



MeteoIO as a data publication service in the context of Arctic PASSION and WMO GCW

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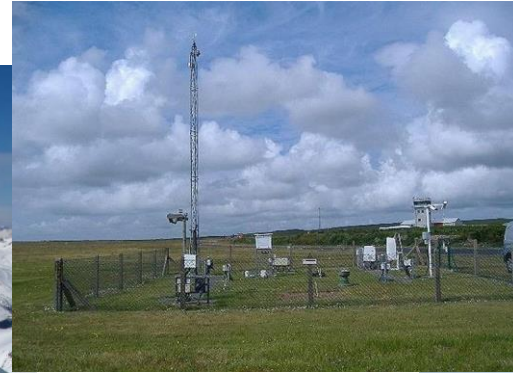


This software has received funding from the World Meteorological Organization under grant agreement No. 29539/2022-1.9 as well as the European Union's Horizon 2020 research and innovation program under grant agreement No. 101003472 (**Arctic Passion**).

Focus: research AWS

Large monitoring networks: lots of identical stations (WMO, etc)

Research AWS: stations installed to answer a specific scientific question



First Challenge: diversity



- Measured parameters, sampling rates
- Sources of data (database, webservice, files)
- Data formats (all variants of csv, ...)
- Changes in the station setup at any time during the station's lifetime

Example: Davos Stillberg station

```
1;2;3;4;5;6;7;8;9; [97 more fields]
YEAR;MONTH;DAY;TIME;TEMP_ENGL_H;TEMP_ASP;TEMP_S100;TEMP_S50;TEMP_S10; [97 more fields]
No;No;No;No;°C;°C;°C;°C;°C; [97 more fields]
No;No;No;No;0.01;0.01;0.01;0.01;0.01; [97 more fields]
76;1;1;30;-177;-175;95;54;-10; [97 more fields]
76;1;1;130;-200;-202;94;53;-11; [97 more fields]
76;1;1;230;-186;-179;94;53;-11; [97 more fields]
76;1;1;330;-228;-235;94;53;-11; [97 more fields]
```

Sensors from multiple stations
within 1 file

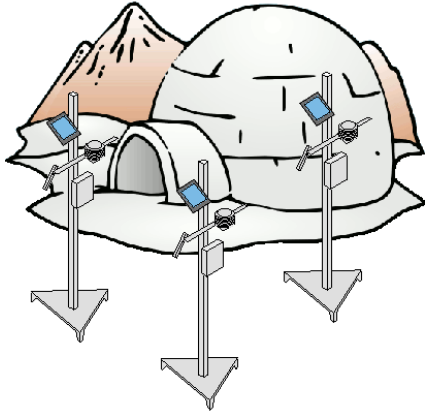
+ Changes in # of sensors within 1 file + sensors
swapped over time (not matching the headers)

```
1;2;3;4;5;6;7;8;9; [24 more fields]
1;2;3;4;No;No;5;6;30; [24 more fields]
STAT_NR;YEAR;DAY_OF_YEAR;TIME;TEMP_VTP6;RH_VTP6; [27 more fields]
No;No;No;No;°C;%;°C;%;mm; [24 more fields]
No;No;No;No;1;1;1;1;1; [24 more fields]
350;2000;272;920;9.46;64.14;-6999;-6999;0; [24 more fields]
350;2000;272;930;10.73;63;-64.1;-25;0; [24 more fields]
350;2000;272;940;9.92;59;-64.1;-25;0; [24 more fields]
```

- AWS since 1975
- Lots of changes in types & number of sensors, different sampling rates
- Several full rebuild
- Nobody really looked into the old data

Ultimate goal

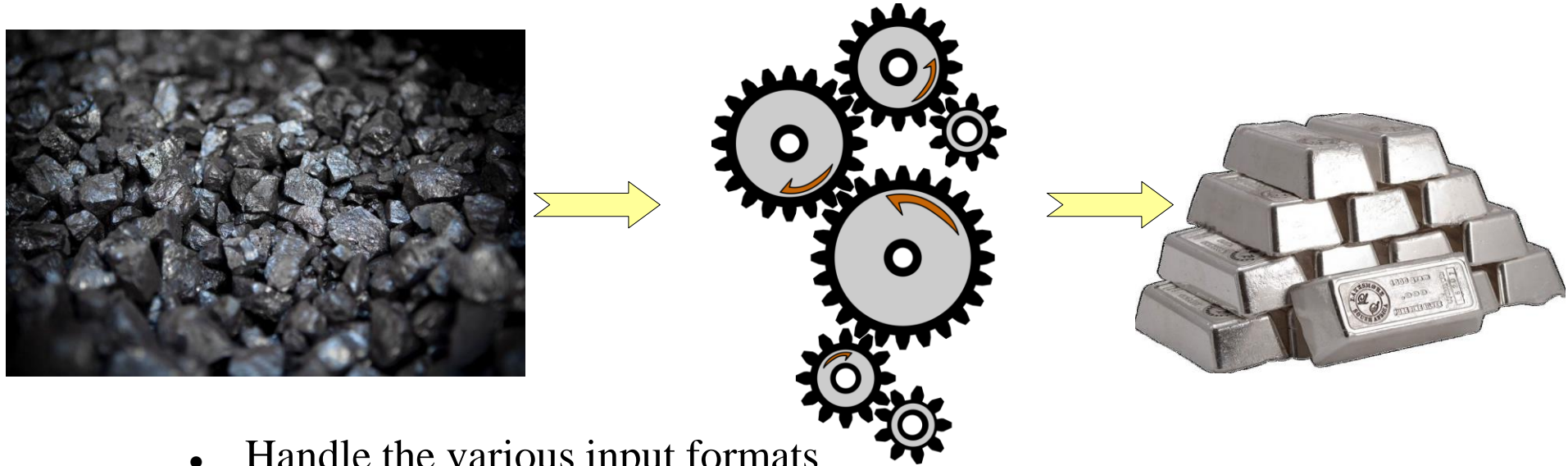
Research stations



Findable 
Accessible 
Interoperable 
Reusable 



Requirement 1: standardization



- Handle the various input formats
- Same output format
- Same parameter naming
- Same metadata standard

Requirement 2: reproducibility

- Document ALL processing steps;
- no manual editing of data, generated on the fly;
- for any period of the station's lifetime!



Our new system: user experience


MeteoIO Guest

METEOROLOGICAL DATA OWNERS PLATFORM

SUPPORTING TIME SERIES PROCESSING WITH METEOROIO

Authorized users can create their online workspace, upload their datasets and MeteoroIO configurations, keep a revisions log and schedule cron jobs.

As a guest, you will be able to view published datasets or, after ORCID Login, submit jobs to process data with MeteoroIO and have the result temporarily available for you to download.

 Login with ORCID ID

Explore Datasets

Documentation

This software has received funding from the [World Meteorological Organization](#) under grant agreement No. 29539/2022-1.9 as well as the European Union's [Horizon 2020](#) research and innovation programme under grant agreement No. 101003472.

- Go to our web service home page
- Login with your Orcid ID



Our new system: user experience



MeteoIO User 74ddd77

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- Explore Datasets
- Guest Job Submission
- Documentation

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Select «Guest Job Submission»

Our new system: user experience


 **MeteoIO** User 74ddd77

Guest Job Submission

[View last submissions](#)

Working directory

Upload here ! 1.13 KB

 STB_Orion_example_raw.csv 279 B

+ Add files...


2 files, 1.41 KB

INI configuration

STB_Orion.ini ▼

Select the INI file to configure MeteoIO

Range End

1970-09-26T00:00:00 

...or insert a duration

Current Time

...or select an end date

Resolution

Value from INI configuration SAMPLING_RATE_MIN ⌵

... or specify a duration

Launch Job

- Upload data file
- Provide start and end time
- And launch job!

Our new system: user experie

MeteoIO User 74dddd77

Job Result

[View last submissions](#)

ID: 018b6d96-4e7d-7efa-bf49-aff9ce15c400
Created: seconds ago
Status: Finished.
Wait time: 19ms
Processing time: 188ms
Disk usage: 46.82 KB

[Output](#) [Files](#) [Logs](#)



STB_Orion.nc 1.41 KB

```
netcdf STB_Orion {
dimensions:
  time = UNLIMITED ; // (3 currently)
variables:
  float time(time) ;
  time:standard_name = "time" ;
  time:units = "minutes since 1976-01-01 00:00:00" ;
  time:calendar = "gregorian" ;
  time:axis = "T" ;
  float orog ;
  orog:standard_name = "surface_altitude" ;
  orog:long_name = "height above mean sea level" ;
  orog:units = "m" ;
  orog:_FillValue = -999.f ;
  orog:positive = "up" ;
  orog:axis = "Z" ;
  float latitude ;
  latitude:standard_name = "latitude" ;
  latitude:units = "degree_north" ;
  latitude:_FillValue = -999.f ;
  latitude:axis = "Y" ;
  float longitude ;
  longitude:standard_name = "longitude" ;
  longitude:units = "degree_east" ;
  longitude:_FillValue = -999.f ;
  longitude:axis = "X" ;
  float slope ;
  slope:standard_name = "slope_angle" ;
  slope:long_name = "slope angle" ;
  slope:units = "degrees from horizontal" ;
  slope:_FillValue = -999.f ;
  float azimuth ;
  azimuth:standard_name = "slope_azimuth" ;
  azimuth:long_name = "slope azimuth" ;
  azimuth:units = "degrees from north" ;
  azimuth:_FillValue = -999.f ;
```

And get a standardized file
back!




Yes, there is a trick...

 **MeteoIO**  User 74dddd77

Guest Job Submission [View last submissions](#)

Working directory

Upload here !	1.13 KB
 STB_Orion_example_raw.csv	279 B
+ Add files...	


2 files, 1.41 KB

INI configuration

STB_Orion.ini ▼

Select the INI file to configure MeteoIO

Range End

1970-09-26T00:00:00 	Current Time
...or insert a duration	...or select an end date

Resolution

Value from INI configuration SAMPLING_RATE_MIN ▼

... or specify a duration

Launch Job



Yes, there is a trick...



=> This single configuration file (per station) describes ALL the processing for the whole life of the station

Using the configuration file

Research stations

METEIO

Magic!

F indable 

A ccessible 

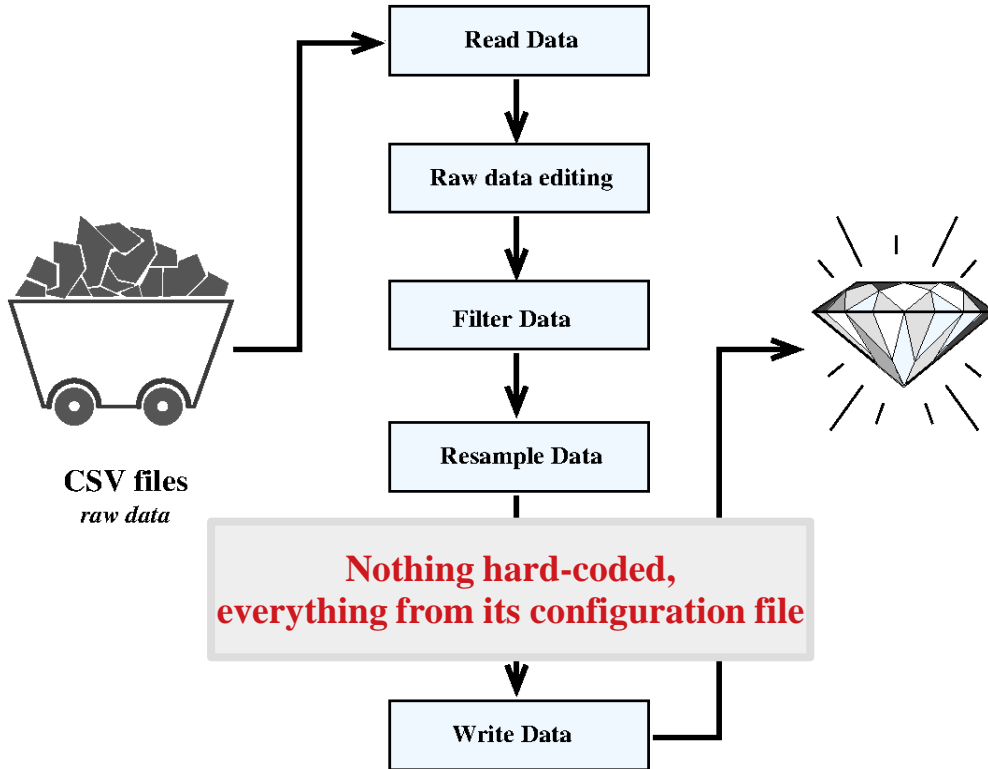
I nteroperable 

R eusable 

Processing provided by our
MeteoIO meteorological data pre-
processing library:

- Started in late 2008
- In operational use for avalanche warning applications
- Open source

MeteoIO: principle of operation



- Fixed processing steps
- Many input formats to choose from (through plugins)
- Many editing / filters / corrections to choose from
- several output formats (through plugins)
- Nothing is hard-coded, everything comes from its config file
- Configuration file should be understandable by a human in 50+ years

MeteoIO: example configuration file

[General]

```
BUFFER_SIZE = ${370*3}
BUFF_BEFORE = 1.5
```

[Input]

```
METEO = CSV
METEOPATH = input
```

```
COORDSYS = CH1903+
TIME_ZONE = 1.00
CSV_NAME = Weissfluhjoch
CSV_ID = WFJ_MET
POSITION = latlon (46.75, 9.80, 2200)
```

```
CSV_DELIMITER = ,
CSV_NR_HEADERS = 5
CSV_HEADER_REPEAT_MK = rawarchiver appending at
CSV_FIELDS = timestamp skip VW VW_MAX DW TA RH skip skip TSS
CSV_TIMESTAMP = COMBINED
CSV_DATETIME_SPEC = "YYYY-MM-DD HH24:MI:SS"
```

```
STATION1 = 2018/SCIENCE_5WFJ_MET_meteo.csv
STATION2 = 2019/SCIENCE_5WFJ_MET_meteo.csv
STATION3 = 2020/SCIENCE_5WFJ_MET_meteo.csv
STATION4 = 2021/SCIENCE_5WFJ_MET_meteo.csv
```

[Filters]

```
TA::FILTER1 = UNVENTILATED_T
TA::ARG1::TYPE = Huwald
TA::ARG1::SOIL_ALB = 0.80
```

[Output]

```
COORDSYS = CH1903
TIME_ZONE = 1.00
```

```
METEO = NETCDF
METEOPATH = output
NETCDF_SCHEMA_METEO = CF-1.6
ACDD_METADATA = TRUE
ACDD_SUMMARY = Research meteo Station at Davos Weissfluhjoch
WIGOS_ID = 0-20000-0-06780
ACDD_CREATOR = Mathias Bavy
ACDD_LICENSE = CC-BY-NC
```

```
SAMPLING_RATE_MIN = 10
```

The INI file is structured in sections

MeteoIO: example configuration file

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```
BUFFER_SIZE = ${370*3}  
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```

[Input]

```
METEO = CSV  
METEOPATH = input
```

File reading plugin & location

```
COORDSYS = CH1903+  
TIME_ZONE = 1.00  
CSV_NAME = Weissfluhjoch  
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```

Basic geographic metadata

```
CSV_DELIMITER = ,  
CSV_NR_HEADERS = 5  
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```

```
SAMPLING_RATE_MIN = 10
```

Description of the files structure

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STATION4 = 2021/SCIENCE_5WFJ_MET_meteo.csv
```

All files that are read by this dataset (per file config keys are supported)

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```

[Output]

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SAMPLING_RATE_MIN = 10
```

Applying some corrections on the data

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ACDD_CREATOR = Mathias Bavay
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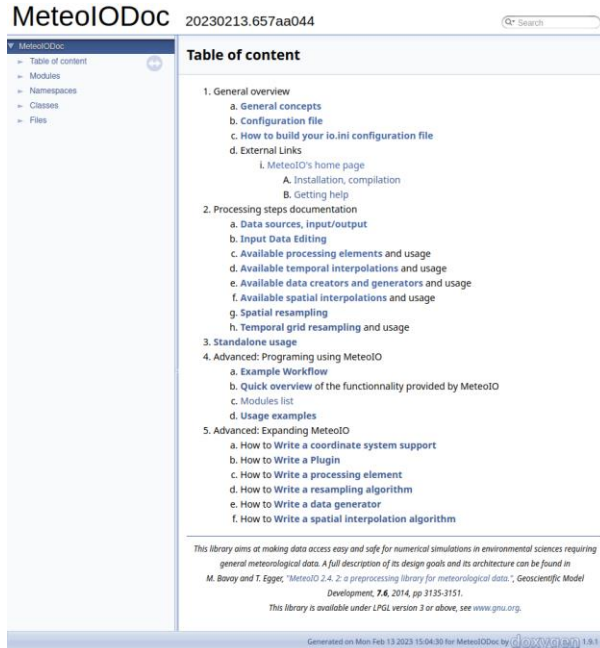
SAMPLING_RATE_MIN = 10
```

Output format & metadata to be added

Writing INI files

Writing INI files is key to the system

Extensive online documentation



MeteolODoc 20230213.657aa044

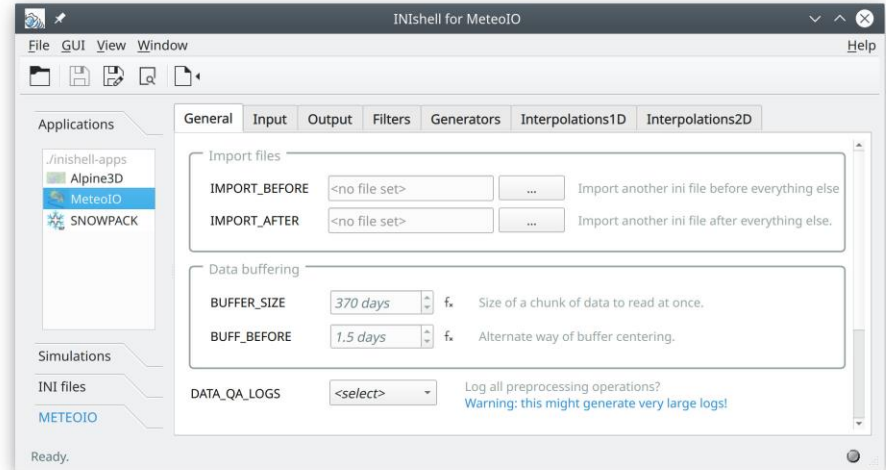
Table of content

1. General overview
 - a. General concepts
 - b. Configuration file
 - c. How to build your io.ini configuration file
 - d. External Links
 - I. MeteolO's home page
 - A. Installation, compilation
 - B. Getting help
2. Processing steps documentation
 - a. Data sources, input/output
 - b. Input Data Editing
 - c. Available processing elements and usage
 - d. Available temporal interpolations and usage
 - e. Available data creators and generators and usage
 - f. Available spatial interpolations and usage
 - g. Spatial resampling
 - h. Temporal grid resampling and usage
3. Standalone usage
 - a. Advanced: Programming using MeteolO
 - b. Quick overview of the functionality provided by MeteolO
 - c. Modules list
 - d. Usage examples
 5. Advanced: Expanding MeteolO
 - a. How to Write a coordinate system support
 - b. How to Write a Plugin
 - c. How to Write a processing element
 - d. How to Write a resampling algorithm
 - e. How to Write a data generator
 - f. How to Write a spatial interpolation algorithm

This library aims at making data access easy and safe for numerical simulations in environmental sciences requiring general meteorological data. A full description of its design goals and its architecture can be found in M. Bavy and T. Egger, "MeteolO 2.4.2: a preprocessing library for meteorological data.", Geoscientific Model Development, 7, 4, 2014, pp 3125-3151.
This library is available under LGPL version 3 or above, see www.gnu.org.

Generated on Mon Feb 13 2023 15:04:30 for MeteolODoc by www.gnu.org 1.8.1

Dynamically generated GUI, direct links to the online documentation



INishell for MeteolO

File GUI View Window Help

Applications

- ./inshell-apps
- Alpine3D
- MeteolO
- SNOWPACK

Simulations

- INI files
- METEOLIO

Ready.

General Input Output Filters Generators Interpolations1D Interpolations2D

Import files

IMPORT_BEFORE <no file set> ... Import another ini file before everything else

IMPORT_AFTER <no file set> ... Import another ini file after everything else.

Data buffering

BUFFER_SIZE 370 days f. Size of a chunk of data to read at once.

BUFF_BEFORE 1.5 days f. Alternate way of buffer centering.

DATA_QA_LOGS <select> Log all preprocessing operations?
Warning: this might generate very large logs!

“Inishell 2.0: semantically driven automatic GUI generation for scientific models”,

Bavay et al., 2022, gmd

<https://doi.org/10.5194/gmd-15-365-2022>



MeteoIO: Data QA/QC

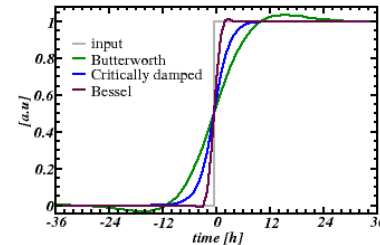
- Currently, 41 filters to choose from
- Stack as many filters as you want, per parameter
- Extensive documentation



Infinite Impulse Response (IIR) filter.

This filter can either be used as a low pass or high pass filter. It is based on a Critically Damped, 2 poles filter (considering that it is better avoid overshooting even at the cost of a gentler falloff). It takes the following arguments:

- **FREQ_RESPONSE**: frequency response, either LP (for *Low Pass*) or HP (for *High Pass*);
- **CUTOFF**: The cutoff **period** (defined as the frequency at a -3dB gain) given in seconds;
- **TYPE**: either **CRITICALLY_DAMPED** (default), **BUTTERWORTH** or **BESSEL** (see figure below);
- **SINGLE_PASS**: Normally, the phase is removed by bidirectional filtering, ie. running the filter twice, first backward and then forward (this also squares the amplitude response). If set to **TRUE**, this bidirectional filtering is disabled.



Infinite Impulse Response filter: step response, LP bidirectional filtering over 24 hours

```
HS::filter1 = IIR
HS::arg1::freq_response = LP
HS::arg1::type = CRITICALLY_DAMPED
HS::arg1::cutoff = 10800 ;ie. 3 hours
```

To know more: <http://unicorn.us.com/trading/allpolefilters.html> and <http://www.dspguide.com/ch19/4.htm>.

MeteoIO: Data QA/QC

Enable the “DATA_QA” option, then request some data...

Filtering	ARO2::HS::MAD	2018-09-30T22:00:00
Filtering	SIM2::HS::MIN	2018-09-25T14:00:00
Resampling	ALI2::RH::LINEAR	2018-09-27T06:00:00
Resampling	PAR2::RSWR::LINEAR	2018-09-27T06:00:00
Missing	DAV5::TSG	2018-09-27T06:00:00
Missing	ELS2::RH	2018-09-27T06:00:00

Data Quality Tool

Station ▲▼	PSUM ▲▼	RSWR ▲▼	TA ▲▼	TSG ▲▼	SUM ▲▼
BER3	128	128	128	128	512
SCH2	1			336	337
OBW3	47				47
DIA2					0
CAM3	0
ATT2					0

Not only guest, but as Data Owner

MeteoIO User 74ddd77

Your datasets + Create a new Dataset

- Davos Dataset: IMIS meteorological timeseries** (Private)
Wannengrat 1 station
CC-BY-SA
- Davos Stillberg Orion station** (Private)
Long-term meteorological station Stillberg, Davos, Switzerland at 2090 m a.s.l.
CC-BY-SA
- Davos Stillberg meteorological timeseries** (Public)
CC-BY-SA

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Davos Stillberg Orion station User 74ddd77

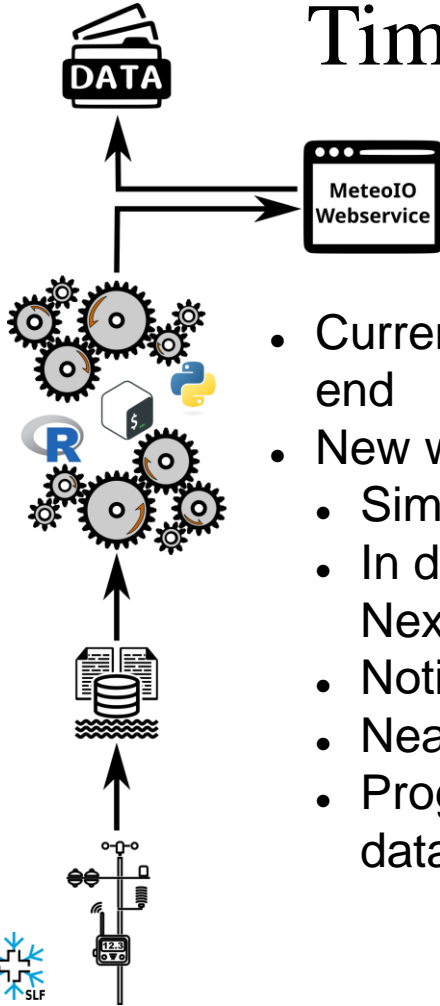
Output Source Data INI configuration Cron Logs Settings

+ Add... Folder

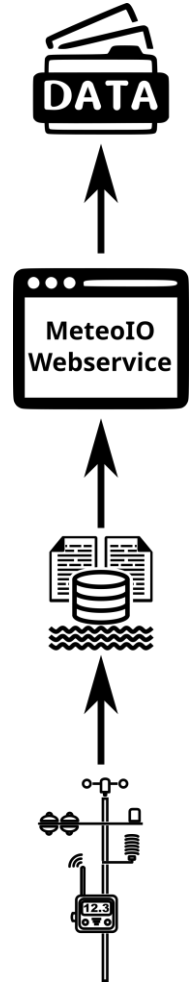
Name ↑	Date	Size
input	12 days ago	4.1 KB
acdd.ini		
STB_Orion_envidat.ini		

- Datasets permanently on the system
- Provide source data & INI file
- Automation with sftp + cronjob
- Anonymous users can see your public datasets
- Deliver up-to-date data as well as on-demand

Time to re-think our workflow!



- Current way, as presented: MeteoIO on the side, in the end
- New way: MeteoIO from the start
 - Simpler workflow
 - In dev: getting data from shared drives, Amazon S3, Nextcloud
 - Notifications from data QA → quick reaction
 - Near-real time data delivery to operational users
 - Progressive data refining, snapshot to publish research dataset



New workflow in real life



Real life:

- Very little time to care for AWS data in research...
- Often neglected

New workflow:

- Empower Data Owners;
- Make production of data more robust;
- Increase data quality;
- **As a side effect:** data is standardized and FAIR, and it comes for free!



More information

- Data processor: MeteoIO pre-processing library, see (Bavay & Egger, 2014, gmd)

<https://doi.org/10.5194/gmd-7-3135-2014>



- GUI for configuration file: Inishell see (Bavay et al., 2022, gmd)

<https://doi.org/10.5194/gmd-15-365-2022>



- Earlier version for the WMO Global Cryosphere Watch, see (Bavay et al., 2020, dsj)

<http://doi.org/10.5334/dsj-2020-006>

