WIND IS WIND POWER
KNOWLEDGE

Recent developments

WindSim 14th User Meeting, Tønsberg 5-6 June 2019

PRESENTED BY: Dr. Catherine Meissner, Matteo Mana, Tejo de Groot

windsim

Content

- Most important features in WindSim 9.0
- New features in WindSim 10.0
- Ongoing R&D projects
- Cloud Computing

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- Most important features in WindSim 9.0
- New features in WindSim 10.0
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New features WindSim 9.0

- Rotor equivalent wind speed
- Export to the new CFD input format of WindPRO - FLOWRES
- Export to Google Earth

- Faster energy module calculation
- Reduced files in binary format

- TI map for 15m/s bin in wind resource module
- Site compliance file
- Excel tools for FMV, C2 value determination, IEC plots
- Spot value plots with logarithmic scale
- Select spot value height
- Easy access to folders

- WindSim Express improvements

- Integration towards Windplanner

Export to the new CFD input format of WindPRO

• WindPRO has defined a FLOWRES format which will make it possible to give directly the wind speed and turbulence results from WindSim into WindPRO

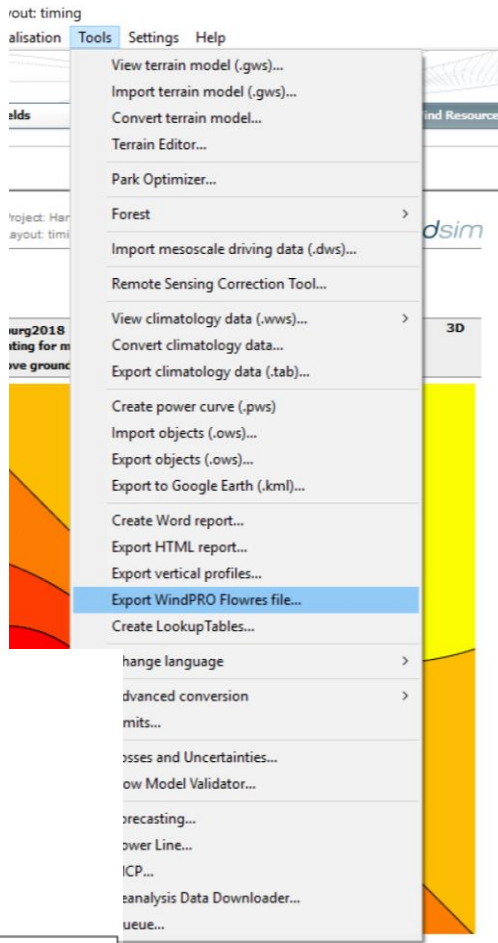
• That format is based on xml files

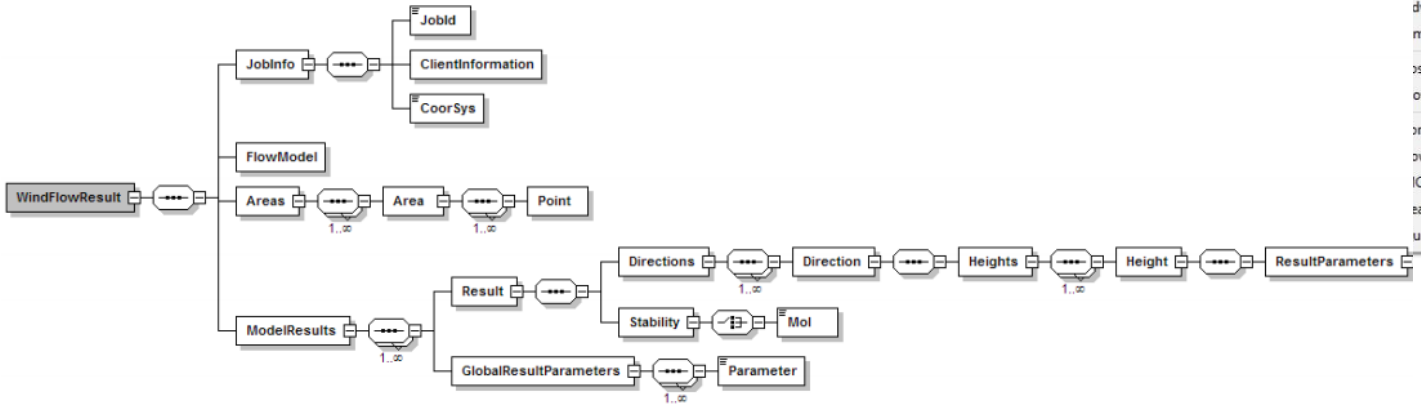
• Per today only export of identical atmospheric conditions for all sectors is possible. Once WindPRO has opened up for variable non-neutral simulations we will adapt to that

Export to the new CFD input format of WindPRO

How it works today In WindSim:

1) You run your windfield simulation
2) You go to Tools/Export WindPRO Flowres file
3) You get the file in the windfield folder named: flow_EMD.flowres
4) You import that file to WindPRO





Export to the new CFD input format of WindPRO

<u>Vision</u> workflow windPRO-WindSim:

I. In windPRO:

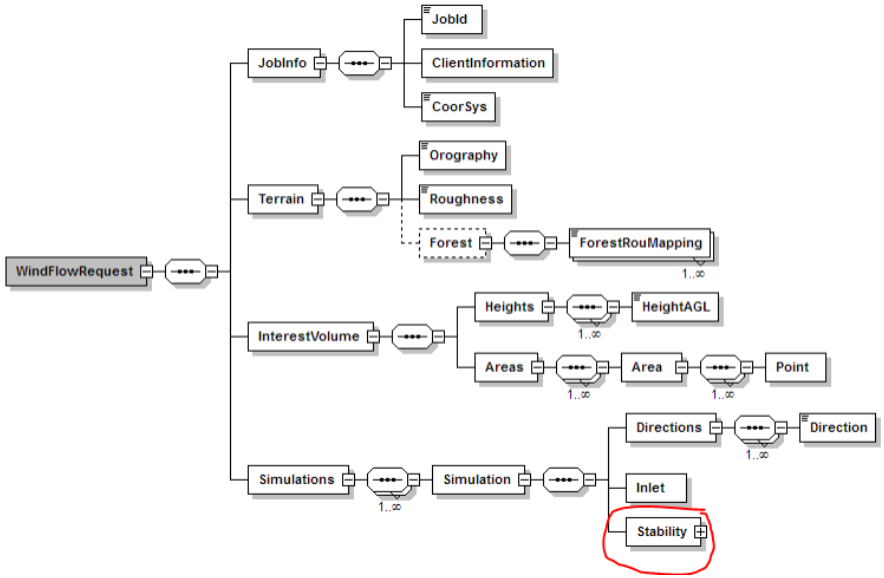
Estimate 1/L statistics in METEO
Decide stability classes for each sector
Export "Flowreq"

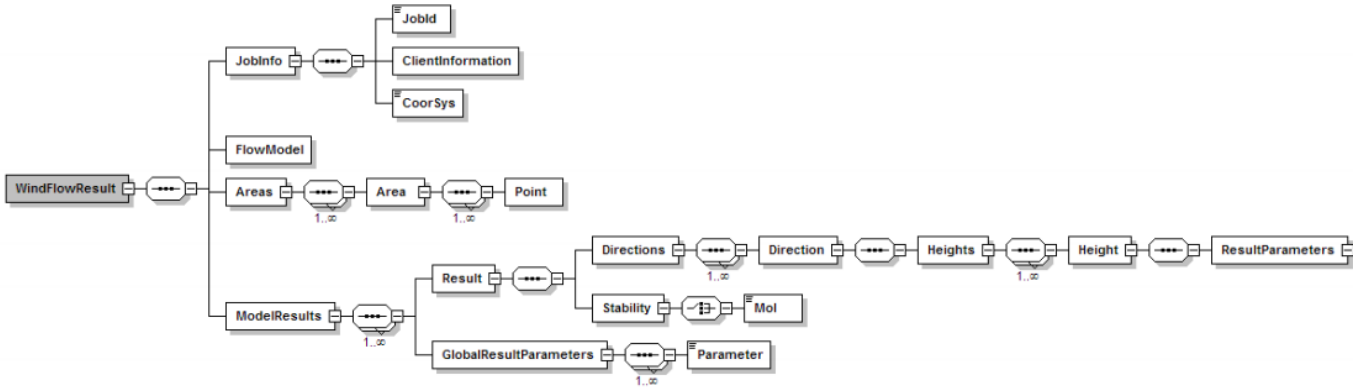
II. In WindSim:

Load Flowreq and run simulations, Ls/
Visualize, check convergence etc.
Export "Flowres"

III. In windPRO:

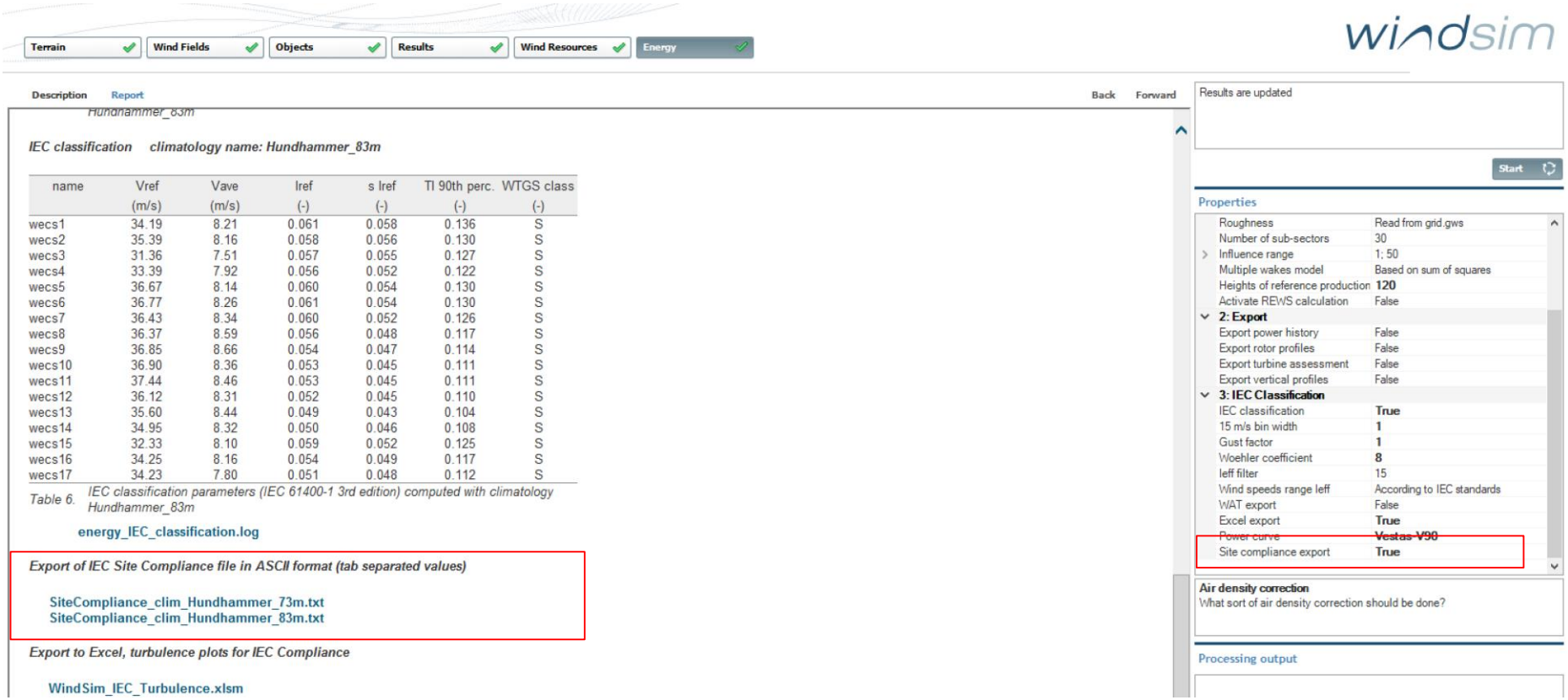
Load Flowres
Do whatever you are used to





Site compliance file

All information necessary for a site compliance study in one file



Site compliance file

All information necessary for a site compliance study in one file

Project name Hamburg2018
Date 2018-09-25

Label wecs1
Coord system Not known Not known Z XX
Easting 325869.00
Northing 7185782.00
Z / Height a.s.l. [m] 171.74
Hub height a.g.l. [m] 80.00
Extreme wind speed (Vref) [m/s] 34.71
Air density [kg/m^3] 1.150
Rotor diameter 90.0

Description	S0	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	All			
Sector direction [deg]	0	30	60	90	120	150	180	210	240	270	300	330	All			
Flow inclination [deg]	-4.227	-4.520	-3.321	-0.844	2.161	4.747	6.051	6.313	4.828	2.696	0.412	-2.504	N/A			
Weibull scale [m/s]	6.551	4.584	3.265	8.455	10.559	8.820	7.659	9.021	11.126	9.994	7.793	8.502	8.920			
Weibull shape [-]	1.907	2.145	1.495	1.856	1.962	1.782	1.943	1.635	2.051	1.624	1.319	1.631	1.620			
Mean wind speed [m/s]	10.750	9.603	8.874	9.001	9.781	10.693	10.680	9.833	9.275	8.999	9.458	10.230	8.170			
Frequency [%]	4.709	3.010	1.860	6.698	17.821	15.646	10.796	6.068	9.611	9.699	7.618	6.462	99.999			
Wind shear [-]	0.001	0.058	0.104	0.076	0.019	-0.024	-0.016	0.022	0.062	0.072	0.047	-0.005	0.017			
Sector direction [deg]	0	30	60	90	120	150	180	210	240	270	300	330				
Terrain complexity 20*HH Complex [YES / NO]	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	NO	NO			
Terrain complexity 10*HH Complex [YES / NO]	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	NO	NO	NO			
Terrain complexity 5*HH Complex [YES / NO]	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES			

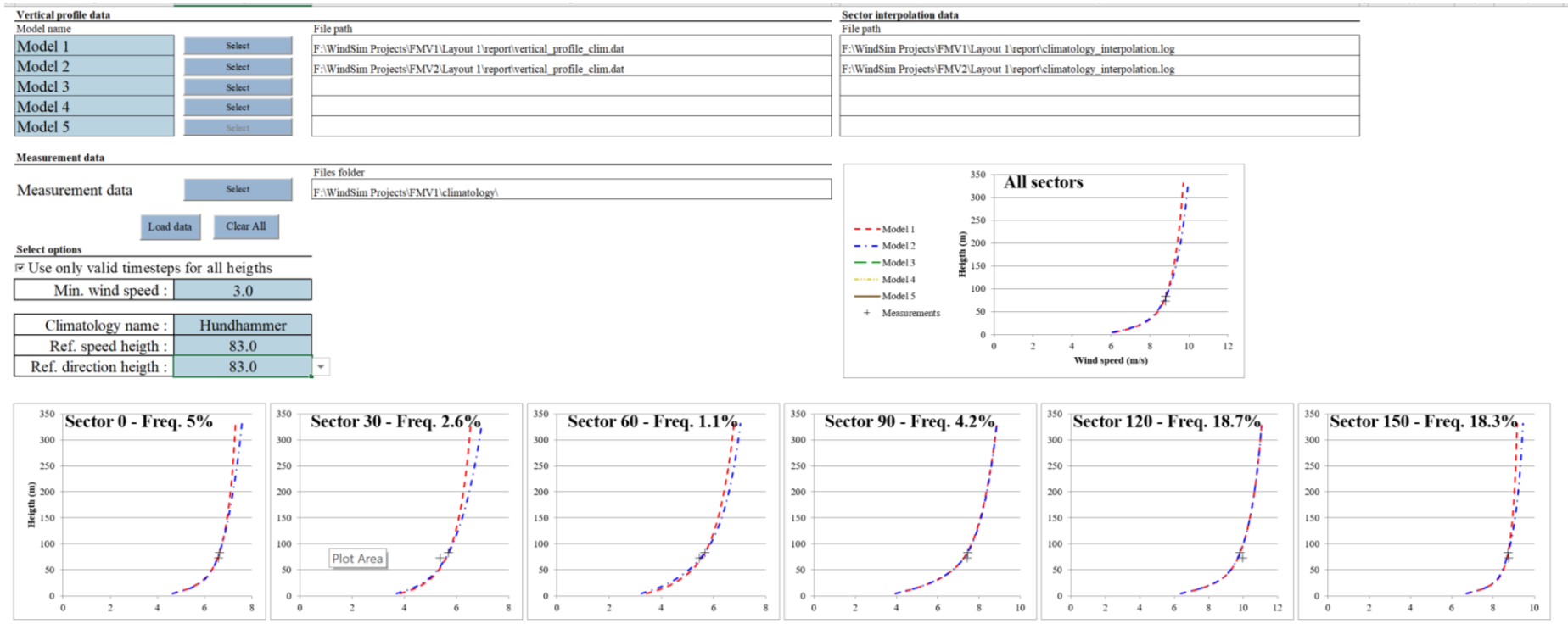
Effective TI m = 3.5

Description	S0	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11				
Wind speed [m/s] \ Sector direction [deg]					0	30	60	90	120	150	180	210	240	270	300	330
3	0.672	0.366	0.296	0.336	0.443	0.480	0.518	0.582	0.869	1.140	1.076	0.990				
4	0.587	0.263	0.209	0.274	0.319	0.355	0.405	0.429	0.582	0.792	0.901	0.771				
5	0.459	0.254	0.172	0.224	0.265	0.283	0.337	0.365	0.528	0.687	0.688	0.651				
6	0.429	0.250	0.161	0.191	0.215	0.242	0.258	0.299	0.423	0.577	0.563	0.560				
7	0.364	0.247	0.135	0.165	0.189	0.208	0.233	0.261	0.365	0.484	0.466	0.452				
8	0.326	0.251	0.127	0.146	0.159	0.195	0.202	0.243	0.306	0.406	0.412	0.402				
9	0.287	0.241	0.127	0.127	0.141	0.185	0.187	0.204	0.274	0.393	0.376	0.340				
10	0.303	0.232	0.112	0.111	0.131	0.170	0.180	0.177	0.256	0.337	0.347	0.332				
11	0.238	0.205	0.091	0.110	0.122	0.145	0.168	0.172	0.228	0.310	0.330	0.305				
12	0.225	0.185	0.077	0.102	0.116	0.130	0.153	0.161	0.218	0.311	0.316	0.259				
13	0.261	0.169	0.063	0.123	0.122	0.127	0.150	0.156	0.194	0.274	0.299	0.284				
14	0.024	0.149	0.056	0.135	0.126	0.116	0.133	0.119	0.197	0.247	0.237	0.245				

Excel Tools

Flow Model Validator

Stand-alone tool to compare vertical profiles of wind speed and TI of several CFD simulations with measurements (Tools/Flow Model Validator)



Excel Tools

Automatic C2 value determination

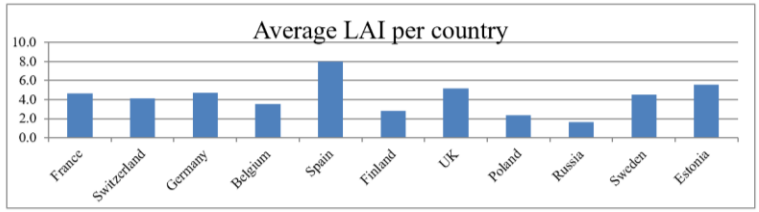
Global data base to find Leaf Area Index in your region and calculation of a suitable C2 value depending on forest height and forest type (Tools/Forest)

windsim
Leaf Area Index (LAI) Finder

Species : Pinus sylvestris — Filter by species
Country : France — Filter by country
Close to : Your location
Latitude (°) 49.0000
Longitude (°) 5.0000
Radio (km) 300 — Filter by location

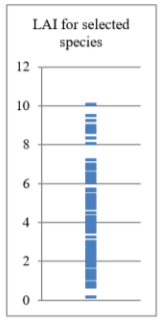
Source : Iio, A., and A. Ito. 2014. A Global Database of Field-observed Leaf Area Index in Woody Plant Species, 1932-2011. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1231

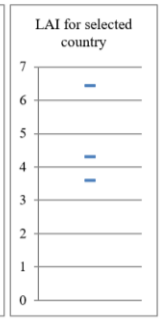
Link : https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=1231

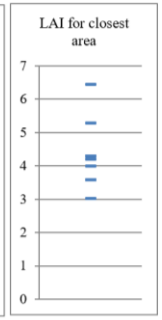


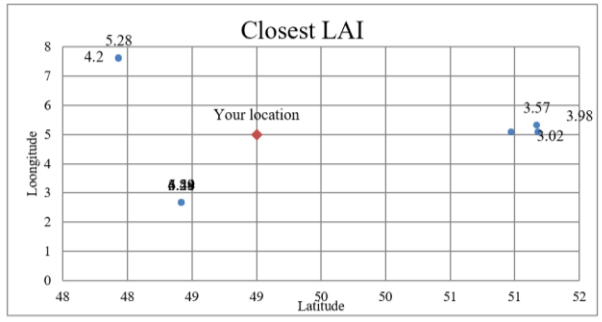
Summary

LAI	Average	Max	Min	Std.	Samples
Worldwide	4.21	10.08	0.15	2.41	90
France	4.65	6.44	3.58	1.07	4
Closest	4.29	6.44	3.02	0.96	9







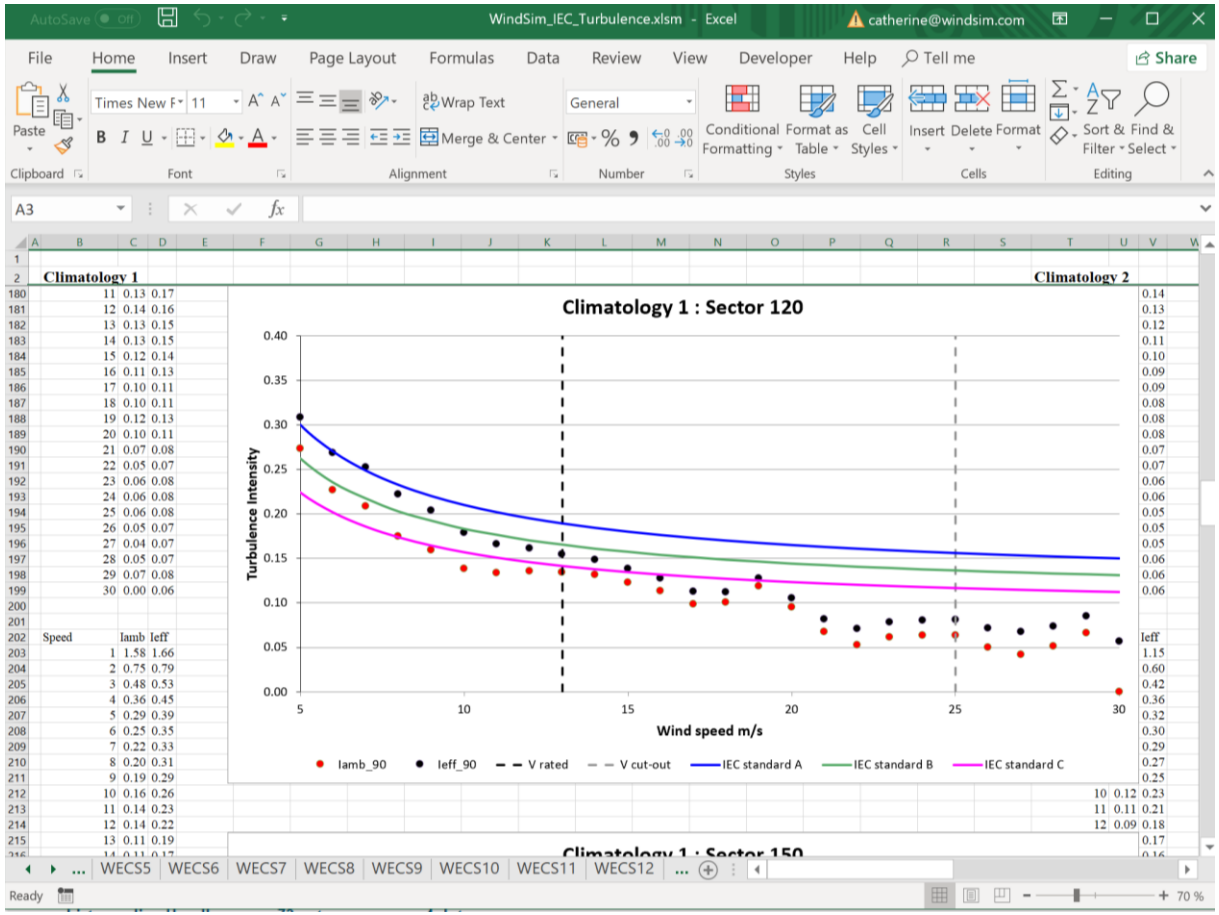


	forest height H in meter	very sparse				forest height H in meter	slightly sparse				forest height H in meter	slightly dense				forest height H in meter	very dense			
LAI			0.25					1					4					16		
drag coefficient Cd		Single Deciduous Tree	Mixed Forest	Row of Deciduous Trees	Evergreen Coniferous		Single Deciduous Tree	Mixed Forest	Row of Deciduous Trees	Evergreen Coniferous		Single Deciduous Tree	Mixed Forest	Row of Deciduous Trees	Evergreen Coniferous		Single Deciduous Tree	Mixed Forest	Row of Deciduous Trees	Evergreen Coniferous
drag coefficient Cd		0.15	0.2	0.5	1		0.15	0.2	0.5	1		0.15	0.2	0.5	1		0.15	0.2	0.5	1
	5	0.0075	0.0100	0.0250	0.0500	5	0.0300	0.0400	0.1000	0.2000	5	0.1200	0.1600	0.4000	0.8000	5	0.4800	0.6400	1.6000	3.2000
	10	0.0038	0.0050	0.0125	0.0250	10	0.0150	0.0200	0.0500	0.1000	10	0.0600	0.0800	0.2000	0.4000	10	0.2400	0.3200	0.8000	1.6000
	20	0.0019	0.0025	0.0063	0.0125	20	0.0075	0.0100	0.0250	0.0500	20	0.0300	0.0400	0.1000	0.2000	20	0.1200	0.1600	0.4000	0.8000
	30	0.0013	0.0017	0.0042	0.0083	30	0.0050	0.0067	0.0167	0.0333	30	0.0200	0.0267	0.0667	0.1333	30	0.0800	0.1067	0.2667	0.5333

Excel Tools

IEC plots

Compare simulated turbulence intensity to the IEC class values



WindSim Express

- GLC30 land use data set included (30 m resolution)
    - http://www.globallandcover.com/GLC30Download/index.aspx
    - 10 different land use types
- Editable roughness table
- Usage of map files easier as you do not need to give a coordinate system
- Write out ows file in the beginning => WindSim Express as quick creation tool for tws and ows files

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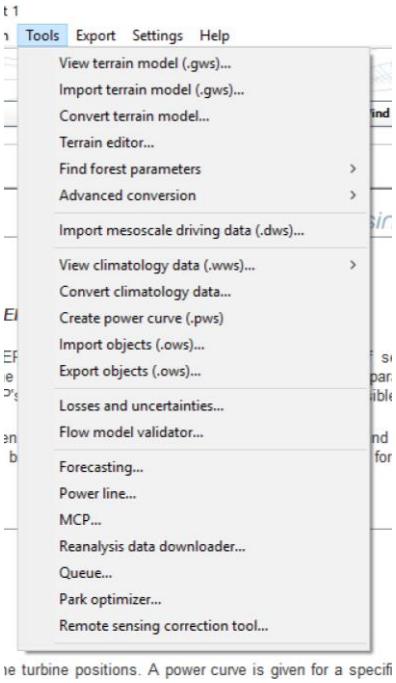
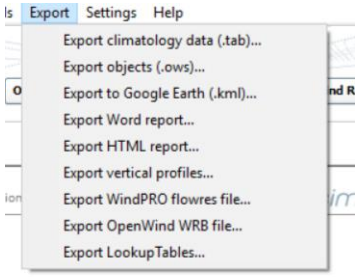
- Ongoing research projects
- Cloud Computing

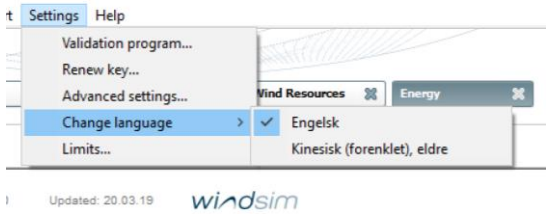
New features WindSim 10.0

New structure in the header

The Tools menu has been split into Tools and Export and some settings under Tools have been moved to Settings



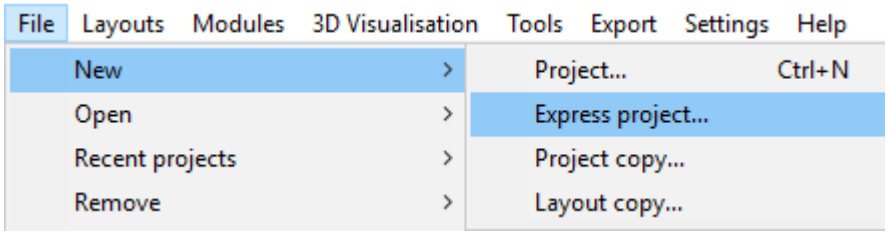


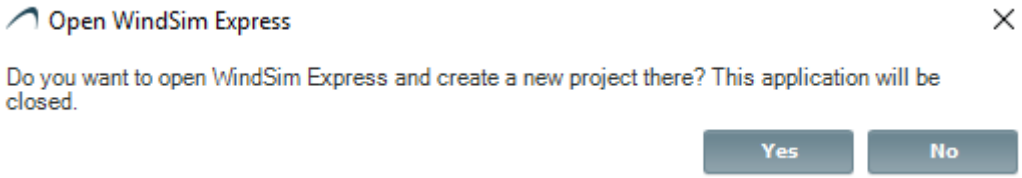


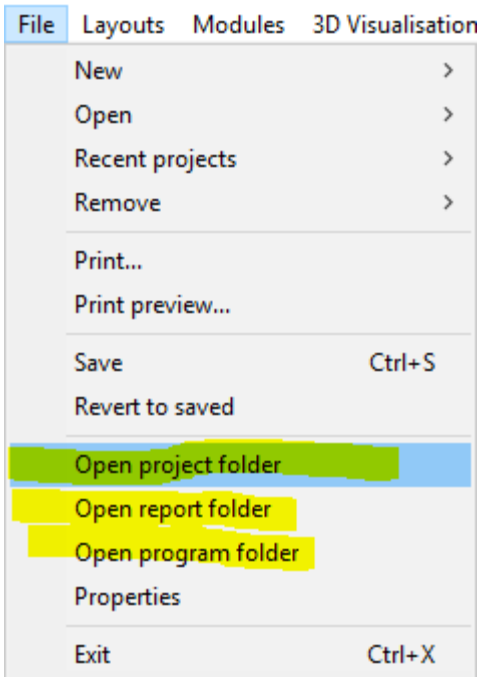
New features WindSim 10.0

New structure in the header

New menu item to WindSim Express
New menu items to special folders

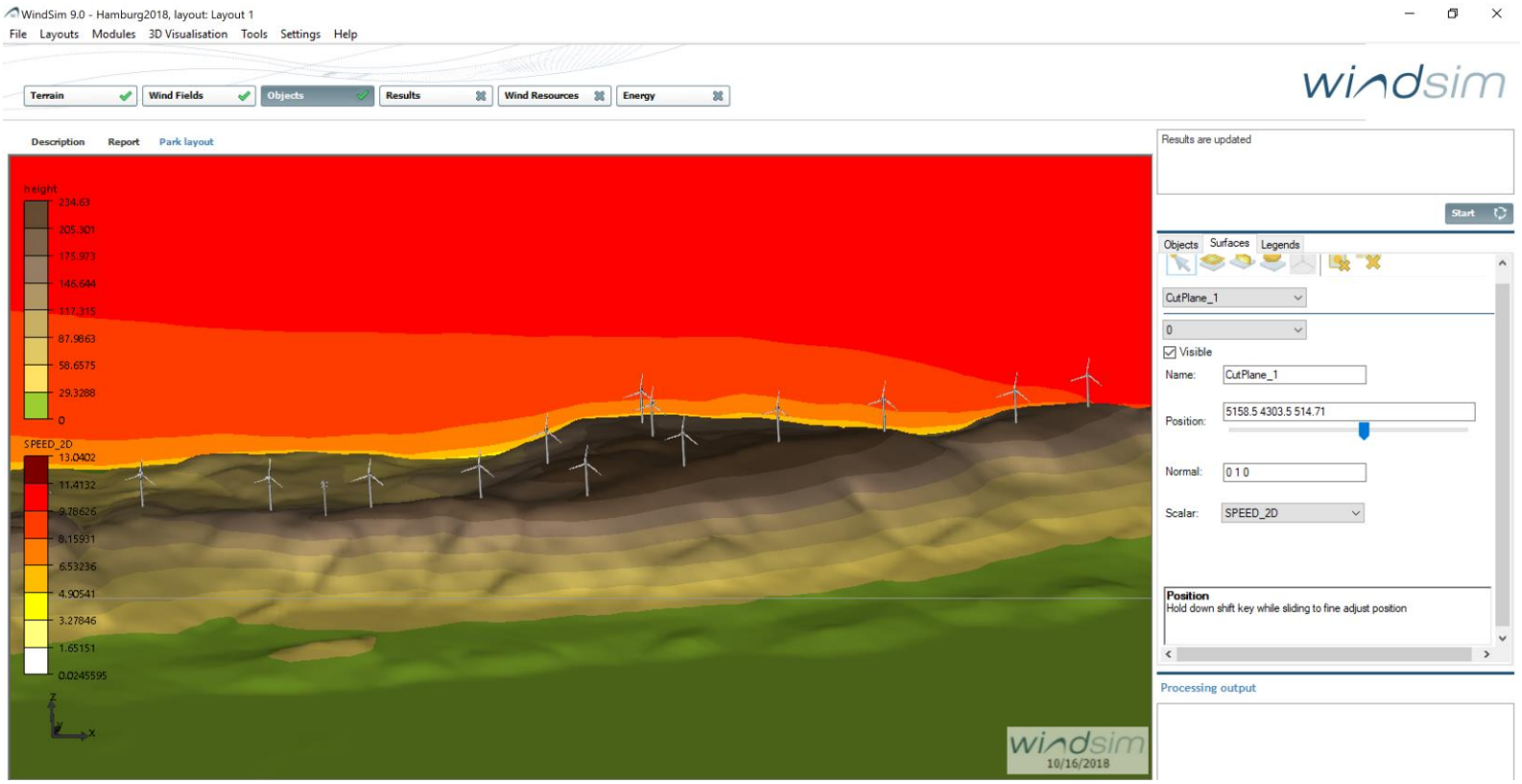






New features WindSim 10.0

New 3D component for visualization



The largest models can be directly visualized in WindSim
Easier navigation with keyboard (home, up, down, left, right, pageup, pagedown)

New features WindSim 10.0

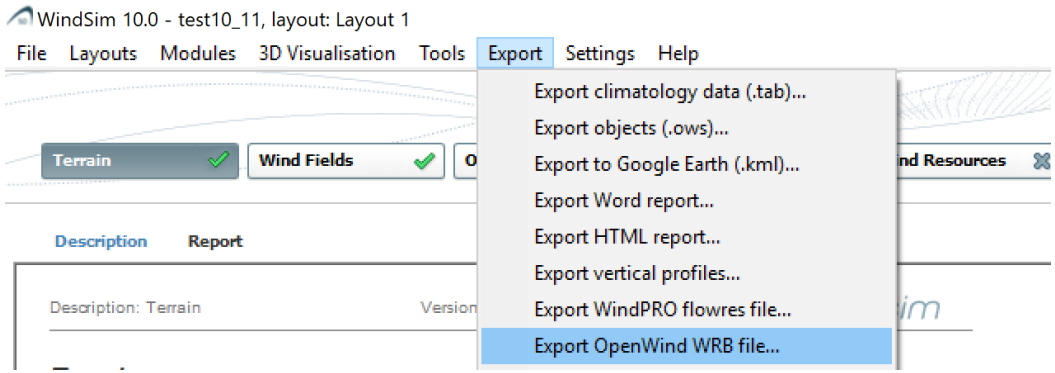
WRB file (export to OpenWind)

The project design grid format can contain all the same data as a Flowres, contains all results of a windfield simulations.

It can also contain:

- Roughness
- inflow angles
- turbulence intensity variation across the site
- wind shear exponent and so on.

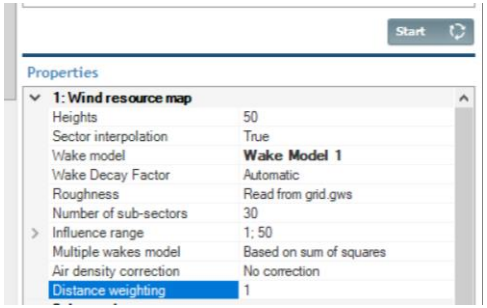
This file can be easily loaded into the Openwind software.

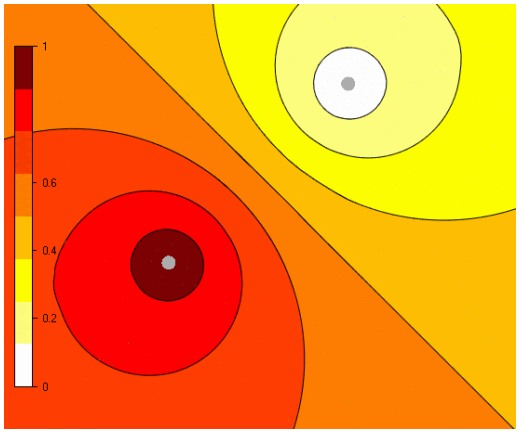


New features WindSim 10.0

Weighting of wind resource map and energy calculation by:

1) inverse distance power 1, 2, 3…..





2) trust

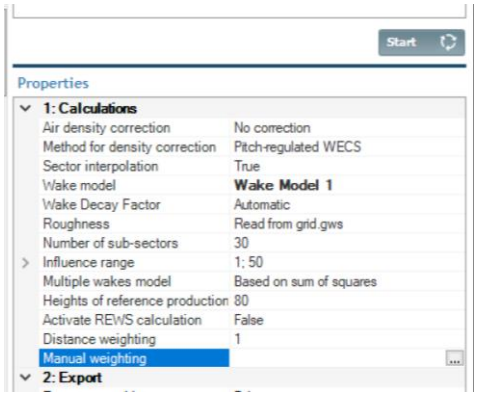
name	x	y	z	z (agl)	Reliability	climatology file
Hundhammer_73m	326703.8	7185926.0	129.3	73.0	1.0	Hundhammer.._tws
Hundhammer_83m	326703.8	7185926.0	129.3	83.0	1.0	Hundhammer.._tws

Table 1. Climatology objects.

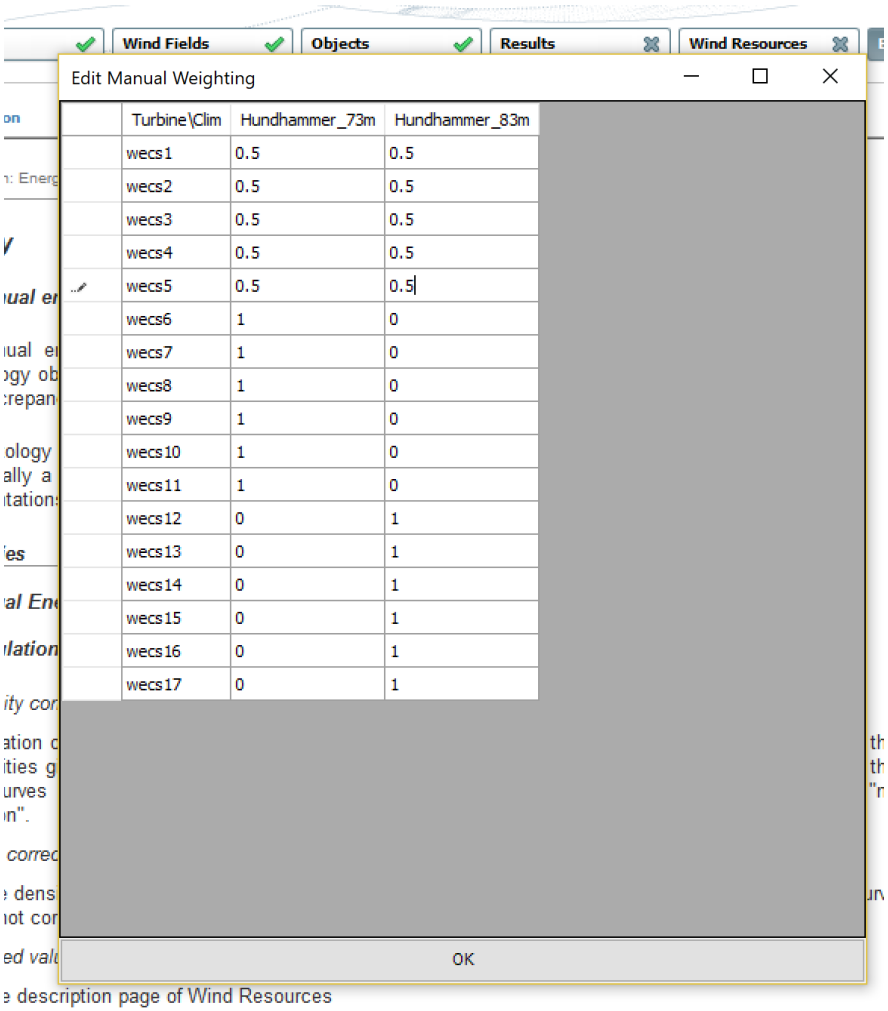
The actual weight which a climatology has for a grid point is then a combination of the inverse distance from the climatology to that point and the trust which has been defined for that climatology

New features WindSim 10.0

Manual weighting of energy calculation :



The actual weight which a climatology has for a turbine can be defined manually. E.g. the turbines closest to HH73 are only weighted by that climatology. The turbines closest to HH83 are weighted only by HH83 and the turbines which are in the middle between those two climatologies are weighted 50% to 50%

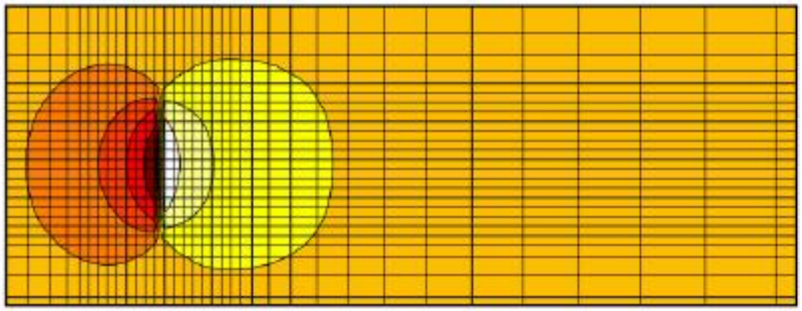


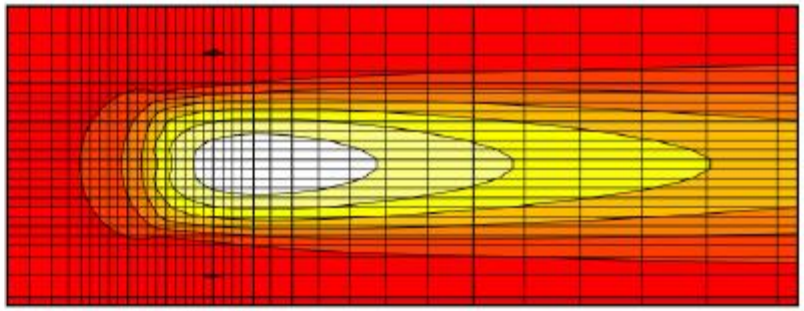
	Turbine\Clim	Hundhammer_73m	Hundhammer_83m
	wecs1	0.5	0.5
	wecs2	0.5	0.5
	wecs3	0.5	0.5
	wecs4	0.5	0.5
	wecs5	0.5	0.5
	wecs6	1	0
	wecs7	1	0
	wecs8	1	0
	wecs9	1	0
	wecs10	1	0
	wecs11	1	0
	wecs12	0	1
	wecs13	0	1
	wecs14	0	1
	wecs15	0	1
	wecs16	0	1
	wecs17	0	1

New features WindSim 10.0

New add on module “actuator disc“

- Faster actuator disc calculation by less source terms
- Able to run larger models
- Able to calculate the energy output for a certain wind speed





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Atmospheric Stability

- Atmospheric Stability is implemented into WindSim since almost 10 years
- A lot of other CFD codes have copied WindSim's approach
- Still not many people use atmospheric stability in CFD and the reasons are:
    - The lack of qualitatively good measurements or modelled data to determine the atmospheric stability parameter.
    - The lack of understanding of how to handle atmospheric stability, what atmospheric stability means for the wind speed profile and for which sites accounting for atmospheric stability can improve the CFD results.

Atmospheric Stability

- Therefore, WindSim thought it was a good idea to involve all necessary parties into a collaboration: site assessment engineers, measurement device producers, mesoscale modelers ad CFD code developers. The goal was to give: Best practices for quantifying, interpreting, and utilizing atmospheric stability measurements using standard wind resource assessment sensors and CFD simulations => collaboration between EON, NRG Systems, Vortex, and WindSim

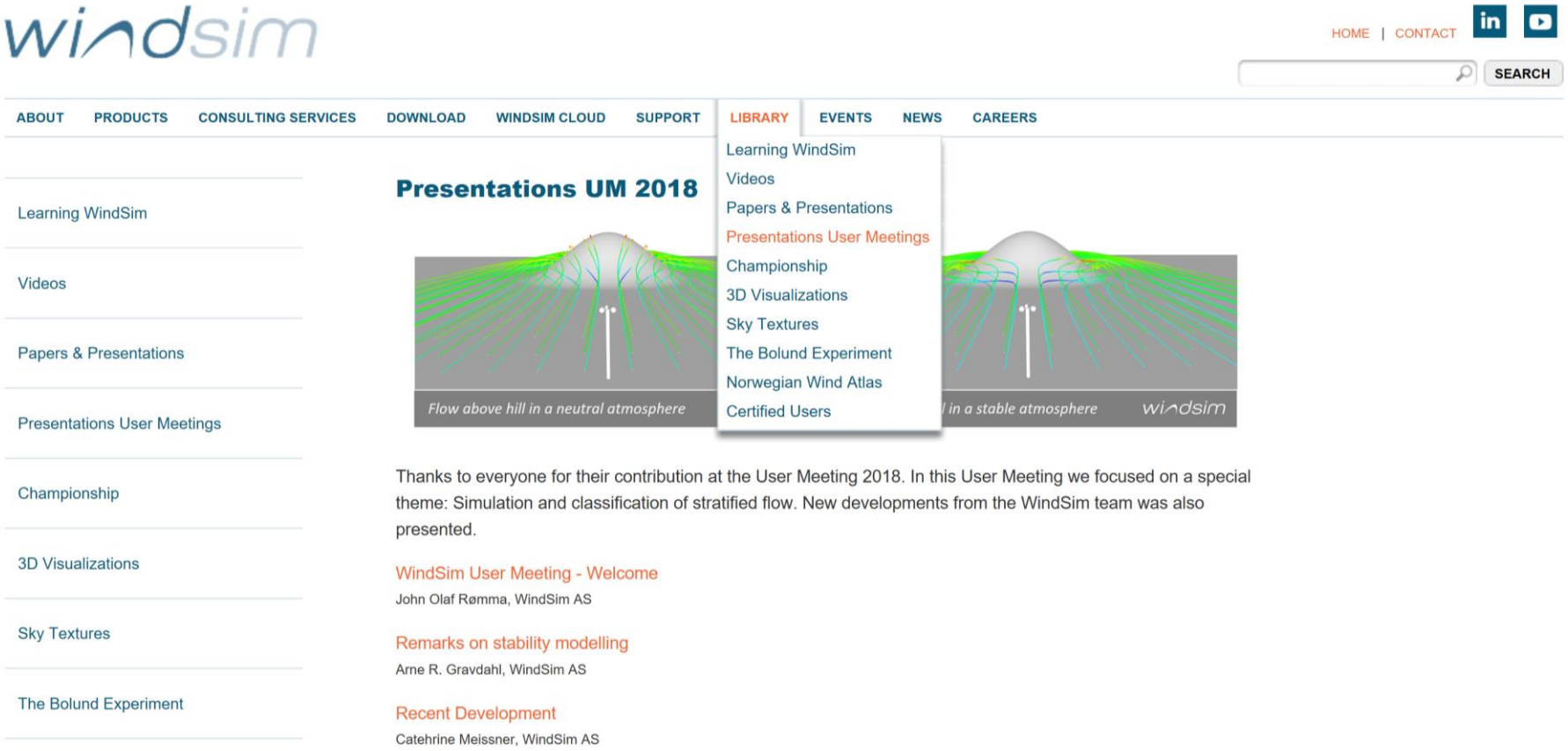
- We have come quite far and had oral presentations at the AWEA Wind Resource & Project Energy Assessment Conference in Austin and at WindEurope in Hamburg this year

- The goal for WindSim is to have an automated stability classification from measurements in the software and give advice how to set-up the simulations

Atmospheric Stability

- The presentation can be found here:

http://www.windsim.com/documentation/UM2018/1809_WindSim_UM_EON_Gibson_Kersting.pdf



Meso-Microscale Coupling

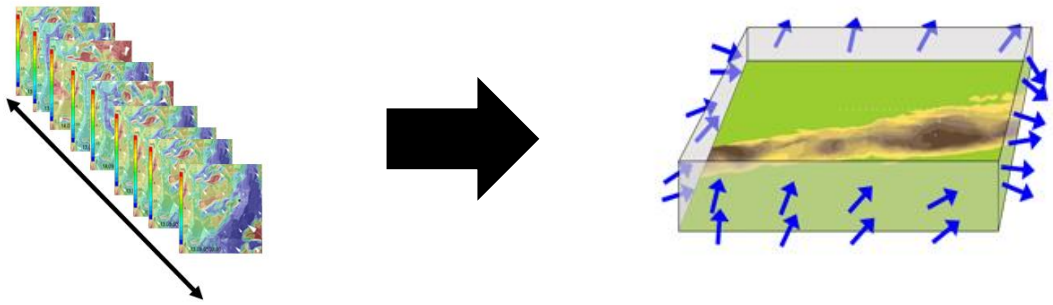
- There are sites where knowing the atmospheric stability is not enough => The atmospheric flow patterns are too complex

- Phd on Meso-Microscale Coupling done by Pablo Duran:

  - Investigating meso-microscale coupling together with the Novia University of Applied Sciences, Finland – finished this year and results are on our website: http://www.windsim.com/library/papers--presentations.aspx

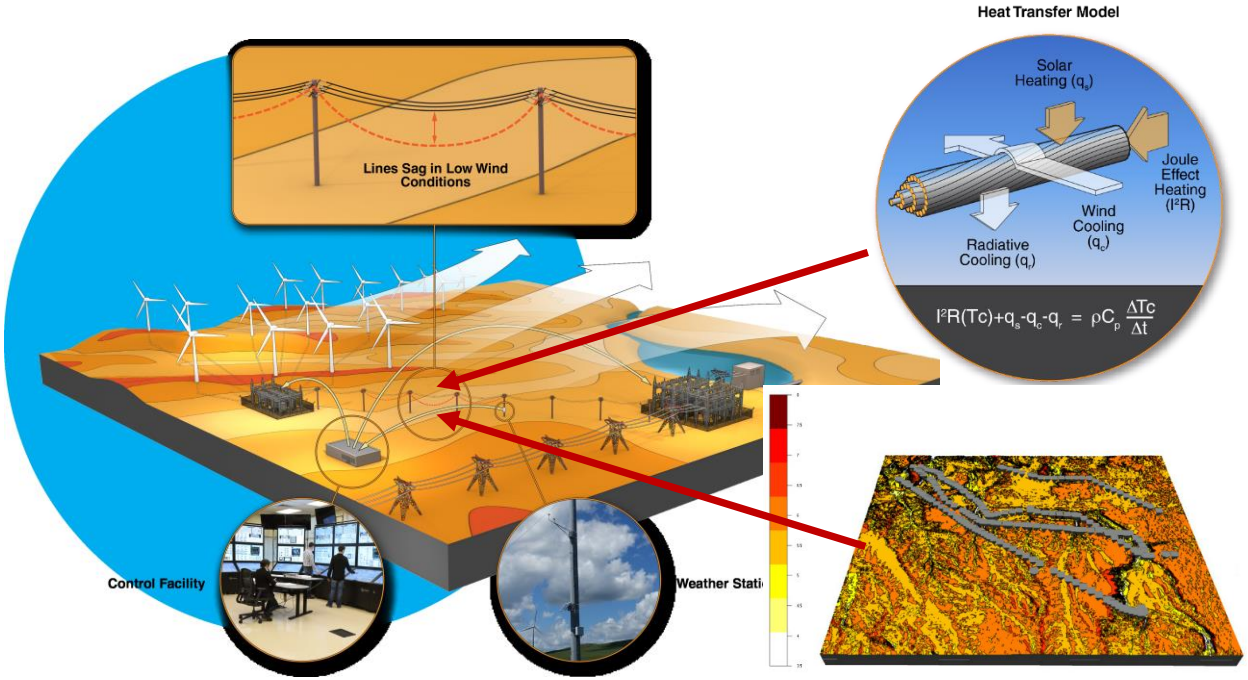
  - Now investigating meso-microscale coupling on flat sites with thermal flow patterns and on complex sites => so far very promising results

- Pablo will tell more tomorrow



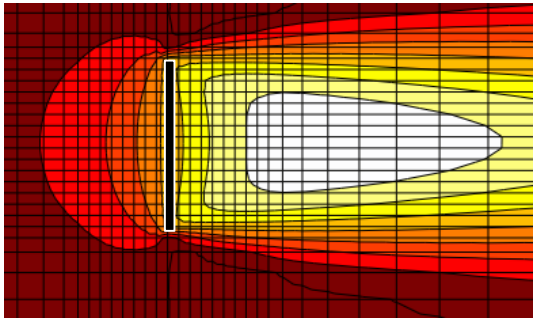
Ongoing research projects

- NowWind: Nowcasting for wind energy production - an integrated modelling approach
  - Presentation from WindEurope 2018 on our website
- Innovation Norway funding for Dynamic Line Rating based on CFD
  - nominated for the R&D 100 award in the USA

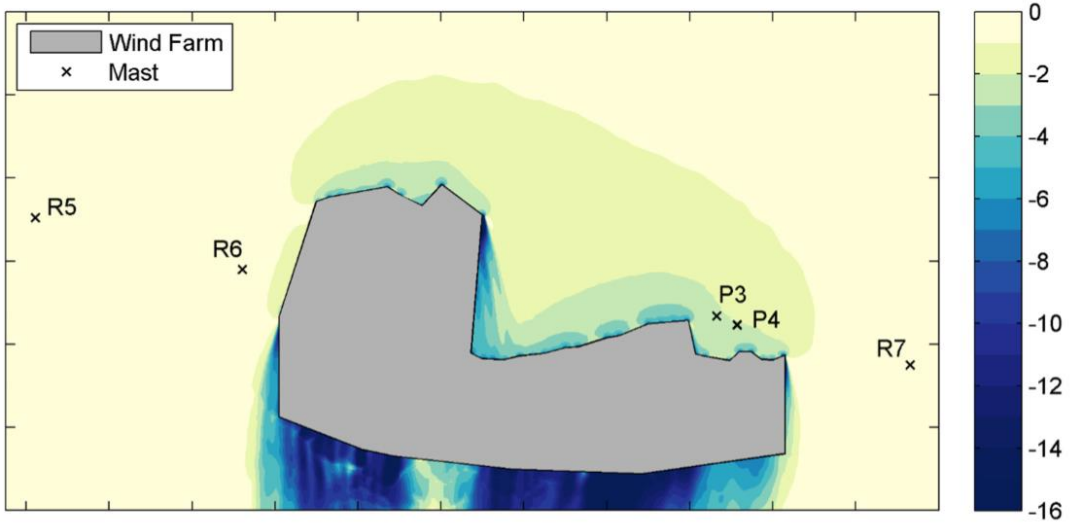


Blockage effect

- Turbines reduce the wind speed also upfront a turbine



- For large wind farms that effect can be quite important (source DNV GL):



Blockage effect

- The actuator disc model has shown good results in simulating this effect
- We need a more flexible gridding and good validation cases
- A JIP project is there to get this in place

Content

- Most important features in WindSim 9.0
- New features in WindSim 10.0
- Ongoing research projects
- Cloud Computing

Cloud Computing - Current

- You can rent a Virtual Machine in the Cloud with WindSim installed from us

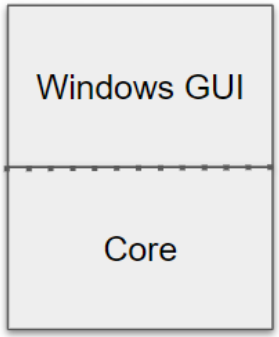
- You can send your project to us and we run the WindFields on our machines (consulting)

- You can run WindSim on your own Virtual Machine in the Cloud
    - Challenge is the hardware key
        - Can not plug in directly
        - Need to be plugged in a local machine
        - Need a fast reliable internet connection
    - We will change from hardware based license key to software based for easier running in the future

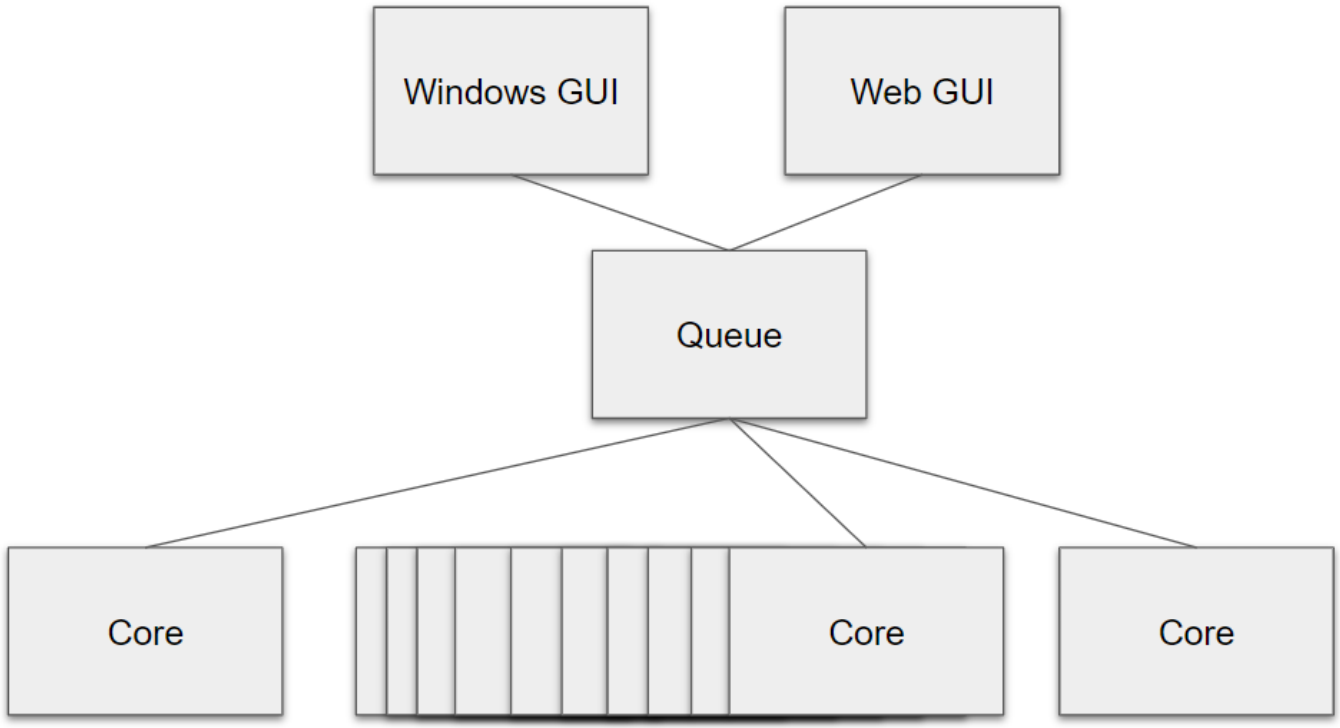
Cloud Computing - Future

- A Web interface with similar features as current WindSim
- A Queue which can dispatch several jobs to different servers/containers

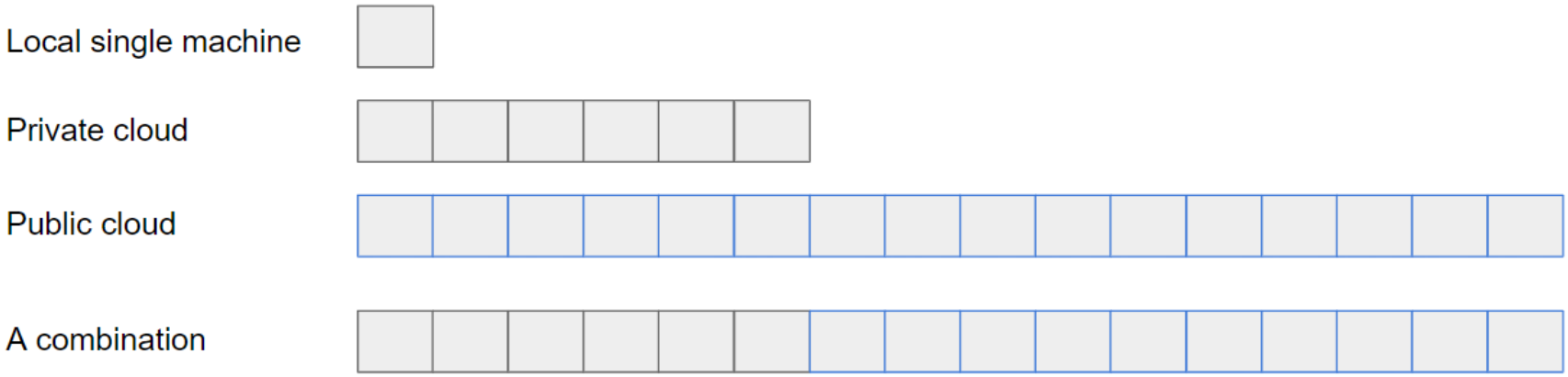
•Now:



Future:



Cloud Computing - Queue



Cloud Computing - Advantages

- A web enabled cloud version of WindSim can be easily deployed on
  - Public Cloud (Microsoft Azure, Amazon EC2, Google Cloud ++)
  - Private Cloud
  - Local

- A Public Cloud is Scalable (horizontal and vertical)

- You only pay for what you use (in seconds)

Cloud Computing - Pricing

Running 1 machine for 100 hours = Running 100 machines for 1 hour

Cloud Computing - Security

- Online banking
    - Do you trust your bank?

- Microsoft/Amazon/Google has much better security than your own servers

Cloud Computing - Questions

- Would you use a Cloud solution?
    - If not, what are your concerns?

Thank you

catherine.meissner@windsim.com

WindSim AS
Fjordgaten 15
3125 Tønsberg, Norway
Tel: +47 33 38 18 00

WindSim Americas
2945 Townsgate Road Westlake Village
California 91361, USA
Tel: +1 805 216 0785

WindSim Brasil
Market Place II, Av. Doutor Chucri Zaidan, 940
16º andar, Vila Gertrudes
São Paulo – SP 04583-110, Brasil
Tel: +55 11 5095 3430

WindSim China
No. 101 Shaoyang Beili
Chaoyang District
100029 Beijing, China
Tel: +86 186 1029 1570

WindSim India
Suite # 617 Regus Milenia Business Park
Phase 2, Level - 6, Campus 4B, No - 1 43,
Dr.M.G.R Road Kandanchavady, Perungudi
Chennai 600 096, India
Tel: +91 98 4032 2786

WindSim Sub-Saharan Africa
16th Floor Norton Rose House Riebeeck Street
Cape Town, 8000, South Africa
Tel: +27 79 367 2593