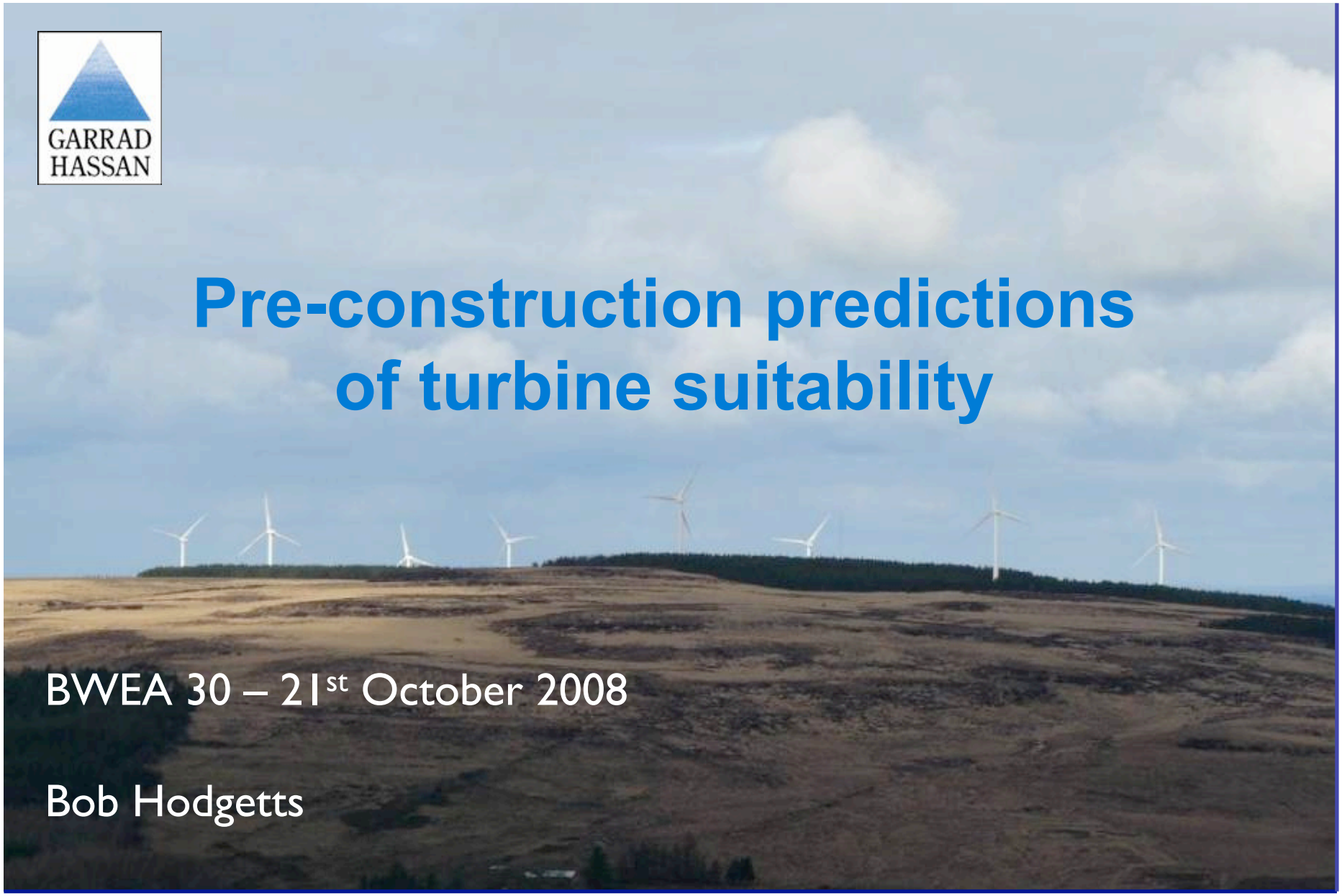


GARRAD HASSAN

Pre-construction predictions of turbine suitability

BWEA 30 – 21st October 2008

Bob Hodgetts

Wind Energy Experts worldw de

Why review turbine suitability?

Turbines classified to different site conditions

Developers point of view

- Need to optimise wind farm economics
- Minimise capital costs and maximise energy production
- Therefore squeeze in lower class machines

Manufacturers point of view

- Minimise contractual risks

Onus very much on developers to supply manufacturer accurate site conditions

Background - turbine certification

Majority of wind turbines are certified to IEC61400-1 1999

Key environmental attributes of different classes:

Turbine class	I	II	III	IV
Annual mean wind speed [m/s]	10	8.5	7.5	6
50 year maximum 3-second gust [m/s]	70	59.5	52.5	42
50 year maximum 10-minute mean [m/s]	50	42.5	37.5	30

Other key environmental attributes which effect all classes

- Turbulence intensity at 15 m/s - sub class A up to 18%
  - sub class B up to 16%
- Wind speed boundary layer profile - power law shear exponent up to 0.20
- Inclination of flow to horizontal - up to 8 degrees
- Temperature range
- Air density

Need to consider entire wind speed range

Energy production assessments

Key steps of an energy production assessment

- Site wind data quality reviewed
- Correlate to reference station **(MCP)**
- Long-term wind regime predicted at masts
- **Wind shear** extrapolation
- Site wind speed variations modelled
- Wake effects modelled (**turbulence intensity** required)
- Site **air density** predicted
- Loss factors reviewed
- Net energy production (P50)
- Uncertainty analysis (P75 & P90)

Most of this needs to be completed before a site conditions assessment

Site conditions assessment

A typical scope of work will include predictions of:

- Mean hub height wind speed
- Extreme wind speed
- Turbulence intensity, ambient and wake generated
- Wind shear
- Flow inclination
- Temperature
- Air density

These need additional work

Most of the site conditions already considered in the energy production assessment

Extreme wind speed predictions

The British Standard Building Code – BS6399

- Should always be considered
- Requires no site measurements
- Results need to be treated with caution at high elevations

Method of Independent Storms (MIS)

Requires 7+ years of time series data

Options 1) Measure 7 years of site data

2) Synthesise historical data from meteorological station via MCP

Annual Maxima Gumbel analysis

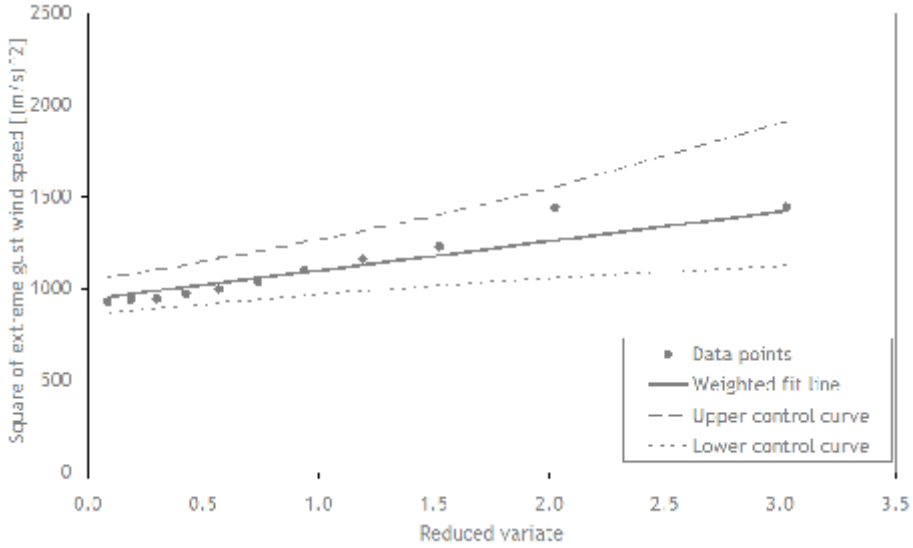
Requires 10+ years of annual maximums, most likely from a meteorological station.

Reasonable correlation to site measurements

Other statistical methods can also be used

Typical MIS prediction

- 2 years of on site wind measurements
- Correlate to reference station with 7+ years consistent data
- Predict long-term time series at site mast
- Run a MIS or similar model to predict extreme wind speed, usually a ten-minute of hourly value
- Analyse site gust ratio to factor ten-minute or hourly extreme to 3 second gust value



Differences in MCP review compared to energy assessments

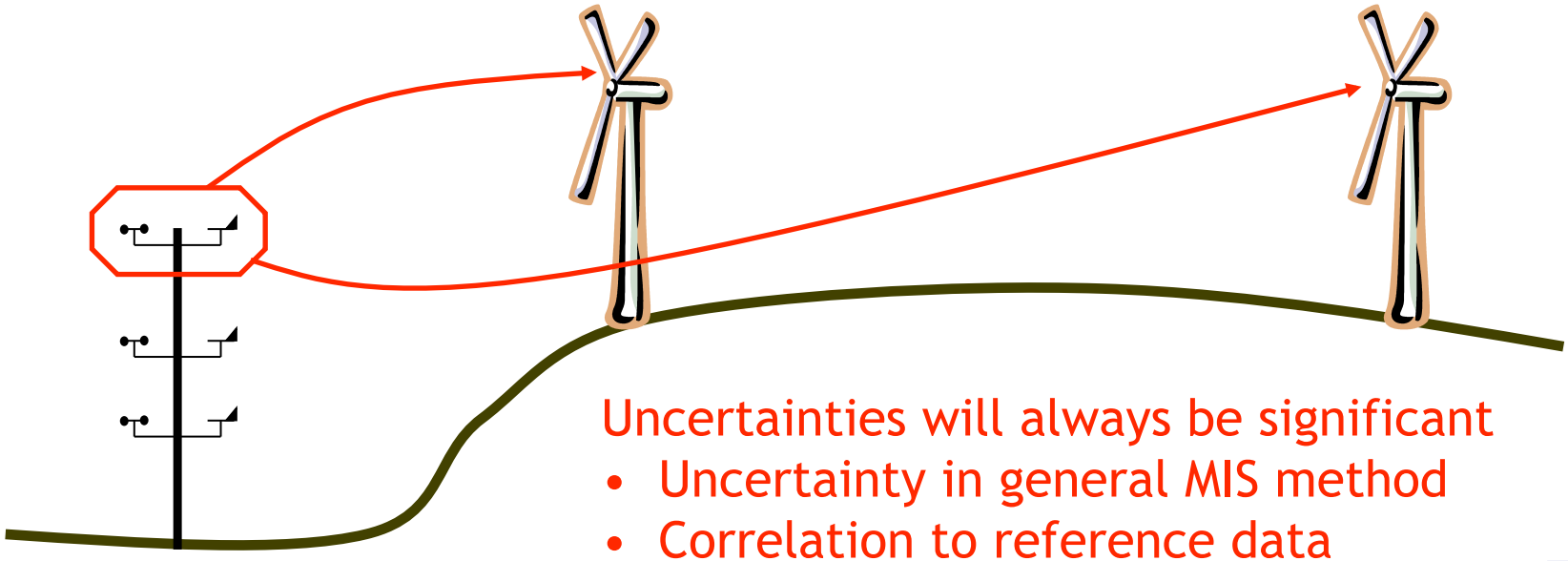
Pro: Does the quality of the correlation need to be as good?

Con: Need 7+ years of time series data which is expensive in UK

MIS predictions at turbines

- Extreme wind speeds predicted at masts
- Long-term time series synthesised at turbines from mast using directional speed-ups determined in wind flow model
- MIS model run for each turbine
- Gust ratios predicted to turbines

(based on assumption of constant standard deviation of wind speed)

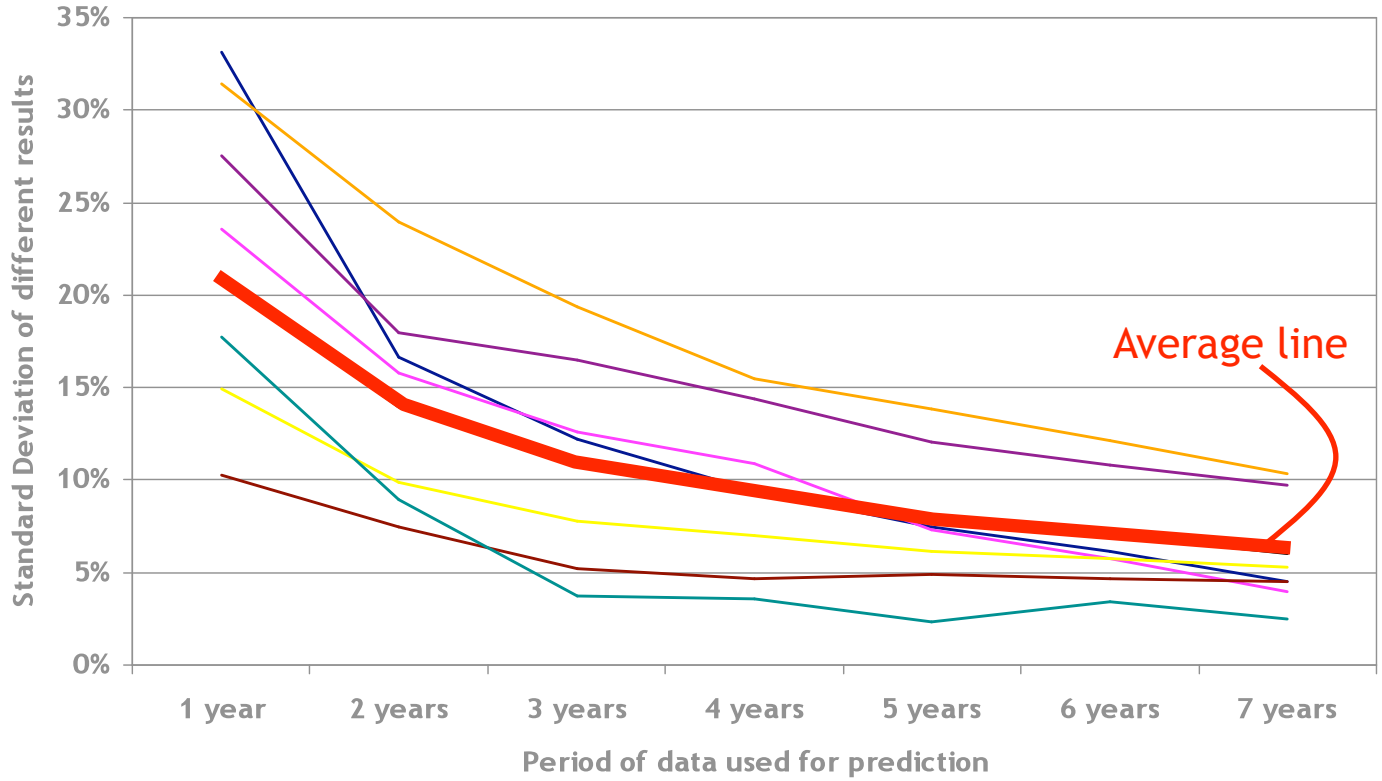


Uncertainties will always be significant

- Uncertainty in general MIS method
- Correlation to reference data
- Wind flow model

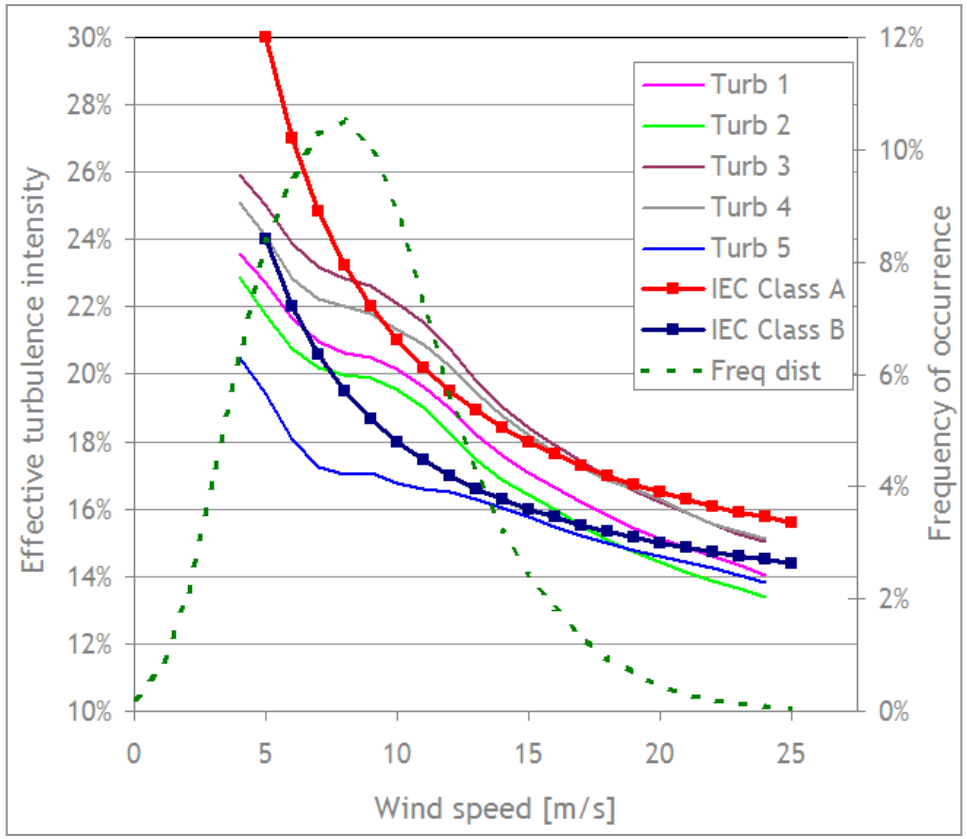
Indication of uncertainty in MIS

- Seven long-term reference stations considered
- Periods of consistent data from 11 to 20 years
- Each station time series cut-up into lots of shorter periods and run through MIS prediction
- Results are standard deviations of all results obtained about the mean result for each station



Turbulence intensity at turbines

Sten Frandsen model of design equivalent turbulence (implemented in GH WindFarmer)



Inputs

- Ambient mean and standard deviation of turbulence at wind flow model initiation masts
- Mean wind speed predicted at each turbine (from wind flow model)
- Turbine characteristics

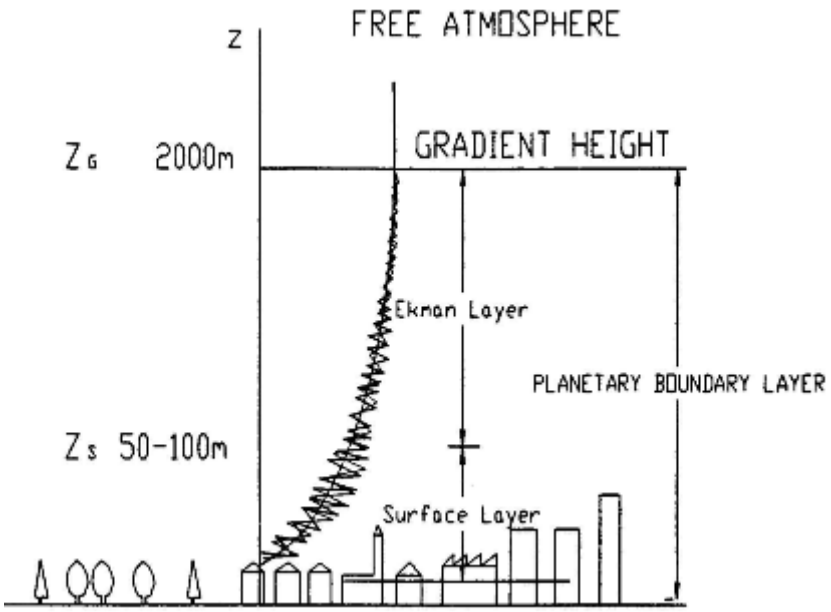
Output

- Predicted design equivalent turbulence intensity at each turbine
- Predictions include wake effects
- Puts emphasis on components most susceptible to fatigue loads
- Comparable to IEC classification

Wind shear at turbines

- Need to rely on wind flow model as no measurements at all turbines
- Review quality of the wind measurements
- Validate model against measurements
- Predict likely wind shear across turbine rotor

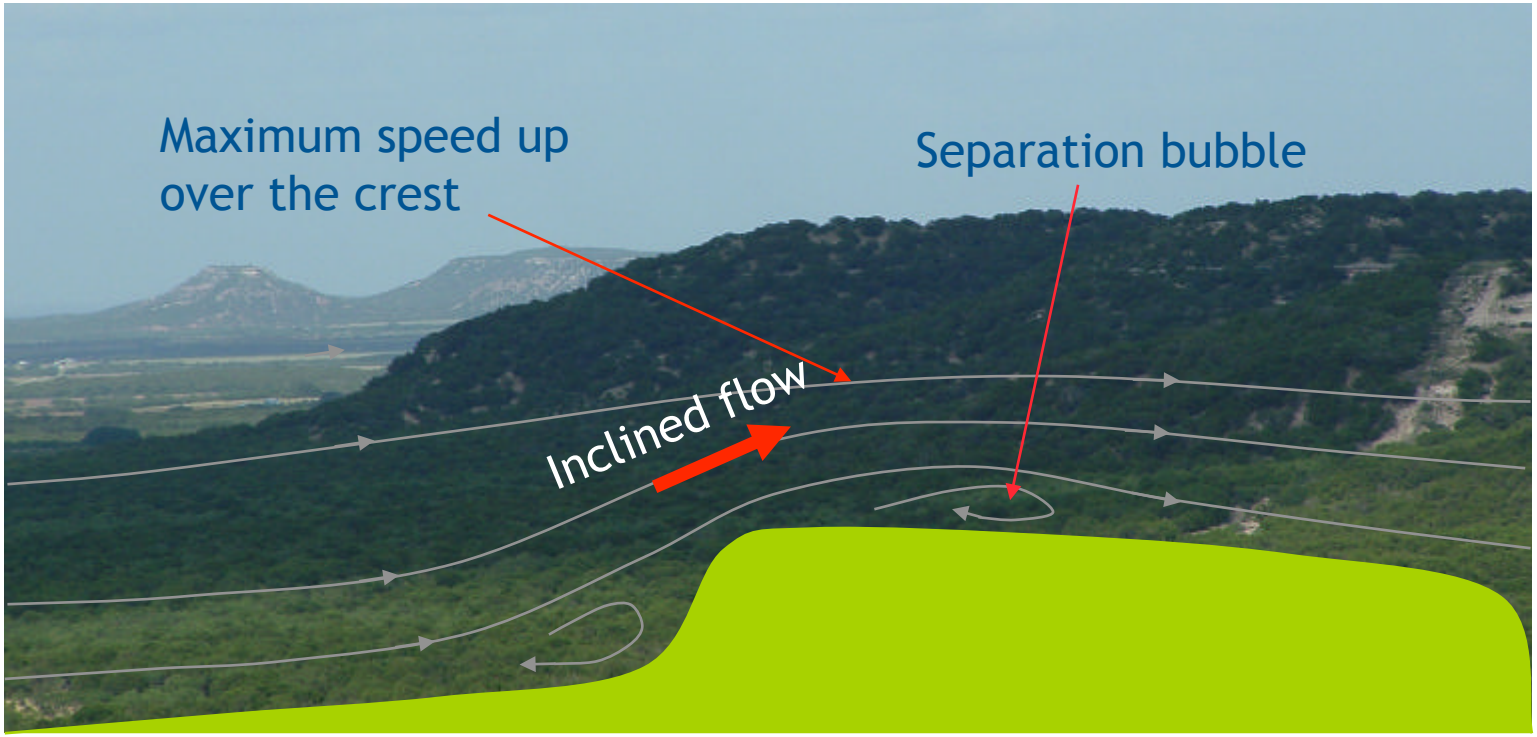
Don't forget uncertainty in the original wind flow predictions!!



SODAR/LIDAR can reduce uncertainties here

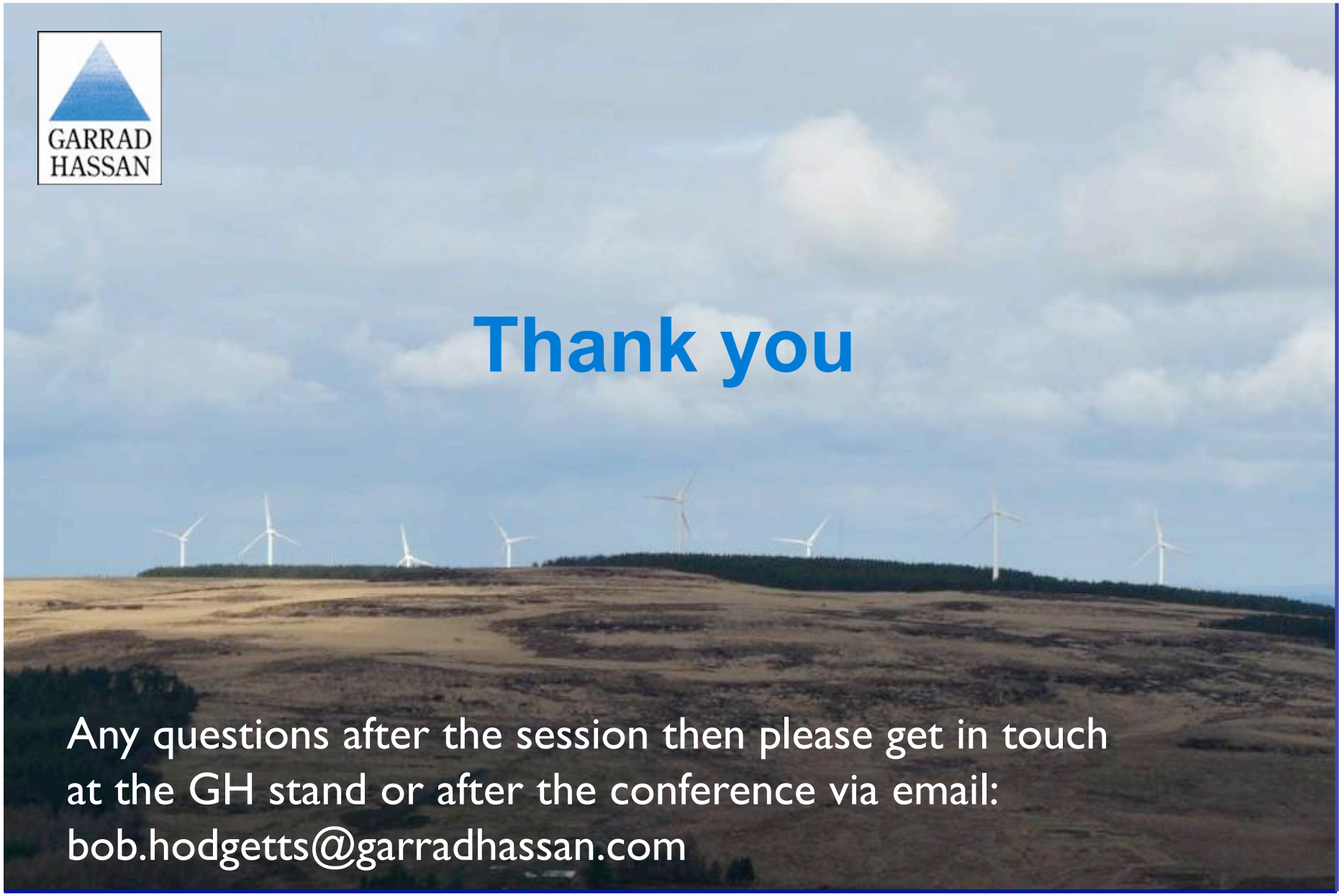
Flow inclination

- Make measurements in representative locations
- In absence of measurements then predict based on slopes



Practical steps to aid development

1. Avoid tight turbine spacing (especially in forestry)
2. Use higher turbine hub heights in forestry
3. Maximise long-term period of site wind measurements
4. Don’t economise on wind monitoring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Thank you
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