Houtribdijk monitoring and research program

Data report

Client: Rijkswaterstaat GPO

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Final report

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1 Introduction

1.1 The project

Rijkswaterstaat has partly reinforced the Houtribdijk between the lakes Markermeer and IJsselmeer with sandy shores. The sandy shores break the power of the waves before they reach the dike body. The use of sandy shores for flood risk reduction in a freshwater lake area is a global first. To follow the development of the sandy shores and to be able to use this adaptive and nature-friendly solution more often, Rijkswaterstaat has set up the Houtribdijk Research and Monitoring Program in collaboration with TU Delft. The main objective is to develop knowledge for management and maintenance of the sandy shore in a freshwater lake without tide. For more information, see: https://www.rijkswaterstaat.nl/versterkinghoutribdijk

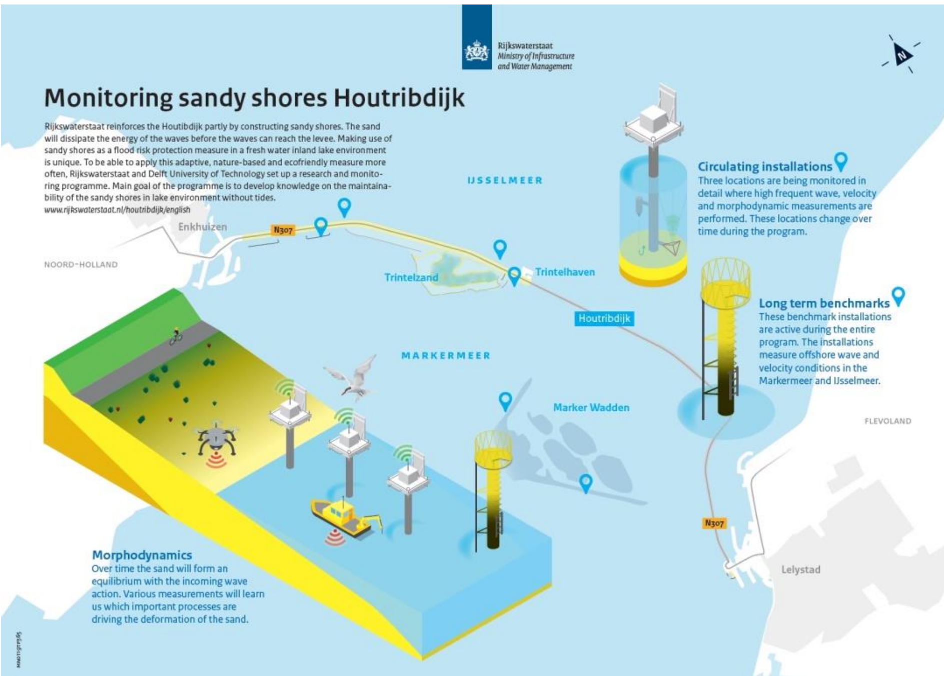


Figure 1
Infographic on the project Research and Monitoring Houtribdijk

The measurement data being generated by the research and monitoring program, is used in the project LakeSIDE (Lake Shore Interconnecting Defense and Environment), a project of the Delft University of Technology funded by Rijkswaterstaat. LakeSIDE focuses on sandy beaches in environments without high waves and tides, such as in Markermeer and IJsselmeer. LakeSIDE is part of Rijkswaterstaat's research and monitoring program for efficient and effective management and maintenance of the sandy reinforcement.

The measurement campaign has run from March 2019 until March 2021. In this way, a lot of information has been gathered on the characteristics and morphological behavior of the sandy foreshores along the Houtribdijk. The aim is to better understand and predict the development of the sandy shores and to optimize maintenance.

1.2 Aim

This data report aims to describe the measurements and the resulting datasets of the Houtribdijk measurement campaign. Since measurement locations have changed over time, different versions of this data report were published. The current version is the final version, after finalization of the measurement campaign. The goal of the data report is to document the monitoring process and to provide sufficient information for current and future analysis of the data.

1.3 Data management

Within this program, the combination HKV, Tauw and Iv-infra is responsible for the data management. Through this combination, a data management system (DMS) was set up and managed by a data manager, who - together with Rijkswaterstaat - actively steered the process of data gathering, processing and disclosure. The research and monitoring program (in which the collected data is used) started in November 2018 and runs until 2022.

The objectives for the data management project Houtribdijk include:

- Storage of raw data;
- Data validation;
- Data standardization;
- Data processing;
- Making the data available;
- Archiving for future use.

The archived database can be found via the following url:
https://rwsprojectarchief.openearth.nl/downloads/houtribdijk/

1.4 Combination HKV and Tauw

The project commissioned by RWS GPO was carried out in collaboration with HKV and Tauw under framework contract SO3. HKV was the lead party in this combination for this project.

HKV was responsible for the realization and management of the DMS. These activities included - in addition to the technical management of the data management system - the retrieval and validation of the measurement data and the processing of the data: the conversion of the raw measurement data into useful information for the purpose of research into sandy shores. The data was continuously made available to the users via web-based services.

Tauw acted as the data manager in the project. The data manager was the central point of contact and the link between the project team of the combination, the data suppliers and the users of data. The data manager was responsible for the organization, coordination, and agreements regarding the data management process, particularly in the first phase of the project.

Experts from **Deltares** were involved for advice while setting up a method for processing the ADV data (see section 3.4.3).

1.5 Disclaimer

All parties involved in the measurements and data processing have taken the greatest possible care for the purposes for which the datasets were collected. However, the correctness and completeness of the data cannot be fully guaranteed for all purposes, because not all data have been validated extensively. All parties involved exclude any liability for both direct and indirect damage, of whatever nature, related to the use of this data.

2 Measurement campaign

This chapter describes the measurement locations, instruments, and the way in which they were deployed.

2.1 Measurement locations

Measurements were carried out at six locations (see Figure 2):
- Two locations at the IJsselmeer side of the Houtribdijk (location 1, FL70, at a depth of NAP-3.8 m, and location 2, FL69, at a depth of NAP-1.9 m),
- Two locations at the Markermeer side of the Houtribdijk (location 3, FL67, at a depth of NAP-2.9 m, and location 4, FL68, at a depth of NAP-3.5 m),
- Two locations at the sandy beaches of the Marker Wadden (location 5, FL66, at a depth of NAP-4.4 m and location 6, FL65, at NAP-4.5 m).

Figure 2
Study area and measurement locations.

At each of the six locations, a permanent offshore measurement pole was present, named FL65 up to FL70, see Figure 3. An example of such a large permanent pole is shown in Figure 5. In addition, six instruments were available for deployment on two times three smaller nearshore measurement poles, called A (near the shoreline), B (in the middle) and C (most offshore), see Figure 4. The instruments on these smaller poles were temporarily deployed at two of the six locations. Therefore, these locations are indicated as 'mobile locations'. If deployed at FL69, as shown in Figure 4, they are named FL69A, FL69B and FL69C. Figure 6 shows the mobile locations while being deployed at FL65 (Marker Wadden).

For power supply, all systems were equipped with large batteries. The batteries were designed to last at least a week without charging and were charged via solar panels. In most conditions the solar panels provided ample charge, however in challenging winter conditions like long durations of heavy cloud cover, snow or heavy fog combined with shorter days with less solar irradiation has occasionally led to undervoltage events where the systems stopped. The lower capacity and higher charging losses at low temperatures were also a part of the problem. The solution to this was either swapping the batteries or waiting for more favorable conditions for charging the batteries where the system automatically restarted at a certain voltage level.

The datalink from offshore to shore was provided by a redundant 4G connection, with the modem being able to switch between two networks. Although coverage on the location was sparse, the addition of a high gain narrowband antenna negated this completely. The data created by the sensors was stored by the data logger on a SD card and forwarded to an FTP server. The SD card provided at least 60 days of storage in case of an outage or failure of the modem. As RF signals are hard to isolate, the system was protected by an overvoltage protection. The advantage of this is that voltages higher than that which the modem can isolate will be absorbed. The disadvantage is that the modem modules can isolate the overvoltage but may not survive such an overvoltage.

Figure 3
Overview of the 6 permanent measurement locations. The location of the wind measurement station Houtribdijk is shown in blue.

Figure 4
Example of mobile locations A, B and C at location FL69

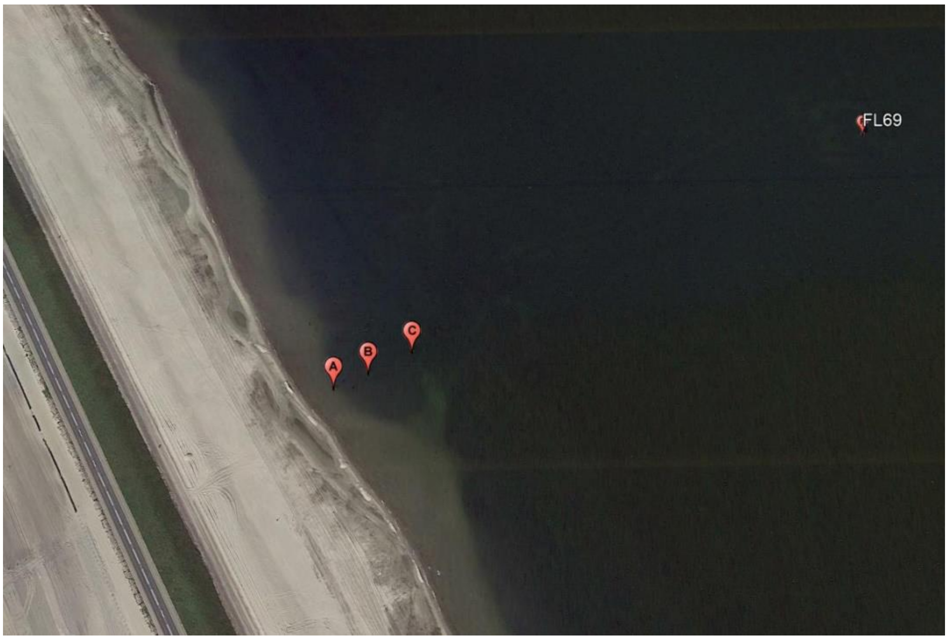


Figure 5
Large measurement pole at a permanent location (Photo: Jan-Willem Mol, RWS)

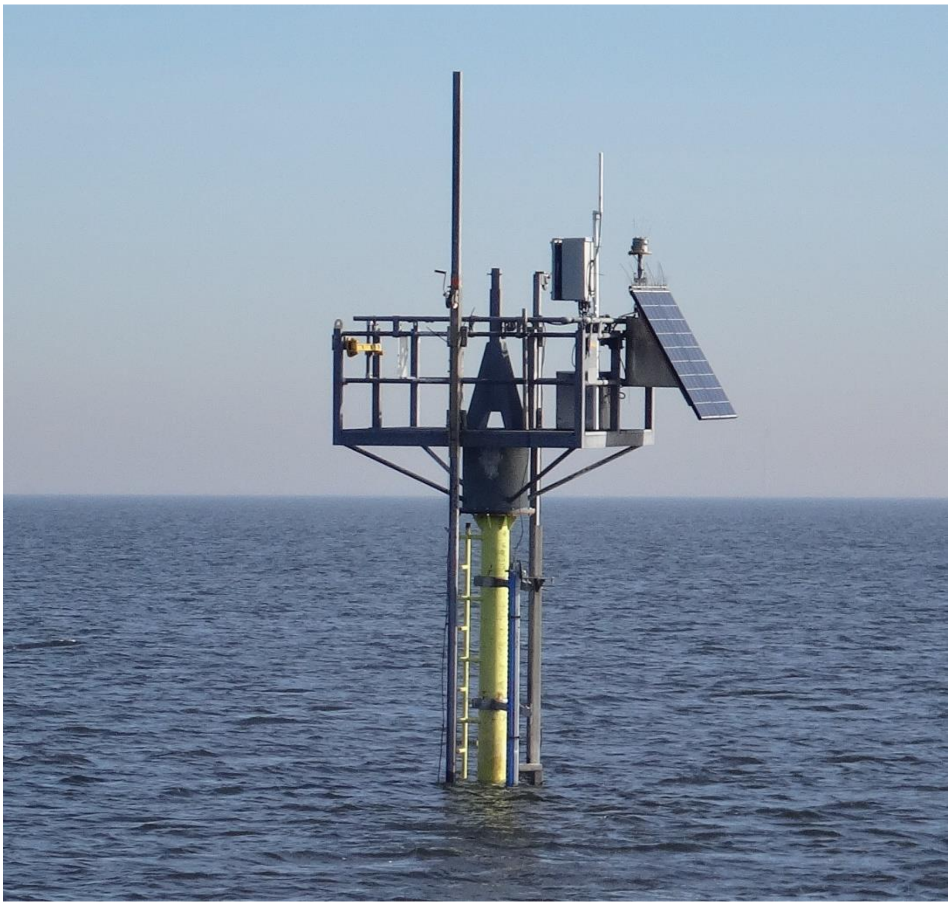
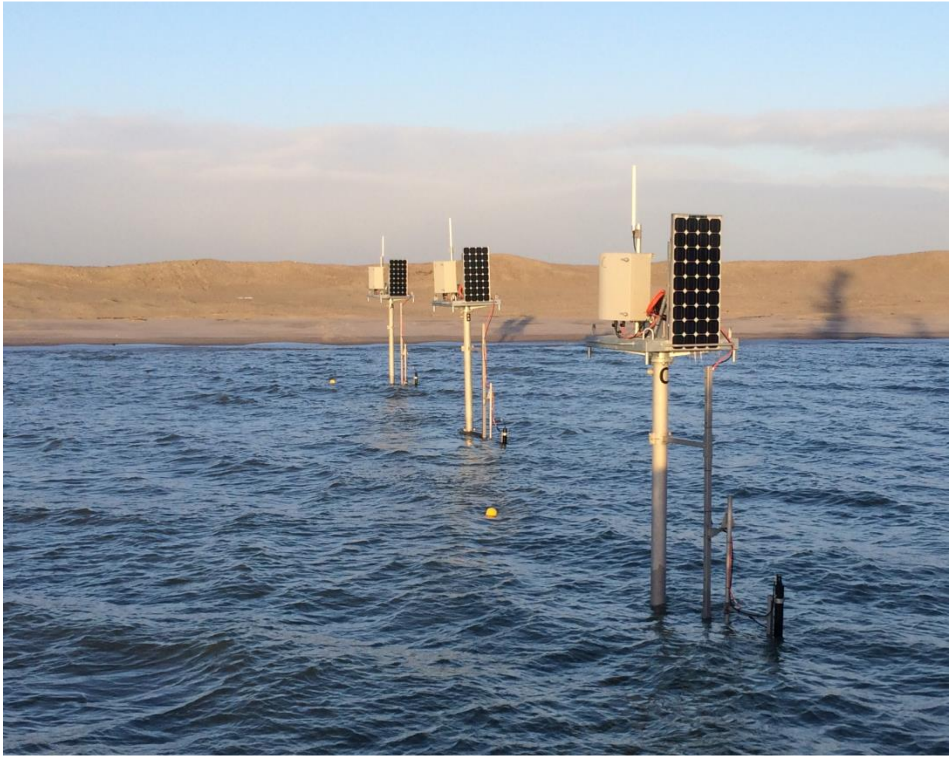


Figure 6
Three small measurement poles at mobile locations, FL65a,b,c (Photo: Jan-Willem Mol, RWS)



2.2 Instruments

This section describes the different types of instruments that were deployed in the field and their purpose.

Table 1
Overview of instruments and their 3-letter abbreviations

Instrument	Abbreviation
Step gauge	STB
Acoustic Current Doppler Profiler (ADCP)	ADC
Vector Acoustic Doppler Velocimeter (ADV)	ADV
Aquadopp HR	AQD
Altimeter	ALT
Multi Parameter Probe	MPP

2.2.1 Step gauge

The step gauge (stappenbaak in Dutch, STB) measures water levels via a series of contact sensors every 5 cm along its 3 m long shaft. Thanks to its high sampling frequency, information about wave heights and wave periods can also be obtained after post-processing the step gauge data.

Figure 7
Step gauge

Type: Etrometa, type: E46400.

2.2.2 ADCP

The Acoustic Current Doppler Profiler (ADCP) measures the flow at different vertical positions (layers). The main purpose of this instrument is to measure the flow velocity and direction at multiple positions in the vertical.

Figure 8
ADCP

Type: TRDI Workhorse Monitor, type: ADCP 1200 ZedHed.

2.2.3 Vector ADV

The Acoustic Doppler Velocimeter (ADV) measures the pressure and velocity in three directions, at a high frequency. Based on this signal, information about wave height, wave period and also wave direction can be estimated.

Figure 9
Vector ADV

Type: Nortek, type: Vector ADV

2.2.4 Aquadopp HR

The Aquadopp HR (AQD) can be considered as an ADCP with high resolution, able to measure at high frequencies and with thin vertical layers. The Aquadopps were deployed to provide detailed insight in the near-bottom flow, and can for example be used for bed load transport calculations. Also wave information can be obtained from the high-frequent pressure and/or velocity measurements.

Figure 10
Aquadopp HR

Type: Nortek, type: Aquadopp HR

2.2.5 Altimeter

The altimeter (ALT) is a single-beam echosounder, used to investigate how the bottom moves in the vertical direction (accretion and erosion), for example due to storm impact.

Figure 11
Altimeter

Type: Impact Subsea, type: ISA500

2.2.6 Multi parameter probe

The Multi Parameter Probe (MPP) measures temperature, pH, chlorophyll content and turbidity.

Figure 12
Multi Parameter Probe at FL67. Photo: Vincent Vuik

Type: YSI, type: 6600v2-4

2.2.7 Distribution of instruments over locations

At all permanent locations, a step gauge and an ADCP were present. FL67 and FL69 were deployed with some extra instruments (MPP and ADV), since these two locations were considered most representative for the conditions at both sides of the Houtribdijk. The ADV's enabled comparison of calculated wave parameters based on either the step gauge or the ADV data.

The mobile locations were present close to the shoreline, since most morphological activity was expected there. The poles were equipped with an altimeter and an ADV or Aquadopp. The two ADV's were present at the first and third location to measure wave transformation (wave height, period and direction) from deep water towards the shoreline, and an Aquadopp was placed in between for more detailed analysis of currents near the bottom.

Figure 13 provides an overview of the deployment of the instruments at the mobile locations. At the start of the measurement campaign until September 2019, instruments were attached to the small poles at FL65A,B,C and FL69A,B,C. In September 2019, the instruments were moved to FL67A,B,C and FL70A,B,C. In May/June 2020, instruments from FL70A,B,C were moved back to FL69A,B,C. In December 2020 and January 2021, these instruments were placed at FL65A,B,C. In February 2021, instruments were taken out because of ice formation in the lakes. In March 2021, measurements were performed at FL68ABC.

Figure 13
Overview of the deployment of instruments at the mobile locations in time, indicated with the grey bars. The numbers in the grey bars concern the start and stop day of the deployment in that month.

jaar	maand	FL65ABC	FL67ABC	FL68ABC	FL69ABC	FL70ABC
2019	2	14			14	
	3					
	4					
	5					
	6					
	7					
	8					
	9	9	16		10	18
	10					
	11					
	12					
2020	1					
	2					
	3					
	4					
	5					19
	6				10	
	7					
	8					
	9					
	10					
	11				3	
	12	14				
2021	1	26	26			
	2		26			
	3		29	1-30		

2.3 Deployment

2.3.1 Step gauge

A step gauge was present at each of the six permanent poles for measuring water levels from approximately -1.5 to +1.5 m with respect to the still water level, with a vertical accuracy of 5 cm.

Measurement frequency: 4 Hz, continuous
Output type: ASCII
Output frequency: 1 file / 40 minutes
File size: 355 KB per file
6 instruments: 77 MB/day or 28 GB/year

2.3.2 ADCP

An ADCP was present at each of the permanent poles, deployed near the bottom in upward-looking mode, with 24 layers, a layer thickness of 25 cm, 500 pings per ensemble of 10 minutes.

Measurement frequency: mean values, every 10 minutes
Output type: ASCII
Output frequency: 1 file / 4 hours
File size: 40 KB per file
6 instruments: 1.4 MB/day or 526 MB/year

2.3.3 ADV

Frequency: 4 Hz continuously
Output type: Binary
Output frequency: 1 file/30 minutes
Size: 223 KB per file
6 instruments: 64 MB/day or 23 GB/year

The ADVs were deployed in downward-looking mode. The pressure sensor was present at the bottom of the housing, and the sampling volume for the velocity measurement was present below the transducers. The distance between the pressure sensor and the sampling volume for the velocities was 0.368 m (Figure 15). The height of the pressure sensor varied per location and was in the range between approximately NAP-0.5 m (most shallow locations) and NAP-1.5 m (locations at deeper water), at a mean lake level between NAP-0.2 and NAP-0.4 m (excluding wind set-up).

Figure 14
Deployment planning of the ADVs

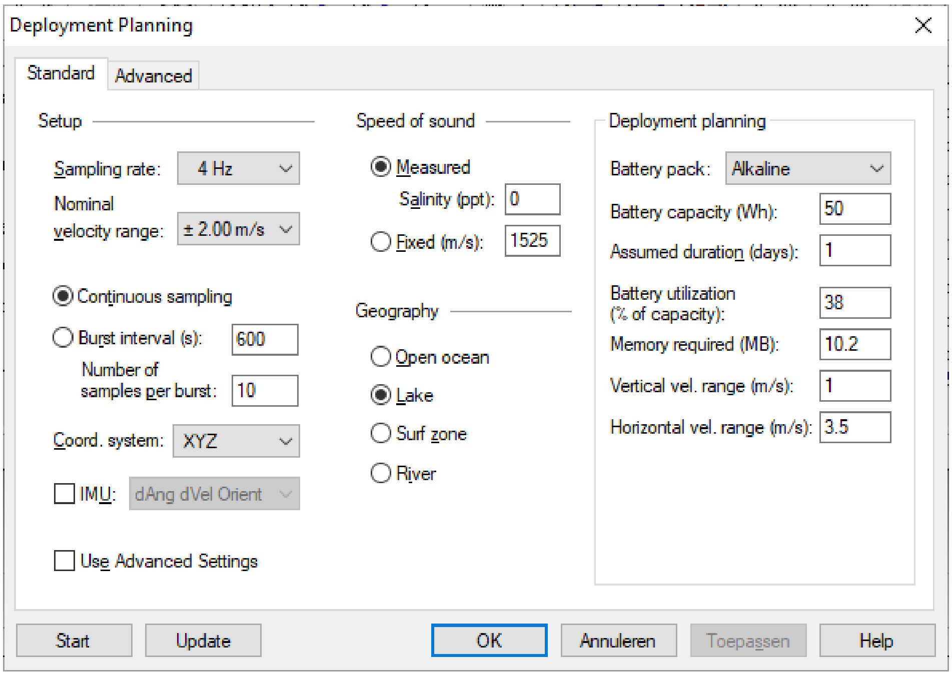
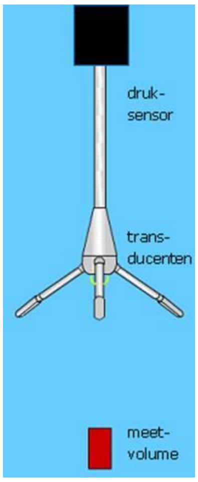


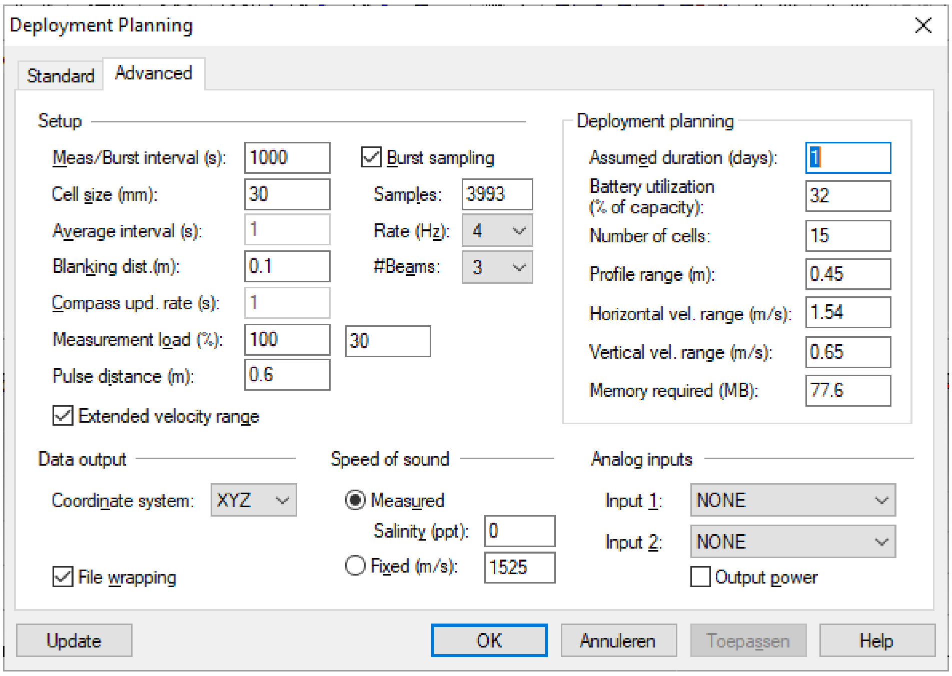
Figure 15
Pressure sensor, transducers and sampling volume (red) of the ADVs



2.3.4 Aquadopp HR

Frequency: 4 Hz (system data: 1 Hz)
Blanking distance: 10 cm
Number of layers: 15
Pulse distance: 60 cm
Layer size: 3 cm

Figure 16
Deployment planning of the Aquadopps



Output type: Binary
Output frequency: 1 file/30 minutes
Size: 1.6 MB per file
2 instruments: 154 MB/day or 56 GB/year

The Aquadopps were deployed in downward-looking mode. Starting from approximately 18 September 2019, the burst duration was changed into 14 minutes, with 1 minute interval, so one burst every 15 minutes.

The height of the pressure sensor at the bottom of the housing varied per location and was in the range between approximately NAP-1.0 m and NAP-1.5 m, at a mean lake level between NAP-0.2 and NAP-0.4 m (excluding wind set-up).

2.3.5 Altimeter

Frequency: 1 measurement per minute
Output type: ASCII
Output frequency: 1 file/100 minutes
Size: 5 KB per file
6 instruments: 430 KB/day or 158 MB/year

From 13-8-2019 onward, the altimeters were placed under an angle of 25-30 degrees, to improve the signal to noise ratio.

Figure 17
Altimeter settings

serial number value	1339-0038		autonomos output rate value	9999
firmware version value	V1.8.9		enable interrogation string value	TRUE
serial mode value	RS232		interrogation string value	#p%0D
speed of sound value	1500		heading offset value	0
min range value	0.4		pitch offset value	0
max range value	0.7		roll offset value	0
distance offset value	0		horizontal value	FALSE
frequency value	500000		inverted value	FALSE
tx pulse width us value	200		output string id value	1
tx pulse amplitude value	50		enable trigger input value	FALSE
echo analyse mode value	strongest		trigger edge rising value	FALSE
detection mode value	correlation		enable autonomos output value	FALSE
correlation threashold low value	0.1		autonomos output rate value	1000
correlation threashold high value	0.2		enable interrogation string value	TRUE
use tilt correction value	FALSE		interrogation string value	#r
use max value for missed ping value	FALSE		mode value	off
output string id value	1		min range value	0
enable trigger input value	FALSE		max range value	120
trigger edge rising value	FALSE		min value	0
enable autonomos output value	FALSE		max value	5

2.3.6 Multi parameter probe

The two MPPs were deployed to measure temperature, conductivity, pH, turbidity and chlorophyll.

Frequency: one measurement every 10 minutes
Output type: ASCII
Output frequency: 1 file/4 hours
Size: 2 KB per file
2 instruments: 24 KB/day or 9 MB/year

3 Data processing

This chapter contains information about the data processing from raw data at an FTP server to standard and tailored data at a THREDDS server, from which it was made accessible for users. Al hardware, tools and scripts together are defined as the DMS (Data Management System). A detailed overview of the structure of the DMS is included in Appendix B, in the form of so-called swimming lanes.

3.1 Data flow

The general data flow in the DMS is shown in Figure 18. Data was sent from the instruments to the FTP server via a mobile internet connection. Data was pulled to the DMS and stored in a version-controlled and back-upped SVN database, following the OpenEarth philosophy. Furthermore, all scripts and its versions were stored in this database. In the SVN database, data was stored in files at the intervals as described in section 2.3. These individual files were all imported into FEWS and combined into complete time series. Some basic operations were carried out in FEWS, such as the combination of measured pressure and air pressure. In a last step, data was converted to standard and tailored data, and stored on a THREDDS server, from where the data can be accessed by users.

Figure 18
Data flow in the DMS.

The following definitions are used in this data report:

- **Raw data** is the original measurement data, as stored in files by the instruments itself.
- **Standard data** is data at the same frequency as the measurement frequency, however stored in standardized format, and combined with metadata to get SI-units and elevations with respect to standard vertical datums (i.e., NAP in the Netherlands).
- **Tailored data** is aggregated data, containing (statistical) properties of the data per time interval, such as mean water levels, significant wave heights or wave spectra per 15 minutes.

3.2 Raw data handling

3.2.1 FTP to data server

Data was pulled to the DMS and stored in a version-controlled SVN database. A check was performed to validate that the data on the SVN-server was fully identical to the original files on the FTP-server. Finally, a back-up was made of the SVN-server.

3.2.2 Conversion binary files

Data from the ADV and AQD were provided in binary format. No software was available for automatic conversion of these binary files in ASCII format, in an operational system. Therefore, two programs were written in C, to convert the binary files into ASCII format (adv2asc.exe and aqd2asc.exe).

3.2.3 Storage in FEWS

Data was read from the ASCII files with raw data using Python scripts, and written to the FEWS database via the hkvfewspy Python package (following the REST protocol).

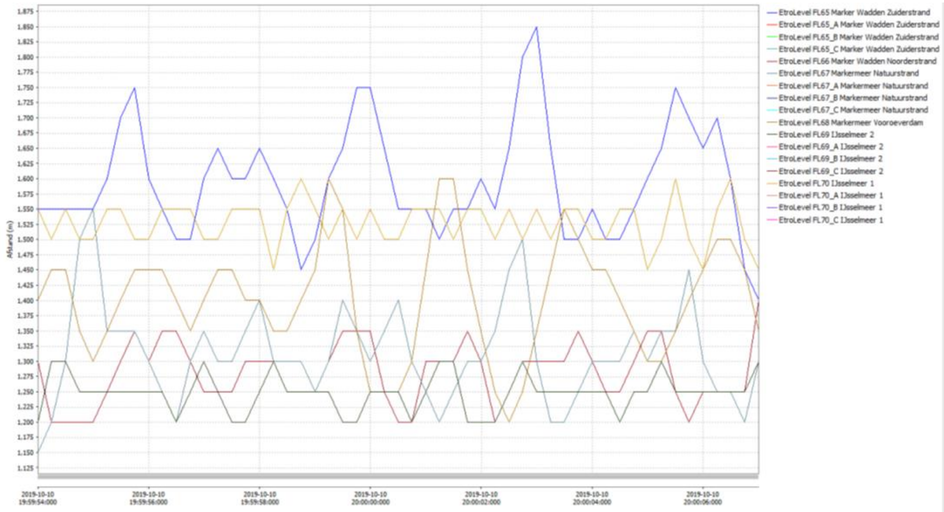


Figure 19 Example of STB data (EtroLevel), stored in time series in FEWS.

3.3 Conversion to standard data

3.3.1 THREDDS server and NetCDF files

Standard data was stored in NetCDF files, following the OPeNDAP protocol. The NetCDF files exist of global attributes, dimensions and variables. During the measurement campaign, they were available at a THREDDS server hosted by HKV.

After completion of the campaign, the data has been archived in Waterinfo Extra, where it can be downloaded via the following url:

https://rwsprojectarchief.openearth.nl/downloads/houtribdijk/

Global attributes provide general information about the file, the data and metadata. An example is shown in Figure 20. The serial number of the instrument is included (sensor_serialnumber), the date for which metadata was measured in the field (metadata_timestamp), such as the local RTK-DGPS bed level measurement (bed_level). Further, all Python functions used are listed (functions_used) with their Subversion revision number. In this way, reproducibility of the data is guaranteed.

Action: Get ASCII | Get Binary | Show Help

Data URL: https://thredds.dmhoutribdijk.nl/thredds/dodsC/HKV/data_standard/STB/FL68/STB_FL68

Global Attributes:

```
summary: data measured by STB sensor at platform FL68
time_start: 2019-12-08 00:00:00.000000
time_end: 2019-12-09 00:00:00.000000
time_duration: 1 day, 0:00:00
sensor: STB
sensor_serialnumber: 5494
metadata_timestamp: 2019-12-08
platform_id: FL68
platform_name: FL68 Markermeer Vooroeverdam
bed_level: -3.5138 m+NAP
functions_used: RUN.py, Revision: 394352; ProcessData.py, Revision:
420912; importData.py, Revision: 382143; getData.py, Revision:
417463; ReadMetaDataAdjusted_NoLog.py, Revision: 394439; readAquo.py,
Revision: 387493; writeNetCDF.py, Revision: 420912;
golf_parameters.py, Revision: 407352; spectrum1D.py, Revision:
380303; calcmoments.py, Revision: 380303;
publisher_name: HKV Consultants, Tauw, Iv-Infra
publisher_url: https://www.hkv.nl
publisher_institution: HKV Consultants
publisher_email: info@hkv.nl
ncfile_created: 2019-12-18 15:51:11
measurement_frequency: 4 Hz
```

Figure 20
Example of a NetCDF file in the OPeNDAP Dataset Access Form, and its global attributes

For most instruments, the only non-zero dimension is time. For the ADCP and Aquadopp, an extra dimension is present to store the data for the multiple layers.

Variables are different for each type of instrument. However, some variables are more generic: latitude, longitude (WGS84 reference system), X, Y (RD reference system), time (seconds or milliseconds since 1970/1/1), and Z (sensor height with respect to NAP).

3.3.2 Step gauge

The step gauges produce the parameter EtroLevel at 4 Hz, which is the distance along the shaft of the instrument over which water is present. The EtroLevel was converted to water level at the same frequency, by adding the vertical position of the lower end of the step gauge with respect to NAP. The vertical position at each point in time was extracted from an Excel sheet with metadata. The Excel sheet was updated when RTK-GPS measurements during a monthly maintenance survey displayed significant differences.

The NetCDF files with standard data for the step gauges contain just one instrument-specific variable, see Table 2.

Table 2 Variables for standard data of step gauges

Variable	Short name	Units
WATHTE	water level	m+NAP

3.3.3 ADCP

No processing was performed for the ADCP data. The raw data was only converted into standardized units and NetCDF format.

The main variables written to the NetCDF files with standard data for the ADCP's are shown in Table 3.

Table 3 Variables for standard data of ADCP's

Variable	Short name	Units
layer_level	layer level	m+NAP
RICHTING	flow direction (Cartesian)	degrees
STROOMSHD_NOORD	velocity north	m/s
STROOMSHD_OOST	velocity east	m/s
STROOMSHD_OMHOOG	velocity up	m/s
T	water temperature	˚C

3.3.4 ADV

An ADV stores the velocity components in the raw data relative to the instrument. In the DMS, the heading, pitch and roll information of the ADV compass was used to convert these data in velocity components in East, North and Upward direction, by means of a transformation matrix. This transformation was already applied on the data before it was submitted to the FEWS database.

Water pressure was calculated by subtracting the air pressure and pressure offset from the measured pressure. The air pressure was obtained from KNMI station Lelystad. The pressure offset was determined in an additional analysis, by comparing the mean water levels based on the ADV pressure signal with the mean water level (inter-calibration) at the nearest LakeSide step gauge and the measurement poles from Rijkswaterstaat (e.g., Markermeer Midden and Krabbersgatsluis Noord). This comparison was regularly carried out for days with low wind speeds. The pressure offset was provided to the DMS via a separate file with pressure offsets per instrument, per period.

The pressure fluctuation was converted into water level fluctuation, taking into account the attenuation of pressure fluctuations with increasing depth, following linear wave theory.

The main variables written to the NetCDF files with standard data for the ADV's are shown in Table 4. For quality checks, also correlations and amplitudes for the three echo pulses are present, as well as the heading, pitch and roll of the compass.

Table 4 Variables for standard data of ADV's and AQD's

Variable	Short name	Units
STROOMSHD_NOORD	velocity north	m/s
STROOMSHD_OOST	velocity east	m/s
STROOMSHD_OMHOOG	velocity up	m/s
DRUK	pressure	hPa
WATHTE	water level	m+NAP
T	water temperature	˚C

3.3.5 Aquadopp HR

The pressure was converted into water levels via the same procedure as applied for the ADV's, and also the coordinate transformation of velocity components was performed identically. The content of the NetCDF files is identical to that of the ADV's, except that velocities, correlations and amplitudes are saved for multiple (14) layers.

3.3.6 Altimeter

Altimeters measure the distance between the instrument and the bottom. The bed level with respect to vertical datum (NAP) was determined by subtracting this distance (m) from the sensor height (m+NAP) in the metadata sheet. The metadata sheet was updated when the sensor height changed significantly according to RTK-GPS measurements during the monthly maintenance surveys.

The NetCDF files with standard data for the altimeters contain just one instrument-specific variable, see Table 5.

Table 5 Variables for standard data of altimeters

Variable	Short name	Units
BODHTE	bed level	m+NAP

3.3.7 Multi parameter probe

No processing was performed for the MPP data. The raw data was only converted into a standardized units and standardized format, and saved to NetCDF files.

The NetCDF files with standard data for the multi parameter probes contain the instrument-specific variables as listed in Table 6.

Table 6
Variables for standard data of multi parameter probes

Variable	Short name	Units
GELDHD	conductivity	mS/cm
CHLF	(mass) concentration chlorophyll-a	µg/L
TRB	turbidity	NTU
pH	acidity	-
T	water temperature	°C
O2	(mass) concentration oxygen	mg/L
O2_VERZDGGD	saturation level oxygen	%

3.4 Conversion to tailored data

3.4.1 Step gauge

Water level fluctuations, based on pressure fluctuations, were used to calculate one-dimensional wave spectra (i.e., the distribution of wave energy over the frequencies, without directional information). The calculation method was based on Fourier Analysis (FFT).

Details of the Fourier Analysis:
- Burst length: 15 min
- Samples per burst: 3600
- Window type: Hann
- Overlap between windows: 0.5

Wave parameters such as significant wave height, wave peak period and mean wave period were calculated, based on the spectrum, for the frequency range of 0.1-1.5 Hz.

The NetCDF files with tailored data for the step gauges contain the variables as shown in Table 7. The dimensions of the variables are time (each 15 minutes) and, in case of the spectra, frequency (0-2 Hz).

Table 7
Variables for tailored data of the step gauges.

Variable	Short name	Units
frequency	frequency (0-2 Hz)	Hz
GEM_WATHTE	average water level	m+NAP
Hm0	significant wave height	m
Tp	peak period	s
Tm01	wave period from m_0 and m_1	s
Tm02	wave period from m_0 and m_2	s
Tmm10	wave period from m_{-1} and m_0	s
Czz	wave variance density spectrum	m^2/Hz

3.4.2 ADCP

No conversion to tailored data was performed for the ADCPs.

3.4.3 ADV

The pressure and the three velocity components (east, north, up) were used to calculate 2D wave spectra (i.e., the distribution of wave energy over frequencies and directions). For this purpose, the Maximum Entropy Method (MEM) has been applied. A Matlab script was provided by prof. Reniers (TU Delft), based on Lygre and Krogstad (1986). The function was tested in idealized conditions by Robert McCall (Deltares). Finally, for implementation in the DMS, the functions were converted from Matlab to Python, by applying the minimization and cross spectral density functions of the Scipy package.

A correction was applied for pressure attenuation with increasing distance of the pressure sensor below the still water surface, based on linear wave theory. The correction was only applied in the frequency range 0.05-1.00 Hz. The correction factor was limited to 5 in terms of pressure variations, which is equivalent to a factor 25 in terms of variance density.

Details of the MEM:

- Burst length: 15 minutes
- Samples (pressure and velocity components) changed in NaN if:
  - value outside the range of $\mu \pm 4\sigma$, or
  - difference between consecutive points in time > 4σ
- After that, interpolation was performed if <1% of the samples was NaN
- Estimates of cross-spectra: scipy.signal.csd
- Minimization of the cost function: scipy.optimize.minimize
- Minimization method: BFGS
- Window type: Hann
- Number of samples per window: 2^7 = 128

Note that MEM provides the most likely estimate of the 2D wave spectrum. No unambiguous solution can be given. Furthermore, the result of the routine strongly depends on its settings, such as the number of samples per window, see Figure 21. The test in this figure is based on typical Markermeer conditions, with 2 m water depth and 1 m wave height. A known 2D wave spectrum was converted into pressure and velocity fluctuations. The MEM was applied to these time series for different numbers of samples per window. More samples means a higher level of detail, whereas less samples results in a smoother result. The result was compared with the original input spectrum. Based on this comparison, a value of 2^7 samples per window was chosen.

The NetCDF files with tailored data for the ADV's contain the variables as shown in Table 8. The dimensions of the variables are time (each 15 minutes) and, in case of the 2D spectra, frequency (0-2 Hz) and wave direction (0-2π radians, Cartesian convention). 1D spectra were calculated by integration of the 2D spectra over the wave directions.

Table 8
Variables for tailored data of the ADV's

Variable	Short name	Units
frequency	frequency (0-2 Hz)	Hz
GEM_WATHTE	average water level	m+NAP
Hm0	significant wave height	m
Tp	peak period	s
Tm01	wave period from m_0 and m_1	s
Tm02	wave period from m_0 and m_2	s
Tmm10	wave period from m_{-1} and m_0	s
Czz	variance density spectrum	m^2/Hz
Th0	average wave direction	degrees
S0BH	directional spreading	degrees
Czz_2D	2D variance density spectrum	m^2/Hz/rad

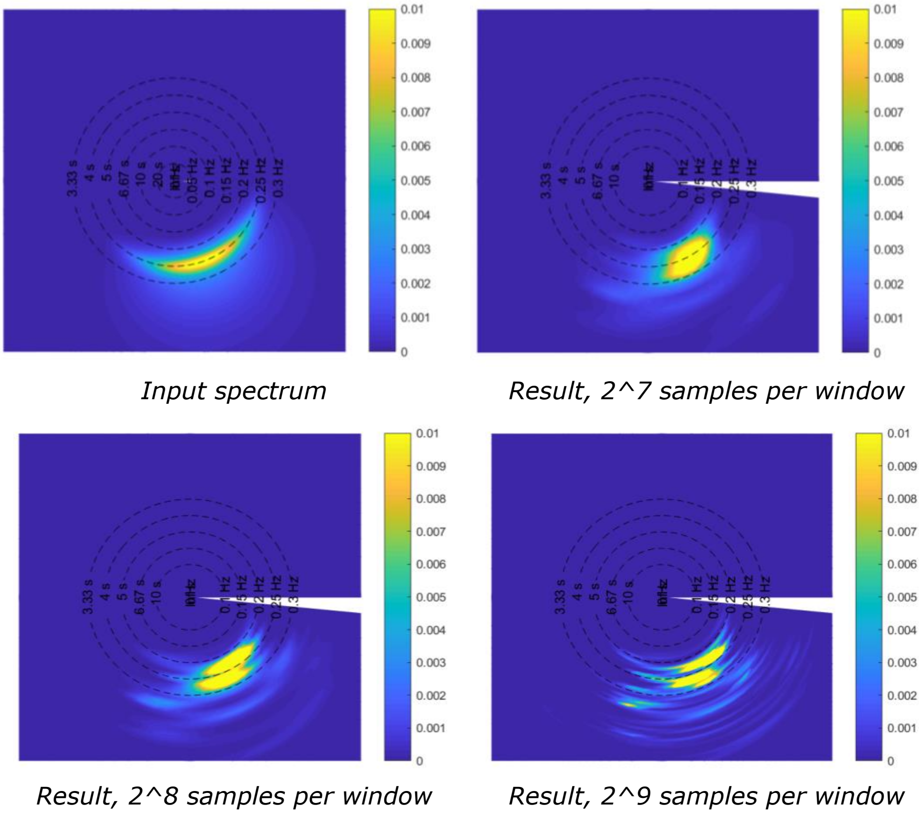


Figure 21
The outcome of the MEM for an elementary test, with a known input spectrum (upper left) for different numbers of samples per window.

3.4.4 Aquadopp HR

For the Aquadopps, the computed water level signal (see standard data) was converted to 1D wave spectra and associated wave conditions, for bursts of 14 minutes, each 15 minutes. The procedure and resulting files were identical to that of the step gauge. Remark: conversion to tailored data was not performed for the period before October 2019, since bursts of 18 minutes were applied here with 1 minute interval, which led to irregular start and stop times over the day.

3.4.5 Altimeter

No conversion to tailored data was performed for the altimeters.

3.4.6 Multi parameter probe

No conversion to tailored data was performed for the multi parameter probes.

3.5 Data validation

This section describes the procedures and tools for validating the data in the DMS.

3.5.1 Monitor

A monitor was built to allow for a quick overview of the presence of files on the FTP server and the THREDDS server. The monitor basically compared the number of files present with an expected number. If a low percentage appeared in the monitor of the FTP server, there was possibly a problem with the instrument itself (e.g., the battery status), or with the data connection via the modem.

Files on the THREDDS server were generated after a delay of 10 days. In these 10 days, for example metadata could be changed in the metadata sheet after field visits or changes to the instrument configurations.

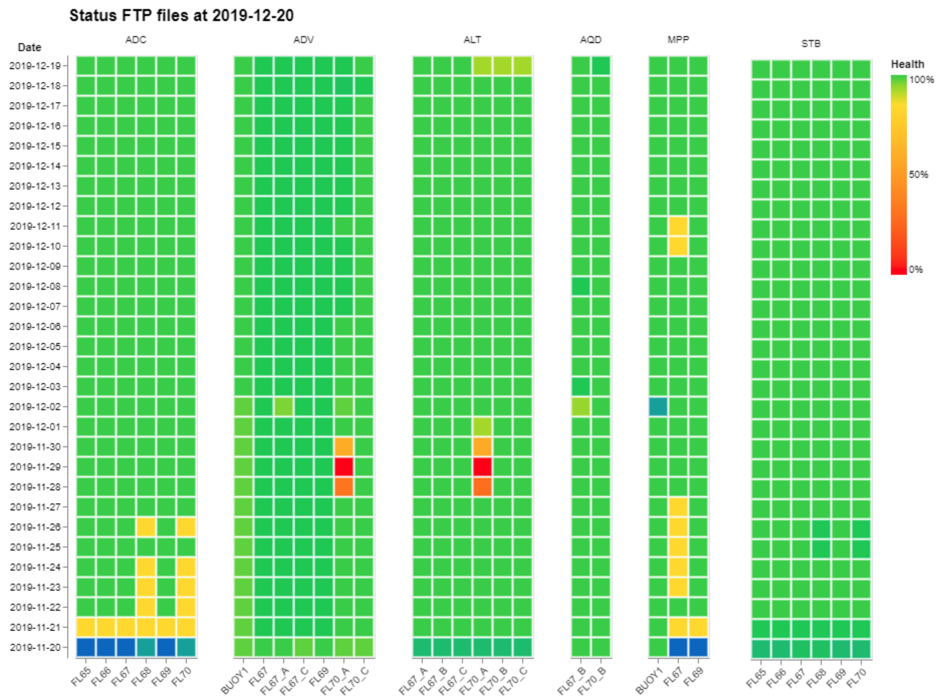


Figure 22
Screenshot of the monitor for the FTP server

Figure 23
Screenshot of the monitor for the THREDDS server with standard data

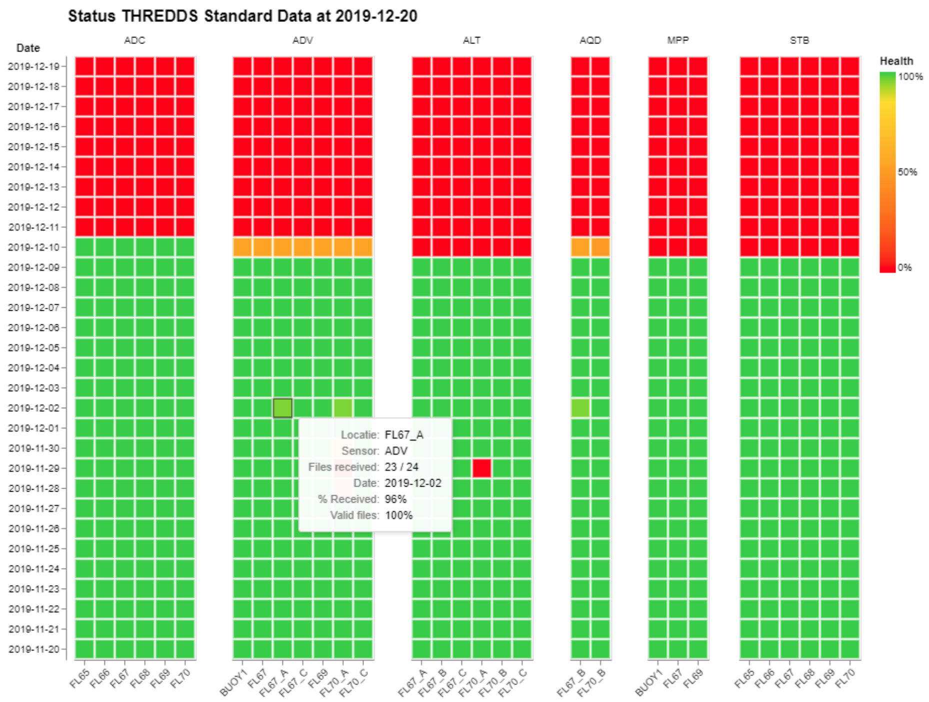
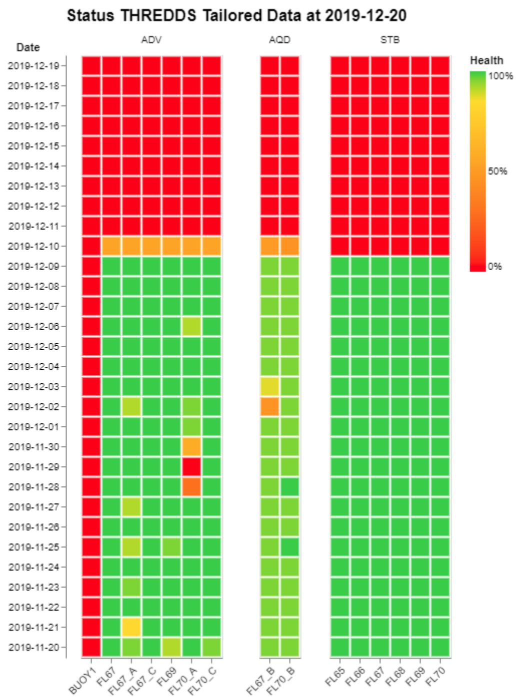


Figure 24
Screenshot of the monitor for the THREDDS server with tailored data



3.5.2 Raw data checks

In FEWS, the following checks were performed on the raw data, on a daily basis:

1. The number of values present
2. The number of ‘not-a-number’ values in the data
3. The number of values outside a pre-defined range per parameter

Value checks:
- STB: distance along shaft (EtroLevel) between 0.05 and 5 m.
- ADCP: flow in eastward direction between -1 and 1 m/s.
- ADV and AQD: pressure between -100 and 400 hPa (without offset and air pressure), flow in eastward direction between -1 and +1 m/s.
- ALT: distance between altimeter and bottom (varies per location).
- MPP: turbidity between 0.1 and 250 NTU, water temperature between 0.1 and 25 °C.

An overview of the main known issues with the instruments is included in Appendix A.

3.5.3 Standard and tailored data checks

Checks were performed on the NetCDF files with standard and tailored data, on a daily basis, with a delay equal to the delay at which the files were being processed (10 days).

Two types of checks were defined:
1. Value checks: if all individual values or mean values were within a pre-defined range. Table 9 gives an overview of the checks.
2. Cross-checks: if value differences between instruments at nearby locations were within a pre-defined range. Table 10 gives an overview of the active cross-checks. The difference in the last column are examples, as the allowable difference depends on the distance between the locations that are compared. For example differences in mean water level between the ADV's at FL67A and FL67C should be very small, while differences between the STB's at FL65 and FL67 could be larger due to wind set-up.

Table 9
Value checks on standard and tailored data

Instrument	Parameter	Type	Value
STB & ADV	Water level (m+NAP)	Standard	[-2, 2]
STB & ADV	Mean water level (m+NAP)	Tailored	[-1, 1]
STB & ADV	Significant wave height (m)	Tailored	[0, 2]
ADC & AQD	Eastward velocity (m/s)	Standard	[-1, 1]
MPP	Water temperature (°C)	Standard	[-5, 25]

Table 10
Cross-checks on standard and tailored data

Instrument	Parameter difference	Type	Difference
STB & ADV	Mean water level (m)	Standard	[-0.2, 0.2]
STB & ADV	Mean water level (m)	Tailored	[-0.2, 0.2]
STB & ADV	Significant wave height (m)	Tailored	[-0.3, 0.3]
MPP	Water temperature (°C)	Standard	[-5, 5]

3.5.4 Water level checks

After each field visit, Rijkswaterstaat provided an update of the metadata, such as the vertical positions of the instruments. Sometimes, these measurements suffered from inaccuracies of for example the RTK-DGPS measurements. This could result in errors in water levels, and differences between water levels at different locations. These checks were regularly performed, to validate the truth value of the metadata (vertical positions, pressure offsets) for the instruments STB, ADV and AQD.

Figure 25 shows an example of the water level checks. Daily mean water levels were compared to the step gauges at FL67 (Markermeer side) and FL69 (IJsselmeer side) for days with a maximum significant wave height of 0.30 m over all step gauges. Mean water levels at the AQD at 67B and the ADV at 70A deviated too much from the water levels at the step gauges for this period, so metadata had to be adjusted based on this check, and data had to be reprocessed.

Figure 25
Example of water level checks

Date	Hm0max	Include	hSTBFL65	hSTBFL66	hSTBFL67	hADVFL67	hADVFL67_A	hAQDFL67_B	hADVFL67_C	hSTBFL68	hSTBFL69	hADVFL69	hSTBFL70	hADVFL70_A	hAQDFL70_B	hADVFL70_C
14-11-2019	0.26	1	-0.03	-0.02		-0.06	0.13	0.28	-0.03	0.02		-0.07	0.02	0.18	0.09	-0.07
15-11-2019	0.35	0														
16-11-2019	0.26	1	-0.04	-0.03		-0.06	0.10	0.27	-0.04	0.01		-0.08	0.01	0.19	0.08	-0.09
17-11-2019	0.16	1	-0.03	-0.02		-0.05	0.14	0.28	-0.03	0.01		-0.07	0.01	0.19	0.08	-0.08
18-11-2019	0.37	0														
19-11-2019	0.26	1	-0.03	-0.03		-0.06	0.11	0.27	-0.04	-0.01		-0.08	0.00	0.16	0.06	-0.09
20-11-2019	0.16	1	-0.03	-0.02		-0.05	0.11	0.28	-0.03	0.01		-0.07	0.01	0.18	0.08	-0.07
21-11-2019	0.26	1	-0.03	-0.02		-0.07	0.10	0.26	-0.05	0.01		-0.02	0.07	0.25	0.14	-0.01
22-11-2019	0.20	1	-0.03	-0.02		-0.06	0.11	0.28	-0.03	0.01		-0.07	0.02	0.20	0.09	-0.07
23-11-2019	0.32	0														
24-11-2019	0.16	1	-0.03	-0.02		-0.06	0.11	0.28	-0.04	0.01		-0.07	0.02	0.19	0.08	-0.08
25-11-2019	0.14	1	-0.03	-0.02		-0.06	0.11	0.28	-0.03	0.01		-0.07	0.02	0.19	0.09	-0.07
26-11-2019	0.24	1	-0.04	-0.03		-0.06	0.12	0.28	-0.03	0.01		-0.07	0.02	0.20	0.10	-0.07
27-11-2019	0.31	0														
28-11-2019	0.45	0														
29-11-2019	0.31	0														
30-11-2019	0.12	1	-0.03	-0.03		-0.06	0.11	0.27	-0.03	-0.01		-0.07	0.01	0.18	0.07	-0.08
1-12-2019	0.09	1	-0.03	-0.04		-0.06	0.10	0.27	-0.04	-0.01		-0.07	0.00	0.18	0.07	-0.07
2-12-2019	0.22	1	-0.03	-0.03		-0.07	0.09	0.27	-0.03	-0.01		-0.07	0.01	0.18	0.07	-0.08
3-12-2019	0.30	1	-0.04	-0.03		-0.05	0.08	0.20	-0.03	0.00		-0.07	0.02	0.19	0.08	-0.03
4-12-2019	0.25	1	-0.04	-0.03		-0.05	0.09	0.20	-0.03	0.01		-0.06	0.02	0.19	0.08	-0.03

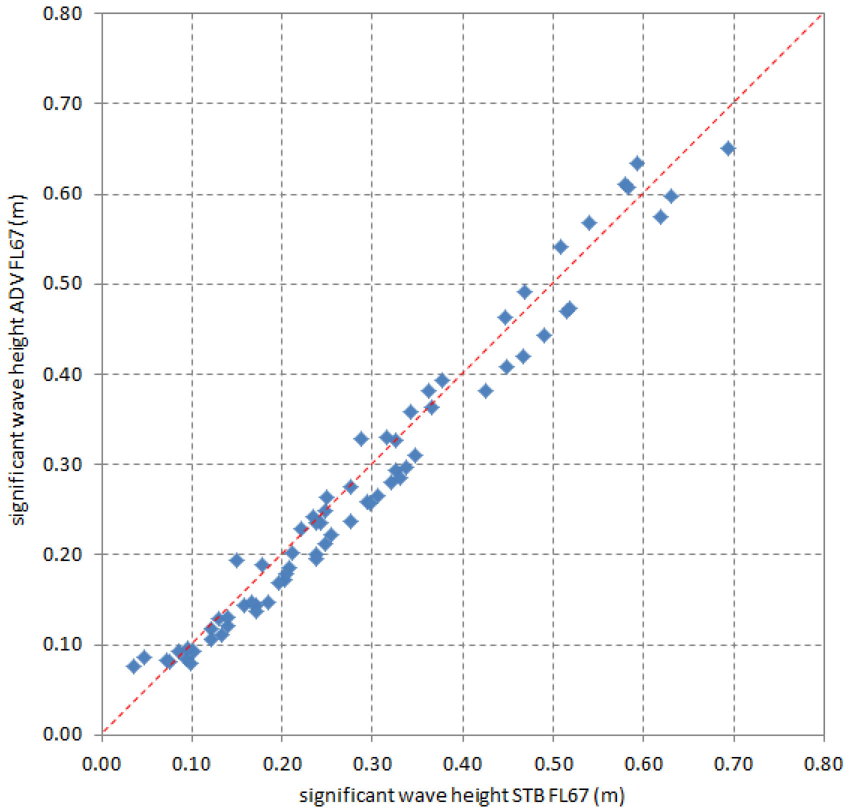
3.5.5 Interpretation

Additional checks were irregularly performed to validate the performance of the post processing Python functions in the DMS. Some examples are shown in this section.

Figure 26 shows the comparison between wave heights, computed with spectral analysis of the STB data versus application of the Maximum Entropy Method to the ADV data. The data is nicely positioned around the 1:1 line. Also low waves (with short periods) are correctly represented, based on the pressure data from the ADV, which indicates that the correction for pressure attenuation with depth is valid, and correctly applied here.

Furthermore, the mean wave direction from the ADV's was compared to the wind direction (KNMI data from station Lelystad), see Figure 27. The wave direction is close to the wind direction for wind directions more or less perpendicular to the shoreline. For wind, parallel to the dike, the wave direction deviates from the wind direction due to refraction.

Figure 26
Significant wave height at FL67 (top) and FL69 (bottom), computed based on the STB and ADV data.



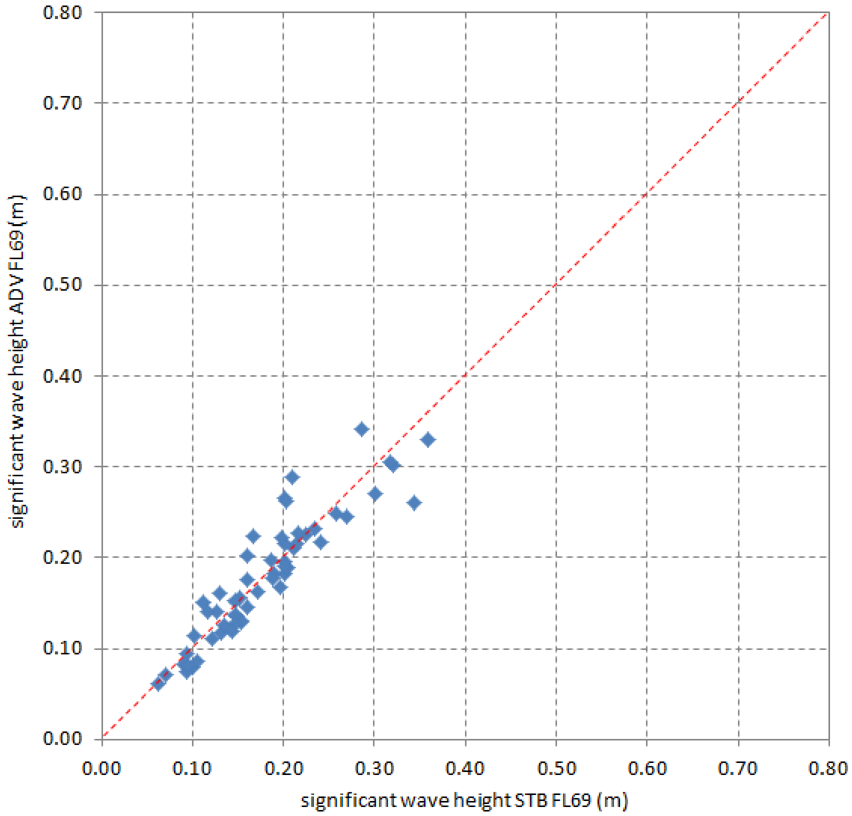
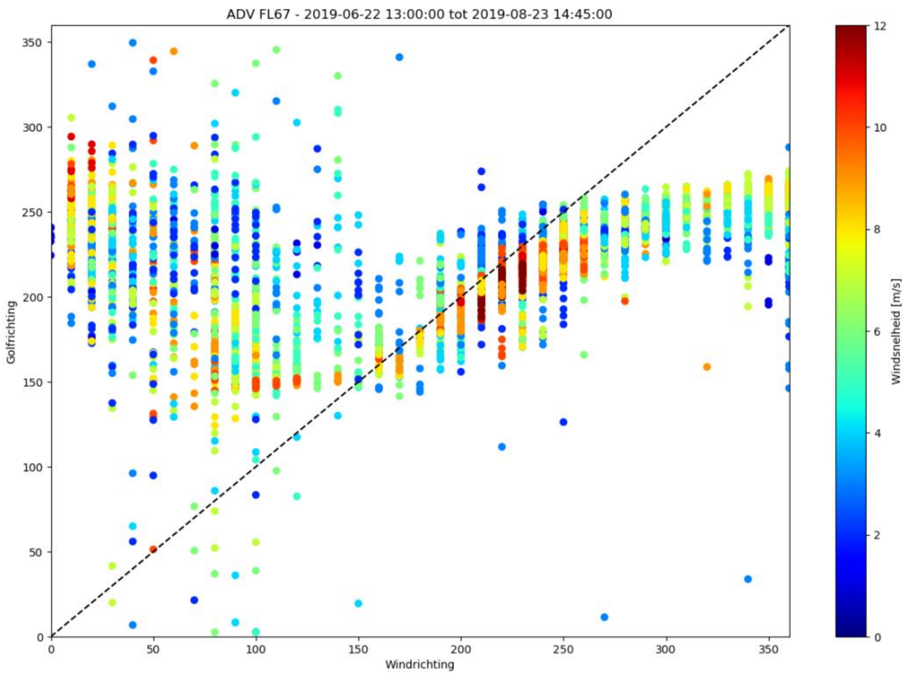
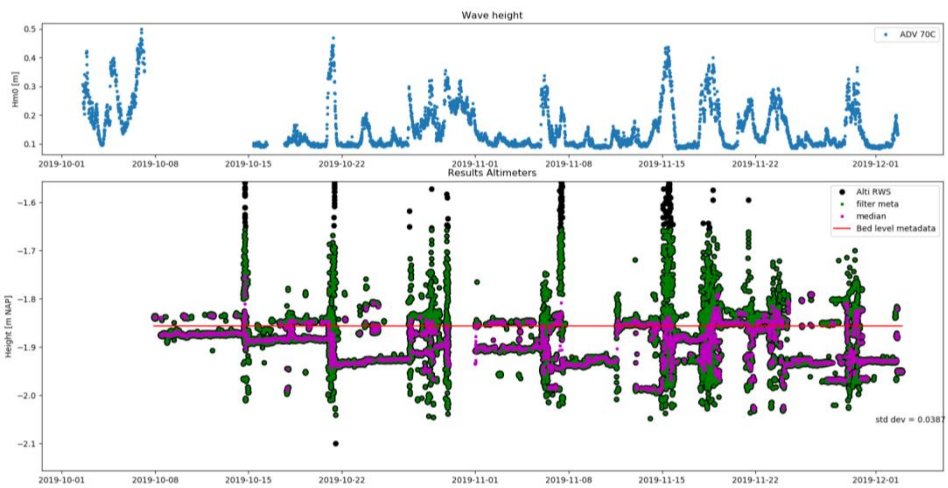


Figure 27
Comparison mean wave direction ADV at FL67 and wind direction at KNMI station Lelystad. Figure: Anne Ton.



Bed level measurements based on the ALT were compared to the bed level from metadata (RTK-DGPS measurements, with only monthly updates). See Figure 28 for an example for FL70B. In the DMS, only the original data (the black dots) are present. During episodes with high waves, the ALT signal is quite noisy due to high turbulence and turbidity. Only the signal during calm periods is reliable.

Figure 28
Comparison of ALT bed level at FL70B, (black dots) with the bed levels in the metadata (red line), incidentally measured with RTK-GPS. ALT data filtered on distance to metadata in green dots, and median of the filtered ALT data in purple dots. The top panel shows the wave height for comparison. Figure: Anne Ton.



4 Results

This section contains some examples of the data on the NetCDF files for 8 December 2019, a day with relatively high wind speeds (up to 16 m/s, 7 Bft), wind set-up and waves.

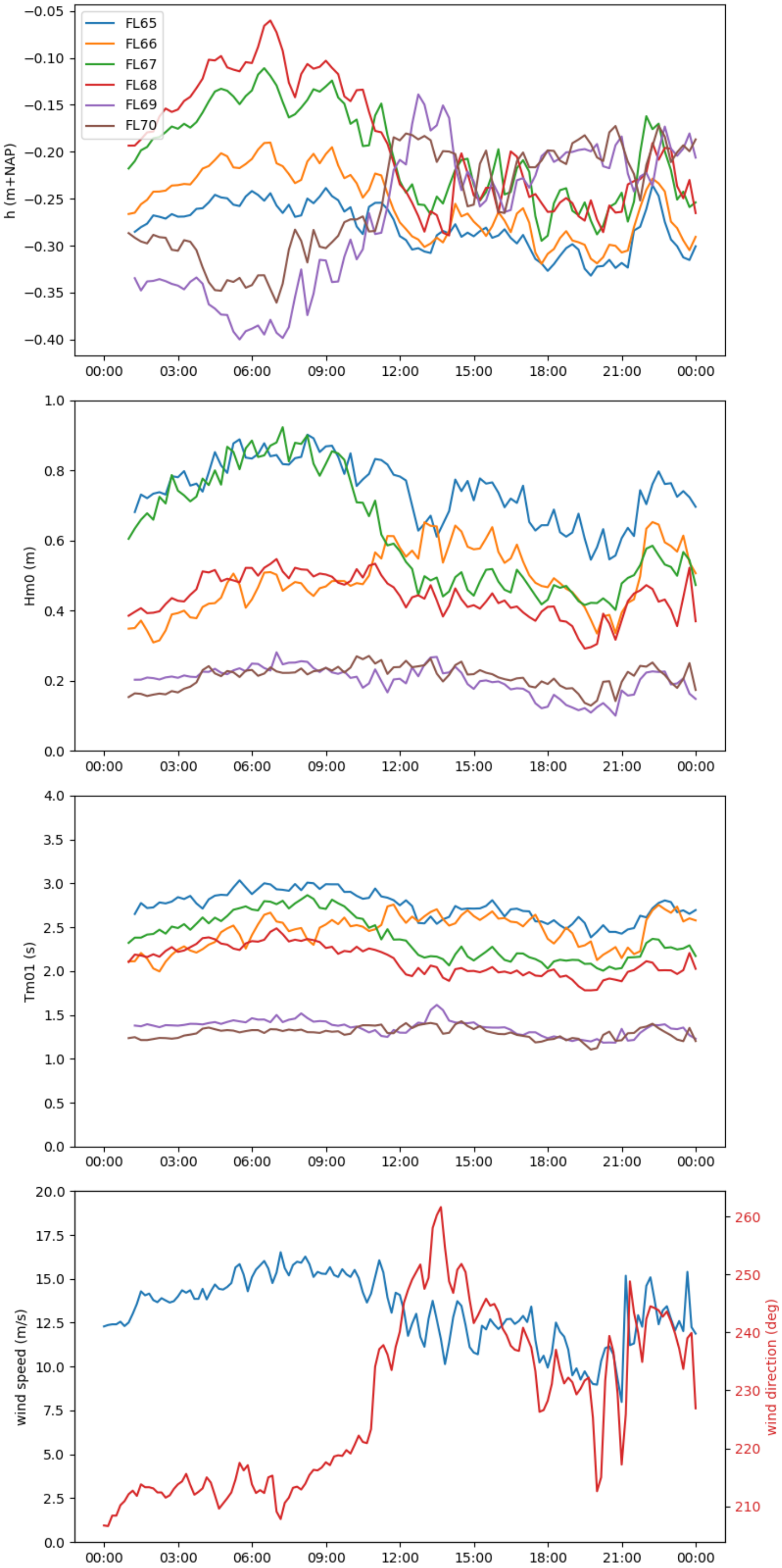
4.1 Step gauges

Figure 29 shows water levels *h*, significant wave heights H_{m0} and mean wave period T_{m01} for the six step gauges. For reference, the wind conditions at station Houtribdijk are included (see Figure 3).

The undisturbed water level at both sides of the Houtribdijk was approximately -0.3 m+NAP. In the morning of 8 December, the wind direction was 210-220 degrees (SSW). This resulted in an increase in water levels (set-up) of 20-25 cm at the Markermeer side of the Houtribdijk (FL67, FL68), and a decrease (set-down) of 5-10 cm at the IJsselmeer side (FL69, FL70). In the afternoon, the wind direction turned to 230-260 degrees (WSW), resulting in set-up of 10-15 cm at the IJsselmeer side. Water levels near the Marker Wadden (FL65, FL66) displayed less variation, since these poles were situated closer to the centre of the lake.

The significant wave height reached values of approximately 0.8 m at FL65 (Marker Wadden) and FL67 (Houtribdijk, Markermeer side). When the wind turned to the west, wave heights at FL67 dropped due to the sheltering presence of Trintelzand, and wave heights at the North-western beach of the Marker Wadden (FL66) increased. During the full day, wave heights and wave periods at the IJsselmeer side of the Houtribdijk were low (0.2 m, 1.5 s) due to the short fetch.

Figure 29
Still water levels (top panel), significant wave heights (2nd panel) and mean wave periods (3rd panel) for the six step gauges at 8 December 2019, and the wind speed and direction (bottom) at station Houtribdijk



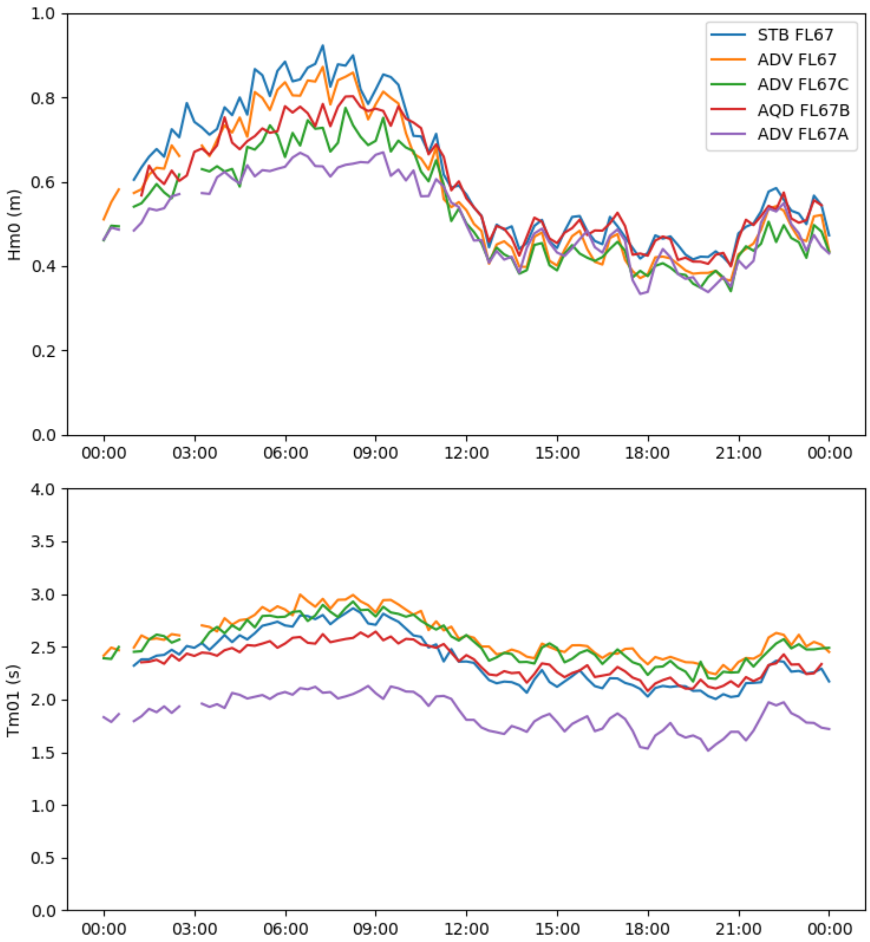
4.2 ADCP

Flow velocities were generally low at all locations (<0.10 m/s) at all vertical positions (layers).

4.3 ADV

Figure 30 shows the wave height and wave period for the offshore pole (FL67), where both a step gauge (STB) and ADV were present, and for the three nearshore poles, with from offshore to nearshore an ADV at FL67C, an Aquadopp at FL67B and an ADV at FL67A. Wave heights based on the three instruments were in the same range. Differences between the ADV and STB can be attributed to differences in measurement technique: direct water level measurement via contact sensors for the STB (§2.2.1) and indirect water level measurement via a pressure sensor and linear wave theory for the ADV (§3.3.4). Spatial differences were the result of physical processes such as shoaling and wave breaking.

Figure 30 Significant wave height (top panel), mean wave period (middle panel) at 8 December 2019 for the different instruments and locations at FL67.



The wave period at FL67A was significantly shorter than at the locations more offshore due to spectral deformation. Figure 32 shows that the variance density near the peak frequency was strongly reduced at FL67A, whereas some high-frequent energy appeared. These two factors led to a relatively short mean wave period. The peak period was constant over the locations, about 3.2 s. Differences between the ADV and STB can again be attributed to differences in measurement technique and postprocessing method.

Figure 31 shows the wave direction at the ADV's of FL67, FL67C and FL67A. The wave direction was very close to the wind direction at station Houtribdijk and responded almost instantaneously. For a wave direction of 200 degrees, waves turned to 210 degrees at FL67C and to 220 degrees at FL67A due to refraction. For a wave direction of 240 degrees, this refraction was absent, which suggests that this direction is nearly perpendicular to the depth contours in this area. The correspondence between wave and wind direction shows that the Maximum Entropy Method correctly performs in the DMS.

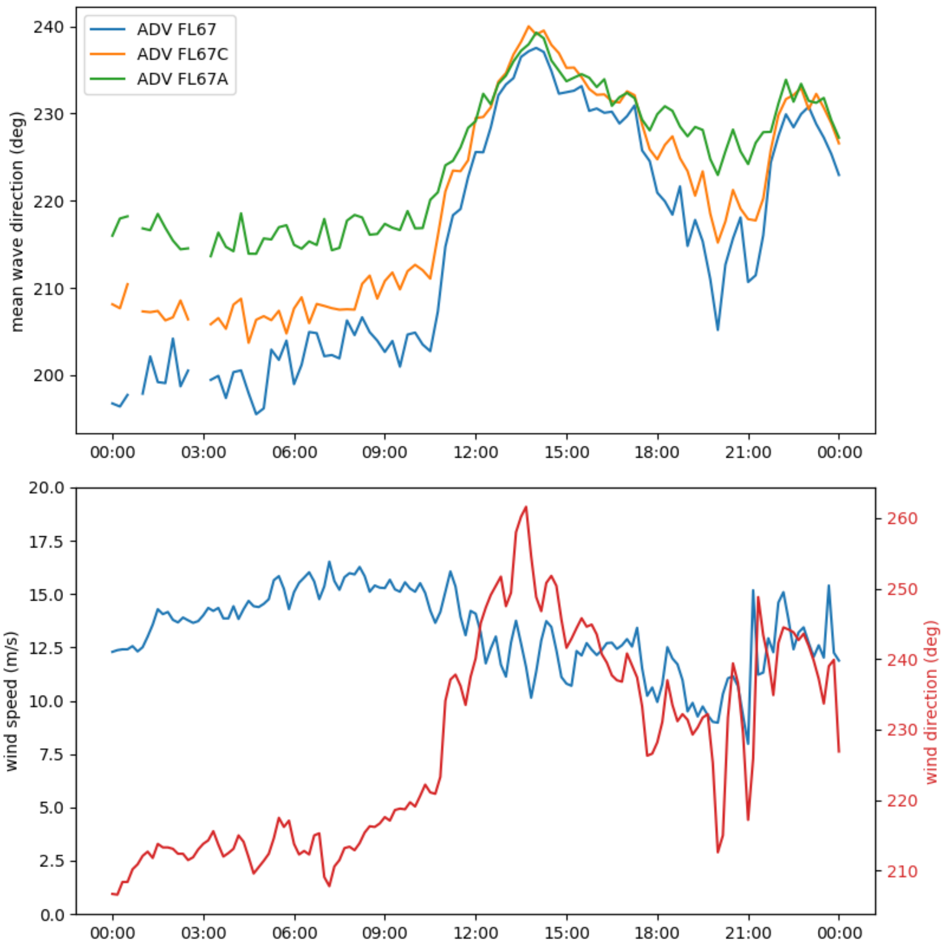
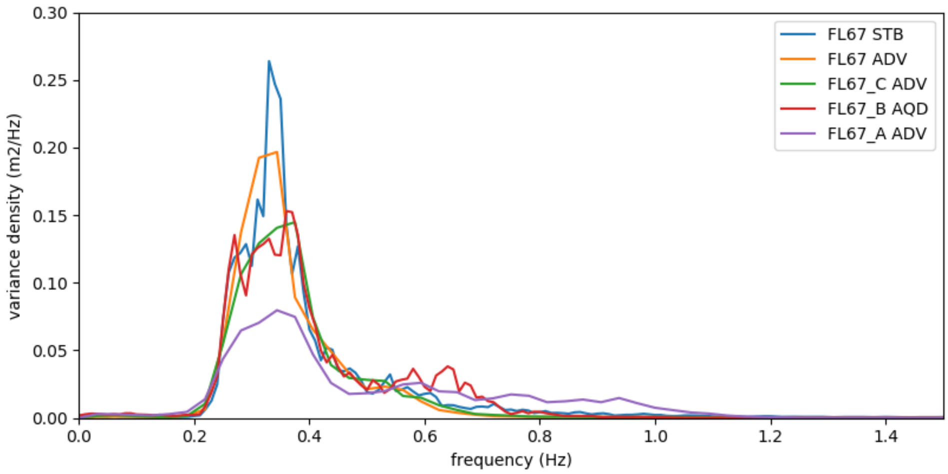


Figure 31
Mean wave direction (top panel) at the 3 ADV's of location FL67 (nautical convention) at 8 December 2019, and the wind speed and direction (bottom panel) at station Houtribdijk

Figure 32
1D wave spectra for the instruments at FL67, 8 December 2019, 11:00.



4.4 Altimeter

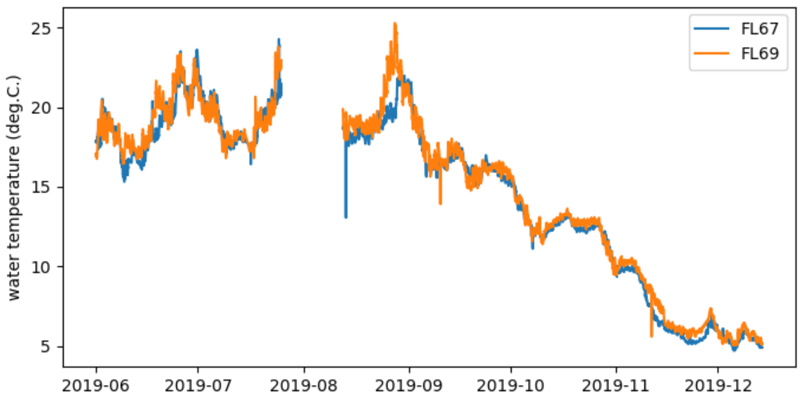
An example of altimeter data is shown in Figure 28. The altimeters, deployed at FL65A,B,C displayed a lot of noise. Therefore, settings were optimized in consultation with the producer of the altimeters. Still, the conditions in the lakes, with a relatively high turbidity, appeared to be challenging for these instruments. Only during calm periods, a stable signal could be obtained. Unfortunately, these instruments are not able to write the original backscatter data; only the best guess for the bed level is saved.

The water at the IJsselmeer side of the Houtribdijk is mostly less turbid than in the Markermeer, and wave heights were lower for the prevailing wind direction (SW). Therefore, the altimeter data of FL69 and FL70 is more useful than the data of the sites in the Markermeer, such as FL65, FL67 and FL68.

4.5 Multi parameter probe

The figures below show the water temperature, chlorophyll concentration and turbidity for the two MPP's. The MPP at the IJsselmeer side of the Houtribdijk (FL69) stopped measuring realistic values for the turbidity and chlorophyll concentration in September 2019.

Figure 33
Example of water temperature at the MPPs



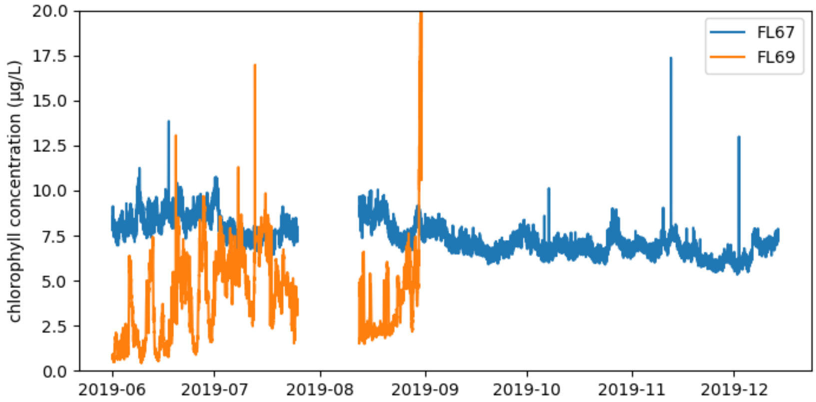


Figure 34
Example of chloro-phyll concentration at the MPPs

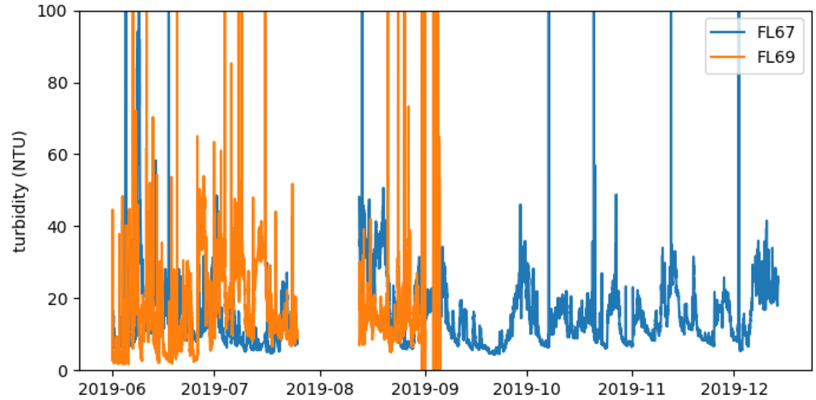


Figure 35
Turbidity at the MPPs

5 References

Lygre and Krogstad (1986)

Lygre, A., & Krogstad, H. E. (1986). Maximum entropy estimation of the directional distribution in ocean wave spectra. Journal of Physical Oceanography, 16(12), 2052-2060.

Van der Werf et al. (2019)

Van der Werf, J. et al. (2019). Data report Kustgenese 2.0 measurements. Deltares report 1220339-015-ZKS-0004. 18 July 2019.

Appendices

A List of known issues

This appendix contains an overview of known issues with the different instruments. This overview is not complete, but can be helpful to explain gaps or unrealistic values in the data.

A.1 Step gauge

Table 11
Overview of known issues for the step gauges

From	To	Issue
04-02-2021	26-02-2021	No data; instruments were taken out because of the risk of ice formation.

A.2 ADCP

Table 12
Overview of known issues for the ADCP's

From	To	Issue
20-11-2020	26-01-2021	Cable at FL66 defect, only zeros in data
04-02-2021	26-02-2021	No data; instruments were taken out because of the risk of ice formation.

A.3 ADV

Table 13
Overview of known issues for the ADV's

From	To	Issue
24-08-2019	16-09-2019	No data for FL65C, problem with data connection
27-12-2019	07-01-2020	Gaps in the data at FL67C because of low battery voltage
29-01-2020	05-02-2020	Gaps in the data at FL67C and FL70C because of low battery voltage
24-02-2020	26-02-2020	Gaps in the data at FL67A and FL67C because of low battery voltage
03-12-2020	18-12-2020	Gaps in the data at FL67A and FL67C because of low battery voltage
05-01-2021	08-01-2021	Gaps in the data at FL65A because of low battery voltage
19-01-2021	22-01-2021	Gaps in the data at FL65A because of low battery voltage
04-02-2021	26-02-2021	No data; instruments were taken out because of the risk of ice formation.

From	To	Issue
05-03-2021	07-03-2021	Deviation of water levels at FL68C, data useful from 08-03-2021

A.4 Aquadopp HR

Table 14
Overview of known issues for the Aquadopp's

From	To	Issue
14-02-2019	17-03-2019	Too many raw data files per day, interval was reduced to 30 minutes between files at 17-3
24-08-2019	16-09-2019	No data for FL65B, problem with data cables and data connection
24-02-2020	26-02-2020	Gaps in the data at FL67B because of low battery voltage
04-02-2021	26-02-2021	No data; instruments were taken out because of the risk of ice formation.

A.5 Altimeter

Table 15
Overview of known issues for the altimeters

From	To	Issue
14-02-2019	02-08-2019	Original configuration, a lot of noise
02-08-2019	13-08-2019	Optimization configuration, altimeters placed under an angle of 25-30 degrees
24-08-2019	16-09-2019	No data for FL65B and FL65C, problem with data cables and data connection
08-10-2019	23-03-2020	TU Delft altimeters deployed at FL67ABC for comparison. Data available at TU Delft (not in DMS)
27-12-2019	07-01-2020	Gaps in the data at FL67A and FL67C because of low battery voltage
29-01-2020	05-02-2020	Gaps in the data at FL67C and FL70C be-cause of low battery voltage
24-02-2020	26-02-2020	Gaps in the data at FL67A and FL67C because of low battery voltage
	14-07-2020	Altimeter FL69B was replaced
03-12-2020	18-12-2020	Gaps in the data at FL67A and FL67C because of low battery voltage
05-01-2021	08-01-2021	Gaps in the data at FL65A because of low battery voltage
19-01-2021	22-01-2021	Gaps in the data at FL65A because of low battery voltage
04-02-2021	26-02-2021	No data; instruments were taken out because of the risk of ice formation.

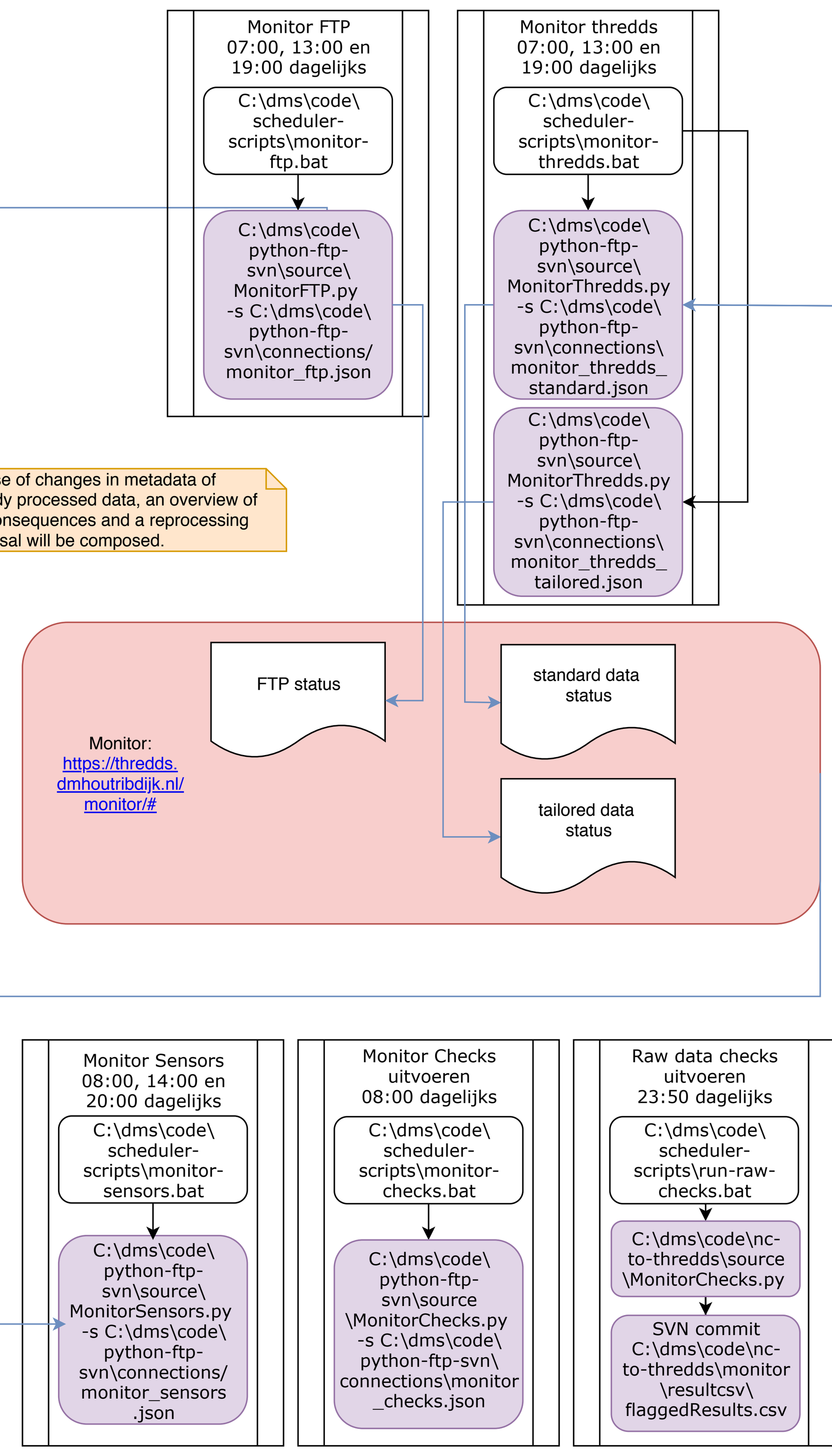
A.6 Multi parameter probe

Table 16
Overview of known issues for the multi parameter probes

From	To	Issue
16-01-2020	27-01-2020	No data for FL67
03-08-2020	07-09-2020	Unrealistic turbidity measurements. Defective MPP was replaced at FL67 at 07-09-2020
03-08-2020	08-09-2020	Unrealistic turbidity measurements. Defective MPP was replaced at FL69 at 08-09-2020
	30-11-2020	MPP was replaced again at FL67 because of defective turbidity probe
04-02-2021	26-02-2021	No data; instruments were taken out because of the risk of ice formation.

B Swimming lanes

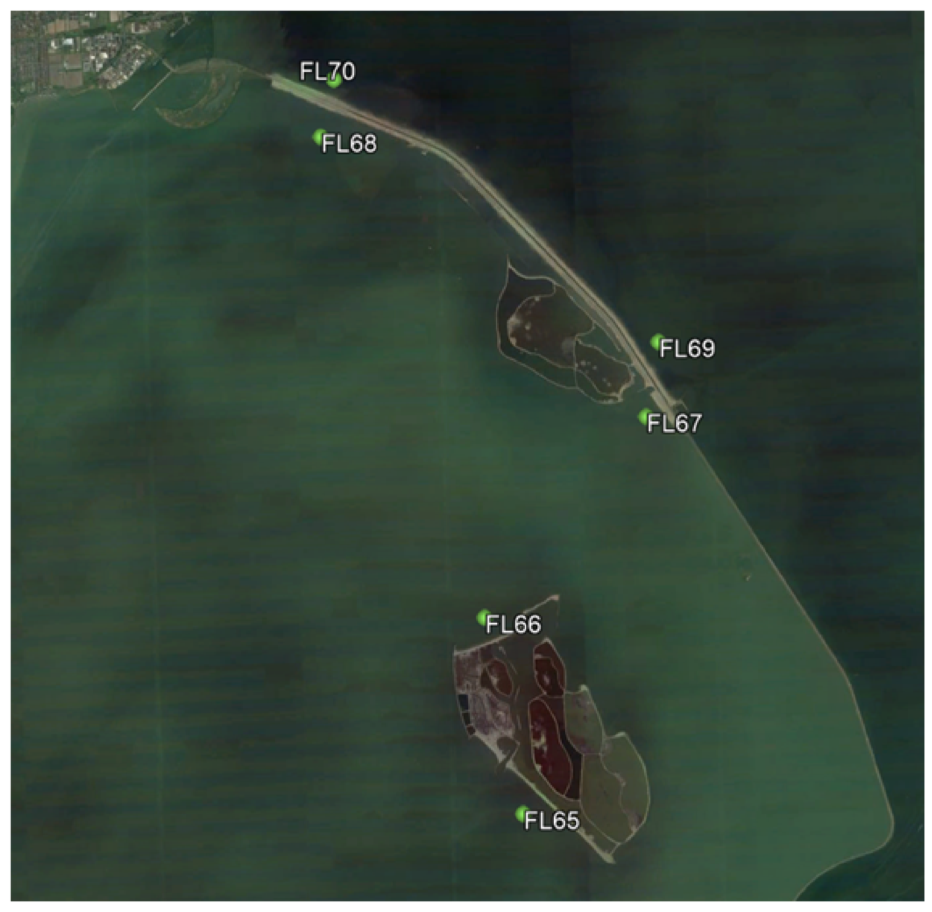
This appendix contains a swimming lanes impression of all scripts used in the DMS. In this impression all process steps are displayed in vertical ‘swimming lanes’. Resulting data is presented in horizontal blocks. Each swimming lane represents the processes for a certain measuring instrument (e.g. STB, MPP, etc.). Each horizontal block represents a data storage (e.g. the FTP server, SVN, FEWS, THREDDS, etc.). The swimming lanes impression on next page, does not contains all scripts in detail. Instead references are included to additional process schemas (also part of this appendix).



Location	STB	ADC	ALT	ADV	AQD	MPP
FL65	P	P				
FL65_A			V	V		
FL65_B			V		V	
FL65_C			V	V		
FL66	P	P				
FL67	P	P		P		P
FL67_A			A	A		
FL67_B			A		A	
FL67_C			A	A		
FL68	P	P				
FL69	P	P		P		P
FL69_A			V	V		
FL69_B			V		V	
FL69_C			V	V		
FL70	P	P				
FL70_A			A	A		
FL70_B			A		A	
FL70_C			A	A		

standard	x	x	x	x	x	x
tailored	x			x	x	

P — Permanent measurements
V — Removed mobile measurement location (until sep 2019)
A — Active modile measurement location (since sep 2019)

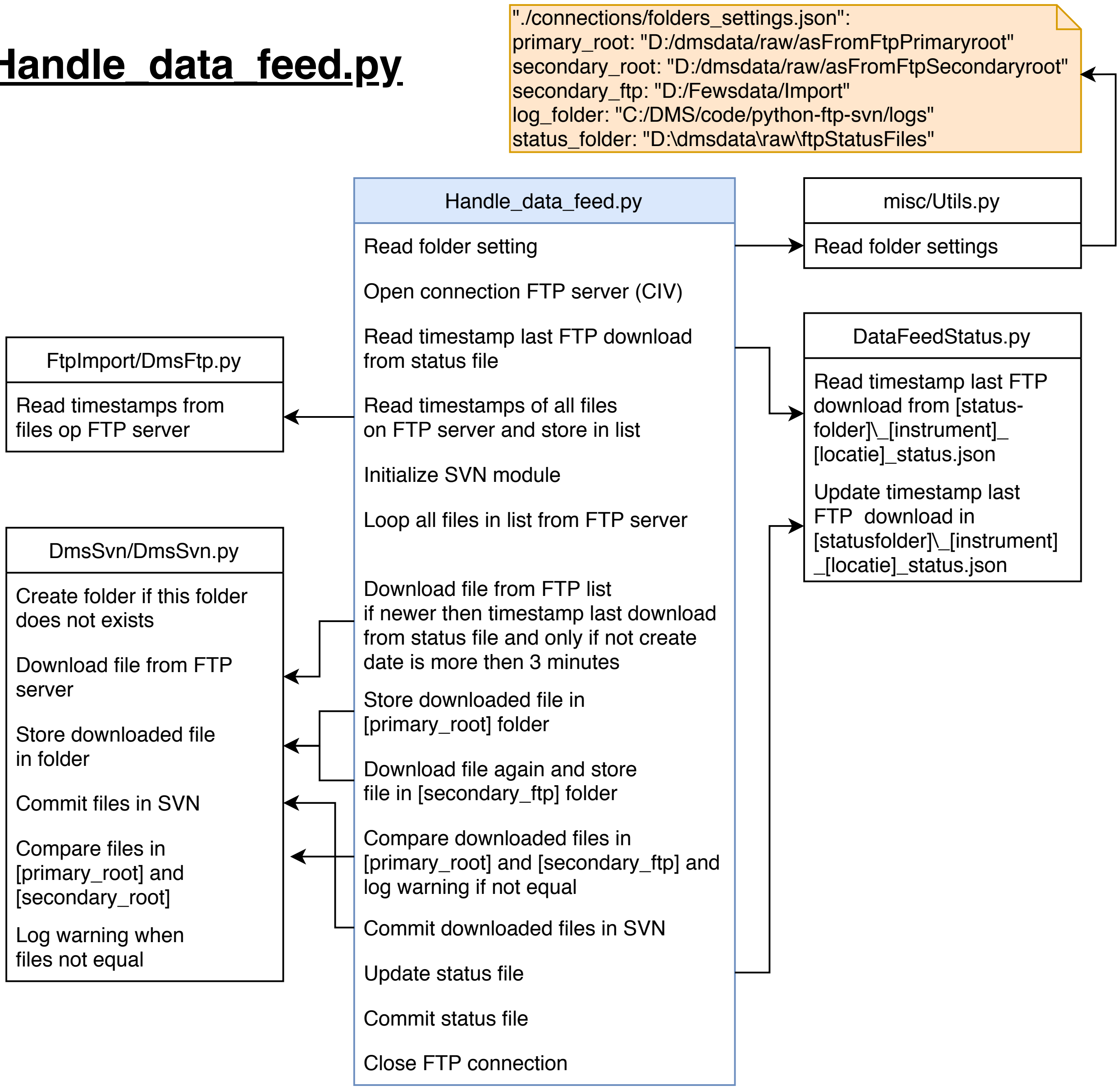


DMS Overview

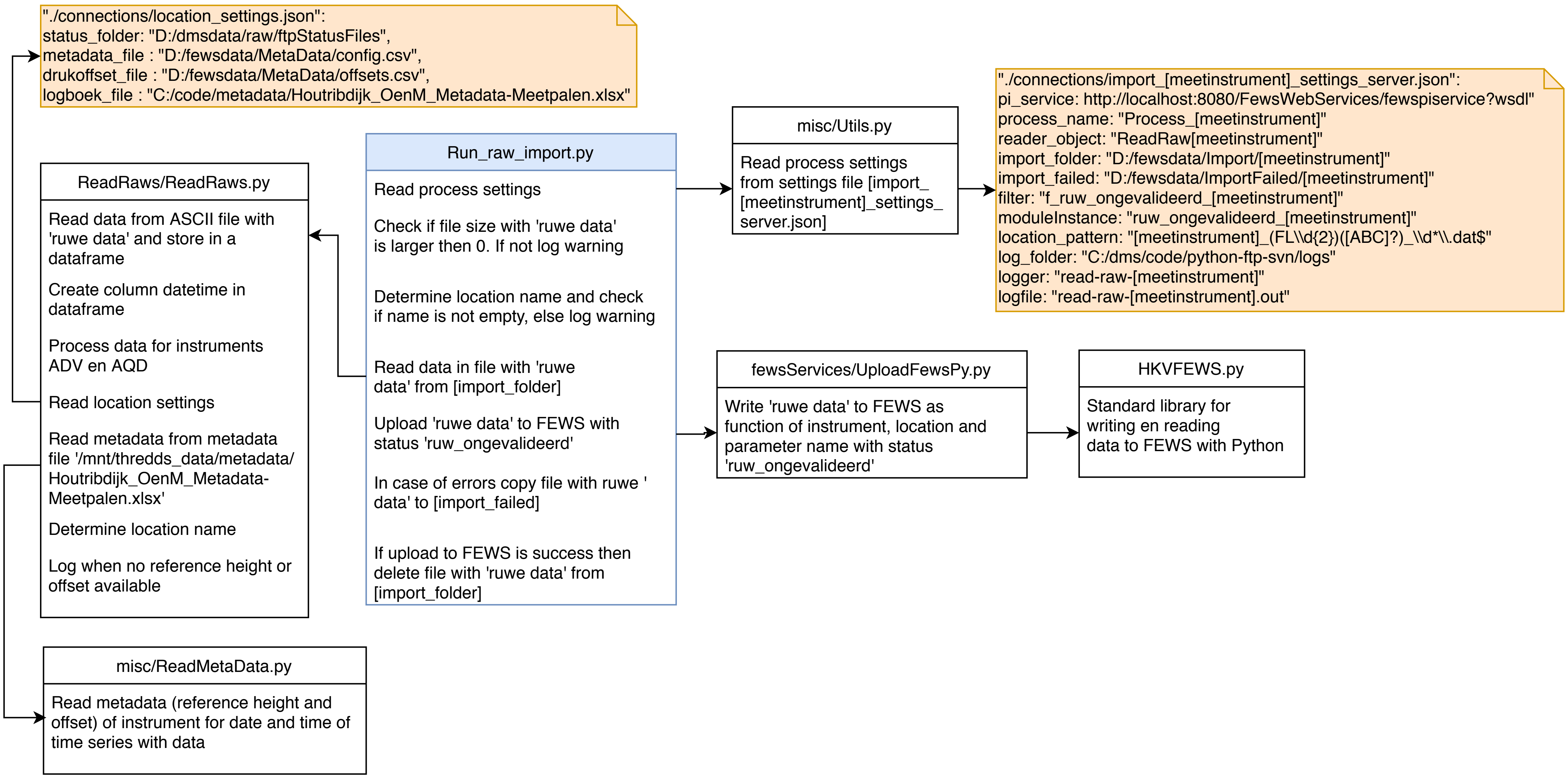
LEGENDA

FILE | Schedular | PROCESS | SCRIPTS

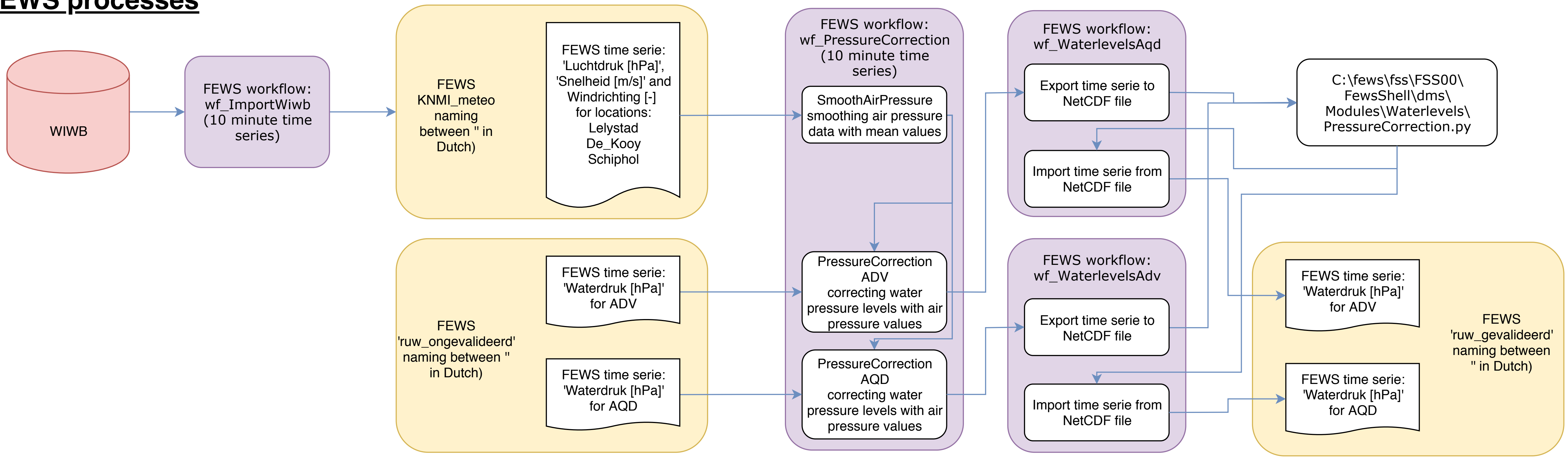
Handle_data_feed.py



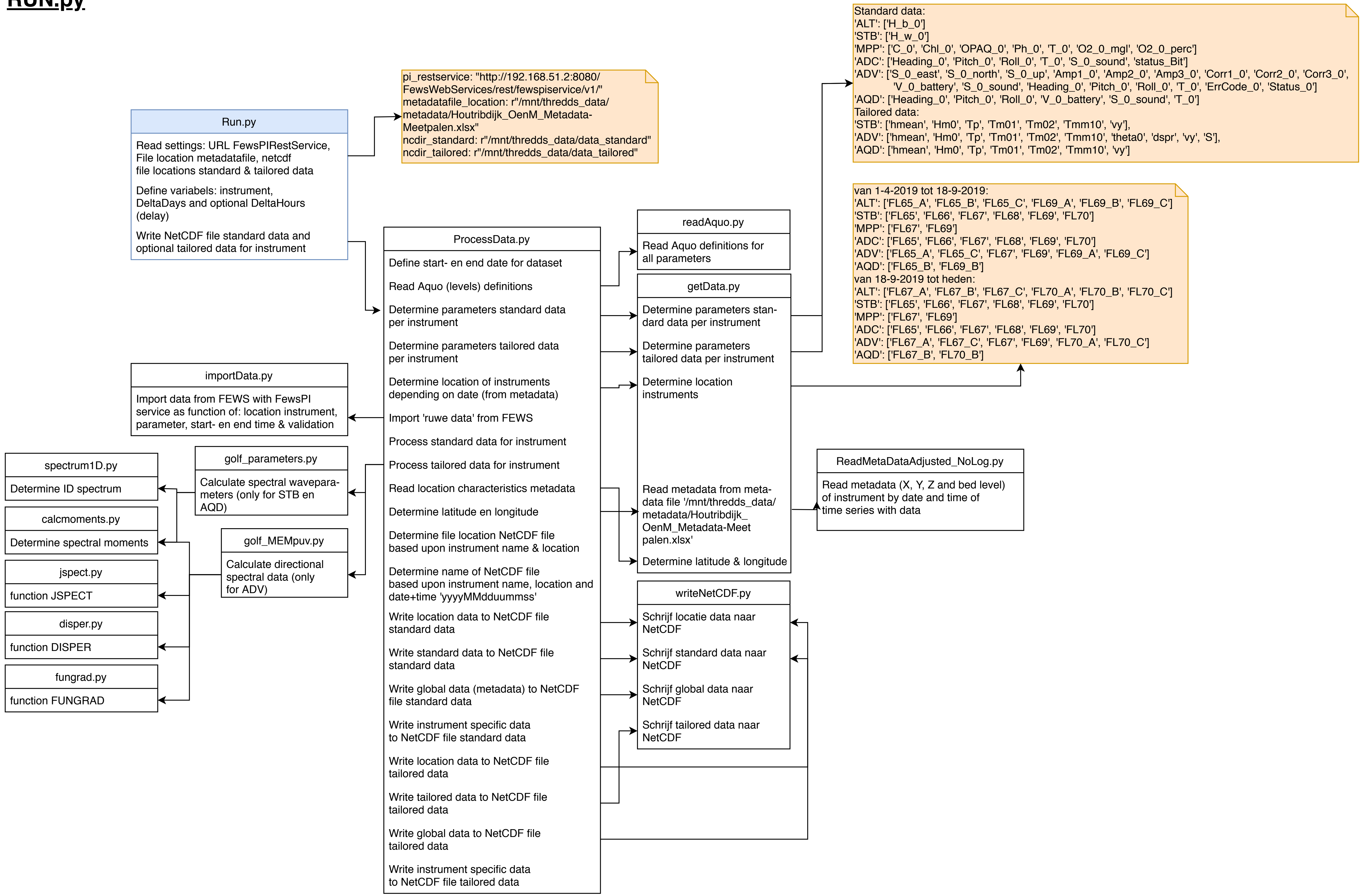
RUN_raw_import.py



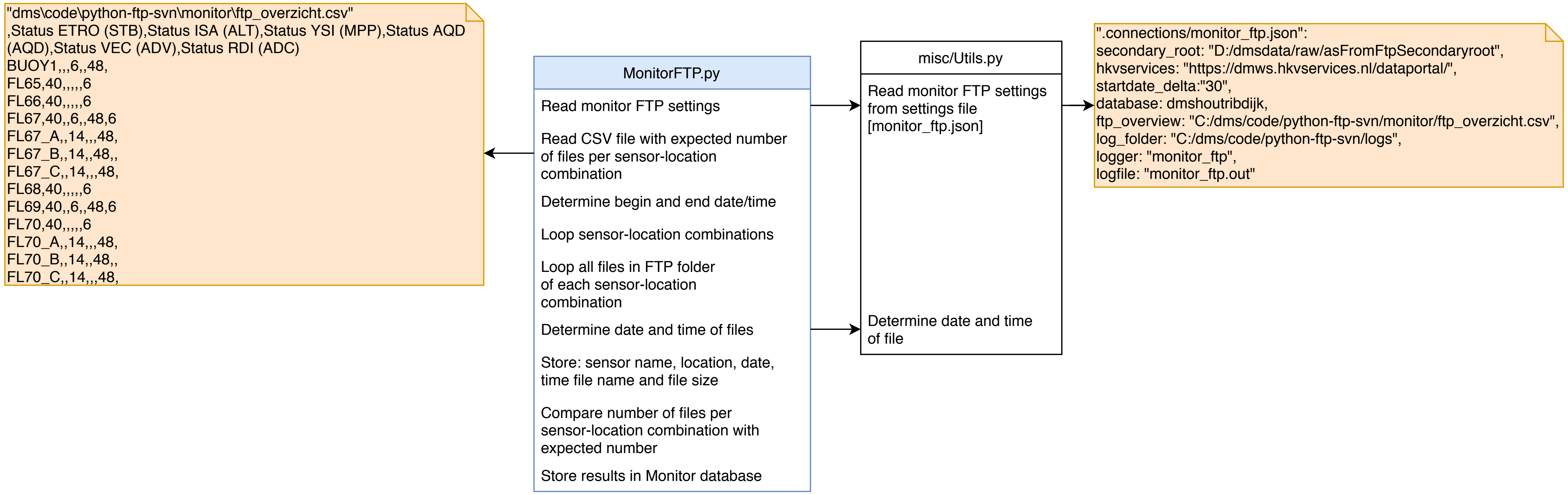
FEWS processes



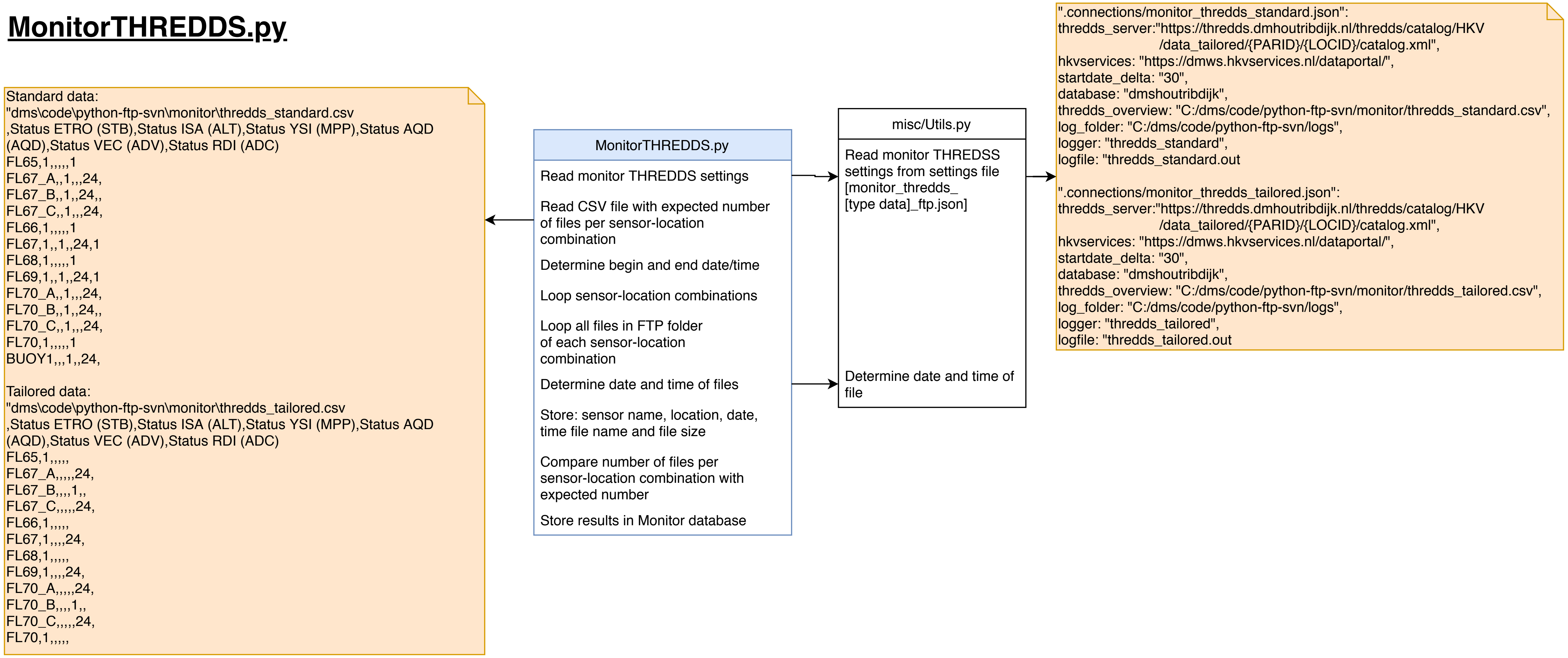
RUN.py


Run.py
Read settings: URL FewsPIRestService, File location metadatafile, netcdf file locations standard & tailored data
Define variabels: instrument, DeltaDays and optional DeltaHours (delay)
Write NetCDF file standard data and optional tailored data for instrument
pi_restservice: "http://192.168.51.2:8080/FewsWebServices/rest/fewspiservice/v1/"
metadatafile_location: r"/mnt/thredds_data/metadata/Houtribdijk_OenM_Metadata-Meetpalen.xlsx"
ncdir_standard: r"/mnt/thredds_data/data_standard"
ncdir_tailored: r"/mnt/thredds_data/data_tailored"
Standard data:
'ALT': ['H_b_0']
'STB': ['H_w_0']
'MPP': ['C_0', 'Chl_0', 'OPAQ_0', 'Ph_0', 'T_0', 'O2_0_mgl', 'O2_0_perc']
'ADC': ['Heading_0', 'Pitch_0', 'Roll_0', 'T_0', 'S_0_sound', 'status_Bit']
'ADV': ['S_0_east', 'S_0_north', 'S_0_up', 'Amp1_0', 'Amp2_0', 'Amp3_0', 'Corr1_0', 'Corr2_0', 'Corr3_0', 'V_0_battery', 'S_0_sound', 'Heading_0', 'Pitch_0', 'Roll_0', 'T_0', 'ErrCode_0', 'Status_0']
'AQD': ['Heading_0', 'Pitch_0', 'Roll_0', 'V_0_battery', 'S_0_sound', 'T_0']
Tailored data:
'STB': ['hmean', 'Hm0', 'Tp', 'Tm01', 'Tm02', 'Tmm10', 'vy'],
'ADV': ['hmean', 'Hm0', 'Tp', 'Tm01', 'Tm02', 'Tmm10', 'theta0', 'dspr', 'vy', 'S'],
'AQD': ['hmean', 'Hm0', 'Tp', 'Tm01', 'Tm02', 'Tmm10', 'vy']
van 1-4-2019 tot 18-9-2019:
'ALT': ['FL65_A', 'FL65_B', 'FL65_C', 'FL69_A', 'FL69_B', 'FL69_C']
'STB': ['FL65', 'FL66', 'FL67', 'FL68', 'FL69', 'FL70']
'MPP': ['FL67', 'FL69']
'ADC': ['FL65', 'FL66', 'FL67', 'FL68', 'FL69', 'FL70']
'ADV': ['FL65_A', 'FL65_C', 'FL67', 'FL69', 'FL69_A', 'FL69_C']
'AQD': ['FL65_B', 'FL69_B']
van 18-9-2019 tot heden:
'ALT': ['FL67_A', 'FL67_B', 'FL67_C', 'FL70_A', 'FL70_B', 'FL70_C']
'STB': ['FL65', 'FL66', 'FL67', 'FL68', 'FL69', 'FL70']
'MPP': ['FL67', 'FL69']
'ADC': ['FL65', 'FL66', 'FL67', 'FL68', 'FL69', 'FL70']
'ADV': ['FL67_A', 'FL67_C', 'FL67', 'FL69', 'FL70_A', 'FL70_C']
'AQD': ['FL67_B', 'FL70_B']
ProcessData.py
Define start- en end date for dataset
Read Aquo (levels) definitions
Determine parameters standard data per instrument
Determine parameters tailored data per instrument
Determine location of instruments depending on date (from metadata)
Import 'ruwe data' from FEWS
Process standard data for instrument
Process tailored data for instrument
Read location characteristics metadata
Determine latitude en longitude
Determine file location NetCDF file based upon instrument name & location
Determine name of NetCDF file based upon instrument name, location and date+time 'yyyyMMdduummss'
Write location data to NetCDF file standard data
Write standard data to NetCDF file standard data
Write global data (metadata) to NetCDF file standard data
Write instrument specific data to NetCDF file standard data
Write location data to NetCDF file tailored data
Write tailored data to NetCDF file tailored data
Write global data to NetCDF file tailored data
Write instrument specific data to NetCDF file tailored data
readAquo.py
Read Aquo definitions for all parameters
getData.py
Determine parameters standard data per instrument
Determine parameters tailored data per instrument
Determine location instruments
Read metadata from metadata file '/mnt/thredds_data/metadata/Houtribdijk_OenM_Metadata-Meetpalen.xlsx'
Determine latitude & longitude
ReadMetaDataAdjusted_NoLog.py
Read metadata (X, Y, Z and bed level) of instrument by date and time of time series with data
writeNetCDF.py
Schrijf locatie data naar NetCDF
Schrijf standard data naar NetCDF
Schrijf global data naar NetCDF
Schrijf tailored data naar NetCDF
importData.py
Import data from FEWS with FewsPI service as function of: location instrument, parameter, start- en end time & validation
golf_parameters.py
Calculate spectral waveparameters (only for STB en AQD)
golf_MEMpuv.py
Calculate directional spectral data (only for ADV)
spectrum1D.py
Determine ID spectrum
calcmoments.py
Determine spectral moments
jspect.py
function JSPECT
disper.py
function DISPER
fungrad.py
function FUNGRAD

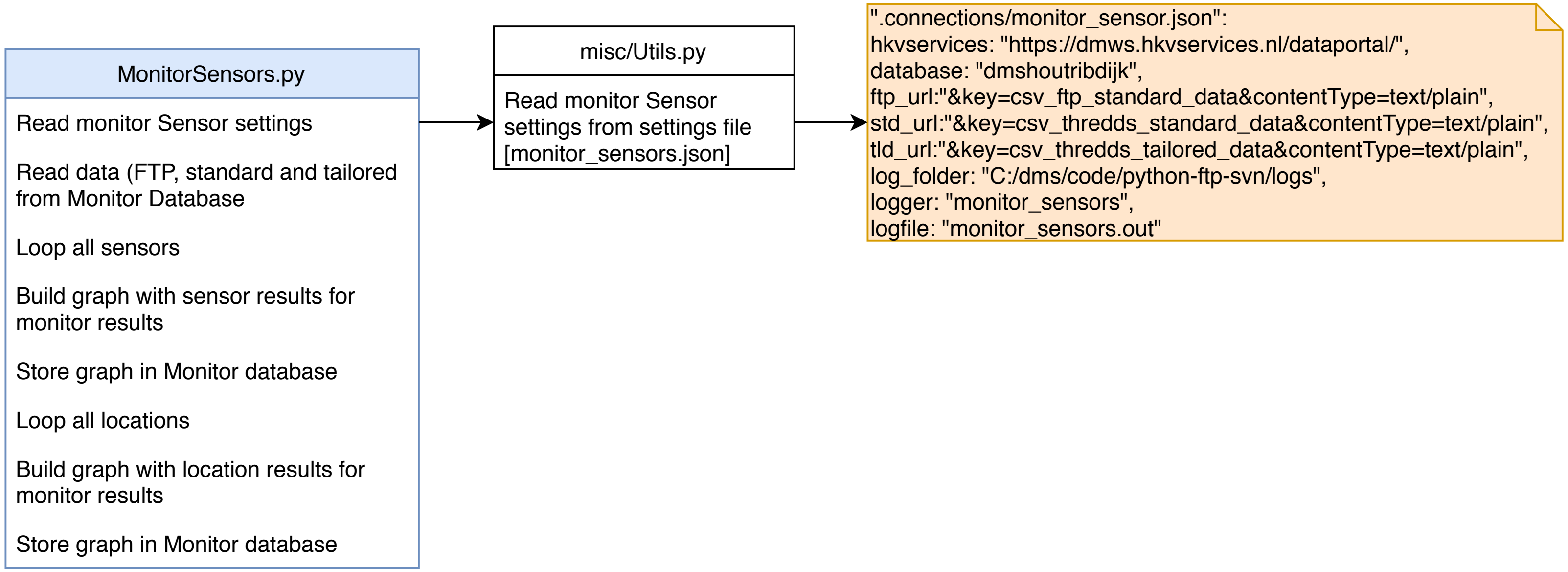
MonitorFTP.py



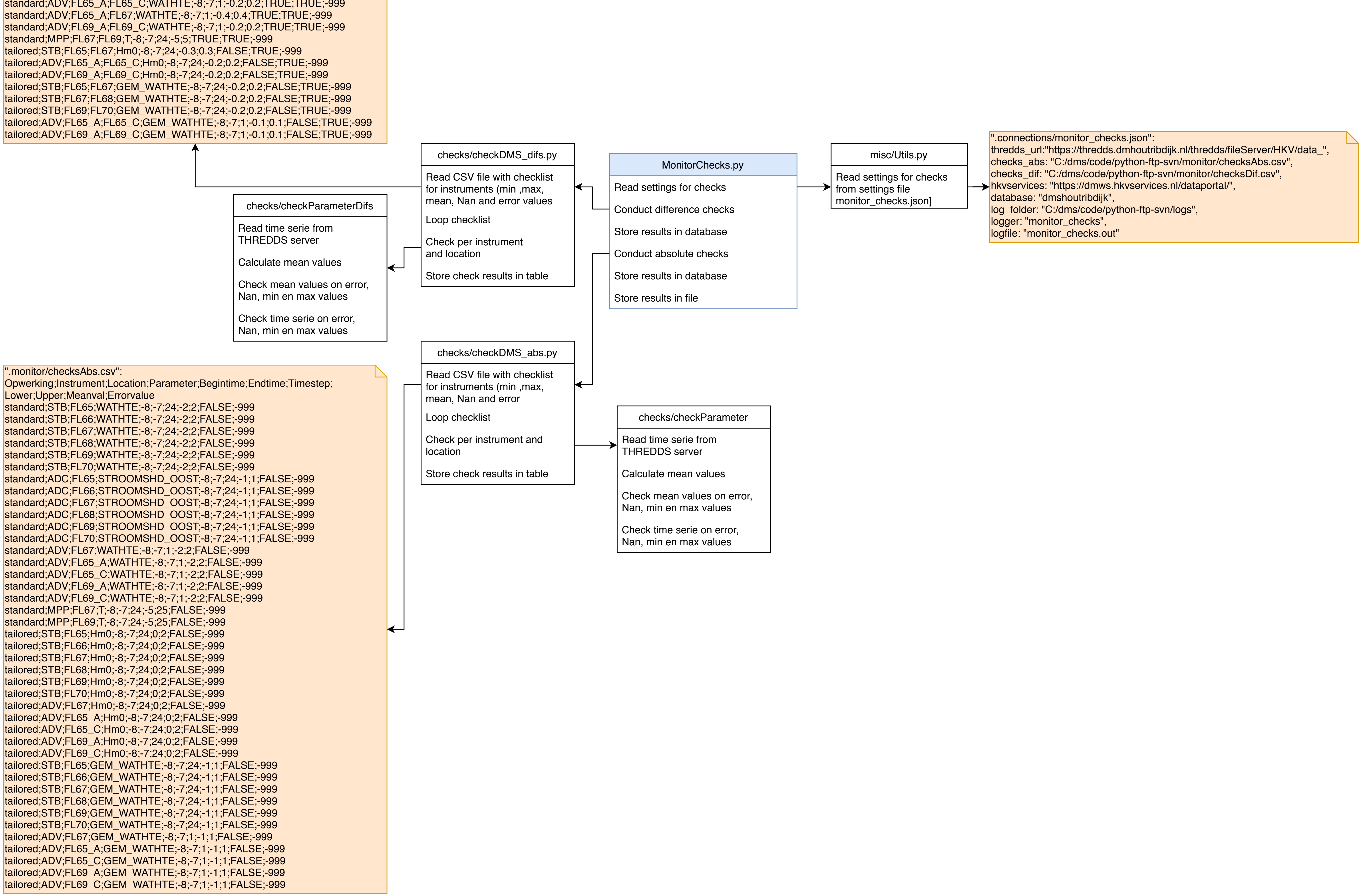
MonitorTHREDDS.py



MonitorSensors.py



MonitorChecks.py



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