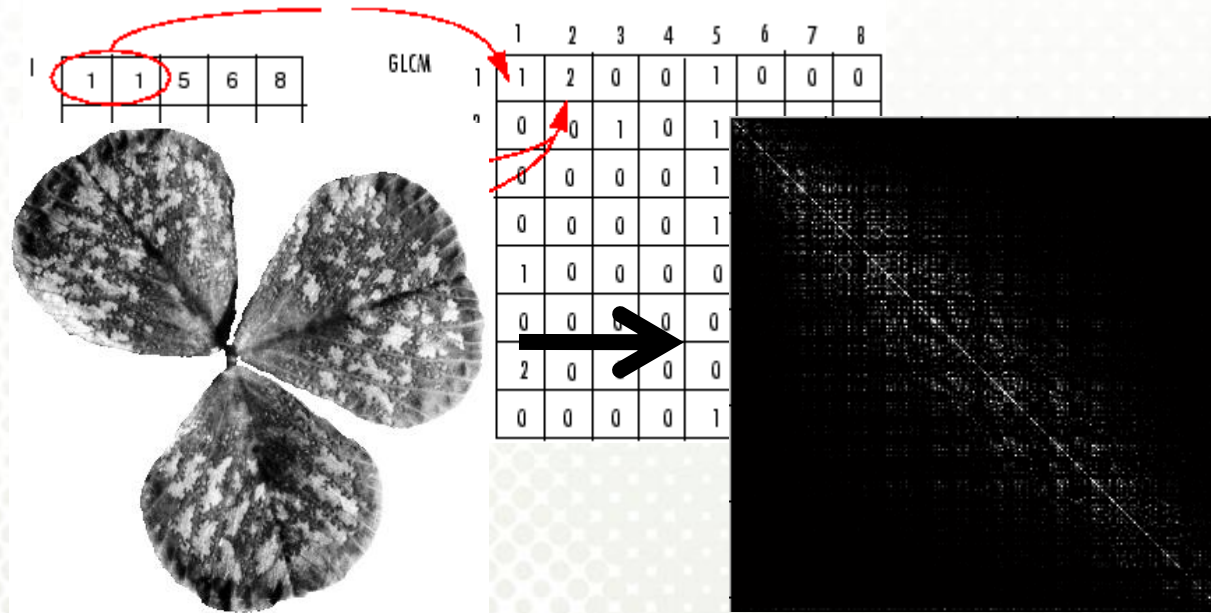


- Calculate statistical parameters for the histograms

Parameter	Healthy leaf	Injured leaf
Mean	124	114
Skewness	6.3	7.4
Entropy	5.18	4.87
Uniformity	0.16	0.23

Gray-level co-occurrence matrix (glcm)

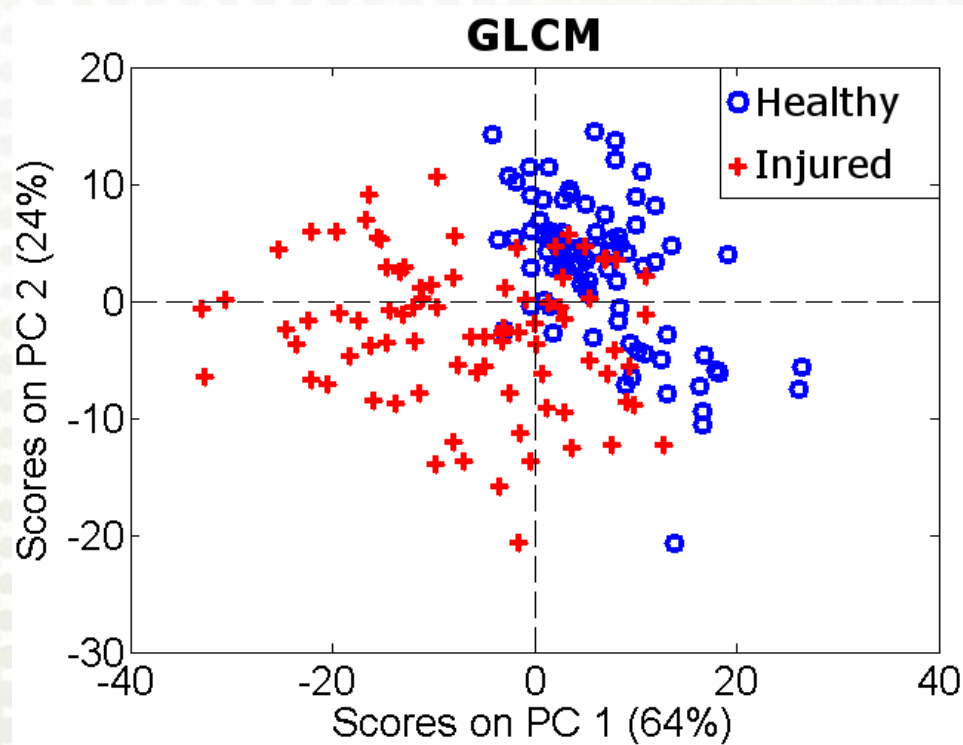
- GLCM looks at the intensity of neighbouring pixels



- Statistical parameters are calculated from the GLCM matrix

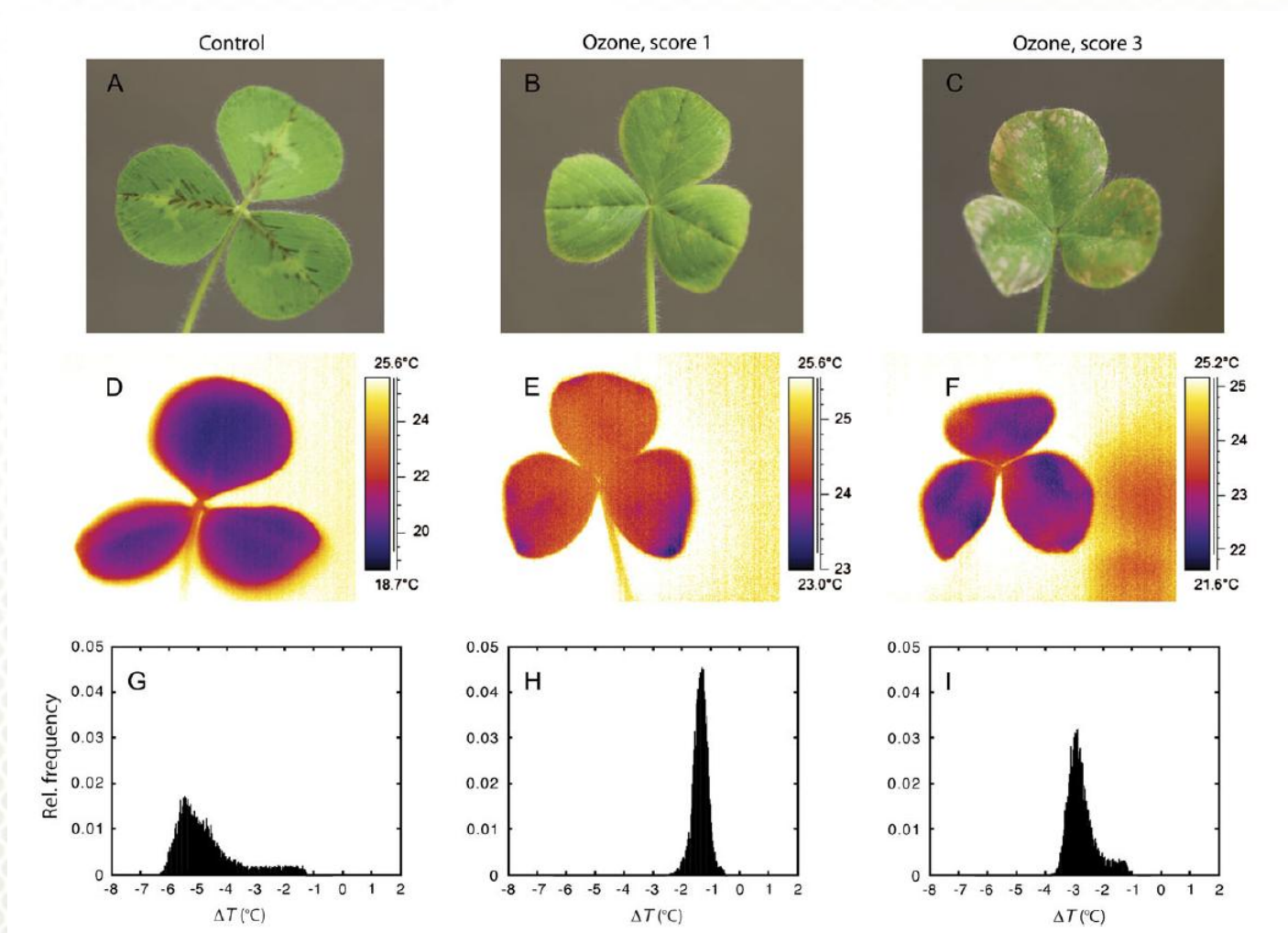
Method comparison

- PCA used to analyse GLCM, SVD and Histogram parameters
- Images classified into two groups: (1) unexposed leaves (healthy) and (2) ozone exposed leaves (injured)
- Performance: GLCM > SVD > Histogram



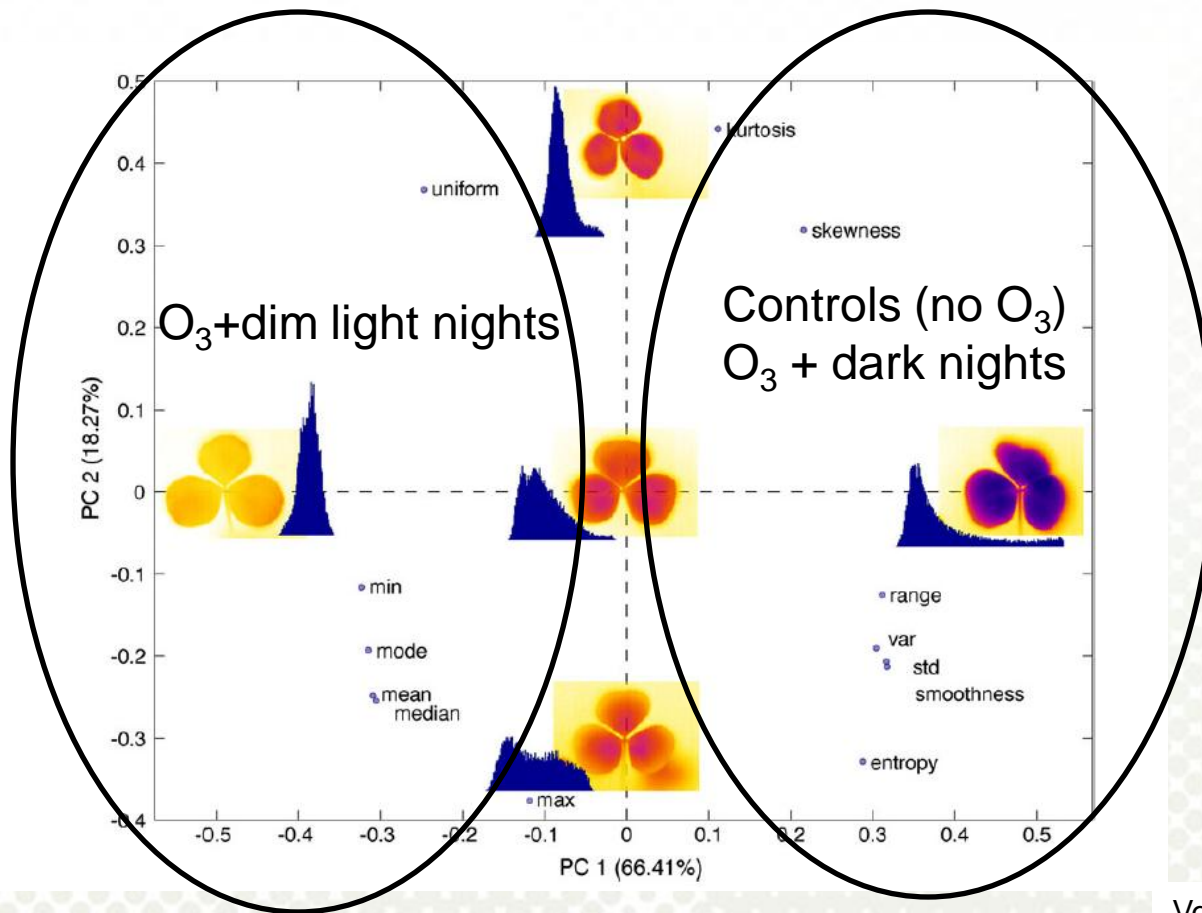
Infra-red imaging

Leaf function: temperature regulation



Ozone damages leaf temperature regulation

Leaf temperature and night-time light conditions



Vollnes et al. 2009.
 J. Exp. Bot. 60

- PCA of histograms of infrared images
- Dim light during the night damages leaf temperature regulation
- Persistent changes, lasting throughout as well as after ozone exposure

Conclusions

- Texture analysis of images enables identification of healthy and injured leaves
- GLCM was the best method
 - 100 % correct classification of healthy leaves
 - 89 % correct classification of exposed leaves
 - Not all exposed leaves displayed ozone lesions
- Robust and rapid automated classification is possible
- The next step is to automatically pick out which areas of leaf is damaged
 - Calculate degree of injury, e.g. 10 % of leaf surface damaged, using MIA (Multivariate Image Analysis)
- Twilight summer nights at northern latitudes increases ozone damage in some species

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