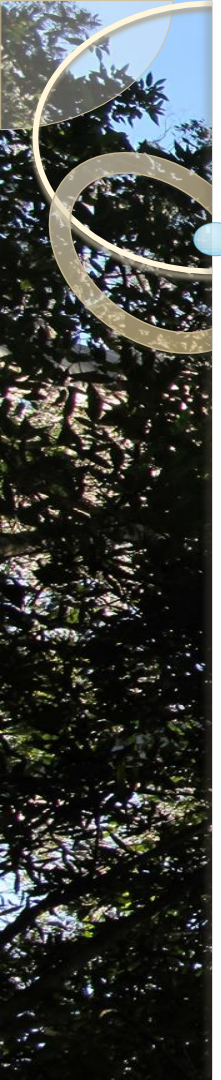

MAUP and LiDAR derived forest structure

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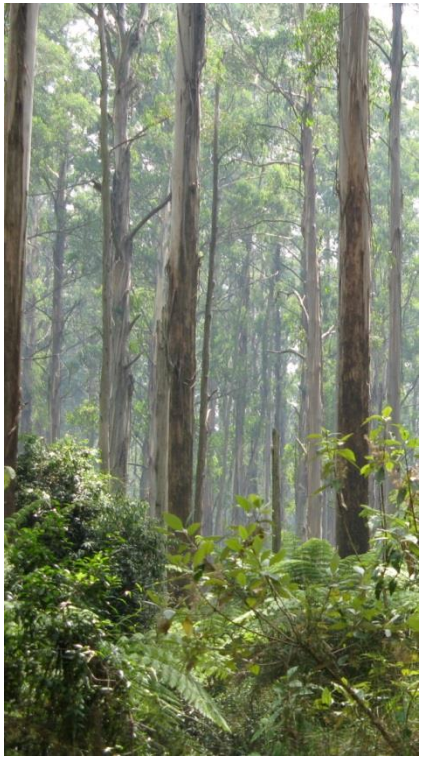
Outline

- Background to CRCSI 2.07 project
- Data acquisition and processing
- Introduction to the Modifiable Areal Unit Problem (MAUP)
- Probability Density Functions (PDF) to characterise forest structure
- Results from a structurally simple forest
- Unknown forest = unknown parameters

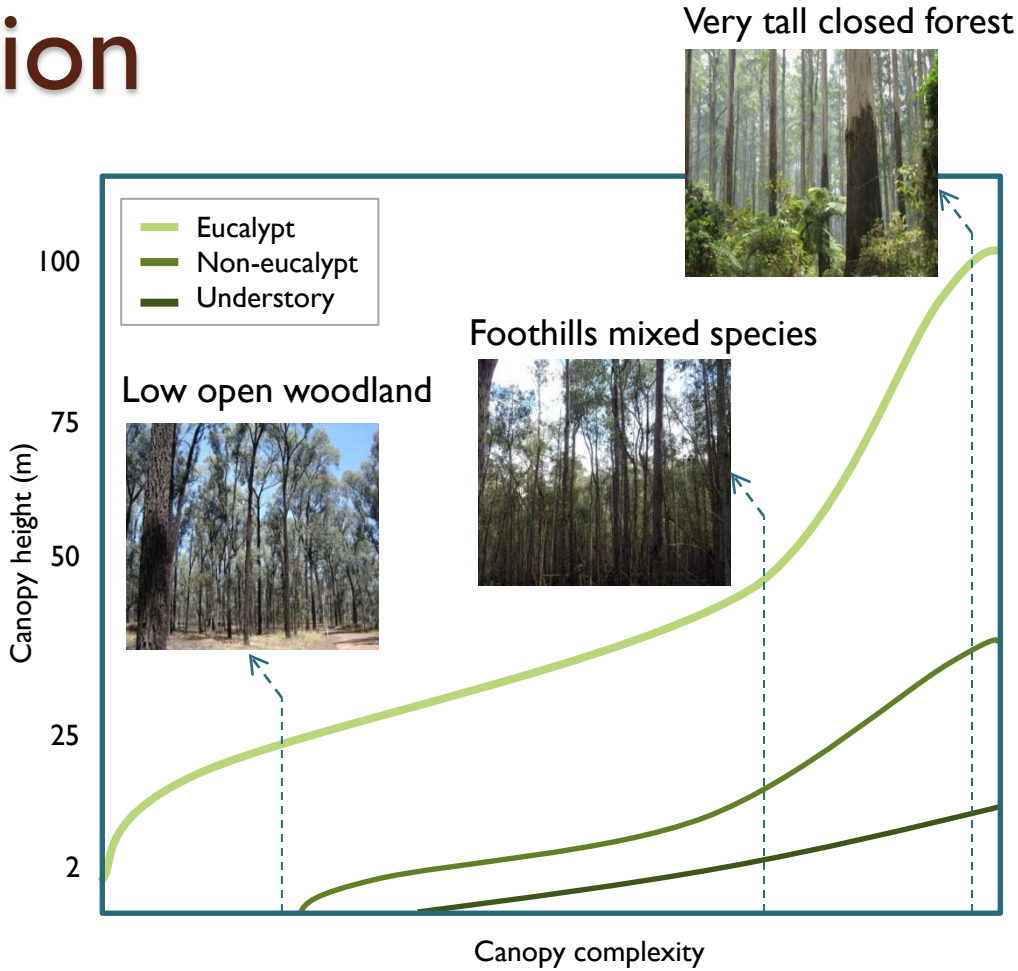


Background to CRCSI project 2.07

- Woody vegetation feature extraction at the landscape scale
- Phase I
  - Derive important attributes of forest architecture
  - At the "**landscape**" level
    - Canopies not crowns
- Phase II
  - Combine attributes to extract features
    - Forest extent
    - Habitat suitability
- Develop a "toolkit" for land managers and forest scientists to characterise forest at the landscape scale

Data collection

- 3 archetypal forest types
- 5 x 5 km sites
- Airborne LiDAR and hyperspectral data
- 27 0.04 ha coincident ground plots
- Leaf sampling (spectrometry, chemistry)
- Open source software (Python, R, MySQL etc.)

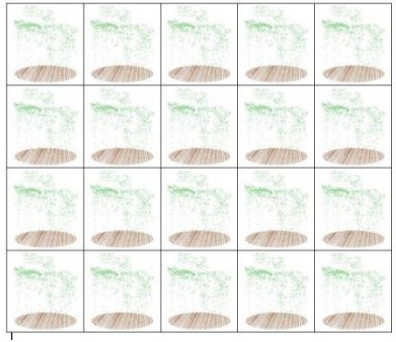


Point clouds to parameters

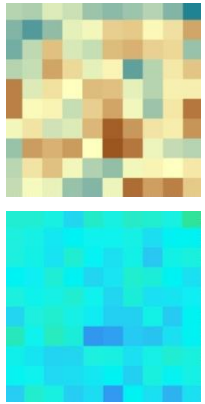
```
Dominant height: 20.5 m
Understorey: Absent
Canopy cover: 45%
LAI: 1.5
Mean DBH: 0.25 m
```

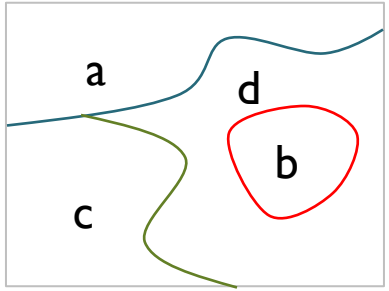
PLOT

LANDSCAPE



Third-party



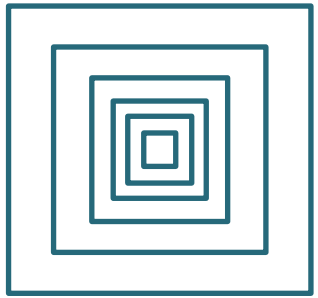


Modifiable Areal Unit Problem (MAUP)

"*the areal units used in many geographical studies are arbitrary, modifiable, and subject to the whims and fancies of whoever is doing, or did, the aggregating*"

Openshaw (1984)

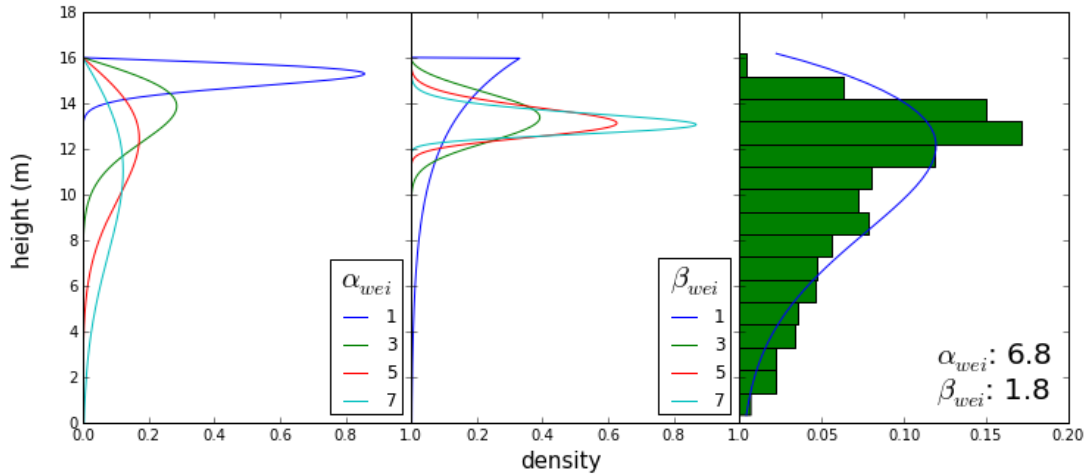
- MAUP is a two-fold problem of:
  - Scale problem
  - Aggregation problem
- Science of scale (Marceau and Hay, 1999)
- The Factor Scale in Remote Sensing (Woodcock & Strahler 1987)
- Dependent on;
  - Information required
  - Analysis method
  - Spatial structure of the scene
- Application to LiDAR (Lovell et al. 2003)



Canopy height profile

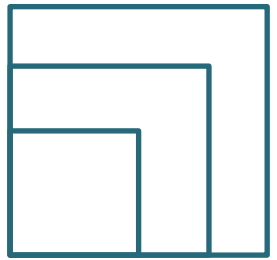
- Characterise distribution of vegetation along the vertical axis
- Fitting of probability density functions (PDF)
- 2-parameter Weibull PDF (Lovell et al. 2003, Coops et al. 2007)

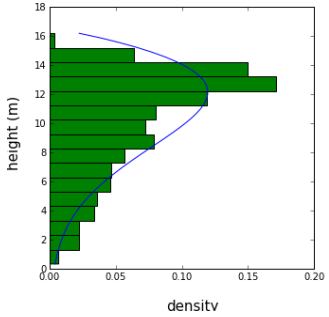
$$p(x) = \frac{\beta}{\alpha}\left(\frac{x}{\alpha}\right)^{\beta-1} e^{-(x/\alpha)^{\beta}}$$; α > 0 (scale) ; β > 0 (shape)

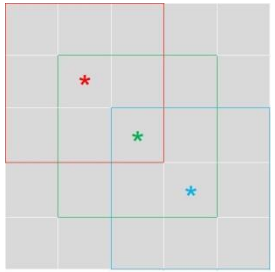


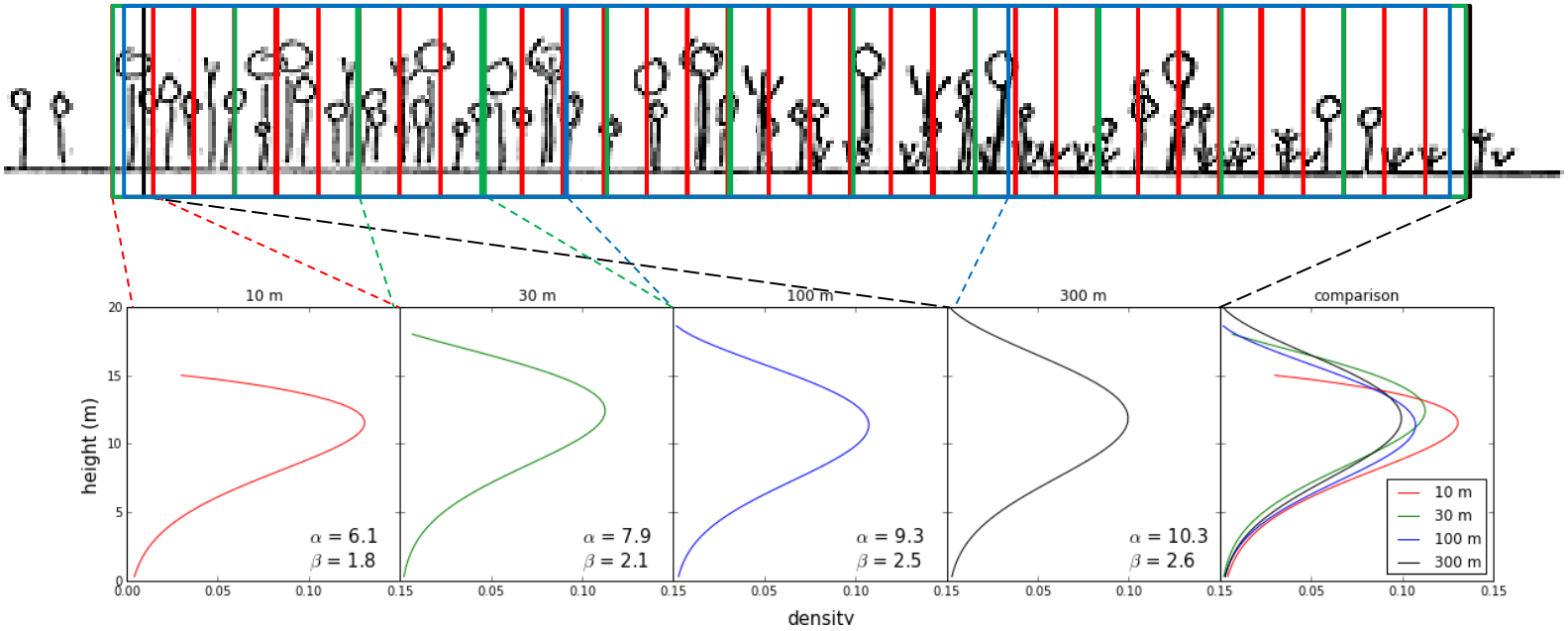
LiDAR, MAUP and localised variance

- Box Iron Bark (1 km^2)
- ~9 points m^{-2}
- Filtered returns <0.3 m and >99.999 percentile
- Aggregated returns into plots of increasing size (10, 20, 30, 50, 80, 100, 150, 200, 300 m)
- Weibull PDF using maximum likelihood
- Rasterised α_{wei} and β_{wei}
- 3x3 moving window calculated standard deviation as localised variance
- Mean localised variance
- Woodcock and Strahler (1987)

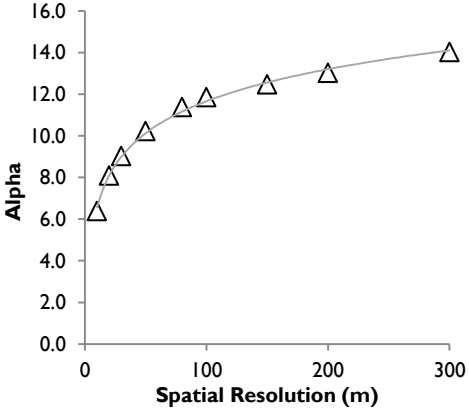




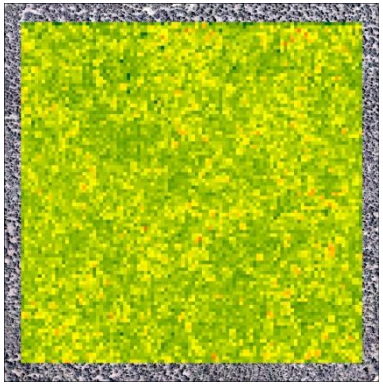



10 m
30 m
100 m
300 m
comparison
height (m)
density
α = 6.1
β = 1.8
α = 7.9
β = 2.1
α = 9.3
β = 2.5
α = 10.3
β = 2.6
10 m
30 m
100 m
300 m

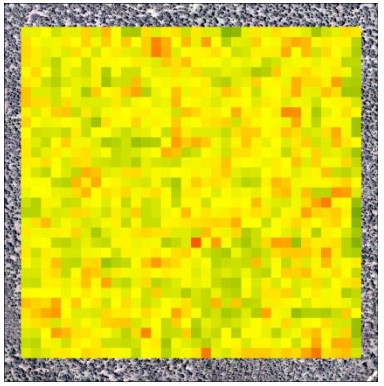
Mean α

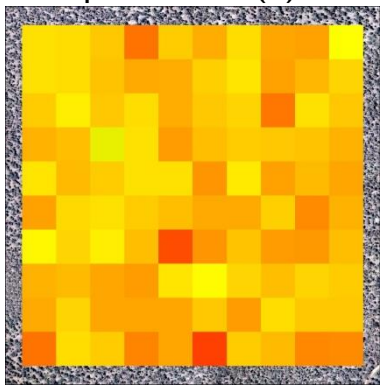


10 m

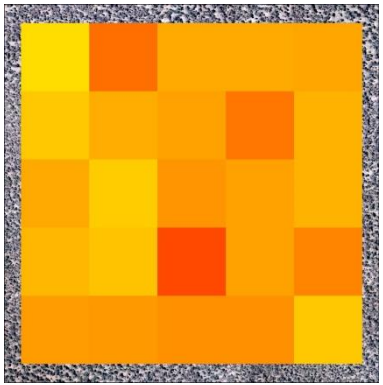


30 m

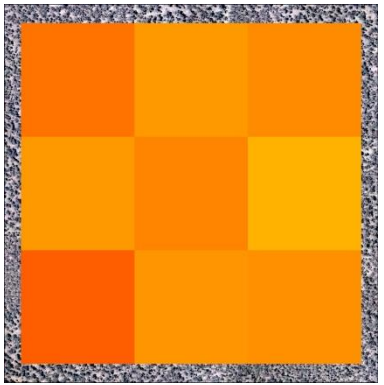




100 m

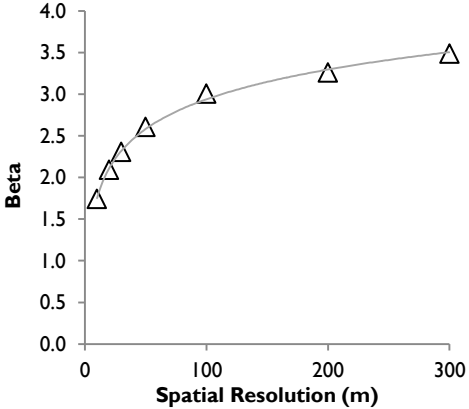


200 m

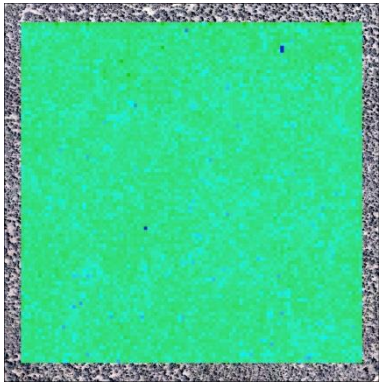


300 m

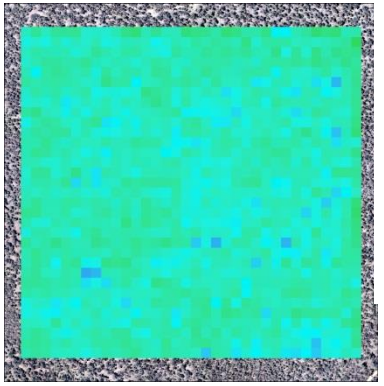
Mean β

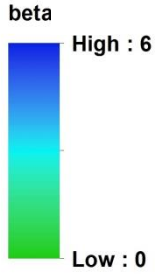


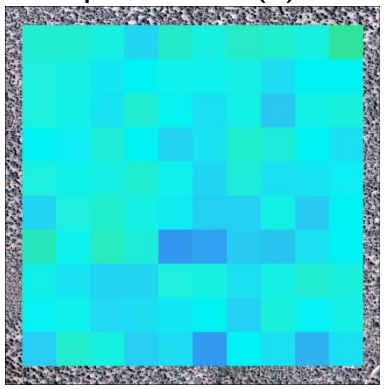
10 m



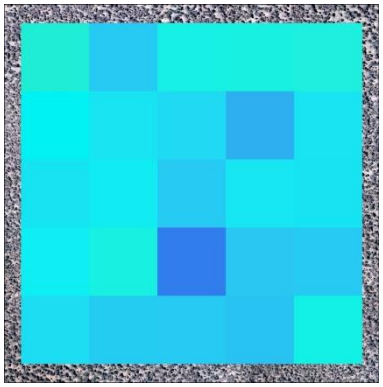
30 m



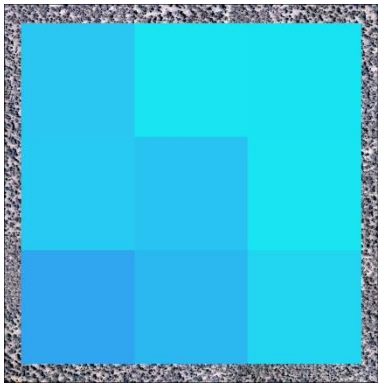




100 m

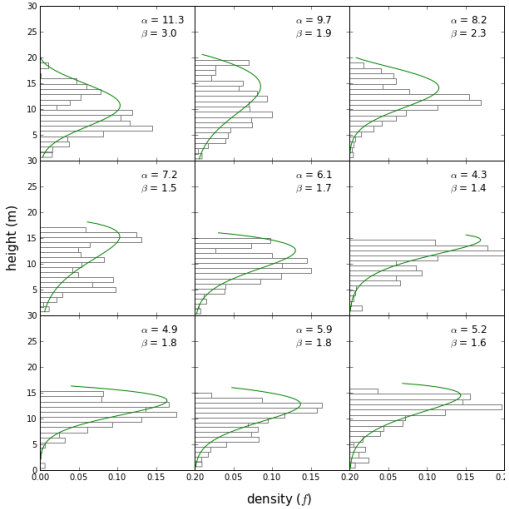


200 m

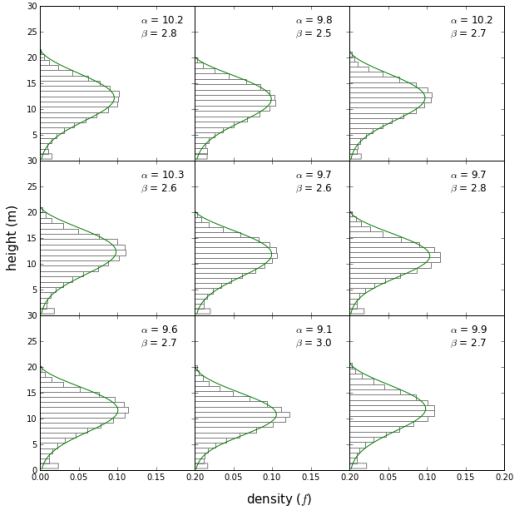


300 m

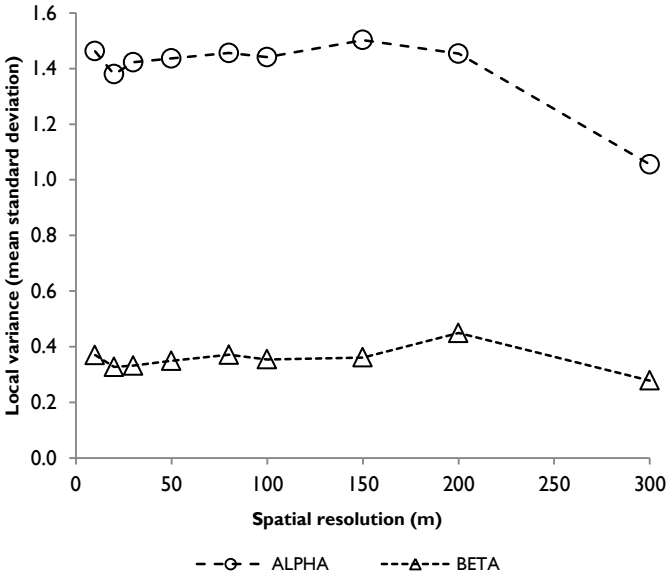
10 m



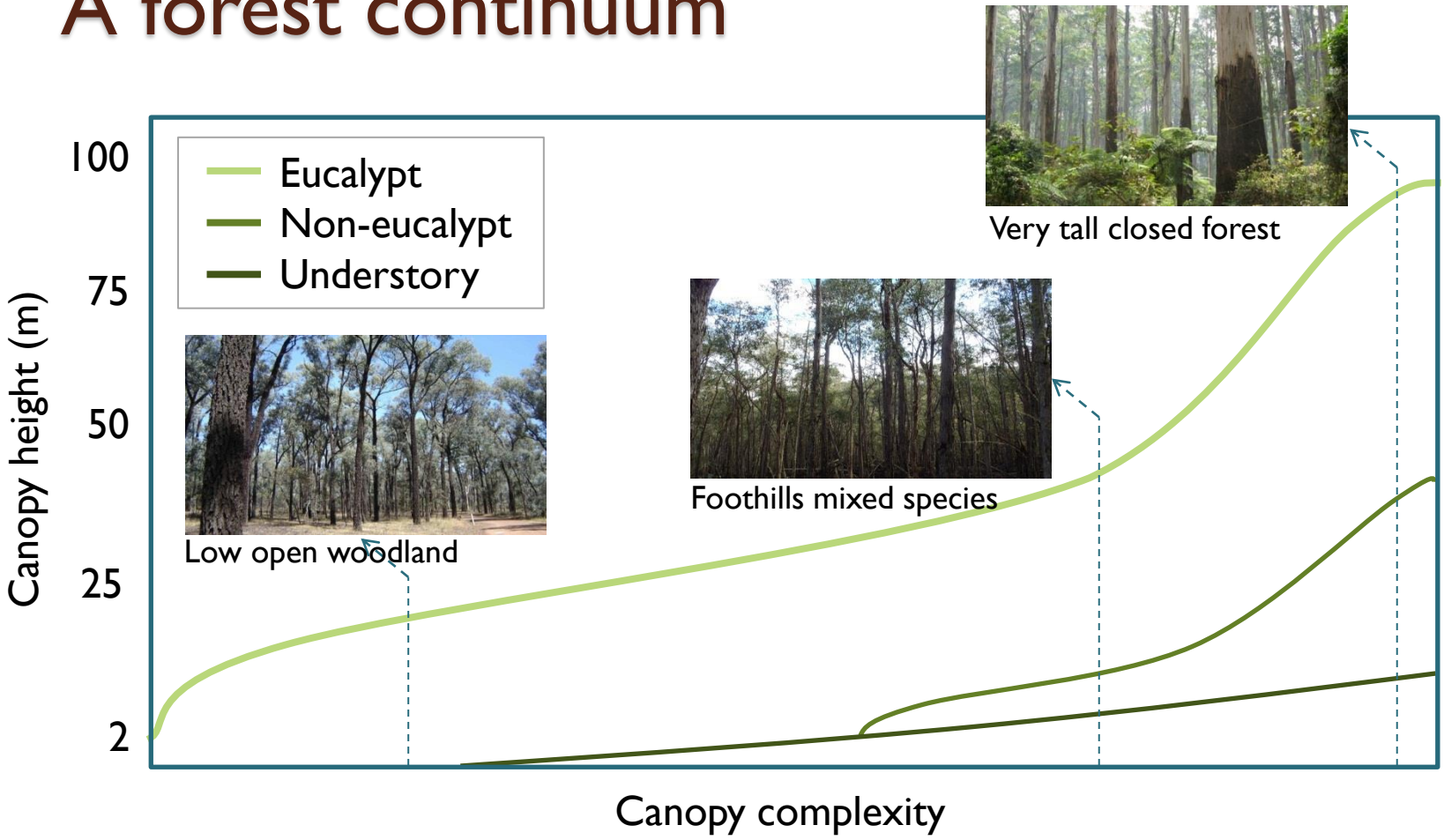
300 m



Local variance



A forest continuum



Canopy layers

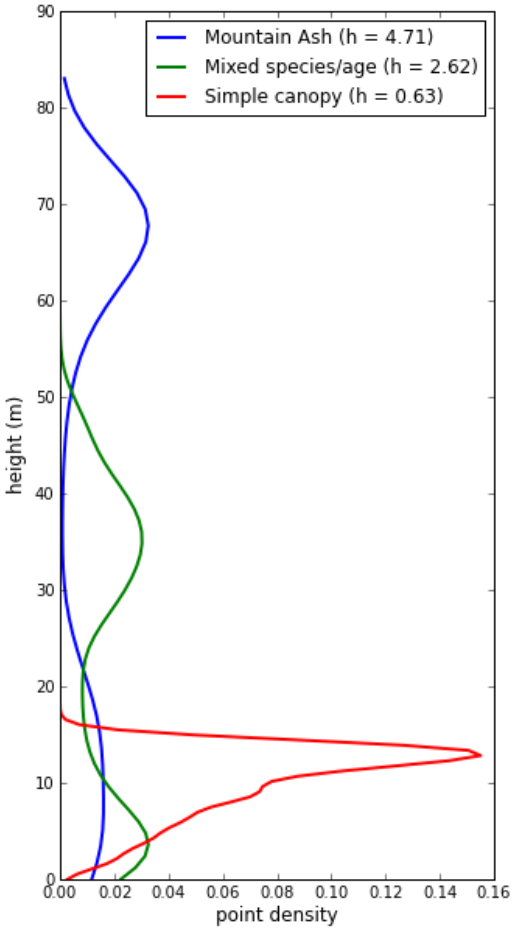
- Parameterise layers e.g. depth, CC etc.
- Vertical density of points
- Mixture modelling e.g. expectation-maximisation

$$p(x|\Theta) = \sum_{i=n}^{K} a_k p_k(x|\theta_k)$$

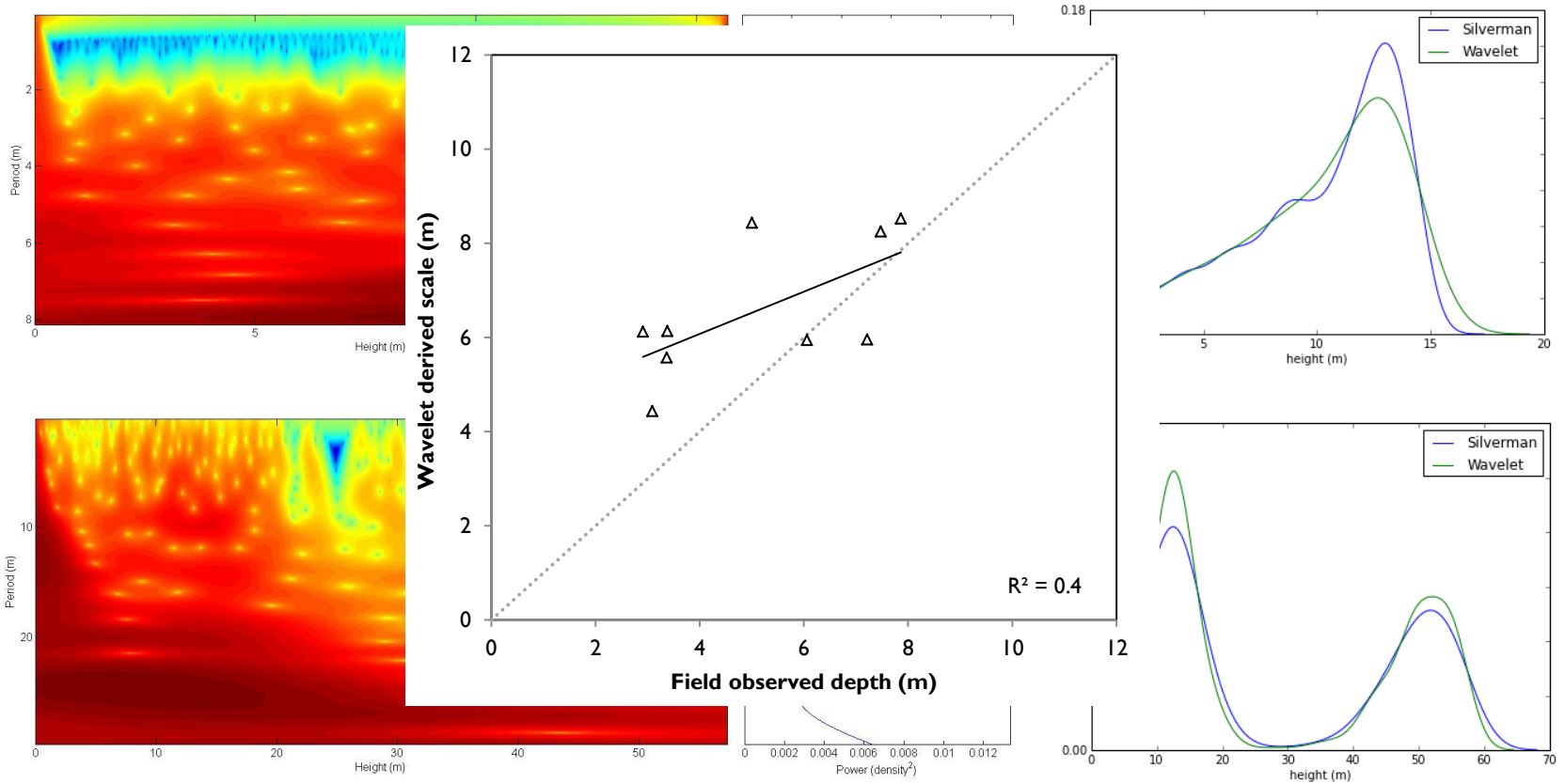
- How to determine k?
- Automated and at the **landscape** level

Pseudo-waveform

- Nonparametric Gaussian kernel density estimate
- Silverman's "Rule of Thumb" (1983)
  - $h = 0.9An^{-0.2}$
  - *A:* standard deviation
  - *n:* number of points
- # local maxima = # of strata
- Scale of analysis



Wavelet transformation



Conclusion

- Scale of analysis is a fundamental attribute of spatially explicit studies
- Simple canopy height profiles are well characterised by the Weibull PDF
- Modifying the scale of analysis changes the form of the function
- Expand the scope of this study to include a more heterogeneous scene
- New tools are required for more structurally complex forests
- Wavelet analysis shows promise for determining the appropriate scale at which to analyse complex and unknown forests

MAUP and LiDAR derived forest structure

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Thank you!

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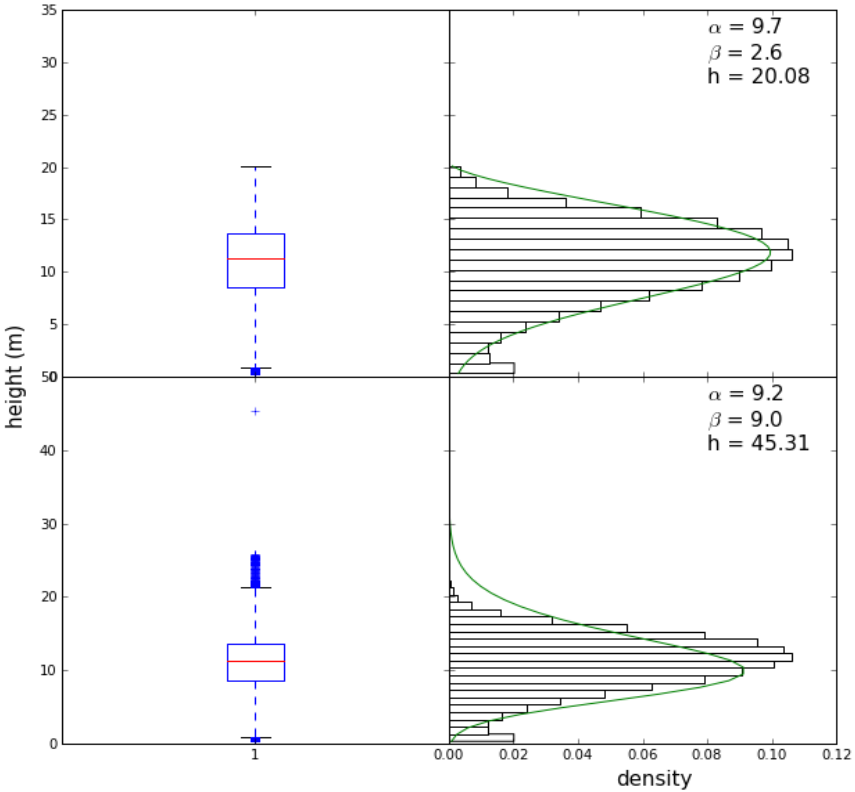
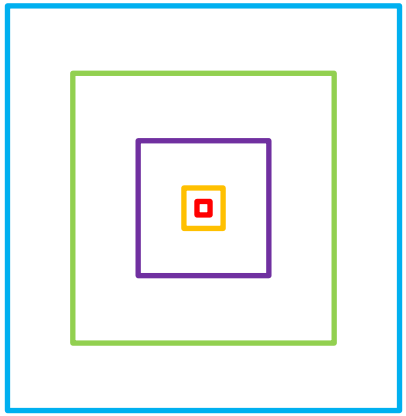
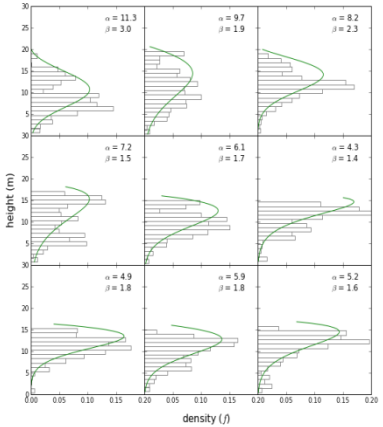
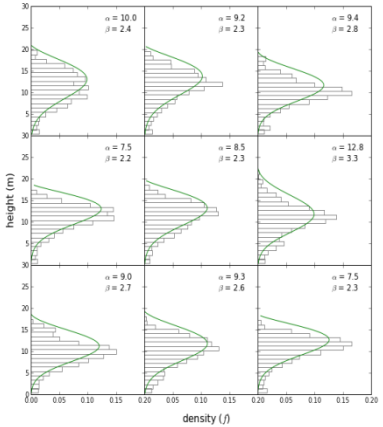

α = 9.7
β = 2.6
h = 20.08
α = 9.2
β = 9.0
h = 45.31
height (m)
density
0
5
10
15
20
25
30
35
40
45
50
1
0.00
0.02
0.04
0.06
0.08
0.10
0.12

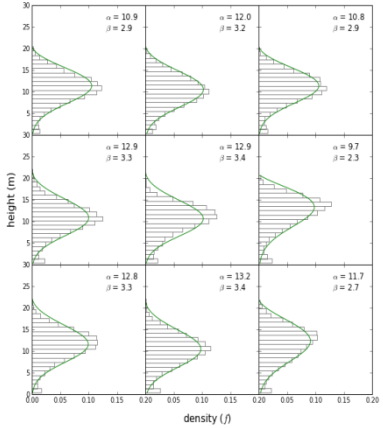


10 m

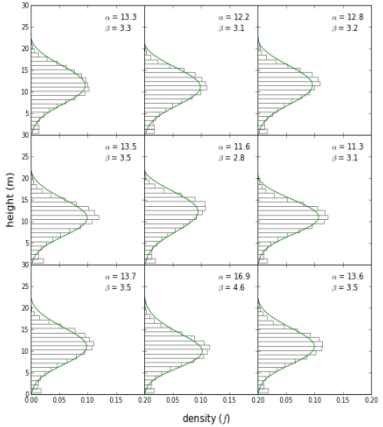


30 m

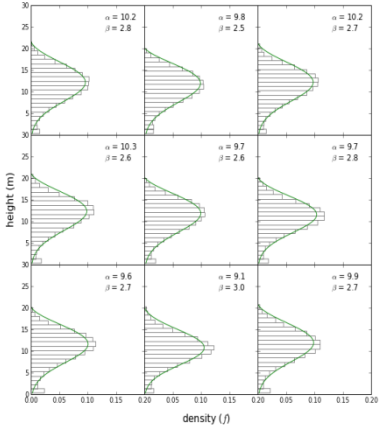




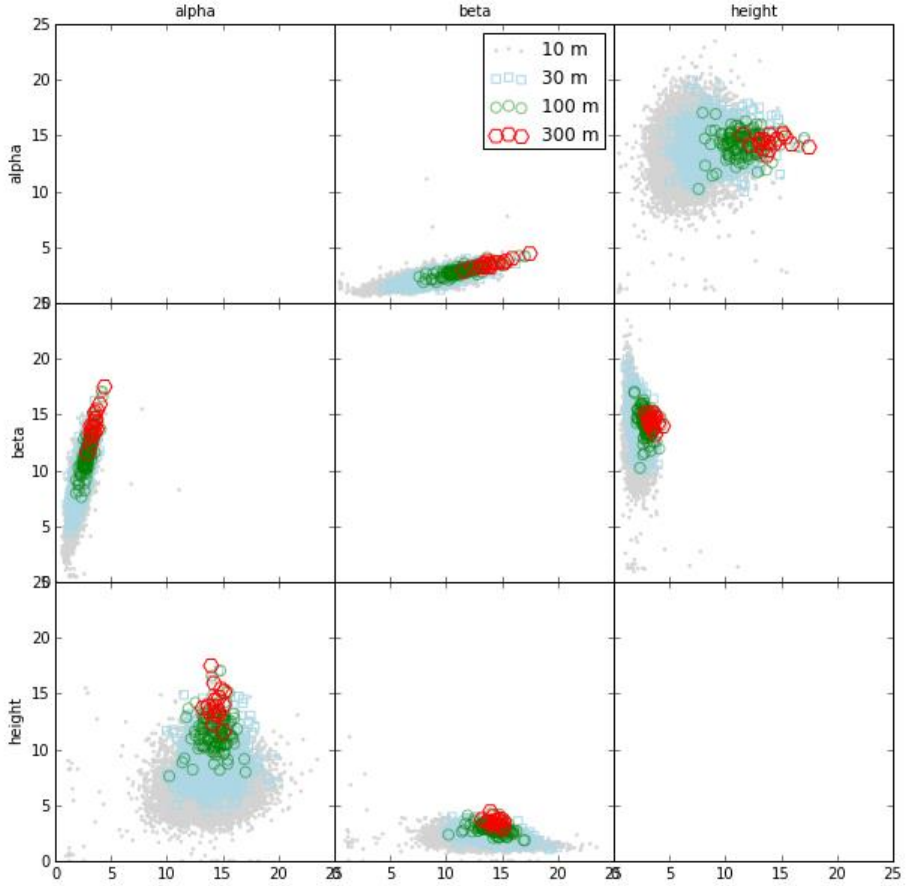
100 m



200 m



300 m


alpha
beta
height
10 m
30 m
100 m
300 m
alpha
beta
height
0
5
10
15
20
25