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Technical note:

Generalized Flow request and result format

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Introduction

In windPRO 2.9 WAsP-CFD was introduced as a new flow model that allowed windPRO users to perform high-resolution CFD calculations on a remote cluster. The flow results from the model are used in the classical wind atlas approach, where measured wind distributions are used to generate a generalized wind atlas (wind statistics) that can then be used to calculate wind distributions at other locations in the region. In windPRO 3.0 we introduced time-varying calculations that use the raw flow-results from WAsP-CFD to transfer wind measurements from one location to another. In order to allow for integration of other flow models within windPRO we have defined two new formats:

- a request file from windPRO (or any other client) to a flow model
- a result format from the flow model to windPRO (or any other client)

This document describes these two formats so that it will be possible for flow model developers to support them. The formats are described in the following sections:

- [Flow request format](#)
- [Flow result format](#)



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Flow request format

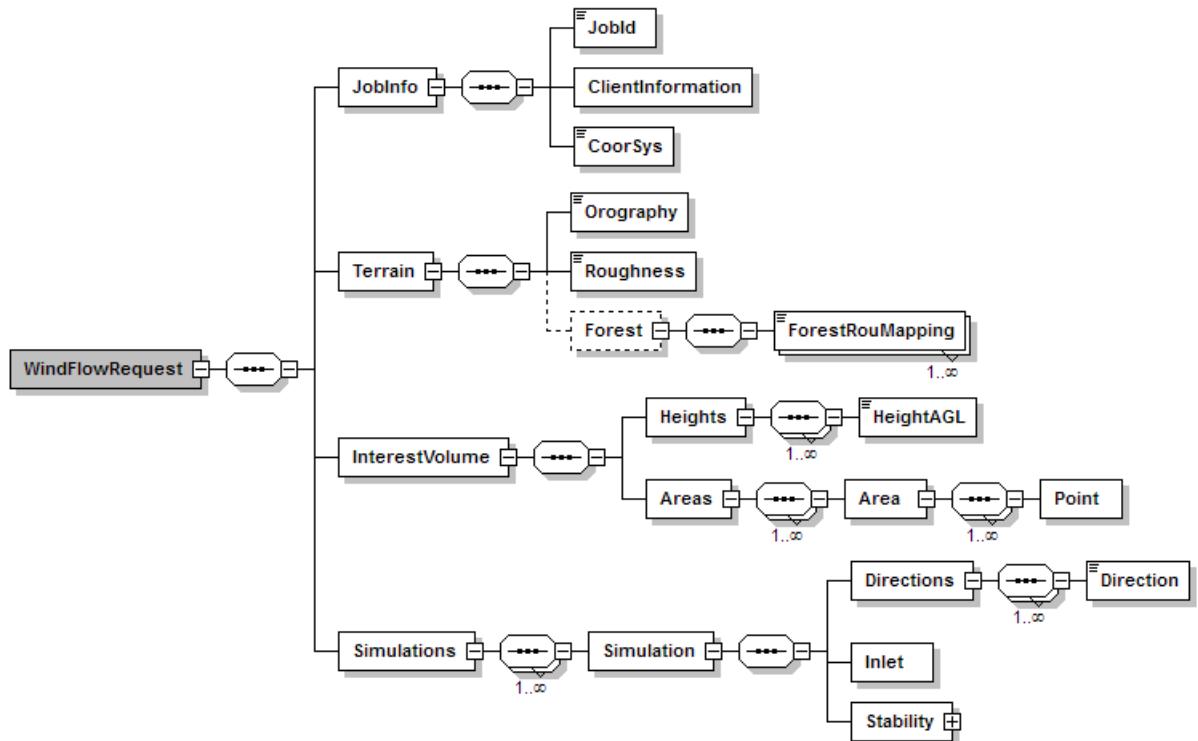
The purpose of the flow request format is to export data from windPRO and to define:

- Meta data such as coordinate system and client information
 - The terrain for the site including possible forest definitions
 - The interest volume which consist of the horizontal areas of interest and the heights needed in the result
 - The simulations that the user wants to be performed. A simulation consists of the directions that are needed and the stability conditions needed

The flow request file does not contain specific flow model settings such as buffer around interest area, net generating/smoothing parameters, convergence criteria etc. These settings are still controlled in the flow model software either as user options or automatically defined by the terrain and directions.

A flow request file is a compressed zip file that has the extension “.flowreq”. Inside the “.flowreq” file there can be a number of files needed for the calculation. The main file in the “.flowreq” file is called WindFlowRequest.xml which as the name indicates is an XML file that describes the request. In the following the contents and options in the XML file will be described.

The overall structure of a flow request XML file is shown in the figure below.



The XML Schema Definition can be found [here](#):

<http://www.emd.dk/files/flow/WindFlowRequest.xsd>

An example of a “.flowreq” file can be found [here](#) (rename to .zip to inspect):

An example of a flowreq file can be found at



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JobInfo

The first part of the XML is the *JobInfo* node which contains meta data for the requests that the flow model is expected to copy to the result format (described later in this document). An example of the first part of a flow request XML file:

```
<WindFlowRequest Version="0.9">
  <JobInfo>
    <JobId>CC1CC95F-A7D2-4D07-8E4A-938EF7C8BFF6</JobId>
    <CoorSys Type="WINDPRO">60: 22: 10: 0, UTM (south)-WGS84 Zone: 22</CoorSys>
    <ClientInformation Name="windPRO" Version="3.1.999" UserName="tgs@emd.dk"/>
  </JobInfo>
```

Terrain

The next part of the XML is the *Terrain* node which defines the terrain for the flow calculation. An example of the *Terrain* node:

```
<Terrain Latitude="-28.793670">
  <Orography Type="MAP">mixed_97_0_0.map</Orography>
  <Roughness Type="MAP">mixed_97_0_0.map</Roughness>
  <Forest>
    <ForestRouMapping RouMin="0.3" RouMax="0.4" Height="15" Density="5">
      <ForestRouMapping RouMin="0.4" RouMax="0.5" Height="25" Density="10">
    </Forest>
  </Terrain>
```

In this example the terrain is defined by orography and roughness in a combined WAsP .map file named “mixed_97_0_0.map” that is contained in the “.flowres” file (the compressed zip file which also contains the flow request XML). It is also possible to have separate .map files for orography and roughness. Furthermore, the terrain can also be defined in XYZ grid files in which case the *Type* attribute would be XYZ instead of MAP as in the example above.

The *Terrain* node can also contain the forest definition which is optional. The only supported forest definition at the moment is to define forest areas by their roughness length in the roughness terrain file. Each roughness mapping defines the height and density of the forest. In the future there will be other options and attributes added to the forest definition. If the flow model has a more sophisticated approach to defining forest, it is also possible to use that and leave it out of the flow request from windPRO.

InterestVolume

The *InterestVolume* node contains two child nodes:

```
<InterestVolume>
  <Heights>
  <Areas>
</InterestVolume>
```

The *Heights* node defines the heights above ground level that the user is interested in:

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```
<Heights>
  <HeightAGL>5</HeightAGL>
  <HeightAGL>10</HeightAGL>
  <HeightAGL>20</HeightAGL>
  <HeightAGL>33</HeightAGL>
  <HeightAGL>48</HeightAGL>
  <HeightAGL>65</HeightAGL>
  <HeightAGL>80</HeightAGL>
  <HeightAGL>100</HeightAGL>
  <HeightAGL>120</HeightAGL>
  <HeightAGL>150</HeightAGL>
  <HeightAGL>200</HeightAGL>
  <HeightAGL>250</HeightAGL>
  <HeightAGL>300</HeightAGL>
</Heights>
```

The *Areas* node defines the horizontal areas that the user is interested in:

```
<Areas>
  <Area Name="Aparados da Serra" Resolution="20">
    <Point x="598239.52" y="6817140.76"/>
    <Point x="601786.74" y="6815535.45"/>
    <Point x="601767.31" y="6813319.49"/>
    <Point x="599815.47" y="6813336.45"/>
    <Point x="596268.68" y="6814941.17"/>
    <Point x="596287.05" y="6817157.11"/>
    <Point x="598239.52" y="6817140.76"/>
  </Area>
</Areas>
```

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 for the result. The flow model will typically use a much larger area around the area of interest in the simulations. Likewise, the *Resolution* defined for the area is merely the requested resolution in the result and the flow model will likely run at a finer resolution during the calculations.

Simulations

The final part of the flow request XML is the *Simulations* node:



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```
<Simulations>
  <Simulation Name="Neutral">
    <Inlet RefSpeed="10" RefHeight="10"/>
    <Directions>
      <Direction z0="0.1">0</Direction>
      <Direction z0="0.1">30</Direction>
      <Direction z0="0.1">60</Direction>
      <Direction z0="0.1">90</Direction>
      <Direction z0="0.1">120</Direction>
      <Direction z0="0.1">150</Direction>
      <Direction z0="0.1">180</Direction>
      <Direction z0="0.1">210</Direction>
      <Direction z0="0.1">240</Direction>
      <Direction z0="0.1">270</Direction>
      <Direction z0="0.1">300</Direction>
      <Direction z0="0.1">330</Direction>
    </Directions>
    <stability>
      <Mol>10000</Mol>
    </Stability>
  </Simulation>
</Simulations>
```

The *Simulations* node contains one or more *Simulation* nodes where each of them can have varying inlet conditions, stability conditions and directions. The overall inlet conditions (in the *Inlet* node) which consist of a reference wind speed and a reference height is defined by the user, but in most cases the flow model results will not vary significantly because of these settings.

The *Directions* node contains one or more *Direction* nodes that define the inlet directions the user is interested in. Normally the directions will be spread evenly around the wind rose, but it is also possible to have directions closer to each other in the main wind directions. For each direction the user (or done automatically in windPRO) can also define a reference roughness *z0* that the flow model can use for the inlet profile. However, the flow model can also override this reference roughness if needed (some models calculates the reference roughness so that the inlet profile reflects the outer terrain).

Finally, the *Simulation* node contains a *Stability* node that defines the stability conditions the user is interested in. The only supported definition of stability is Monin Obukhov Length (MOL). It will be up to the flow model how the defined MOL is simulated and how it influences the inlet profile (the resulting inlet profile for a simulation is defined in the flow result format).



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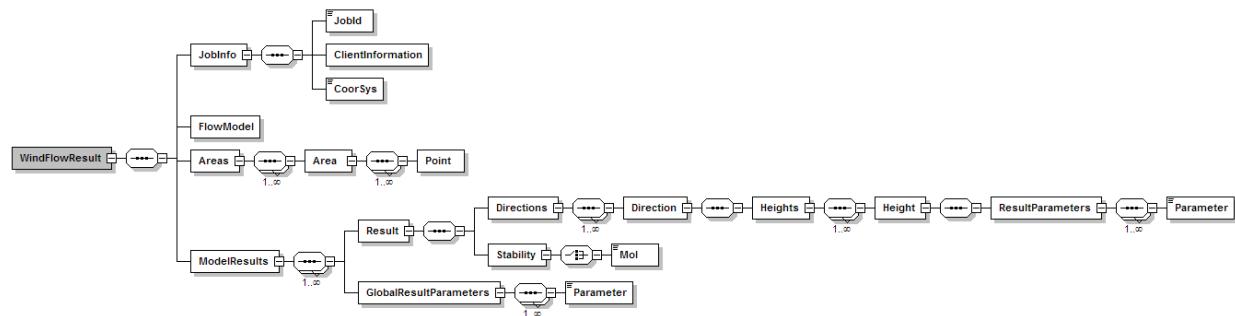
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Flow result format

The flow result format is also a compressed zip file that contains an XML file and a number of files that contains the actual flow results. A flow result file has the extension “.flowres” and it could come from any flow model software that supports it. Normally, the “.flowres” file would correspond to a flow request file (“.flowreq”), but it is a stand-alone file so it could also just be exported from a flow model that was not setup using a “.flowreq” file.

Inside the “.flowres” file there is a XML file called WindFlowResult.xml which describes the contents of the “.flowres” file. The overall structure of this XML is shown below.



The XML Schema Definition can be found here:

<http://www.emd.dk/files/flow/WindFlowResult.xsd>

An example of a “.flowres” can be found here:

http://www.emd.dk/files/flow/flow_12_weng_GRD.flowres

JobInfo

Similar to the flow request file the first part of a result file is the Meta information in the *JobInfo* tag.

```
<JobInfo>
    <JobId>D7199A3D-C194-4E1F-B7B0-6FE8E78F9D1E</JobId>
    <CoorSys Type="WINDPRO">60: 22: 10: 0, UTM (south)-WGS84 Zone: 22</CoorSys>
    <ClientInformation Name="windPRO" Version="3.1.999" UserName="tgs@emd.dk"/>
    <CalculationDateTime>2015-09-09T11:46:55.223+02:00</CalculationDateTime>
</JobInfo>
```

If the result file is produced from a model that was started with a flow request file the *JobId*, *CoorSys* and *ClientInformation* tags are simply copied from the request XML to the result XML. If there is no corresponding request file for the result the *JobId* and *ClientInformation* nodes can be left out of the result XML. The *CoorSys* node can also be left out if the coordinate system is not known, but once the result is used in windPRO the user will be asked to define the coordinate system, so if the flow model has the coordinate system information it should be put in the XML. In the current version there are two ways (*Type*) to define the coordinate system:

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- 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

Areas

The *Areas* node in a result file is identical to the *Areas* node in a request file as described previously in this document. In a result file the *Name* attribute of an *Area* node is used to identify the area later in the result file (Simulations) where the raw flow results are defined.

ModelResults

The *ModelResults* node of the result XML defines where the results from the flow model can be found inside the “.flowres” file. The *ModelResults* node contains one or more *GlobalResultParameters* nodes and one or more *Result* nodes.

The *GlobalResultParameters* node is intended for results that are not specific to a simulation, height or direction. As an example the Elevation of the terrain is a global result parameter:

```
<GlobalResultParameters>
    <Parameter Type="Elevation" Area="Aparados da Serra" FileType="GRD">0_Elevation.grd</Parameter>
</GlobalResultParameters>
```

The *Parameter* node is used both in the *GlobalResultParameters* node and in the *Result* node (described later) to point to a grid of results. The value (text in between the tags) of the *Parameter* node is the filename (e.g. 0_Elevation.grd) that has the result parameter in the “.flowres” file. There are three mandatory attributes for each parameter:

- *Type*: This defines the type of the parameter and the supported types are:
 - o *Elevation*: The elevation of the terrain
 - o *Turn*: The direction deflection from the inlet to a given point
 - o *HorzWindSpeed*: The horizontal wind speed
 - o *Inclination*: The inclination difference between the inlet and a given point
 - o *TurbIntensity*: The turbulence intensity
- *Area*: This refers back to the *Name* of an *Area* in the *Areas* node of the result XML file. It tells which area the parameter is covering
- *FileType*: There are two different types of formats supported for the raw results:
 - o *GRD*: This means that the results are stored in a Surfer Grid format. The Surfer Grid format is a simple format that only holds regular grids with a given resolution in the X and Y direction. If the area covered is not a regular grid the Surfer grid file will contain NaN values for points outside the area.
 - o *FLOWDAT*: This is a file type invented for .flowres files. The format is similar to XYZ files where each line has an x/y coordinate and then a value. In “.flowdat” files it is possible to have more values for each line, so that for a given point it is possible to have values for all simulations, directions, heights and parameters. Another advantage of “.flowdat” files is that it can contain irregular areas compared to Surfer grid files. The format is described in more details later when it comes to actual flow results from the model
- *ColName* (optional): If the *FileType* is FLOWDAT then this attribute defines which column that represents this result parameter in the .flowdat file. See more later under flow results



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The next part of the *ModelResults* node is the actual flow results in one or more *Result* nodes. There will be one *Result* node for each *Simulation* node that was in the request file. The first part of a *Result* node will be:

```
<Result Name="Neutral">
  <Stability>
    <Mol>10000</Mol>
  </Stability>
```

The *Name* attribute will be similar to the name in the request file and the same goes for the *Stability* node. The next part is the *Directions* node which contains one or more *Direction* nodes:

```
<Directions>
  <Direction Dir="0" z0="0.10000">
  <Direction Dir="30" z0="0.10000">
  <Direction Dir="60" z0="0.10000">
  <Direction Dir="90" z0="0.10000">
  <Direction Dir="120" z0="0.10000">
  <Direction Dir="150" z0="0.10000">
  <Direction Dir="180" z0="0.10000">
  <Direction Dir="210" z0="0.10000">
  <Direction Dir="240" z0="0.10000">
  <Direction Dir="270" z0="0.10000">
  <Direction Dir="300" z0="0.10000">
  <Direction Dir="330" z0="0.10000">
</Directions>
```

Each *Direction* node is represented by its inlet direction in the *Dir* attribute and the reference roughness used in the *z0* attribute.

Each of the *Direction* nodes contains a *Heights* node which contains one or more *Height* nodes.

```
<Direction Dir="0" z0="0.10000">
  <Heights>
    <Height AGL="5" WS="8.49">
    <Height AGL="10" WS="10.00">
    <Height AGL="20" WS="11.51">
    <Height AGL="33" WS="12.59">
    <Height AGL="48" WS="13.41">
    <Height AGL="65" WS="14.06">
    <Height AGL="80" WS="14.52">
    <Height AGL="100" WS="15.00">
    <Height AGL="120" WS="15.40">
    <Height AGL="150" WS="15.88">
    <Height AGL="200" WS="16.51">
    <Height AGL="250" WS="16.99">
    <Height AGL="300" WS="17.39">
  </Heights>
</Direction>
```

Each *Height* node is defined by the height above ground level in the *AGL* attribute and the inlet wind speed in the *WS* attribute.



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Each *Height* node contains a *ResultParameters* node that contains one or more *Parameter* nodes:

```
<Direction Dir="0" z0="0.10000">
  <Heights>
    <Height AGL="5" WS="8.49">
      <ResultParameters>
        <Parameter Type="Turn" Area="Aparados da Serra" FileType="GRD">0_0_Turn_000_0005.grd</Parameter>
        <Parameter Type="HorzWindSpeed" Area="Aparados da Serra" FileType="GRD">0_0_HorzWindSpeed_000_0005.grd</Parameter>
      </ResultParameters>
```

The *Parameter* node is described previously in this document. In the above example there are two parameters for the given height. Both parameters are part of the “Aparados de Serra” Area and they are stored as Surfer Grid files in the “.flowres” file. So it means that the “0_0_Turn_000_0005.grd” file contains a grid representing direction deflection for this simulation, direction and height.

The same result could be stored in “.flowdat” files in which case the XML would be:

```
<Direction Dir="0" z0="0.10000">
  <Heights>
    <Height AGL="5" WS="8.49">
      <ResultParameters>
        <Parameter Type="Turn" Area="Aparados da Serra" FileType="FLOWDAT" ColName="d000.Turn">0_0_0005.flowdat</Parameter>
        <Parameter Type="HorzWindSpeed" Area="Aparados da Serra" FileType="FLOWDAT" ColName="d000.HorzWindSpeed">0_0_0005.flowdat</Parameter>
      </ResultParameters>
    </Height>
```

So in this case both the *Turn* and *HorzWindSpeed* parameter is stored in a file called “0_0_0005.flowdat”. Each *Parameter* node then has an attribute called *ColName* which defines the column in the “.flowdat” file.

The overall structure of a “.flowdat” file is:

[Version]
[Type]
[GridDef]
[ColNames]
[DataLine]
...
[DataLine]

The [Version] line will always be 1.0 for now. The [Type] line can be either 1 or 2, where 1 means that the file contains a regular grid and 2 means that it contains an irregular grid. If the [Type] is 1 the [GridDef] line will have this format:

[Lower_Left_X] [Lower_Left_Y] [Resolution] [X_Count] [Y_Count]

and if the [Type] is 2 then the [GridDef] line will be:

[Lower_Left_X] [Lower_Left_Y] [Upper_Right_X] [Upper_Right_Y]

The [ColNames] line is a TAB-separated line which holds the name of each column in the results. There will always be a X and Y column and the rest of the columns depend on what parameters are in the result. The column name in the “.flowdat” file corresponds to the *ColName* attribute of a *Parameter* node.

This is an example of the first part of a “.flowdat” file with a regular grid:



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```
1.0
1
596268.68  6813319.49  50.00   111 78
x   y   Elevation  d000.Turn  d030.Turn  d060.Turn  d090.Turn  d12
596318.69  6814919.50  9.217   -1.417  1.041   2.400   1.353   -1.008
596318.69  6814969.50  9.161   -1.511  0.986   2.439   1.445   -0.951
596318.69  6815019.50  8.575   -1.582  0.947   2.472   1.515   -0.912
596318.69  6815069.50  8.154   -1.617  0.914   2.475   1.550   -0.879
596318.69  6815119.50  7.972   -1.602  0.877   2.428   1.541   -0.846
596318.69  6815169.50  7.853   -1.531  0.843   2.327   1.478   -0.816
596318.69  6815219.50  7.259   -1.401  0.825   2.184   1.360   -0.803
```

An example of a “.flowres” file using “.flowdat” files can be found here:

http://www.emd.dk/files/flow/flow_12_weng_FLOWDAT.flowres