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TECHNICAL NOTE: SITERES

Generalized gridded results format for wind farm site and climate parameters

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Introduction

In several of the last major releases of windPRO, EMD has implemented improved interchange formats to interact with 3rd party tools, such as CFD-models [1, 2] and Optimization models [3]. This document describes the SITERES format, an open and accessible results-format. The SITERES format allows the wind analyst to export and consolidate a complete set of modelled site parameters resulting from a combination of wind measurements and flow conditions. The main purpose is to:

Provide a complete description of the spatial variation of relevant site- and climate-parameters needed to complete a number of wind farm modelling analyses'. The format is to be self-contained.

The SITERES format is - as such - a generalized format and will be useful in wind resource analysis' (AEP-calculations), input to optimization models, particular constraint models, and site-compliance analysis. In windPRO 3.2+, the SITERES format is generated by a windPRO RESOURCE calculation and support is further extended in windPRO 3.5.

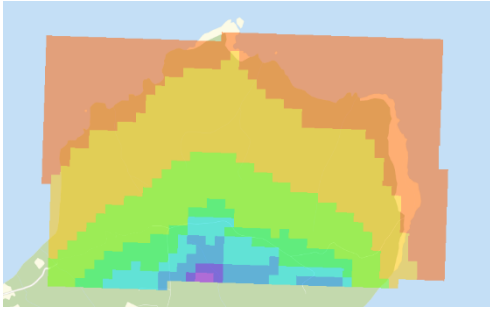

Figure 1: Wind Resources - Loaded into windPRO from SITERES file.

1. Site Results Format

The purpose of the site result format is to consolidate (or export) a set of relevant data to define:

- Site elevations
- Wind resource Weibull parameters
- Turbulence statistics
- Wind shear statistics
- Flow inclination
- Air density
- Wind veer
- Other parameters

All information is contained in a single file (a zipped file, with extension *.siteres, see Figure 2). This file holds an xml-file describing the zip-file content (SiteResult.xml) and several surfer grid files with the actual gridded parameter information (*.grd), one file per parameter, direction and height. The format is self-describing – and allows for inclusion of any parameter that varies in 3D-space – and with a directional dependence – if required.

Elevation_X_X	grd	161,215	2017-05-11 15:21
SiteResult	xml	20,746	2017-05-11 15:21
WeibullA_0_0	grd	139,648	2017-05-11 15:21
WeibullA_0_1	grd	139,648	2017-05-11 15:21
WeibullA_0_2	grd	139,648	2017-05-11 15:21
WeibullA_1_0	grd	139,648	2017-05-11 15:21
WeibullA_1_1	grd	139,648	2017-05-11 15:21
WeibullA_1_2	grd	139,648	2017-05-11 15:21
WeibullA_10_0	grd	148,065	2017-05-11 15:21
WeibullA_10_1	grd	150,375	2017-05-11 15:21
WeibullA_10_2	grd	150,474	2017-05-11 15:21
WeibullA_11_0	grd	139,648	2017-05-11 15:21
WeibullA_11_1	grd	139,648	2017-05-11 15:21
WeibullA_11_2	grd	139,648	2017-05-11 15:21
WeibullA_2_0	grd	139,648	2017-05-11 15:21
WeibullA_2_1	grd	139,648	2017-05-11 15:21
WeibullA_2_2	grd	139,648	2017-05-11 15:21
WeibullA_3_0	grd	139,648	2017-05-11 15:21
WeibullA_3_1	grd	139,648	2017-05-11 15:21
WeibullA_3_2	grd	139,648	2017-05-11 15:21
WeibullA_4_0	grd	150,474	2017-05-11 15:21

Figure 2: Part of contents-listing of a SITERES file.

The overall structure of an SITERES XML file is shown in the Figure 3. A detailed description of each of the nodes is also available in the following section. A sample version of the XML Schema Definition can be found in the download link below, as well as two sample of ".siteres" files, one written from windPRO RESOURCE and one from 'GASP' (Global Atlas of Siting Parameters) available for download from the windPRO/Data menu.

SITERES Request XSD: https://help.emd.dk/knowledgebase/content/Files/SiteResults.xsd
SampleFile (from windPRO): /SiteresSample_Res_200_Hub_80.0_120.0_0.siteres
SampleFile (from GASP): /EMD-GASP_-28.7955_-49.9698_5_5.siteres

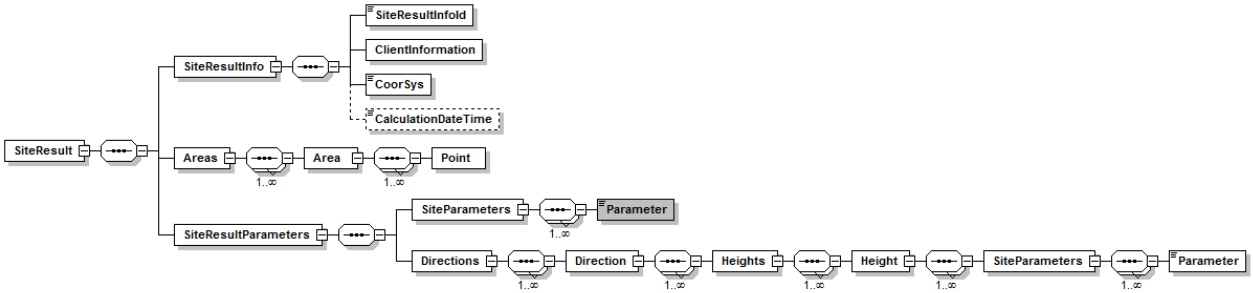

Figure 3: Outline of Site Result Format (XML Schema Definition).

1.1 SiteResultInfo

The first part of a SITERES result file is the meta information in the SiteResultInfo tag. It holds information of the client who generated the information – as well as job-id/folder and calculation time.

```
<SiteResultInfo>
  <SiteResultInfoId>84b4300d-ffd8-4d62-a544-ada528b1cf16</SiteResultInfoId>
  <CoorSys Type="WINDPRO">60: 22: 10: 0, UTM (south)-WGS84 Zone: 22</CoorSys>
  <ClientInformation Name="windPRO" Version="3.5.448" UserName="ls@emd.dk"/>
  <CalculationDateTime>2021-06-23T10:24:13.674+02:00</CalculationDateTime>
</SiteResultInfo>
```

The CoorSys node can also be omitted if the coordinate system is not known, but once the result is used in windPRO, then the user will be asked to define the coordinate system. So, if the generating model knows the coordinate system, then it should be added into XML file. In the current version, there are two ways to define the coordinate system:

- WINDPRO: This type is a string that represents the coordinate system in windPRO and it is normally used in flow request files from windPRO and hence then copied to the result
- EPSG: This type allows the flow model to write the coordinate system as an EPSG code

As an option, it is possible to add a calculation time-stamp to the CalculationDateTime node.

1.2 Areas

The Areas node defines the horizontal areas that the user is interested in. Each Area node contains a number of point nodes which defines the polygon of the area. The area that is defined is only the area of interest. The flow model may use a much larger area around the area of interest in the simulations.

```
<Areas>
  <Area Name="A">
    <Point x="598437.28" y="6811857.53"/>
    <Point x="598437.28" y="6816457.53"/>
    <Point x="602837.28" y="6816457.53"/>
    <Point x="602837.28" y="6811857.53"/>
    <Point x="598437.28" y="6811857.53"/>
  </Area>
</Areas>
```

1.3 SiteResultParameters

SiteResultParameters section holds a description of each individual site parameter, a link to the area covered by the file, the file type and the height – along with a link to the data files. The site result parameters sections are divided into two sections, *one for omni-directional results (SiteParameters)* and *one for directionally-dependent results (Directions).*

1.3.1 SiteParameters

Currently the following parameters listed in the table below are allowed within a SITERES file, those marked with * are required parameters to fulfill minimum requirements for e.g. a Site Compliance fatigue assessment or use the file for optimization with fatigue load constraints (lifetime):

*Table 1: List of possible parameters in a Siteres file together with a description and the possible dependence on direction and height. All required variables are marked by * for resource purpose and by ** for loads purpose, non-marked variables are optional. Similar required minimal resolutions are also marked by *.*

Name	Description	Resolution
Elevation*	Elevation of terrain at site position	omni*
Roughness	Roughness	omni
RefRoughness	Upstream 'WAsP' weighted roughness	sector
WindSpeed	Average wind speed	height, omni, sector
WeibullA*	Weibull scale parameter (A)	height, omni, sector*
WeibullK*	Weibull shape parameter (k)	height, omni, sector*
WeibullF*	Sector frequency	height, sector*
TIMean	Mean turbulence intensity	height, omni, sector
TIMean_a	Mean TI slope of linear fit: σ_μ=au+b	height, omni, sector
TIMean_b	Mean TI off-set of linear fit: σ_μ=au+b	height, omni, sector
TIStd_a	Std TI slope of linear fit: σ_σ=au+b	height, omni, sector
TIStd_b	Std TI off-set of linear fit: σ_σ=au+b	height, omni, sector
TI90_a**	P90 slope of linear fit: σ_{90}=au+b=σ_μ+1.28σ_σ	height, omni, sector*
TI90_b**	P90 off-set of linear fit: σ_{90}=au+b=σ_μ+1.28σ_σ	height, omni, sector*
TI90_15	Mean turbulence intensity at 15m/s	
Cct**	Turbulence structure correction	height, omni*, (sector?)
WindShearMean**	Average wind shear	height, sector*
WindShearStd	Std of wind shear	height, sector
FlowInclination**	Inclination of wind flow (positive up)	Height, sector*
WindVeer	Turning of wind with height in deg/m	sector
SpeedUp	Speed-up relative to inlet/reference conditions	sector
AirDensityNormal**	Air density for normal operation conditions	omni
AirDensityExtremeWind	Air density at high wind speeds, relevant for extreme wind speed	omni
SqrtETA	Partial safety factor correction (IEC ed. 4)	Height, omni
ExtremeWind50y	Extreme wind speed, 50-year return period (2% annual exceedance probability)	height, omni
ExtremeWind50yCorr	Extreme wind speed, 50-year return period including all corrections (AirDensityExtremeWind and SdrtETA)	height, omni
ExtremeWindAlpha**	α - slope/dispersion parameter of Gumbel fit (see LOADs manual Appendix I)	height, omni*
ExtremeWindBeta**	β - off-set/mode parameter of Gumbel fit	height, omni*

An example of from an XML-file is shown in Figure 4 below.

```
<SiteParameters>
  <Parameter Type="WindSpeed" Area="A" FileType="GRD" Height="80">WindSpeed_X_0.grd</Parameter>
  <Parameter Type="WeibullA" Area="A" FileType="GRD" Height="80">WeibullA_X_0.grd</Parameter>
  <Parameter Type="WeibullK" Area="A" FileType="GRD" Height="80">WeibullK_X_0.grd</Parameter>
  <Parameter Type="WindShearMean" Area="A" FileType="GRD" Height="80">WindShearMean_X_0.grd</Parameter>
  <Parameter Type="WindShearStd" Area="A" FileType="GRD" Height="80">WindShearStd_X_0.grd</Parameter>
  <Parameter Type="FlowInclination" Area="A" FileType="GRD" Height="80">FlowInclination_X_0.grd</Parameter>
  <Parameter Type="TIMean" Area="A" FileType="GRD" Height="80">TIMean_X_0.grd</Parameter>
  <Parameter Type="TIMean_a" Area="A" FileType="GRD" Height="80">TIMean_a_X_0.grd</Parameter>
  <Parameter Type="TIMean_b" Area="A" FileType="GRD" Height="80">TIMean_b_X_0.grd</Parameter>
  <Parameter Type="TIStd_a" Area="A" FileType="GRD" Height="80">TIStd_a_X_0.grd</Parameter>
  <Parameter Type="TIStd_b" Area="A" FileType="GRD" Height="80">TIStd_b_X_0.grd</Parameter>
  <Parameter Type="TI90_a" Area="A" FileType="GRD" Height="80">TI90_a_X_0.grd</Parameter>
  <Parameter Type="TI90_b" Area="A" FileType="GRD" Height="80">TI90_b_X_0.grd</Parameter>
```

Figure 4: Omnidirectional Parameters in SITERES-file.

1.3.2 Directions

An example of the directionally dependent part of the SiteResultsParameters-node is shown in Figure 5 below.

```
<Directions>
  <Direction Dir="0">
    <Heights>
      <Height AGL="80">
        <SiteParameters>
          <Parameter Type="WindSpeed" Area="A" FileType="GRD">WindSpeed_0_0.grd</Parameter>
          <Parameter Type="WeibullA" Area="A" FileType="GRD">WeibullA_0_0.grd</Parameter>
          <Parameter Type="WeibullK" Area="A" FileType="GRD">WeibullK_0_0.grd</Parameter>
          <Parameter Type="WeibullF" Area="A" FileType="GRD">WeibullF_0_0.grd</Parameter>
          <Parameter Type="WindShearMean" Area="A" FileType="GRD">WindShearMean_0_0.grd</Parameter>
          <Parameter Type="WindShearStd" Area="A" FileType="GRD">WindShearStd_0_0.grd</Parameter>
          <Parameter Type="FlowInclination" Area="A" FileType="GRD">FlowInclination_0_0.grd</Parameter>
          <Parameter Type="TIMean" Area="A" FileType="GRD">TIMean_0_0.grd</Parameter>
          <Parameter Type="TIMean_a" Area="A" FileType="GRD">TIMean_a_0_0.grd</Parameter>
          <Parameter Type="TIMean_b" Area="A" FileType="GRD">TIMean_b_0_0.grd</Parameter>
          <Parameter Type="TIStd_a" Area="A" FileType="GRD">TIStd_a_0_0.grd</Parameter>
          <Parameter Type="TIStd_b" Area="A" FileType="GRD">TIStd_b_0_0.grd</Parameter>
          <Parameter Type="TI90_a" Area="A" FileType="GRD">TI90_a_0_0.grd</Parameter>
          <Parameter Type="TI90_b" Area="A" FileType="GRD">TI90_b_0_0.grd</Parameter>
          <Parameter Type="TIMean_a" Area="A" FileType="GRD">TIMean_a_0_0.grd</Parameter>
          <Parameter Type="TIMean_b" Area="A" FileType="GRD">TIMean_b_0_0.grd</Parameter>
          <Parameter Type="TIStd_a" Area="A" FileType="GRD">TIStd_a_0_0.grd</Parameter>
          <Parameter Type="TIStd_b" Area="A" FileType="GRD">TIStd_b_0_0.grd</Parameter>
          <Parameter Type="TI90_a" Area="A" FileType="GRD">TI90_a_0_0.grd</Parameter>
          <Parameter Type="TI90_b" Area="A" FileType="GRD">TI90_b_0_0.grd</Parameter>
        </SiteParameters>
      </Height>
      <Height AGL="120">
        <SiteParameters>
          <Parameter Type="WindSpeed" Area="A" FileType="GRD">WindSpeed_0_1.grd</Parameter>
          <Parameter Type="WeibullA" Area="A" FileType="GRD">WeibullA_0_1.grd</Parameter>
          <Parameter Type="WeibullK" Area="A" FileType="GRD">WeibullK_0_1.grd</Parameter>
          <Parameter Type="WeibullF" Area="A" FileType="GRD">WeibullF_0_1.grd</Parameter>
          <Parameter Type="WindShearMean" Area="A" FileType="GRD">WindShearMean_0_1.grd</Parameter>
          <Parameter Type="WindShearStd" Area="A" FileType="GRD">WindShearStd_0_1.grd</Parameter>
          <Parameter Type="FlowInclination" Area="A" FileType="GRD">FlowInclination_0_1.grd</Parameter>
```


Figure 5: Directional Dependent Parameters in SITERES-file.

2. References

[1] Sørensen T.G.: *Generalized Flow request and result format (version 1.4),* EMD A/S, 2016-10-25, available at: http://www.emd.dk/files/flow/EMD_technote_Generalized_Flow_Request_Result.pdf
[2] Svenningsen et al: *WAsP-CFD Validation Report, EMD International*, 2013-07-10, available at: http://help.emd.dk/knowledgebase/content/TechNotes/TechNote_4_WAsPCFD_EMD_ValidationReport.pdf
[3] Thøgersen, M.L.: *GIRAFFA Generalized i/o-format for adapting optimization frameworks for windfarm-applications*, EMD A/S, 2017-05-15, available at: https://help.emd.dk/knowledgebase/content/TechNotes/TechNote_GIRAFFA_Mar_2018.pdf

3. Document History

2020/2021: Draft adaptation for Optimize and GASP projects
2017-05-28: Added more parameters (speedup, windveer, turbulence, inclination) – and updated sample
2018-03-07: Review
2020-05-07: Extension to full set of Site Compliance parameters (LS) – new sample pending
2021-06-22: Prepared for windPRO 3.5 release