1st WindSim Americas User Meeting

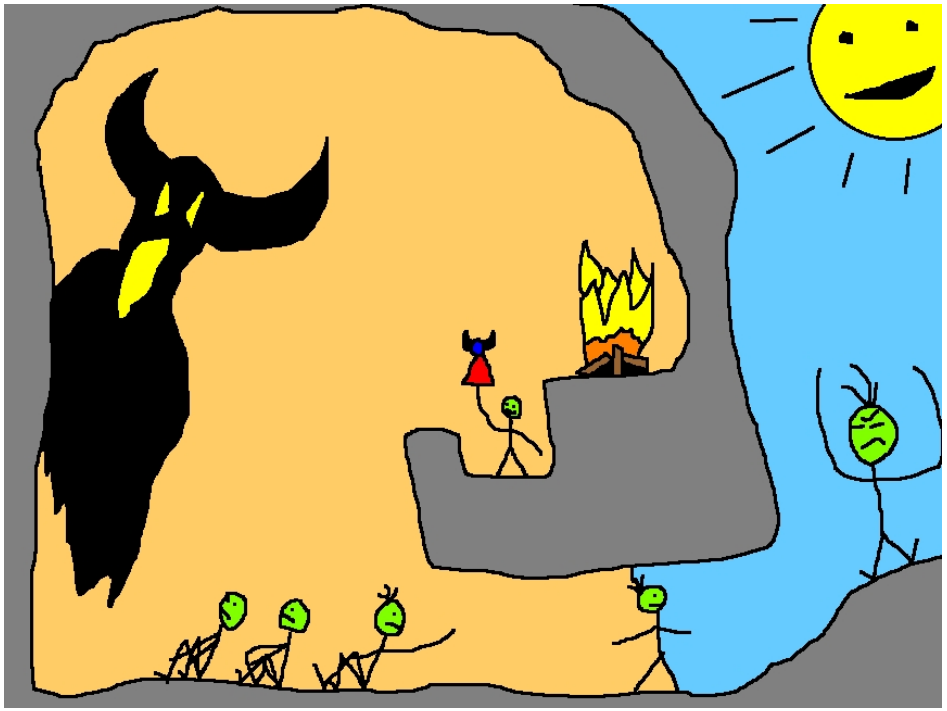
4 December 2014, Orlando

WindSim 7.0

PRESENTED BY: ARNE R. GRAVDAHL, CTO

windsim

Allegory of the Cave

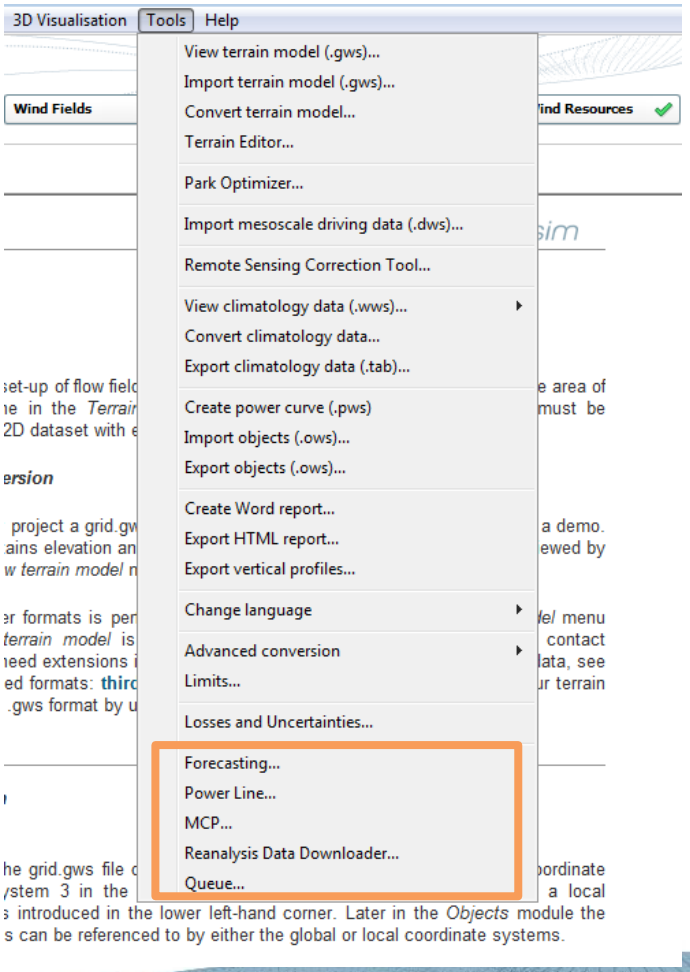


- Prisoners have lived chained to the wall of a cave all of their lives, facing a blank wall
- They watch shadows projected on the wall by things passing in front of a fire behind them, and begin to designate names to these shadows
- The shadows are as close as the prisoners get to viewing reality
- The philosopher is like a prisoner who is freed from the cave and comes to understand that the shadows on the wall do not make up reality at all

Source: Idea stolen from Lasse Johansson in SWECO; Original: Plato*,"The Republic",* 380 BC

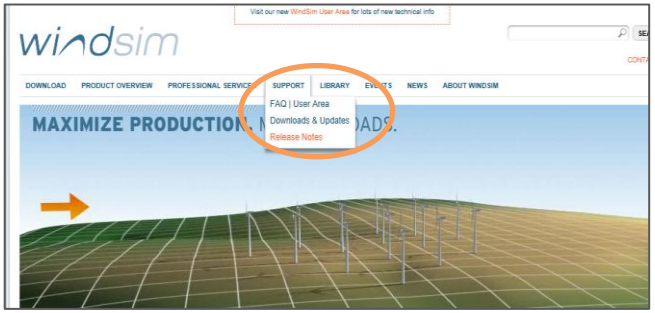
Content – New Features in WindSim 7.0

- Forecasting
- Power Line
- MCP (Measure-Correlate-Predict)
- Reanalysis Data Downloader
- Queuing
- Terrain complexity
- Cross checking – Feed-back form
- Bigger models
- Break a run properly
- New wall functions
- Improved post processing

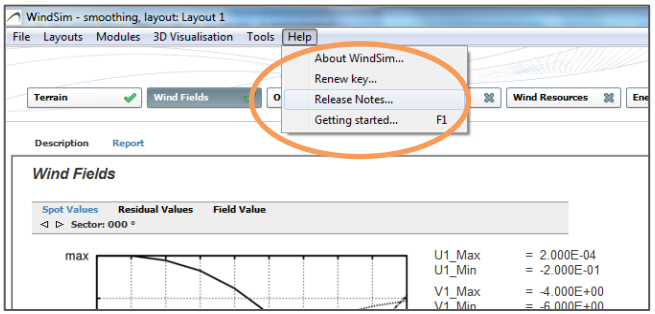


Release Notes

- Check for new releases and updates on the web and in the software
- Download new patches



Web site; www.windsim.com



Software

WindSim 6.2.0 | Patches

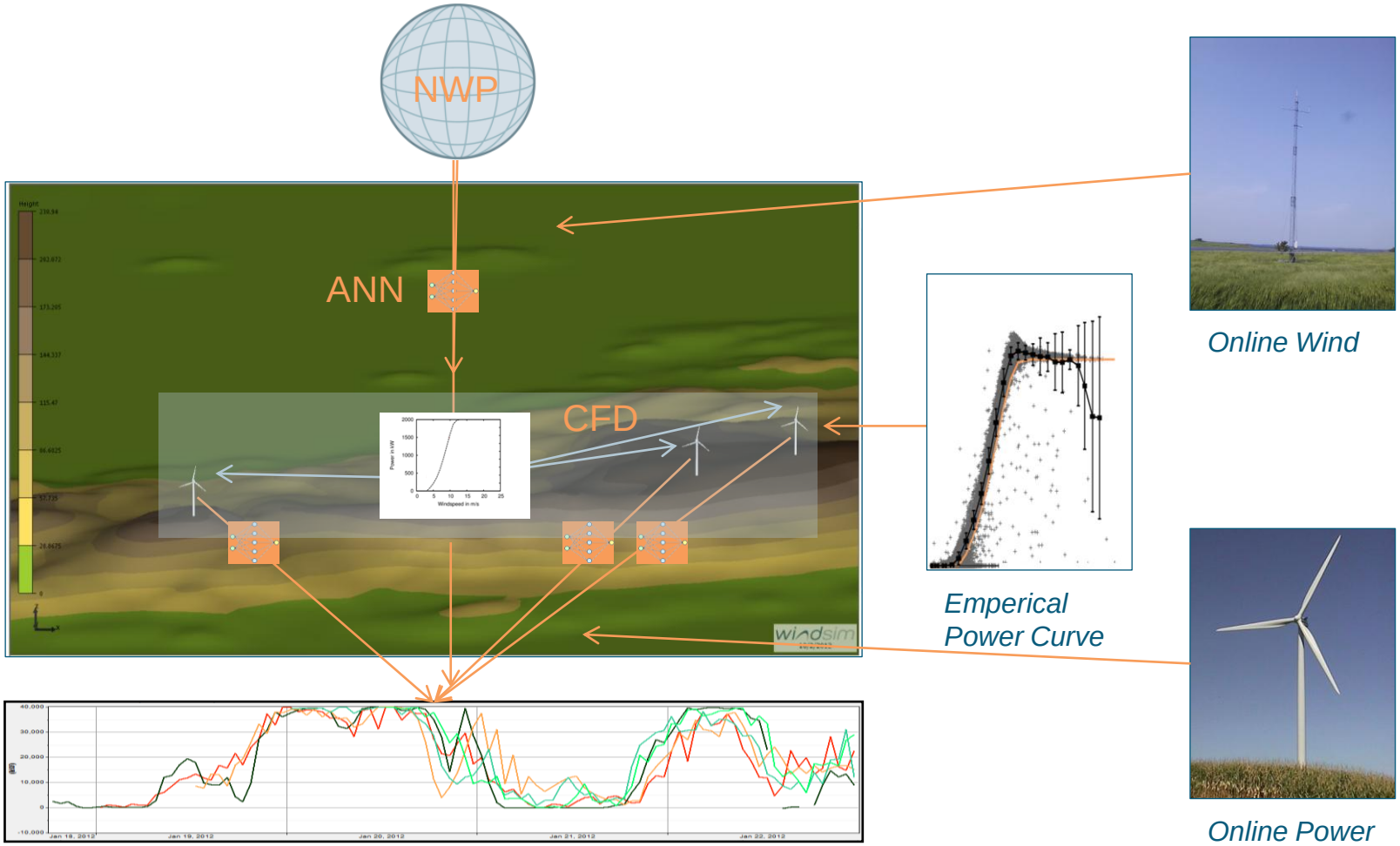
Steps to install the patch:
1) Download and Unzip the file to some folder
2) Run the file patch.exe from the folder

The patch improves the following features

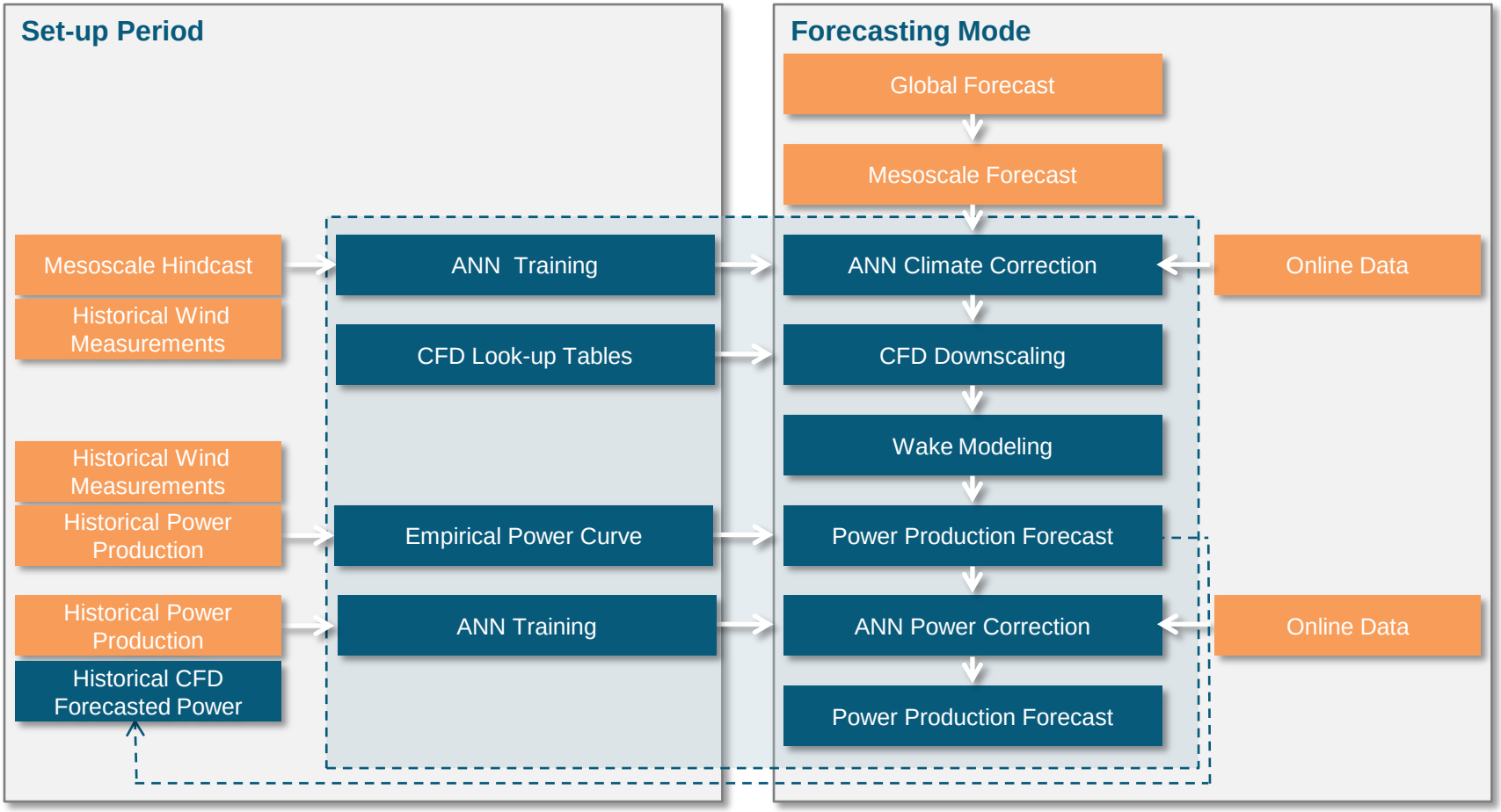
- Wind Resource Module: Correct ambient turbulence
- Wind Resource Module: Correct export size of wrg files
- Wind Field Module: Correct Forest with GCV solver
- Wind Field Module: Nesting with Temperature and GCV solver
- Wind Field Module: Correct display of results for over 100 iterations

Important patch update for WS 6.2

Short-term Power Production Forecast



Short-term Power Production Forecast



Short-term Forecasting using Mesoscale Simulations, Artificial Neural Networks (ANN) and Computational Fluid Dynamics (CFD): Input; WindSim software or data

Short-term Power Production Forecast – Software or service

- Software; User performs the software installation with configuration towards meso forecasts (FTP), ANN training, CFD modeling …..

- Service, Users receives daily forecasts by email or FTP

  - WindSim AS and Met Office (UK) has established a cooperation, and the meso scale forecasts will be based on the Met Office Unified Model data

"Forecast accuracy is becoming increasingly important as balancing costs are increasing in many countries in Europe and energy traders demand improved precision to support both inter-day and intra-day market trading. Penalties for poor forecasting are becoming increasingly onerous in many countries in Europe – and worldwide – so accurate power forecasting is an imperative. Site specific Power Forecasts will be produced by WindSim AS using their Computational Fluid Dynamic technology based on the Met Office site specific Wind Production Forecast(TM) product, with the joint objective of establishing the potentially higher economic benefits of WindSim's CFD model, compared with other traditional forecasting methods, to satisfy the increasing demands for accuracy in the short term power forecasting markets"

MCP (Measure-Correlate-Predict)

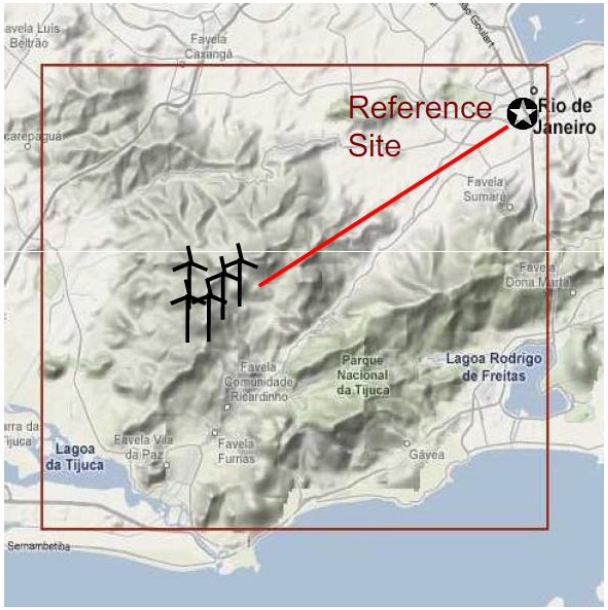
- MCP is a statistical technique used for predicting the long term wind resource at a proposed wind farm site by relating measurements from a short-term measurement campaign to the long term data sets of a reference

- Find statistical relationship between a **reference observation** (usually long term time series) and a on **site observations** (at least one year)

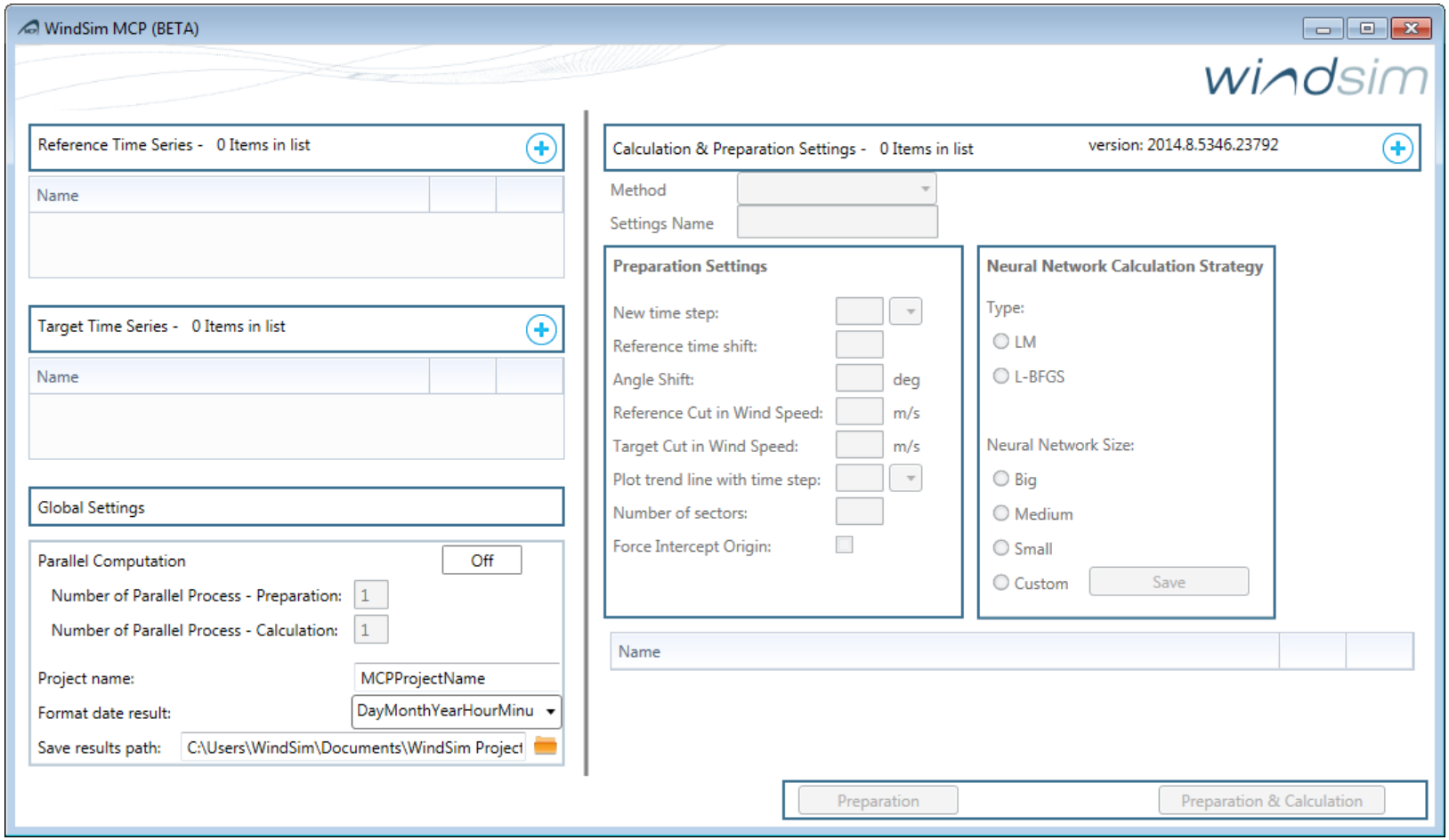
- We have linear methods and artificial neural network methods (ANN)

- Traditional reference: Meteorological observation stations

- Synthetic reference: Forecast models (Merra etc...)

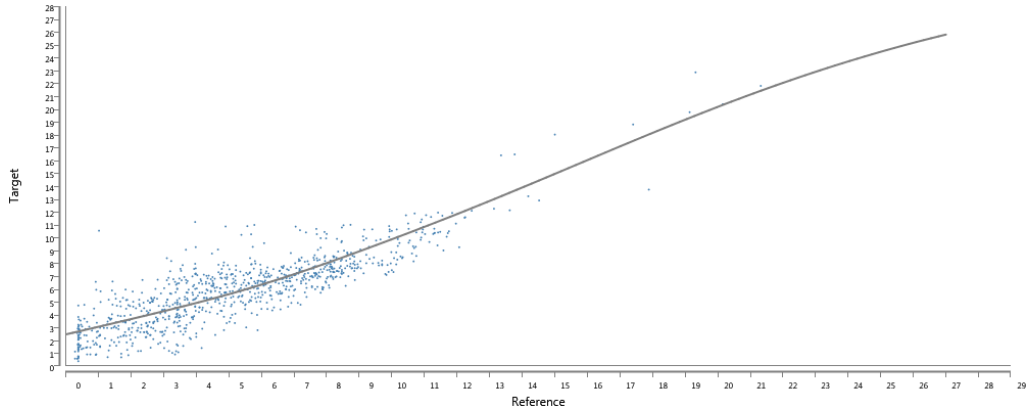


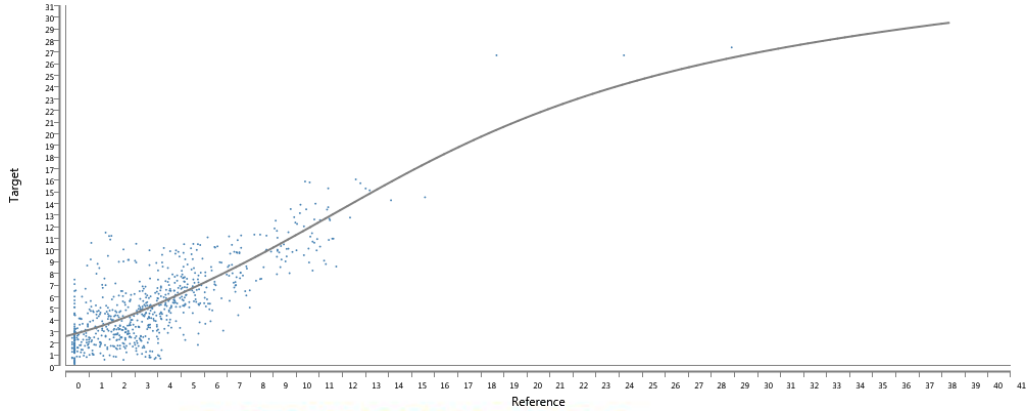
MCP (Measure-Correlate-Predict)



MCP (Measure-Correlate-Predict)

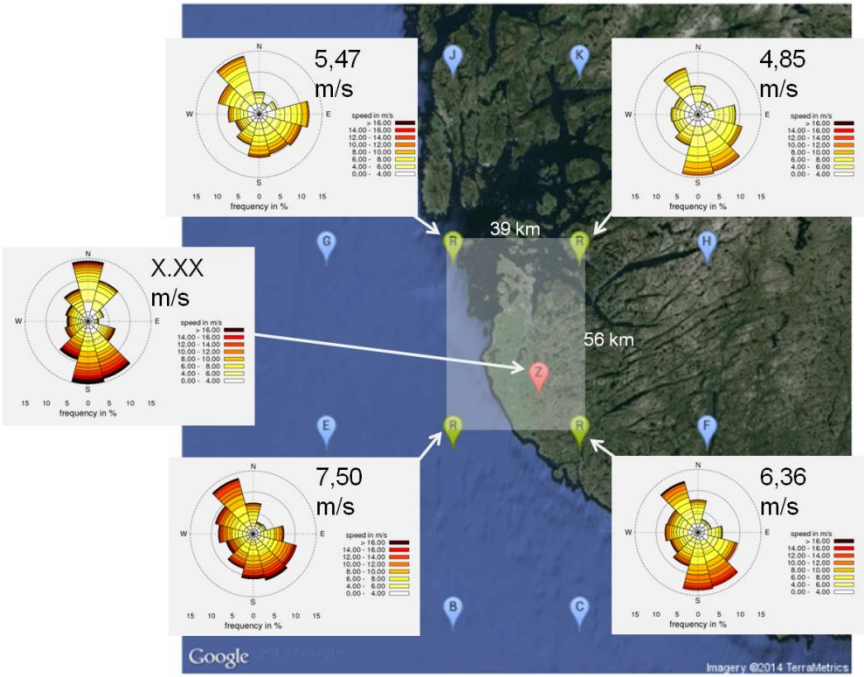
- ANN solves a non linear problem
- The curved lines fit better than straight lines the sector points when using ANN in MCP





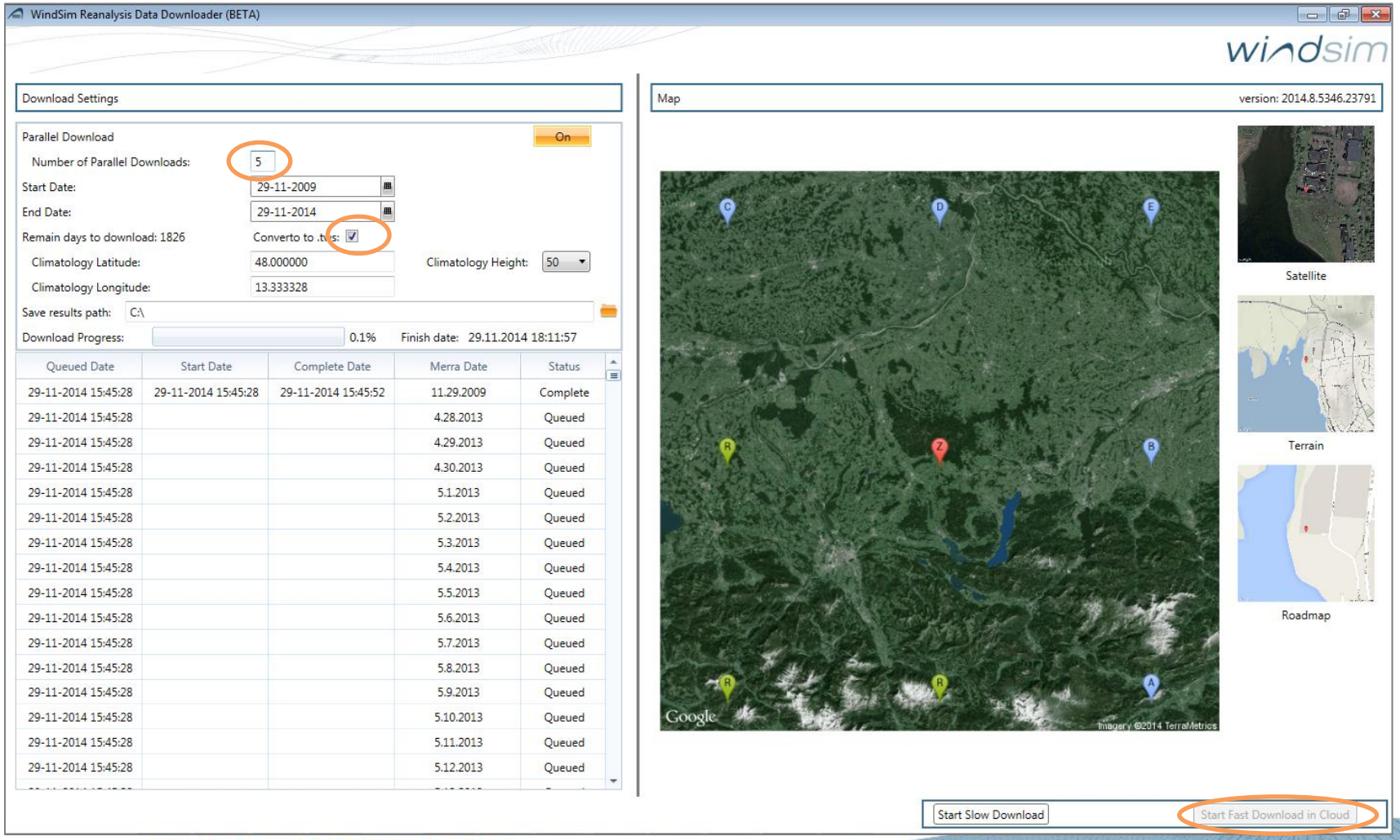
WindSim Reanalysis Data Downloader based on MERRA

- Data for virtual measurement masts – WindSim Express Cloud
- Data for MCP
- Data for stability classification



MERRA download (50 meters height) versus measurements (80 meters height) for the period 01.01.2013 – 31.12.2013. MERRA grid 39x56 km at this location

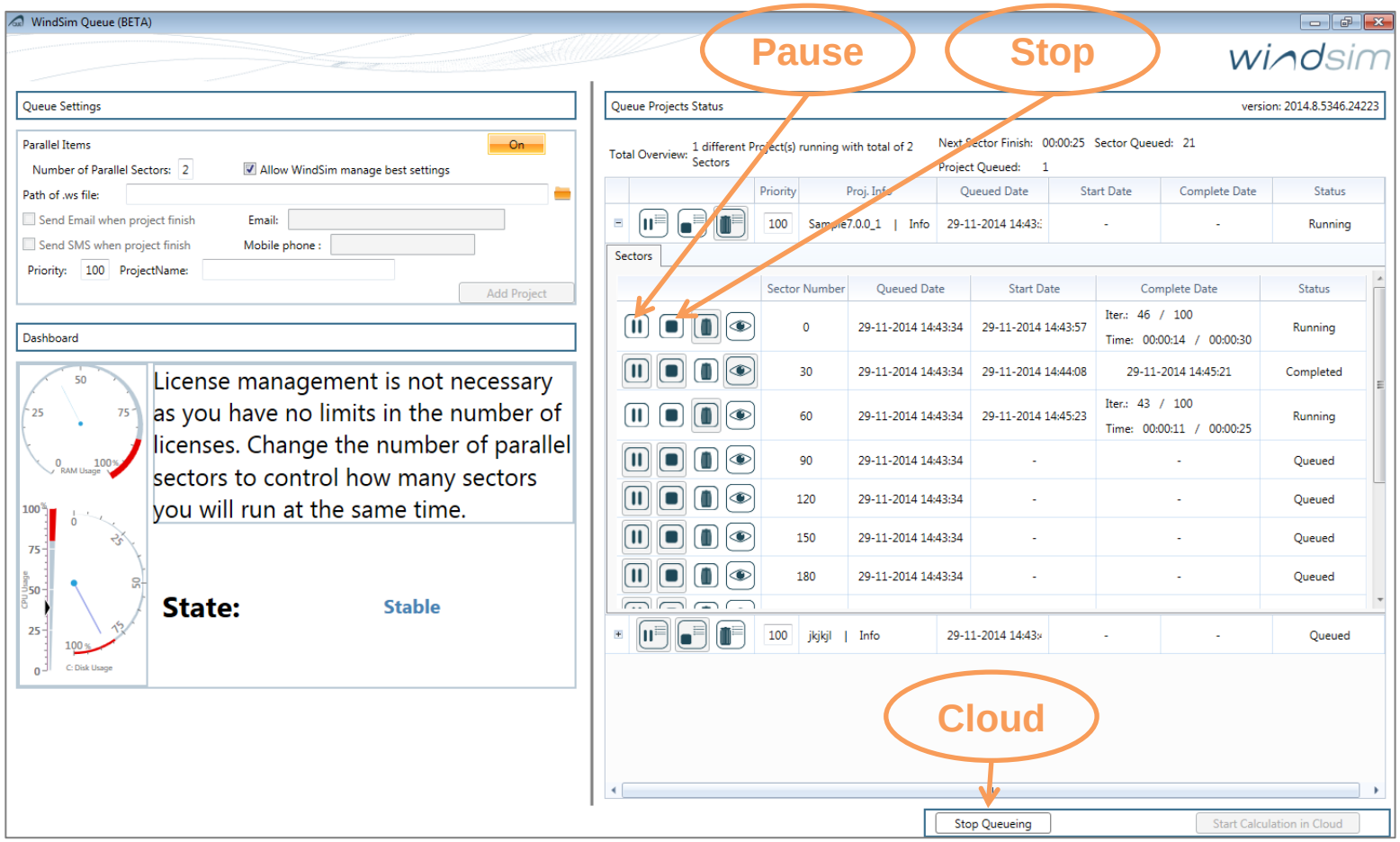
WindSim Reanalysis Data Downloader based on MERRA



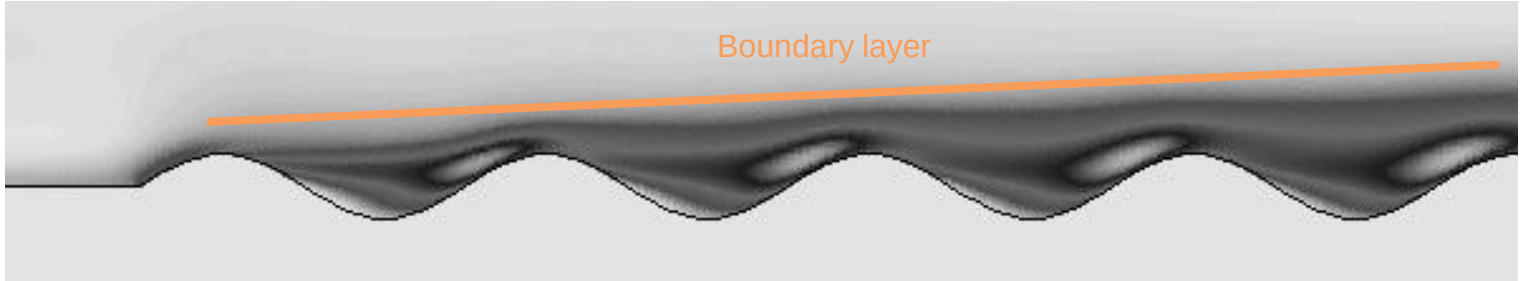
Queuing

- Possibility to run several projects in a consecutive order
- Able to start, stop and pause runs as you would like
- Change of priority in the queue possible
- Check of available memory

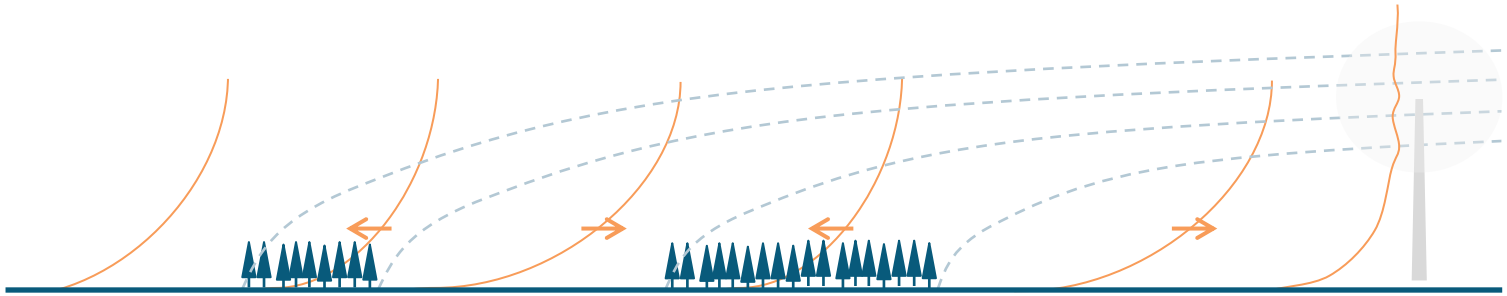
Queuing


WindSim Queue (BETA)
Pause
Stop
windsim
Queue Settings
Parallel Items
On
Number of Parallel Sectors: 2
Allow WindSim manage best settings
Path of .ws file:
Send Email when project finish
Email:
Send SMS when project finish
Mobile phone :
Priority: 100
ProjectName:
Add Project
Dashboard
License management is not necessary as you have no limits in the number of licenses. Change the number of parallel sectors to control how many sectors you will run at the same time.
State:
Stable
Queue Projects Status
version: 2014.8.5346.24223
Total Overview: 1 different Project(s) running with total of 2 Sectors
Next Sector Finish: 00:00:25
Sector Queued: 21
Project Queued: 1
Priority
Proj. Info
Queued Date
Start Date
Complete Date
Status
100
Sample7.0.0_1 | Info
29-11-2014 14:43:
Running
Sectors
Sector Number
Queued Date
Start Date
Complete Date
Status
0
29-11-2014 14:43:34
29-11-2014 14:43:57
Iter.: 46 / 100
Time: 00:00:14 / 00:00:30
Running
30
29-11-2014 14:43:34
29-11-2014 14:44:08
29-11-2014 14:45:21
Completed
60
29-11-2014 14:43:34
29-11-2014 14:45:23
Iter.: 43 / 100
Time: 00:00:11 / 00:00:25
Running
90
29-11-2014 14:43:34
Queued
120
29-11-2014 14:43:34
Queued
150
29-11-2014 14:43:34
Queued
180
29-11-2014 14:43:34
Queued
100
jkjkjl | Info
29-11-2014 14:43:
Queued
Cloud
Stop Queueing
Start Calculation in Cloud

Terrain complexity



Transport of the turbulent kinetic energy in an idealized 2D sinusoidal terrain, illustrating the development of a turbulent boundary layer.



Case with patch wise roughness patterns with developing boundary layers resulting in complex wind speed profiles

Terrain complexity

• In the standard there is a complexity index which tells if you need to add turbulence to the calculated values of linear models

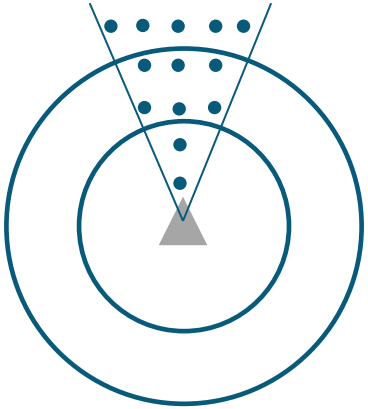
• The complexity index doesn't tell you if the site is complex from a CFD modeling perspective

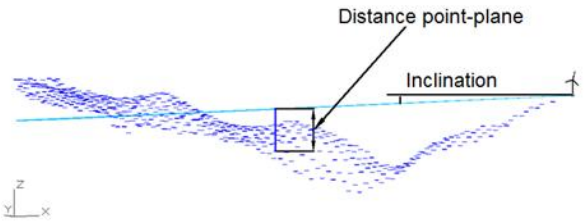
• Therefore we defined a new complexity index based on 4 parameters which can help to get a relation between cross prediction errors and site complexity such that we can on the long term give an estimate for the losses & uncertainty calculation regarding the uncertainty of the flow modeling

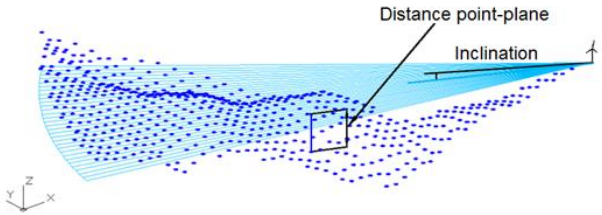
Terrain complexity

Complexity index based on 4 parameters :

a. Inclination
b. Mean absolute distances point-plane
c. Standard deviation of distances point-plane
d. Roughness







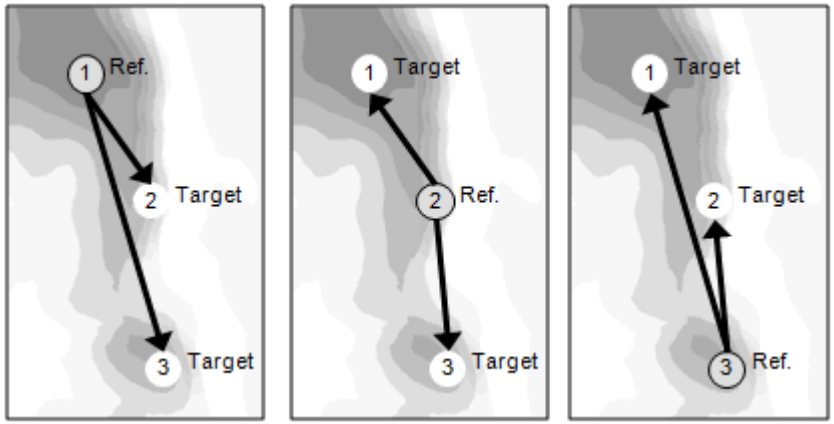
Definition sketches of fitting plane inclination and distances detected from plane and elevation points. Surrounding terrain points are divided into 12 sectors of radius: 10 Zhub (for Inclination and Distances) and 20 Zhub (for Roughness)(illustrations kindly shared by Pasquale Morelli, Edison)

Cross checking

•The cross checking functionality estimates the errors of the numerical model in predicting measurements

• Whenever multiple measurements exist, represented as climatologies with the given time history format .tws, a cross checking can be performed

• All possible pair combinations are cross checked automatically, defining one climatology as the reference and the other climatologies as targets



Cross checking combinations in a project with three climatologies

Cross checking

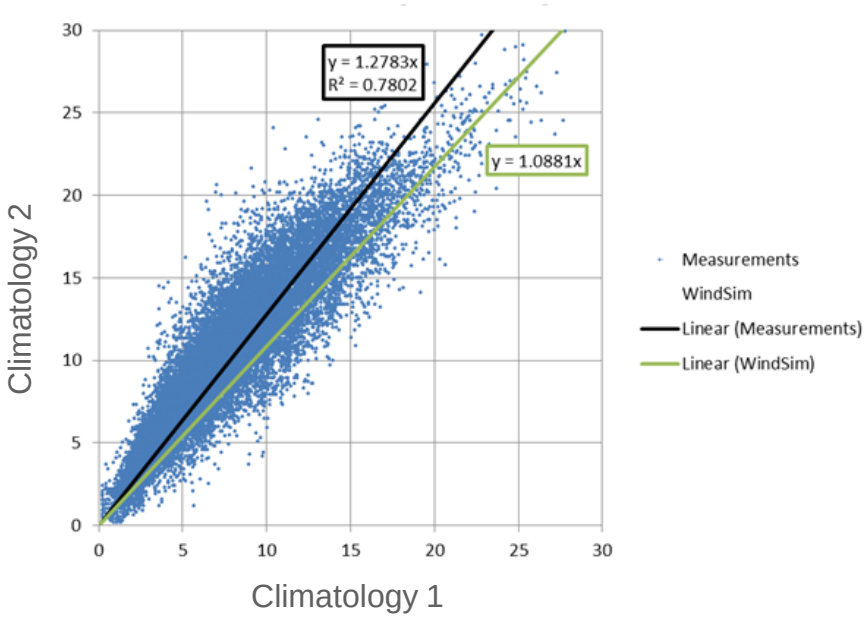
- The cross checking is based on concurrent time series and calculates the ratios of the wind speeds (speed-ups) and ratios of the standard deviations for all concurrent time records of one reference and one target

- These ratios are calculated in two different ways; filtered and unfiltered

- The filtered way includes wind speeds inside the operational range of a typical wind turbine, the default range is from 3 to 25 (m/s)

- Whereas the unfiltered way includes all wind speeds except calm conditions when the wind speed is zero

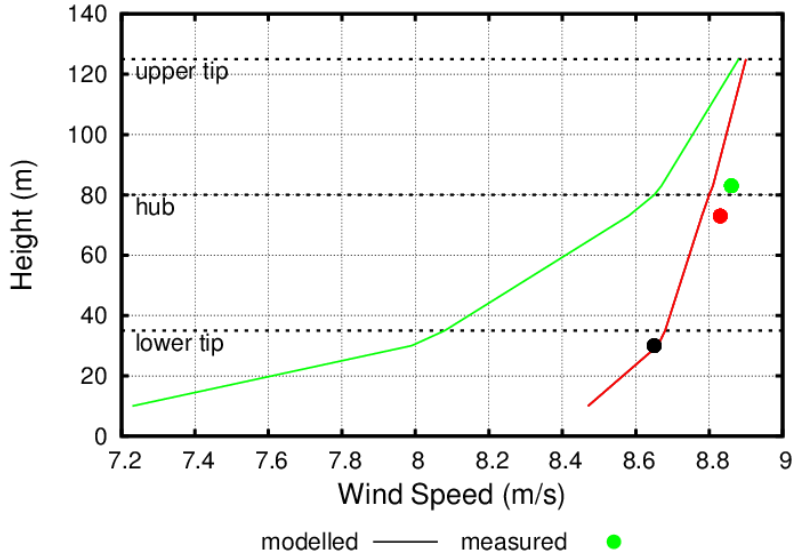
- The errors obtained by filtering should be closer to the errors obtained from the numerical model for the operational range of wind speeds for a wind turbine



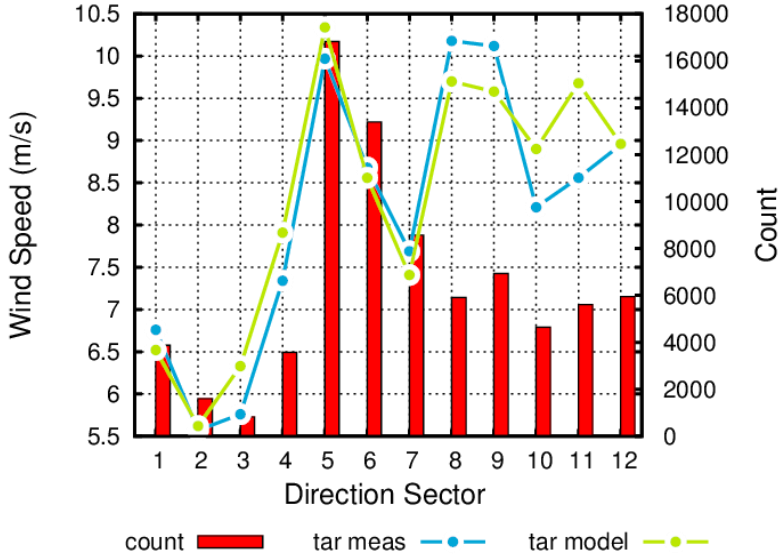
Cross-prediction errors, measured versus simulated results

Cross checking

- Improved post-processing of the cross-checking errors



Scaled profiles for mean wind speed



Sectorwise speed-up comparison

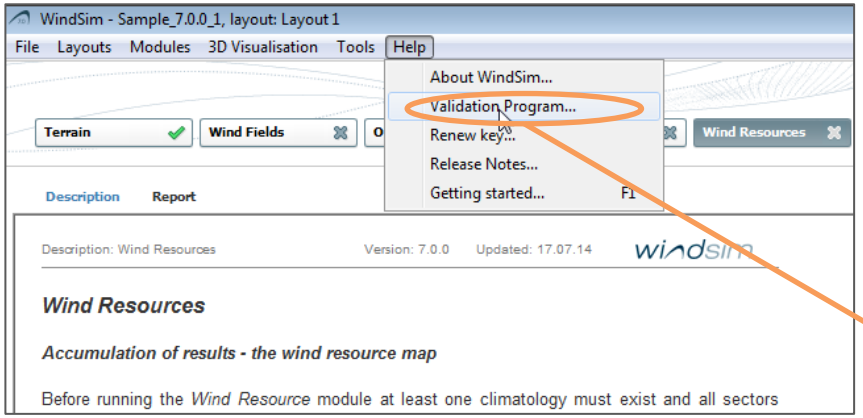
Cross checking – Feed-back form

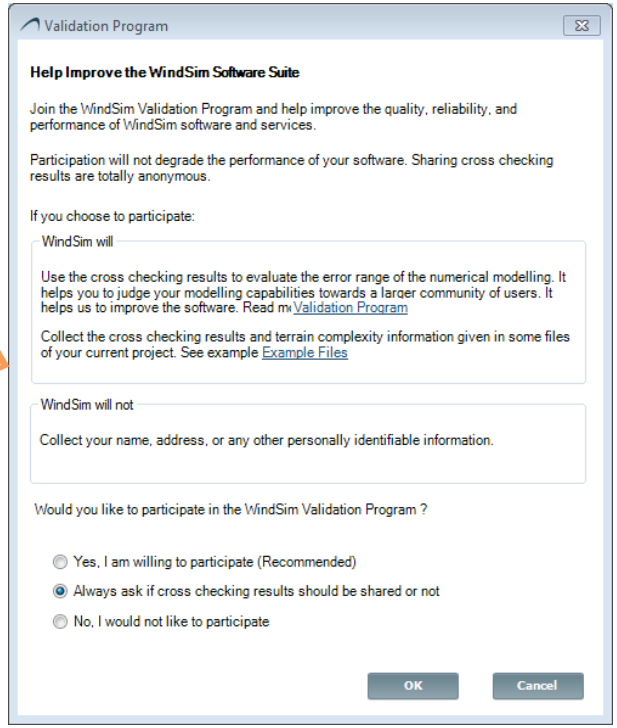
- Idea: Create a user-community sharing cross-prediction errors versus terrain complexity

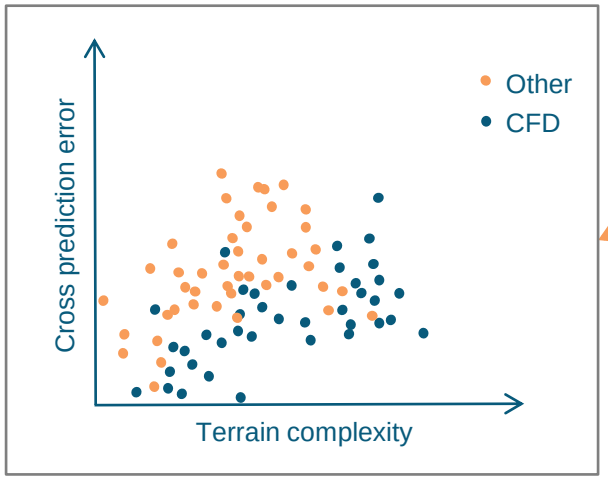
- Anonymous: No geo-referencing of the site
  - Terrain complexity indicators
  - Other anonymous parameters that possibly could bring information about modeling quality, grid resolution at climatology points, distance between climatology points

- Outcome: Statistics on modeling accuracy according to terrain complexity
  - Users would like to be the best
  - Improved understanding of the wind conditions
  - Improved modeling

Cross checking – Feed-back form

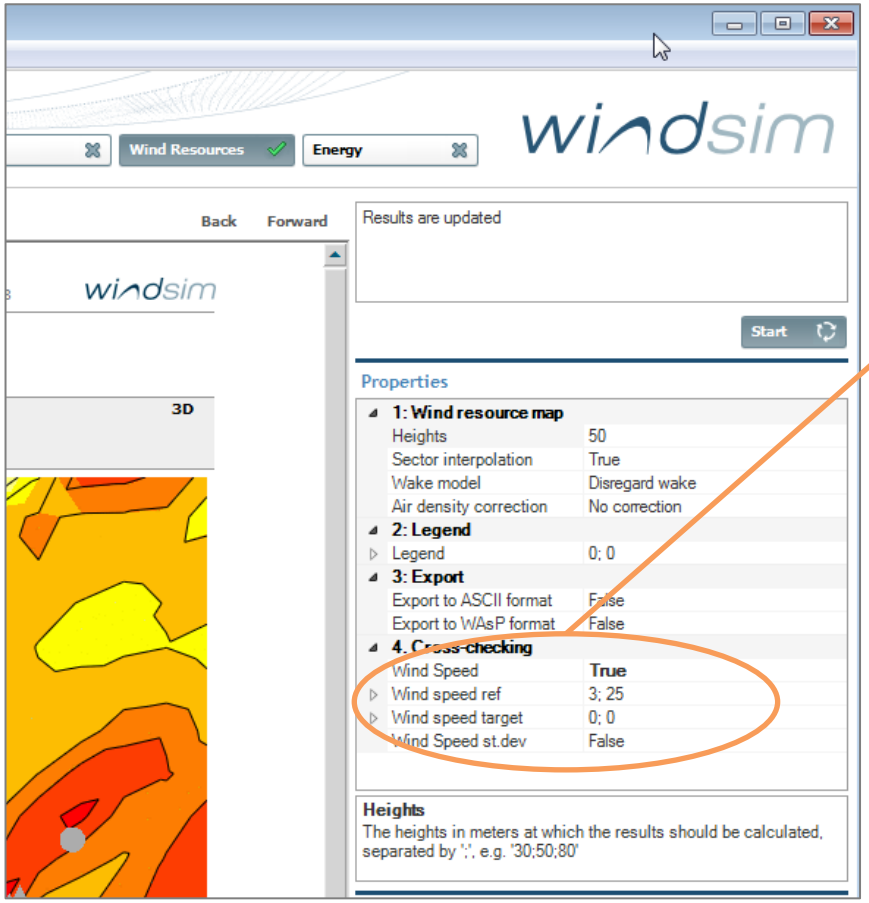


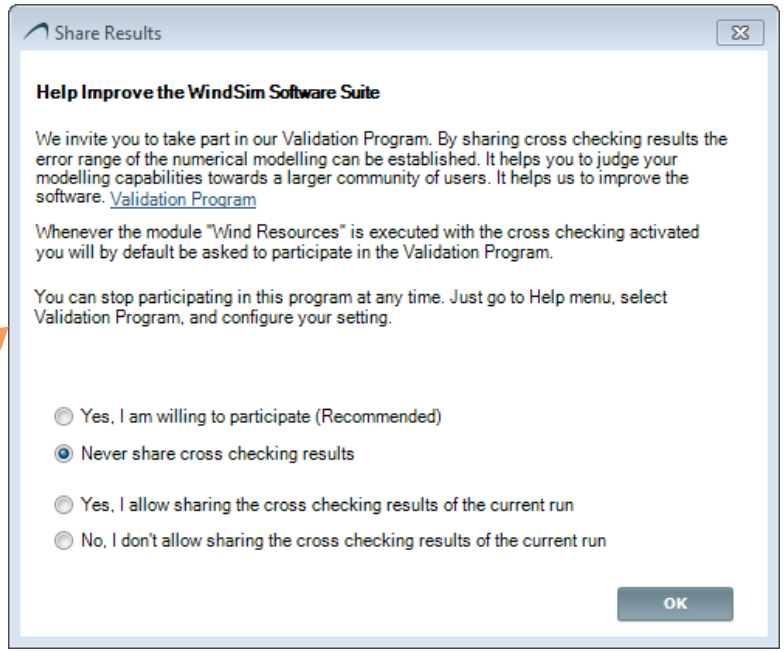




Cross prediction errors, basis for flow modeling uncertainty gradually building up at the WindSim web site

Cross checking – Feed-back form





Cross checking – Feed-back form – Challenges

- What if some users share all cross-checking results, we might get low quality results due to:
    - Low resolution models
    - Poorly specified roughness
    - Poorly specifies physical models
    - Poorly established measurements
        - Short time series
        - Reanalysis data
        - …
    - …

- Define a consistent way of defining cross-checking errors to compare various modeling methods

Bigger models

- So far 1000*1000*60 cells
- We aim to have much more
- More layouts and more climatologies
- More cells in terrain conversion

Break a run properly

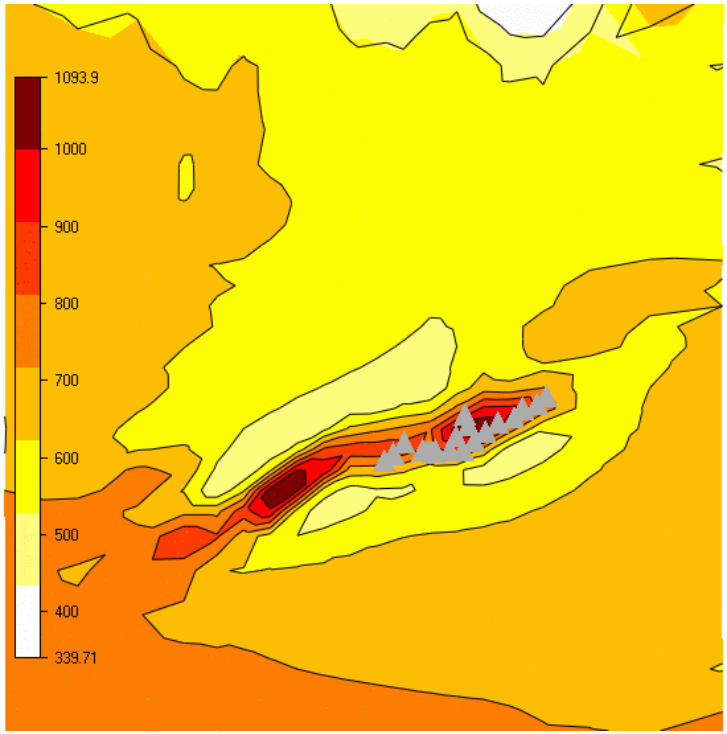
- So far all results are lost when you press the stop button in the wind fields module
- Now you can stop and it will stop at the iteration you are at when you stop

New wall functions

- Deliver the same results as the old functions
- Prevents strong oscillations in residuals in GCV

Improved post-processing

- Power density and mean ambient turbulence plots in the module ”Wind Resources”



Power density (W/m^2)

Improved post-processing

- Restructuring of the energy module

Climatology	Distribution	Gross AEP	Wake loss %
Climatology1	Frequency table	**130.7819**	4.90
Climatology1	Weibull distribution	**128.3603**	5.06
Climatology2	Frequency table	**145.2548**	4.61
Climatology2	Weibull distribution	**142.6373**	4.68
All	Frequency table	**138.0109**	4.75
All	Weibull distribution	**135.4915**	4.86

Table 1. Energy production in GWh/y based on climatology represented by the frequency table and by the Weibull distribution.

Air density (kg/m^3)	Wake model	Multi-wakes model	Roughness (m)	Amb. Turb. Int. (%)	Sub-sectors	Influence range (Rotor diameter)
Individual 1	1	2	Variable	-	5	1.0 - 50.0

Table 2. Site and wake characteristics.

Gross AEP with wake losses in percentage at top level

Improved post-processing

- Restructuring of the energy module

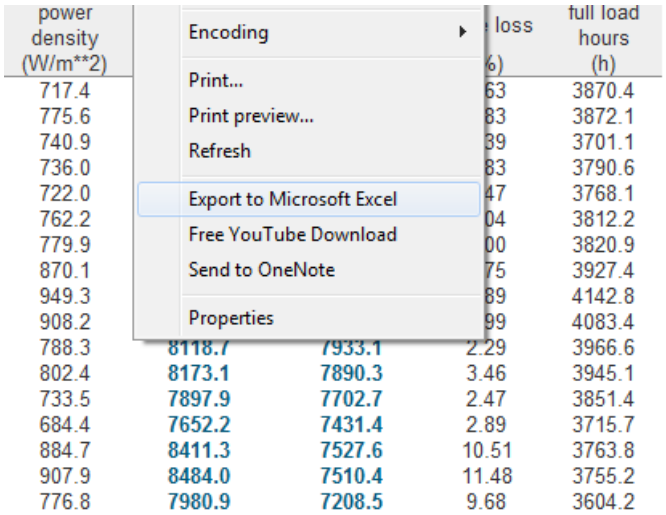
name	power (kW)	hub height (m)	density (kg/m**3)	wind speed (m/s)	power density (W/m**2)	gross AEP (MWh/y)	AEP with wake losses (MWh/y)	wake loss (%)	full load hours (h)
wecs1	2000	80.0	1.204	8.18	717.4	**7789.5**	**7740.7**	0.63	3870.4
wecs2	2000	80.0	1.202	8.41	775.6	**8052.9**	**7744.1**	3.83	3872.1
wecs3	2000	80.0	1.203	8.28	740.9	**7907.1**	**7402.1**	6.39	3701.1
wecs4	2000	80.0	1.203	8.26	736.0	**7882.8**	**7581.2**	3.83	3790.6
wecs5	2000	80.0	1.203	8.20	722.0	**7806.9**	**7536.2**	3.47	3768.1
wecs6	2000	80.0	1.201	8.33	762.2	**7945.2**	**7624.4**	4.04	3812.2
wecs7	2000	80.0	1.201	8.38	779.9	**7960.5**	**7641.9**	4.00	3820.9
wecs8	2000	80.0	1.198	8.72	870.1	**8334.5**	**7854.9**	5.75	3927.4
wecs9	2000	80.0	1.195	9.00	949.3	**8620.8**	**8285.6**	3.89	4142.8
wecs10	2000	80.0	1.197	8.87	908.2	**8506.0**	**8166.8**	3.99	4083.4
wecs11	2000	80.0	1.200	8.47	788.3	**8118.7**	**7933.1**	2.29	3966.6
wecs12	2000	80.0	1.201	8.51	802.4	**8173.1**	**7890.3**	3.46	3945.1
wecs13	2000	80.0	1.205	8.25	733.5	**7897.9**	**7702.7**	2.47	3851.4
wecs14	2000	80.0	1.207	8.04	684.4	**7652.2**	**7431.4**	2.89	3715.7
wecs15	2000	80.0	1.197	8.79	884.7	**8411.3**	**7527.6**	10.51	3763.8
wecs16	2000	80.0	1.196	8.87	907.9	**8484.0**	**7510.4**	11.48	3755.2
wecs17	2000	80.0	1.199	8.39	776.8	**7980.9**	**7208.5**	9.68	3604.2
All	34000	-	-	-	-	137524.3	130781.9	4.90	3846.5
Mean	-	-	1.201	8.47	796.4	-	-	-	-
Reference production at climatology position									
ref..	2000	20.0	1.211	6.82	418.8	**6021.1**	-	-	3010.6
ref..	2000	30.0	1.209	7.26	504.8	**6651.0**	-	-	3325.5
ref..	2000	40.0	1.208	7.50	555.2	**6980.7**	-	-	3490.4
ref..	2000	50.0	1.207	7.71	603.1	**7256.9**	-	-	3628.4
ref..	2000	60.0	1.206	7.86	638.0	**7441.2**	-	-	3720.6
ref..	2000	70.0	1.205	8.01	673.7	**7599.2**	-	-	3799.6
ref..	2000	80.0	1.204	8.11	700.4	**7724.9**	-	-	3862.4
ref..	2000	90.0	1.202	8.22	727.7	**7835.9**	-	-	3917.9
ref..	2000	73.0	1.209	8.04	681.7	**7637.5**	-	-	3818.8

Table 1. Energy production based on the frequency table.

Wake losses, power density and full load hours per turbine, refernce production at climatology point at second level

Improved post-processing

- Excel export



power density (W/m**2)			loss (%)	full load hours (h)
717.4			63	3870.4
775.6			83	3872.1
740.9			39	3701.1
736.0			83	3790.6
722.0			47	3768.1
762.2			04	3812.2
779.9			00	3820.9
870.1			75	3927.4
949.3			89	4142.8
908.2			99	4083.4
788.3	8118.7	7933.1	2.29	3966.6
802.4	8173.1	7890.3	3.46	3945.1
733.5	7897.9	7702.7	2.47	3851.4
684.4	7652.2	7431.4	2.89	3715.7
884.7	8411.3	7527.6	10.51	3763.8
907.9	8484.0	7510.4	11.48	3755.2
776.8	7980.9	7208.5	9.68	3604.2

Direct export to Excel from html tables

Guidelines software development

Where do we get the input for the development plan:

- Company long term strategy
- Commercial potential
- Key customers
- Internal consulting team
- Partners/Resellers
- Support
- Sales

In particular customers share their experiences during the User Meeting, and through surveys

Research activities in WindSim

- Forest
  - Master thesis by Karsten Busch beginning summer 2014
  - Validation data provided by Iberdrola

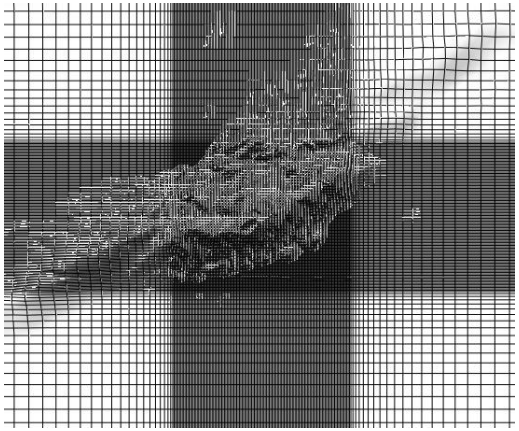
- Actuator disc
  - Phd thesis by Nikolaos Simisiroglou started in 2013
  - Master thesis by Fredrik Seim starts in 2015

- Mesoscale coupling
  - ENERGIX Research project with the UniComputing in Bergen

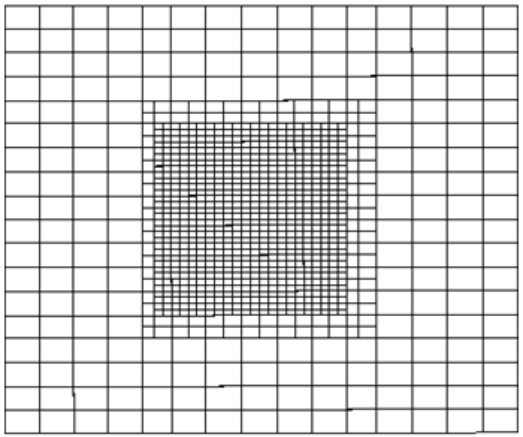
- Forecasting
  - ENERGIX Research project with the UniComputing in Bergen

Gridding

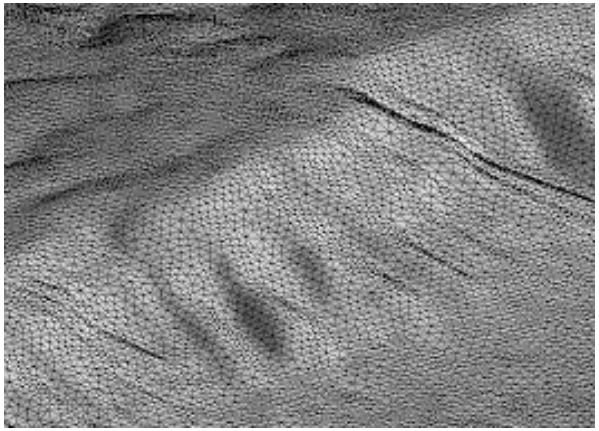
• Structured; available in WindSim including refinement
• Multi-block; available in PHOENICS (CHAM) and other CFD packages (not yet activated in WindSim)
• Unstructured; available in STAR-CCM (CD-adapco), Fluent (ANSYS), OpenFOAM (Open source), PHOENICS (CHAM) and other CFD packages



Structured with refinement



Multi-block



Unstructured

• Structured grids are well proven, but lack the flexibility of an unstructured grid in adapting high and low resolution areas.
• The transition from structured to unstructured grids has been slower than expected. Due to the challenges in creating the optimal grid in a user-friendly way.

Contact

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

WindSim Americas
3505 Lake Lynda Drive
Suite 200, Orlando
FL, 32817, USA
Tel: +1 407 810 9463

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

www.windsim.com
info@windsim.com

WindSim User Meetings

2005 – Francesco and Thomas

2014

WindSim User Meetings

Xuan

Football, blue team against all the others, Chad as goalkeeper (far right)

WindSim User Meetings

Sailing

Shrimps

22:15

Next time:
24-25 June 2015

Tønsberg, Norway