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Visualising Forest Edge Effects

Ralph Torr
Senior Engineer

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Visualising forest edge effects

Carbon Trust Project
Power From Onshore Wind Farms:
Advanced Measurement and Modelling
(POWFARM)

ANSYS®

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RWE npower renewables

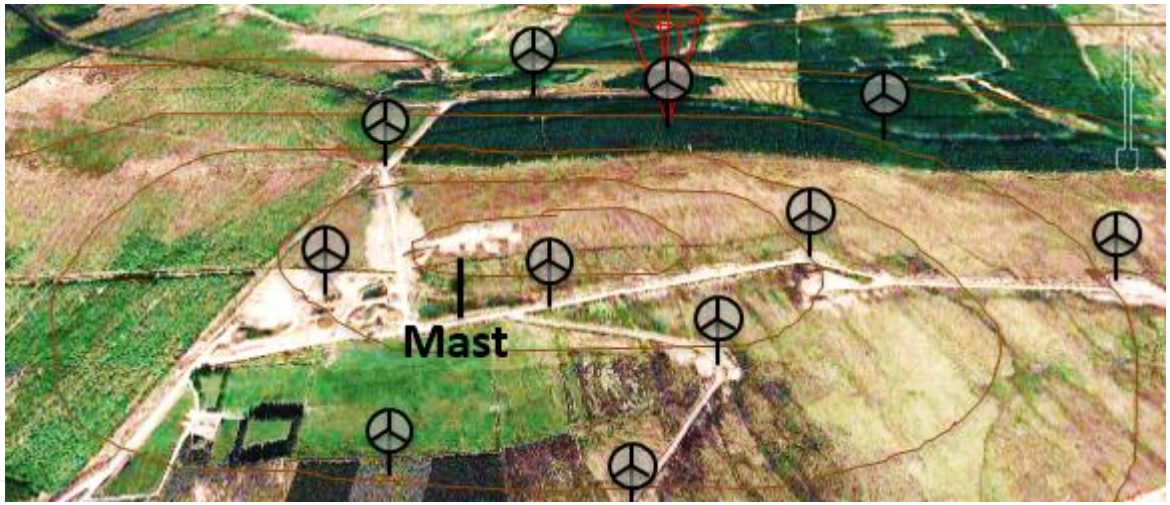
SCOTTISHPOWER RENEWABLES

Acknowledgement of Work Conducted by
Roy Spence & Graham More (SgurrEnergy)

Visualising forest edge effects

Measurements near/in forestry

- Location of masts relative to forestry not representative of WTG locations
- Current heights of masts not enough
  - Measurement of shear profile above forestry effects
  - Hub height measurement is only half the rotor
- Forestry and slopes
- DTU assessments of forest edges using Lidar devices.



Visualising forest edge effects

Carbon Trust – POWFARM

- Develop improved and validated computational flow models for wind farms in complex terrain
- Gain an enhanced understanding of forestry and topography, influenced wind flow interactions through a combination of advanced measurement and modelling technologies
- Developer focus – forestry

    Workstream 1 – advanced measurements

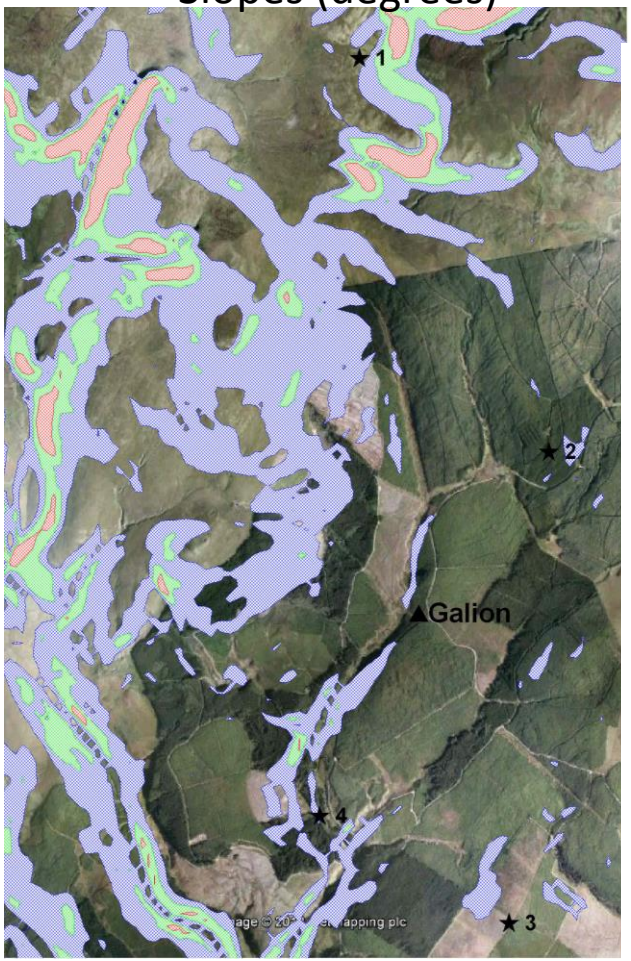
    Workstream 2 – advanced modelling

    Workstream 3 – existing model assessment

Visualising forest edge effects

Site 1: Scotland

Slopes (degrees)



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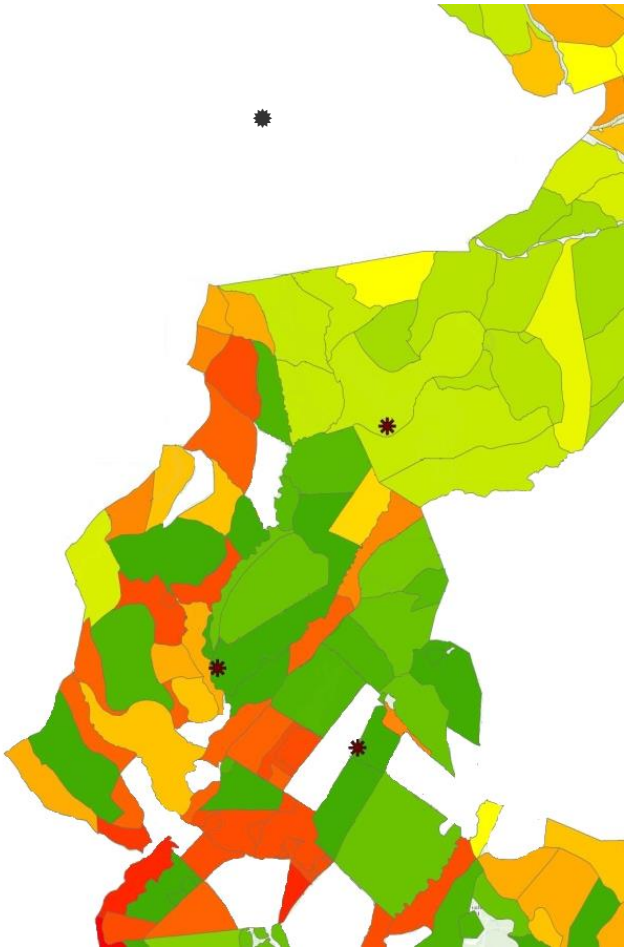
17-22

10-17

Tree Height (0-30 m)



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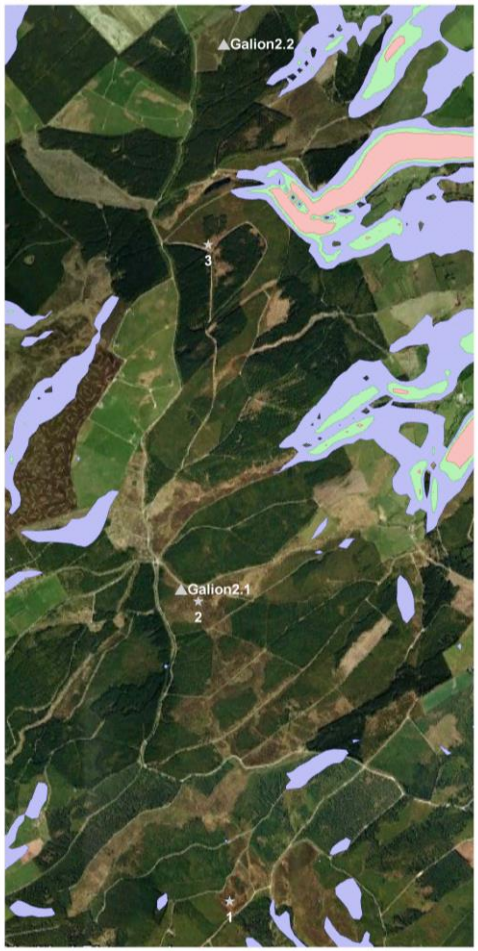
Site 2: Wales

Slopes (degrees)



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17-22

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Tree Height (0-35 m)

Visualising forest edge effects

- Existing model assessment using site mast datasets
  - WAsP
  - WAsP Engineering
  - CFD (Meteodyn)
- Both sites had significant measurement campaigns conducted

Site	Masts	Anemometers	Duration
1	4	70 (x2), 60, 50 & 30 m	6+ years, 6 years, 5 years & 3 years
2	2	70 (x2), 55, 40	4.5 years & 1.5 years
	1	60 (x2), 50, 40	4.5 years

  - All site 1 masts and 1.5 year mast on site 2 have independently calibrated Vector anemometry installed.
  - Both 4.5 year site 2 masts have one top Vector anemometer with all others being NRG anemometers for an initial period and later refitted with all Vector anemometry. All Vector anemometers have independent calibrations.

Visualising forest edge effects

- WAsP roughness/displacement models (18 in total)

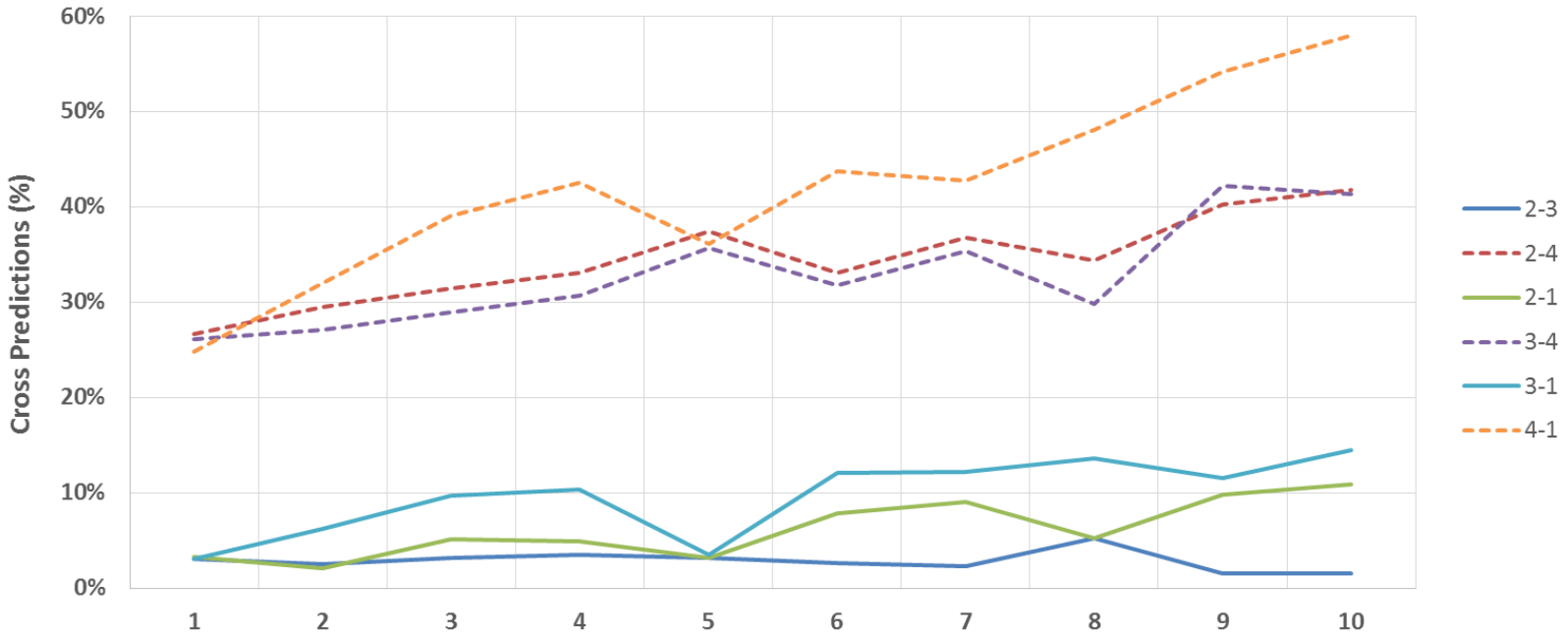
Digitisation complexity	Roughness representation value (α)	Displacement height
Low	Low	No
Low	Low	Yes
Low	Medium	Yes
High	Low	Yes
High	Medium	No
High	Medium	Yes
High	High	Yes
High	Very High	No
High	Very High	Yes

- Low roughness <0.5 for 25 m trees
- Medium roughness >0.5 & <2 for 25 m trees
- High roughness >2 & < 5 for 25 m trees
- Very high roughness >5 for 25 m trees

Visualising forest edge effects

- Site 1: Wind speed cross predictions

WAsP

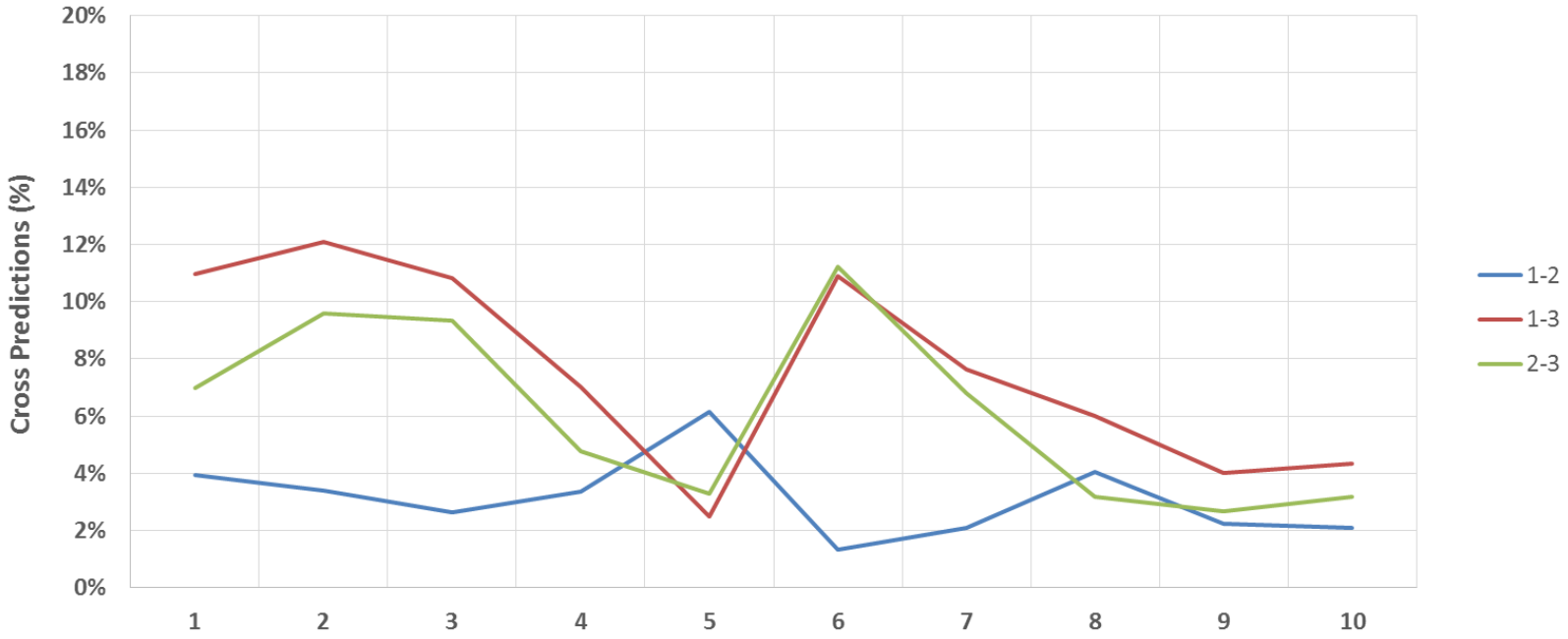


Complexity	H	H	H	L	H	L	H	L	L	H
Roughness	V	H	M	M	V	L	M	M	L	M
Displacement	Y	Y	Y	Y	N	Y	Y	Y	N	N

Visualising forest edge effects

- Site 2: Wind speed cross predictions

WAsP

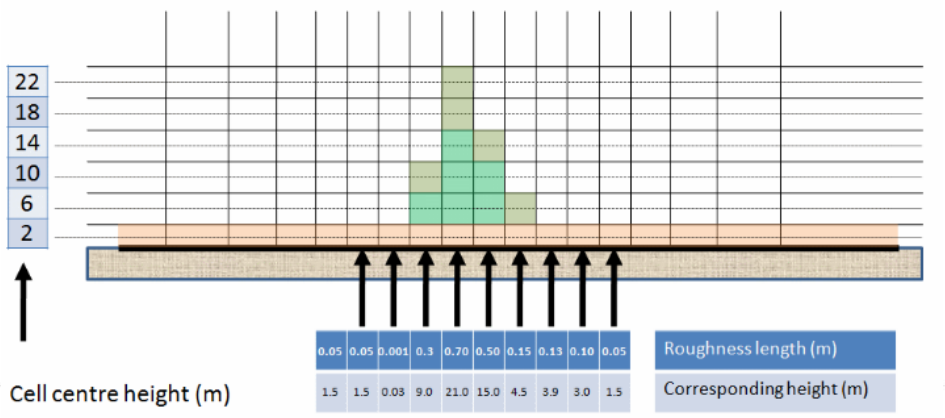


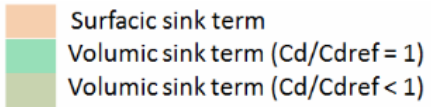
Complexity	H	H	H	L	H	L	H	L	L	H
Roughness	V	H	M	M	V	L	M	M	L	M
Displacement	Y	Y	Y	Y	N	Y	Y	Y	N	N

Visualising forest edge effects

- Intermediate CFD model parameters (approx. 15 models)

Height roughness *	Forest density	Model type	Domain (km)	Sector solution steps	Horizontal mesh size	Vertical mesh size
H/30	Low	Dissipative	30	30	10	2
H/20	Normal	Robust	40	10	15	3
H/15	High				18	4
					22	
* H equals tree height					25	

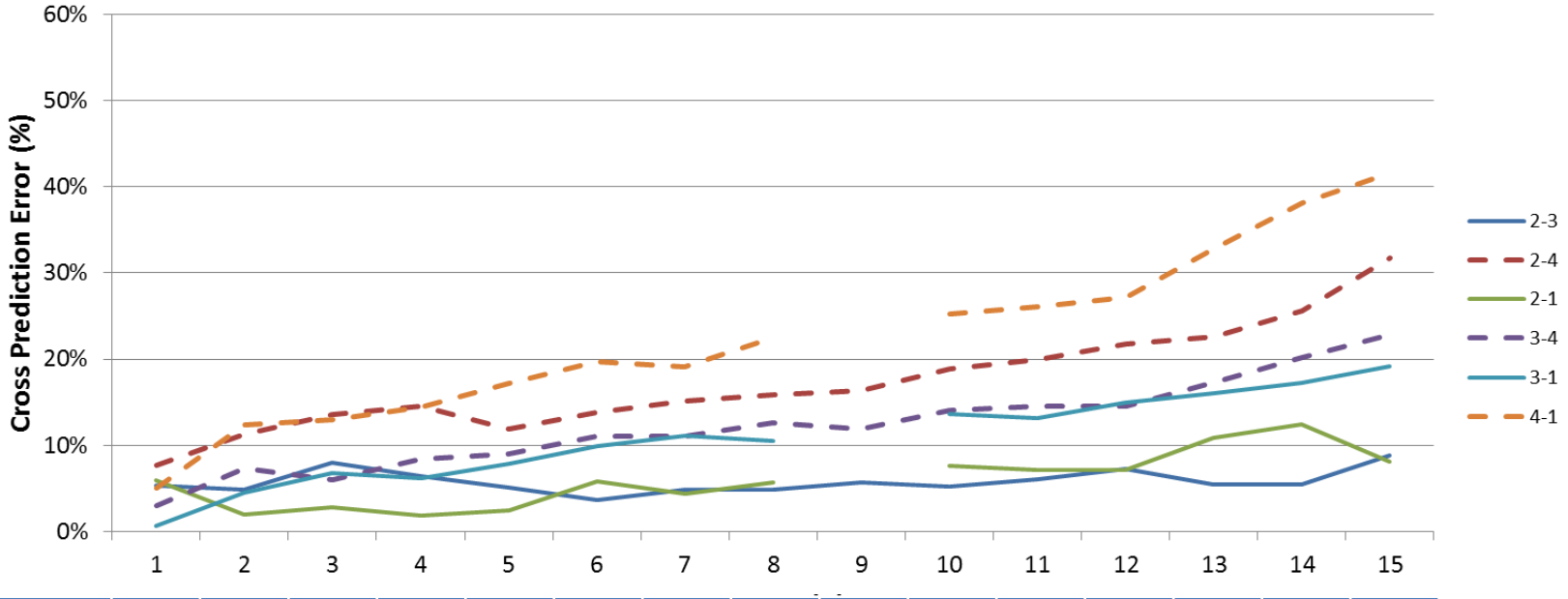




Visualising forest edge effects

- Site 1: Wind speed cross predictions

CFD

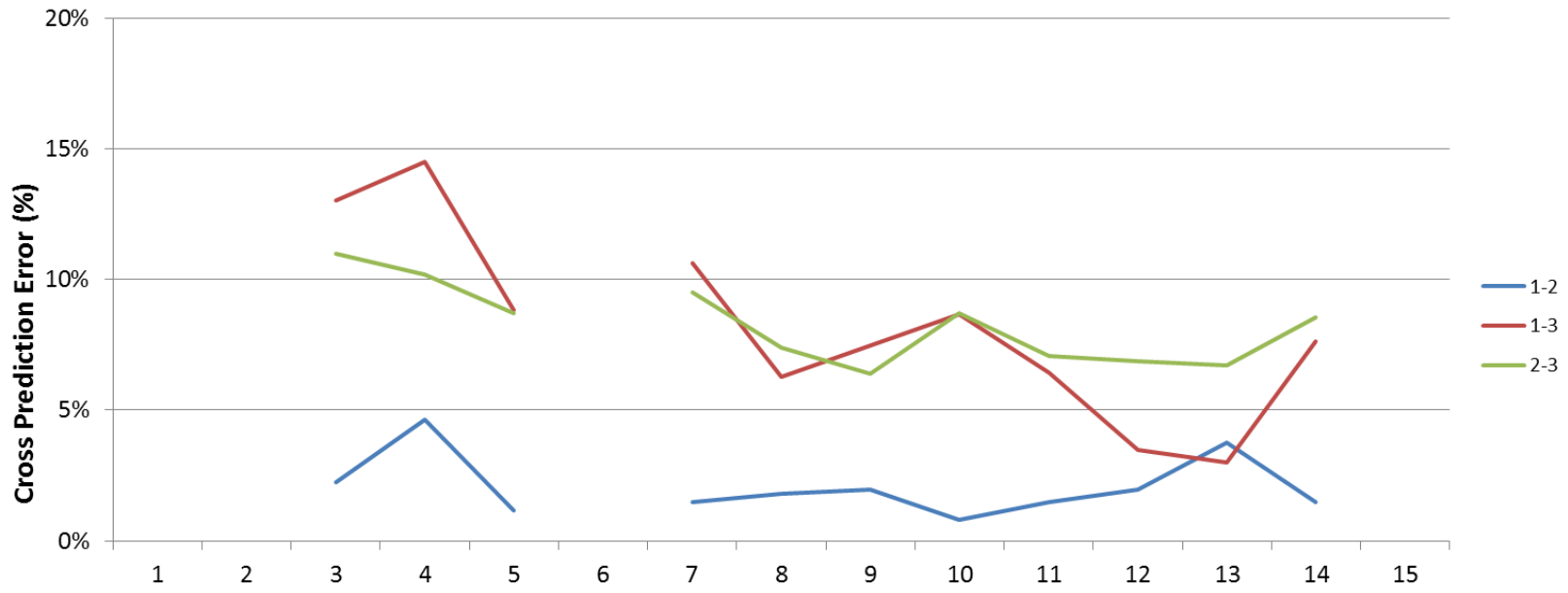


Representation	15	15	15	20	20	15	15	20	20	20	30	20	30	30	15
Density	H	N	N	H	H	N	N	N	N	H	H	H	H	N	L
Model	R	R	R	R	R	D	D	R	D	D	R	D	D	D	R
Sectors	30	30	30	30	10	30	10	30	30	10	30	30	30	30	30

Visualising forest edge effects

- Site 2: Wind speed cross predictions

CFD



Representation	15	15	15	20	20	15	15	20	20	20	3	20	30	30	15
Density	H	N	N	H	H	N	N	N	N	H	H	H	H	N	L
Model	R	R	R	R	R	D	D	R	D	D	R	D	D	D	R
Sectors	30	30	30	30	10	30	10	30	30	10	30	30	30	30	30

Visualising forest edge effects

- Site 2: Turbulence intensity comparison (scaled)

WAsP Engineering	CFD

Site 2: High roughness			
Mast	To		
	1	2	3
1	0.0%	2.5%	0.1%
2	2.1%	0.0%	1.0%
3	4.0%	2.4%	0.0%

Site 2: TI cross prediction			
Mast	To		
	1	2	3
1	0.0%	0.8%	1.0%
2	0.4%	0.0%	1.0%
3	0.0%	2.3%	0.0%

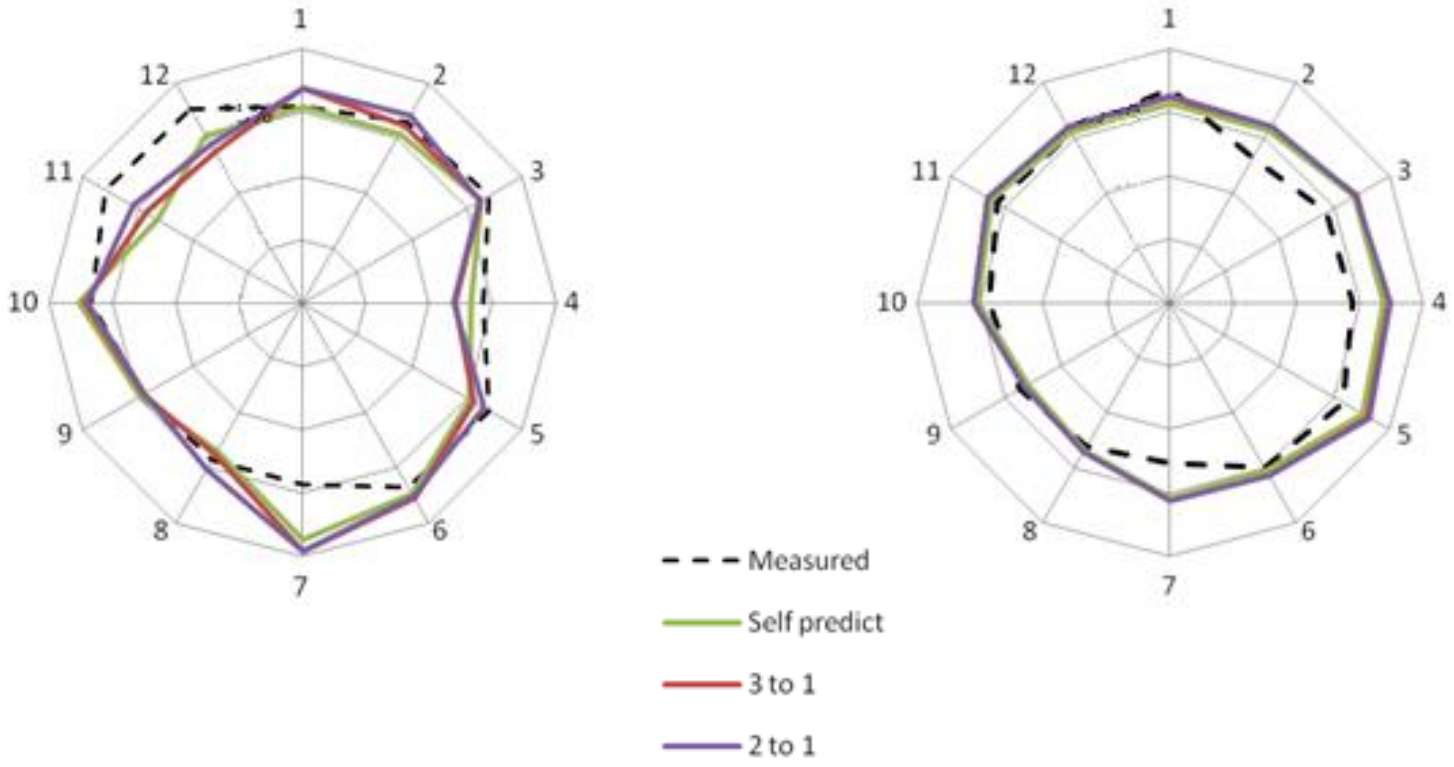
Percentage of the TI percentage value

Visualising forest edge effects

- Site 2: Turbulence intensity comparison

WAsP Engineering	CFD

Site 2: Mast 1

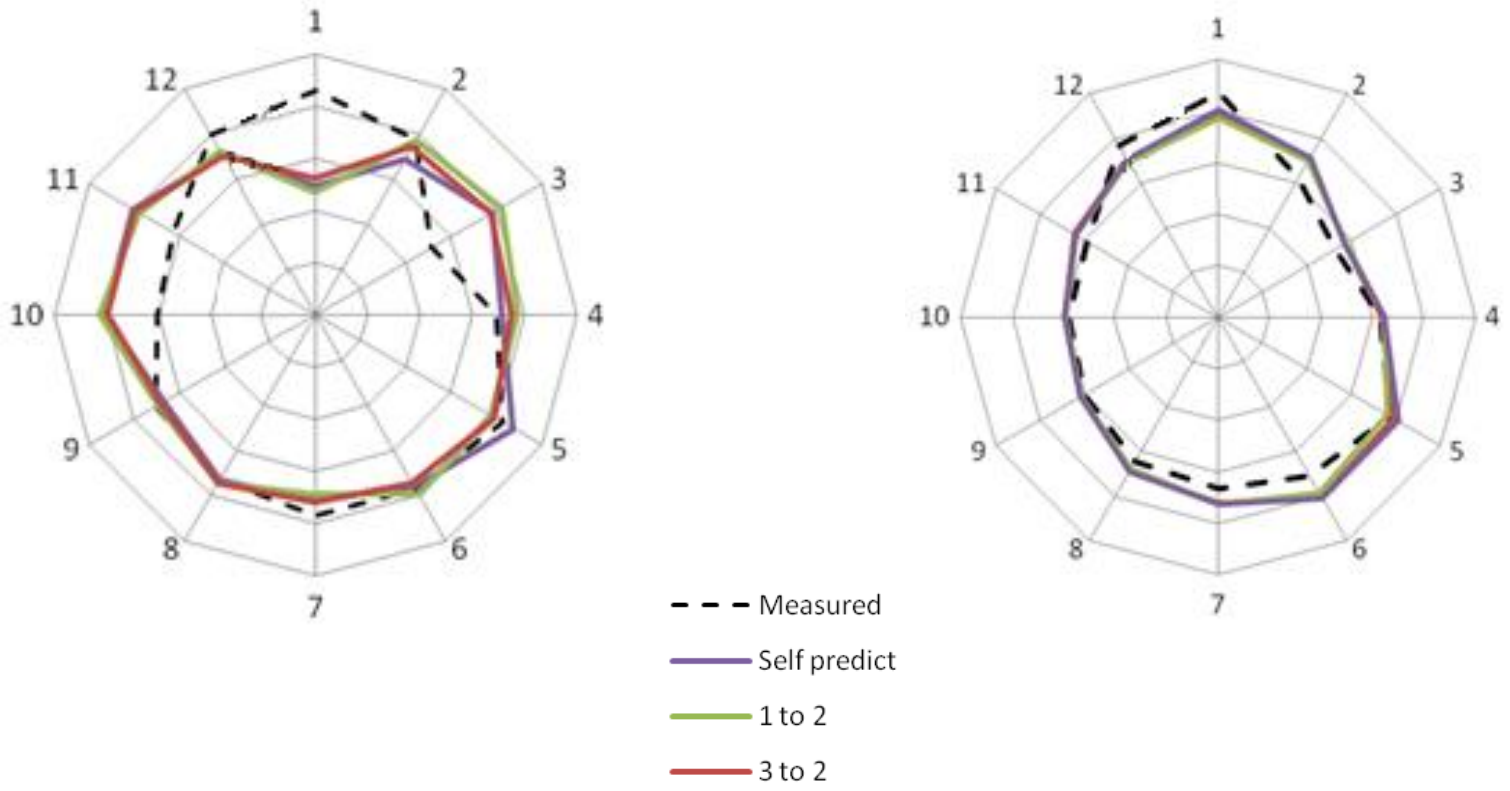


Visualising forest edge effects

- Site 2: Turbulence intensity comparison

WAsP Engineering	CFD

Site 2: Mast 2



Visualising forest edge effects

- Summary
  - WAsP can perform well in low complexity topography, but high complexity forestry
  - WAsP's capability deteriorates significantly in moderately complex terrain and complex forestry
  - CFD offers significant benefits in moderately complex terrain and complex forestry

BUT

  - *A single forestry modelling methodology is not optimal for all sites irrespective of WAsP or CFD modelling*

Visualising forest edge effects

- Summary

  Although there is an inherent uncertainty in modelling turbulence intensity due to the difference between modelled and measured turbulence….

  – Cross predictions using turbulence intensities from a number of masts (concurrent datasets) appears to be within the capabilities of CFD wind flow models.
  – WAsP Engineering has the capability to cross predict the TI rose from one location to another, but is less capable than CFD in predicting the correct mast TI rose shape.
  – CFD provides a greater accuracy in turbulence modelling.

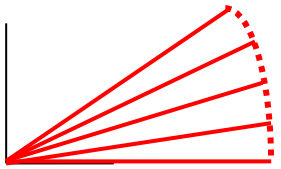
  – ***Measurements are essential***
  – ***Measurements need to be representative of the site (WTG) conditions***
  – ***Models need to be validated***

Visualising forest edge effects

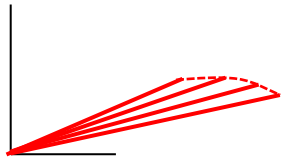
- Site measurement status - current
  - Mast measurements at site
  - Fairly representative of the site
  - Increasingly supplemented by remote sensing data
  - Gain point measurements around a wind farm site
- Site measurement status - ideal
  - Terrain specific wind flow
    - Topographic flow features
    - Forestry edge effects
    - Measuring across rotor heights
- POWFARM
  - Advanced measurements using 2nd Generation Galion Lidar

Visualising forest edge effects

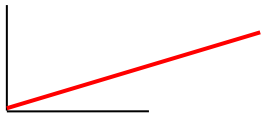
- Galion scanning options
  - RHI (Range Height Indicator) – vertical arc



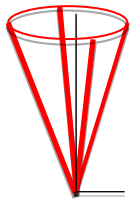
  - PPI (Position Plan Indicator) – horizontal arc



  - Stare – single line [high temporal resolution]

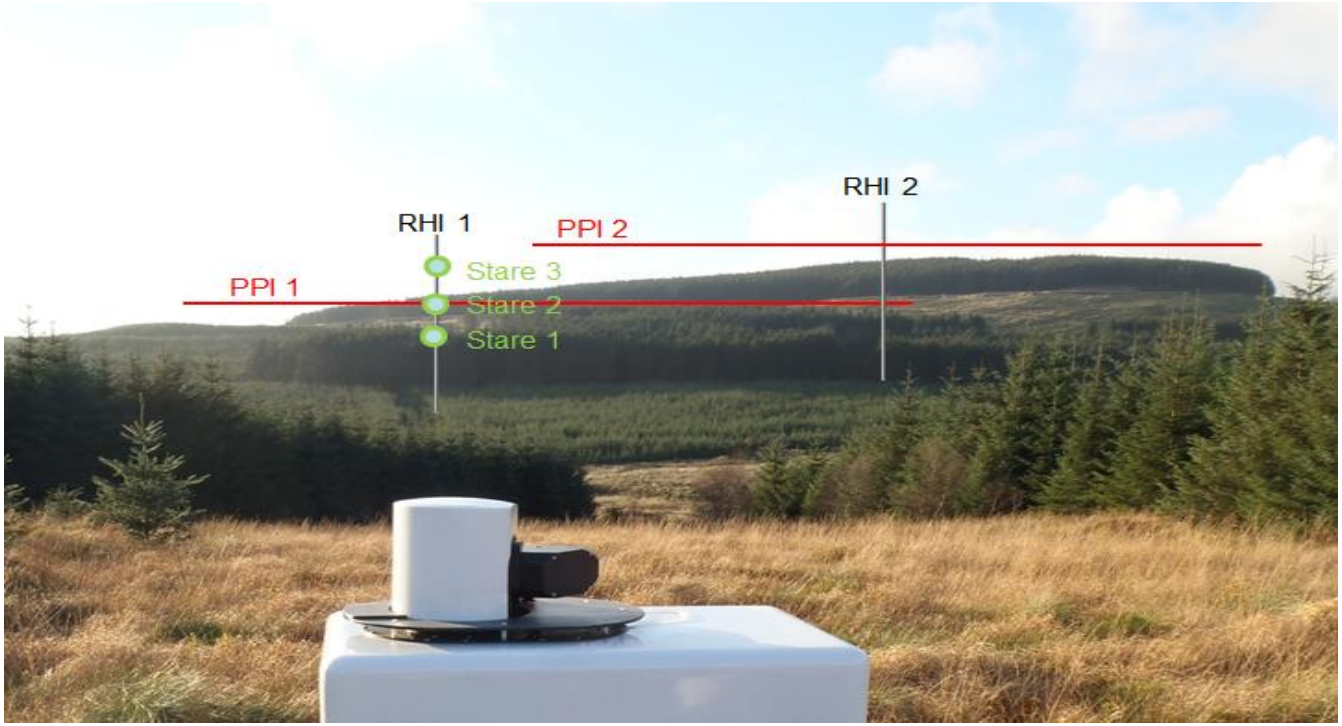


  - VAD (Velocity Azimuth Display)

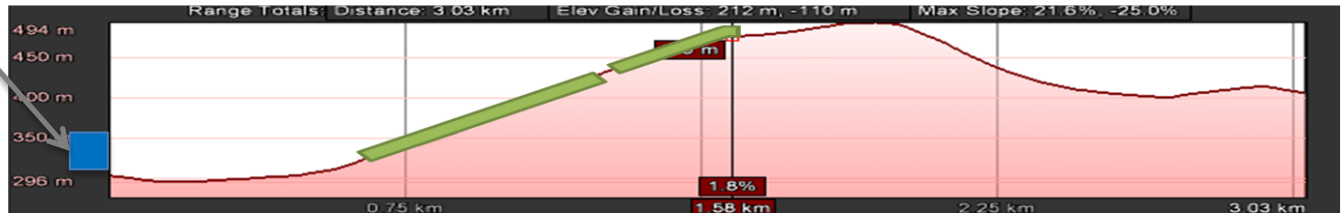


Visualising forest edge effects

- Site 1: Deployment and scan geometry

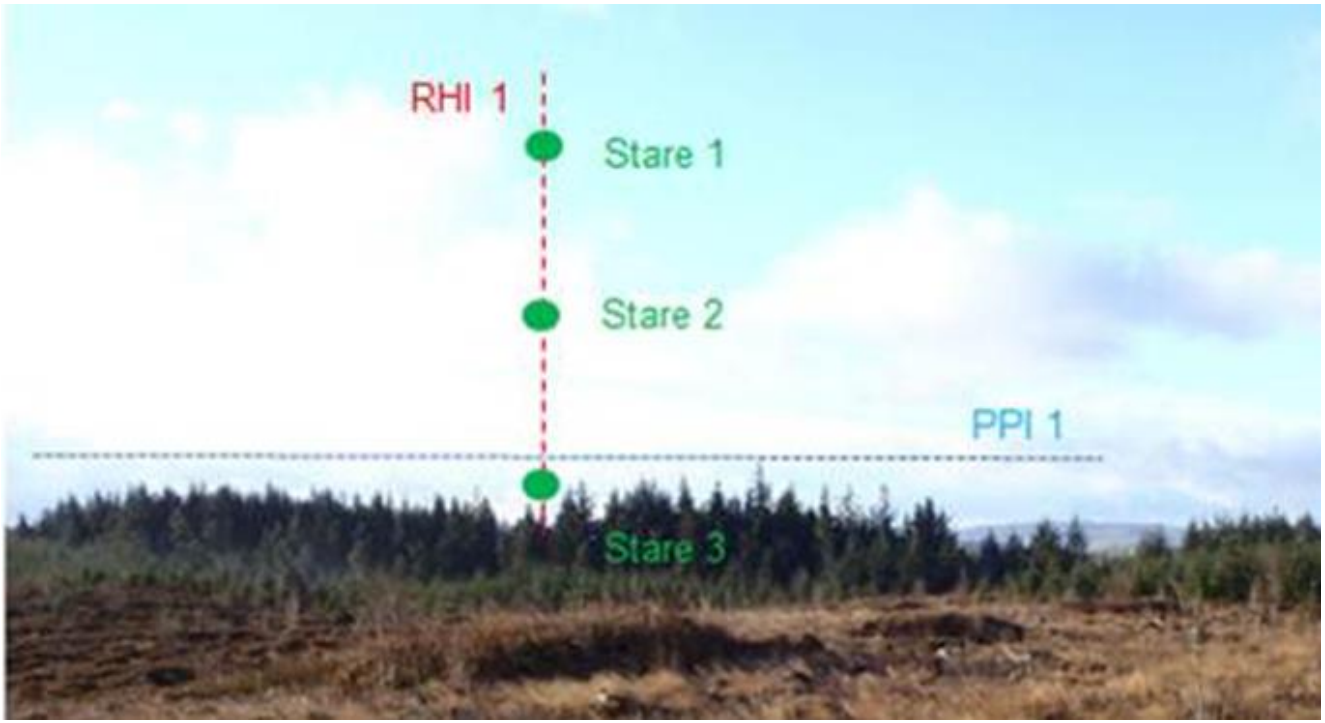


Galion



Visualising forest edge effects

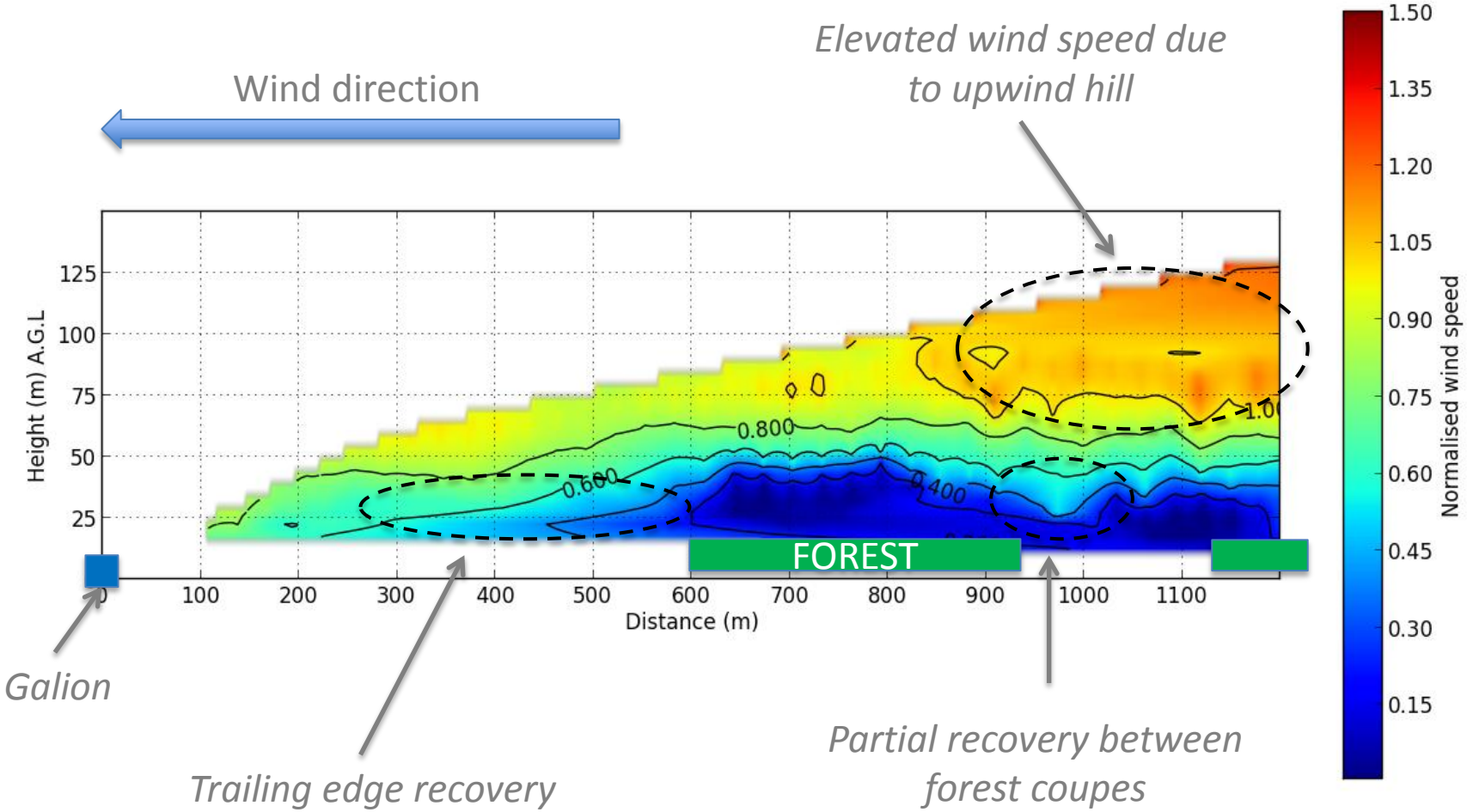
- Site 2.1: Deployment and scan geometry



Galion

Visualising forest edge effects

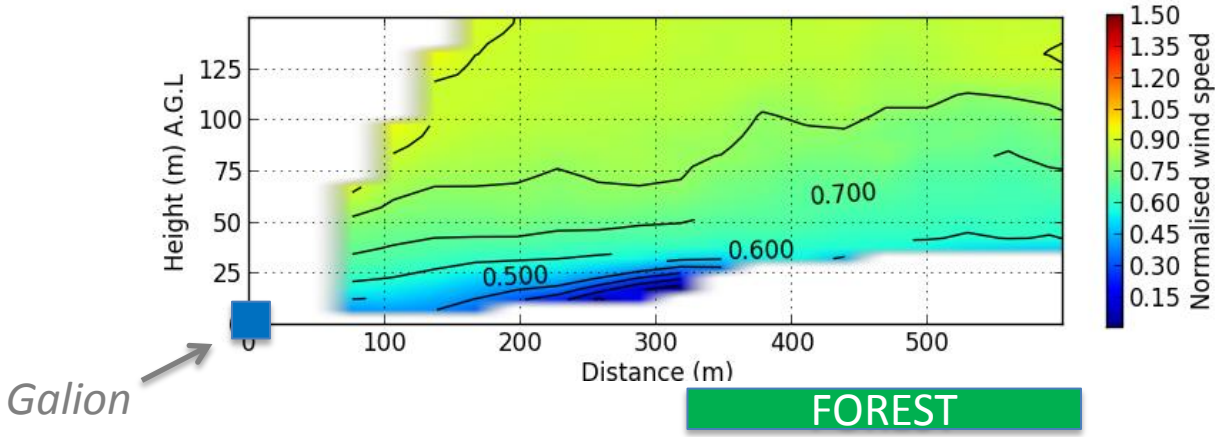
- Galion measurements: Site 1 (wind speed)



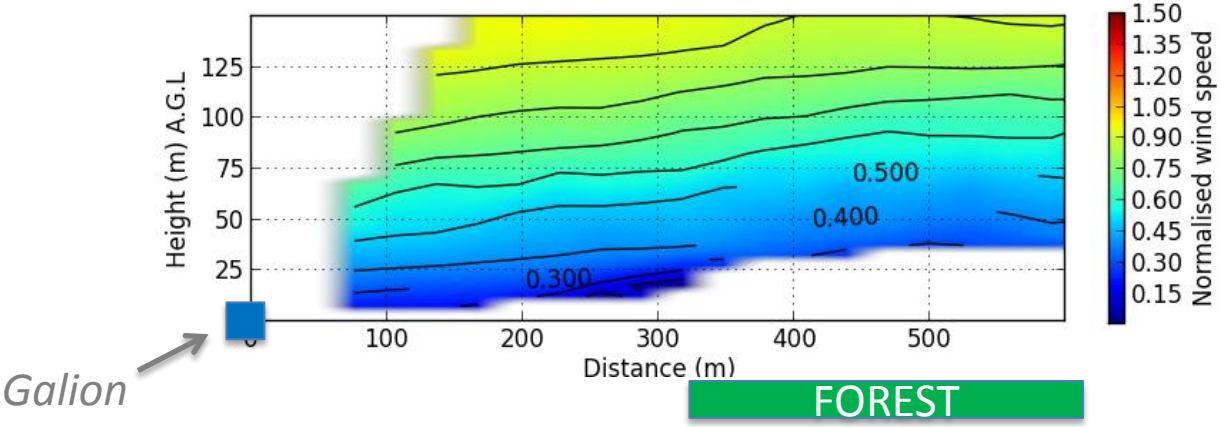
Visualising forest edge effects

- Galion measurements: Site 2 (wind speed) [diurnal variance]

Day-



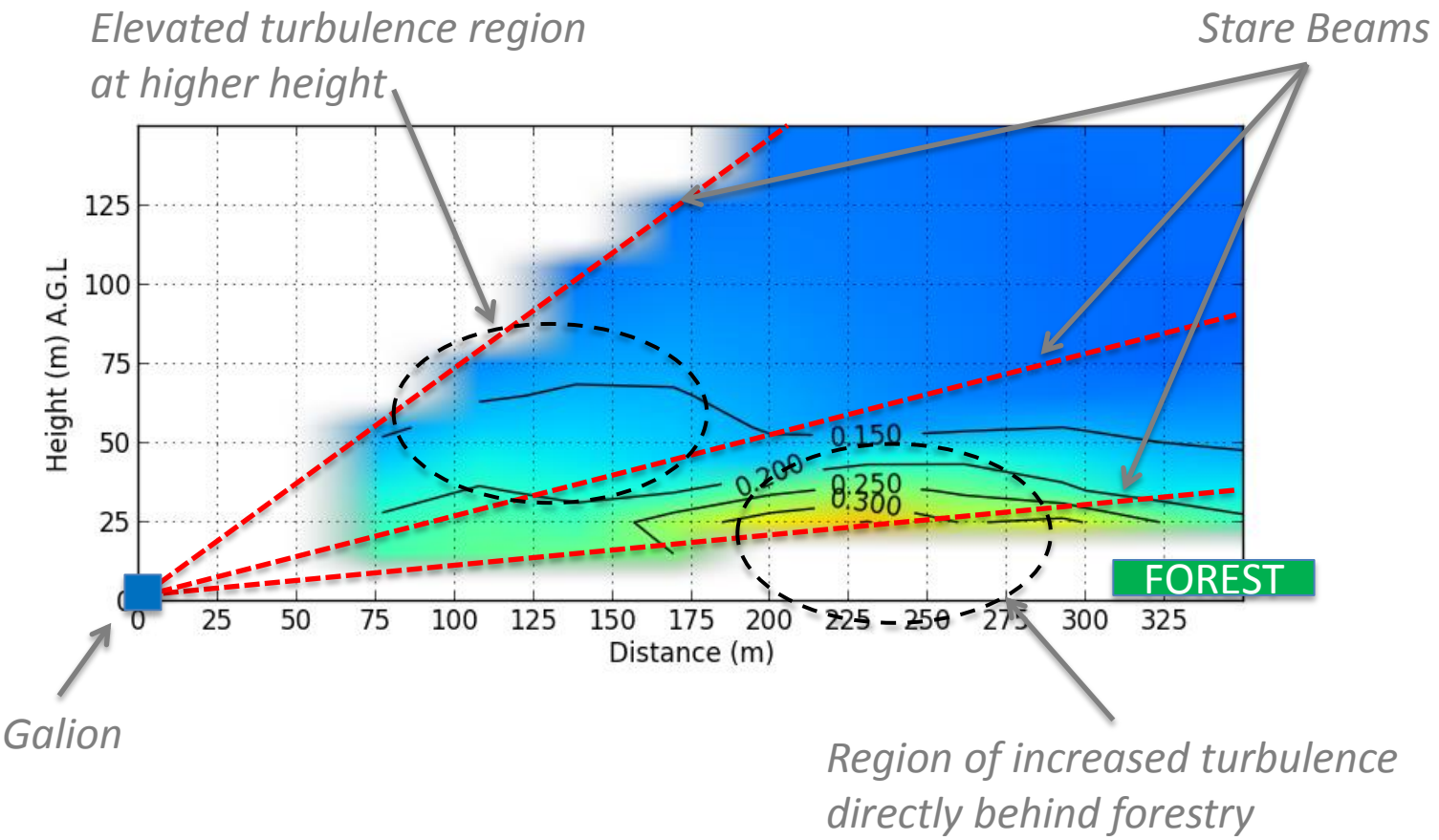
Night-



Wind direction

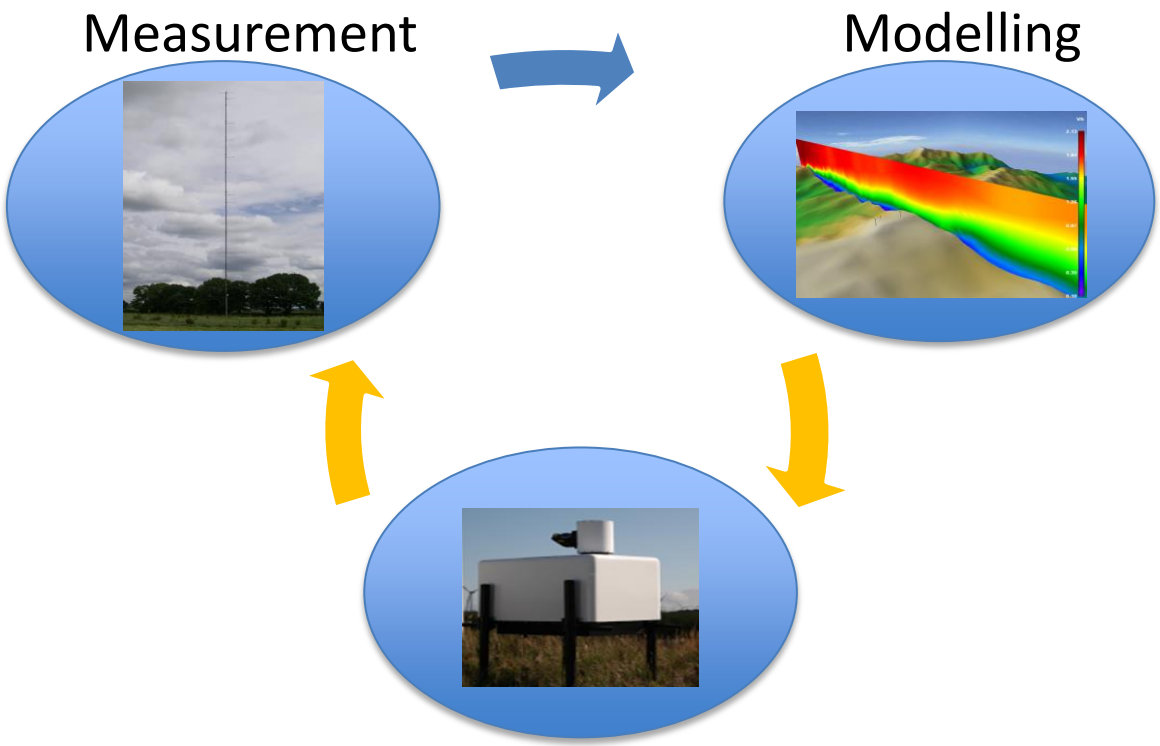
Visualising forest edge effects

- Galion measurements - site 2 (turbulence)



Visualising forest edge effects

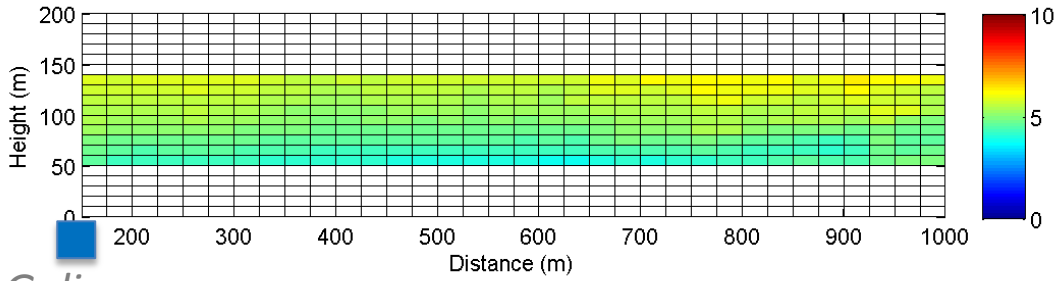
- Advanced Lidar deployments
  - Careful selection of deployment location
    - *Line of sight / Prevailing wind direction*
  - Scan geometry selection
    - *Accuracy / Use of hard target return (HTR) in scan set-up*



Visualising forest edge effects

Galion

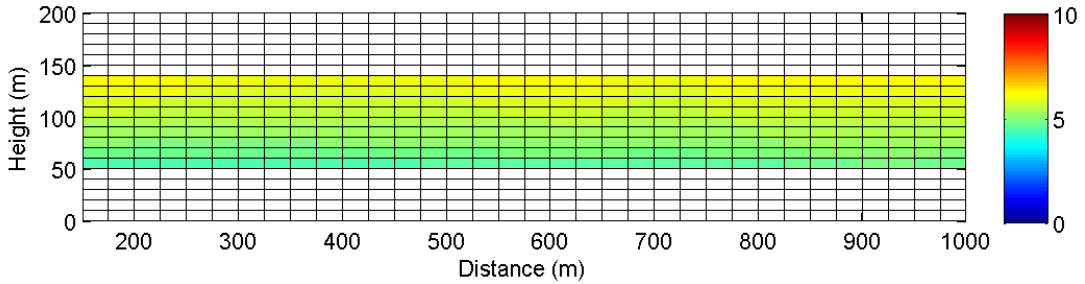
FOREST



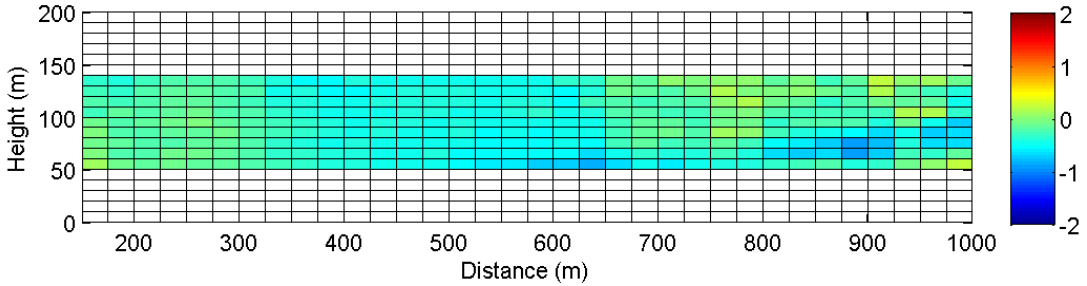
Galion

CFD (Meteodyn)

Wind direction



Showing Galion minus CFD



Further Galion / CFD comparison data presented by ANSYS in “Modelling of wind speed and turbulence intensity for a forested site in complex terrain”, C Montavon et al, presented a EWEA 2012.

Visualising forest edge effects

- **Conclusions**
  - Advanced modelling and measurement capabilities are available
  - Require detailed knowledge of the site and careful model set-up to gain most useful data
  - They are able to capture terrain specific flows related to WTG wind regime
    - Topographic effects
    - Forest edge effects

Models can only be as good as the measurements they are validated against

Visualising forest edge effects

- **Further work**
  - Building up database of slope and forestry measurements
  - Further validation of CFD wind flow models using the Galion measurements
  - Forestry management questions
    - Continuous canopy?
    - Keyholing – how large?
    - Clear-fell - how far?

Visualising forest edge effects

Models can only be as good as the measurements they are validated against

Any questions?

roy.spence@sgurrenergy.com

0141 227 1700

www.sgurrenergy.com

225 Bath Street, Glasgow, G2 4GZ