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| CFARS Complex Flow Subgroup  |
| Meeting Minutes + Follow Up |
| 19 October 2021 |



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# Meeting Minutes

Attendees: Mark Stoelinga (ArcVera), Iain Campbell (RES), Graeme Watson (Natural Power), Christiane Montavon (DNV), Josiah Mault (DNV), Andrew Lammers (Pattern), Mithu Debnath (NREL), Johannes Cordes (DWG), Rory Curtis (RES), Taurin Spalding (Natural Power),

**Introduction**

Andrew Black:

* Topics for today:
	+ Standardisation of terrain classification
	+ Additional measurement uncertainty associated with complex flow compensation schemes; and
	+ Creating a standard / recommend practice that the industry can refer to for use of remote sensing in complex terrain.
* Renewed motivation. We will not be a discussion group!

**Discussion (speakers noted where recorded)**

Graeme Watson:

* Goal is finance grade yield assessments.
* Very short masts vs. hub height lidar
* Which sites are masts suitable? Which are not suitable?
* Cases with no choice: live with elevated uncertainty
* Need to assess all uncertainties
* Round Robin exercise. Multiple models on same sites, compare results
* Find extreme locations
* Natural Power advise to use lidars. Where is the red line?
* NP did their own side by side evaluation
* General uncertainty yields a conversion factor
* Problem: how to validate without giving away to much data?
* Full EYA comparison between mast data and corrected lidar data.
* None / Moderate / High

Josiah Mault

* Framework for measurement uncertainty
* Consensus on CF measurement uncertainty
* Standard: what is in it?

Johannes Cordes

* Measnet: 0.5 x correction
* Also language present in TR6
* This is consensus starting point

Mark Stoelinga

* Perturbation of site location to estimate uncertainty
* Use the models to guess uncertainty

Iain Campbell

* Linear flow models ahead of time
* Never site without using a model
* Try to model shear, inflow, turbulence
* Minimize variation of environmental parameters
* Tradeoff between uncertainties in model and representativeness of site location
* Horizontal, vertical, curvature

General Discussion

* Poorly sited turbines are the ultimate downside of poorly designed complex terrain measurement campaigns
* Measurements with high uncertainty could be better than models: these locations are the most difficult to model
* Use lidars as hotspot detectors. How bad are the flows in this location?
* Key insight: the lidar measurements are real, even if slightly biased, or raw LOS

Christiane Mondavon

* Studying complex flows the last year, 45 sites with variety of sensors
* Sometimes not so clear cut with cups, models, lidars
* “Ignore Cup 1, everything is perfect!”
* In general, take with grain of salt, we don’t have enough data to make definitive statements.
* Grain of salt = expectations of elevated uncertainty
* Very complex VS. moderately complex VS stability effects VS etc etc etc
* Large database necessary, ~100 pairs
* Each bin needs a statistically significant quantity: 5 similar sites in each bin
* Collect all uncertainties, classifications from flow from uncertainties
* Align categories
* Is anyone correcting anemometers?

Taurin Spalding

* No traction with cup manufacturers: no recommended practice
* Some conflicting IEC 61400-12 reports for specific cups in cases where there are >1
* How inclined is the flow? Are lab tilt tests reflective of real-world conditions?
* Use colocation pairs, check sector-wise ratios
* Use direct measurements of vertical windspeed from lidar or USA

General Discussion

* Need for database
* Results only, sector-specific KPIs, definition of site
* Met Mast, Anemometer type, Remote sensing device, CFD Model for correction
* “We have to do it” “We’re happy to do it”
* Standardizing output
* Report TI, report shear, wind speed, etc
* Align with bottom line of projects to demonstrate need (US projects)

Rory Curtis

* Monetize results, tie to overall project uncertainty
* Perform full EYA for Mast Only vs. Corrected Lidar Only

# Framework for White Paper

* Uncertainty
	+ Consensus on promoting use of TR6 / Measnet 0.5 x correction as starting point
	+ CFARS follow-up: use the database to empirically derive uncertainty
	+ Need more engagement with CFD companies on their validations
* Campaign design
	+ Use of model-based siting before campaign
	+ Trade-off on representativeness and complexity
	+ Linear models, full CFD, etc
	+ Include device to measure vertical wind speeds if mast present
	+ Include USA to analyze turbulent overspeeding if mast present
* Analysis
	+ Use IEC Classification of anemometers, including off-axis responses
	+ If there are conflicting IEC anem reports, report it
* Clearly separate Lidar-only and Lidar + Met Mast campaign recommendations
* Database (Include proposal only in this report, no results yet)
	+ Pre-siting analysis results
	+ Results only, sector-specific KPIs, definition of site
	+ Met Mast, Anemometer type, Remote sensing device, CFD Model for correction
	+ Report TI, report shear, wind speed, etc
	+ Full EYA? This could be much more effort
* Statement on elevated uncertainty in most complex sites today
	+ Set expectations for higher uncertainty in complicated cases
	+ We know this is the state of the art: let’s state it clearly

# Database Proposal

## Requirements

* ~100 datasets
* Five similar sites in each bin
* Met Mast, Anemometer type, Remote sensing device, CFD Model for correction

## Bin definitions (AHB SWAG proposal)

* (3) Topography, no forestry (low, medium, high bins of complexity), no water
* (1) Uniform forestry, no topography
* (1) Non-uniform forestry, no topography
* (3) Uniform forestry at (low, medium high) complex sites
* (3) Non-uniform forestry at (low, medium high) complex sites
* (1) Body of water\* (\* = assume non-uniform), no topography, no forestry
* (3) Body of water\*, topography (low, medium, high), no forestry
* (3) Body of water\*, topography (low, medium, high), forestry\*
* 18 proposed categories, 5 per bin, 18 x 5 = 90 sites, pretty good correlation with Christiane’s proposed 100 sites

## KPIs

## Reporting / data sharing structure

## Lifetime of database

## Use Cases for database / research roadmap

# To Do / Follow Up

* Andrew Black: Create shared docs
* Taurin Spalding: list of IEC Classifications of Anemometers
	+ Andrew Black share research + resources
	+ Should there exist a CFARS CFC Shared Resource on this topic?
* Christiane Mondavon: create database requirements
	+ What is required for each bin?
	+ In what format could contributors share validation sites?
	+ What is the best way to share this KPI specification?
	+ Should CFARS build a tool or only a spec?
	+ Is there an IEA Task 43 way to share correlation datasets like we are proposing?
* Iain Campbell: Write + collect descriptions of linear models for used for pre-siting
	+ Get description from Graeme Watson on Natural Power pre-siting tools
	+ Get description from Andrew Black on Vaisala pre-siting tools
	+ Anyone else with pre-siting methodology?
	+ Get description from Mark Stoelinga on “perturbation as a proxy” for pre-siting uncertainty
* Johannes Cordes: Write description of TR6 / Measnet used at DWG as baseline uncertainty
	+ Also: describe CFARS ambition to reduce or fine-tune this uncertainty estimate
	+ We will use the database, and ideas from our collaborations to develop more precise estimates
* Rory Curtis + Josiah Mault: how to better “monetize” this research?
	+ Description of costs associated with elevated uncertainties in complex terrain compared to costs of measurement campaign design: No measurements, Short mast(s) only, Tall mast(s) only, Short mast(s) and Tall mast(s), Short mast(s) and RSD, Tall mast(s) and RSD, RSD only
	+ End-to-end EYA validation
	+ Is this necessary? Consensus seems: “Yes and let’s do it”
	+ Should we aspire to collect post-construction data?
		- Database lives for >5 years, adds post-construction data