



Data Access Made Easy: flexible, on the fly data standardization and processing*

Mathias Bavay¹, Patrick Leibersperger¹, Øystein Godøy², Charles Fierz¹, Rodica Nitu³

¹ WSL Institute for Snow and Avalanche Research SLF, Davos, Switzerland

² Norwegian Meteorological Institute, Oslo, Norway

³ World Meteorological Organization, Geneva, Switzerland

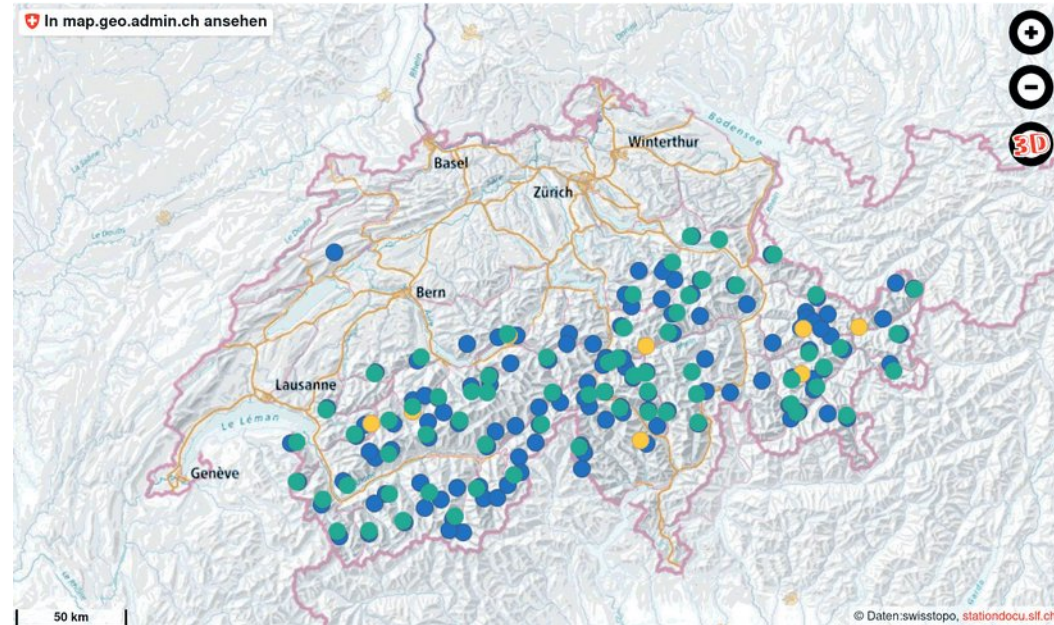
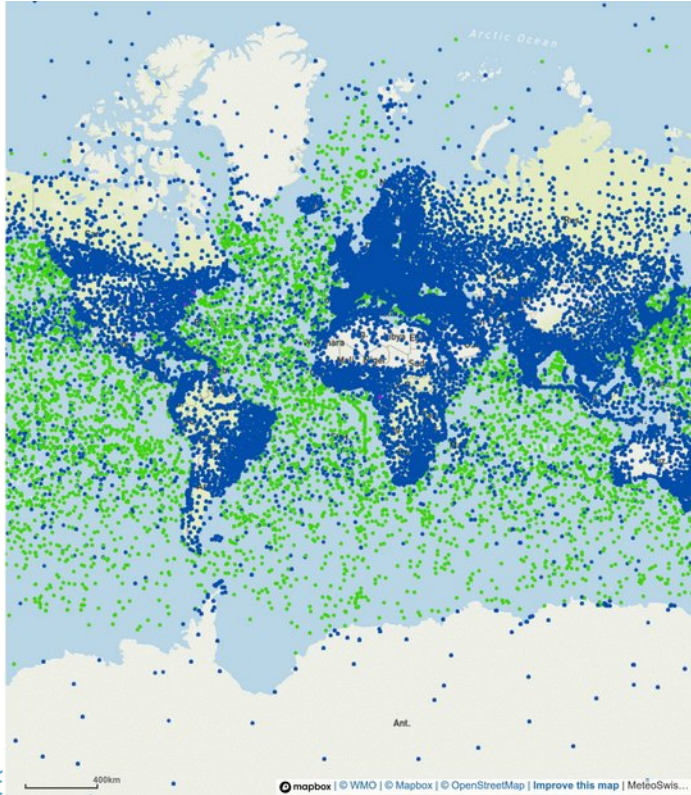
**For research automatic weather stations(AWS)*



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.

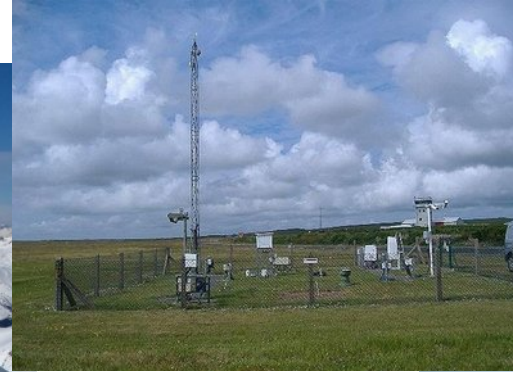
Why? Do we need something?

Large monitoring networks work fine!



Why? Do we need something?

Research AWS: stations installed to answer a specific scientific question, not standardized like in monitoring networks



Challenge: diversity



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

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

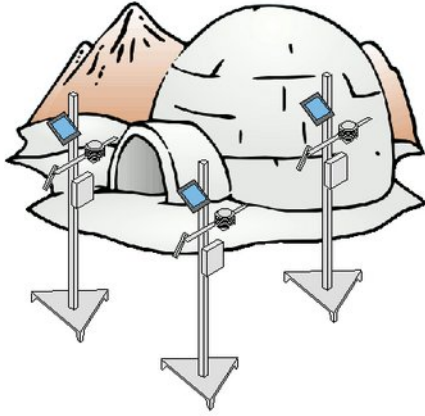
+ Changes in # of sensors within 1 file + sensors swapped over time (not matching the headers)

```
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
- Change of ownership in 2005
- Nobody really looked into the old data

Ultimate goal

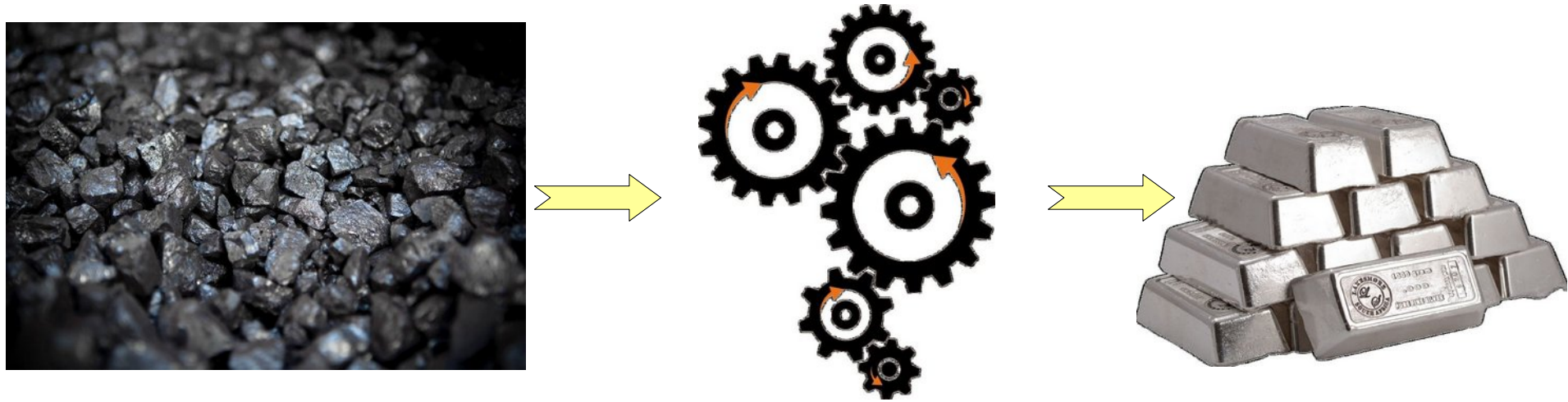
Research stations



Findable 🔍
Accessible 🖱️
Interoperable ⚙️
Reusable ♻️



Requirement 1: standardization



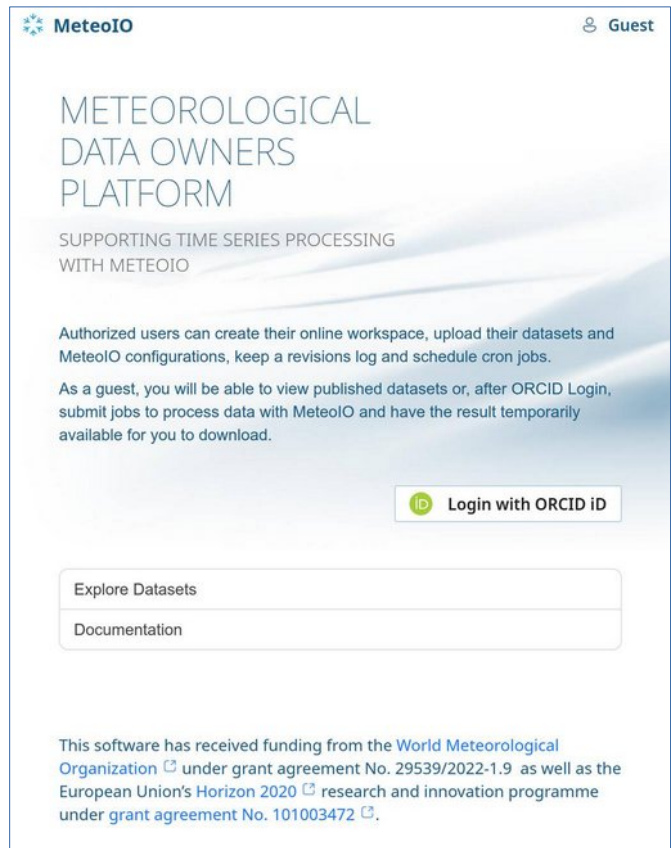
- Handle the various input formats
- Same output format
- Same parameter naming
- Same metadata standard (including ACDD search metadata)

Requirement 2: reproducibility

- tracking the history of changes;
- no manual editing of data, generated on the fly;
- for any period of the station's lifetime!



Our new system: user experience



- Go to our web service home page
(currently only a test server)
- Login with your Orcid ID



Our new system: user experience

 **MeteoIO**

User 74dddd77

METEOROLOGICAL DATA OWNERS PLATFORM

SUPPORTING TIME SERIES PROCESSING
WITH METEOIO

Create your online workspace, upload your datasets and MeteoIO configurations, keep a revisions log and schedule cron jobs.

You can also submit guest jobs to process data with MeteoIO and have the result temporarily available for you to download.

Explore Datasets


Guest Job Submission

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.

Select «Guest Job Submission»


Our new system: user experience

 **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

1970-09-26T00:00:00 

End
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

- 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

And get a standardized file
back!

```
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 horizon" ;
        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 ;
```



Yes, there is a trick...

 **MeteoIO**

User 74dddd77

Guest Job Submission [View last submissions](#)

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Launch Job



Yes, there is a trick...



=> The whole processing is described in a single configuration file (per station) for the whole life of the station

Processing the INI file

Research stations

METEORO

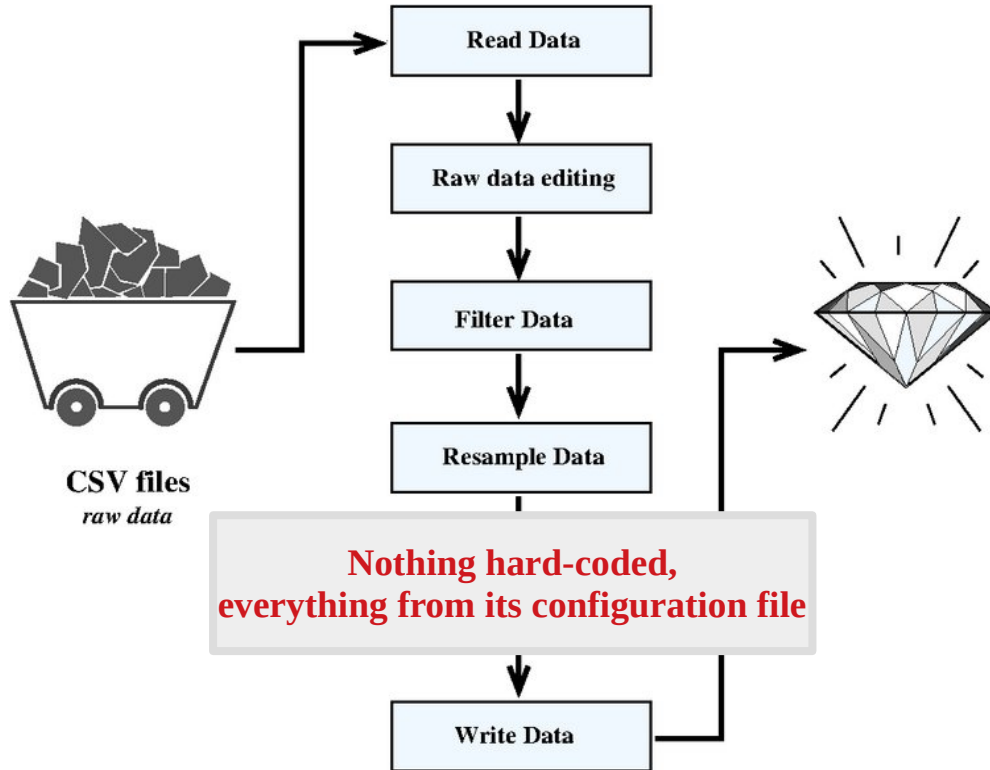
Magic!

F_{indable} 
A_{ccessible} 
I_{nteroperable} 
R_{eusable} 

Processing provided by our
Meteoro 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, several output formats (through plugins)
- Many editing / filters / corrections to choose from
- 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 = 0
```

```
[Input]
COORDSYS = CH1903+
TIME_ZONE = 1
```

```
CSV_ID = 5WFJ_MET
CSV_NAME = Weissfluhjoch
POSITION = xy (780849,189231, 2536)
```

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

```
CSV_DELIMITER = ,
CSV_NR_HEADERS = 5
CSV_HEADER_REPEAT_MK = rawarchiver appending at
CSV_COLUMNS_HEADERS = 2
CSV_DATETIME_SPEC = "YYYY-MM-DD HH24:MI:SS"
CSV_FIELDS = timestamp skip VW VW_MAX DW TA RH skip skip TSS
```

```
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]
TIME::filter1 = suppr
TIME::arg1::type = cleanup
```

```
[Output]
COORDSYS = CH1903+
TIME_ZONE = 1
```

```
METEO = NETCDF
METEOPATH = ./output
NETCDF_SCHEMA = CF-1.6
NC_CREATOR = Mathias Bavay
NC_LICENSE = CC-BY-NC
NC_SUMMARY = Meteo station at Weissfluhjoch research station.
NC_ID = https://sulzfluh.slf.ch/5WFJ_MET.nc
```

```
SAMPLING_RATE_MIN = 10
```

The INI file is structured in sections

MeteoIO: example configuration file

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[General]
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```

Basic geographic metadata

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File reading plugin & location

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Description of the files structure

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```

All files that are read by this dataset

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[Filters]
TIME::filter1 = suppr
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```

Applying some corrections on the data

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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

MeteoIODoc 20230213.657aa044

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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, "MeteoIO 2.4.2: a preprocessing library for meteorological data", Geoscientific Model Development, 7, 4, 2014, pp 3113-3151.

This library is available under LGPL version 3 or above, see www.gnu.org.

Generated on Mon Feb 13 2023 15:04:30 for MeteoIODoc by [gnuplot](http://www.gnuplot.org) 1.8.1

Dynamically generated GUI, direct links to the online documentation

INishell for MeteoIO

File GUI View Window Help

Applications

General Input Output Filters Generators Interpolations1D Interpolations2D

Import files

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

Import another ini file after everything else.

f. Size of a chunk of data to read at once.

f. Alternate way of buffer centering.

Log all preprocessing operations?
Warning: this might generate very large logs!

METEIO

Ready.

"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

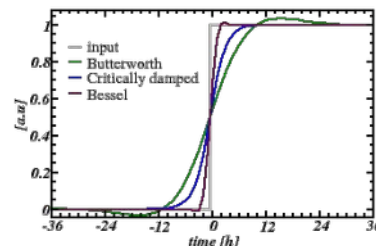


- Currently, 36 filters to choose from
- Stack as many filters as you want, per parameter
- Extensive documentation

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.

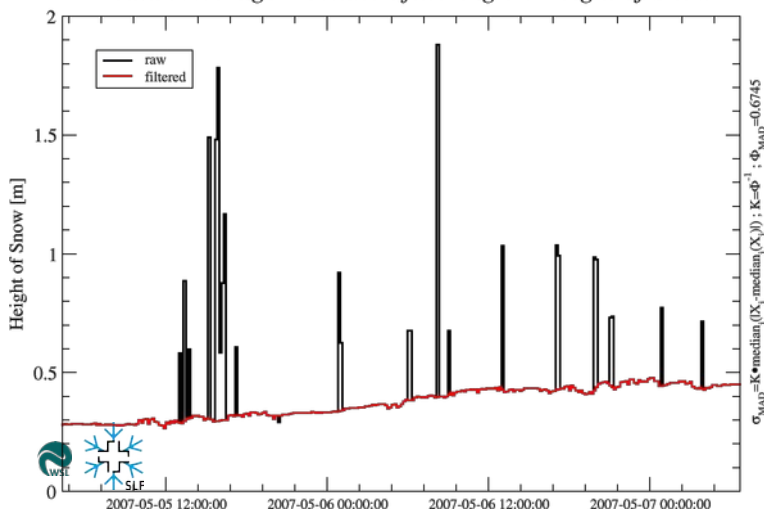


Infinite Impulse Response filter: step response, LP bidirectional filtering over 24 hours

```
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>.

Median Average Deviation filtering on Height of Snow



MeteoIO: Data QA/QC

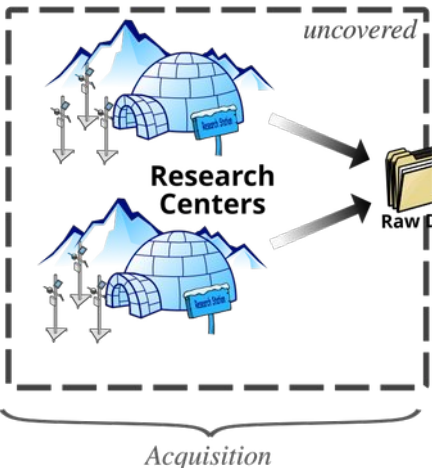
Enable the “DATA_QA” option, then request some data...

Filtering	AR02::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

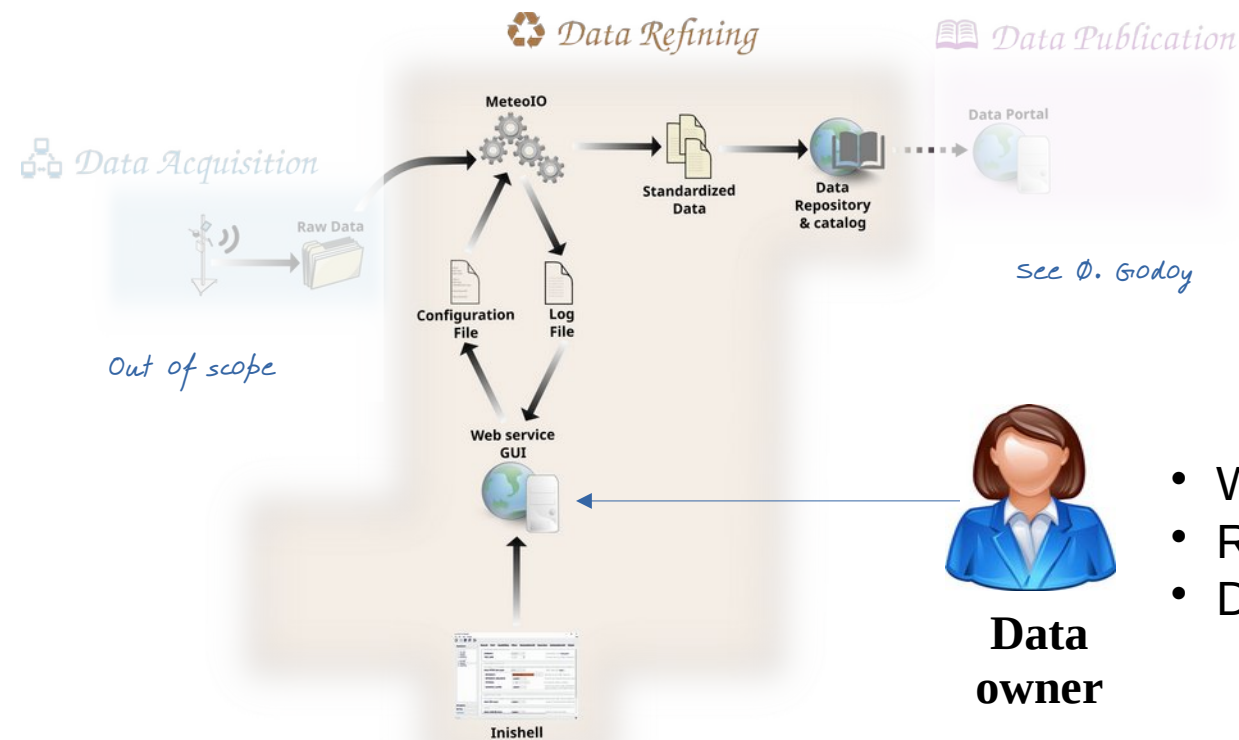
Overview: GCW use case



Mostly automated & decentralized system:

- The research centers provide raw data & metadata
- The users get NetCDF files (CF & ACDD metadata): FAIR data
- The web portal does not contain the data (dynamically requested from OpenDAP). Metadata extracted from the output files.
- MeteolO transforms the raw data into netCDF suitable for OpenDAP

Overview of the system



- Write the INI file
- React to errors / warnings
- Define filters & quality levels

**Data
owner**

Supporting the Data Owner

MeteoIO User 74dddd77

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 74dddd77

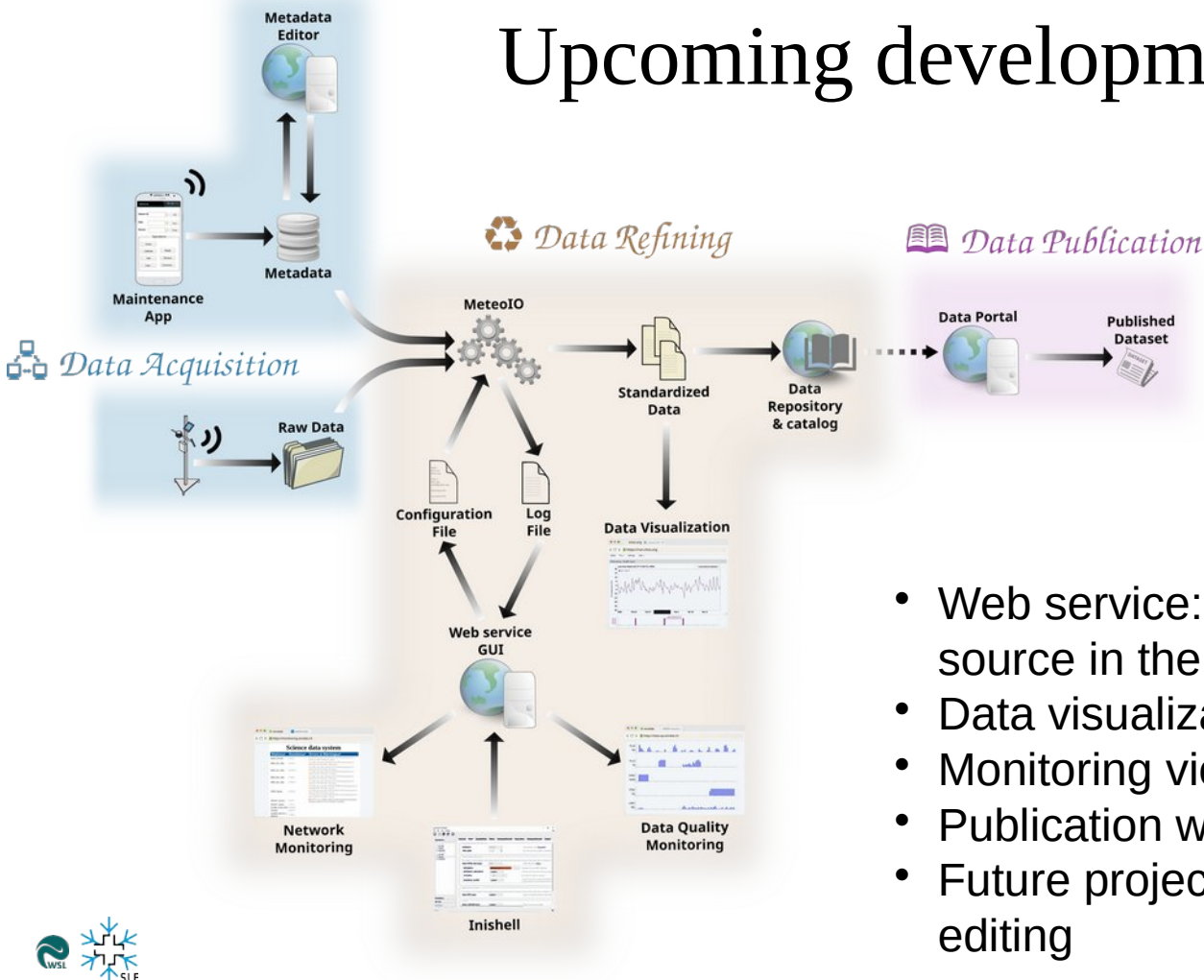
Output **Source Data** INI configuration Cron Logs Settings

+ Add... Folder

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

- Provide source data & INI file
- Automation with sftp + cronjob (easy / advanced) specification
- Anonymous users can see your public datasets
- Deliver up-to-date data as well as on-demand

Upcoming developments



- 2 projects funding the web service
- 1 project funding MeteoIO

- Web service: Formally released as open source in the next few weeks
- Data visualization
- Monitoring views & automatic alerts
- Publication with DOI reservation
- Future projects: Metadata collection & editing

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>

