School of Earth and Environment
FACULTY OF ENVIRONMENT
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Flux measurements in complex, forested terrain

Andrew Ross

With thanks to:

Rosey Grant, Barry Gardiner, Ian Brooks

Field observations on Arran

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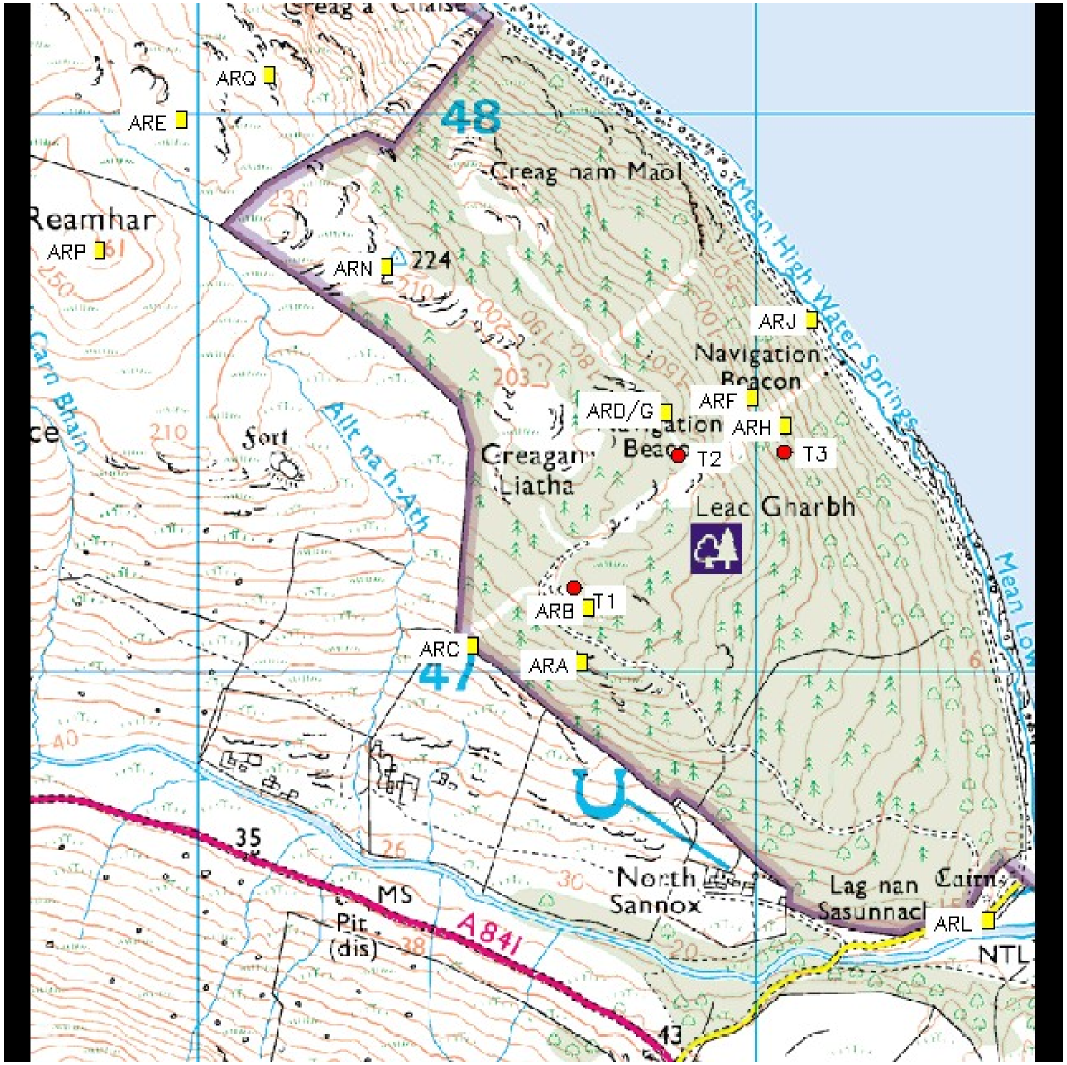
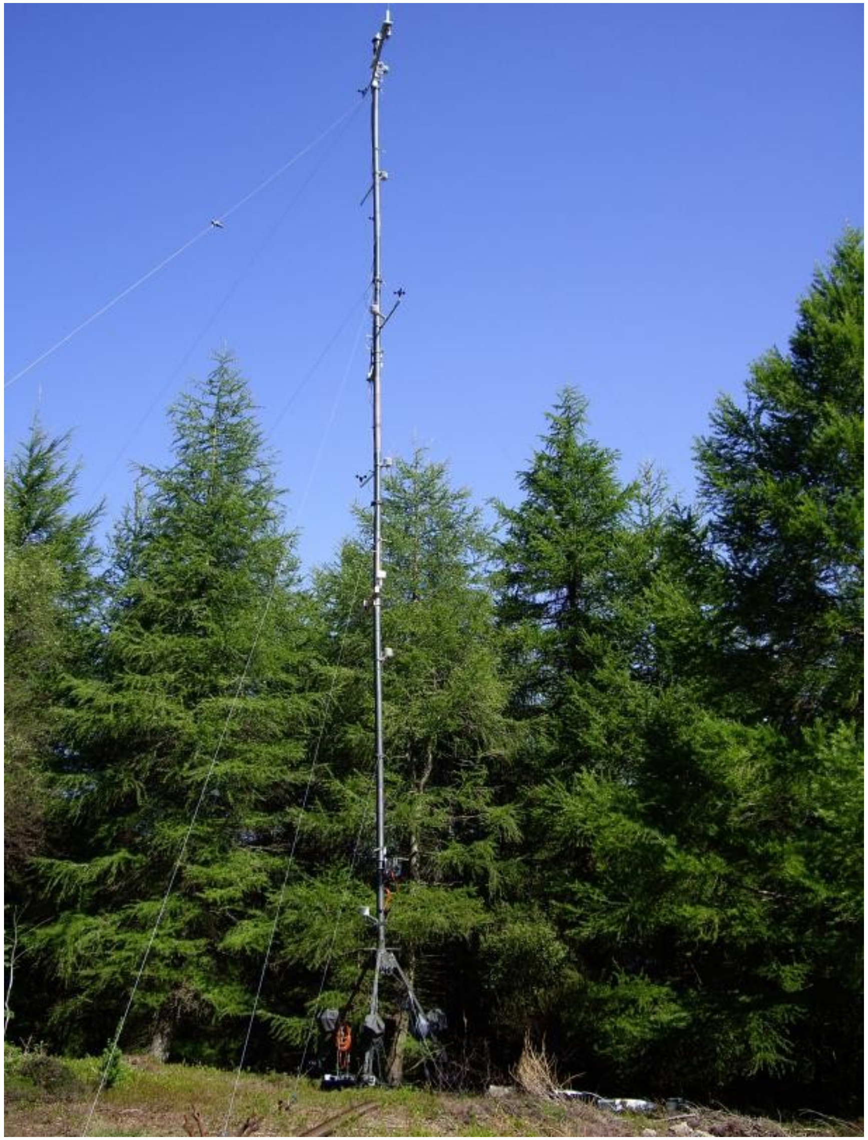


Today concentrating on measurements from 3 x ~20m towers located across ridge.

Each tower has sonic anemometer measurements at 4 heights.

Field observations on Arran

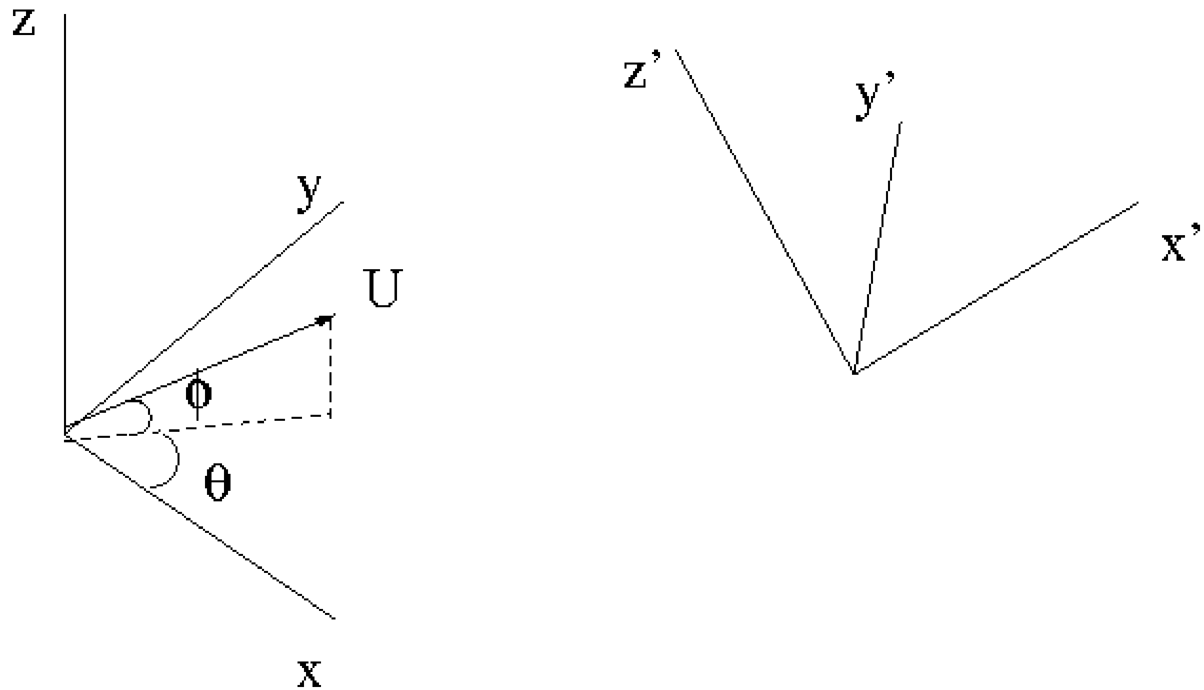


Dealing with turbulence measurements

- Sonic anemometer measures 3 components of wind speed in the instrument frame of reference
- Over complex terrain it is not obvious which frame of reference you should use
  - Instrument frame of reference
  - “World” frame of reference
  - Streamline coordinate system
  - Planar fit coordinate system
- This matters when using the eddy covariance method to calculate scalar and momentum fluxes, for example, where u >> w.

Rotate to streamline coordinates

- For each 15 min block of data calculate mean wind vector.
- Do x-y rotation through angle θ so mean flow is in x-z plane (average v is zero).
- Do x-z rotation through angle φ so mean flow is along x axis (average w is zero).



Planar fit coordinates

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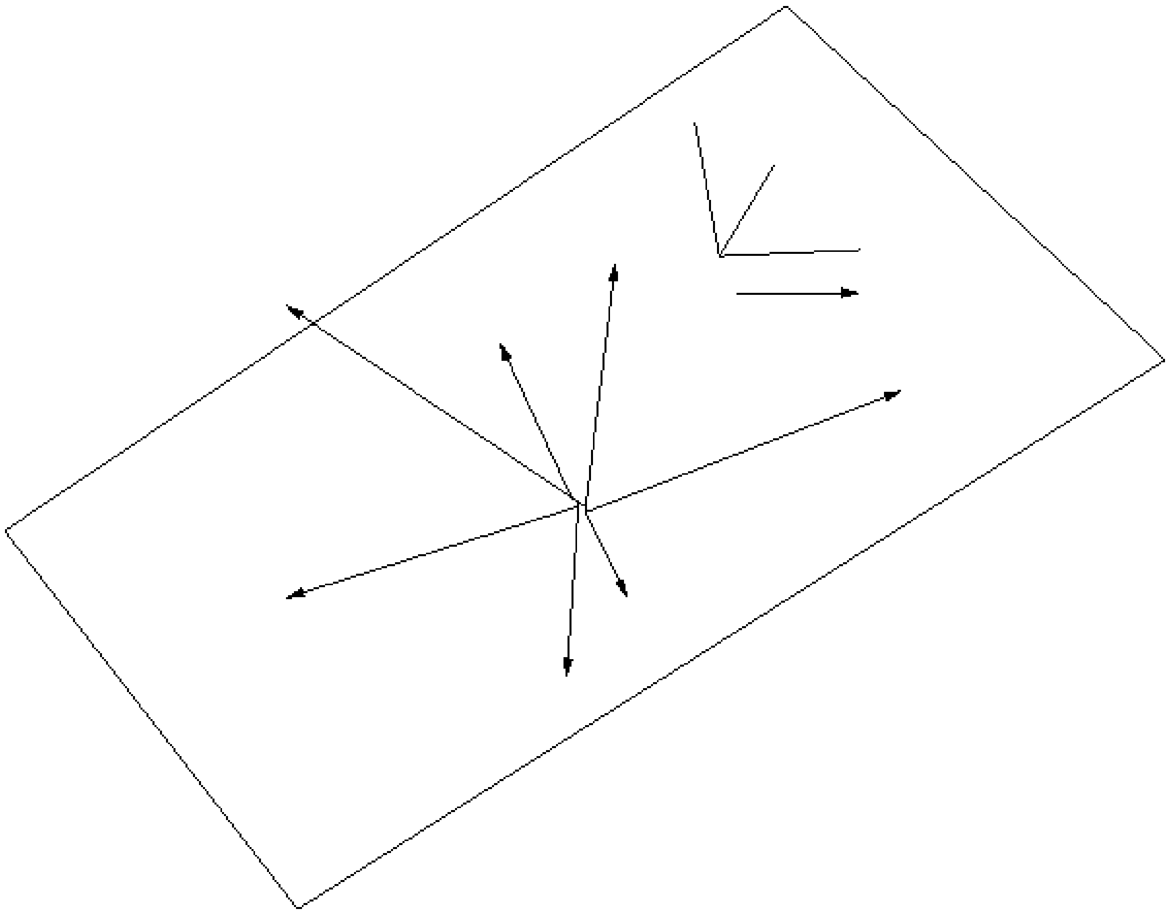
Calculate 15 min average wind vectors for all data set then do a planar least squares fit to the data so $w = b_0 + b_1u + b_2v$



Streamline coordinates

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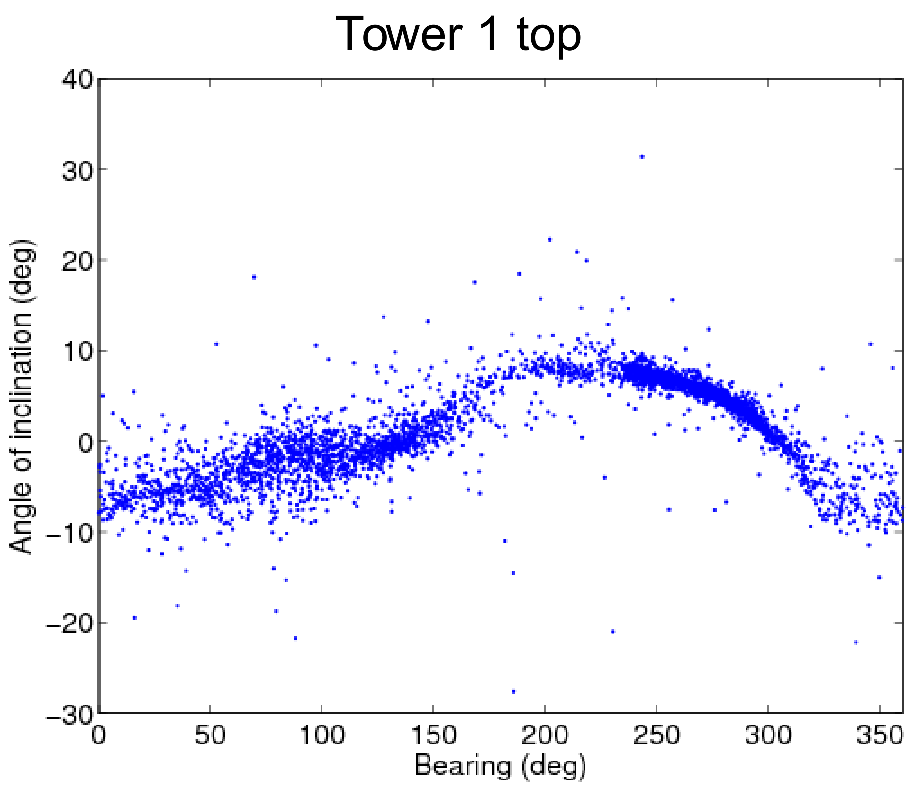

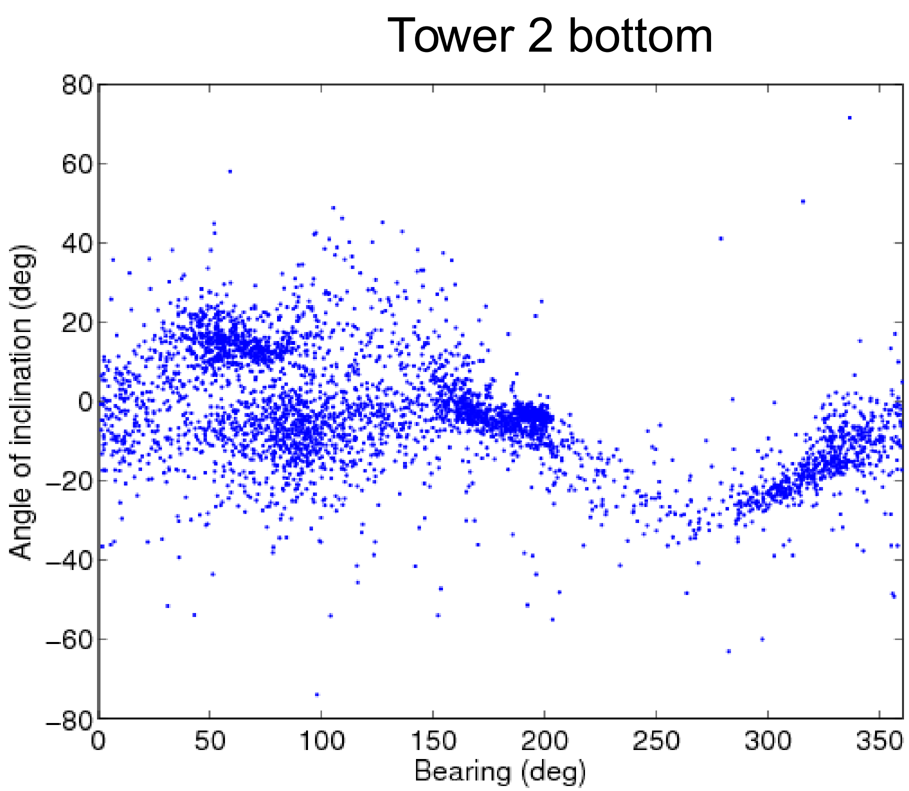

Alternative schemes?

- Sector planar fit: Divide the data up into different wind sectors then do a planar fit on the data in each sector separately. (e.g. Yuan et al, 2011, Met Atmos Phys)

- Here we look at another alternative where the angle of inclination, φ is defined as a function of the wind direction, θ. The question is then how to determine this function from the data.

Continuous planar fit

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- Given the periodic nature of φ it is natural to use a Fourier series expansion

$$\varphi(\theta) = a_0 + \sum_{n=1}^{N} [a_n \cos(n\theta) + b_n \sin(n\theta)]$$

- Obtain the coefficient a_n and b_n by least squares fit to the 15-min streamwise rotated data.
- Can now use this to rotate the raw data into this new continuous planar fit coordinate system.
- Here present results with $N = 8$.

Streamline coordinates

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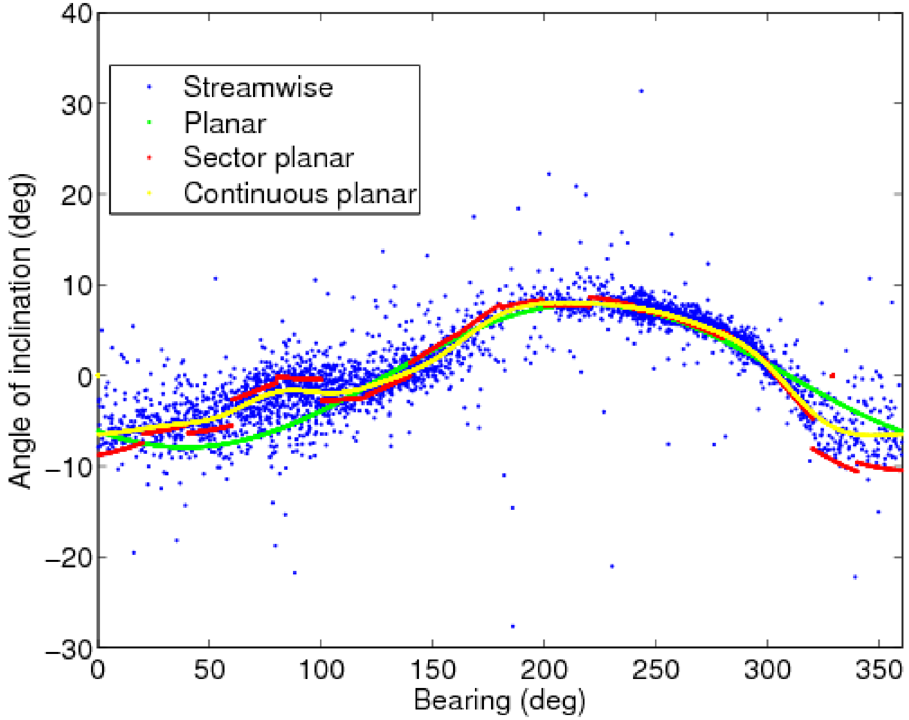
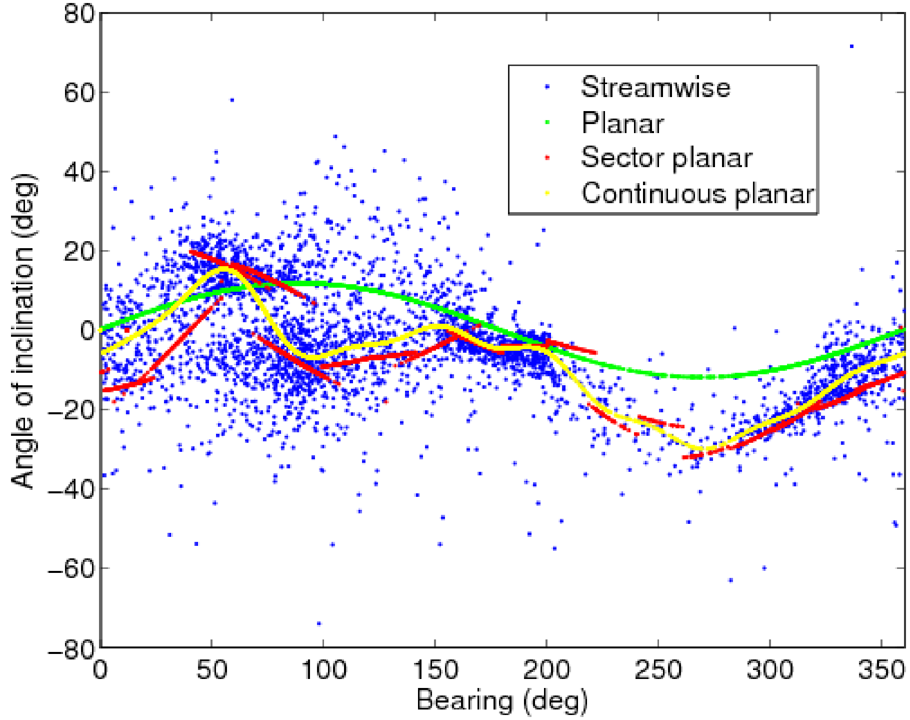
Tower 1 top



Tower 2 bottom



u'w'

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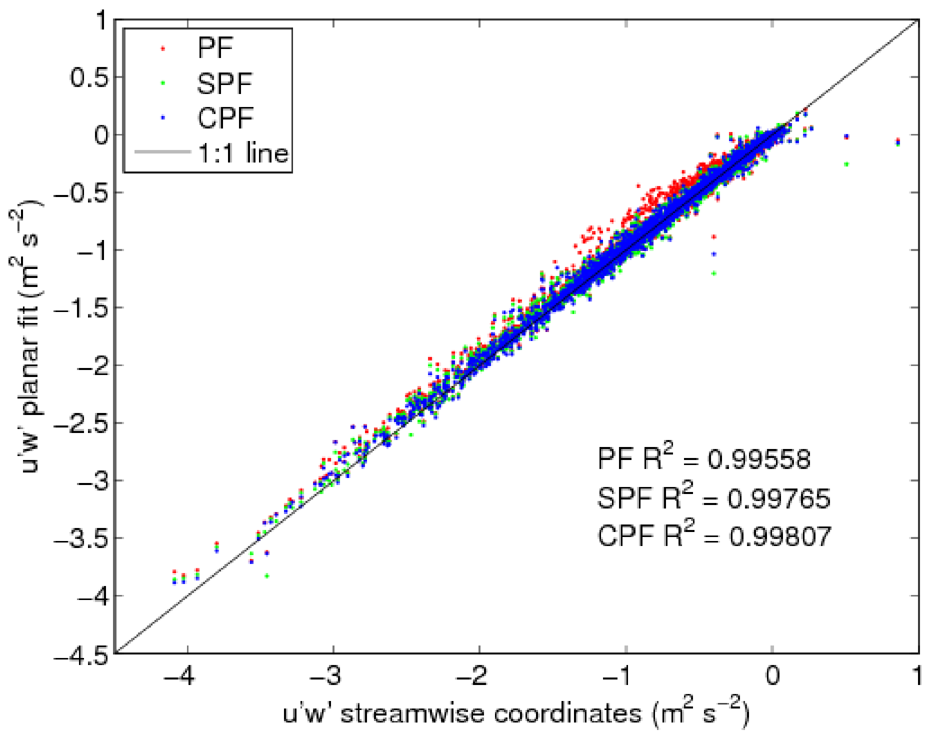
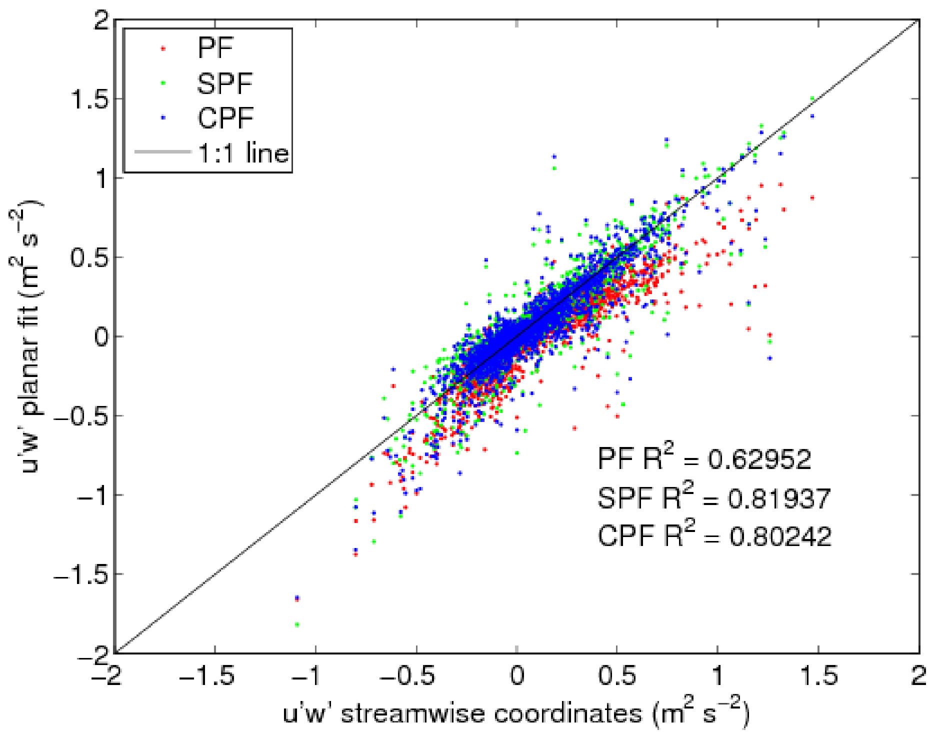
Tower 1 top

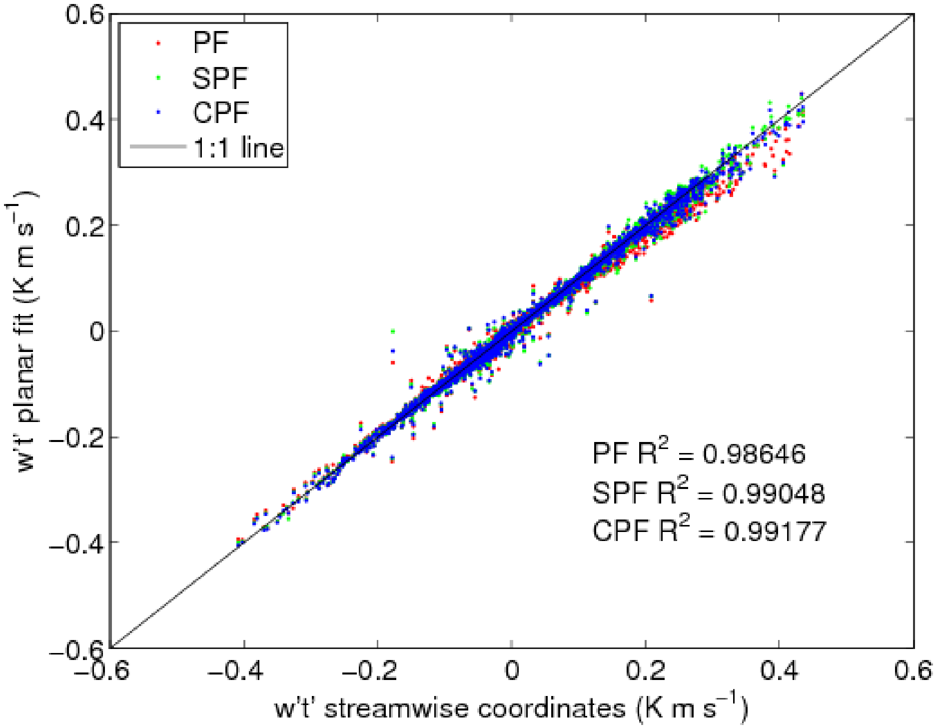


Tower 2 bottom

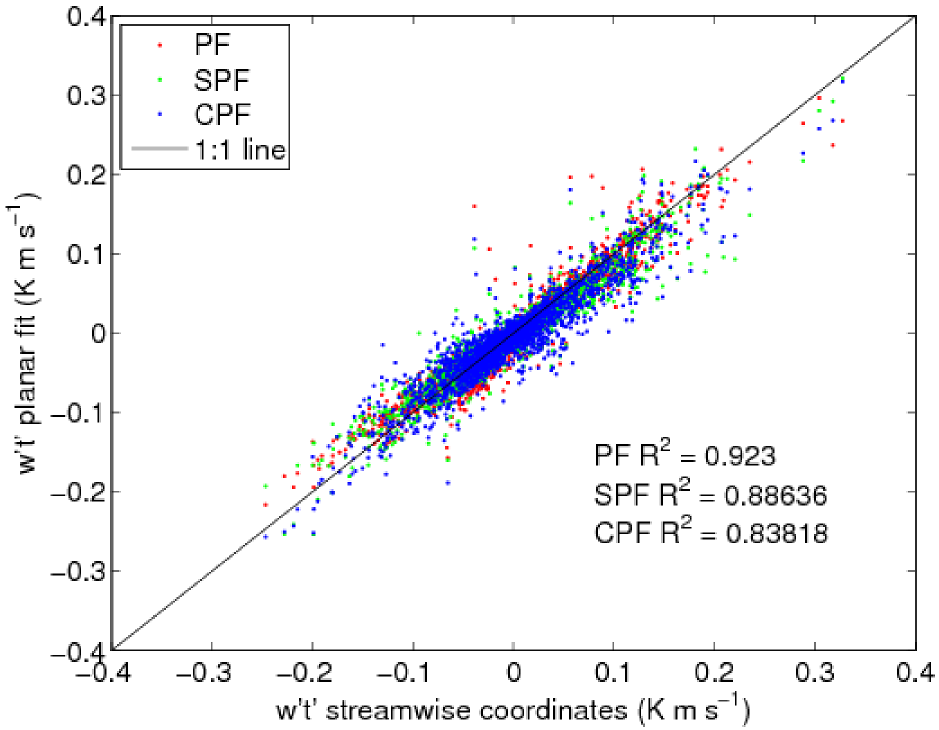


w'T'

Tower 1 top

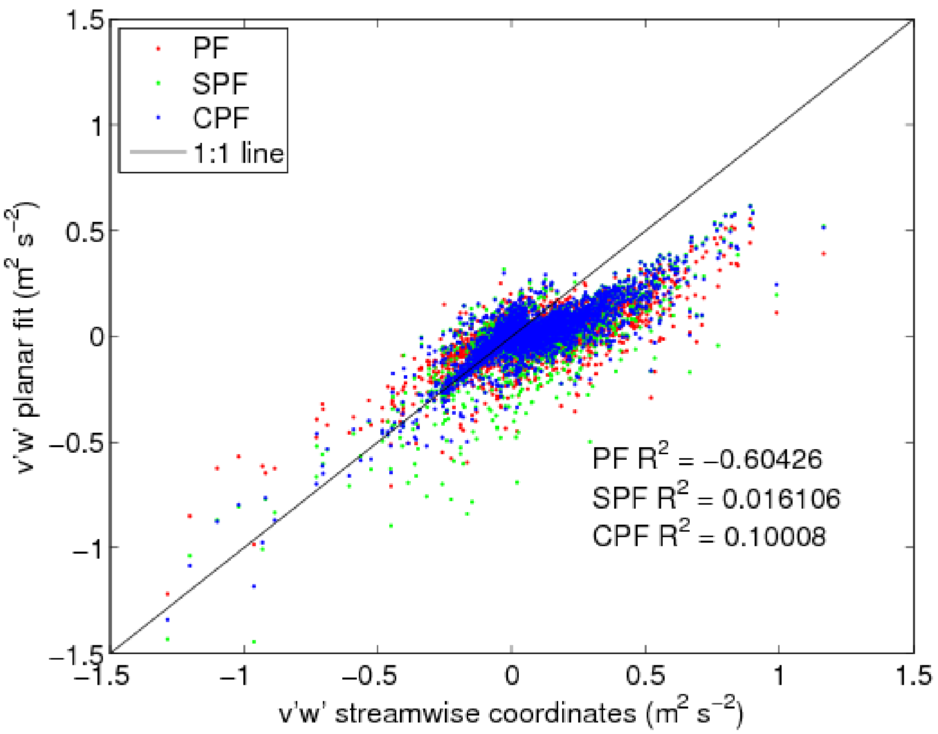


Tower 2 bottom

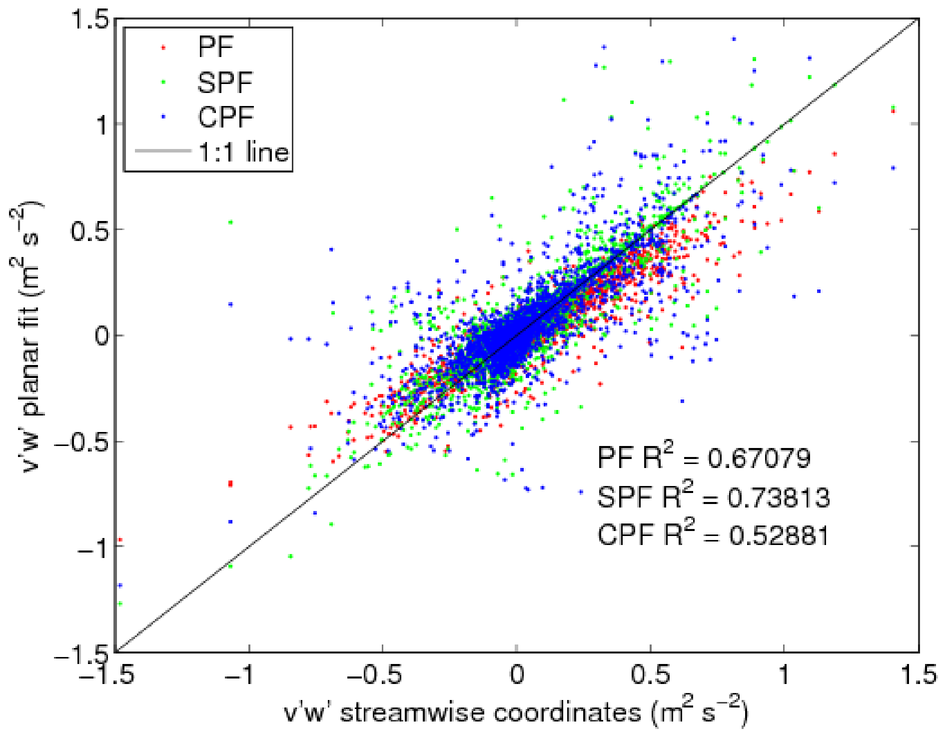


v'w'

Tower 1 top



Tower 2 bottom



Conclusions

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- Alternative to the more traditional planar fit for complex terrain / heterogeneous canopies where the planar fit may not be physically appropriate.
- Better captures the observed variations in inclination of the mean wind with wind direction.
- Avoids the arbitrary discontinuities observed with the sector planar fit method.
- Unlike traditional planar fit it does not allow the offset to be used as an estimate of the instrument error – but this almost certainly fails over complex terrain anyway.