# **General modules**

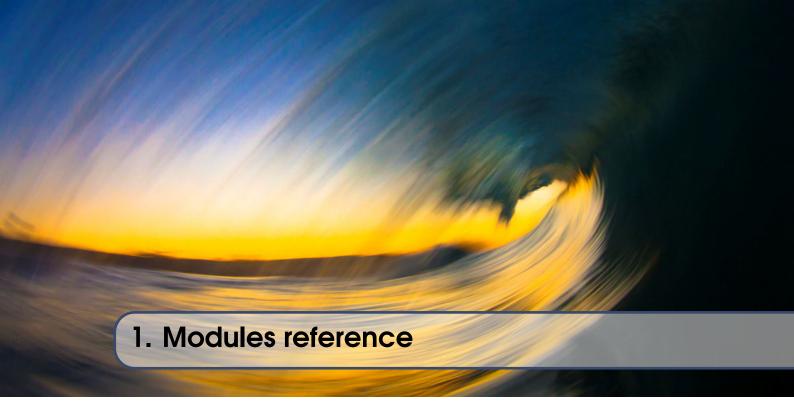
package for iFlow

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The package general provides auxiliary modules that may be used in any simulation. The functionalities of the modules include saving output, loading saved files, sensitivity analyses and calibration. This chapter provides a short overview of all modules in the package general and the required input and expected output. The modules have been ordered into sections for the purpose of providing structure to this chapter.

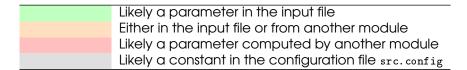
# **Explanation of terms and colours**

Behind the input variables we will mention several data types. While some data types may be obvious, some others are explained in the table below:

Space-separated num- bers	real numbers separated by one or more spaces. Do not use comma's or other markers to separate the numbers.		
Grid-conform array n- dimensional	a numpy array with $n$ (i.e. some number) or fewer (!) dimensions. More dimensions than $n$ is not allowed. All axes should be grid conform. That means that the length of a dimension should either be 1 or equal to the size of the corresponding grid axis. If $n$ is larger than the grid size, the length of this axis is free. Note that a single number counts as a grid-conform array.		
General n-dimensional	either a grid-conform array or a numerical or analytical function. In both cases they may $n$ (i.e. some number) or fewer dimensions.		
iFlow grid	a grid variable with underlying subvariables as described in the manual (Dijkstra, 2017)		

The cells with input variables have been colour-coded to indicate whether the variable is likely to be given in the input file, computed by another module or given in the configuration file. By the very nature of iFlow this is only indicative and depends on the modules used. As an example, almost any variable given in the input file may be used as a variable in a

sensitivity analysis. It then becomes an input parameter of the sensitivity analysis module in the input file. The sensitivity analysis module delivers it to the module that uses this variable.



# 1.1 Output saving and loading

# 1.1.1 Output

The module Output is the standard output module of iFlow. It saves the variables listed after requirements on the output grid to a Python Pickle file. Additionally to the listed variables, it saves the output grid under the name 'grid' and it saves all the configuration and input file variables. For more information and examples, see the iFlow framework manual (Dijkstra, 2017).

Туре		Normal
Submodules		None
Input	requirements	Space-separated strings. The keyword requirements should be placed in the input file. It may be placed anywhere, but it is best practice to put it at the last line. iFlow uses this keyword in general to determine what variables should be computed. The module Output uses this information to determine the variables to save. Additionally Output saves the output grid under the name 'grid' and it saves all the configuration and input file variables.
	path	String. Path to the output folder. May be relative to the working directory or absolute.
	filename	String. File name without extension. If the file name already exists, iFlow will save the output under the file name appended by the smallest available integer to create a unique name. File names allow for dynamic naming, i.e. replacing part of the file name by the value of a variable at runtime. This may be a variable given in the configuration file, input file or computed by a module before Output is called. For this use of, replacing by a DataContainer call. For example of of of the variable Q0 and of of of of the variable Q0 and of of of other list of other list of other lands are second element (i.e. with index 1) in the list/array A0.
	iteratesWith	Optional, module name. Optional input indicates that the output module should be called during every iteration of the module specified in this input variable. For example iteratesWith general. Sensitivity indicates that the output module should be called during every iteration of the module general. Sensitivity.
	saveAnalytica.	1. Optional, space-separated strings. Optional list of variable names. The output module will try to save these variables as analytical functions. If the data type of this variable is indeed a reference to an analytical function, it will not convert the reference to numerical data, but save the reference along with any class variables of the class that this function refers to.

dontConvert	Optional, space-separated strings. Optional list of variable names. These variables will not be converted to the output grid upon saving. This should be used for variables that might seem grid-conform, while they have nothing to do with a grid. For example on a grid with axes $x$ , $z$ , $f$ a variable with axes $a$ , $b$ might seem grid-conform if $a$ and $b$ have the same length as $x$ and $z$ . iFlow will try to convert this to the output grid, while this is not appropriate. Never choose dontConvert for real grid-conform variables. This would mean that the variable is saved on the computational grid, which
	mean that the variable is saved on the computational grid, which is not saved along with the output. It will therefore be hard to reload the saved data.

## 1.1.2 ReadSingle

Read the contents of a single file saved using the standard Output module and restore the contents to a DataContainer structure.

Туре		Normal
Submodules		None
Input	folder	String. File path to folder with the file to read. The path may be relative with respect to the working directory or absolute. String. File name without extension. Alternatively all may be used to read all files in the folder, but only the last file that is read is kept in memory.
	variables	Space-separated strings. List of variables to read from the file or all to read all variables. Other modules will see this input variable as the list of variables that becomes available for them. Therefore it is not recommended to use all, as other modules then do not know what variables are available and it might be impossible to build a call stack.
Output	@variables	Dictionary/DataContainer with variables. Returns a data structure with the loaded variables.

## 1.1.3 ReadMultiple

Read the contents of a multiple files saved using the standard Output module. The results are stored in a variable experimentdata with subvariables equal to the file name. For example consider a folder with files 'file1.p' and 'file2.p', each containing a variable u. Assume a module receives the results of ReadMultiple in a DataContainer self.input.The can then access this data as

#### ■ Code sample 1.1

```
dc1 = self.input.v('experimentdata', 'file1') # returns a DataContainer with contents of file1.p
u1 = dc1.v('u') # extract the variable u from this DataContainer
dc2 = self.input.v('experimentdata', 'file2')
u2 = dc2.v('u')
```

Alternatively, when the file names are unknown, many or difficult a workflow can be

#### ■ Code sample 1.2

```
filenames = self.input.getKeysOf('experimentdata') # loads all subkeys,

#i.e. filenames, under experimentdata
u = []
for file in filenames:
```

```
dc = self.input.v('experimentdata', file) # returns a DataContainer with contents of file
u.append(dc.v('u'))
```

•

Type		Normal	
Submodules	None		
Input	folder	String. File path to folder with the file to read. The path may be relative with respect to the working directory or absolute.	
	files	Space-separates strings. File names without extension. Altern tively all may be used to read all files in the folder.	
	variables	Space-separated strings. List of variables to read from the file or all to read all variables. Other than in the module ReadSingle, ReadMultiple will output a variable experimentdata. Other modules will thus not see the contents of the input variable variables. Using all here thus yields no problems in the creation of the call stack.	
Output	experimentdata	See explanation above.	

# 1.2 Sensitivity and calibration

#### 1.2.1 Sensitivity

The module Sensitivity is a simple yet powerful tool to perform sensitivity studies, i.e. repeat a simulation for multiple values of one or more input variables. The variables and number of variables to include in the sensitivity study can be chosen on input. This is best illustrated using an example of the input file entry of Sensitivity

#### ■ Code sample 1.3 — input file entry of Sensitivity.

The input variables provides a list of the variables to loop over. This can be one or multiple. These variables, here Q1 and ws, should be included as input variables as well. Each should be followed by the values to loop over. In case of Q1 these values are provided as a space-separated list, containing five values. In case of ws this is provided as Python code. This code is interpreted by the module Sensitivity. The Python code here allows for Numpy commands that follow after np.. The variable ws loops over 20 values. Finally, 100pstyle allows for two options permutations or simultaneous. In the first case, all combinations of all variables are taken. In this example this results in 5 times 20 equals 100 simulations. In the case simultaneous is used, the values of all variables are changed simultaneously. This requires all variables to have the same number values and is therefore not possible in this example.

Туре	Iterative	
Submodules	None	
Input	variables	Space-separated strings. See example above.
	@variables	Space-separated numbers or Python code. Values of each variable listed under variables. See example above.
	loopstyle	String. Allows for permutations Or simultaneous. See example above.

O11		values of all the variables listed in the input argument.
Output	@variables	Values at all the variables listed in the input argument
Odipai	e variables	values of all the variables listed in the input digarrient.
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#### 1.2.2 ManualCalibrationPlot

Post-processing and visualisation of a calibration study for the water level elevation in a 2DV simulation. This module requires multiple output files with model results for different values of one or two calibration parameters (e.g. produced by the module Sensitivity). This data should be loaded back into a variable <code>experimentdata</code> (e.g. through the module LoadMultiple). ManualCalibrationPlot will then evaluate a cost function for each of these output files by comparing the modelled water levels to measurements. The results are plotted.

	I	
Туре		Normal
Submodules		None
Input	calibration_parameter	Space-separated strings. Names of one or two calibration parameters
	axis	Space-separated strings. Axis modification for plotting. Number of elements should match the number of calibration parameters. Allows for $\log$ for a logarithmic axis or any other value for a normal linear axis.
	unit	Optional, Space-separated strings. Units to be placed at the axes. Number of elements should match the number of calibration parameters.
	label	Optional, Space-separated strings. Labels to be placed at the axes. Number of elements should match the number of calibration parameters.
	measurementset	String. Name of the variable that contains measurement data.
	@measurementset	<i>iFlow measurementset</i> . Output of a measurement data module. No example given at the moment. Contact the authors for an example module.



Dijkstra, Y. M. (2017). iFlow modelling framework. User manual & technical description.

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