Harmonized ozone profile retrievals from GROMOS and SOMORA: time series description

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Chapter 1

Introduction

The GROund-based Millimeter-wave Ozone Spectrometer (GROMOS) is operated by the Institute of Applied Physics (IAP) at the University of Bern since 1994. It is located on the roof of one of the building, in a controlled temperature chamber. The Stratospheric Ozone MOnitoring RAdiometer (SOMORA) is operated by the Federal Office of Meteorology and Climatology MeteoSwiss in Payerne since 2000. It is also located in a controlled room temperature and has very similar viewing geometry as GROMOS. Figure 1.1 shows the location of both instruments and their approximate field-of-view.

This document contains the detailed description of the harmonized ozone time series from GROMOS and SOMORA. It starts in 2009, when a new FFT spectrometer was installed on both instruments (July on GROMOS and September on SOMORA). It is complementary to the report on the GROMORA retrievals (available on BORIS).

The document is organized as follows. Chapter 2 presents an overview of the GROMOS and SOMORA ozone time series from 2009 to 2021 and lists the most important events during this period. Chapter 3 and 4 provide a year-by-year detailed description of the time series for each instrument. This is intented as a sort of user guide to use these time series, for instance for new trends studies. It should help understand most of the spurious periods detected in the data series in order to treat them accordingly.

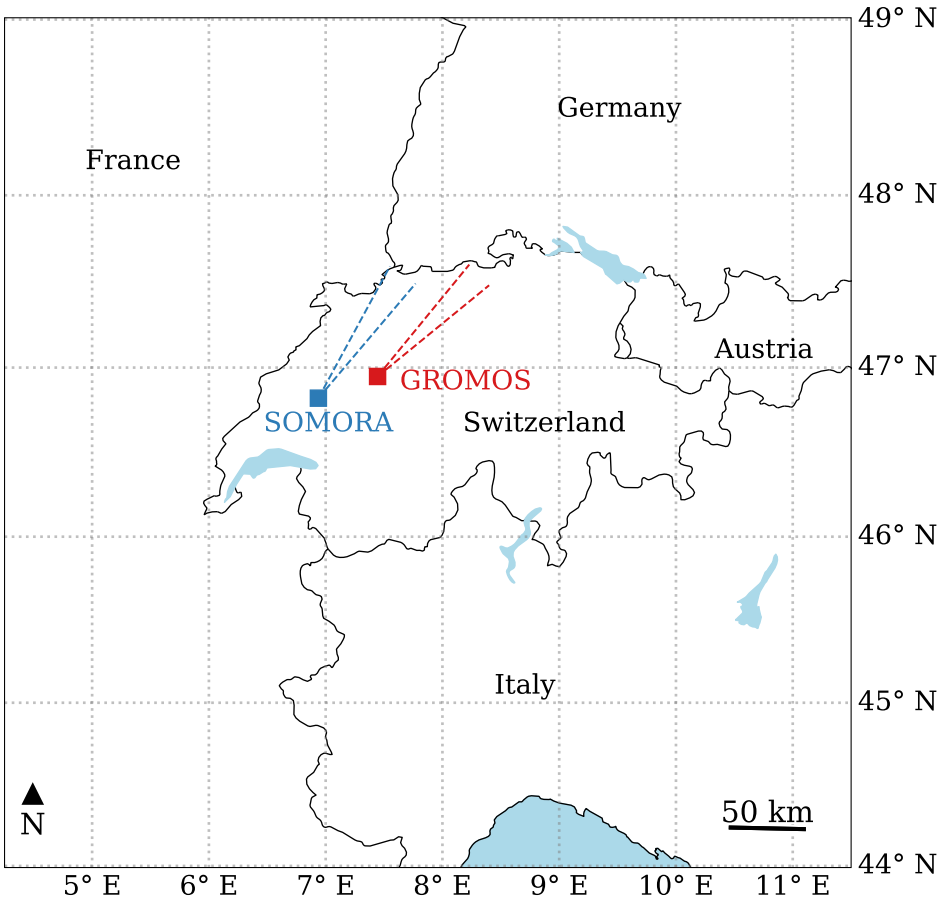


Figure 1.1: Location of GROMOS and SOMORA, with approximate beamwidth directions

Chapter 2

Swiss ozone time series

In this section, we introduce the new harmonized ozone time series from GROMOS and SOMORA. As the comparison of both series if the subject of a dedicated peer-reviewed publication, we only provide here some insights on the main similarities and differences between these new data series. For both series, we highlight the events with significant effect on the ozone retrievals between the years 2009 and 2021.

Figure 2.1 shows the weekly averaged ozone volume mixing ratio (VMR) time series for GROMOS and SOMORA accompanied by the corresponding time series from the Microwave Limb Sounder (MLS) from the Aura satellite.

Figure 2.2 also shows the weekly averaged ozone VMR from GROMOS and SOMORA but this time with the flags applied on the level 2. In addition, the lower panel shows the relative differences between the two instruments. From the relative differences, we can spot some characteristic periods that will be shortly described here. Note that more details can be found in the year-to-year description of the time series.

In fact, for each year and each instrument, we use 7 diagnostics figures and make a detailed list of the most important events taking place on a given year. Note that these figures have been designed to give a first visual impression of the data quality or problems happening for a given year. They are "quick" figures which might sometime lack a unit or could have an improved plotting range of values. This is an assumed choice for the sake of time efficiency and as the code and the data are all freely available, the user should be able to reprocess other or better diagnostic figures easily.

Also listed are the different sinusoidal baseline periods retrieved for each period. They have been computed from fast fourier transform analysis of the residuals obtained from a first set of retrievals without sine baselines included.

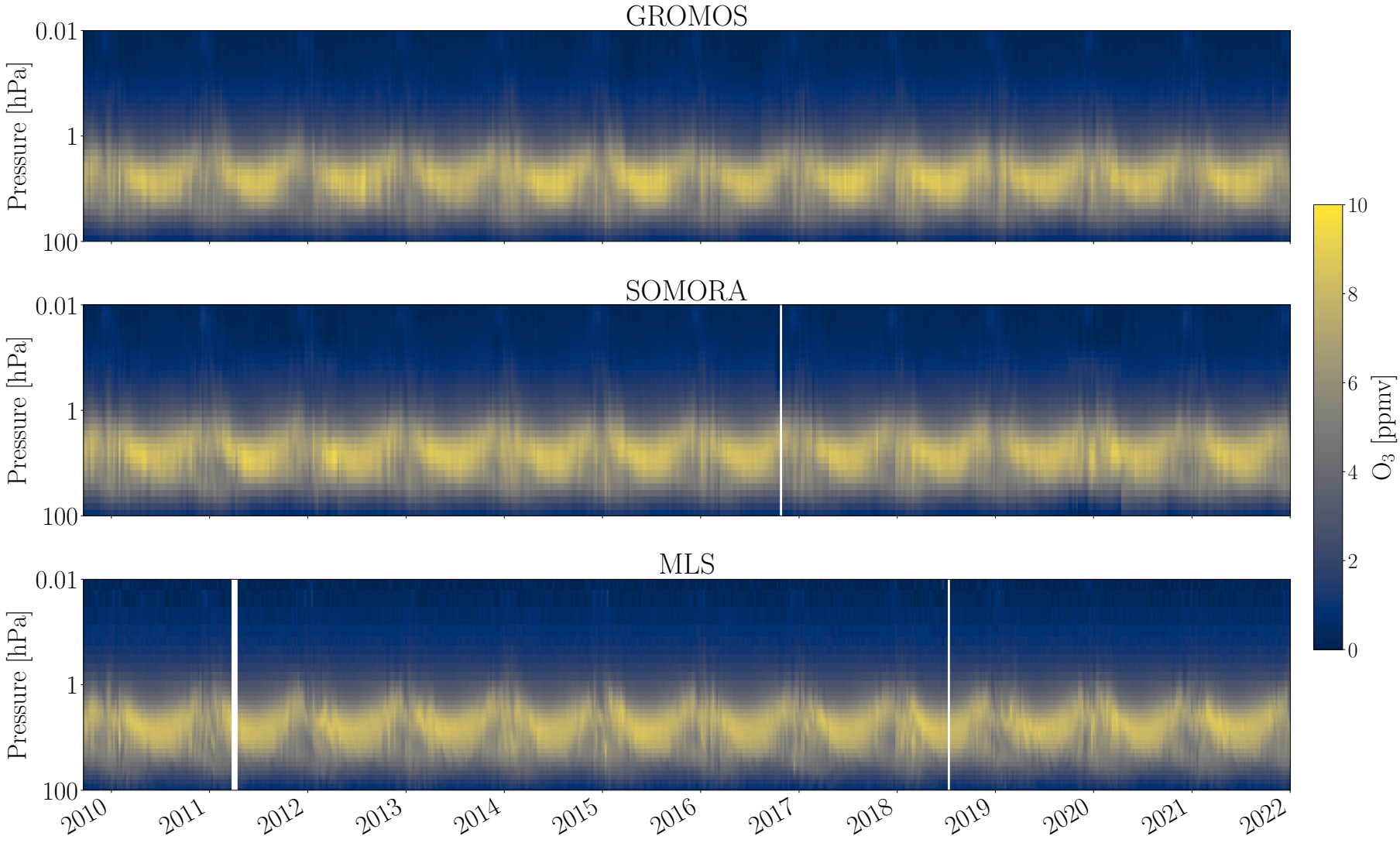


Figure 2.1: GROMORA and MLS weekly averaged ozone profiles 2009-2021 without flags

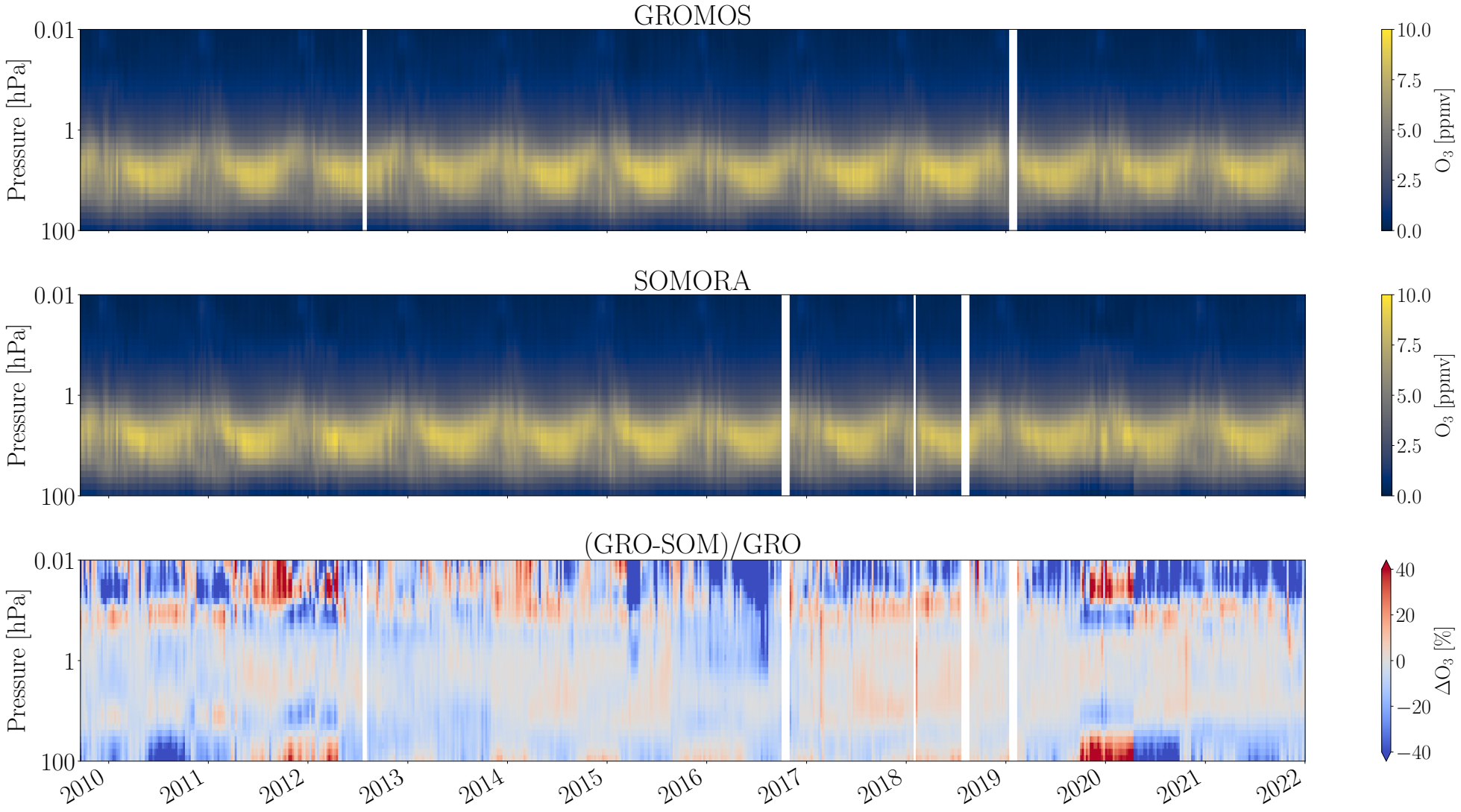


Figure 2.2: GROMORA weekly relative differences 2009-2021, with level 2 flags

Table 2.1: Summary of the main events and their consequences on GROMOS and SOMORA time series.

Dates	**Instrument**	**Event**	**Consequences**
24.04.2012	SOMORA	Change of cold load observation angle.	Large reduction of vertical oscillations
07.11.2013	GROMOS	Jump in Trec for unknown reasons.	Retrievals cost stabilization and reduction of the bias in the statosphere
08 - 09.2014	GROMOS	Problems with the cold load and change of observation angle	negative bias in the mesosphere.
23.02.2015	GROMOS	empty LN2 container	change of sines baseline
14.03.2015	GROMOS	problem with cold load expansion tube	large frequency shift retrieval until 05.2015 with negative bias in the mesosphere
04.07.2016 - 23.08.2016	GROMOS	Problems with the cold load and room temperature control until cleaning	strong negative bias from GROMOS in upper stratosphere and mesosphere
10 - 11.2016	SOMORA	lock problems and hardware upgrade	flagged from 29.09 to 03.11
23.08.2018	SOMORA	cleaning of the cold load	Large jump in Trec and reduction of the baselines present since June 2018.
14.01 - 12.02.2019	GROMOS	cleaning of the cold load	this period is flagged
27.09 - 31.12.2019	SOMORA	cleaning of the cold load and start of power decrease problem	this period is not flagged but should be treated with care
25.01.2020	SOMORA	intervention at IAP to investigate power decrease problem	Large drop of Trec and changes in sine baselines
27.07 - 10.11.2020	SOMORA	multiple hardware changes	final stabilization of SOMORA
10 - 12.2021	GROMOS	5G problems	mostly flagged but still many missing data

Overall, GROMOS and SOMORA are quite stable instruments as they provide a high proportion of "good quality" data since 2009. As shown in Table 2.2, both instruments provided good quality hourly integrated spectra over 85 % of the time. It varies slightly from year-to-year as will be detailed later in this document. After the retrieval process, there remain 76 % of good quality ozone profiles for GROMOS and 84 % for SOMORA. The reason for failed retrieval are mostly related to the high tropospheric opacity cases. Note that we also have some numerical instabilities in the retrievals which sometimes leads to some unphysical ozone values. These are not yet understood but concerns less than 0.4 % of the retrieved profiles and are flagged accordingly.

Also, it seems that GROMOS and SOMORA are quite consistent with seasonal changes. The mean seasonal averaging kernels (AVKs) of the two instrument are very similar and do not vary significantly with the season (Fig. 2.3). In general, the vertical resolution, given by the Full Width at Half Maximum (FWHM) of the AVKs, is slightly lower for GROMOS than for SOMORA (Fig. 2.4). However, their vertical structure is very similar and so are their seasonal variability: the summer season shows a lower vertical resolution than the other seasons at all altitudes. This can be explained by the higher tropospheric opacity during the summertime.

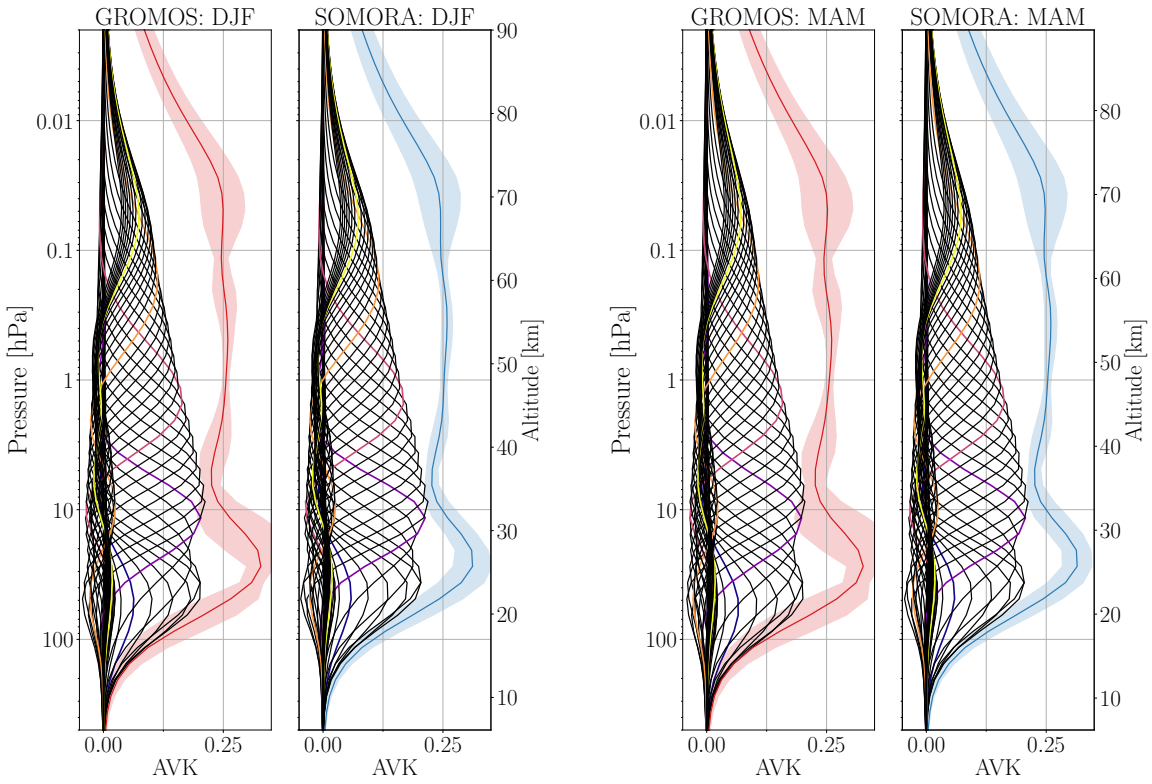
Table 2.2: Proportion of good quality data for the different levels (in [%]).

(a) GROMOS

Year	**L1a**	**L1b**	**L2**
2009	89	87	83
2010	94	89	79
2011	85	90	82
2012	78	81	69
2013	71	73	63
2014	81	81	74
2015	90	92	83
2016	86	88	80
2017	83	87	79
2018	89	93	84
2019	87	89	82
2020	87	89	82
2021	83	83	72
Total:	85	87	76

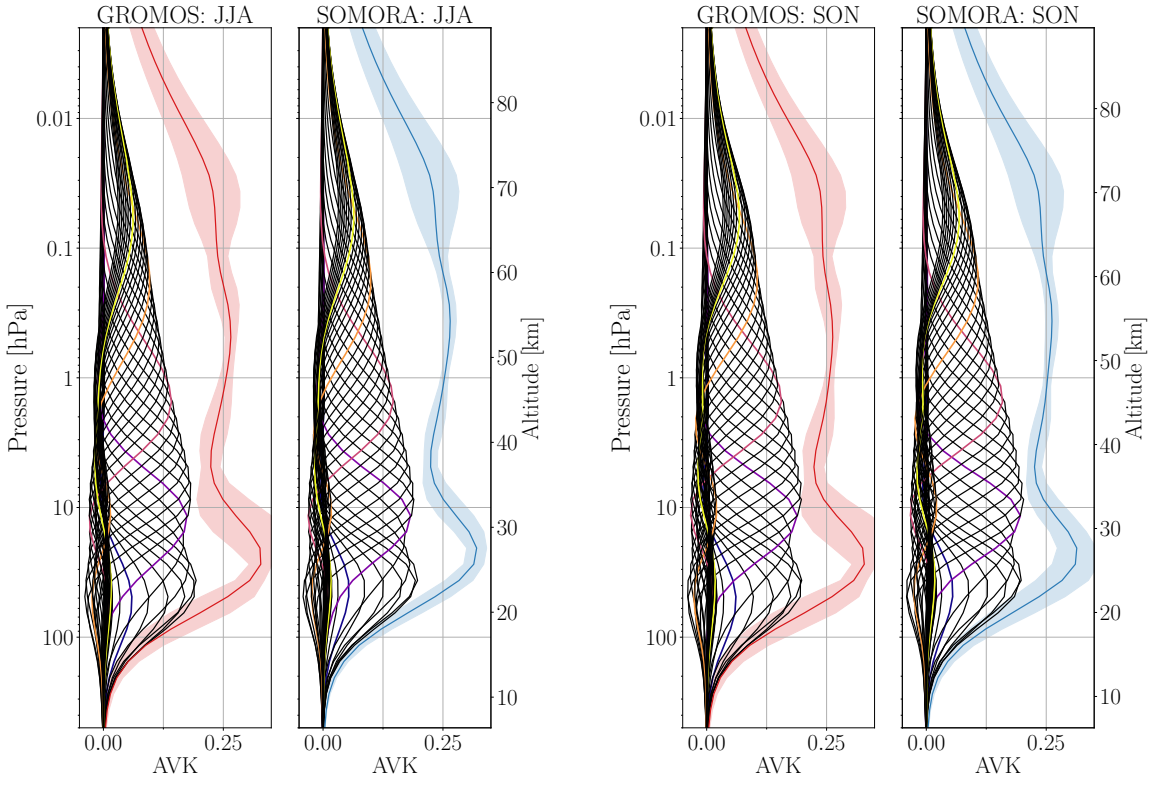
(b) SOMORA

Year	**L1a**	**L1b**	**L2**
2009	87	86	65
2010	89	87	73
2011	91	96	87
2012	92	93	90
2013	89	92	88
2014	88	92	88
2015	87	90	87
2016	84	87	83
2017	84	85	83
2018	83	84	81
2019	87	89	85
2020	82	83	79
2021	86	87	85
Total:	87	89	84



(a) Winter

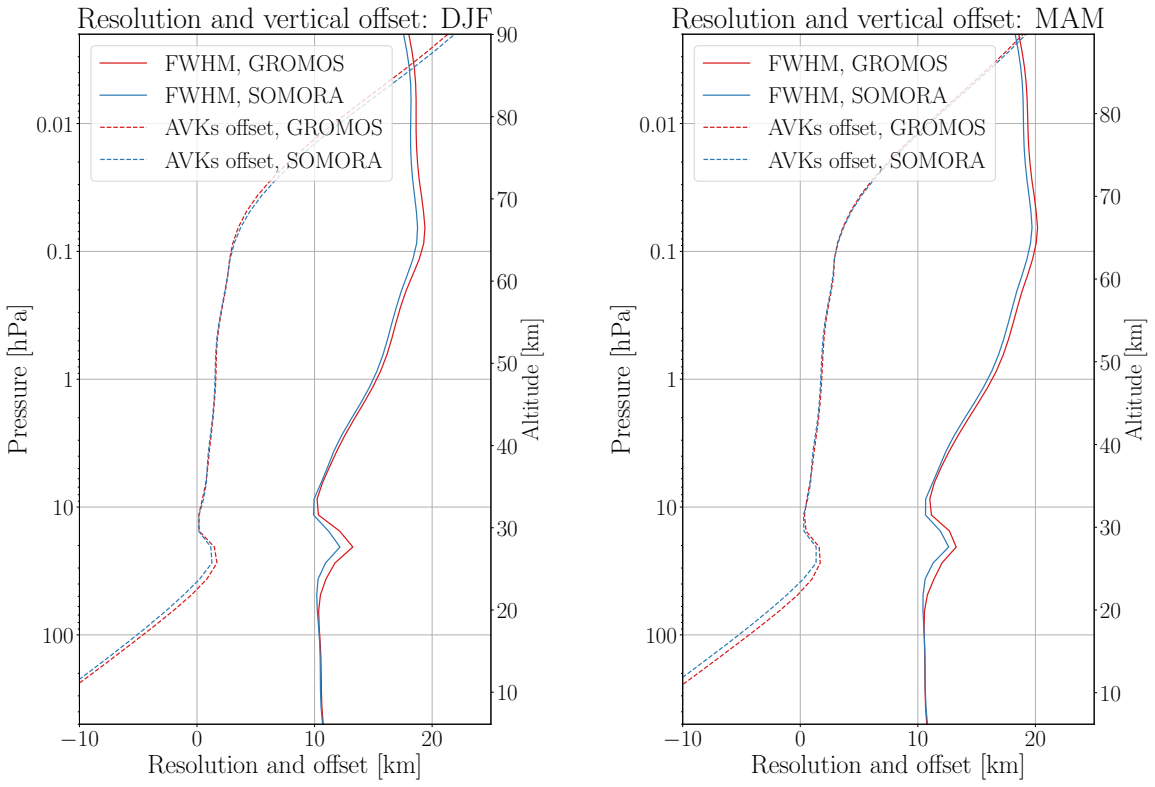
(b) Spring



(c) Summer

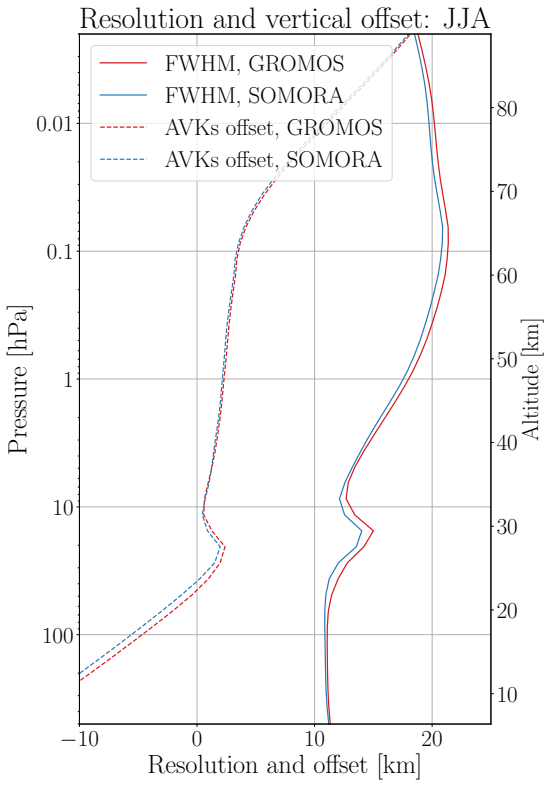
(d) Autumn

Figure 2.3: Mean seasonal AVKs comparison between GROMOS and SOMORA.

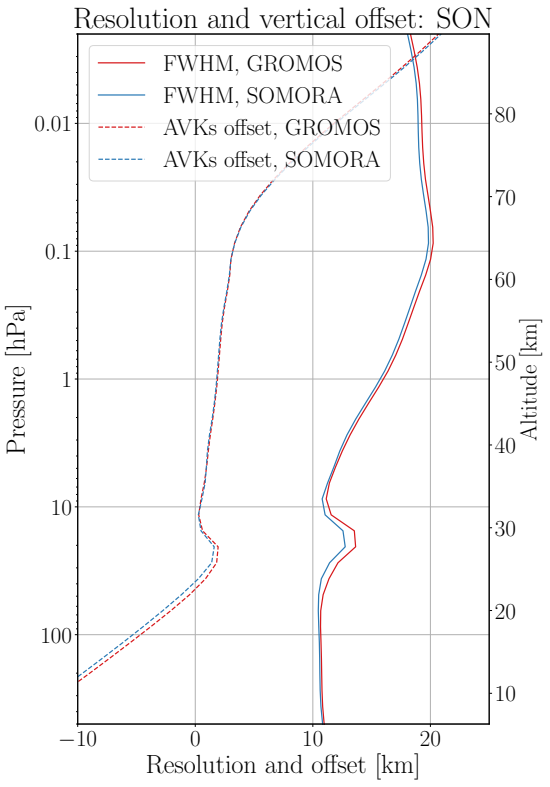


(a) Winter

(b) Spring



(c) Summer



(d) Autumn

Figure 2.4: Mean seasonal resolution (FWHM) and AVKs offset for GROMOS and SOMORA.

Chapter 3

GROMOS

In this chapter, we show a detailed, year-to-year time series description of the GROund-based Millimeter-wave Ozone Spectrometer (GROMOS). If you want to use the GROMOS time series, please contact the PI listed in Table 3.1.

Table 3.1: GROMOS information

	info
Operated by	Institute of Applied Physics, University of Bern, Bern, Switzerland
Principal investigator (PI)	Axel Murk (`axel.murk@unibe.ch`)
Data collector	Eric Sauvageat (`eric.sauvageat@unibe.ch`)

Table 3.2: Sinusoidal baselines GROMOS

Time	**Periods [MHz]**
01.07.2009 –> 23.02.2015	178, 240, 360
23.02.2015 –> 31.08.2015	140, 240, 400
31.08.2015 –> 01.01.2017	160, 240, 360
01.01.2017 –> 01.01.2018	178, 240, 360
01.01.2018 –> 01.01.2019	135, 240, 360
01.01.2019 –> 15.03.2019	155, 240, 360
15.03.2019 –> 16.02.2022	135, 178, 240

2009

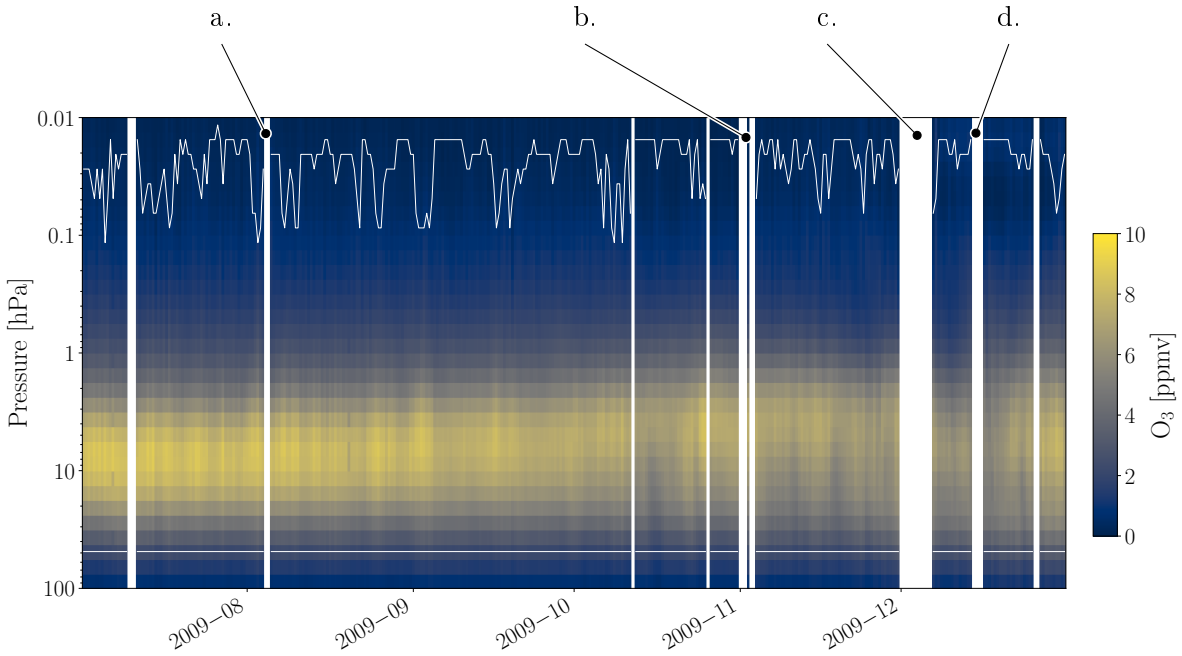


Figure 3.1: GROMOS, 2009

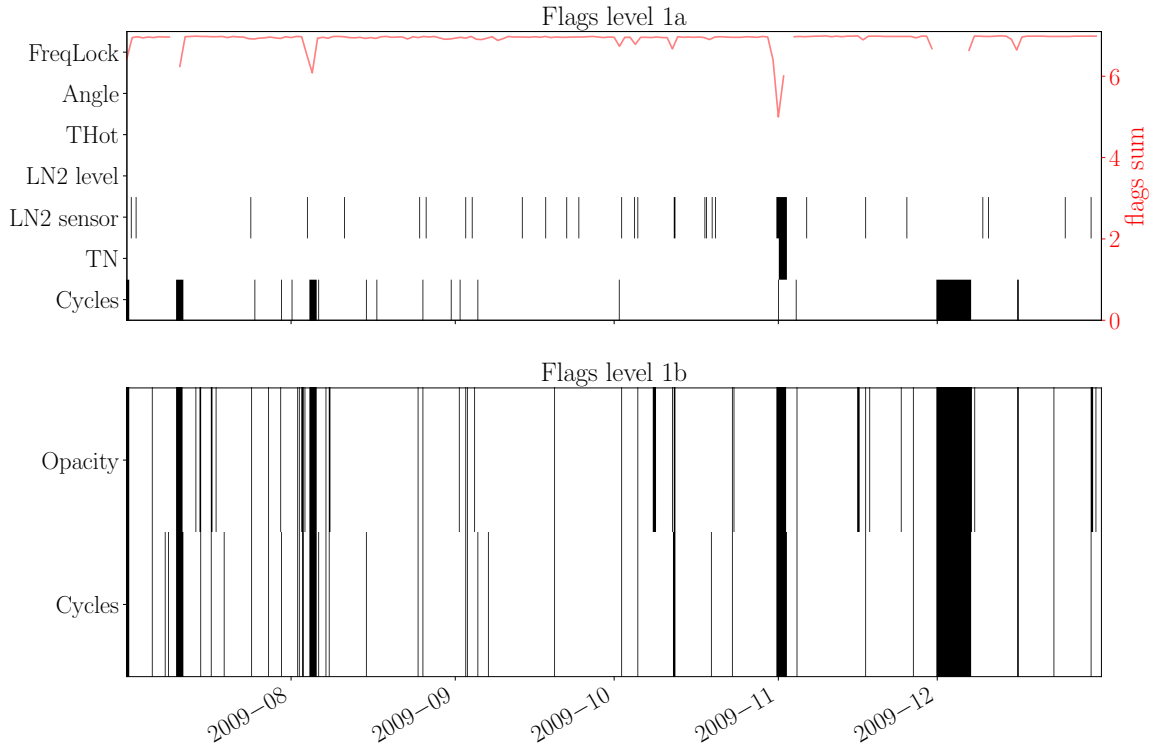


Figure 3.2: GROMOS flags, 2009

a. 05.08.09: no data

b. 03.11.09: Restart nach Rep(aration?) cold load

c. 30.11.09-07.12.09: no FFTS raw data

d. 15-16.12.09: no data in the morning

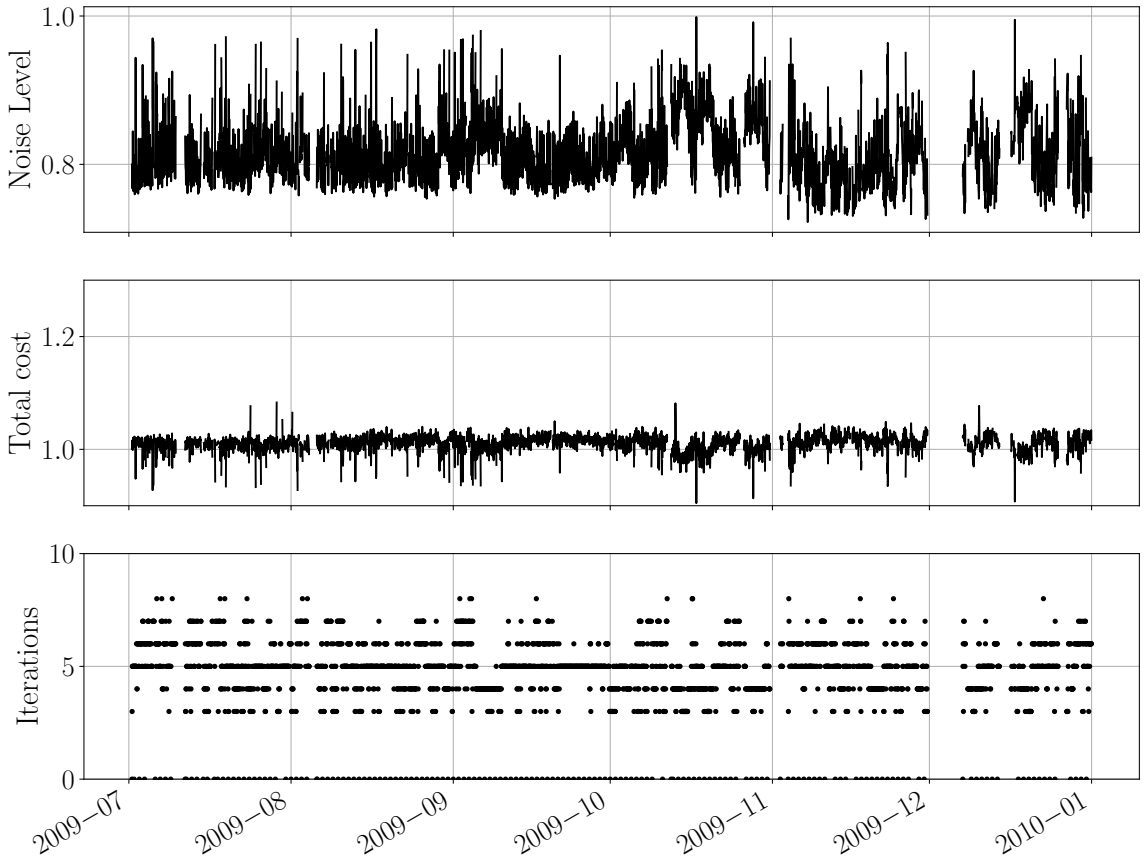


Figure 3.3: GROMOS, 2009

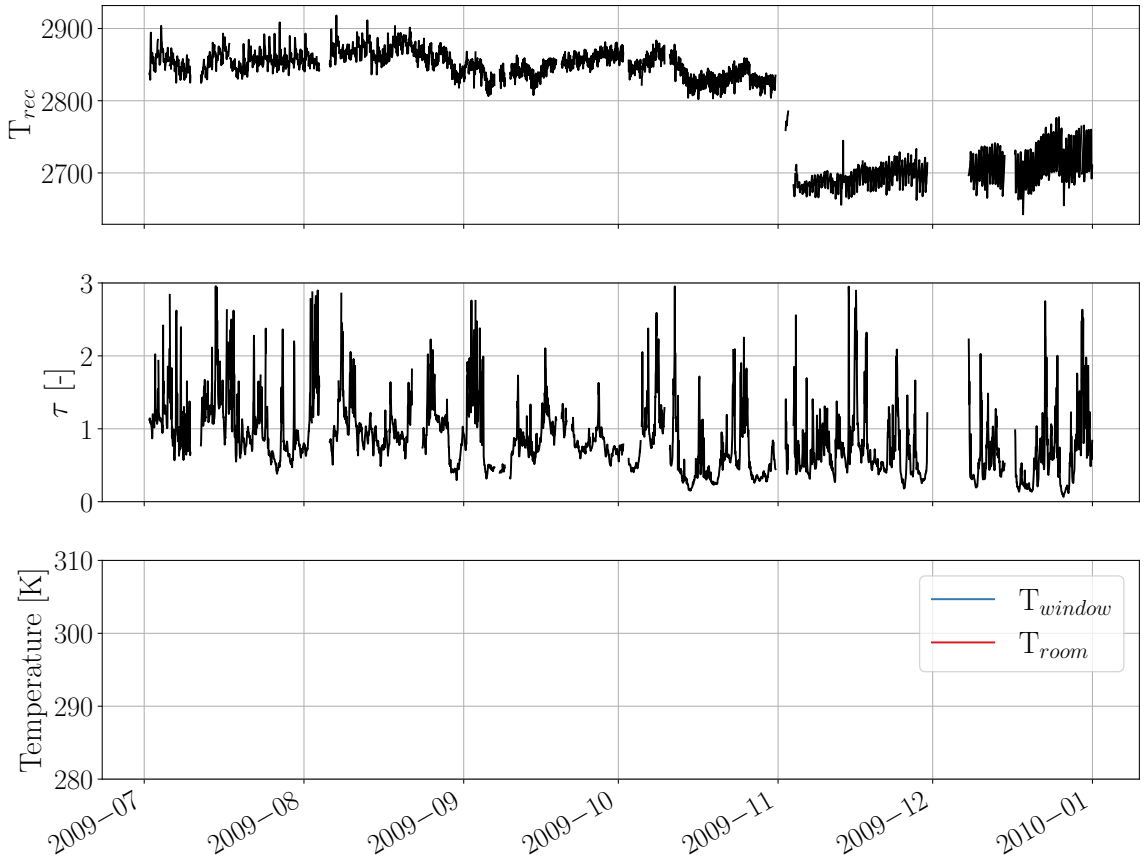


Figure 3.4: GROMOS, 2009

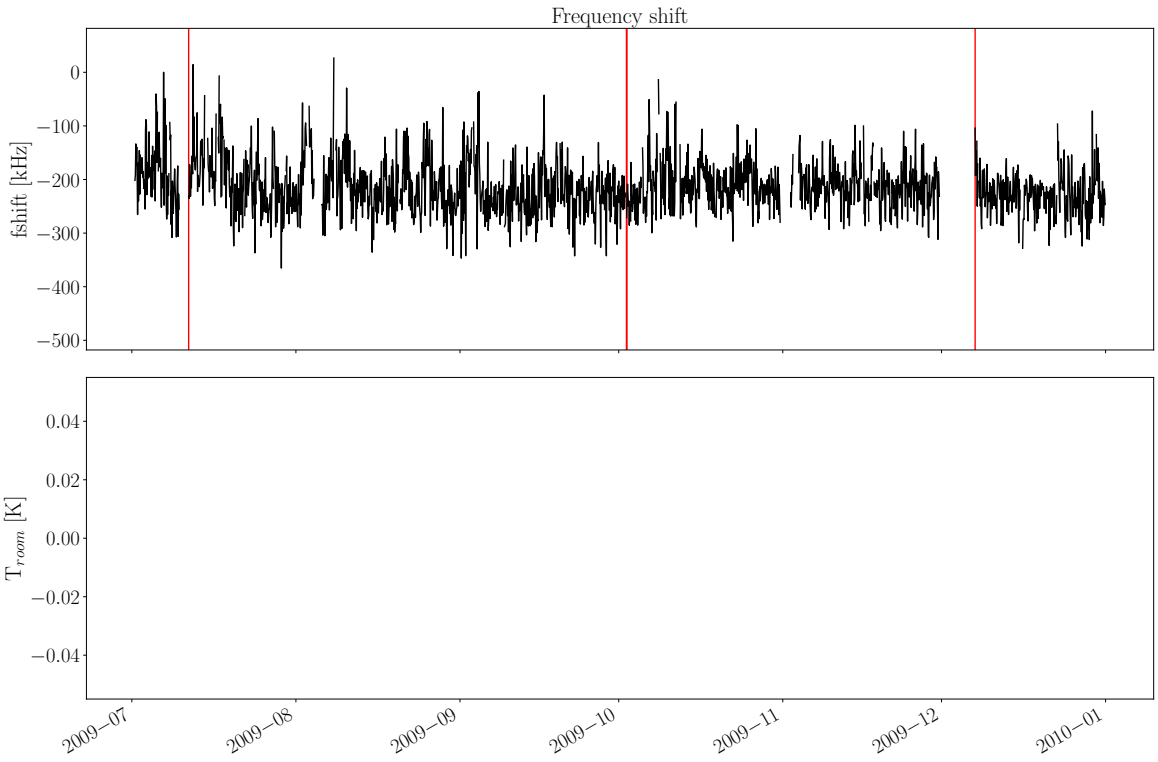


Figure 3.5: GROMOS, 2009

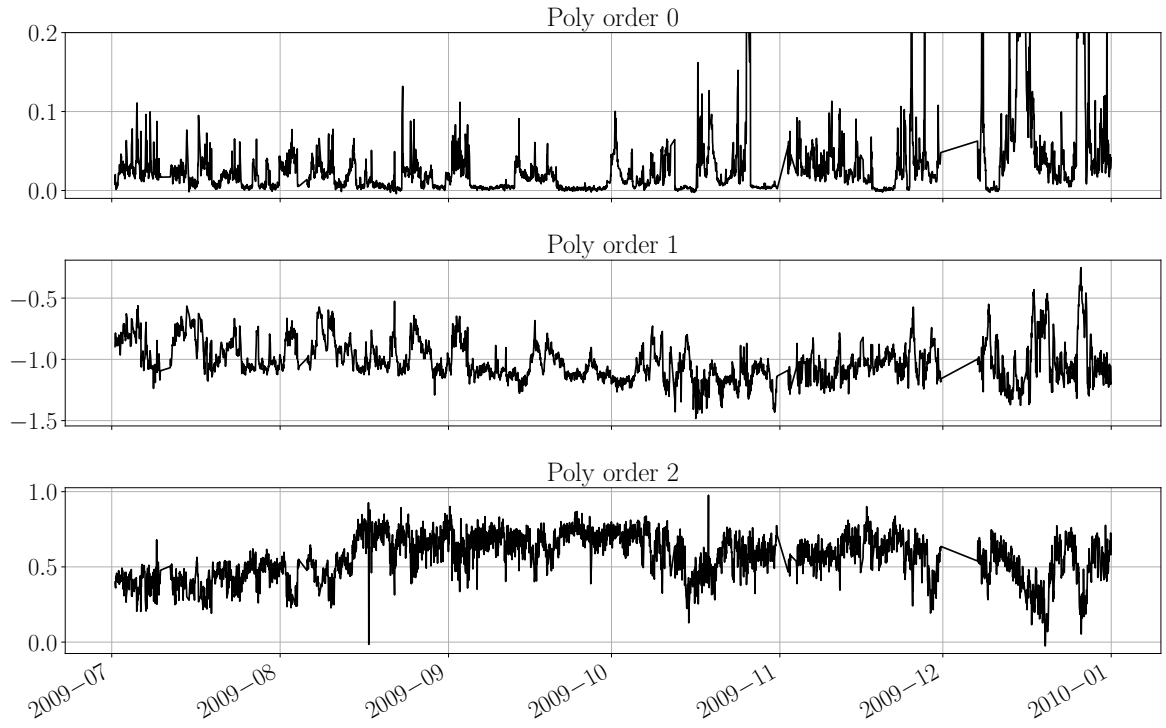


Figure 3.6: GROMOS, 2009

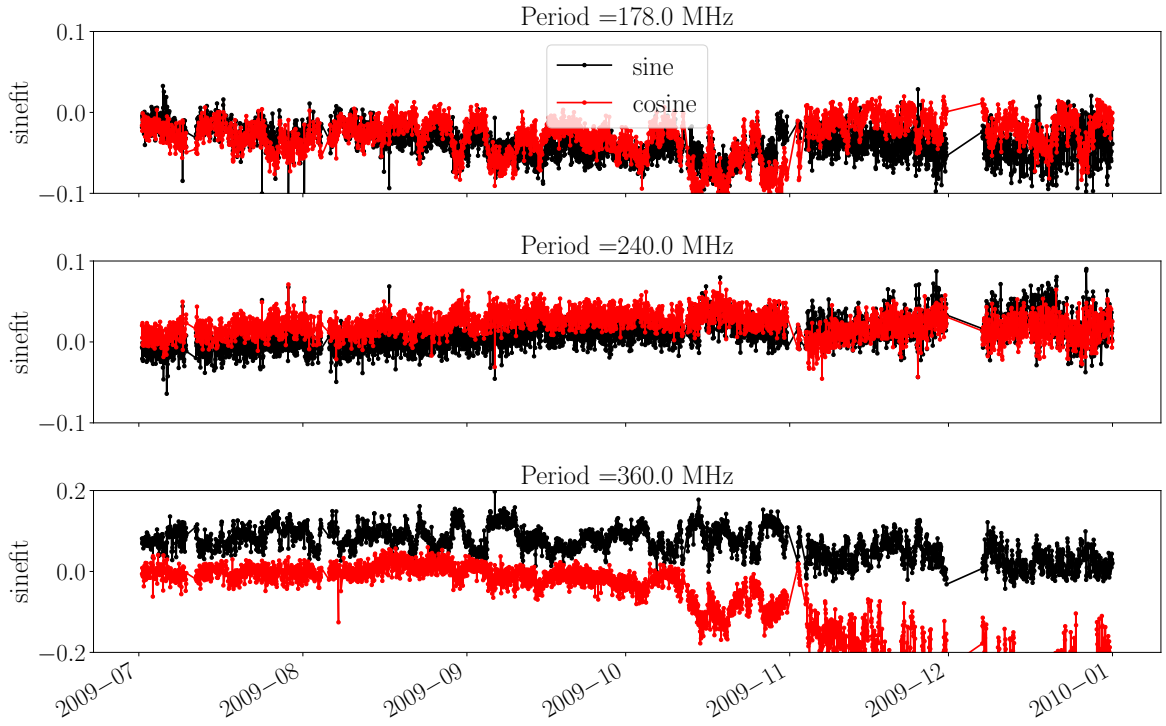


Figure 3.7: GROMOS, 2009

2010

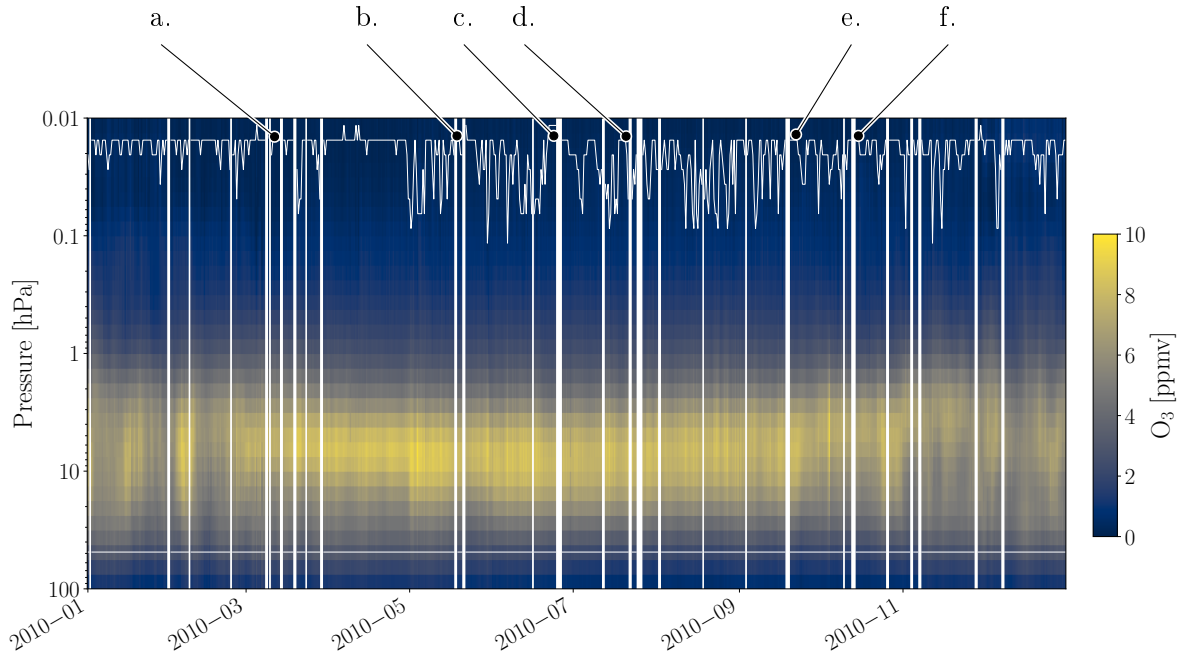


Figure 3.8: GROMOS, 2010

a. 11-19.03.10: ice on cold load + change of the mirror position

b. 18.05.10: ice on cold load

c. 24.06.10: New camera

d. 15.07.10: cleaning of cold load

e. 18-20.09.10: No FFTS data

f. 10-11.10.10: problem with LN2 refilling system

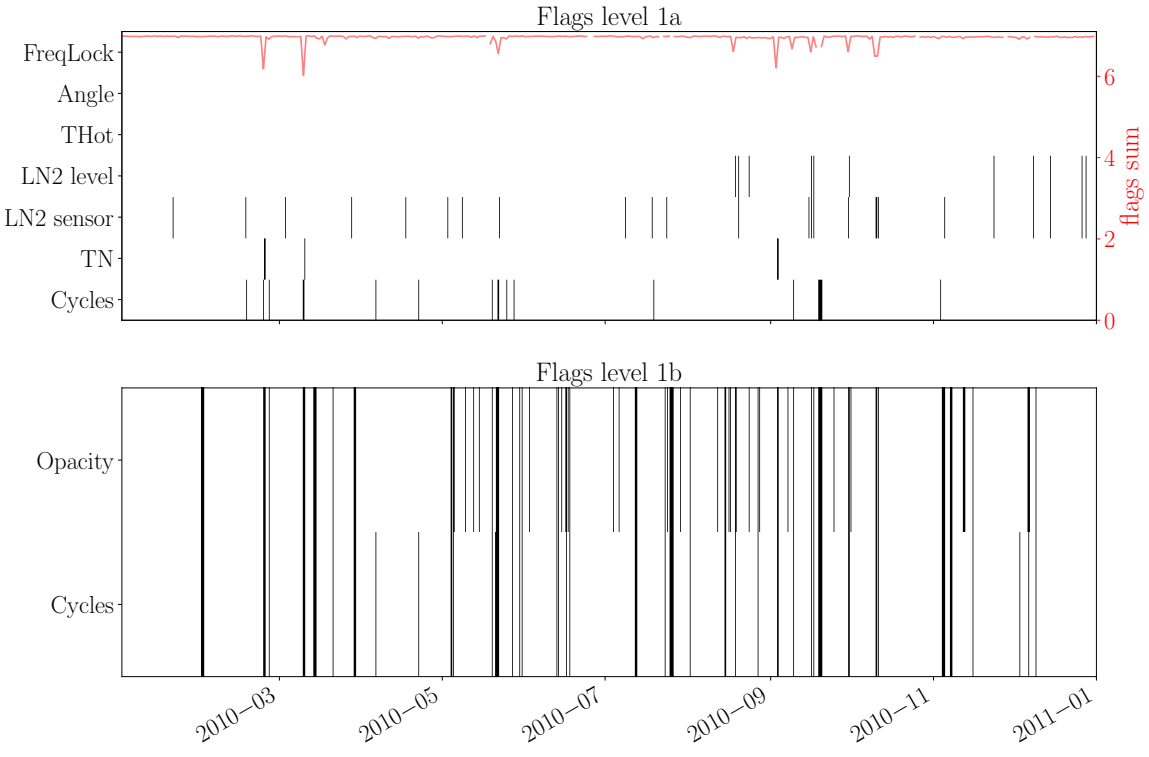


Figure 3.9: GROMOS flags, 2010

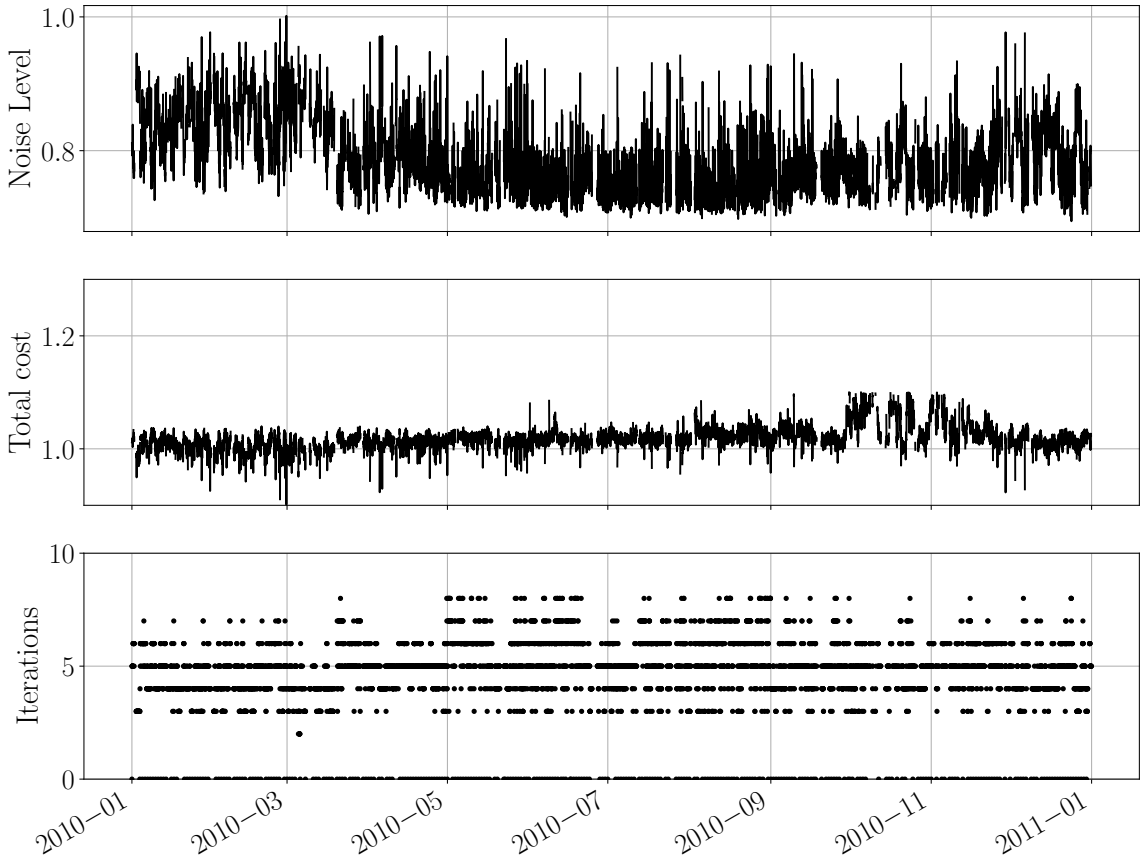


Figure 3.10: GROMOS, 2010

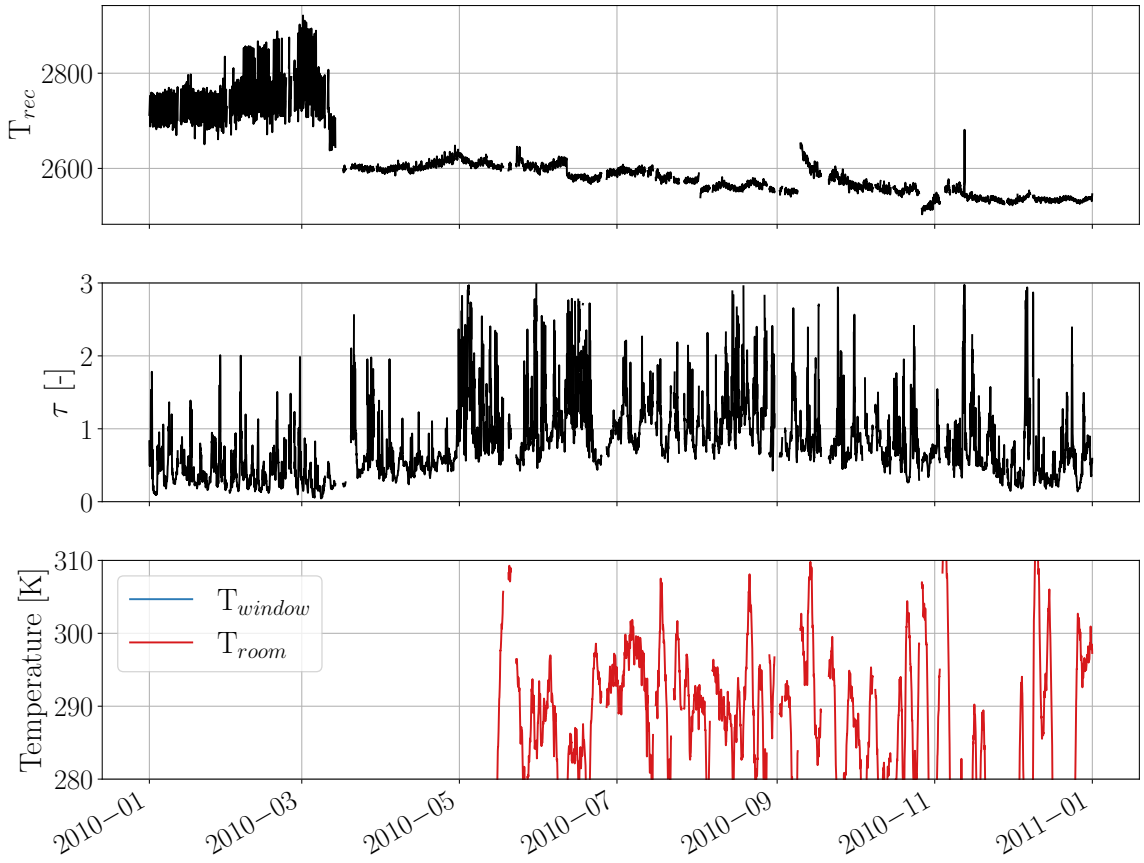


Figure 3.11: GROMOS, 2010

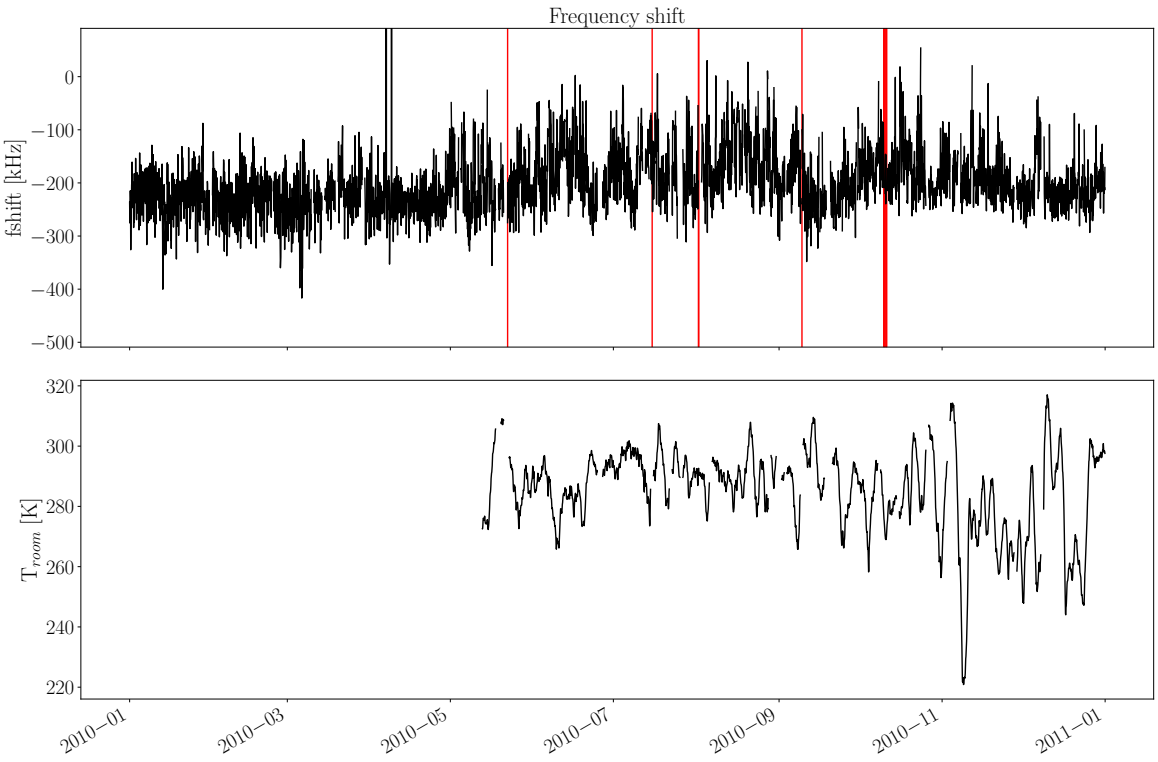


Figure 3.12: GROMOS, 2010

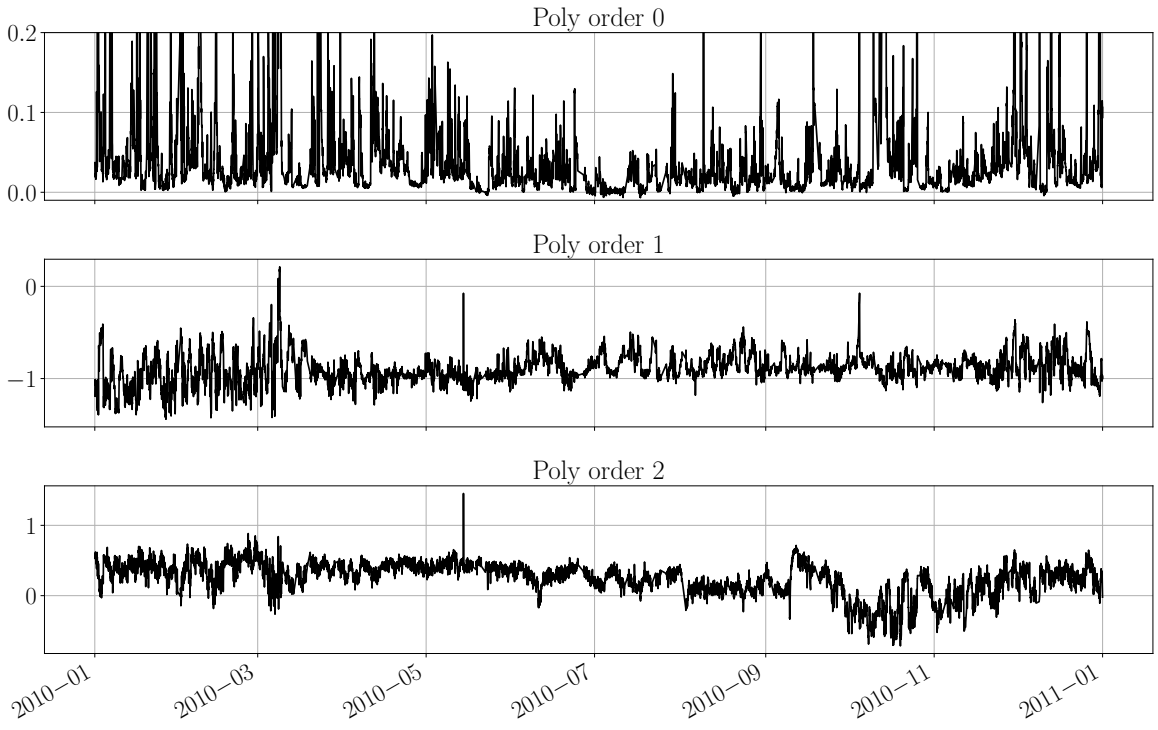


Figure 3.13: GROMOS, 2010

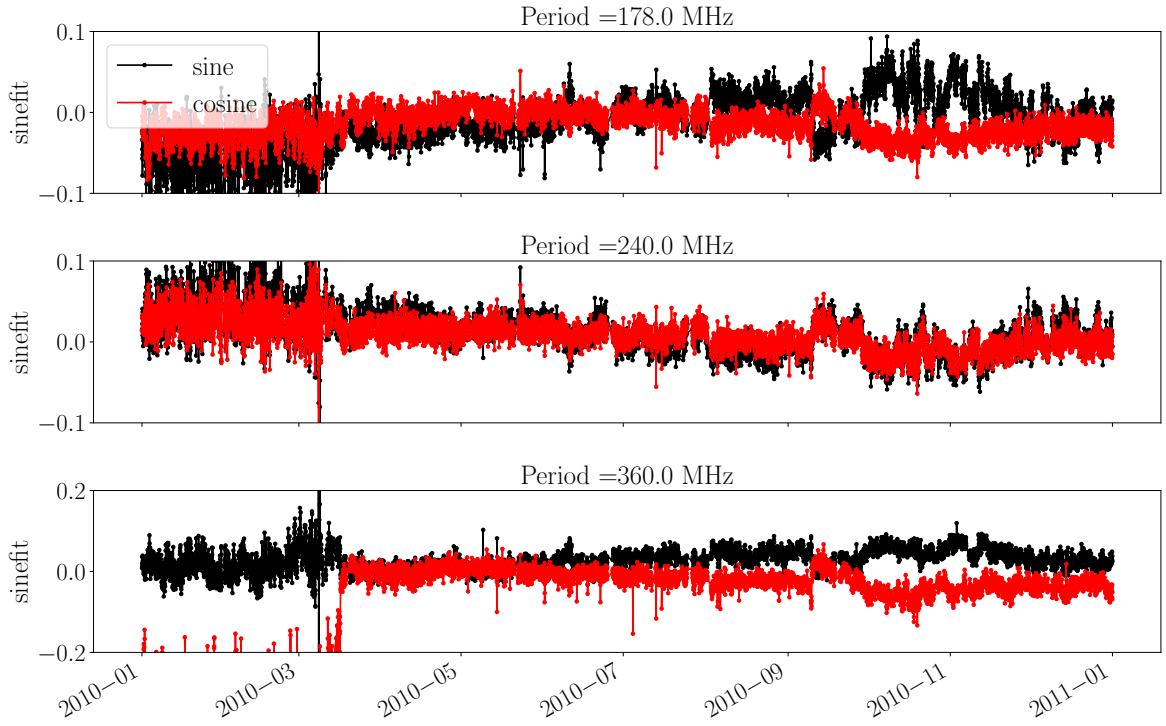


Figure 3.14: GROMOS, 2010

2011

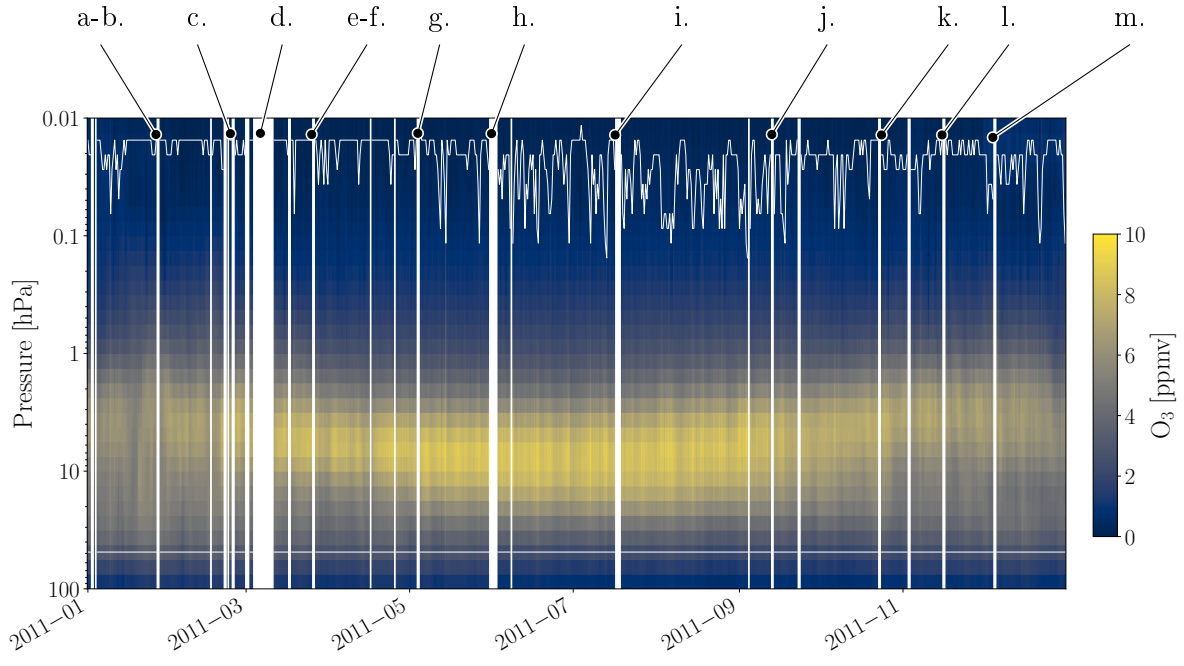


Figure 3.15: GROMOS, 2011

a. 27.01.11: cleaning of cold load

b. 31.01.11: change of cold load angle and multiple lock problems

c. 15-16.02.11: change of LO frequency for test and back

d. 04-11.03.11: no FFTS data -> some test done with new attenuator

e. 25.03.11: new attenuator 3 dB -> jump in counts and Trec

f. 28-30.03.11: test change of FFTS input power

g. 09.05.11: Lock Error

h. 30.05.11-08.06.11: mirror problems

i. 17.07.11: mirror problems

j. 13.09.11: new temperatures measured (see Fig. 3.18)

k. 12.10.11: jump in counts and Trec -> unkwown reason

l. 12-15.11.11: multiple lock errors

m. 05-06.12.11: mirror problems and filterbench unmounted

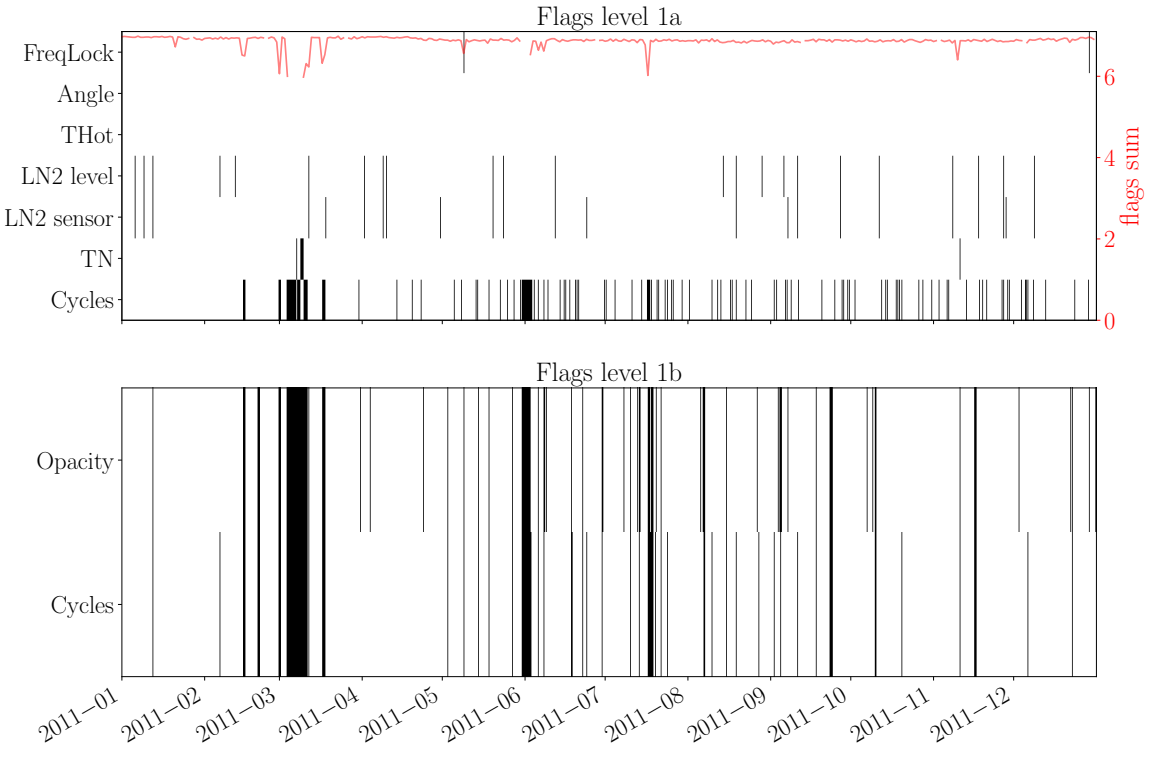


Figure 3.16: GROMOS flags, 2011

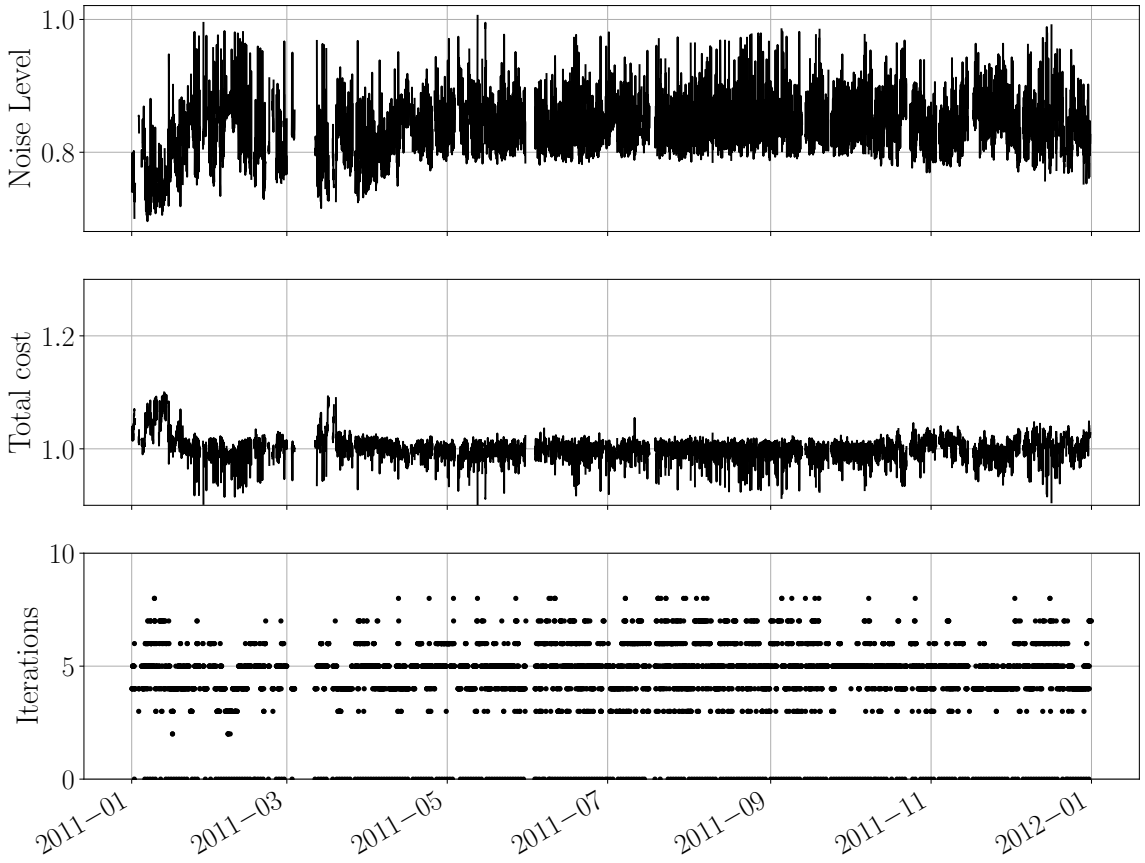


Figure 3.17: GROMOS, 2011

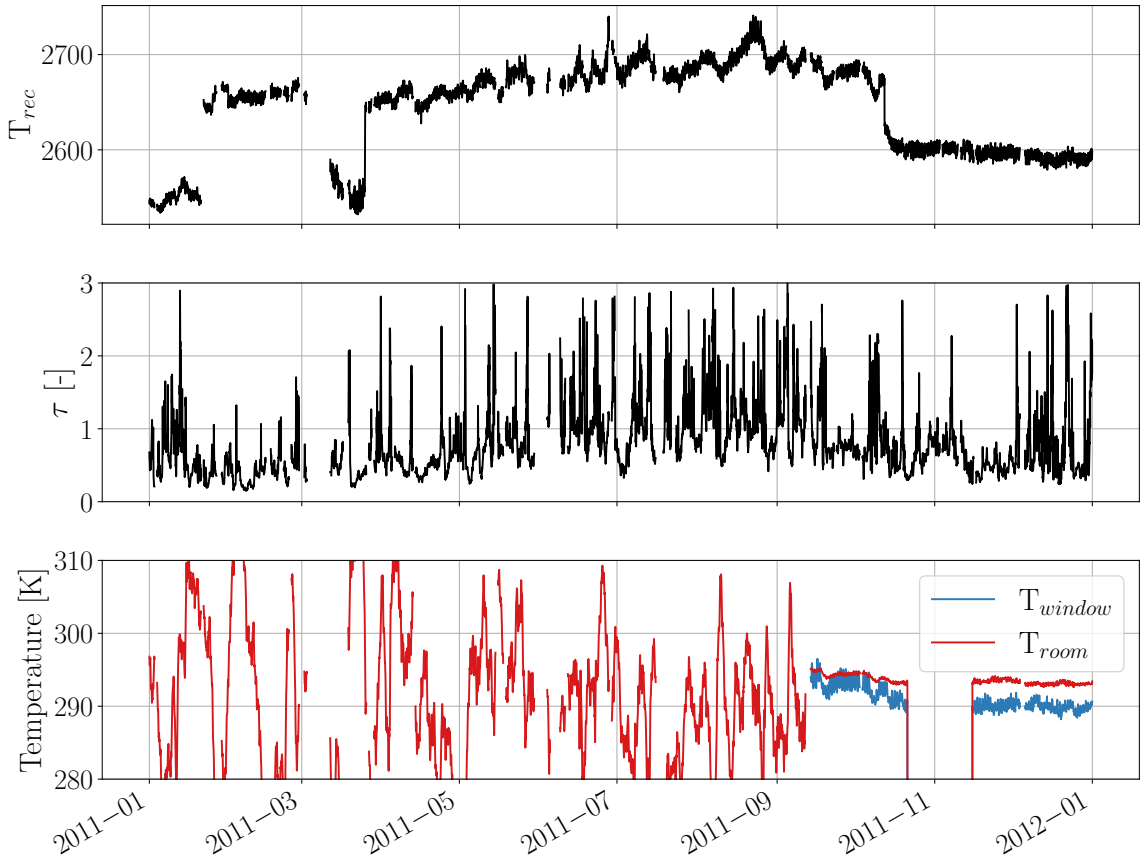


Figure 3.18: GROMOS, 2011

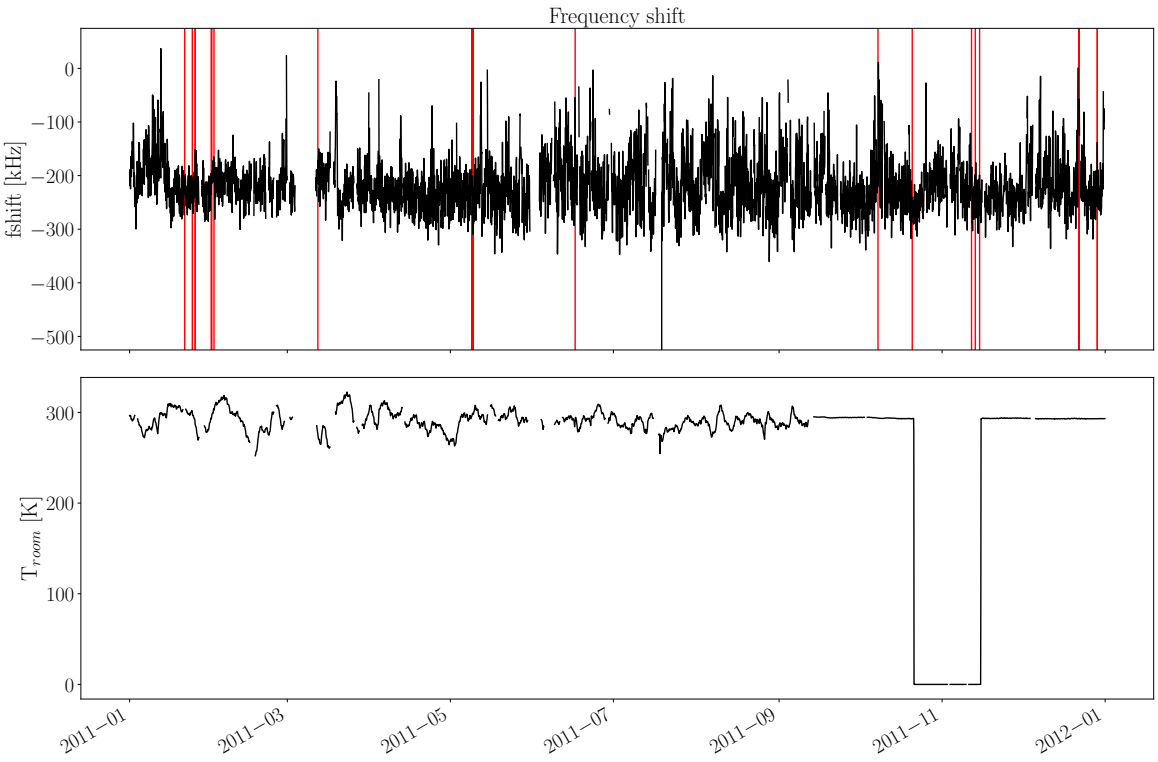


Figure 3.19: GROMOS, 2011

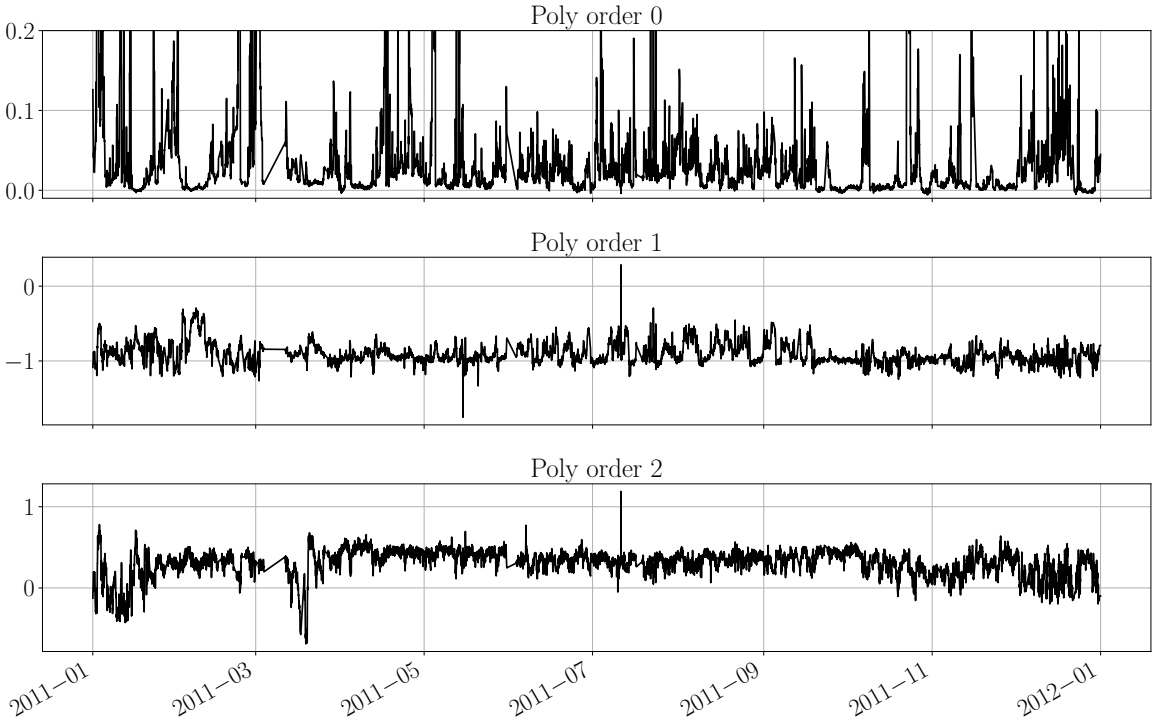


Figure 3.20: GROMOS, 2011

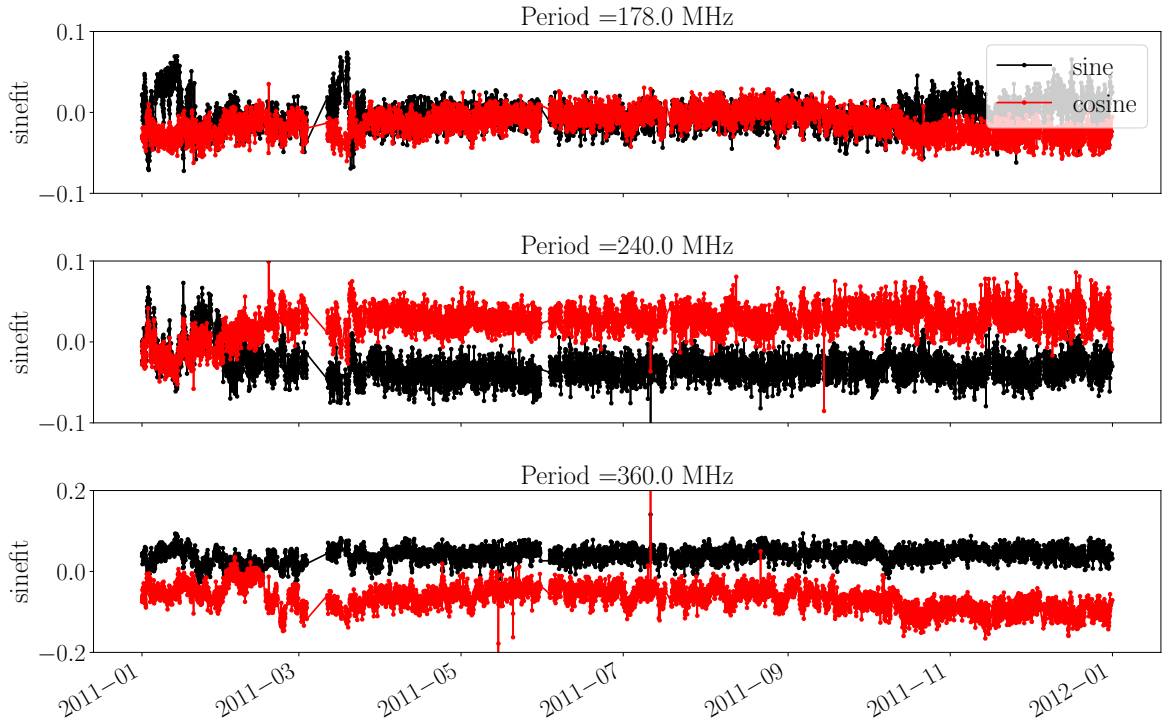


Figure 3.21: GROMOS, 2011

2012

In 2012, quite a lot happened on GROMOS...

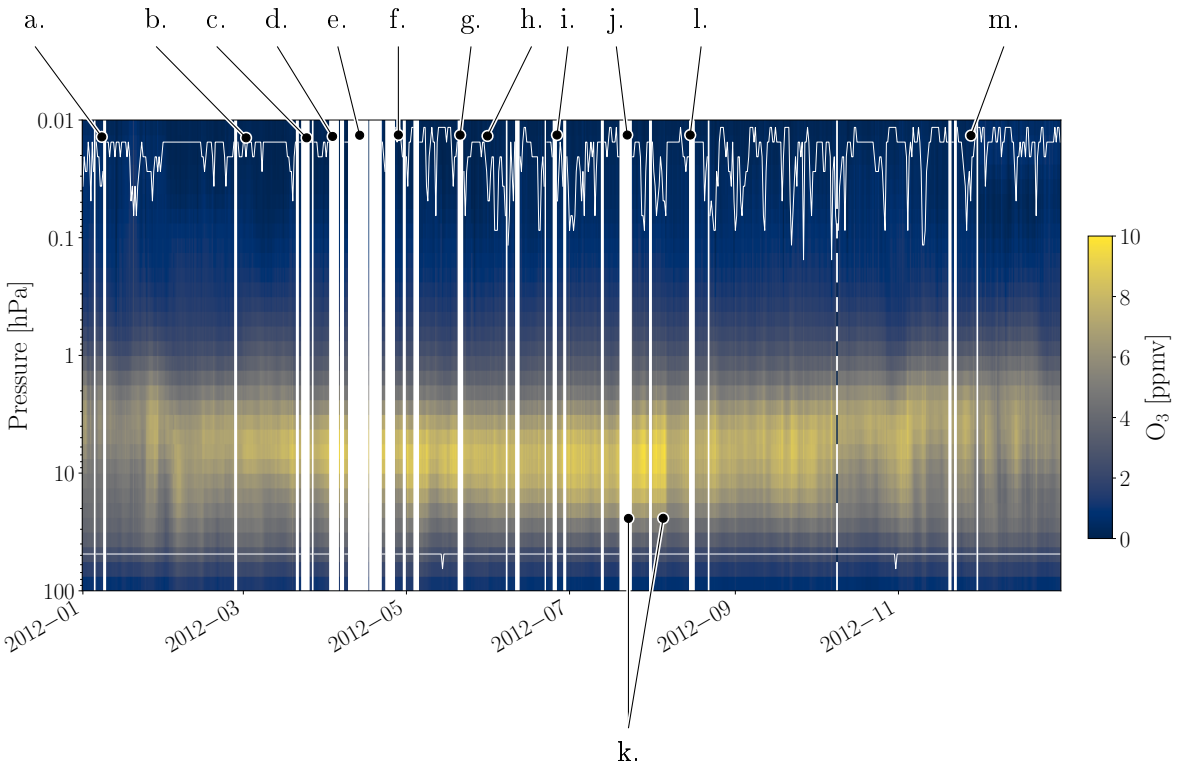


Figure 3.22: GROMOS, 2012

a. 13-15.01.12 + 20.01.12: multiple lock errors

b. 02.03.12: no measurement

c. 23-26.03.12: no FFTS raw data + removal of FB

d. 03-05.04.12: unknown problem

e. 09-17.04.12: retrievals problem

f. 25.04.12-08.05.12: new mirror mechanism, work in GROMOS room with installation of new floor.

g. 14-16.05.12: diverse changes in software and hardware: airflow on cold load, added case for hot load, wobbler ON/OFF.

h. 22-24.05.12: diverse test and added 1 dB of IF signal -> jump in counts and Trec

i. 20-22-29.06.12: test with noise diodes

j. 19-24.07.12: cold load problem -> relais malfunction

k. 24.07.12-07.08.12: During this periods, Trec stayed higher than usual until new filters for the display of calibrated spectra. It should not have impacted the raw data but we still get a jump in Trec and counts back to normal (see Fig. 3.24). -> This period is flagged in L2 final dataset.

l. 22.08.12: LN2 empty

m. 21-27.11.12: multiple lock errors + test with mirror (on 22.11)

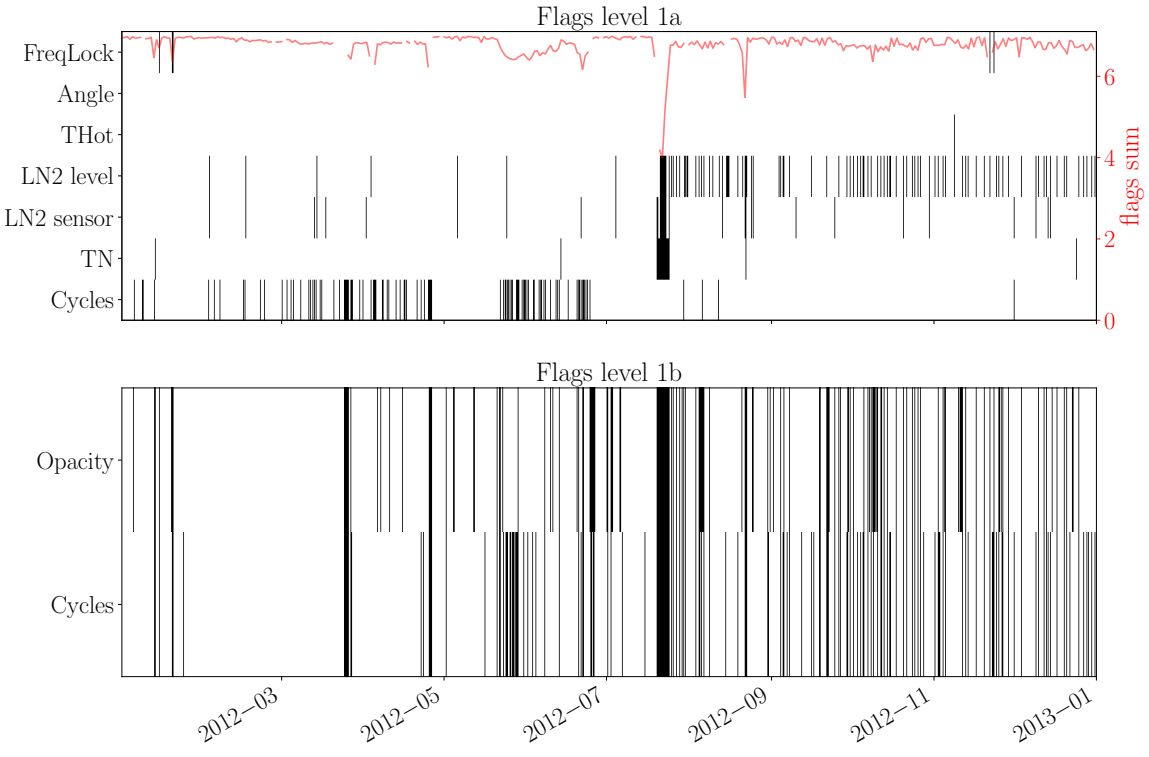


Figure 3.23: GROMOS flags, 2012

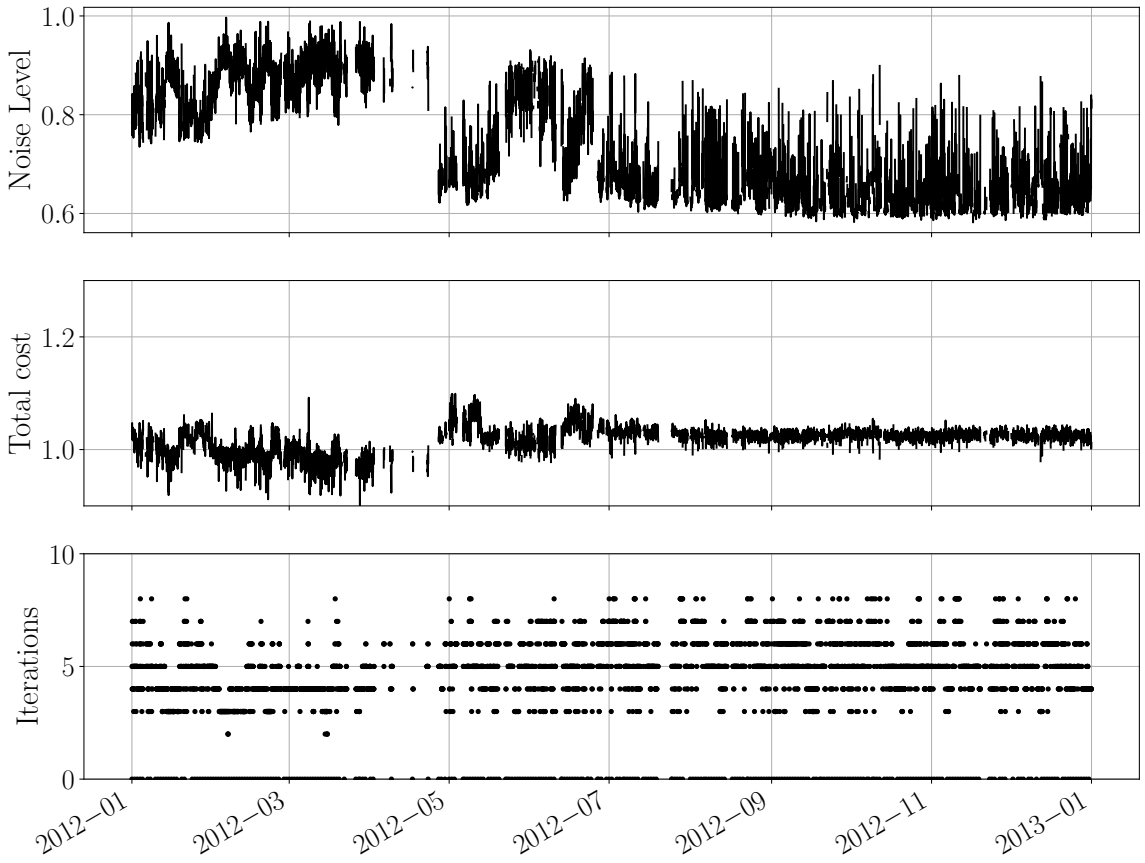


Figure 3.24: GROMOS, 2012

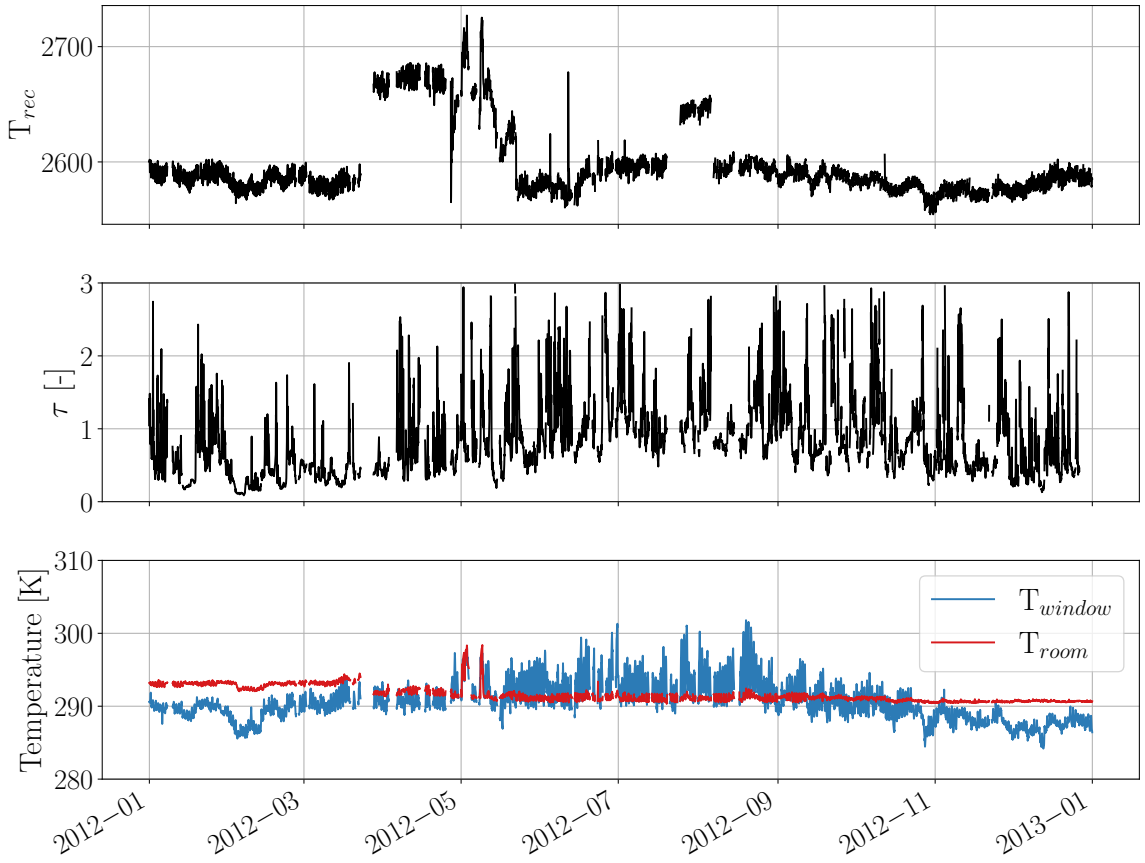


Figure 3.25: GROMOS, 2012

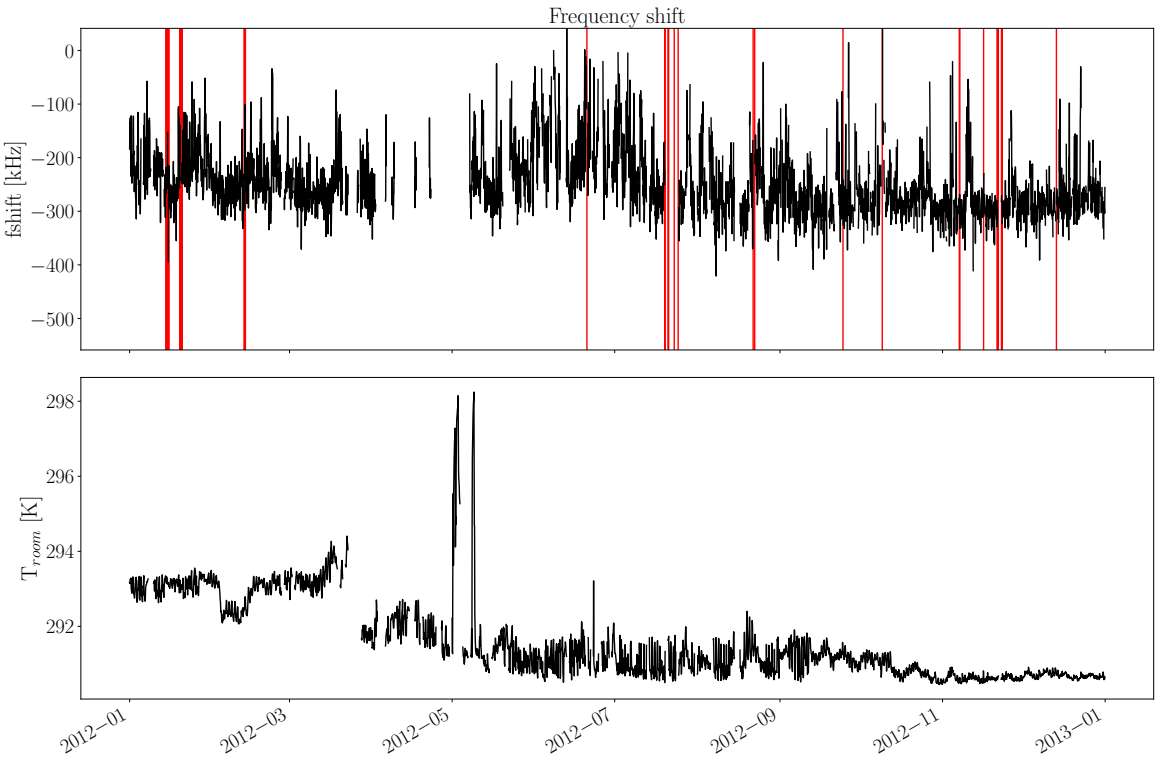


Figure 3.26: GROMOS, 2012

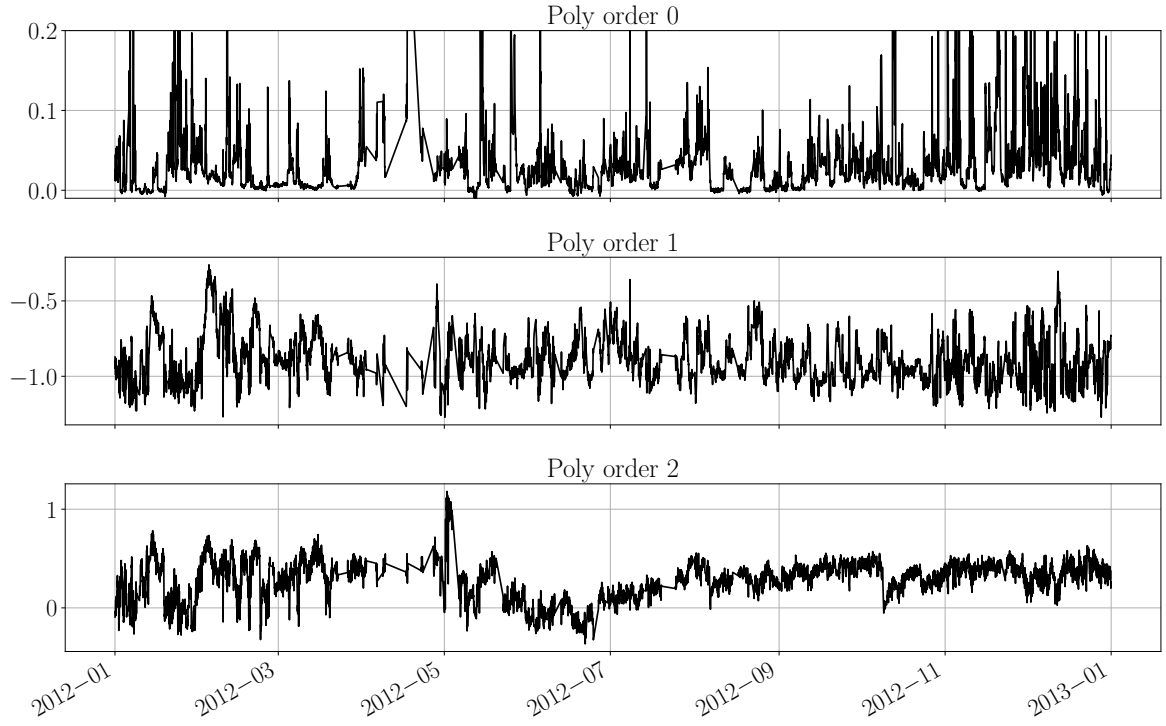


Figure 3.27: GROMOS, 2012

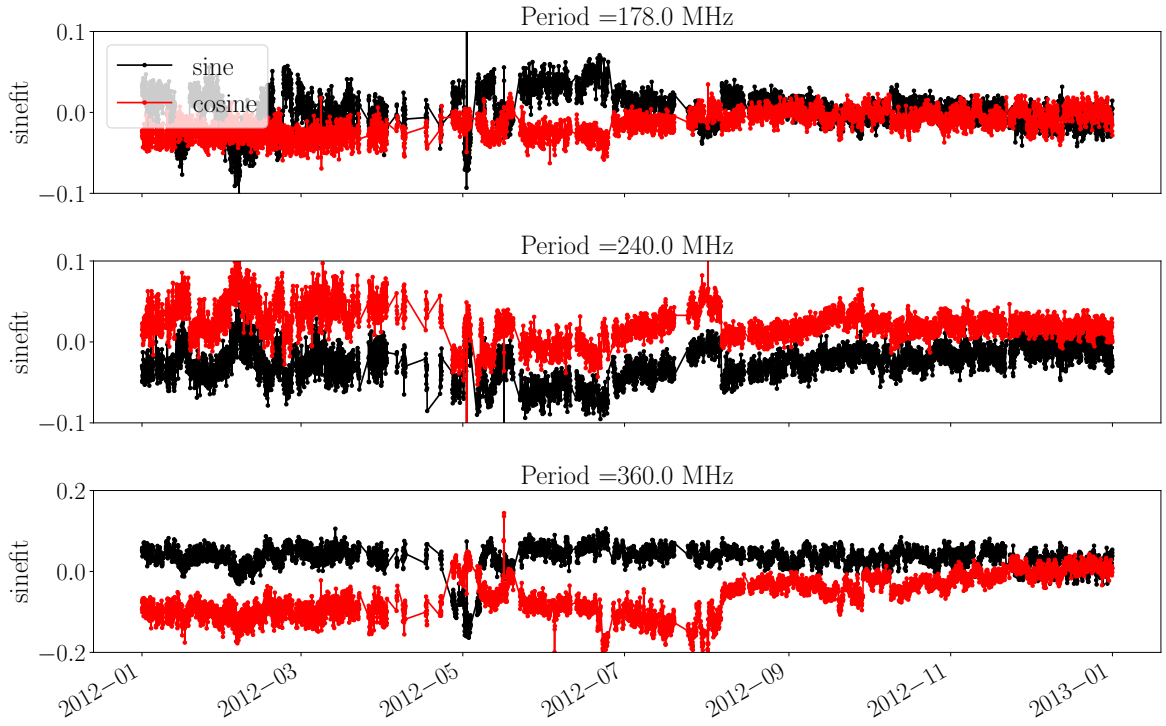


Figure 3.28: GROMOS, 2012

2013

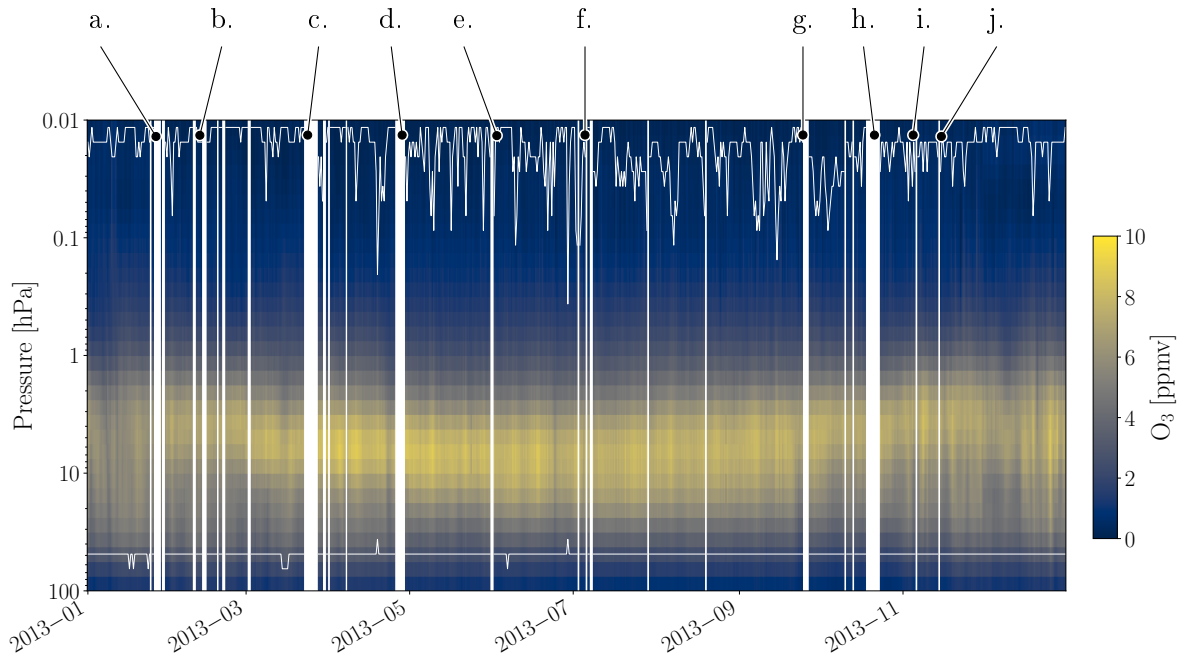


Figure 3.29: GROMOS, 2013

a. 26-29.01.13: no FFTS raw data. Changed cold load angle on 29.01.13 because Trec 100 K too high from restart on 28.01.13 and because the elevation angle was off by 1 degree. No corrections was applied for this as it is not clear since when the angle was wrong ...

b. 09.02.13: problem with the hot load

c. 22-27.03.13: electricity cut

d. 26-28.04.13: no FFTS raw data

e. 18.06.13: ventilation problem on 17.06 and programm needed restart

f. 08.07.13: multiple lock errors and quite large Troom fluctuations (ventilation problems ?)

g. 25-26.09.13: mirror problem -> restart

h. 19-23.10.13: no FFTS raw data due to GROMOS-C prototype tests

i. 07.11.13: Trec jump (+100 K) for unknown reasons (see Fig. 3.32)

j. 14.11.13: mirror problems

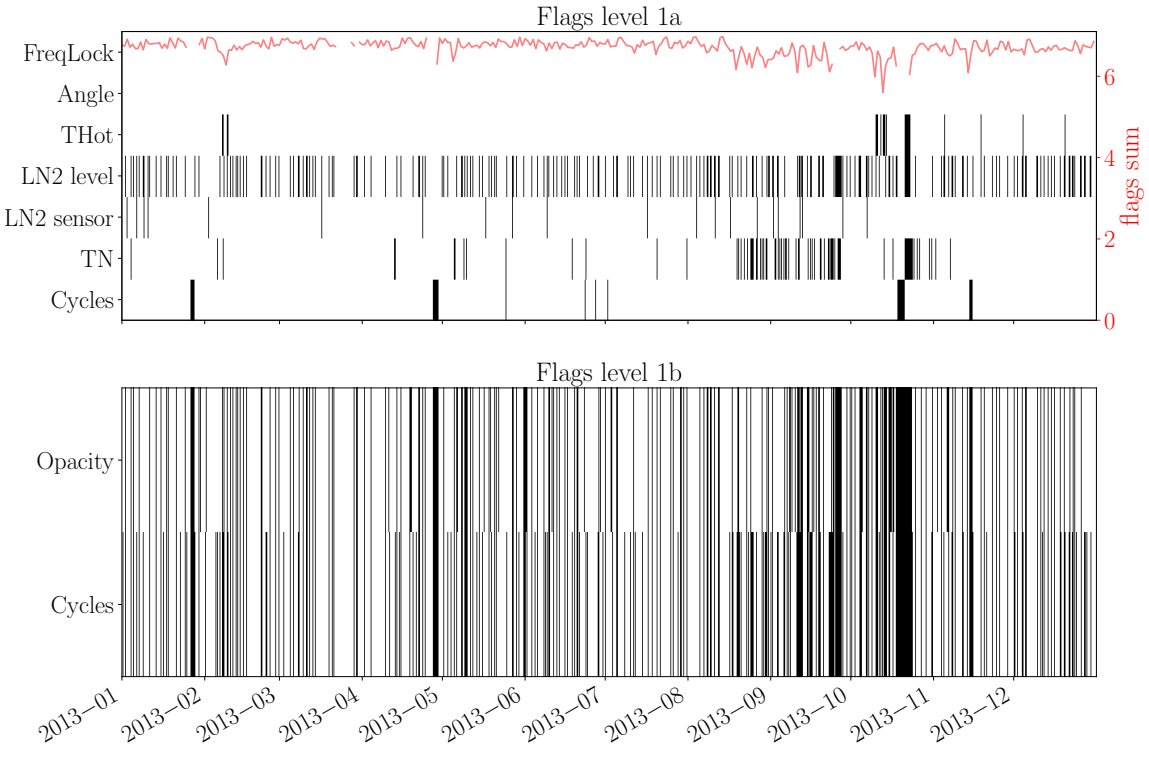


Figure 3.30: GROMOS flags, 2013

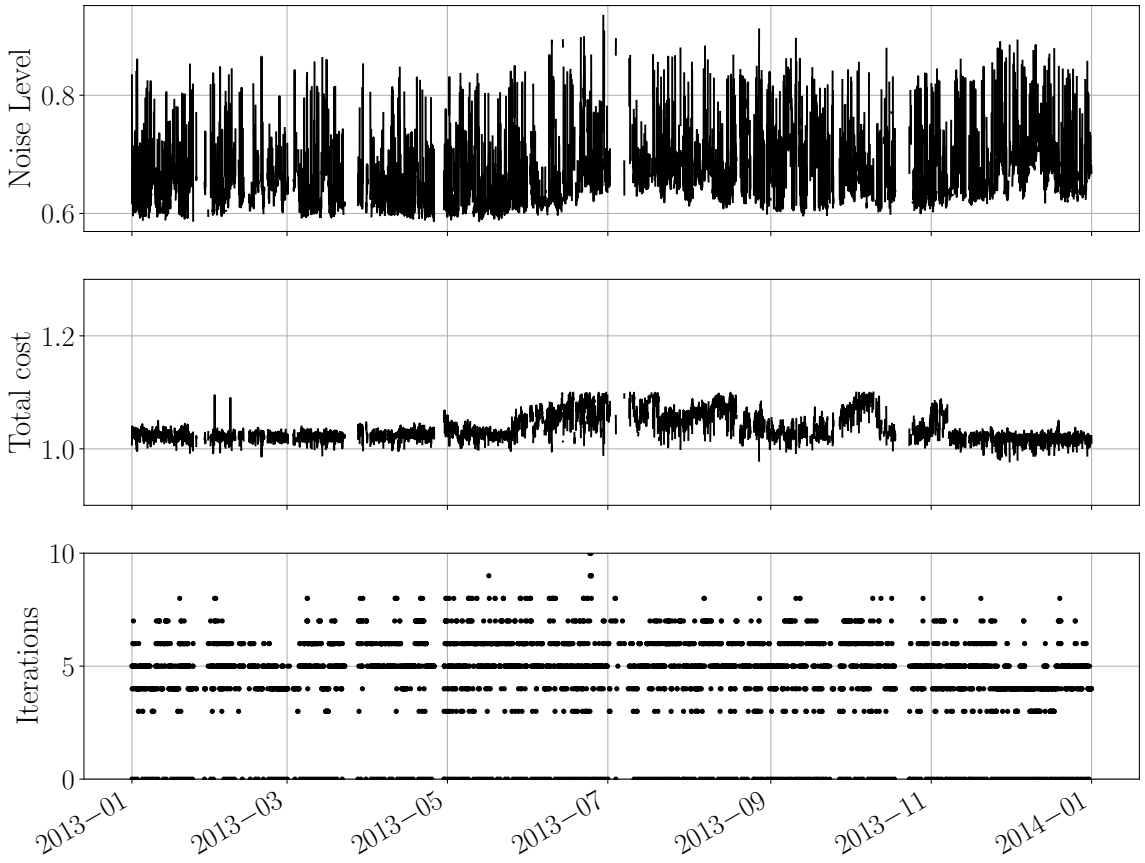


Figure 3.31: GROMOS, 2013

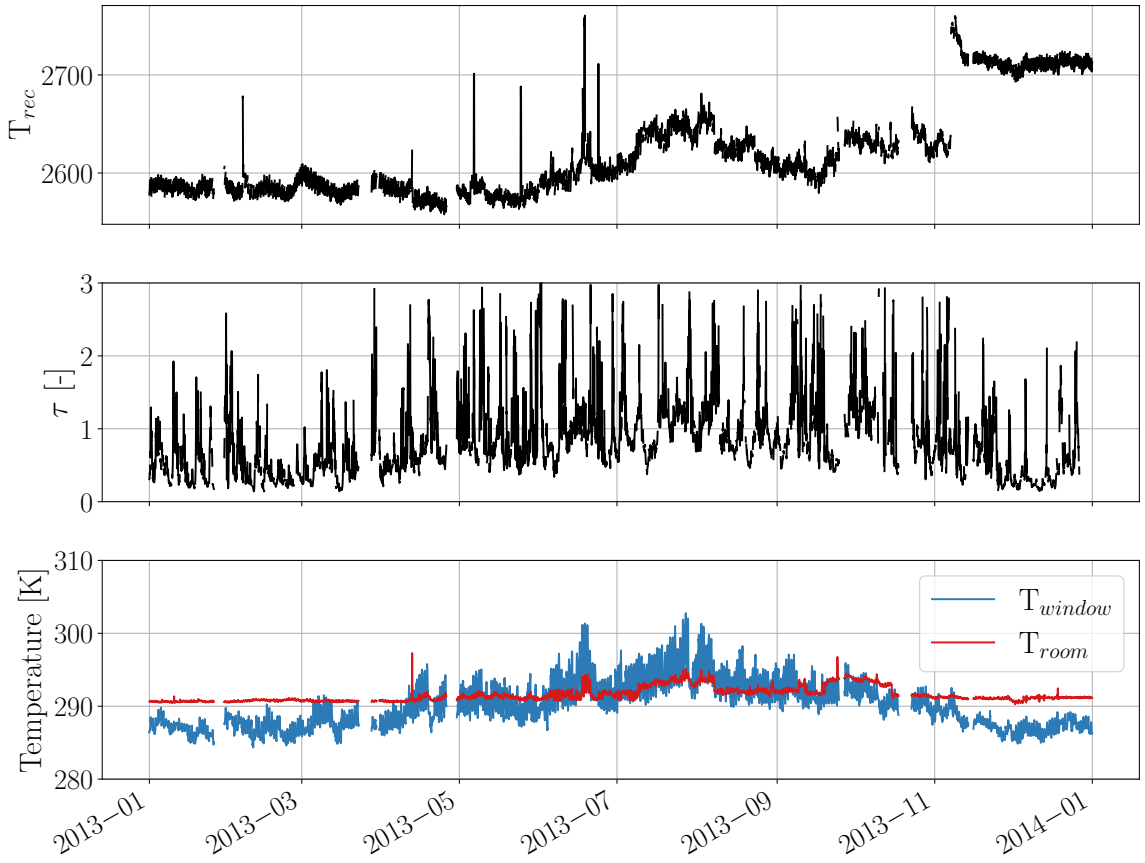


Figure 3.32: GROMOS, 2013

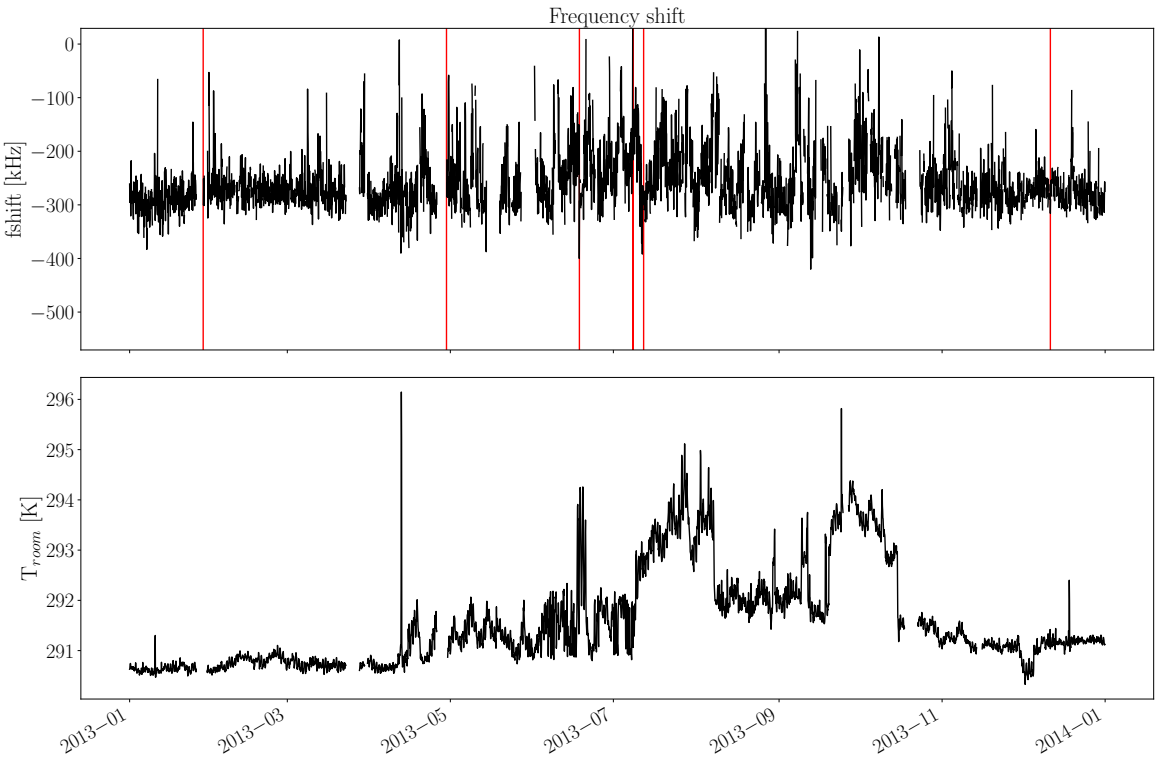


Figure 3.33: GROMOS, 2013

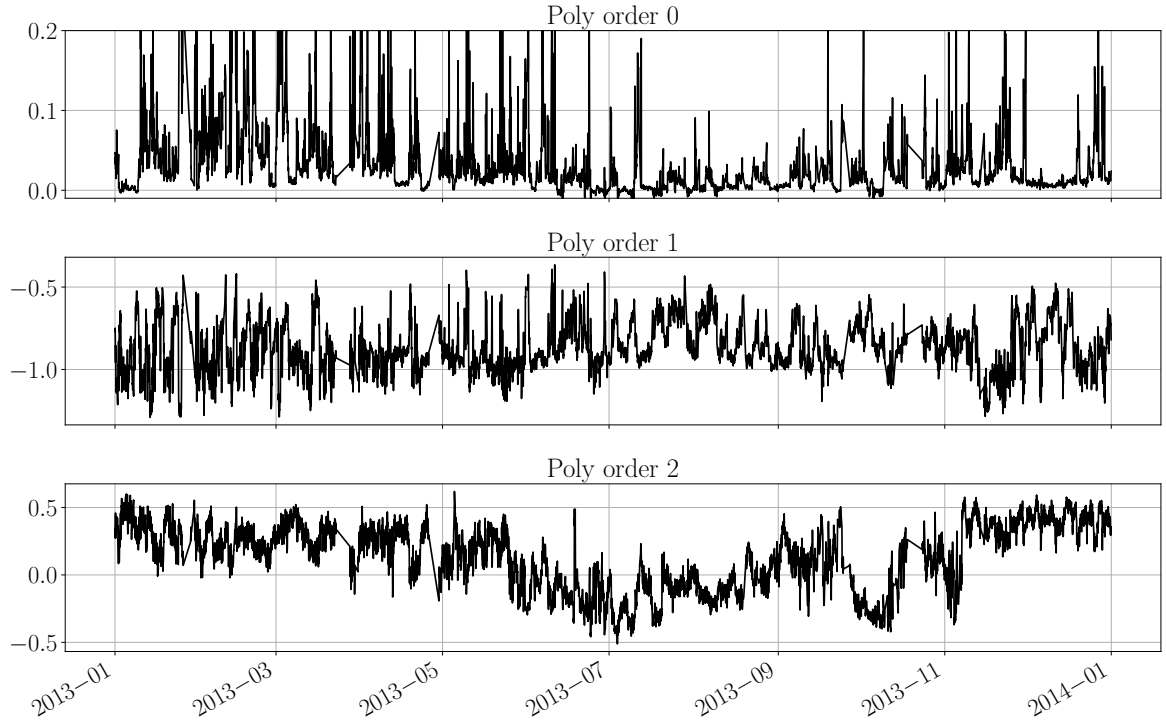


Figure 3.34: GROMOS, 2013

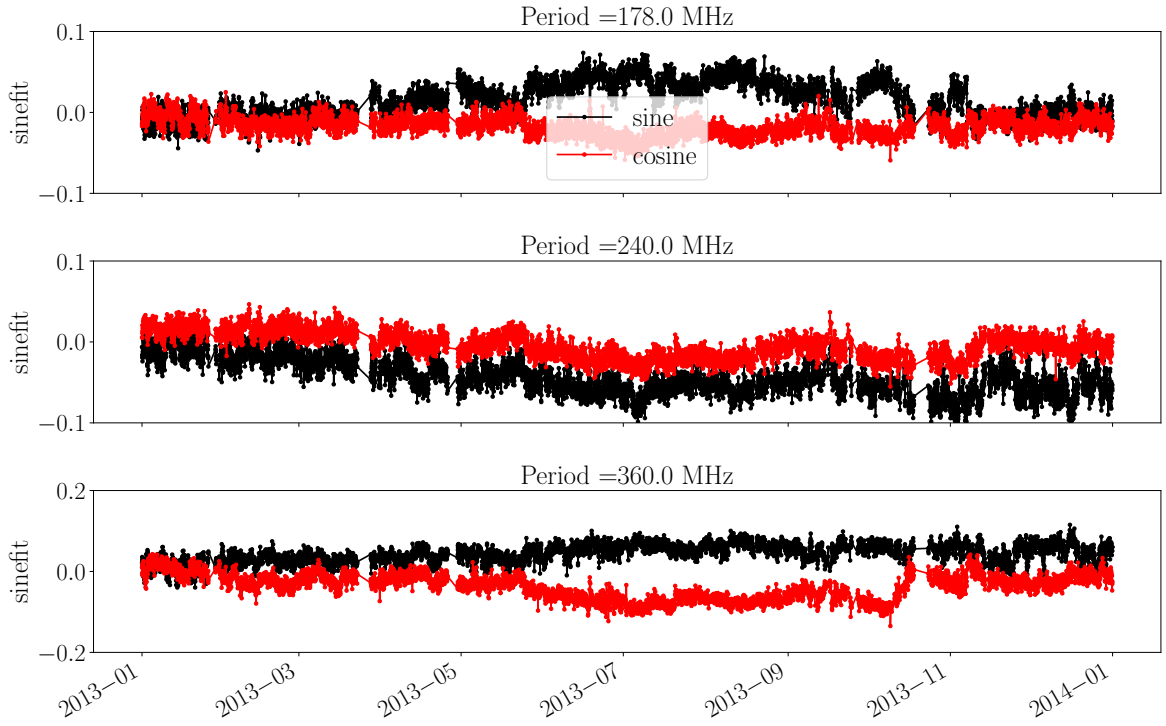


Figure 3.35: GROMOS, 2013

2014

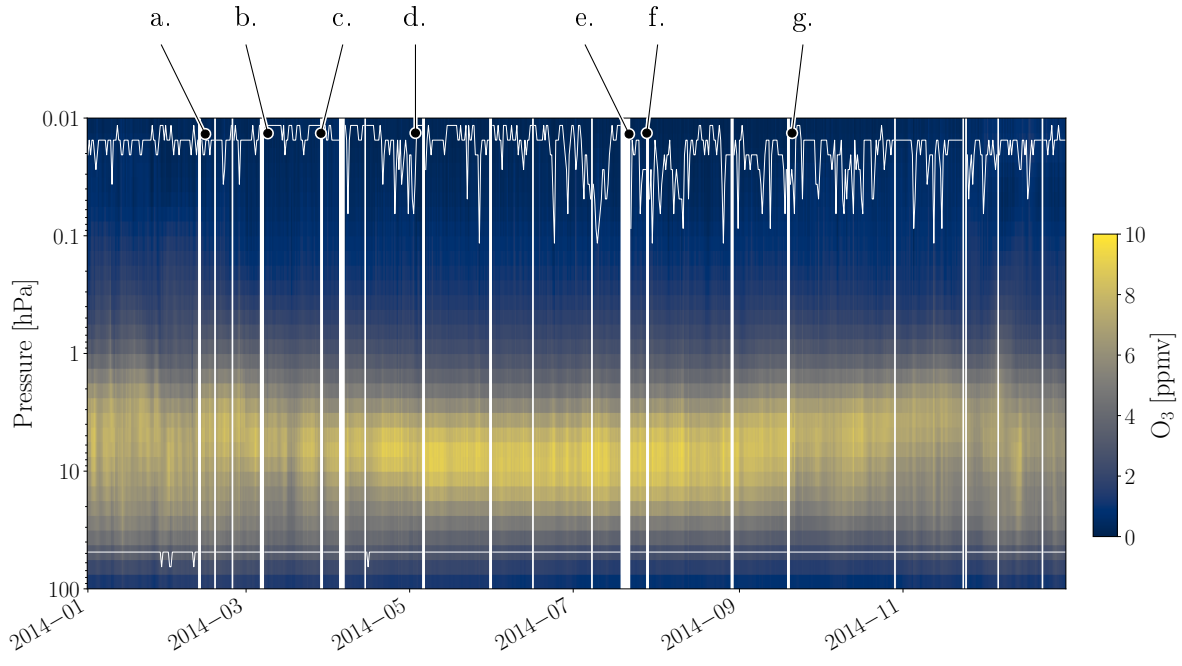


Figure 3.36: GROMOS, 2014

a. February 2014: climatisation problems

b. 07.03.14: no FFTS raw data

c. 29.03.14 + 05-06.04.14: no FFTS raw data

d. 01-05.05.14: strong drift of the frequency shift retrievals for unknown reasons. It ended with some LN2 valve problem.

e. 19-21.07.14: several thunderstorms caused power interruptions on GROMOS

f. 28-29.07.14: cold load airflow stopped -> condensation on cold load window

g. 19.09.14: change of cold load angle -> unkwown reason

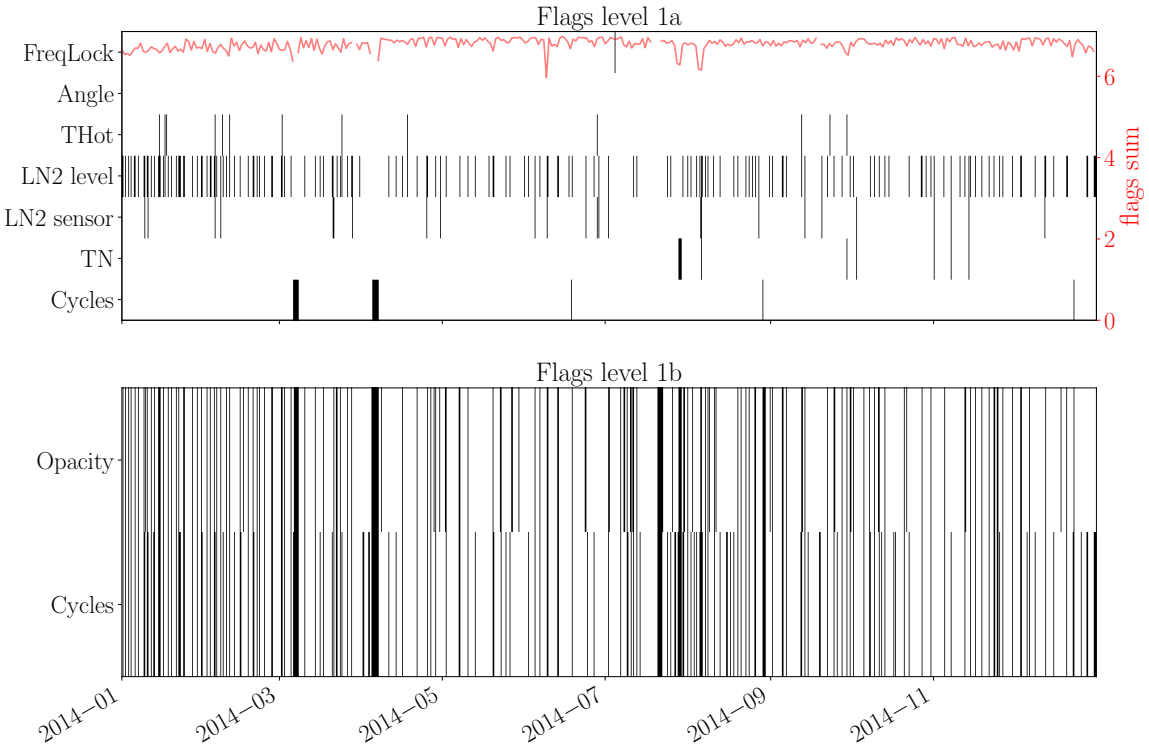


Figure 3.37: GROMOS flags, 2014

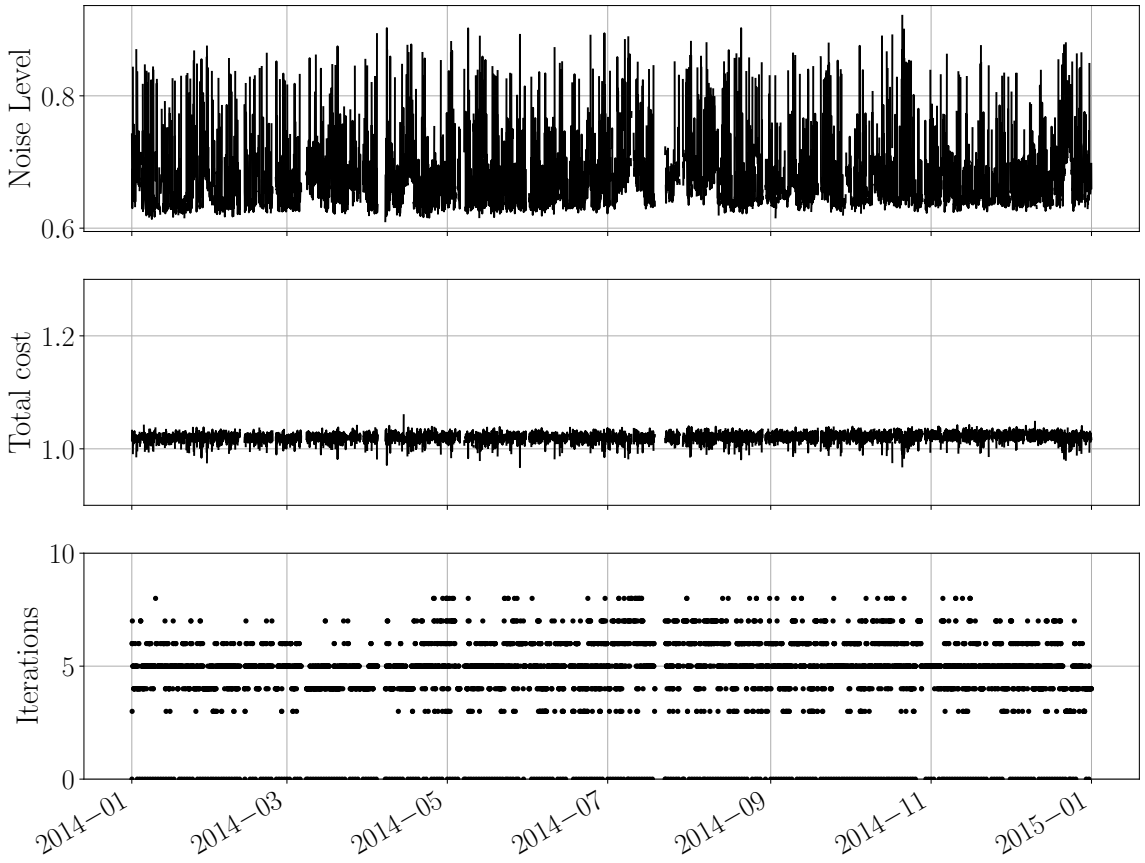


Figure 3.38: GROMOS, 2014

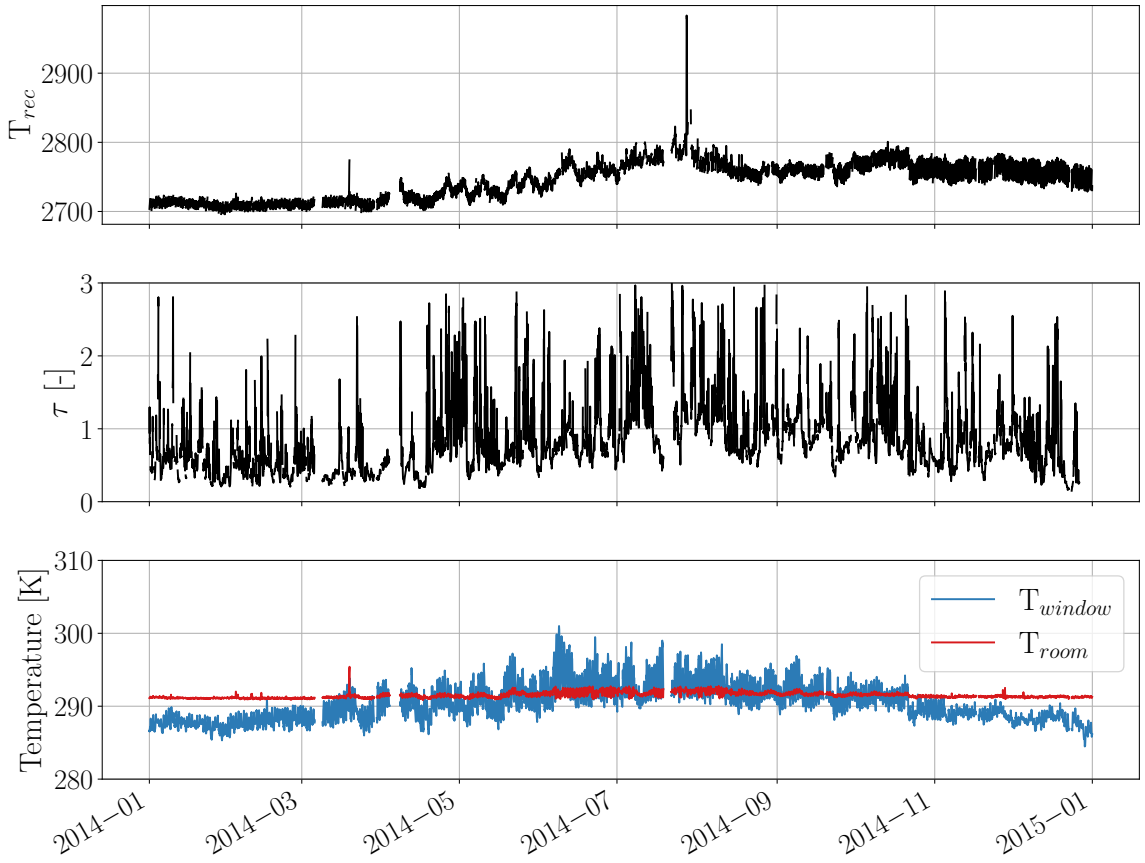


Figure 3.39: GROMOS, 2014

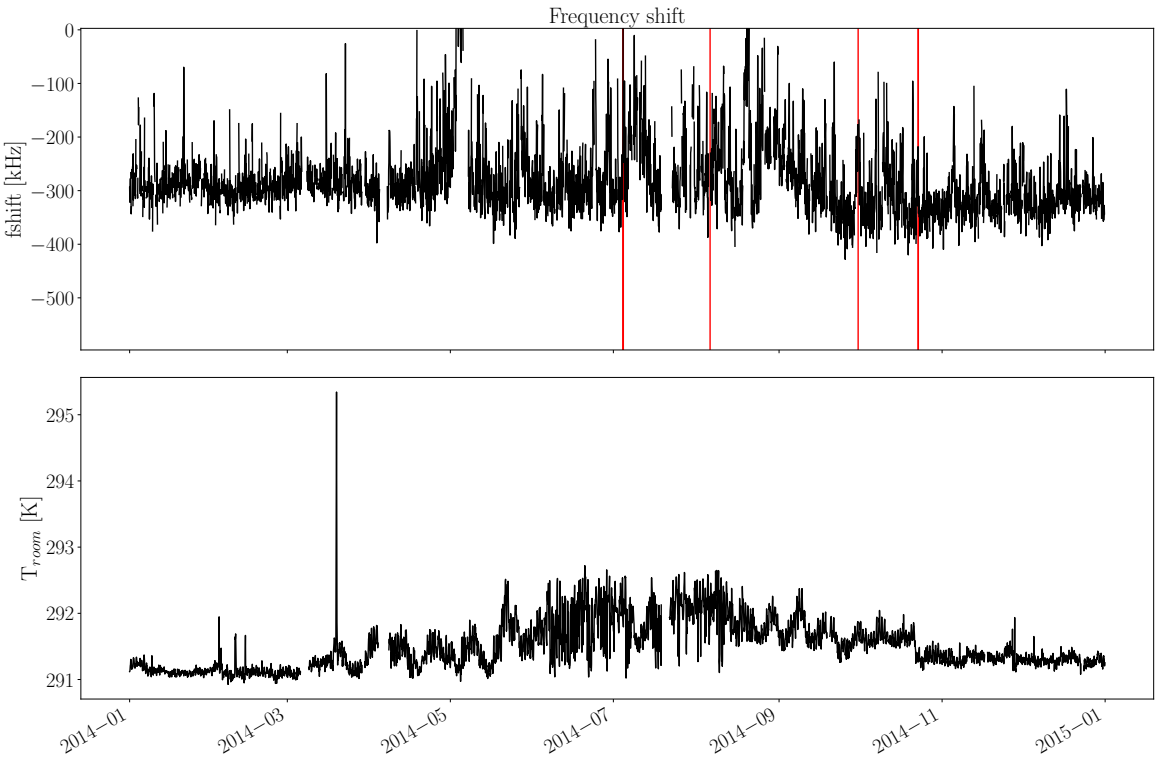


Figure 3.40: GROMOS, 2014

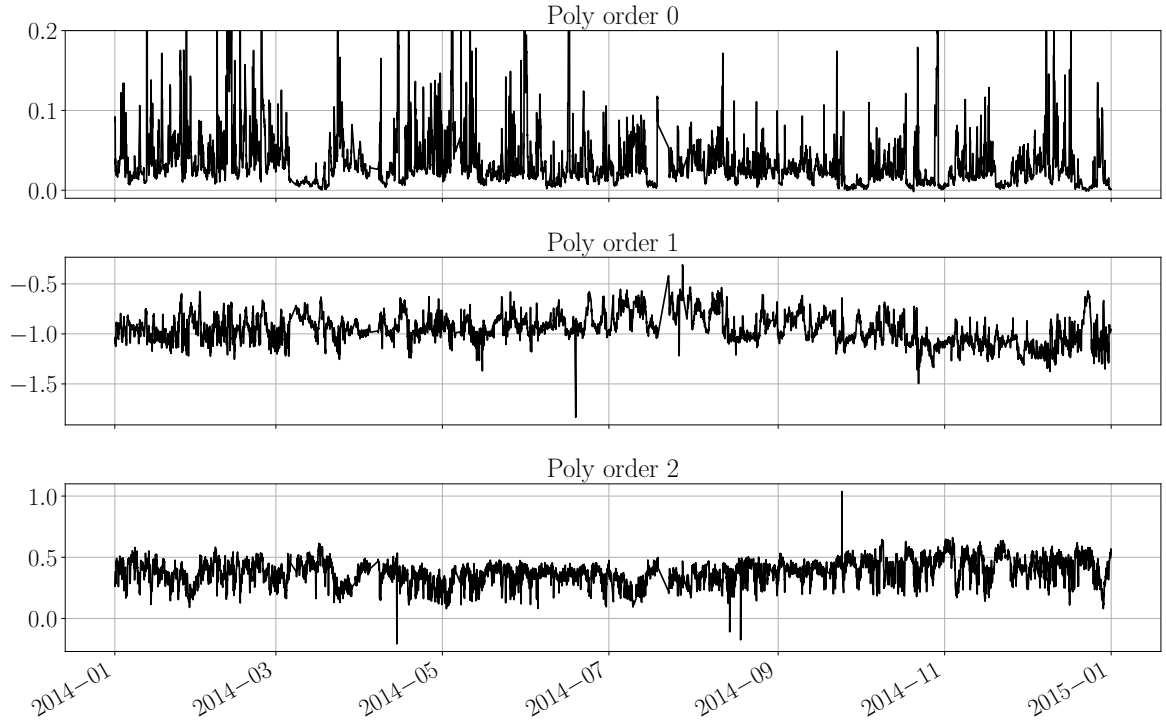


Figure 3.41: GROMOS, 2014

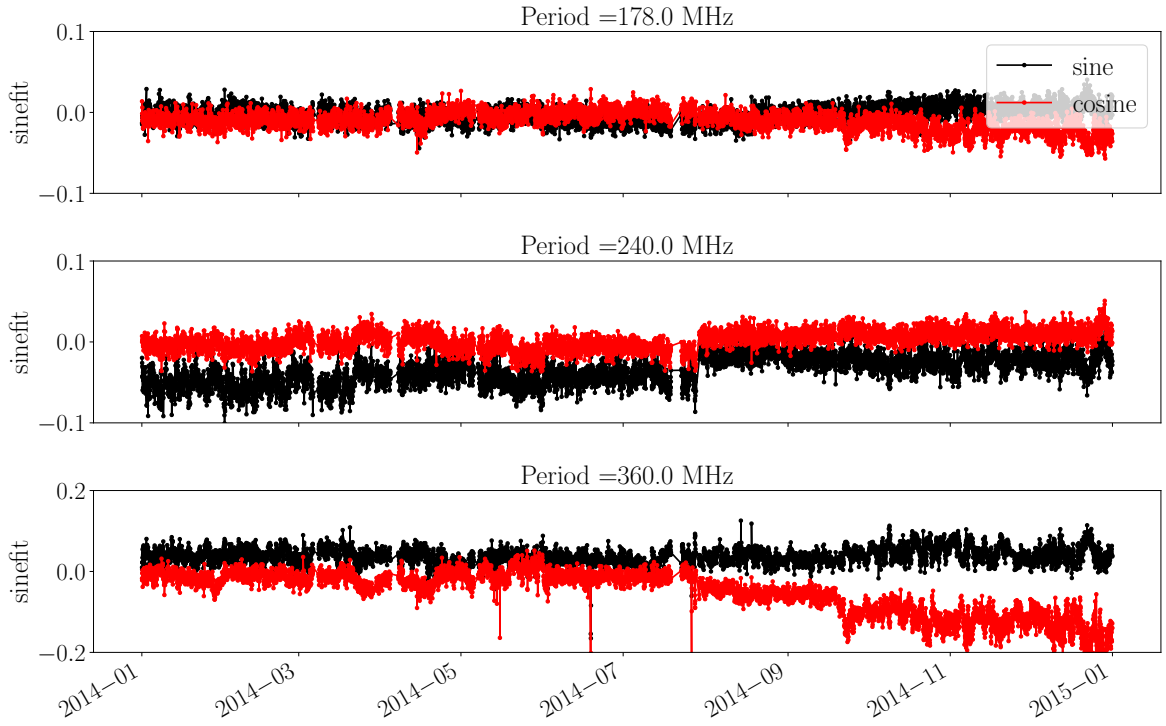


Figure 3.42: GROMOS, 2014

2015

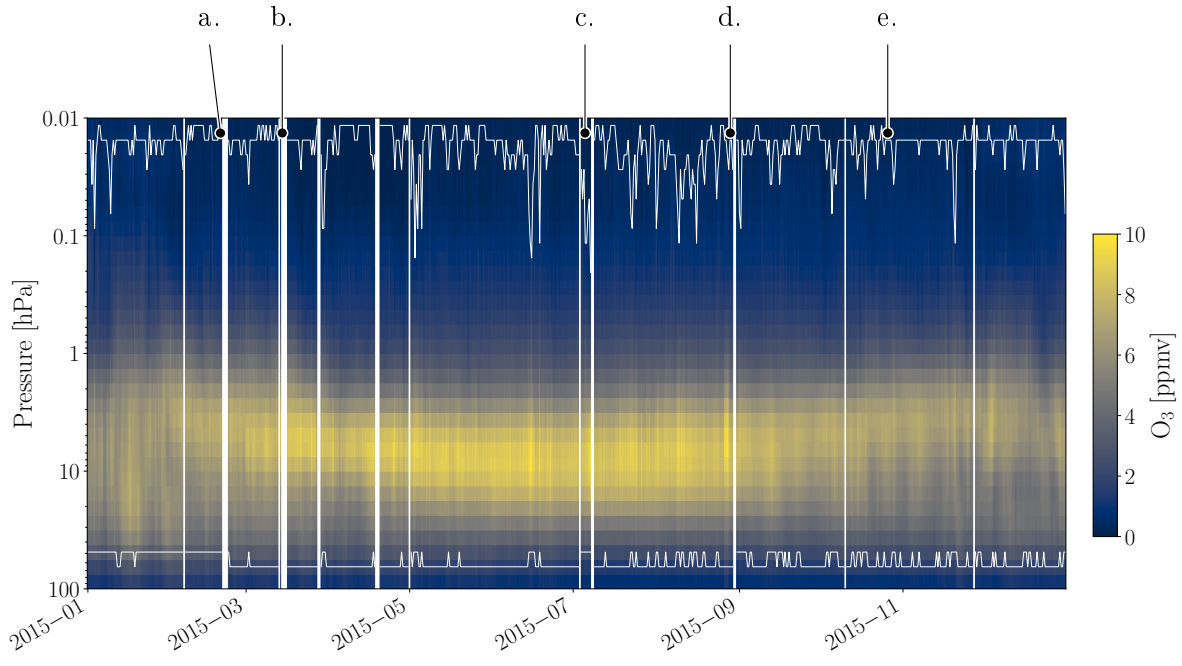


Figure 3.43: GROMOS, 2015

a. 20-22.02.15: LN2 empty which lead to a change in sine baselines on 23.02.15.

b. 14-16.03.15: LN2 empty, expansion tube replaced -> followed by a big frequency shift (see Fig. 3.47)

c. 08-13.07.15: Lock error (not seen in raw files ?) and significant increase of Trec for a few days. Reason is probably that the windows was found on the floor on the 13.07 (see Fig. 3.45)

d. 26-28.08.15: cold load full of ice -> cleaned and mounting of new absorber which leads to a jump in Trec > 200 K (up on 26.08 and back on 28.08). The L2 data between these 2 days is flagged but the data from July-August might be impacted as well. This whole episode resulted in changes of the sine baselines, applied on the 31.08.

e. October and November 2015, few lock errors which do not seem critical.

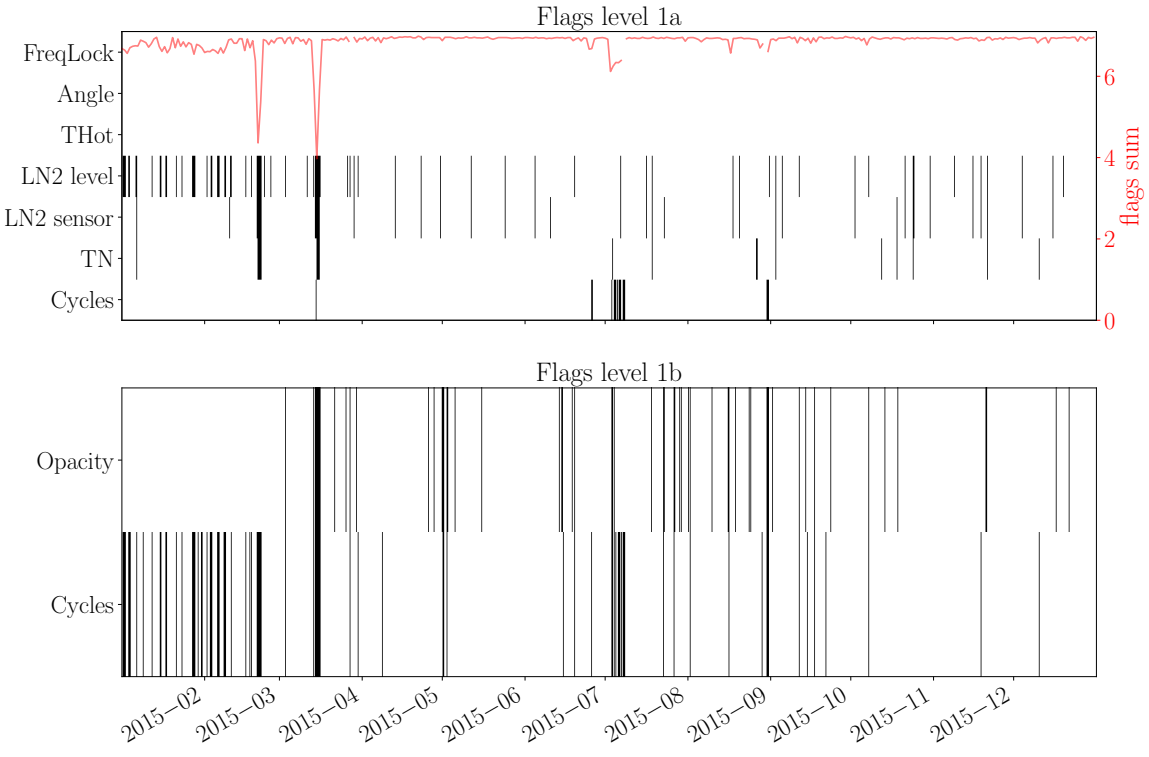


Figure 3.44: GROMOS flags, 2015

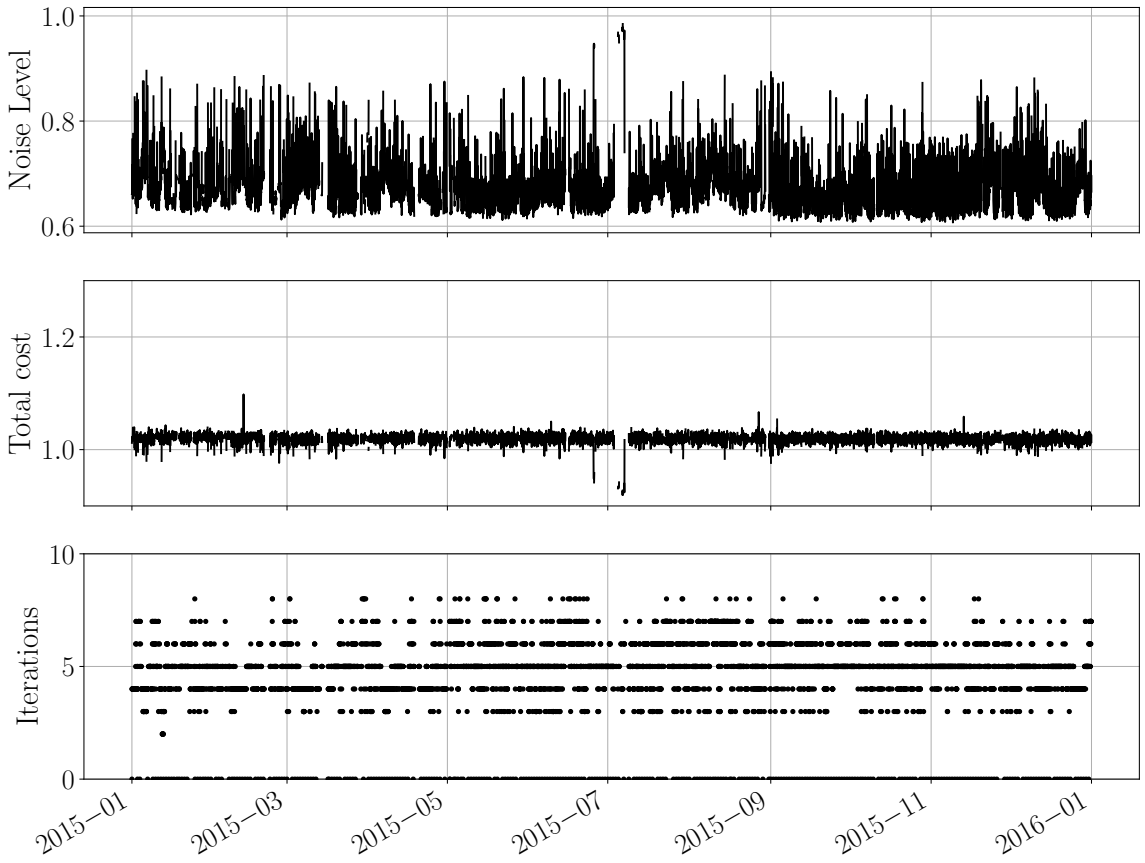


Figure 3.45: GROMOS, 2015

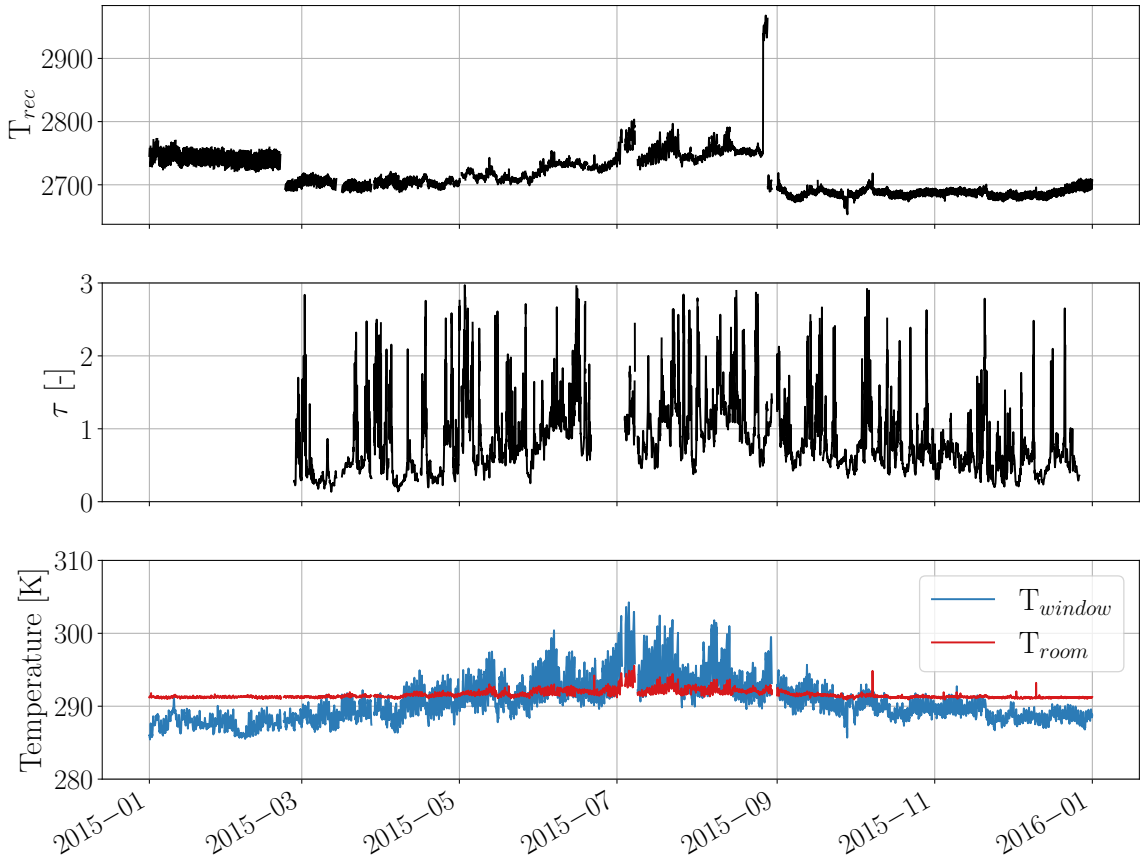


Figure 3.46: GROMOS, 2015

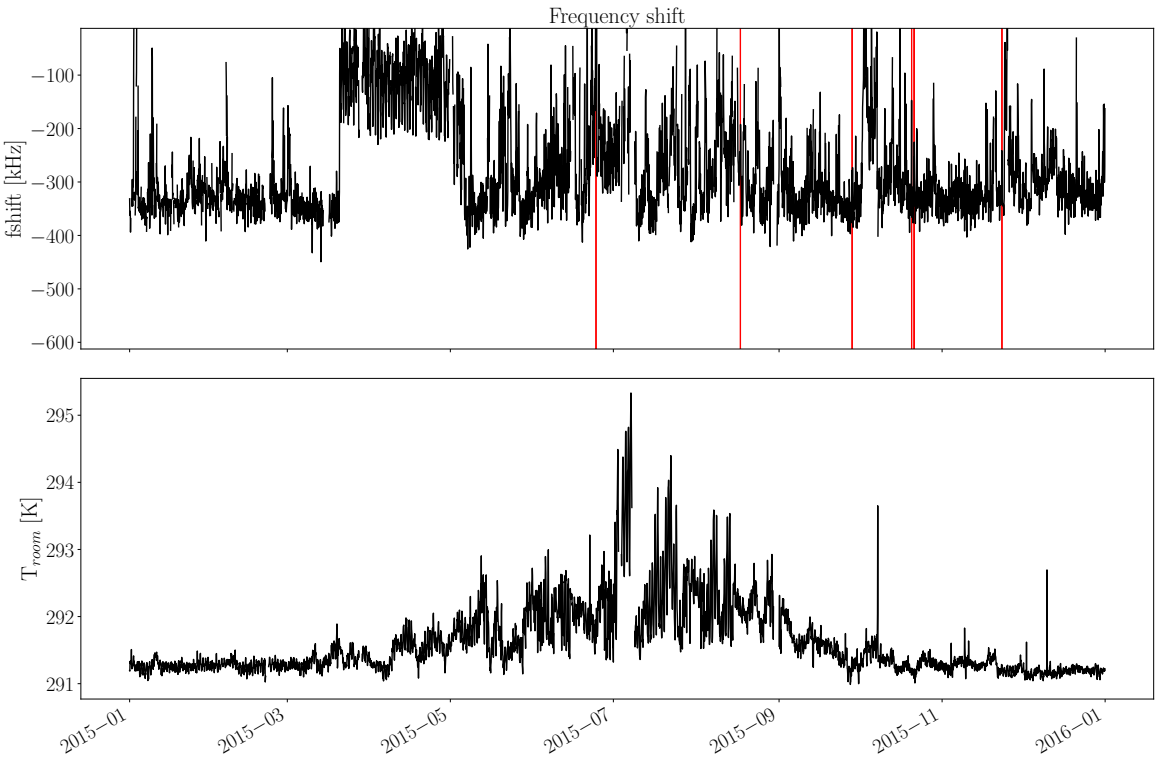


Figure 3.47: GROMOS, 2015

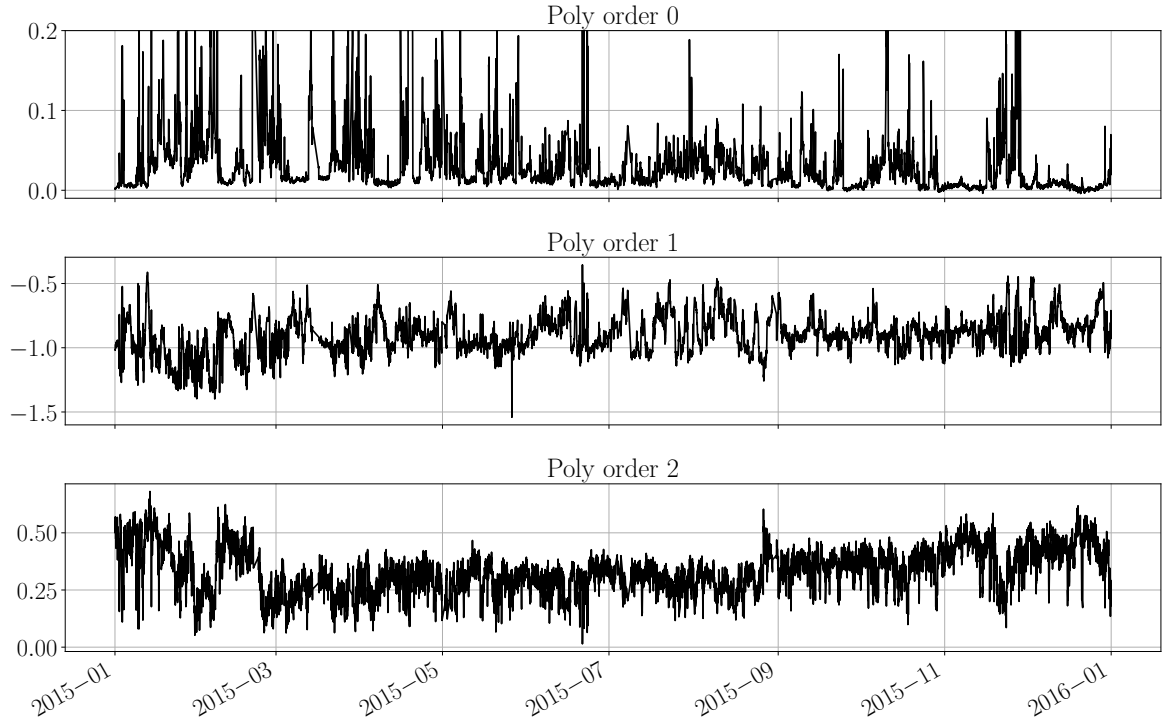


Figure 3.48: GROMOS, 2015

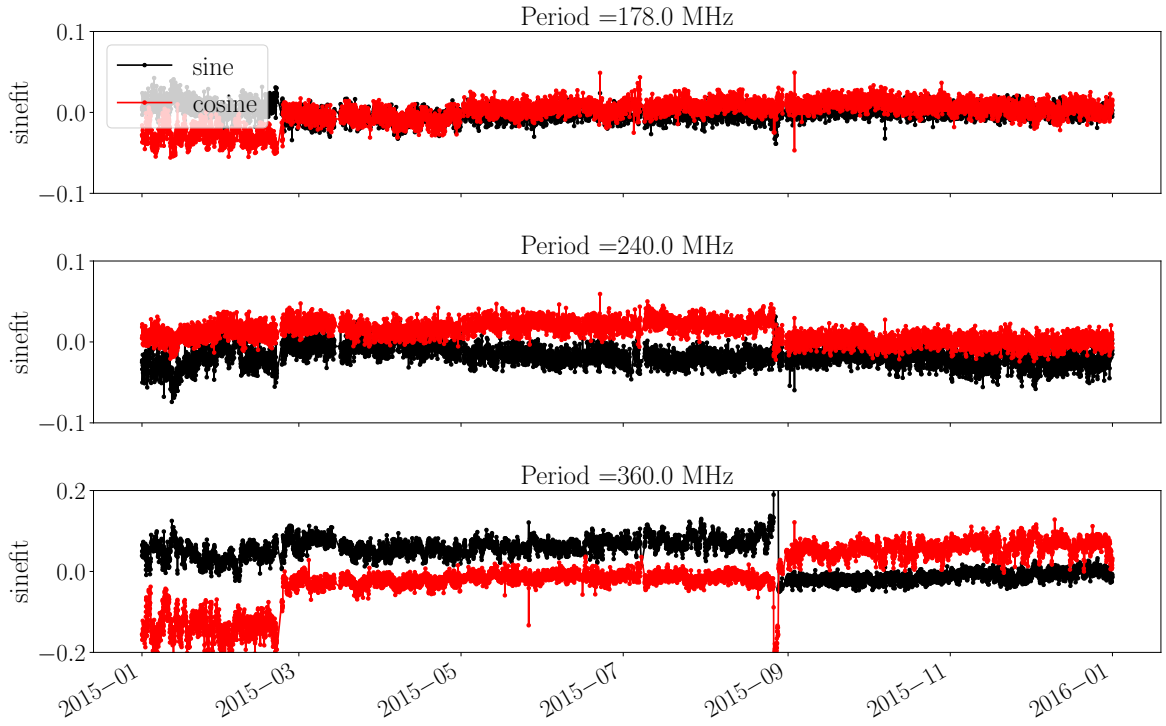


Figure 3.49: GROMOS, 2015

2016

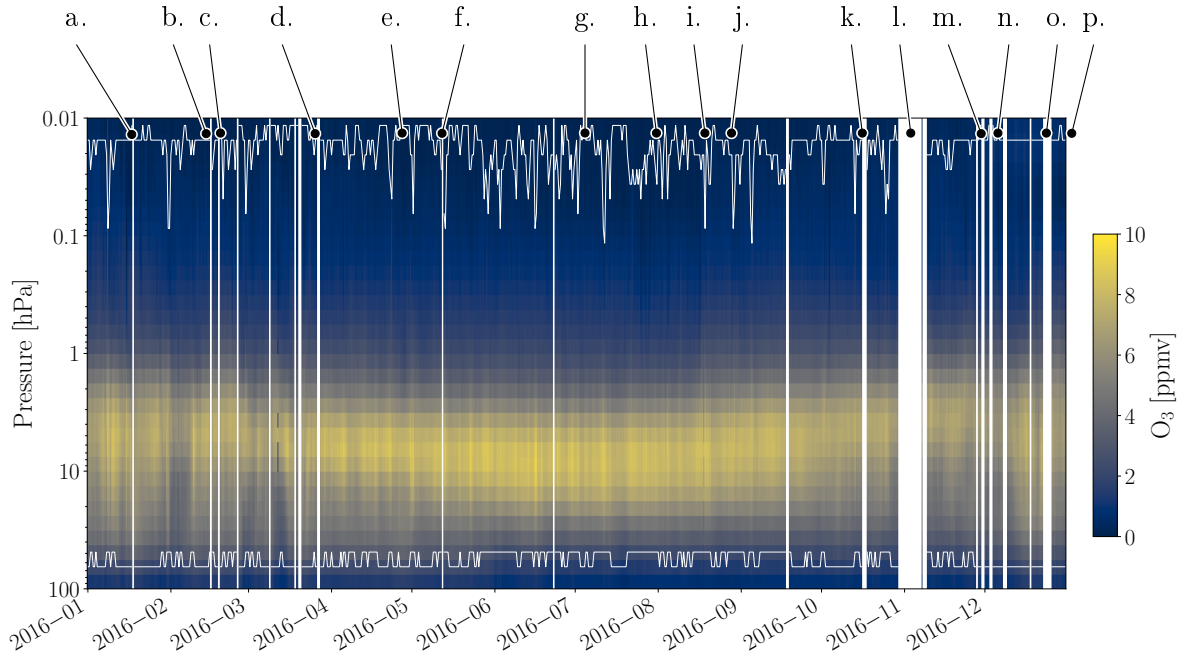


Figure 3.50: GROMOS, 2016

a. 15.01.16: lock error resulting in significant change in frequency shift retrievals (see Fig. 3.54)

b. 15-16.02.16: problem with the mirror

c. 18-19.02.16: LN2 problem, filling tube was broken and replaced.

d. 27.03.16: mirror problem

e. 27.04.16: some lock errors

f. 12-13.05.16: retrievals error due to high atmospheric opacity

g. 04-13.07.16: room temperature control stopped at 04.07 which resulted in increase of Trec in the next days. It stayed high until 13.07 but did not go back fully to normal. On 11.07 we also had some lock errors which lead to changes in frequency shift retrievals. Note that in addition, this periods was characterized by a high troposperic opacity. Troom was also changed (permanently ?) on the 13.07 in the hope to stabilize it.

h. 27-29.07.16: measurement stopped on 27.07 for unknown reasons. On 29.07, cold load full of ice -> cleaned

i. 16.08.16: lock errors leading to massive change in frequency shift retrieval. Also some mirror problems in the following days (18-19.08.16)

j. 23.08.16: cold load full of ice -> cleaned: this ends more or less the very perturbed period of the summer 2016.

k. 16-17.10.16: mirror problem

l. 29.10.16-10.11.16: airflow on cold load down for a few days followed by Windows 7 update. The update resulted in many measurement interruptions during November 2016.

m. 29-30.11.16: electricity cut on 29.11 -> measurement interruptions

n. 07.12.16: change of reference pointing angle (?).

o. 23-26.12.16: measurements interrupted for unknown reasons

p. 01.01.17: change of sine baseline periods (Table 3.2)

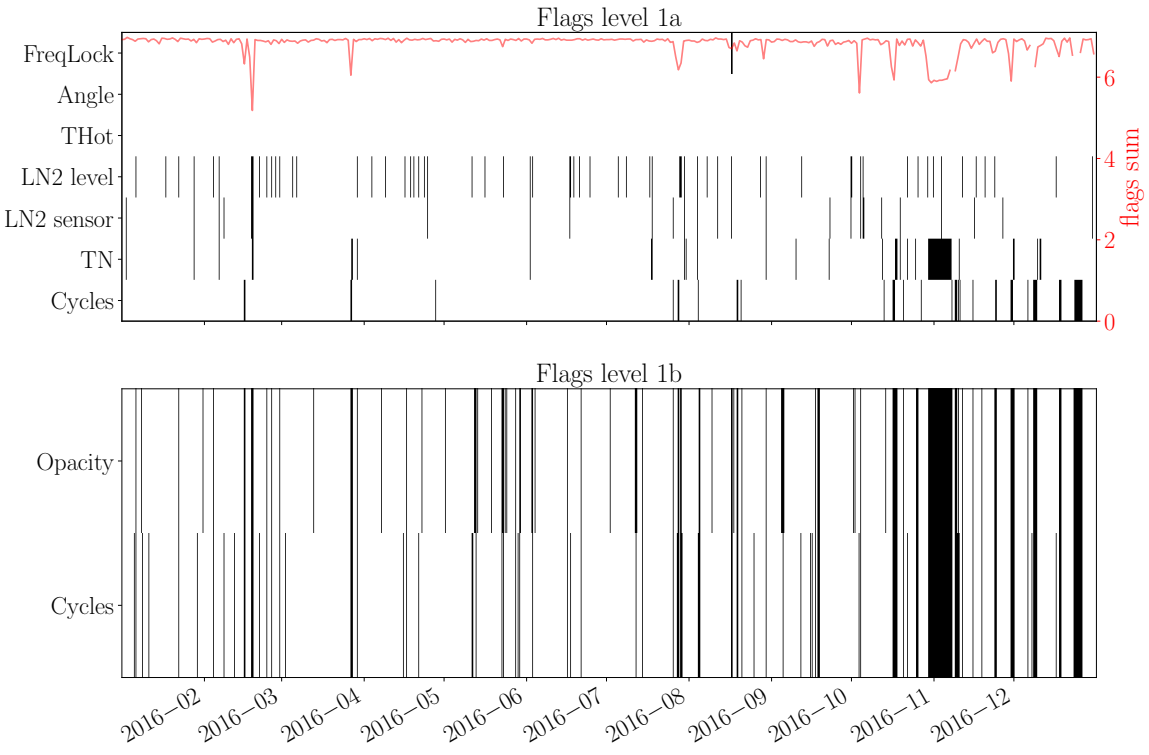


Figure 3.51: GROMOS flags, 2016

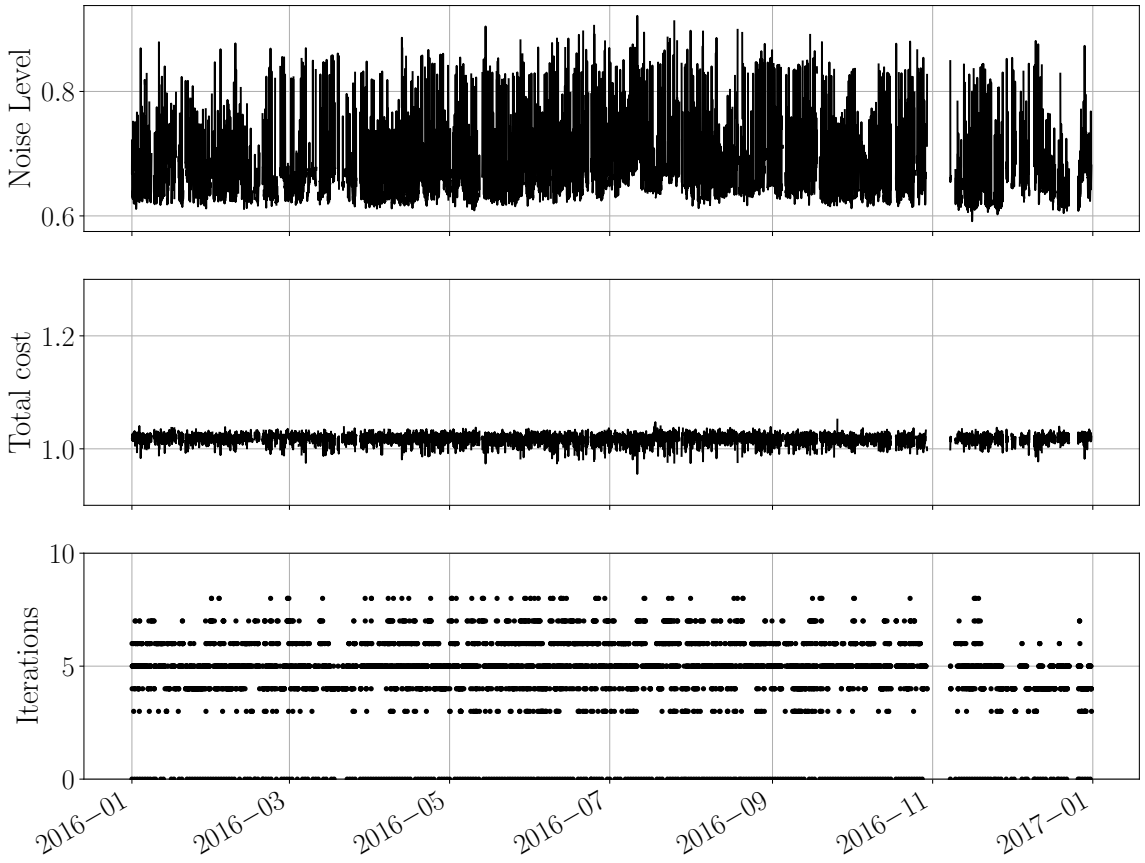


Figure 3.52: GROMOS, 2016

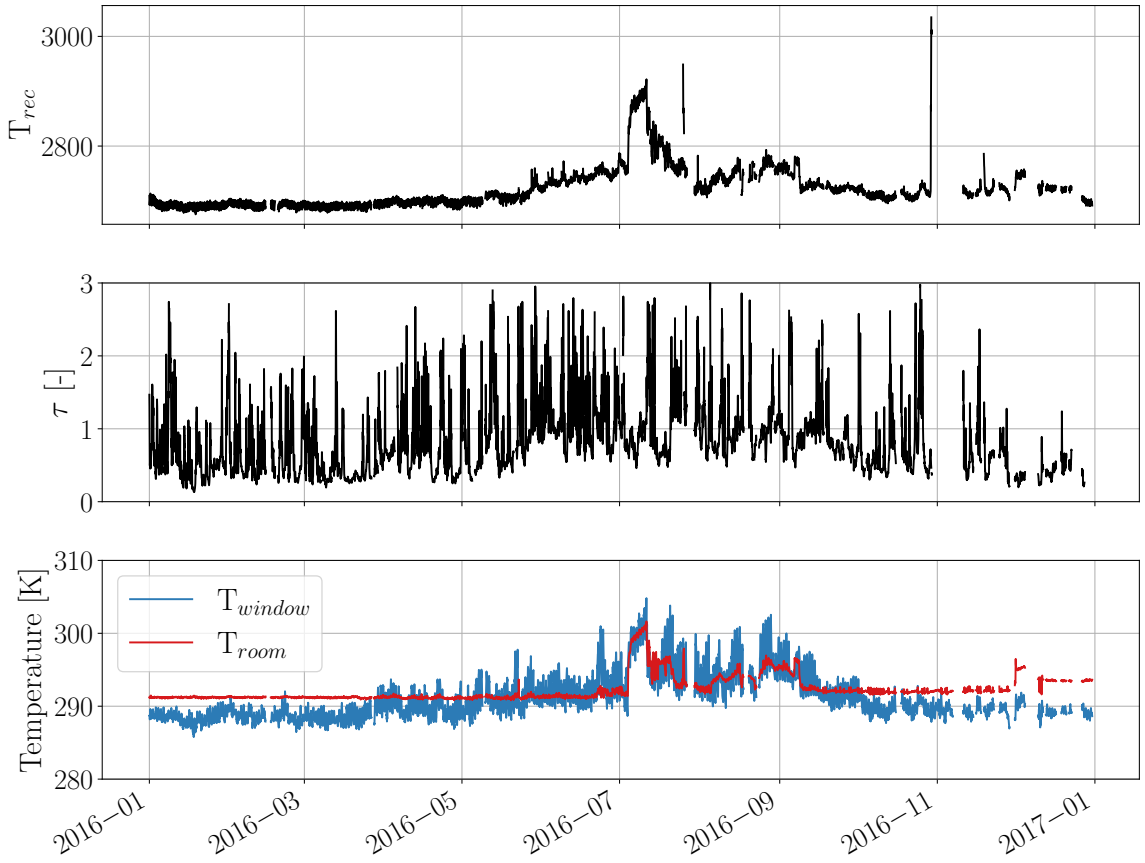


Figure 3.53: GROMOS, 2016

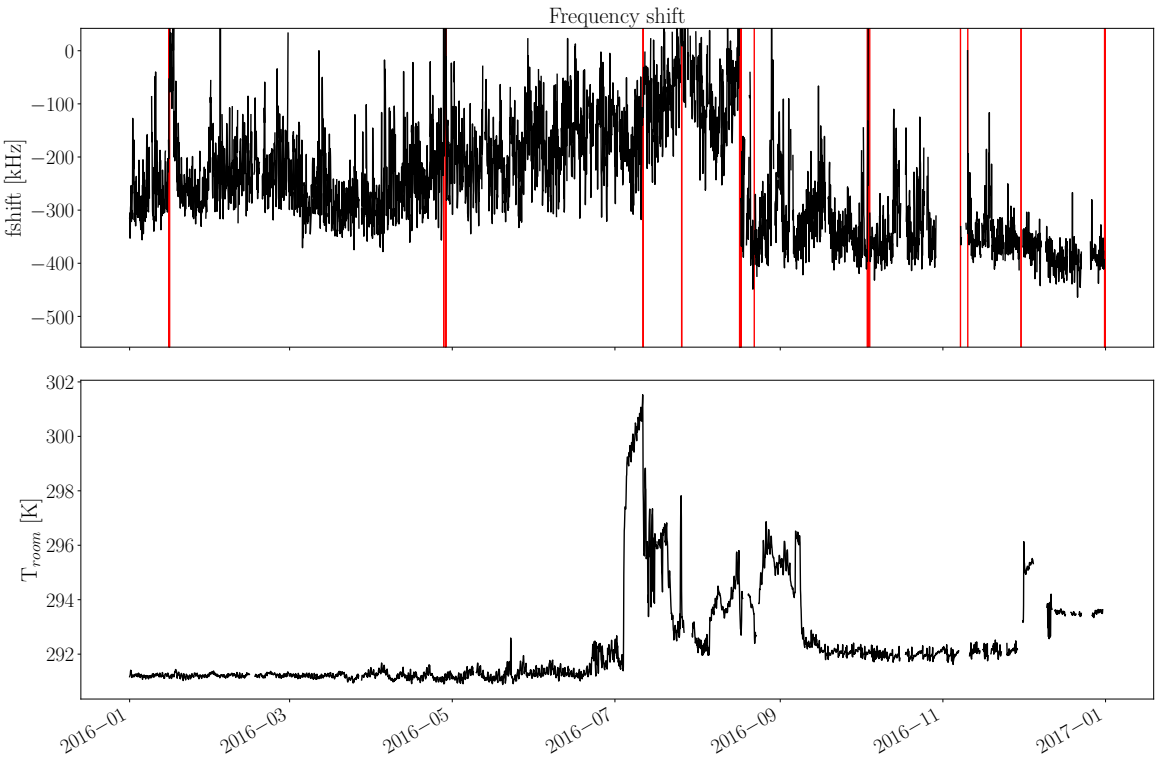


Figure 3.54: GROMOS, 2016

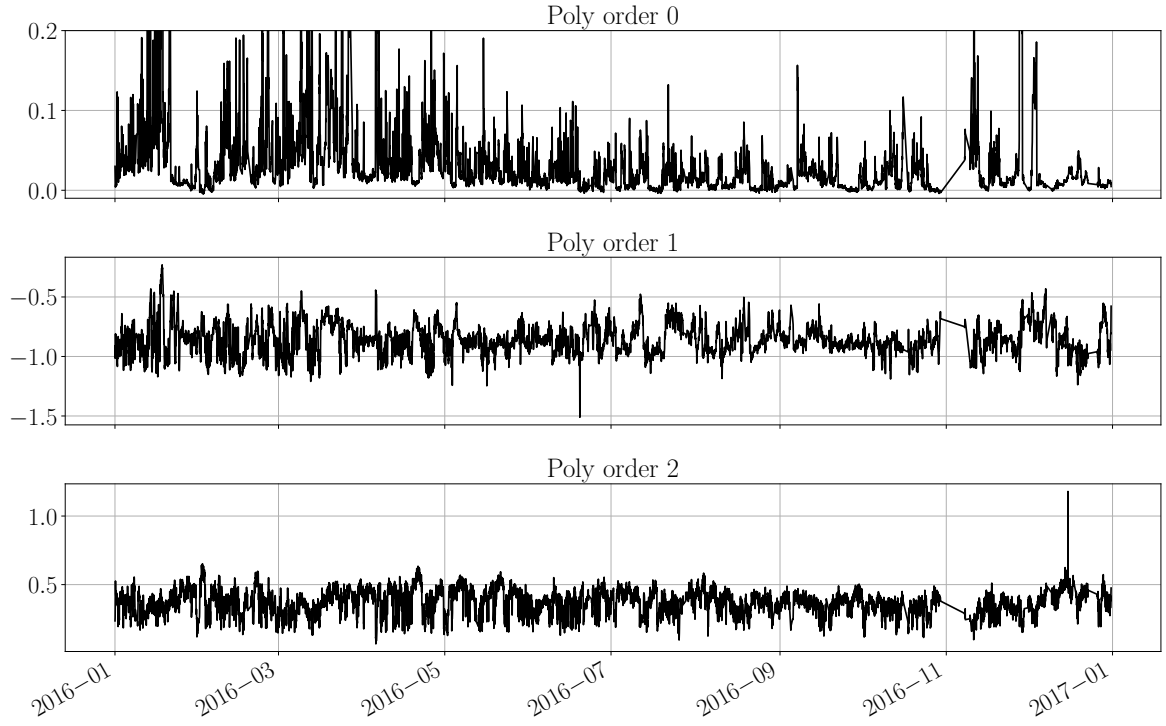


Figure 3.55: GROMOS, 2016

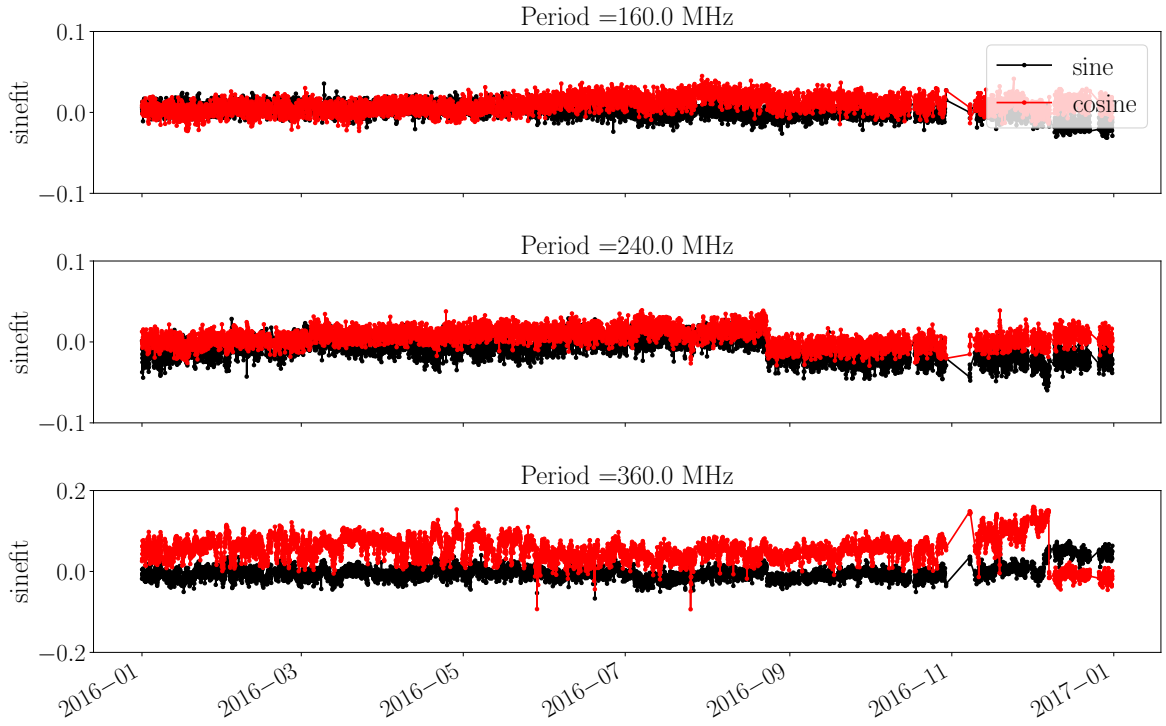


Figure 3.56: GROMOS, 2016

2017

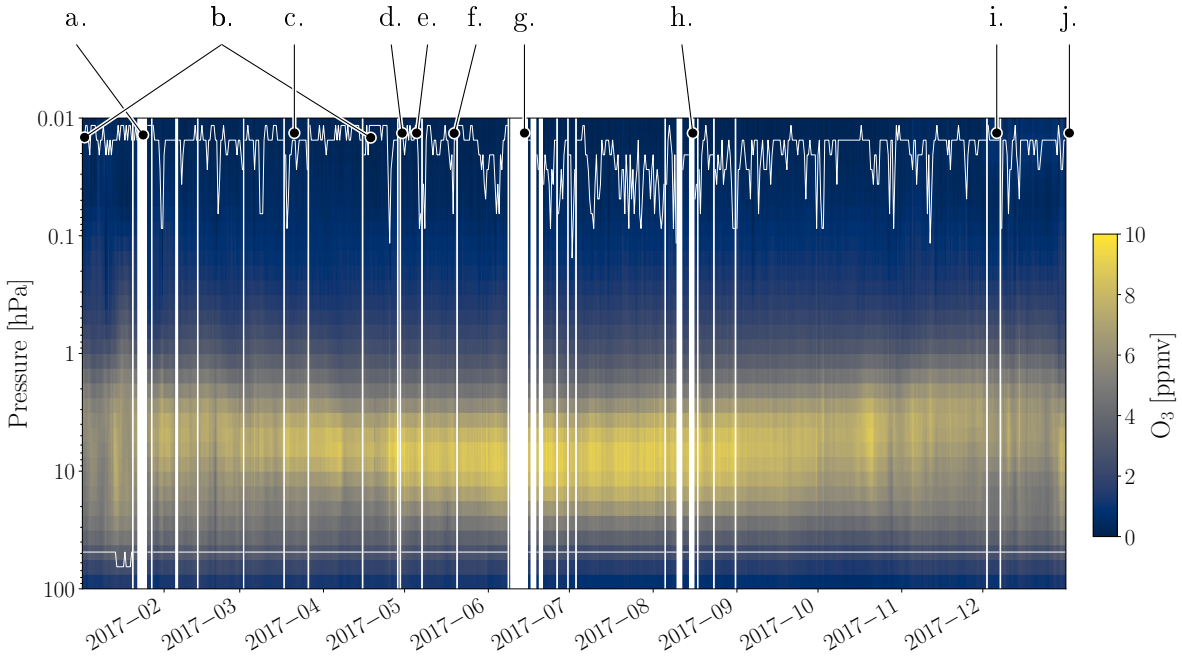


Figure 3.57: GROMOS, 2017

a. 24-25.01.17: changes in task scheduling and Labview restarts -> no data in this period.

b. January-February-March 2017: frequent interruptions following Windows update ?

c. 26.03.17: unknown calibration problems

d. 28.04.17: unknown raw data problems

e. 08.05.17: LN2 valve problem since probably a few days. On 11.05, Trec began to increase and stayed high until June.

f. 14-20.05.17: problem with LN2 refill system (data should be still usable). This periods is followed by many interruptions until beginning of June. Trec went back to normal on the 01.06 (Fig. 3.60)

g. 07-21.06.17: network problems, problems with the mirror and some very high fluctuations of Trec. On 21.06, cold load was full of ice and was cleaned. During this time, a lot of lock errors as well (see Fig. 3.61).

h. 05 and 10-11 and 14-17.08.17: unknown problem during calibration (probably from raw data)

i. Beginning of December: Trec quite spiky, unknown reason

j. 01.01.18: change of sine baseline periods (Table 3.2)

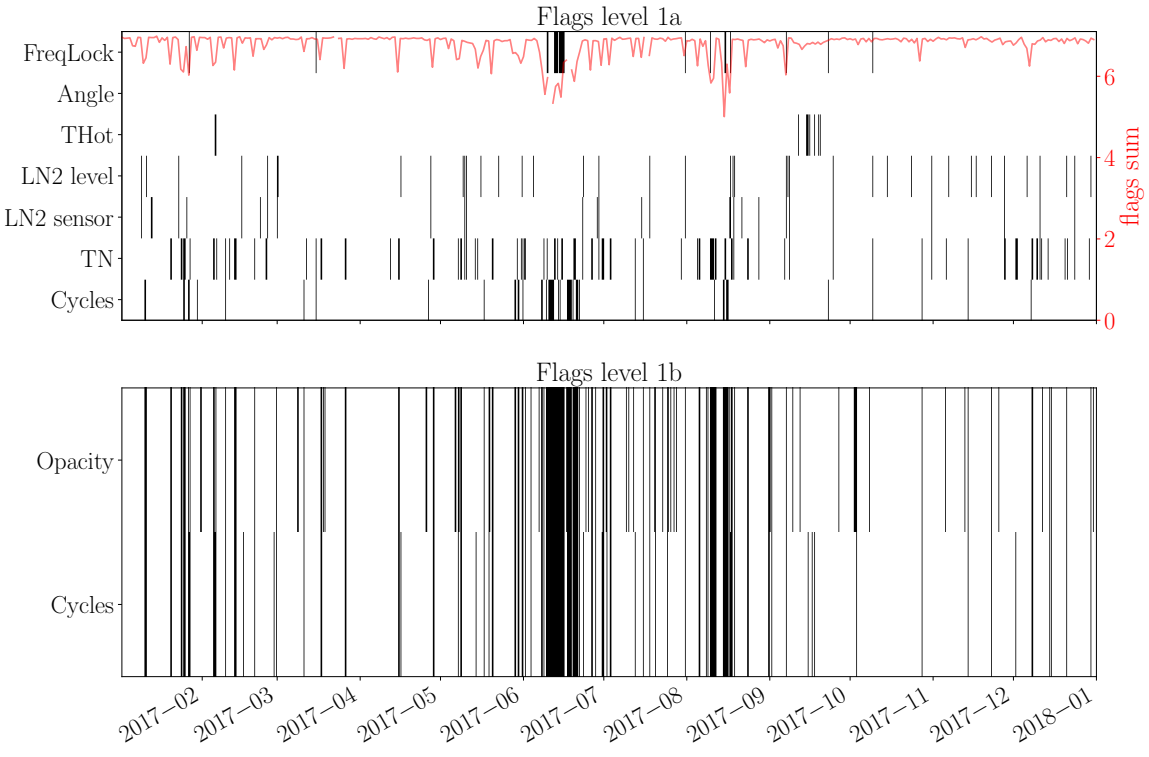


Figure 3.58: GROMOS flags, 2017

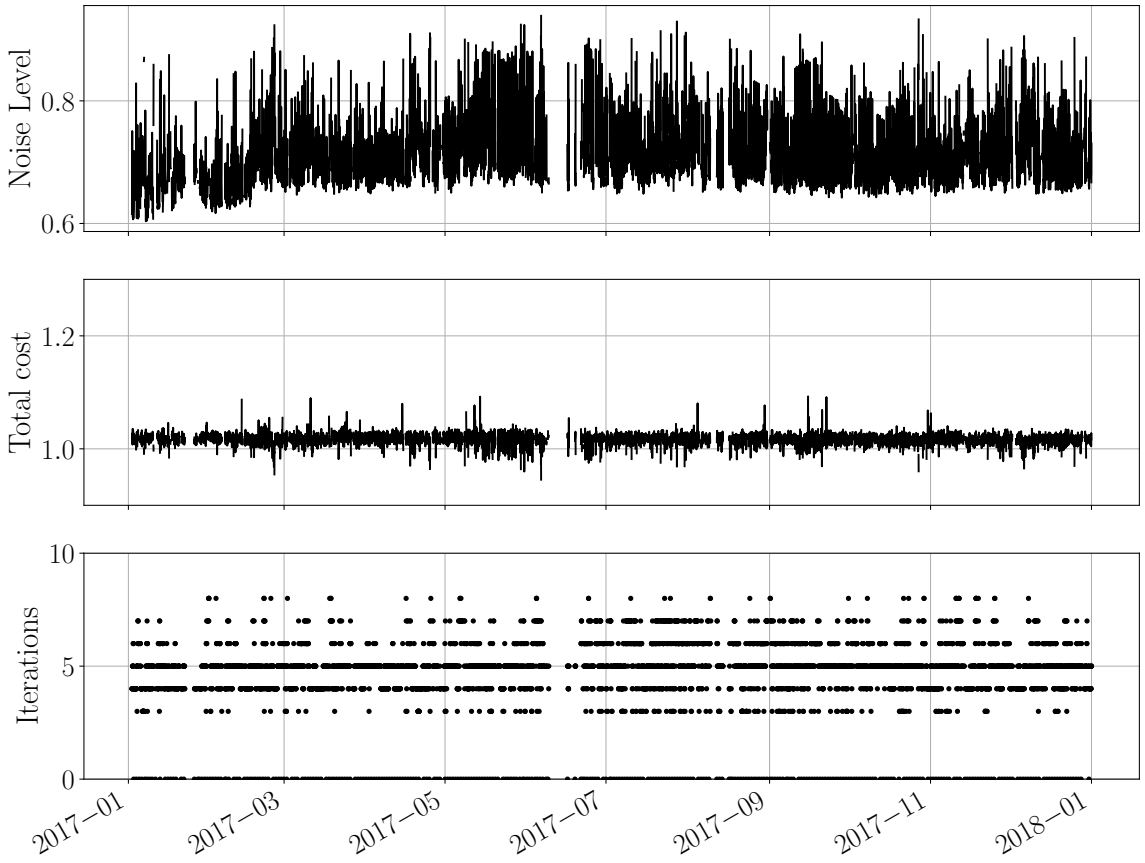


Figure 3.59: GROMOS, 2017

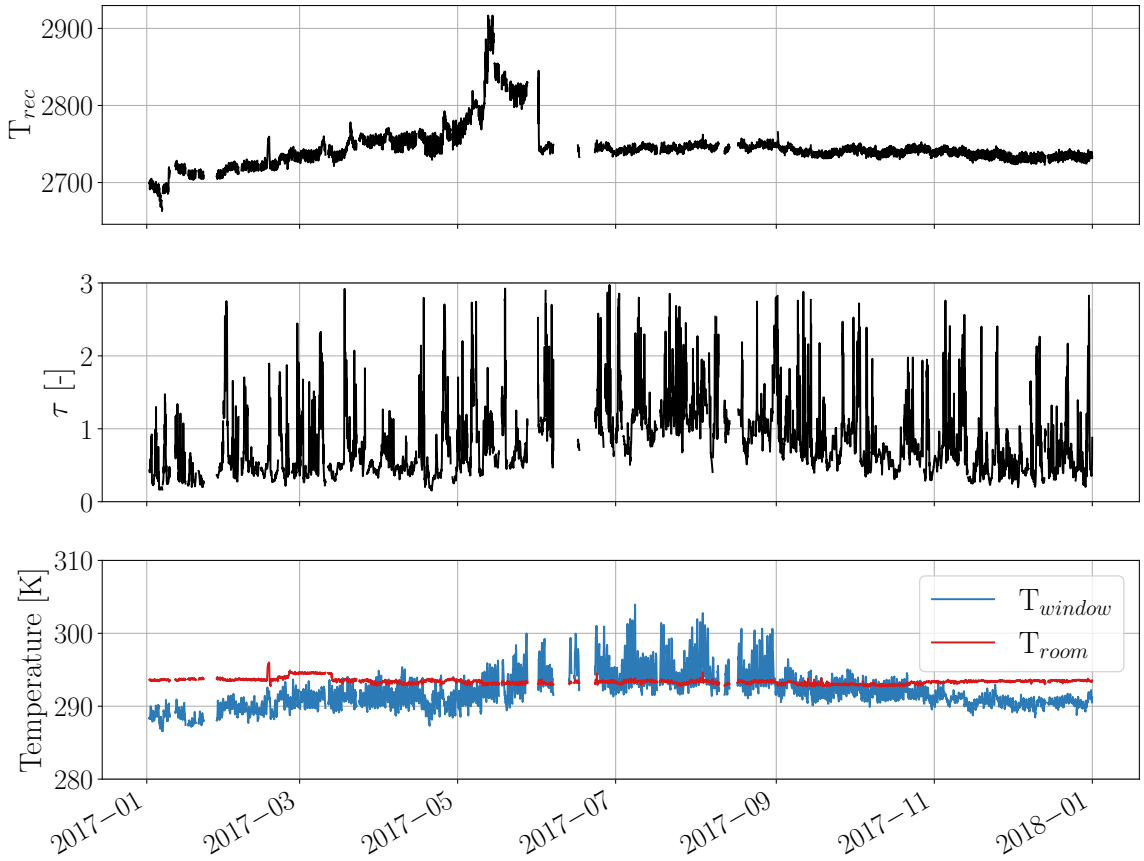


Figure 3.60: GROMOS, 2017

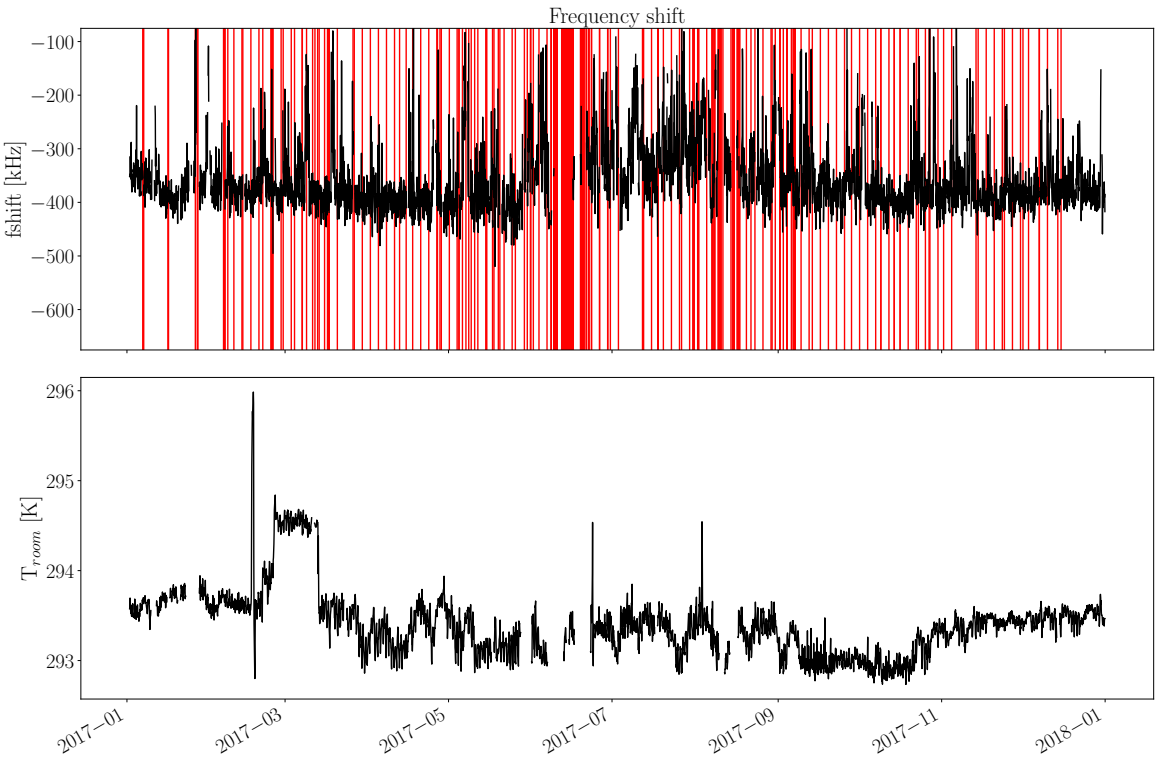


Figure 3.61: GROMOS, 2017

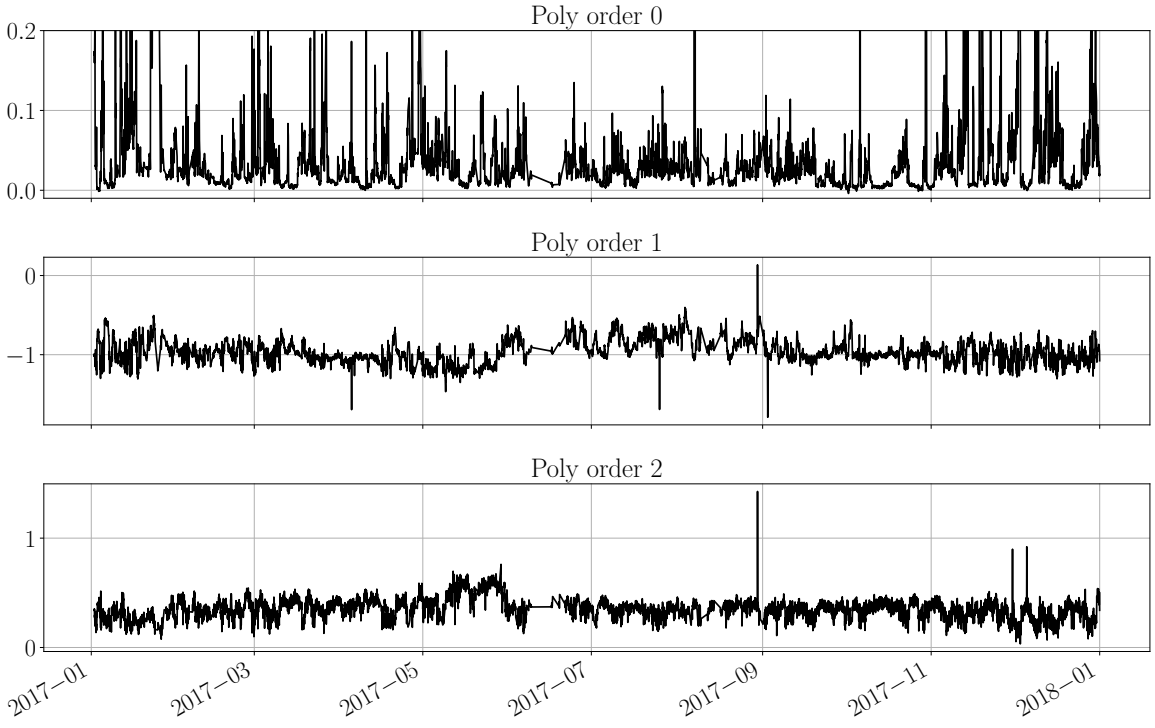


Figure 3.62: GROMOS, 2017

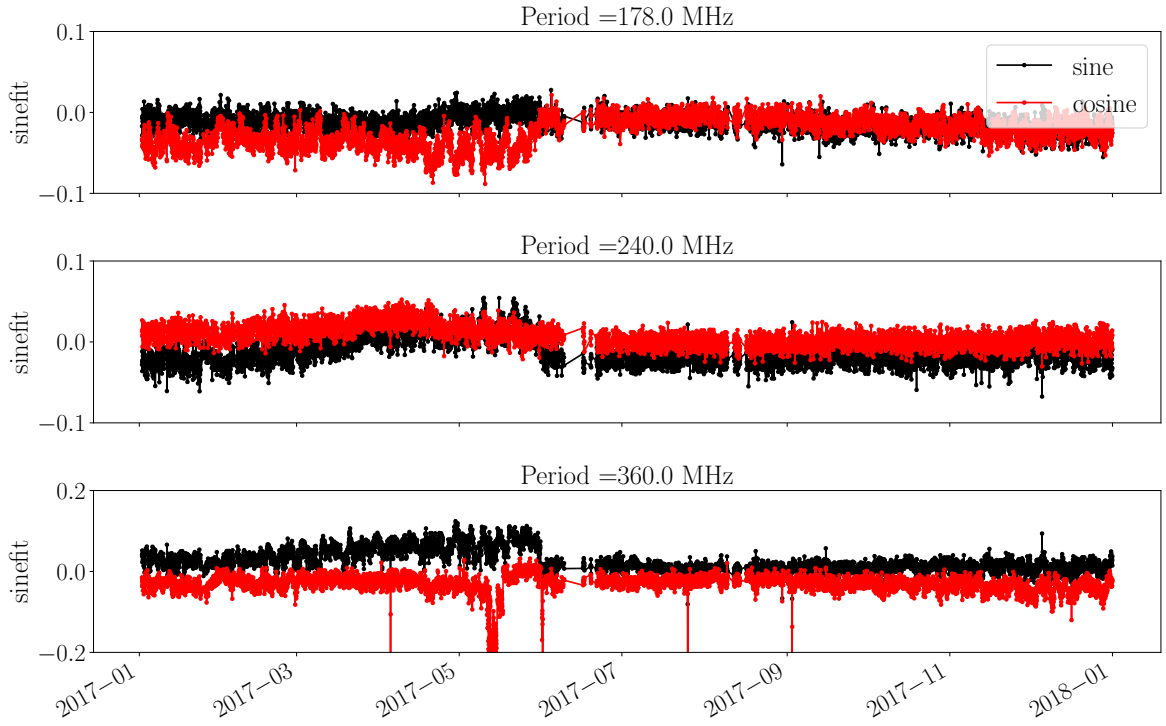


Figure 3.63: GROMOS, 2017

2018

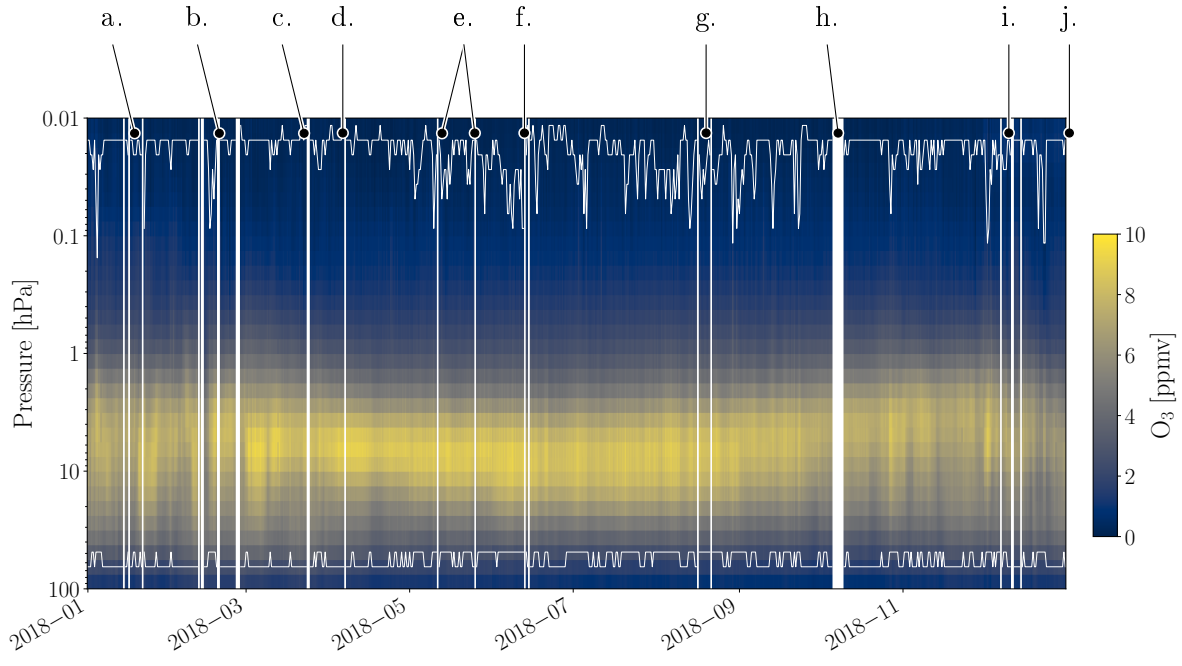


Figure 3.64: GROMOS, 2018

a. 14 and 16.01.18: problem during calibration (probably from raw data)

b. 11-12 and 19-20.02.18: problem during calibration, could be due to Windows updates which caused quite some problem in this period.

c. 22-23.03.18: problem during calibration (probably from raw data)

d. 06-07.04.18: Measurement interruptions (unknown reasons)

e. 11 and 25.05.18: problem during calibration (probably from raw data)

f. 13.06.18: massive jump in frequency shift retrievals (Fig 3.68), reason is unknown)

g. 16 and 21.08.18: problem during calibration (probably from raw data)

h. 05-10.10.18: retrievals problem

i. 07.12.18: problem during calibration (probably from raw data) and generally high opacity around this period.

j. 01.01.19: change of sine baseline periods (Table 3.2)

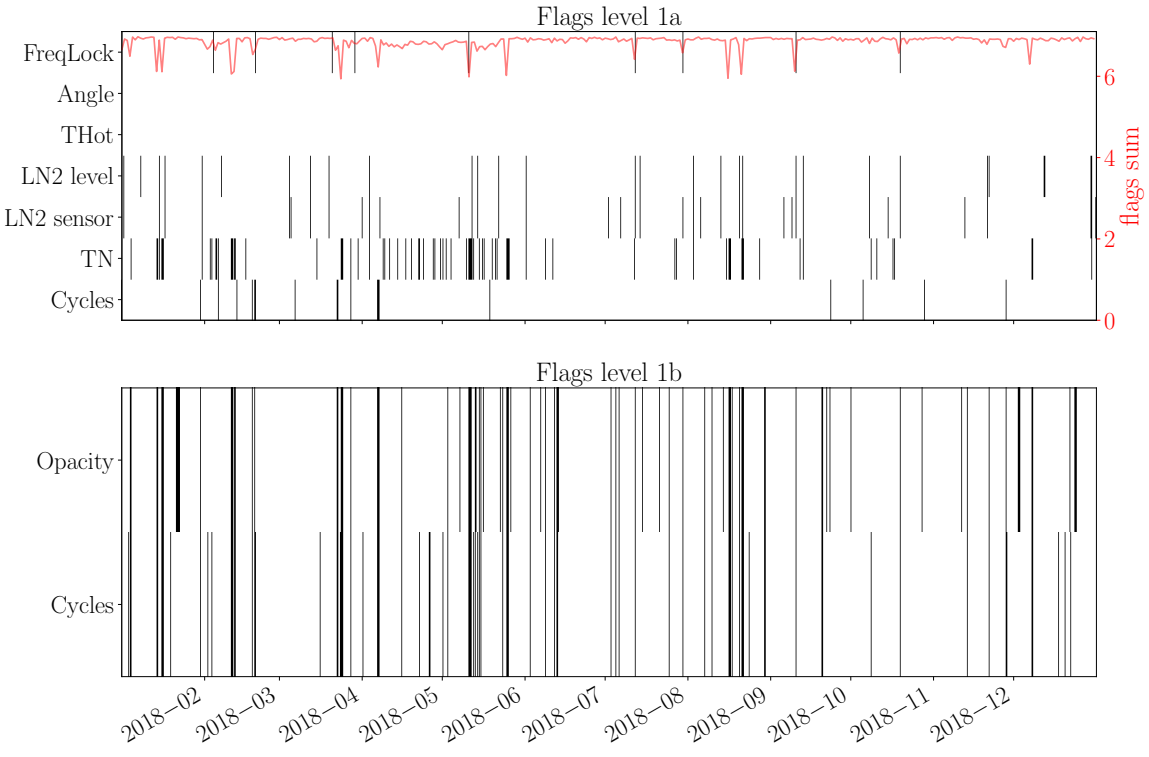


Figure 3.65: GROMOS flags, 2018

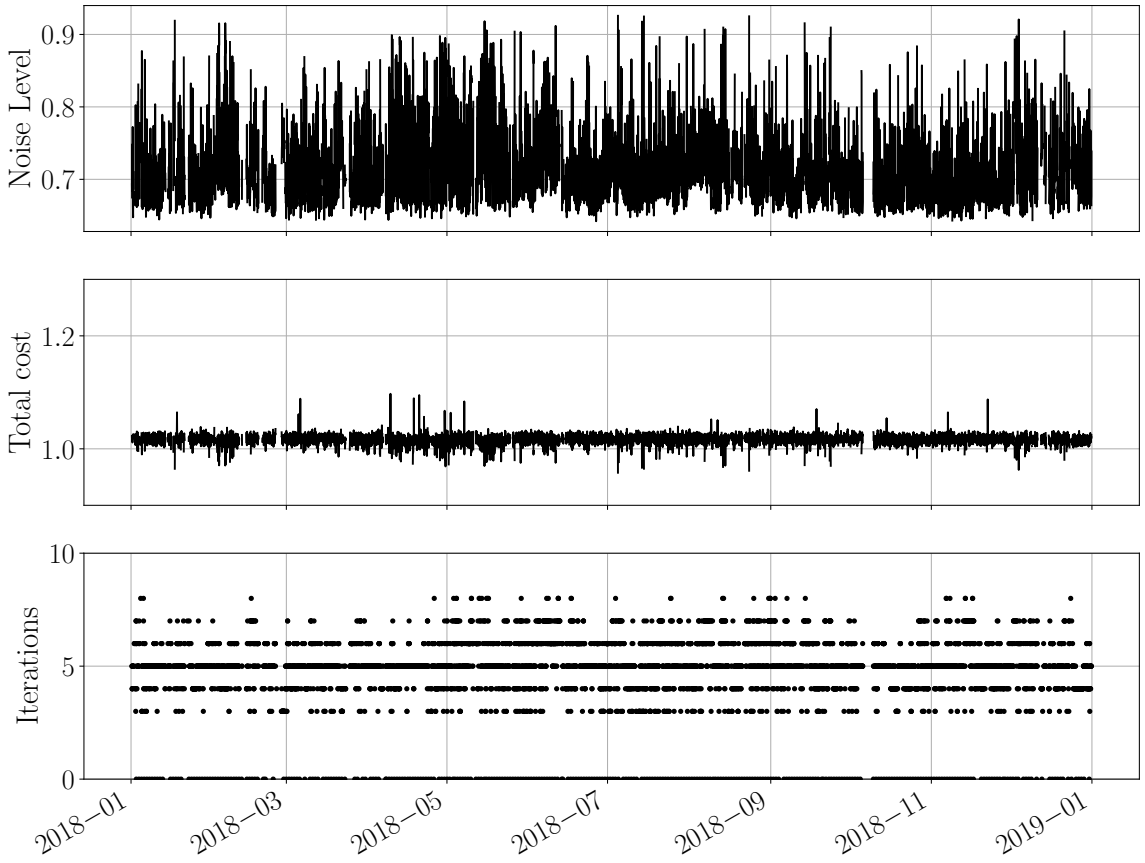


Figure 3.66: GROMOS, 2018

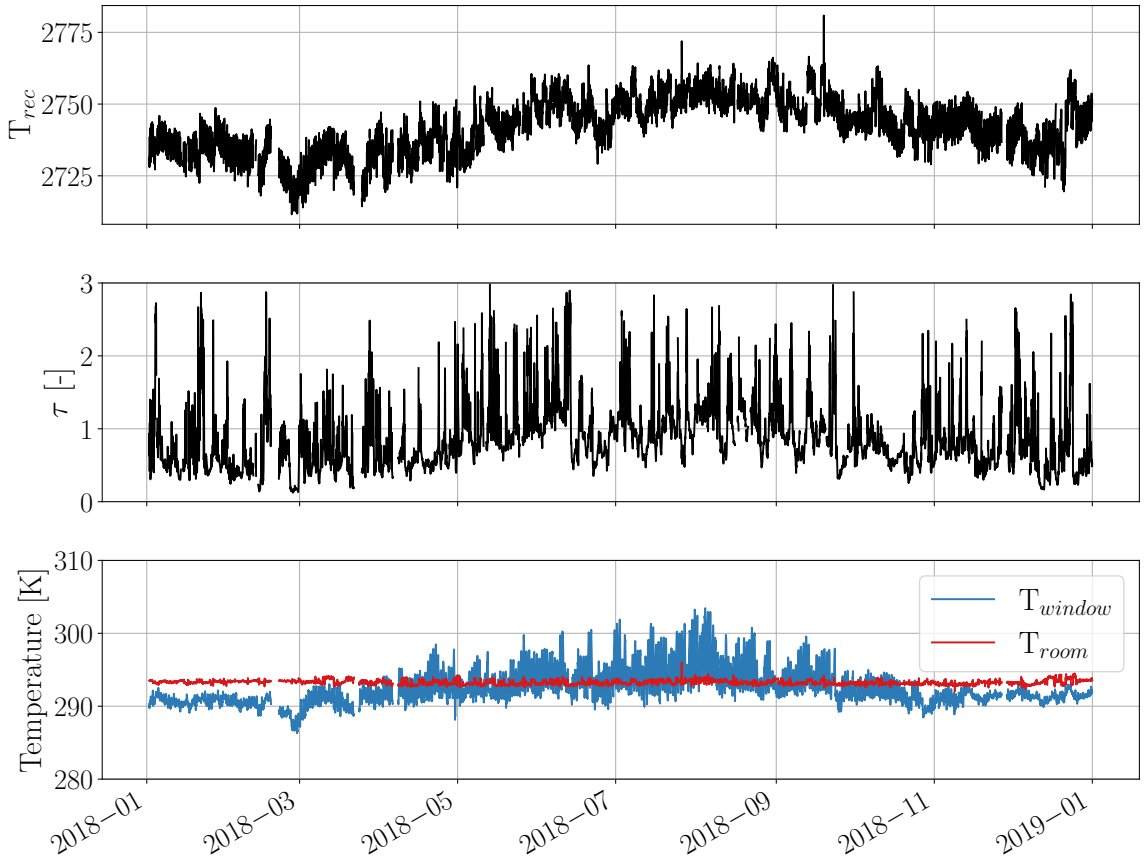


Figure 3.67: GROMOS, 2018

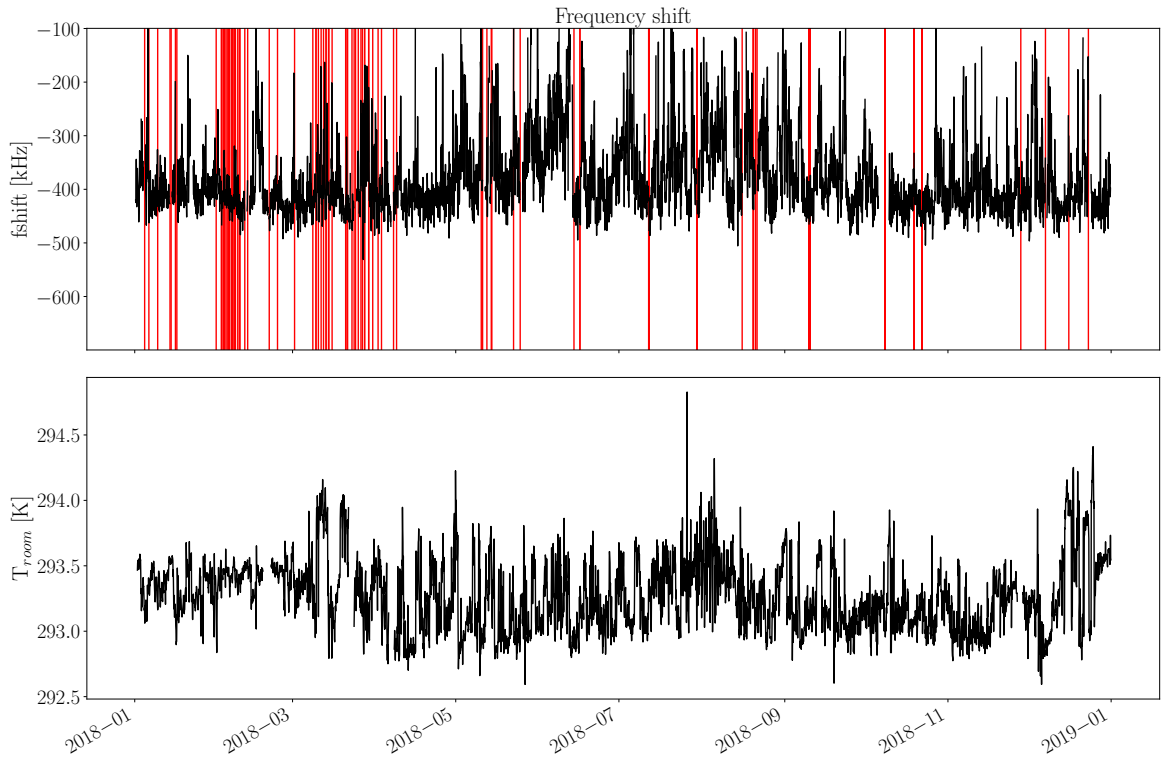


Figure 3.68: GROMOS, 2018

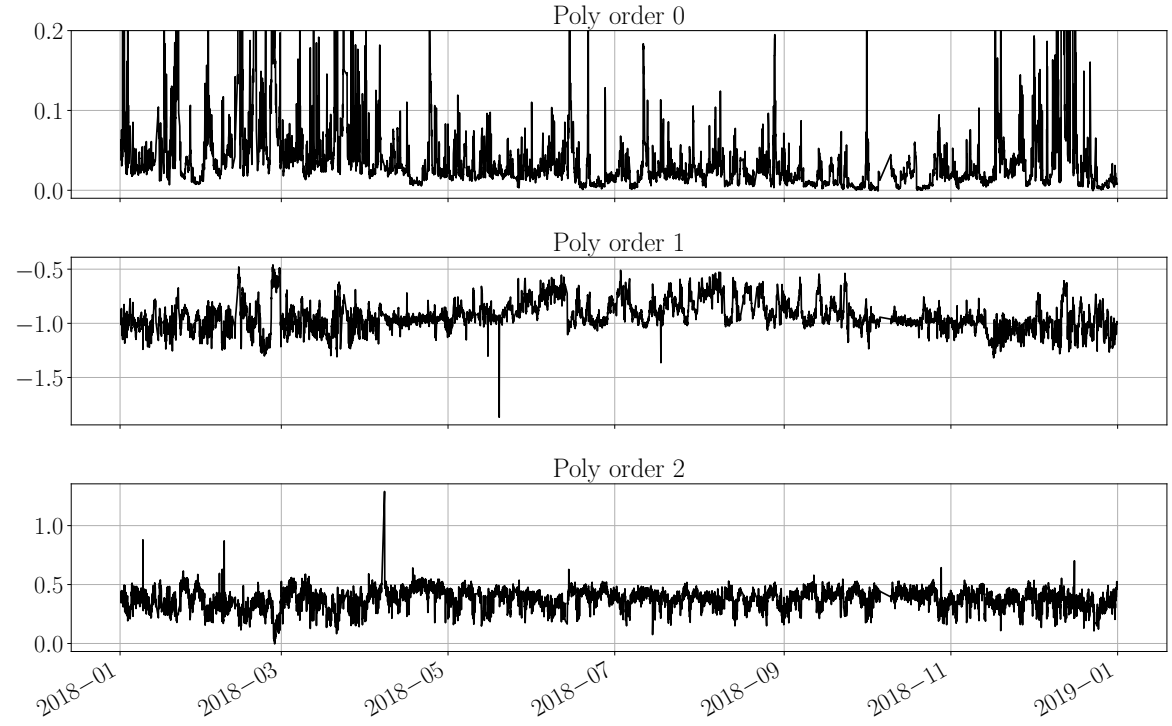


Figure 3.69: GROMOS, 2018

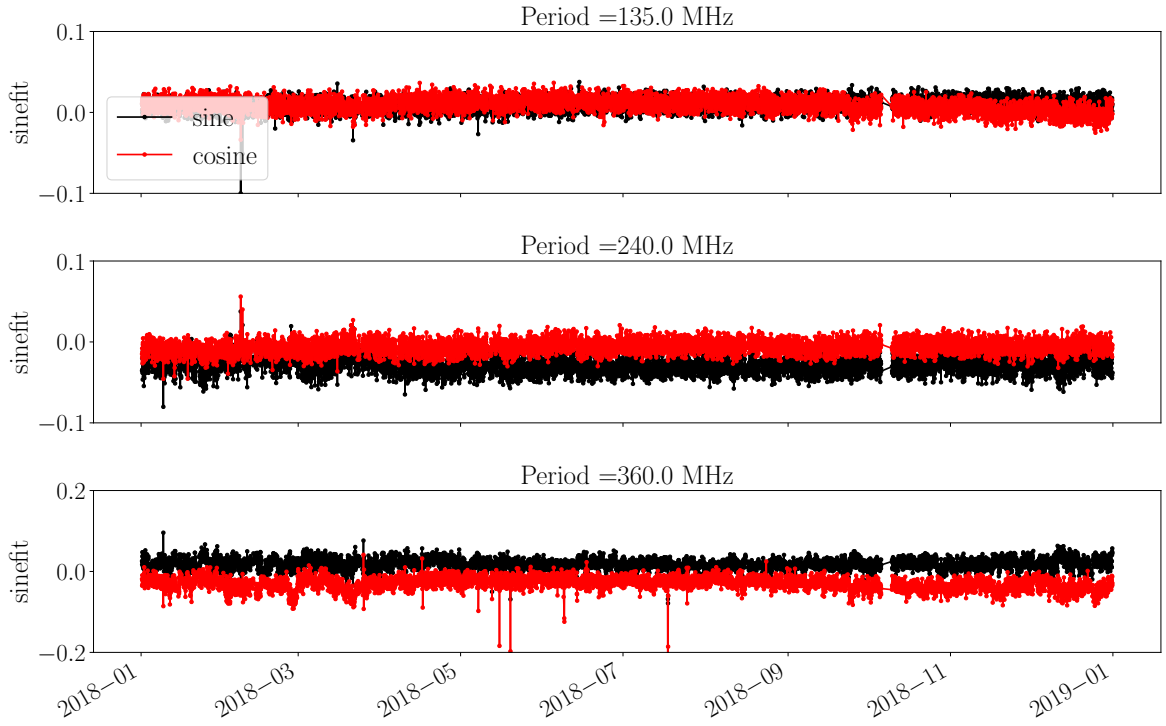


Figure 3.70: GROMOS, 2018

2019

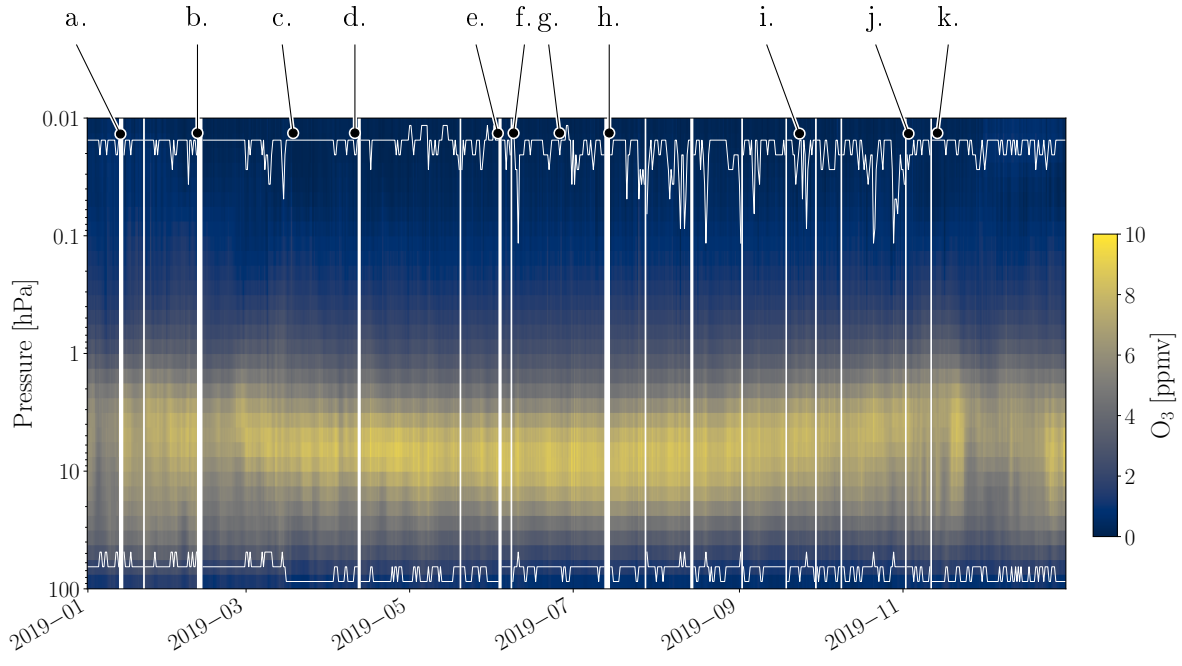


Figure 3.71: GROMOS, 2019

a. 07-08 and 13-14.01.19: problem with the cold load -> resulted in a jump of Trec on the 14.01 and it remained high until 10.02.

b. 11-12.02.19: end of the anomalous high Trec after cleaning of the cold load. This was likely due to incoming humid air in the cold load since the 14.01. On 12.02, the cold load observation angle was also changed. In the log, it says that the observation angle was 5° off for the period 14.01 until 12.03 (also on sky view !). It has been corrected for the retrievals only (the value in the level 1 is not correct) and only from 12.02 to 12.03 based on apriori differences and based on the fact that the cold load angle was touched on the 12.02.

c. 15.03.19: baseline change after all the cold load issue (Table 3.2)

d. 05.04.19: cold load issue

e. 03-04.06.19: problem during retrievals, maybe because meteo data are missing for half days ?

f. 08.06.19: LN2 empty -> dewar joint was broken -> repaired

g. 21.06.19: LN2 empty

h. 09 and 12-15.07.19: some mirrors problem on 09.07 which might have cause problems until the 15.07. No raw FFTS data on 14.07.

i. 20-25.09.19: spiky Trec until an empty LN2 event on 23.09. Also quite some lock errors during this period

j. 28.10 and 01-02.11.19: problem with the cold load resulting in jumps in frequency shift retrievals (Fig. 3.75)

k. 11-12.11.19: problem during calibration (probably from raw data)

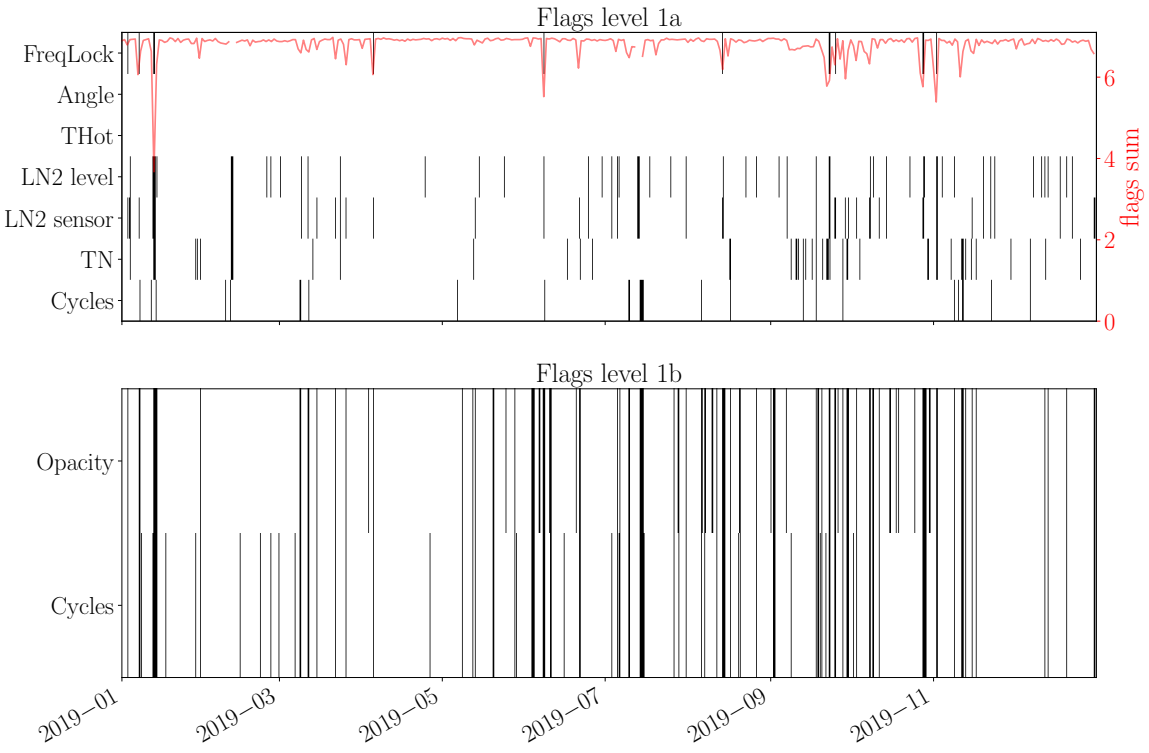


Figure 3.72: GROMOS flags, 2019

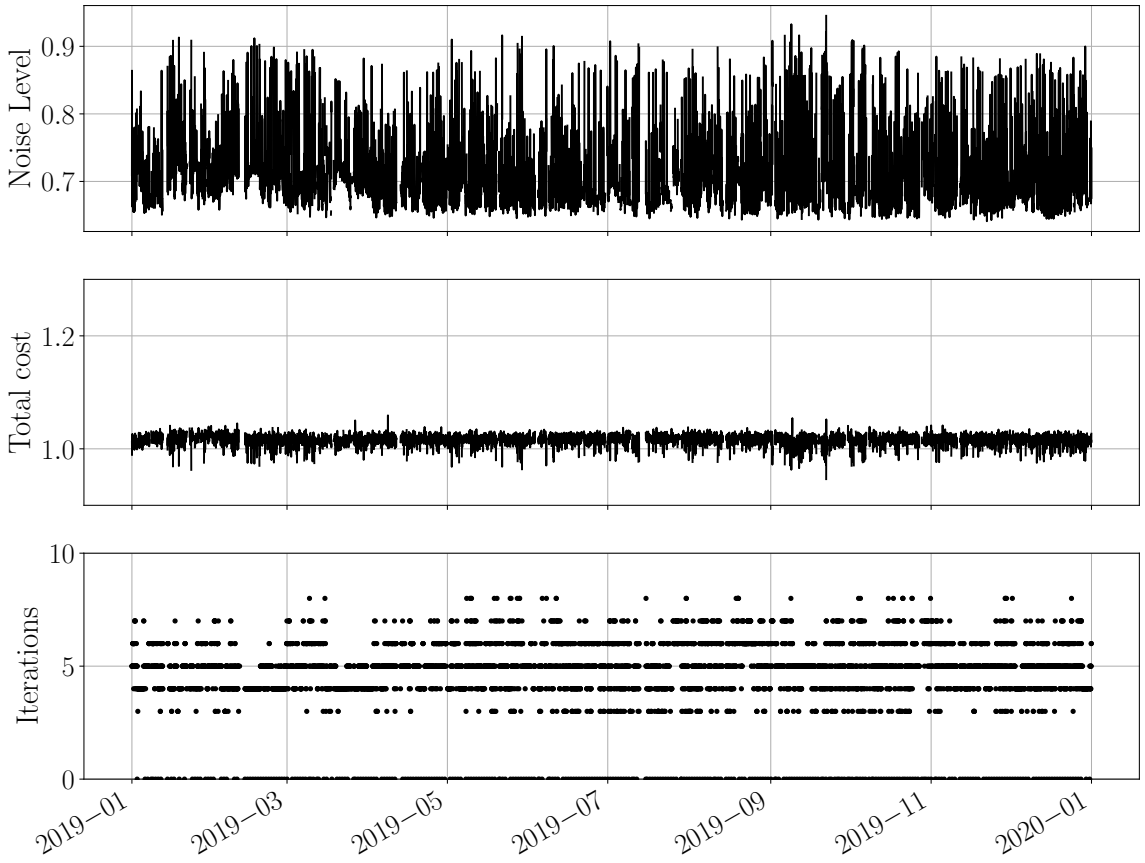


Figure 3.73: GROMOS, 2019

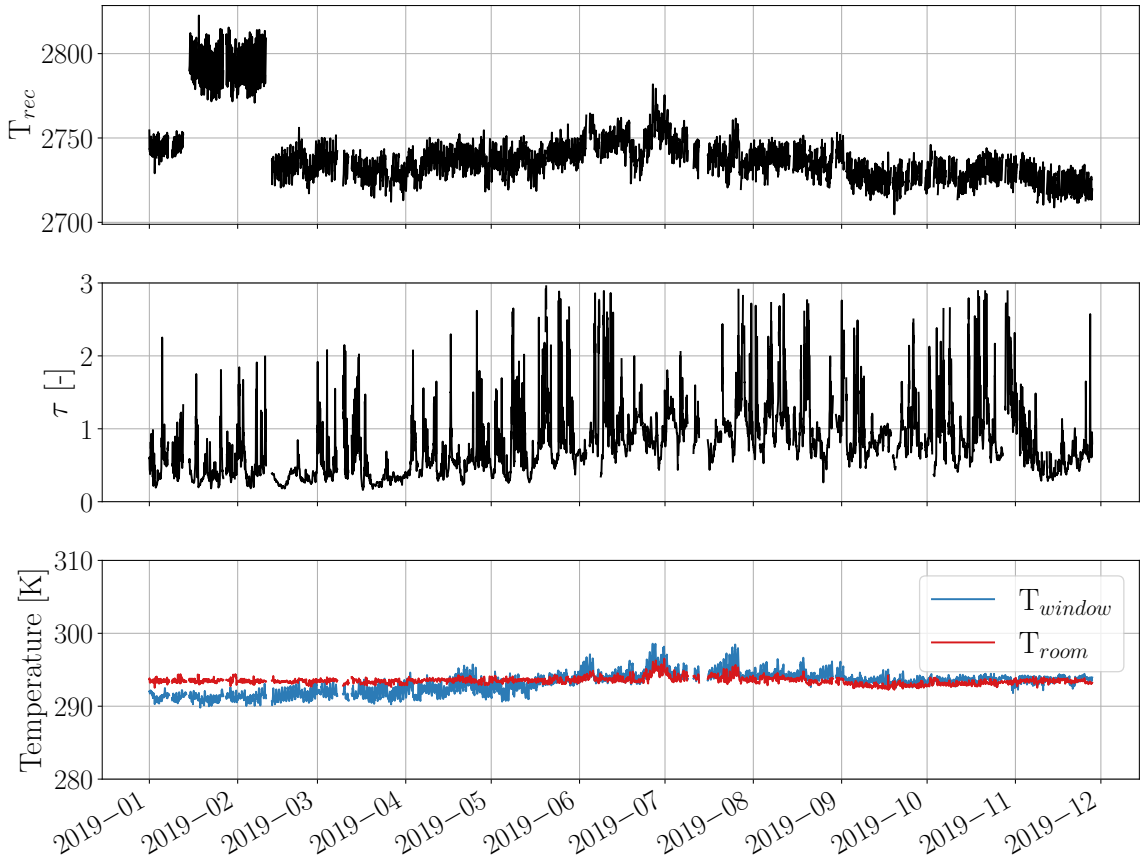


Figure 3.74: GROMOS, 2019

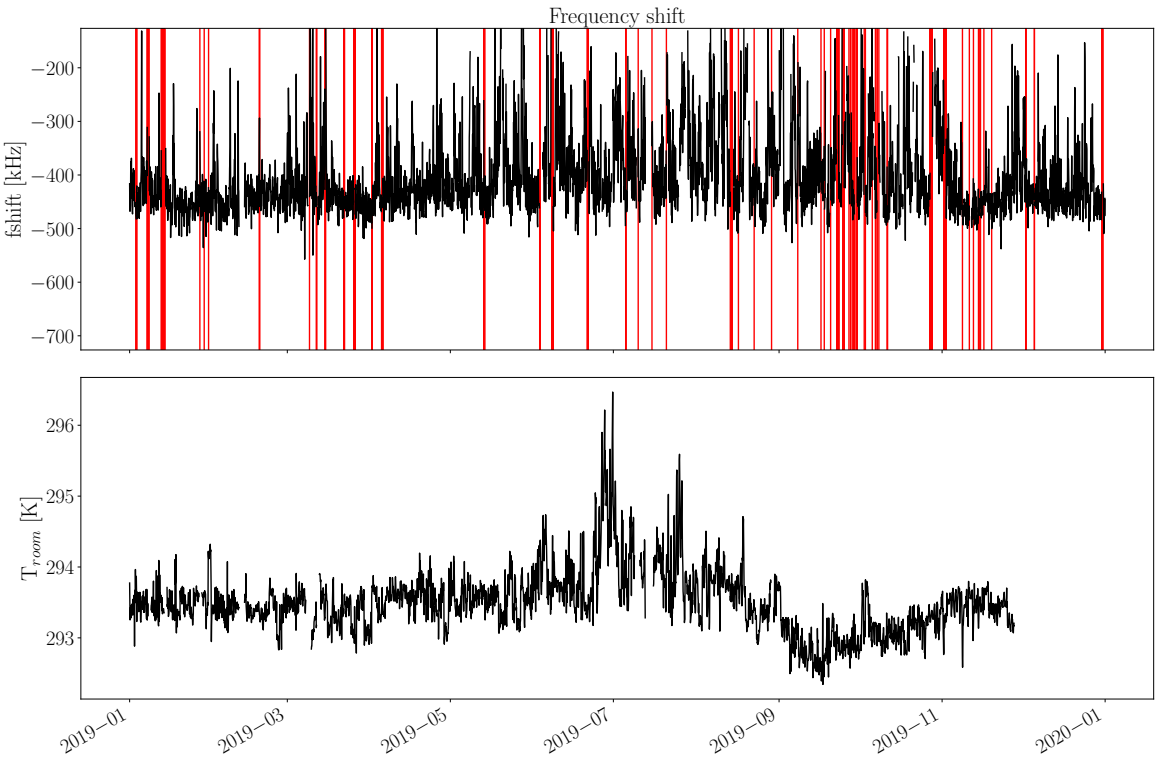


Figure 3.75: GROMOS, 2019

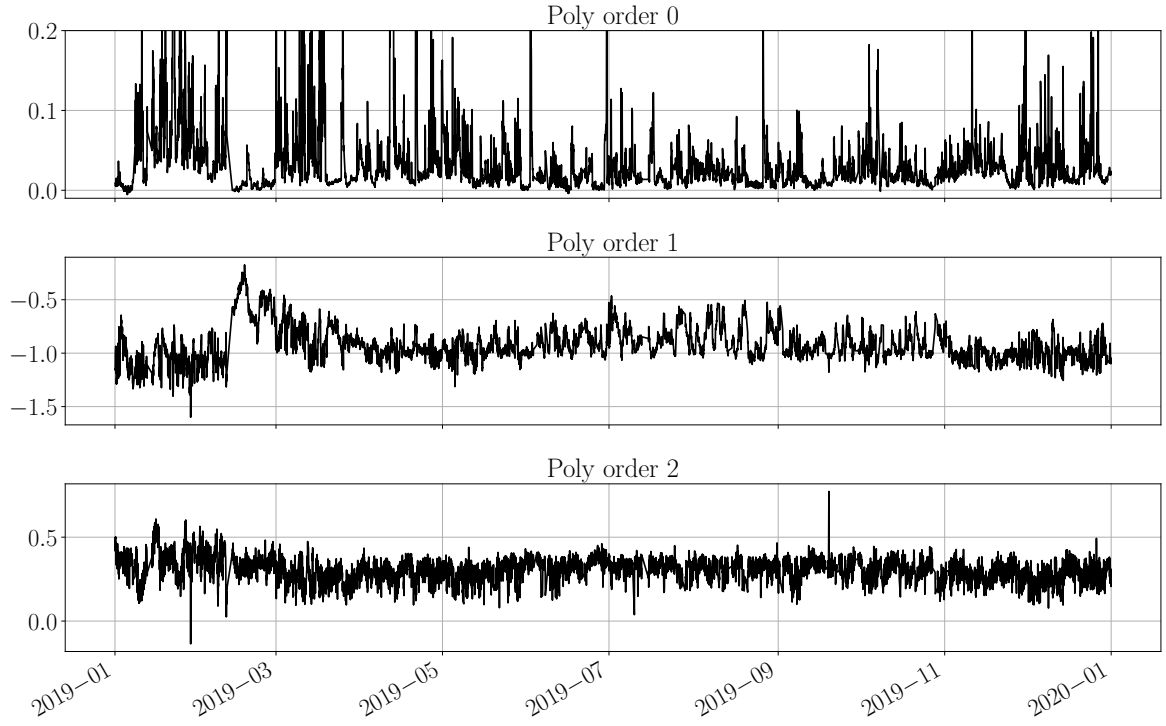


Figure 3.76: GROMOS, 2019

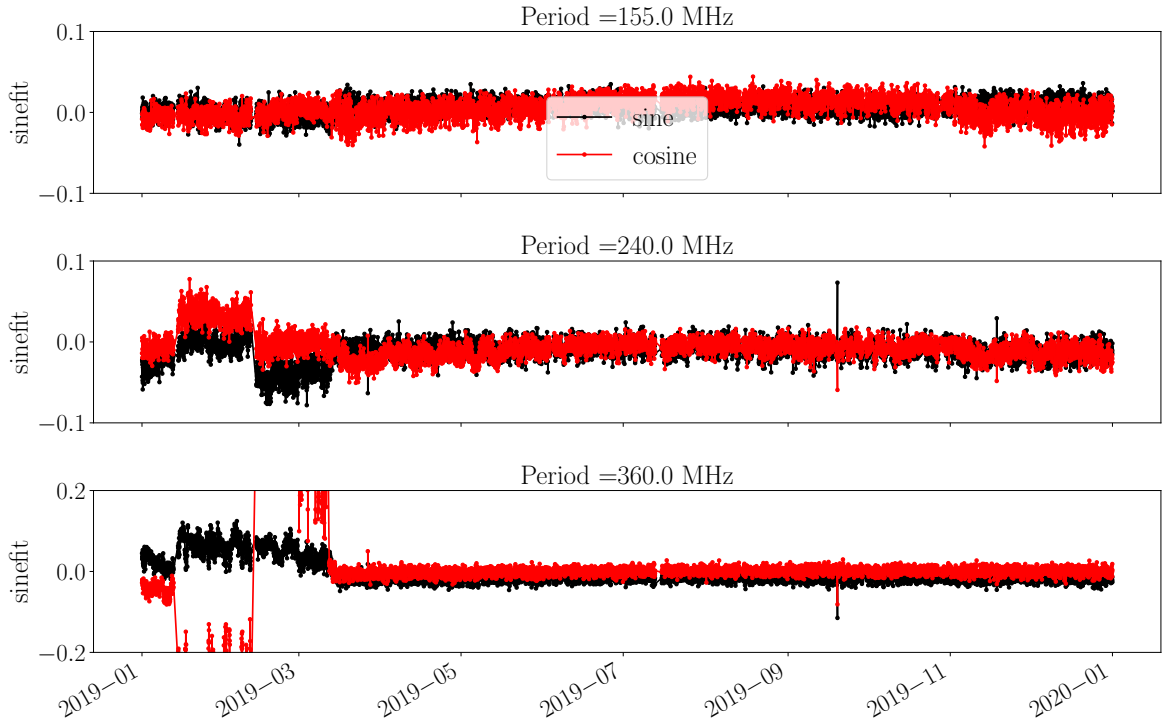


Figure 3.77: GROMOS, 2019

2020

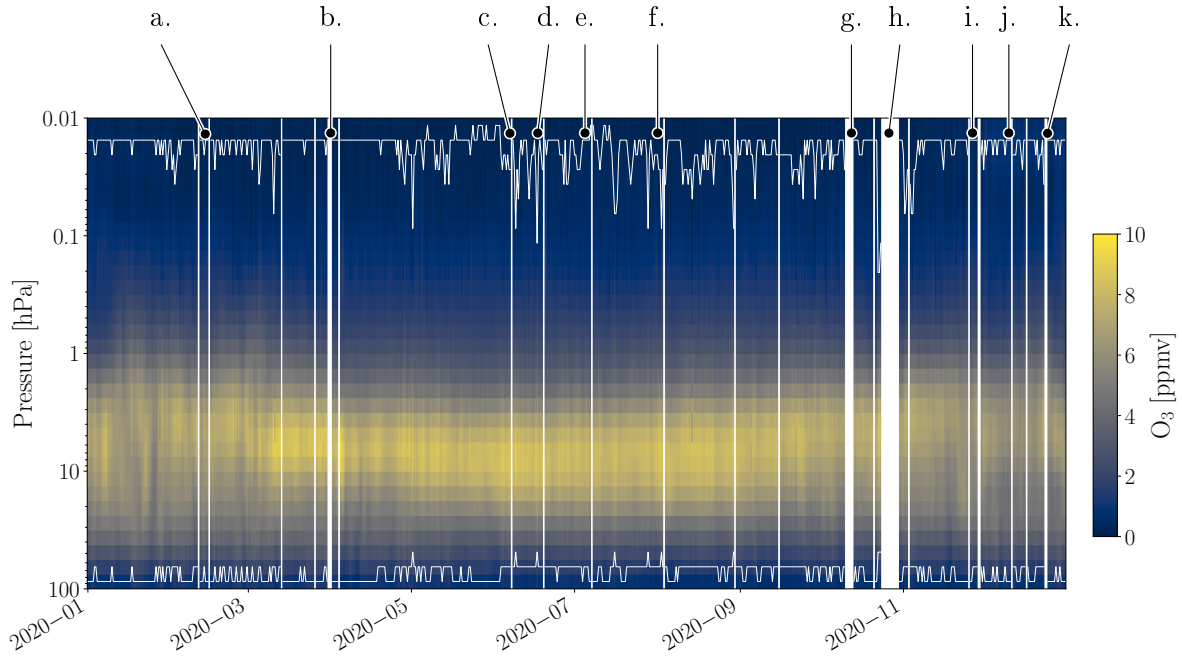


Figure 3.78: GROMOS, 2020

a. 11 and 15.02.20: problem during calibration (probably from raw data)

b. 26-28.03.20: problem with LN2 refills

c. 07-08.06.20: problem with LN2 refills

d. 19-20.06.20: problem with LN2 refills -> installation of new cold load refill controller

e. 07-09.07.20: problem with LN2 refills. Perturbations lasted until end of July with increasing Trec (Fig. 3.81).

f. 31.07.20: installation of a new cold load

g. 10-13.10.20: no FFTS raw data

h. 23-30.10.20: no FFTS raw data

i. 25.11.20: problem during calibration (probably from raw data) -> resulted in a spiky Trec until 01.12.

j. 11.12.20: problem during calibration (probably from raw data)

k. 24.12.20: problem during calibration (probably from raw data)

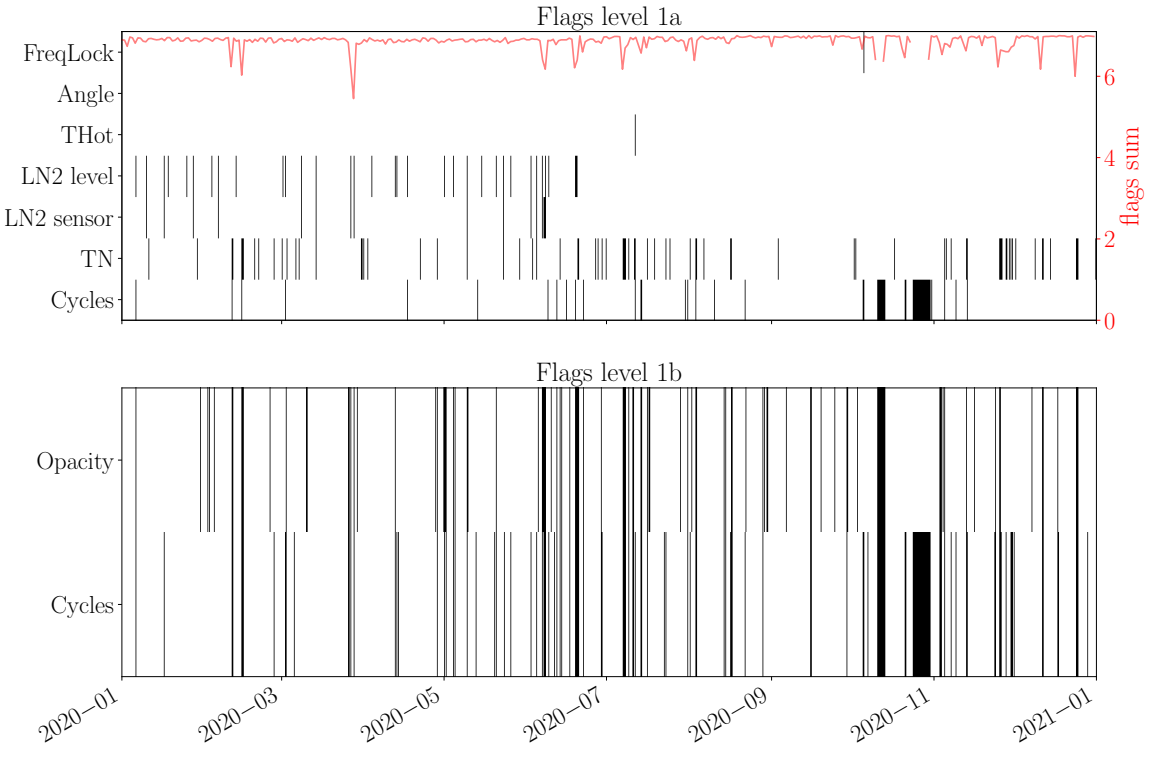


Figure 3.79: GROMOS flags, 2020

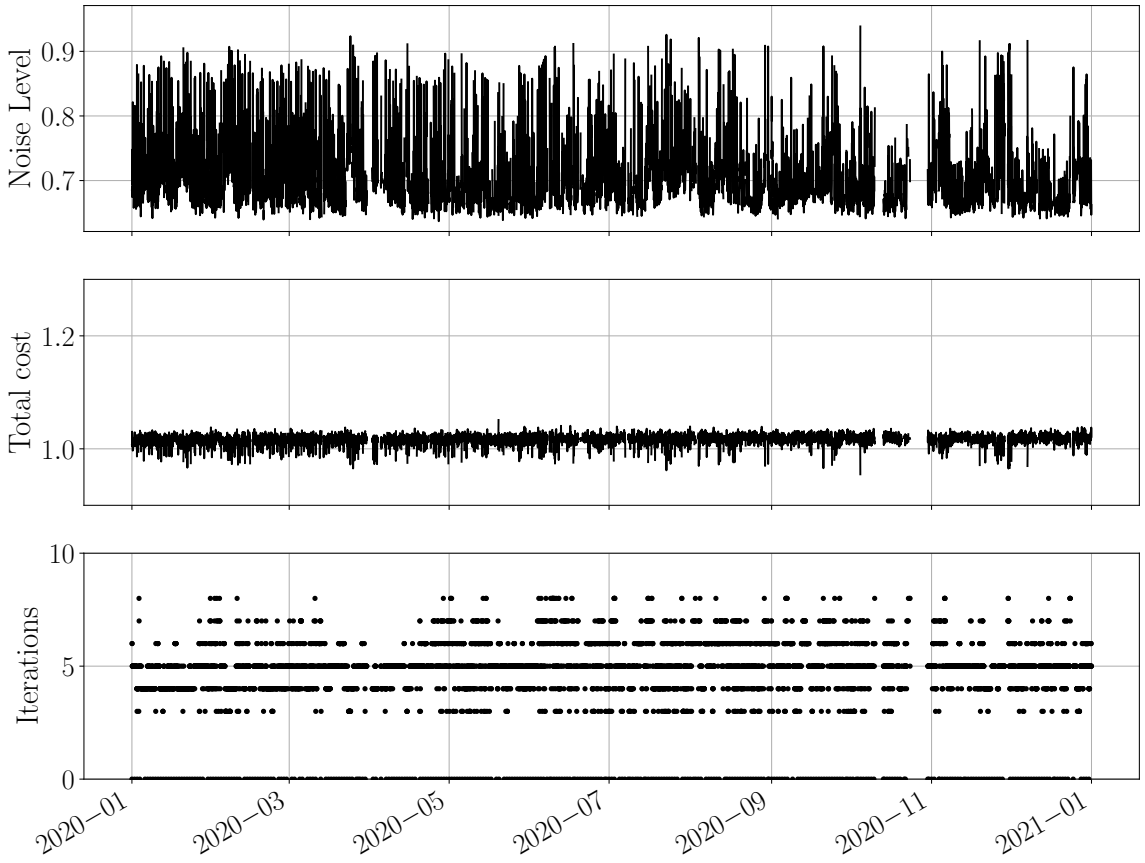


Figure 3.80: GROMOS, 2020

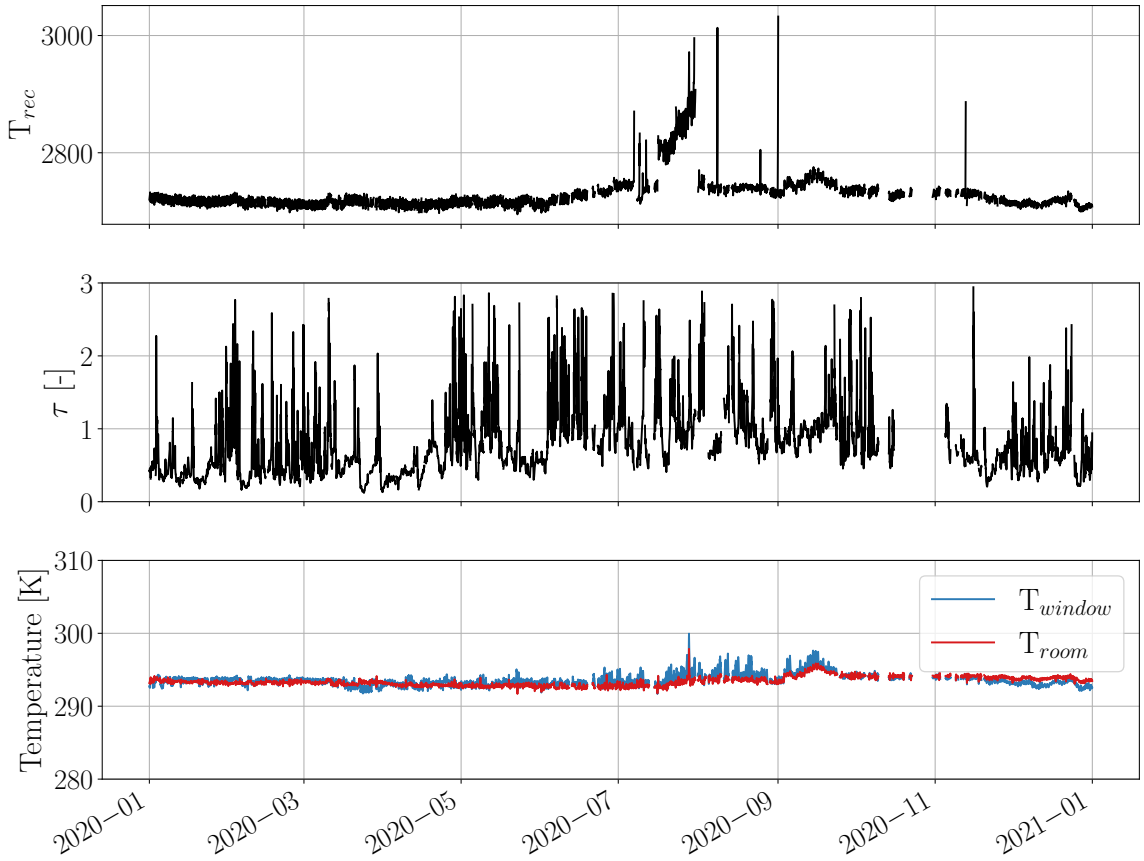


Figure 3.81: GROMOS, 2020

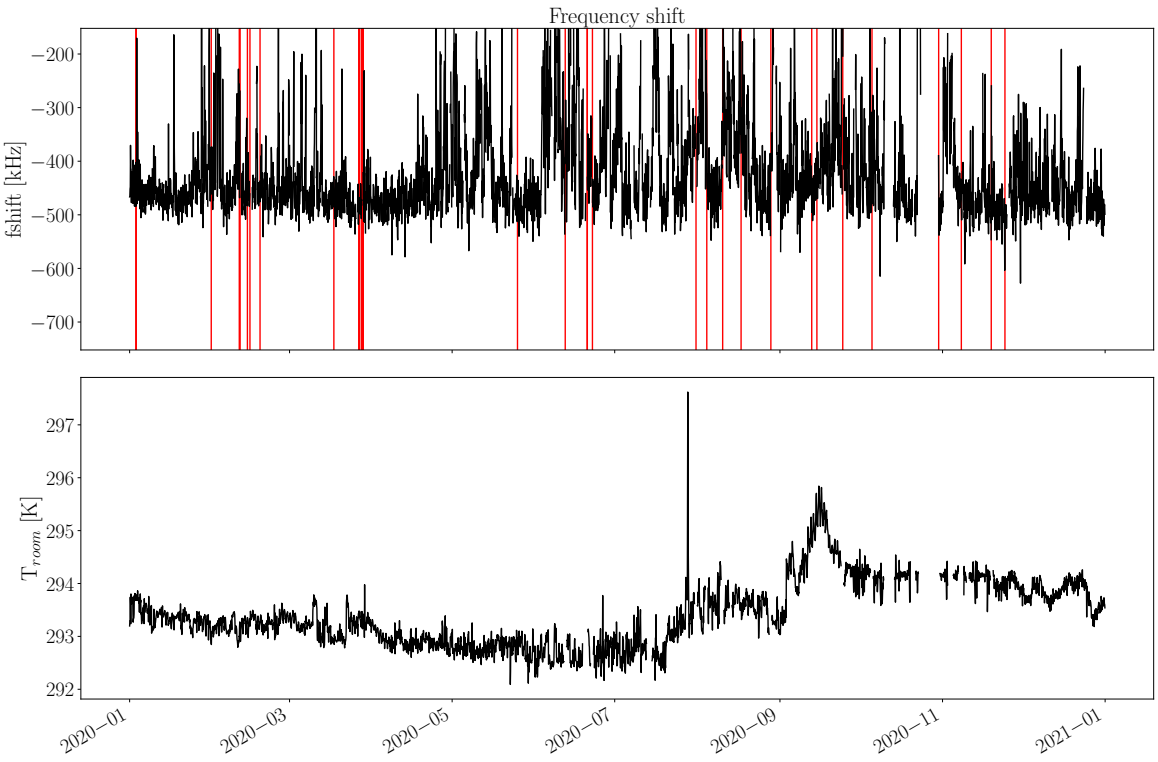


Figure 3.82: GROMOS, 2020

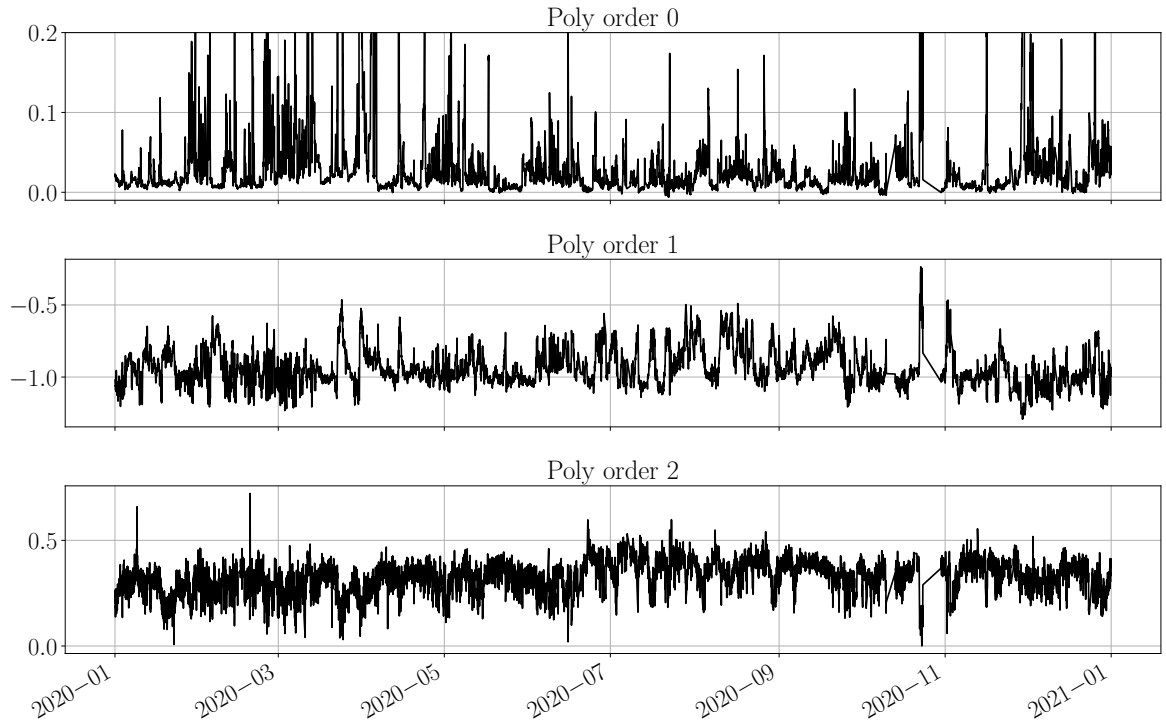


Figure 3.83: GROMOS, 2020

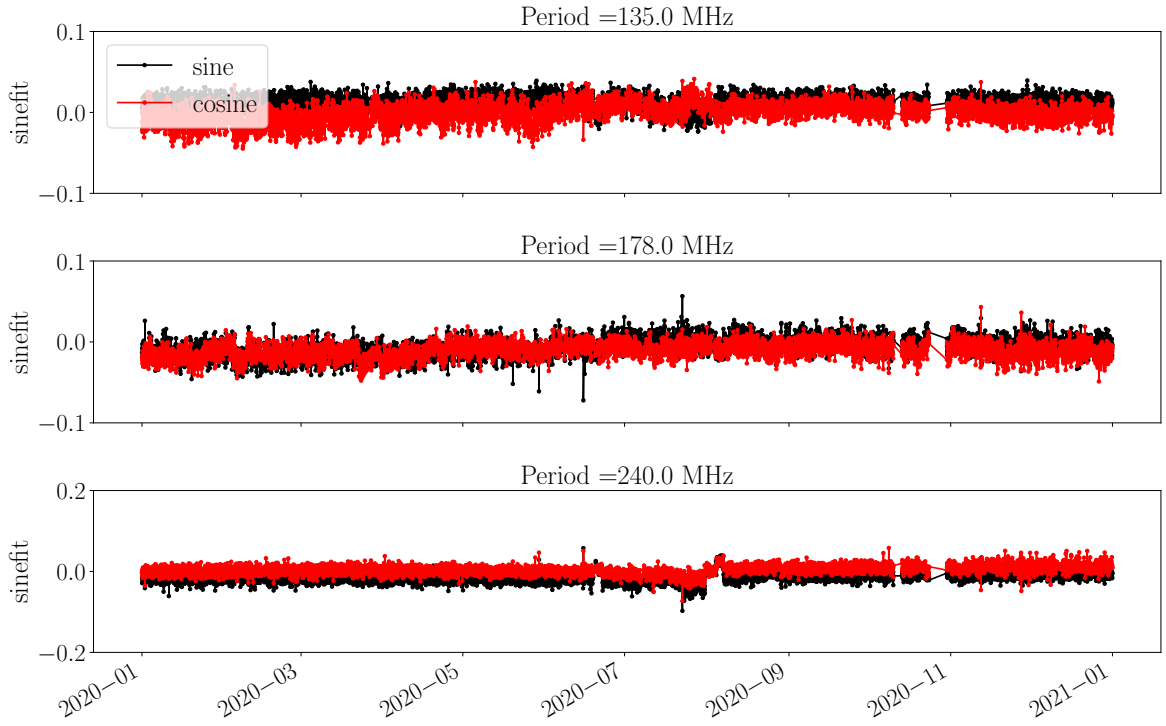


Figure 3.84: GROMOS, 2020

2021

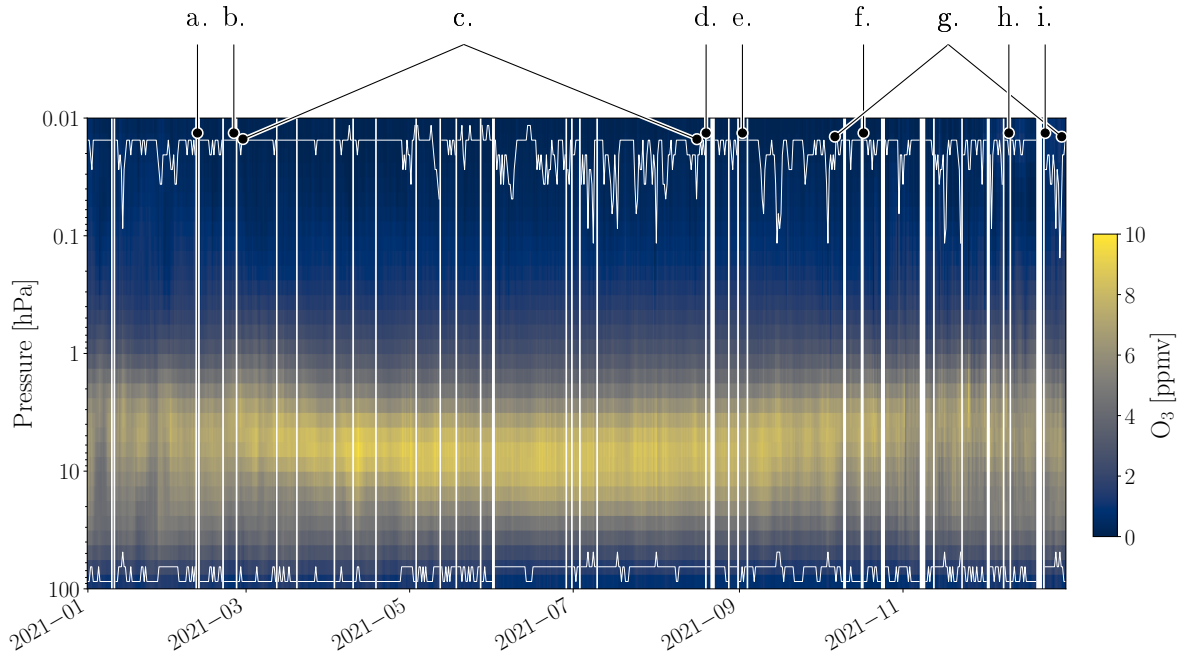


Figure 3.85: GROMOS, 2021

a. 10-11.02.21: problem during calibration (probably from raw data)

b. 16 and 25.02.21: problem during calibration (probably from raw data) on 16.02 which resulted in spiky Trec until 20.02. Similar calibration problem on 25.02

c. 12.03, 18.04, 12.05, 18.05 01.06, 28.06, 30.06, 19.08.21: problem during calibration (probably from raw data). Always same issue and seems to always stop at midnight UTC.

d. 15-16.08.21 and 21-23.08.21: empty LN2

e. 28.08, 31.08 and 04.09.21: missing meteo data on part of the day.

f. 09-11.10.21 and 24-25.10.21: empty LN2

g. October to December 21: impact of 5G network becomes problematic. The flagging seems to work but results in many missing data. During this time also, some interruptions to do RFI protection test.

h. 17.12.21: LNA replaced with temporary RFI shielding -> jump in Trec and counts

i. 23-28.12.21: old LNA removed lock off -> no retrieval and another small jump in Trec and counts

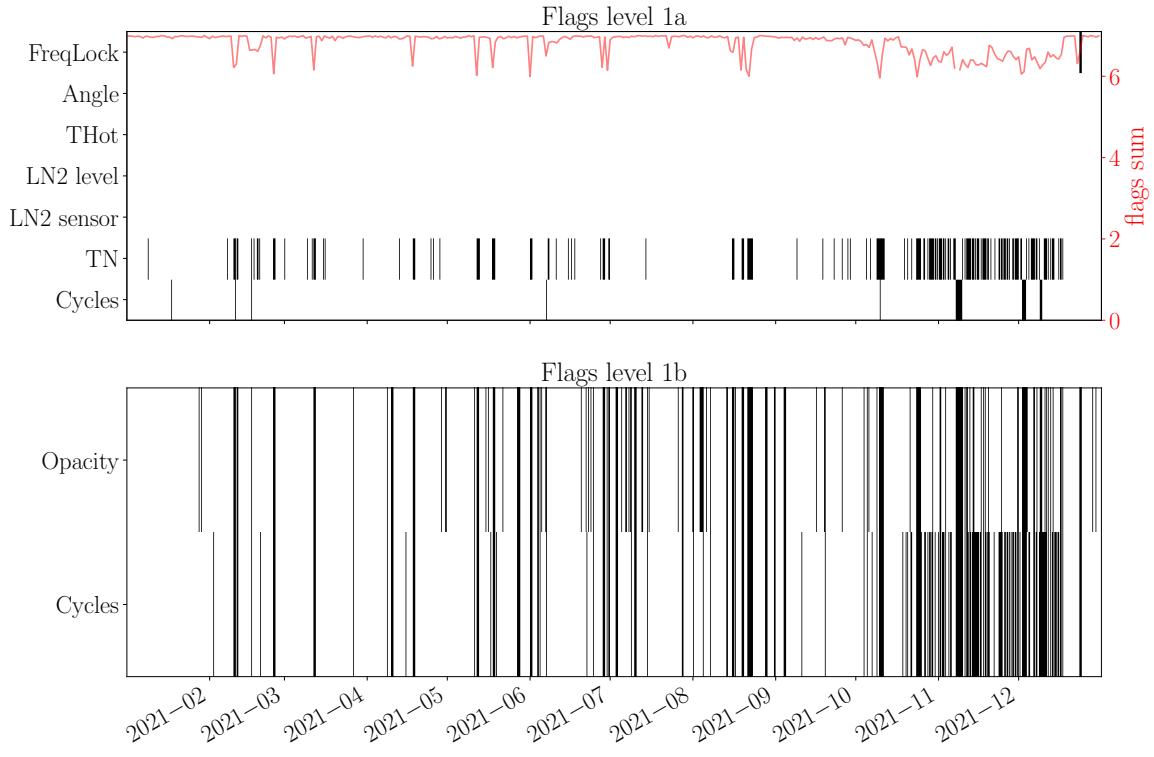


Figure 3.86: GROMOS flags, 2021

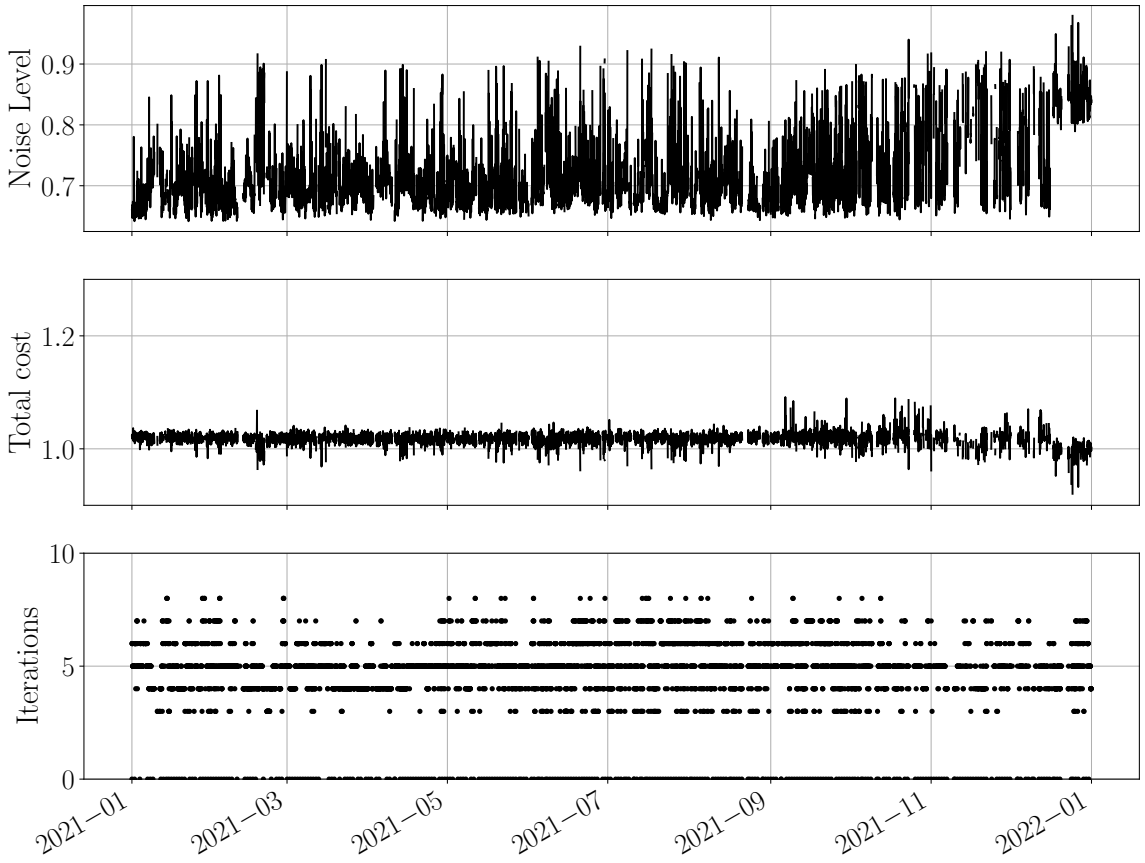


Figure 3.87: GROMOS, 2021

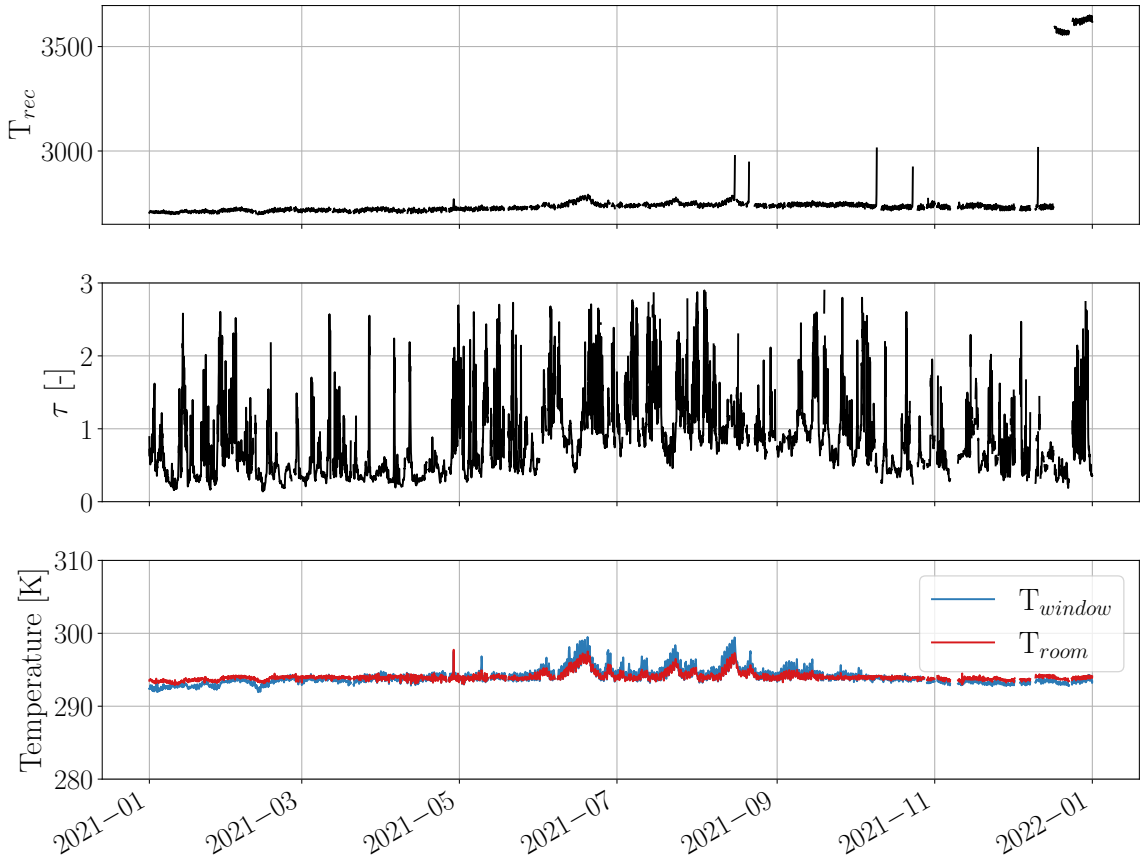


Figure 3.88: GROMOS, 2021

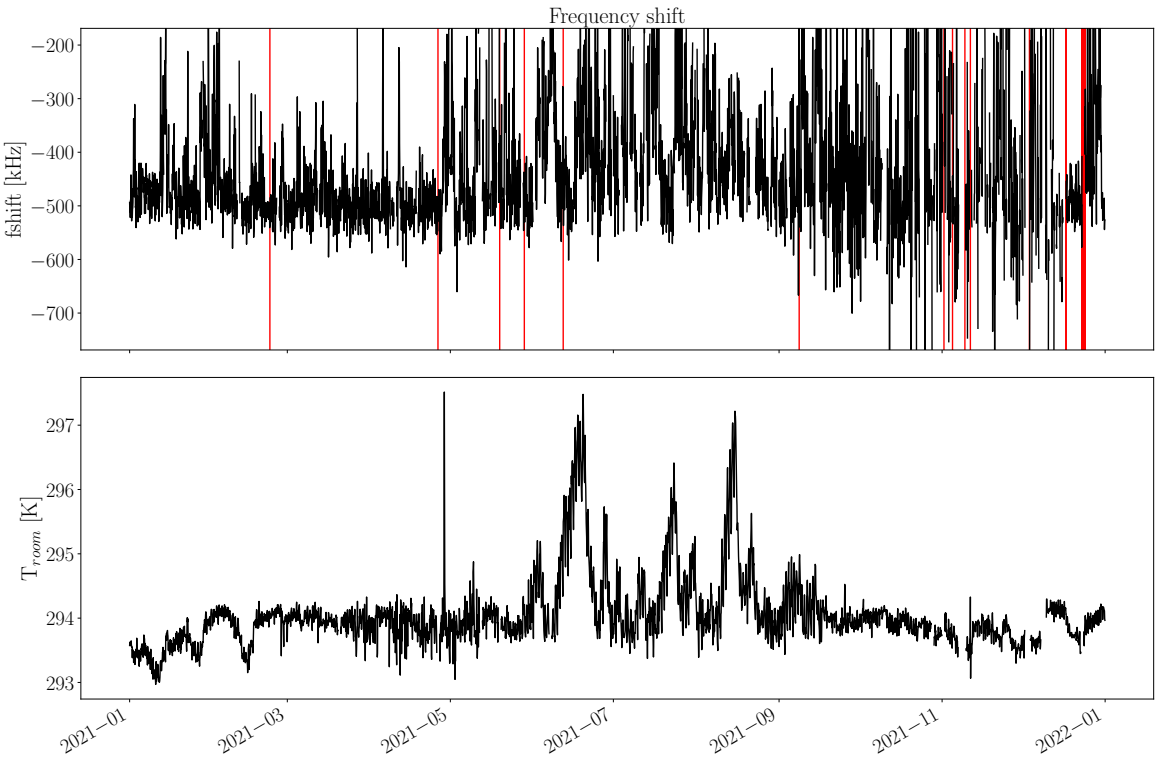


Figure 3.89: GROMOS, 2021

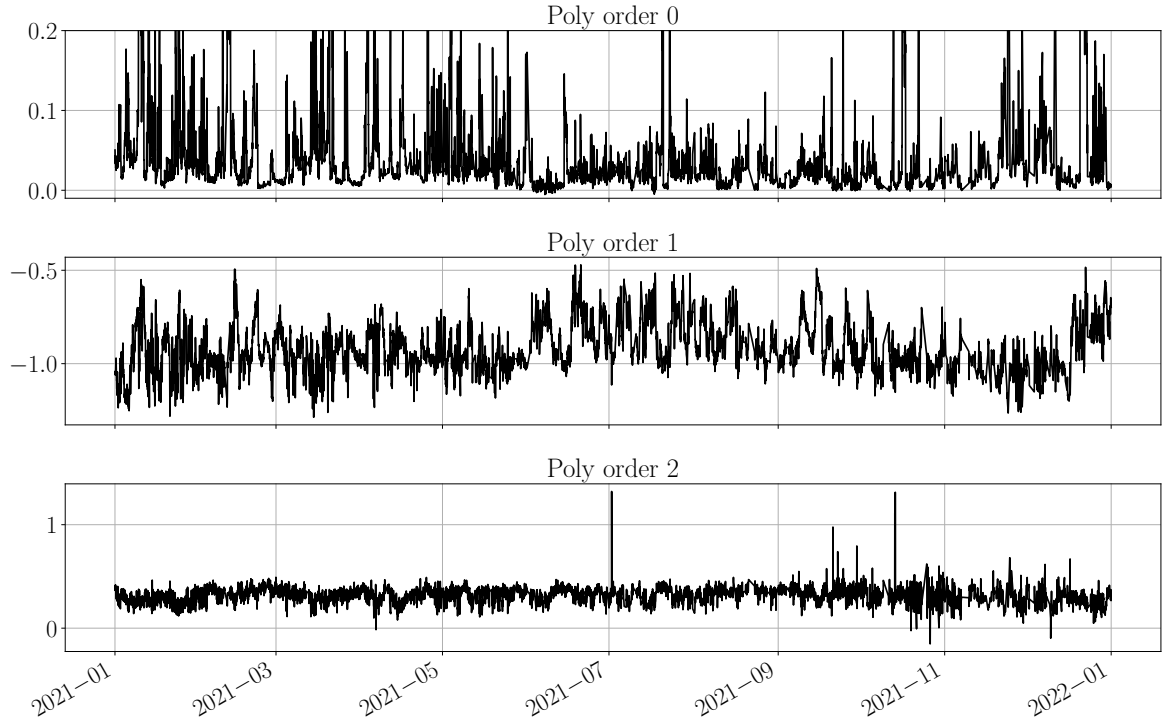


Figure 3.90: GROMOS, 2021

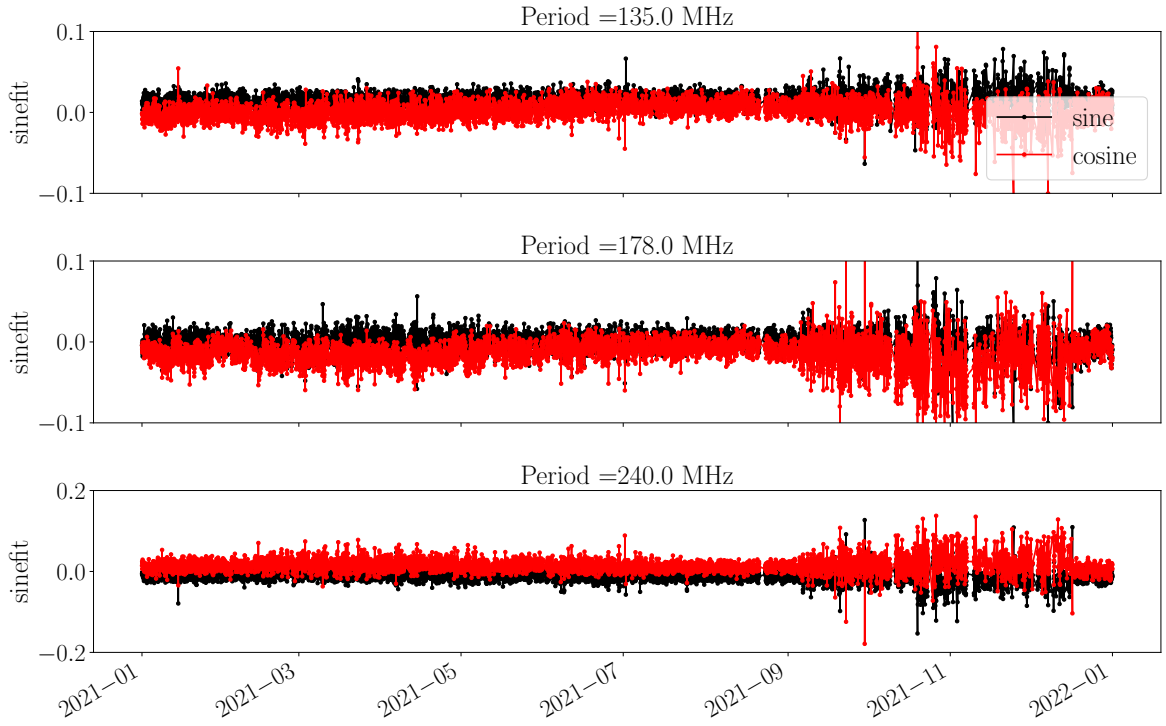


Figure 3.91: GROMOS, 2021

Chapter 4

SOMORA

In this chapter, we show a detailed, year-to-year time series description of the Stratospheric Ozone MOnitoring RAdiometer (SOMORA). If you want to use the GROMOS time series, please contact the PI listed in Table 4.1.

Table 4.1: GROMOS information

	info
Operated by	Federal Office of Meteorology and Climatology MeteoSwiss, Payerne, Switzerland
Principal investigator (PI)	Eliane Maillard Barras (`eliane.maillard@meteoswiss.ch`)
Data collector	Eric Sauvageat (`eric.sauvageat@unibe.ch`)

Table 4.2: Sinusoidal baselines SOMORA

Time	**Periods [MHz]**
22.09.2009 –> 01.10.2019	110, 216, 310
01.10.2019 –> 15.04.2020	140, 186, 347, 888
15.04.2020 –> 30.09.2020	92, 110, 364, 400
30.09.2020 –> 31.01.2021	96, 110, 186, 347, 382

2009

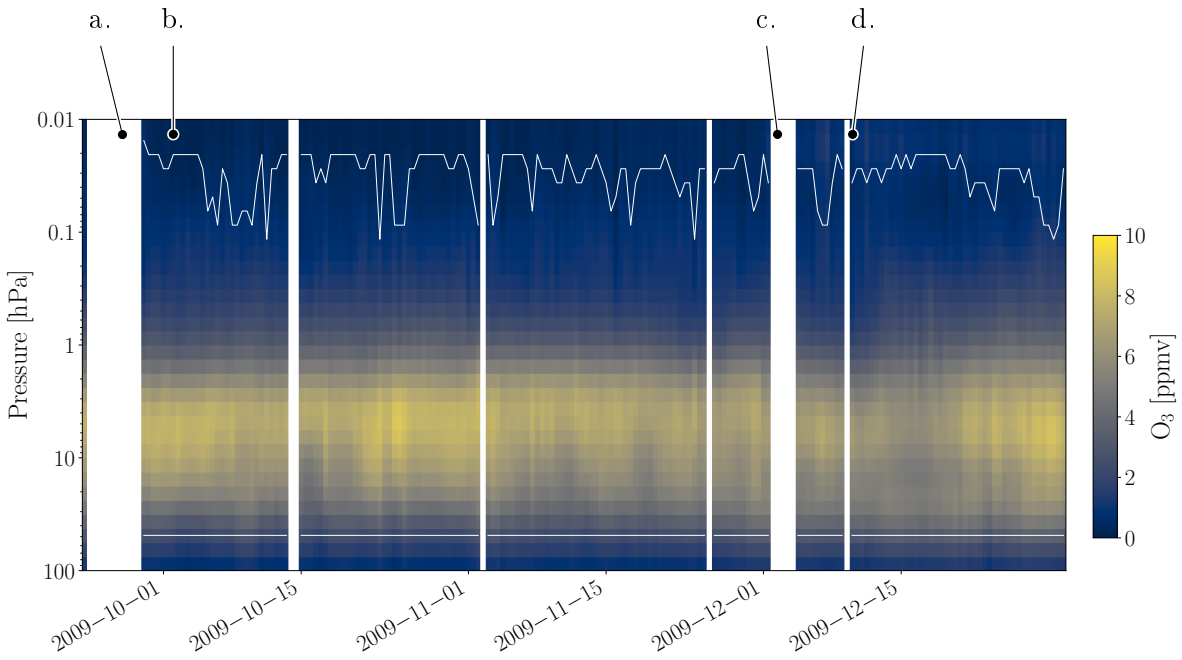


Figure 4.1: SOMORA, 2009

a. 24-28.09.09: no FFTS raw files

b. 01-03.10.09: problem with the retrievals -> high costs

c. 02-03.12.09: new software version on 02.12 and no FFTS raw files on 03.12.

d. 09.12.09: LN2 empty because of valve problem.

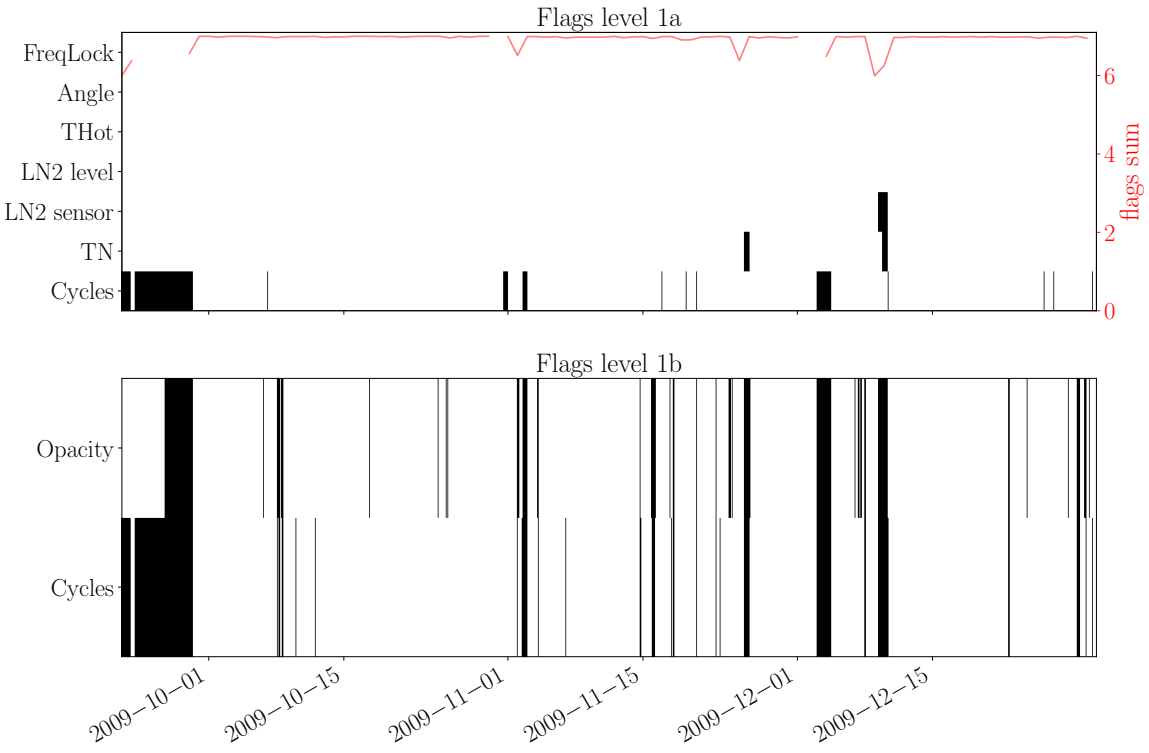


Figure 4.2: SOMORA, 2009

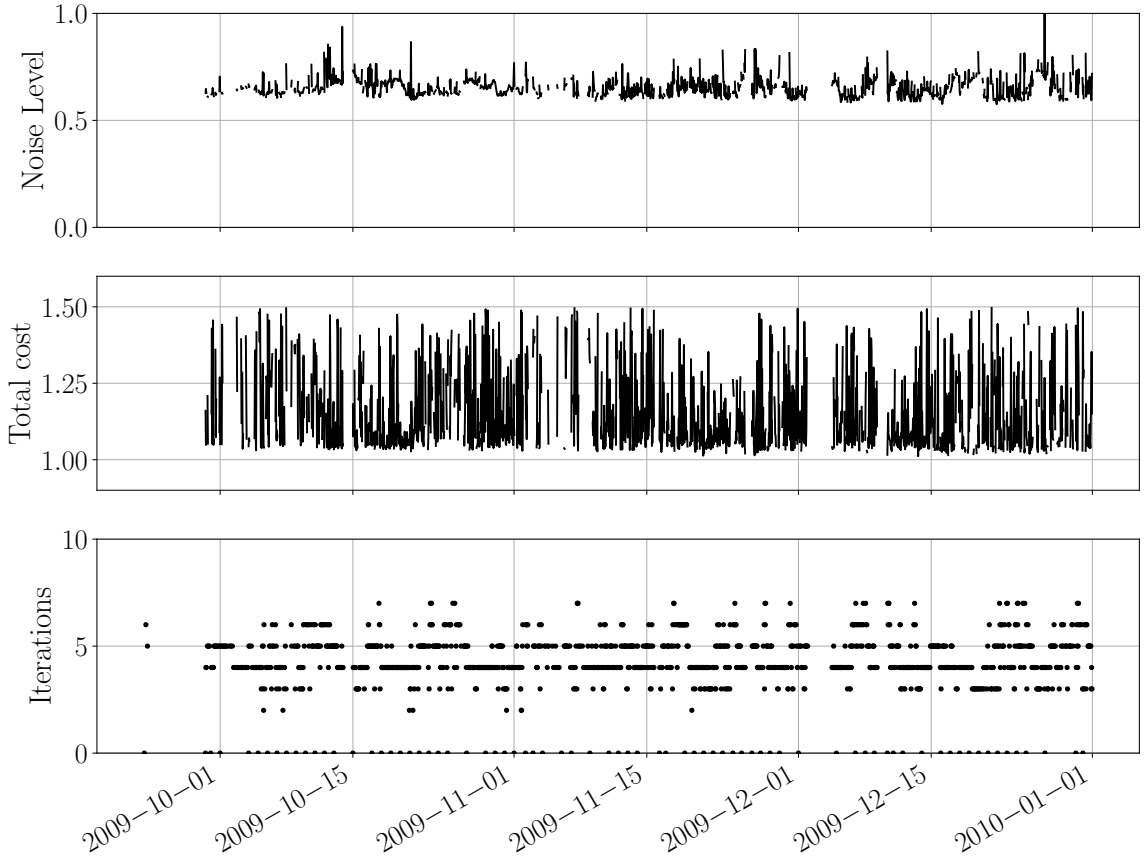


Figure 4.3: SOMORA, 2009

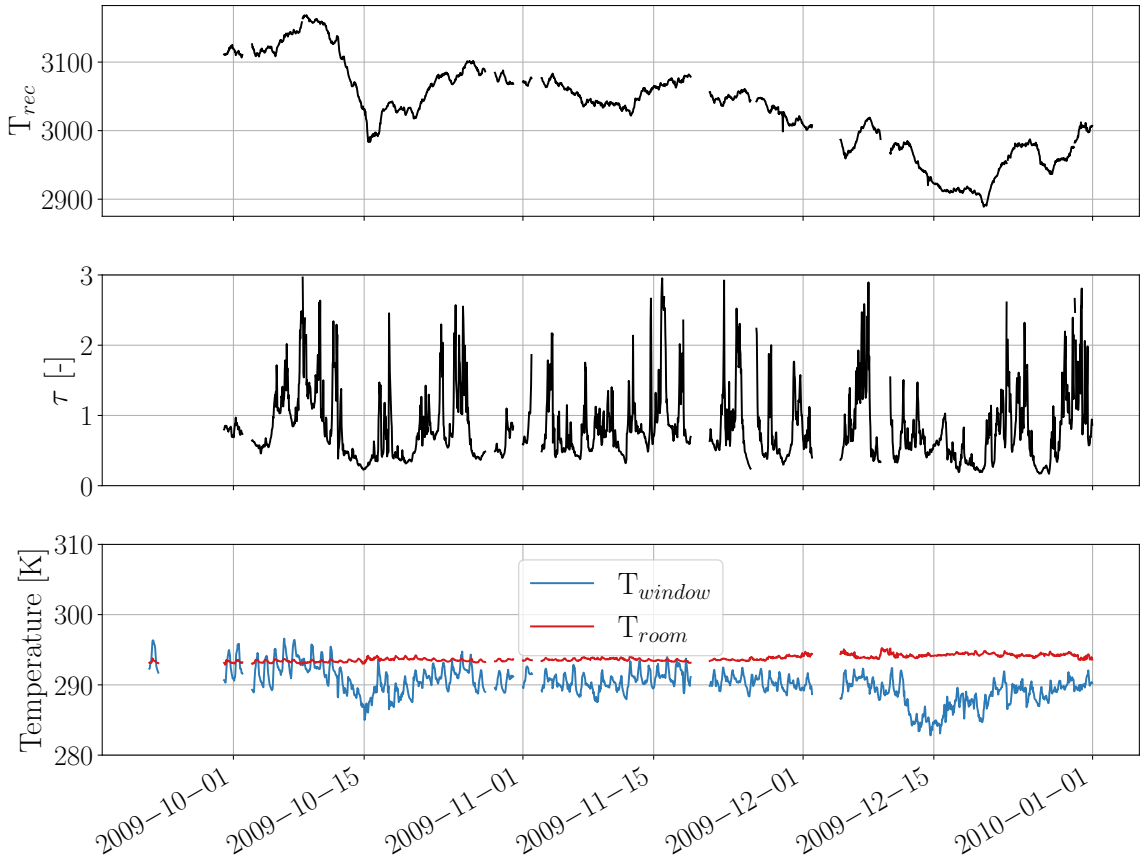


Figure 4.4: SOMORA, 2009

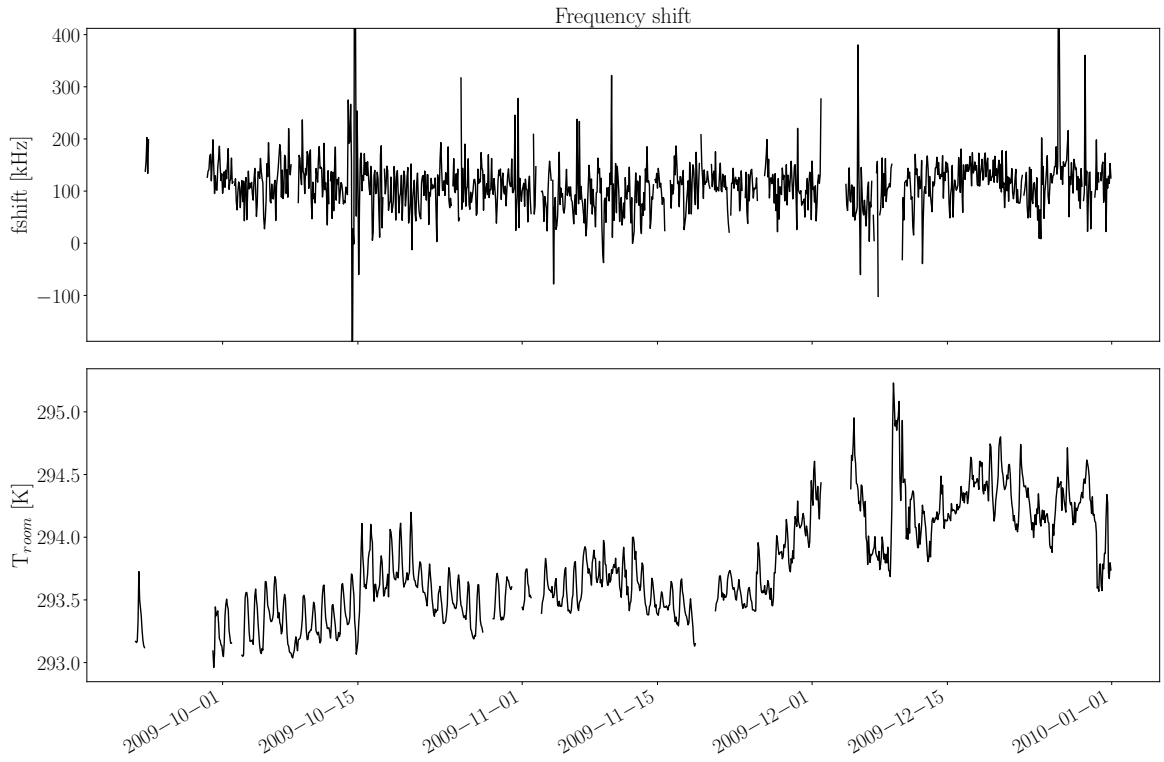


Figure 4.5: SOMORA, 2009

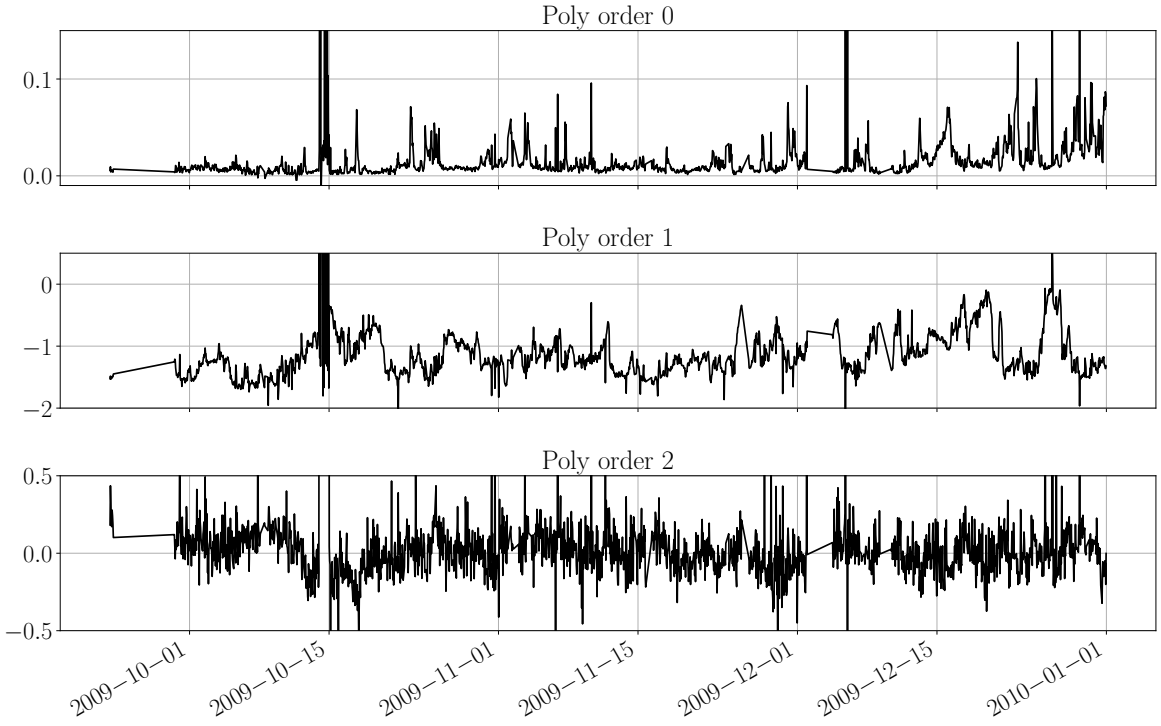


Figure 4.6: SOMORA, 2009

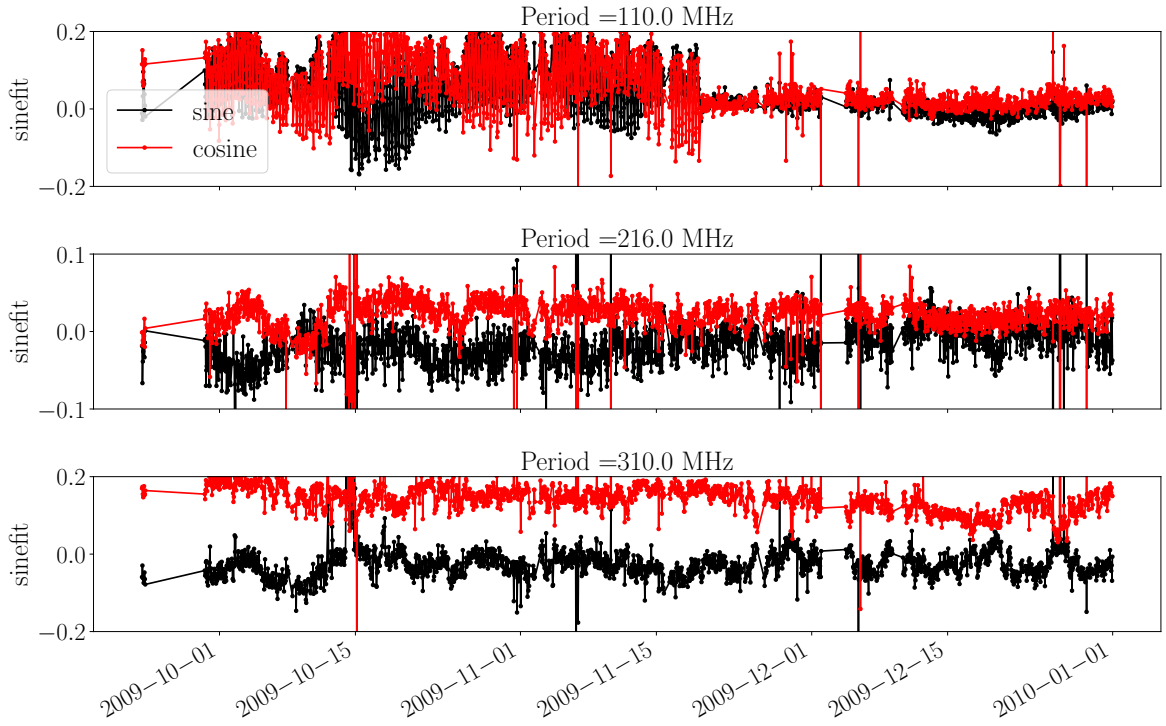


Figure 4.7: SOMORA, 2009

2010

Higher costs associated with bad channels that were not identified at the calibration level.

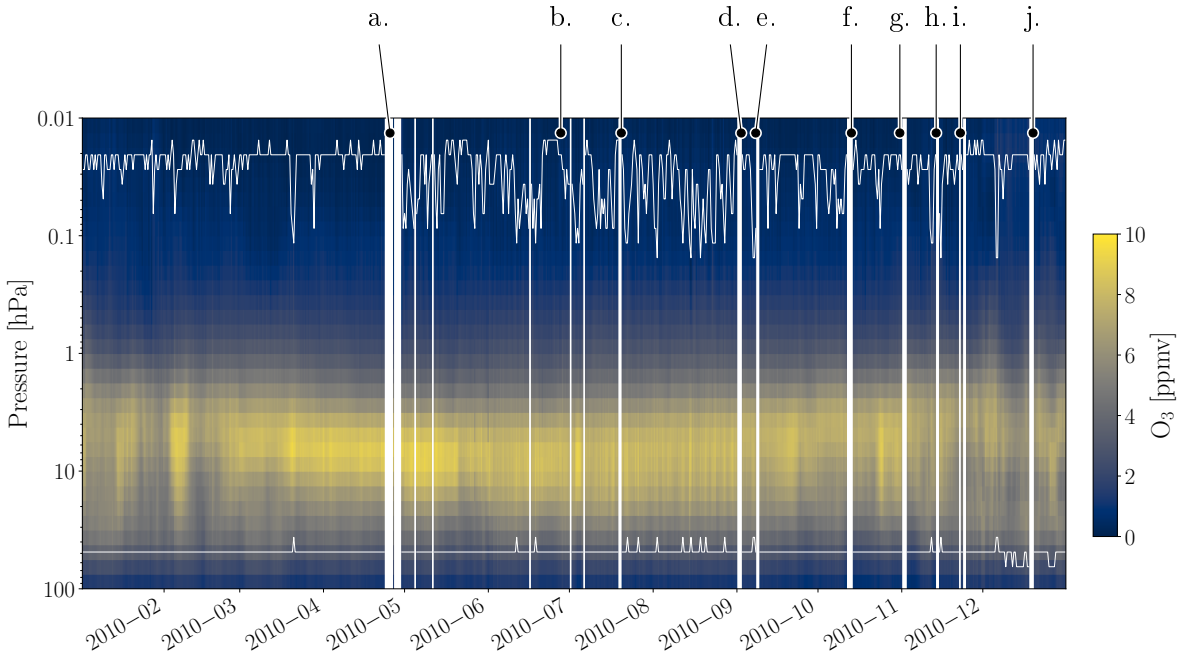


Figure 4.8: SOMORA, 2010

a. 24-30.04.10: AOS down on 24.04 and mirror problems. Also some hot load problems which were repaired on 30.04.

b. 01.07.10: measurement interruptions (unknown reasons)

c. 19-20.07.10: problem with LN2 valve

d. 01-03.09.10: measurement interruptions after a software crash. Probably following a Windows update of 31.08.

e. 08-09.09.10: measurement interruptions (unknown reasons)

f. 12-14.10.10: multiple lock errors and some file conflicts. This date also corresponds to big changes in polyfit retrievals and cost values.

g. 01-02.11.10: IT maintenance and updates

h. 14-15.11.10: problem with the acquisition software and water found on the cold load

i. 24.11.10: multiple lock errors. Some software modification were made on this day due to manual copy process.

j. 06-08 and 13.12.10: problem with the acquisition software followed by some modifications. On 08.12, new measurement cycle introduced for SOMORA and change in integration time for the three observation positions. On 13.12: change of the sky elevation angle.

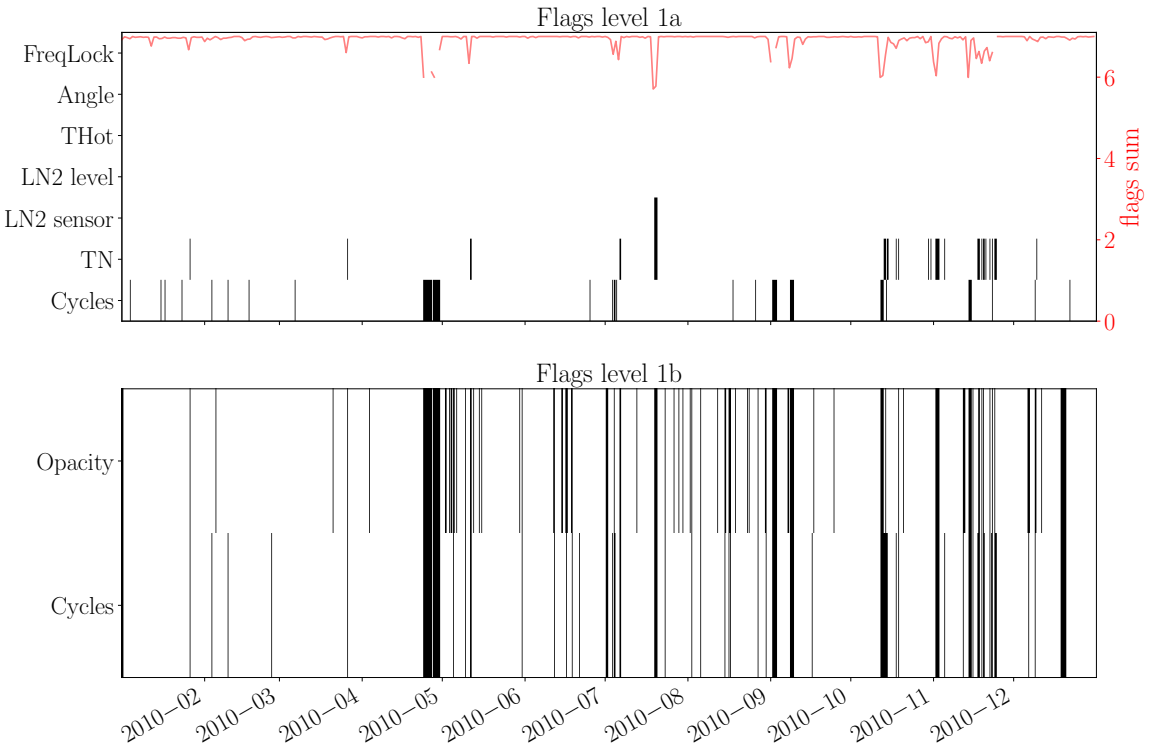


Figure 4.9: SOMORA flags, 2010

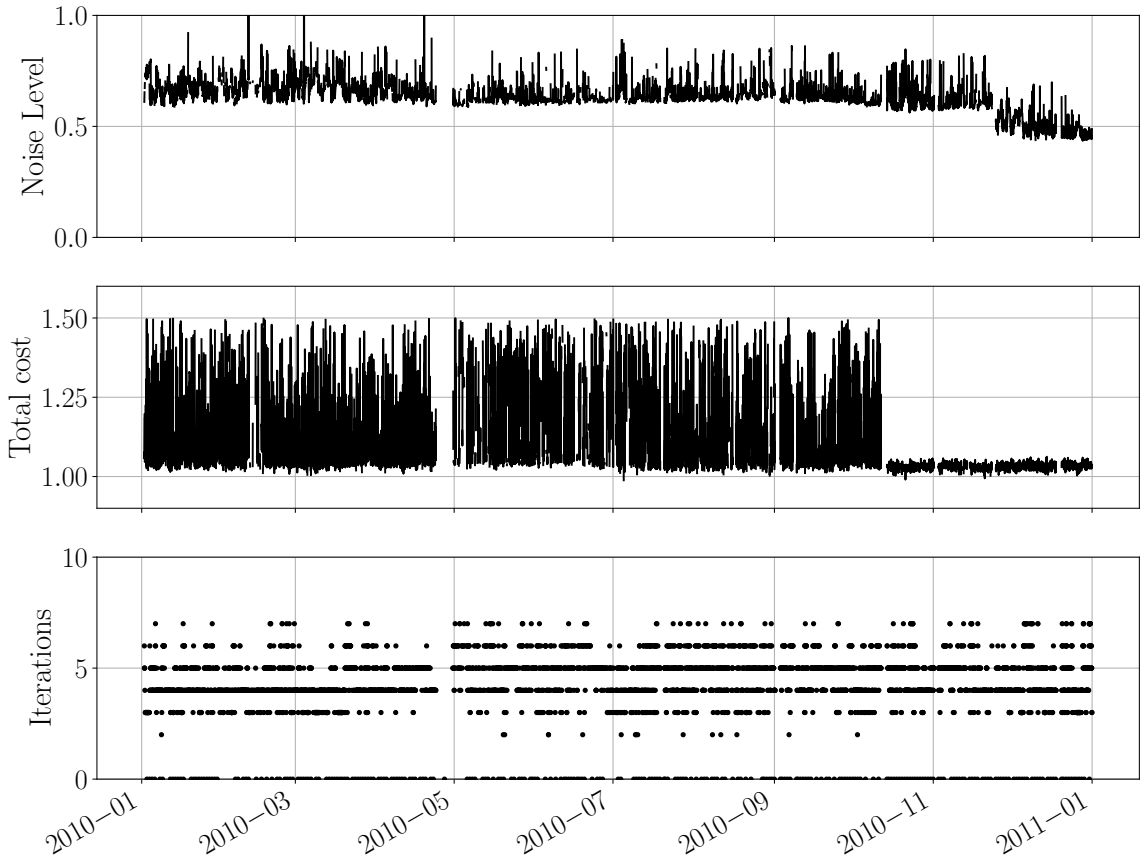


Figure 4.10: SOMORA, 2010

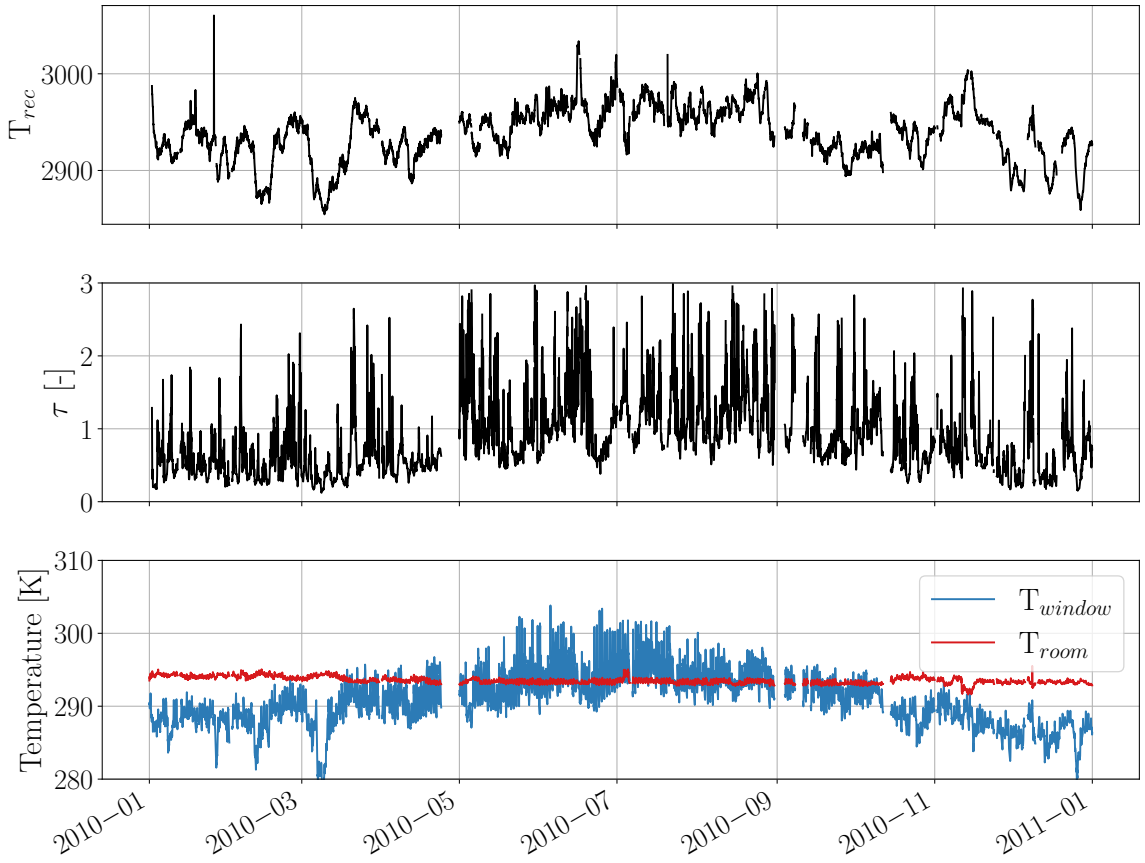


Figure 4.11: SOMORA, 2010

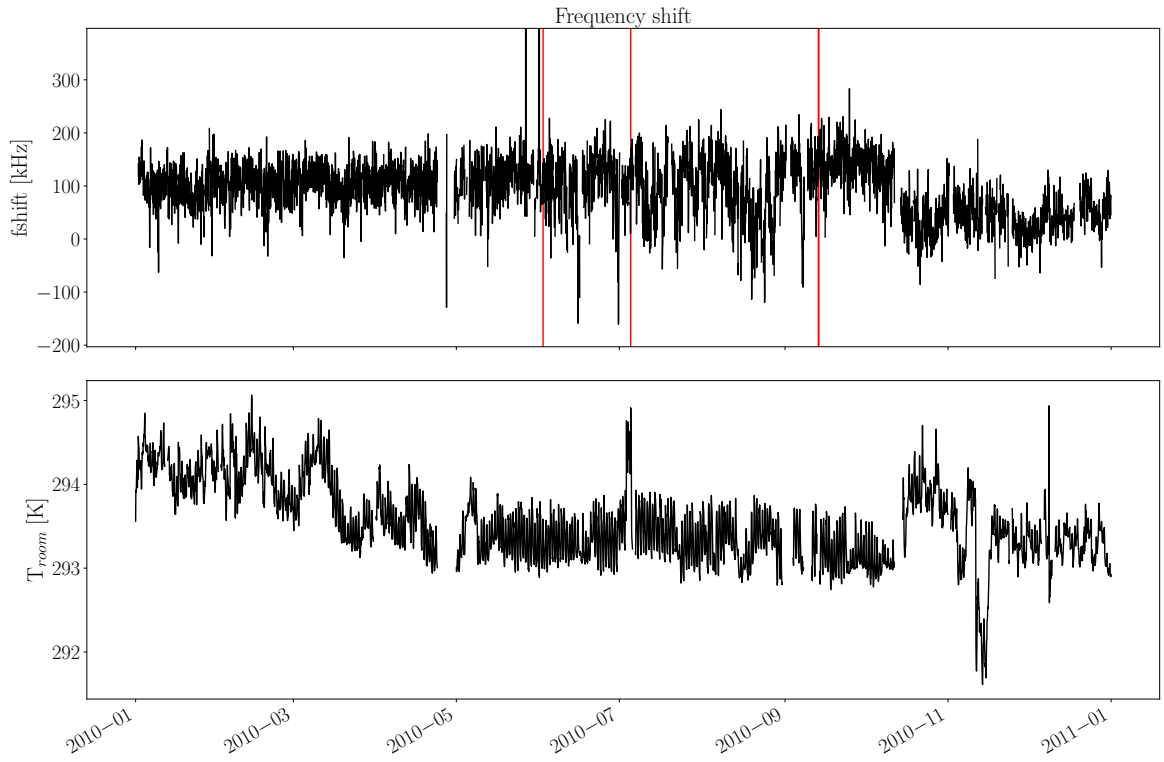


Figure 4.12: SOMORA, 2010

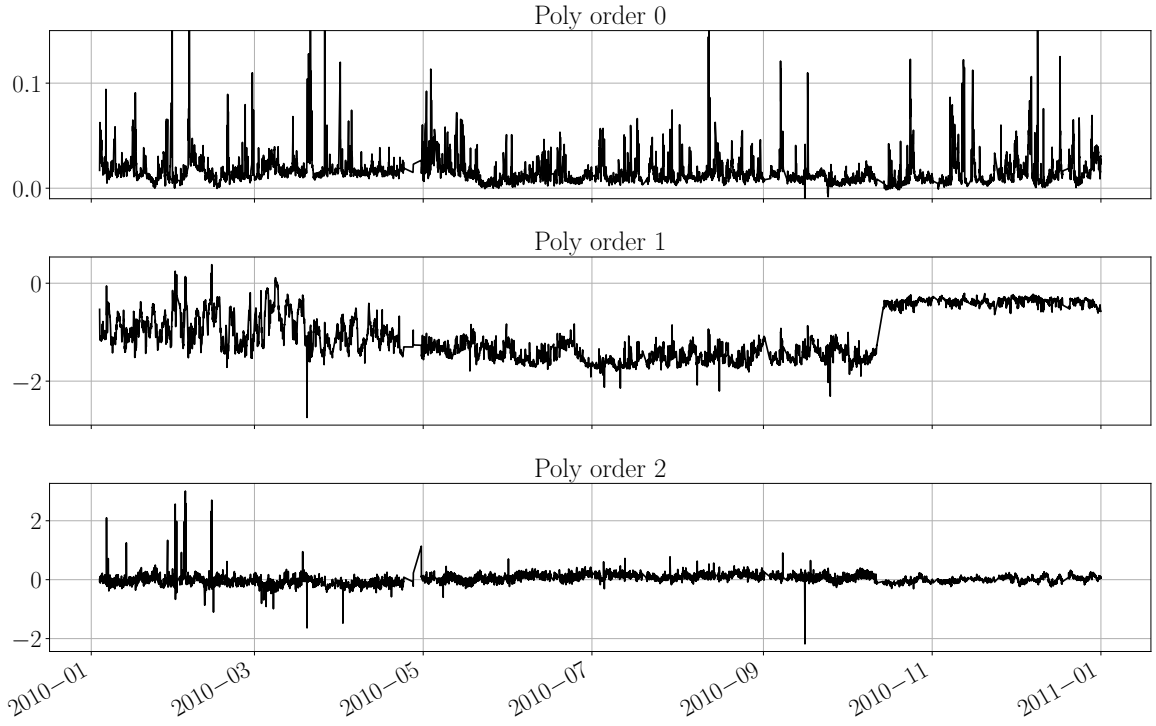


Figure 4.13: SOMORA, 2010

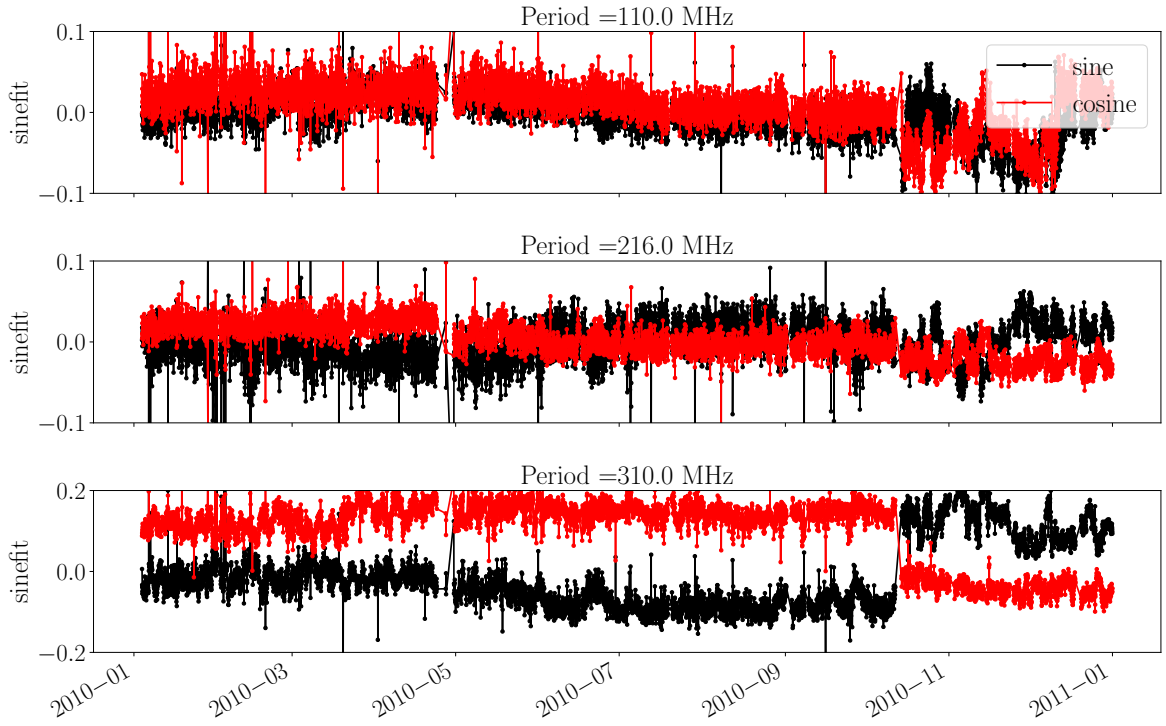


Figure 4.14: SOMORA, 2010

2011

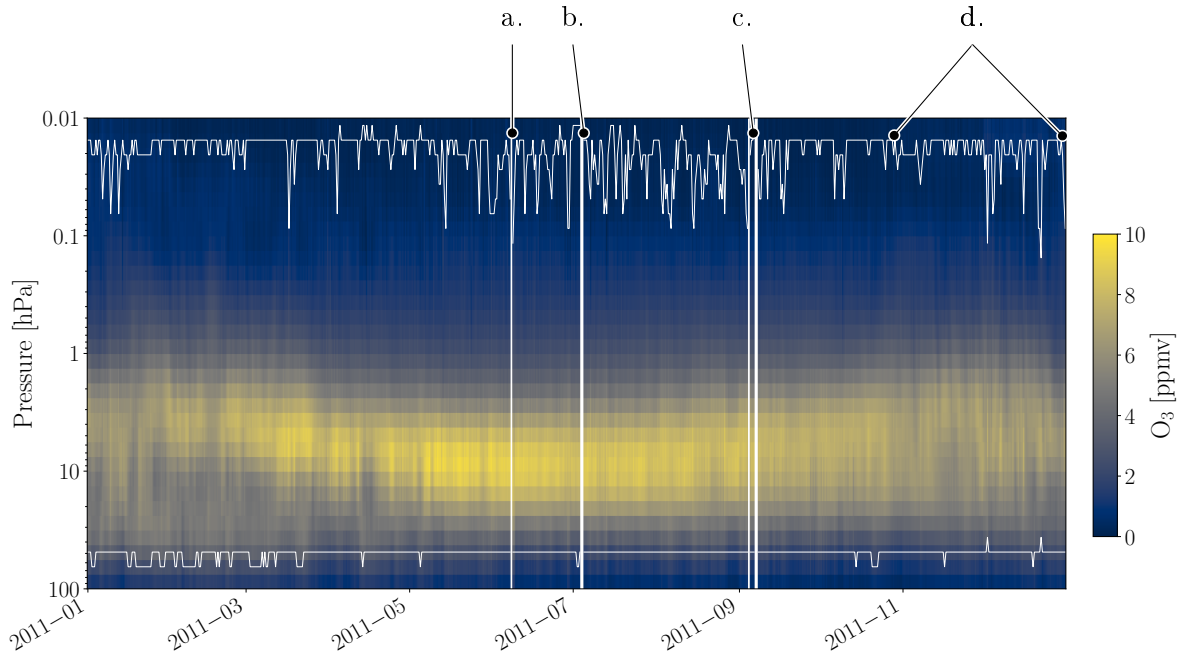


Figure 4.15: SOMORA, 2011

a. 08-10.06.11: icing problem with the cold load and change of absorber and cover. Followed by some problem of LN2 level on the 09.06. It resulted in a negative jump of Trec of $\approx$ 100 K (Fig. 4.18)

b. 28.06-04.07.11: some file writing problems during this period. Measurements seems to always stopped at midnight and had to be manually checked.

c. 06-07.09.11: measurement interruption because of full disk

d. 28.10.11-18.01.12: Trec fluctuations are quite high for this period (unknown reasons). It might be due to room temperature fluctuations which were solved on the 18.01.12. The threshold for the Trec flucutations have been increased for this time period but the measurement look fine. However, the sine baseline retrievals on SOMORA increased quite a lot from November 2011.

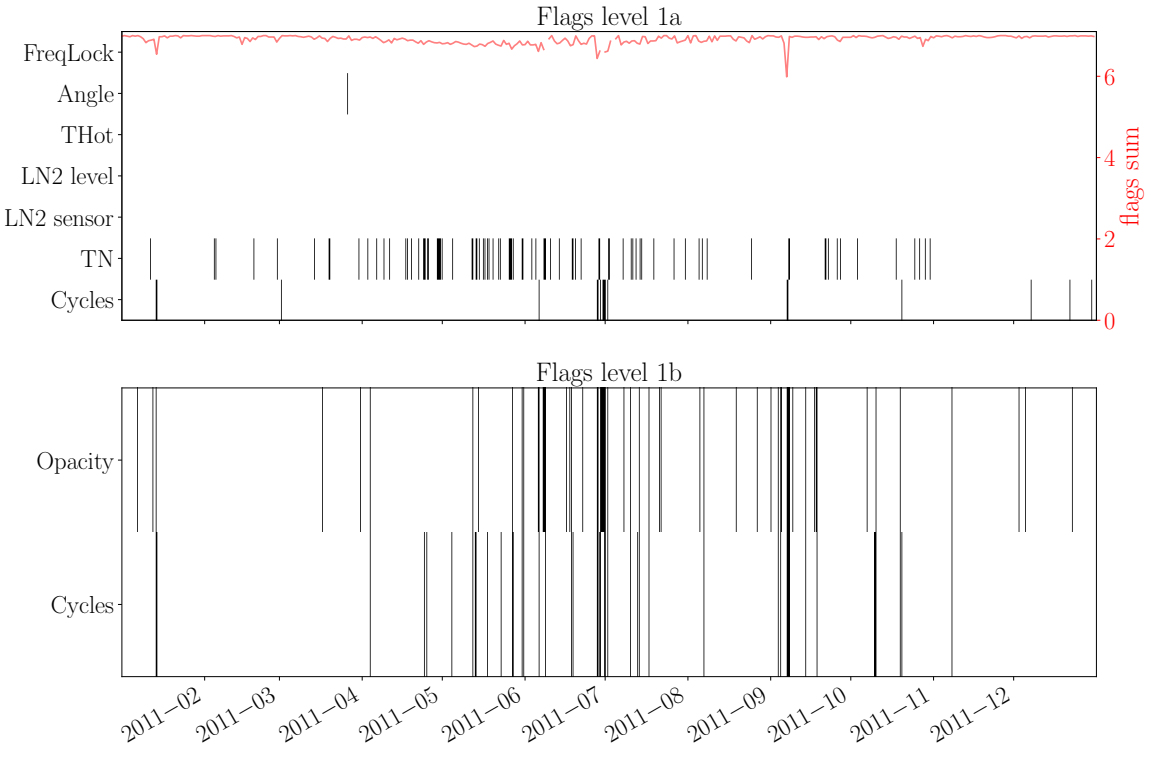


Figure 4.16: SOMORA, 2011

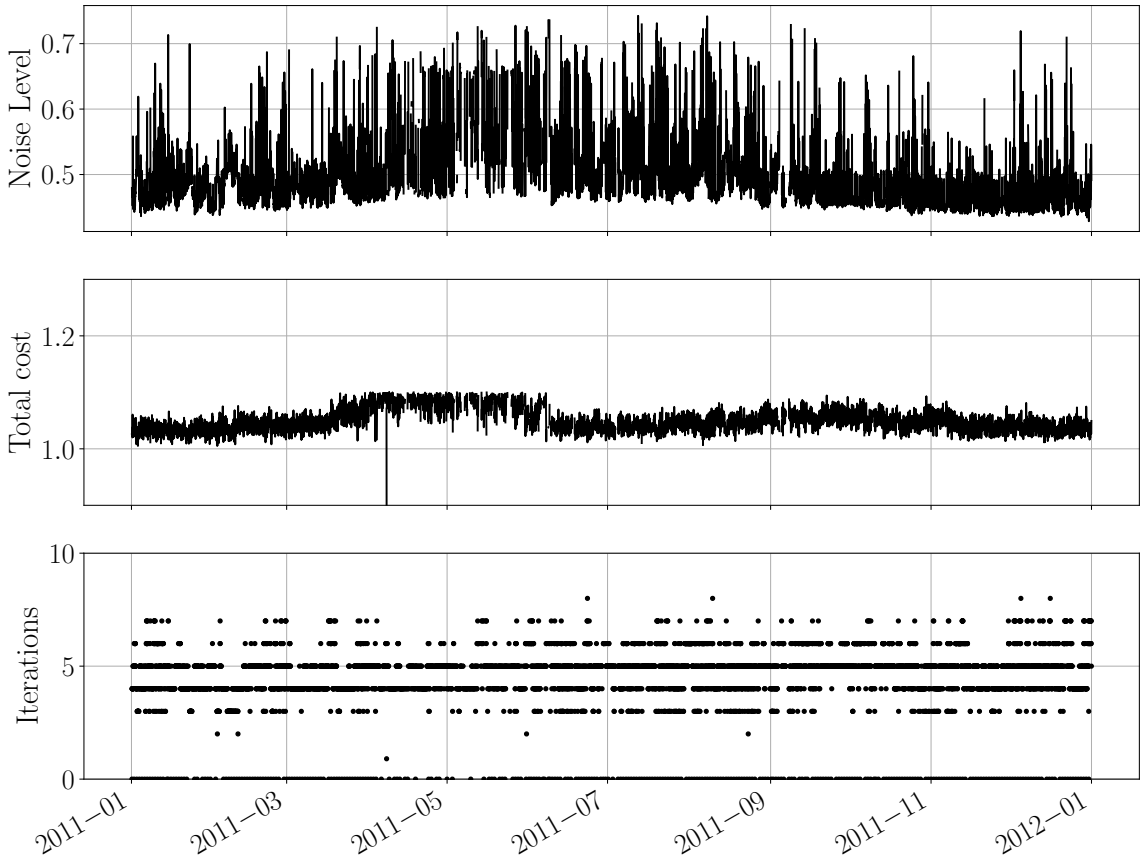


Figure 4.17: SOMORA, 2011

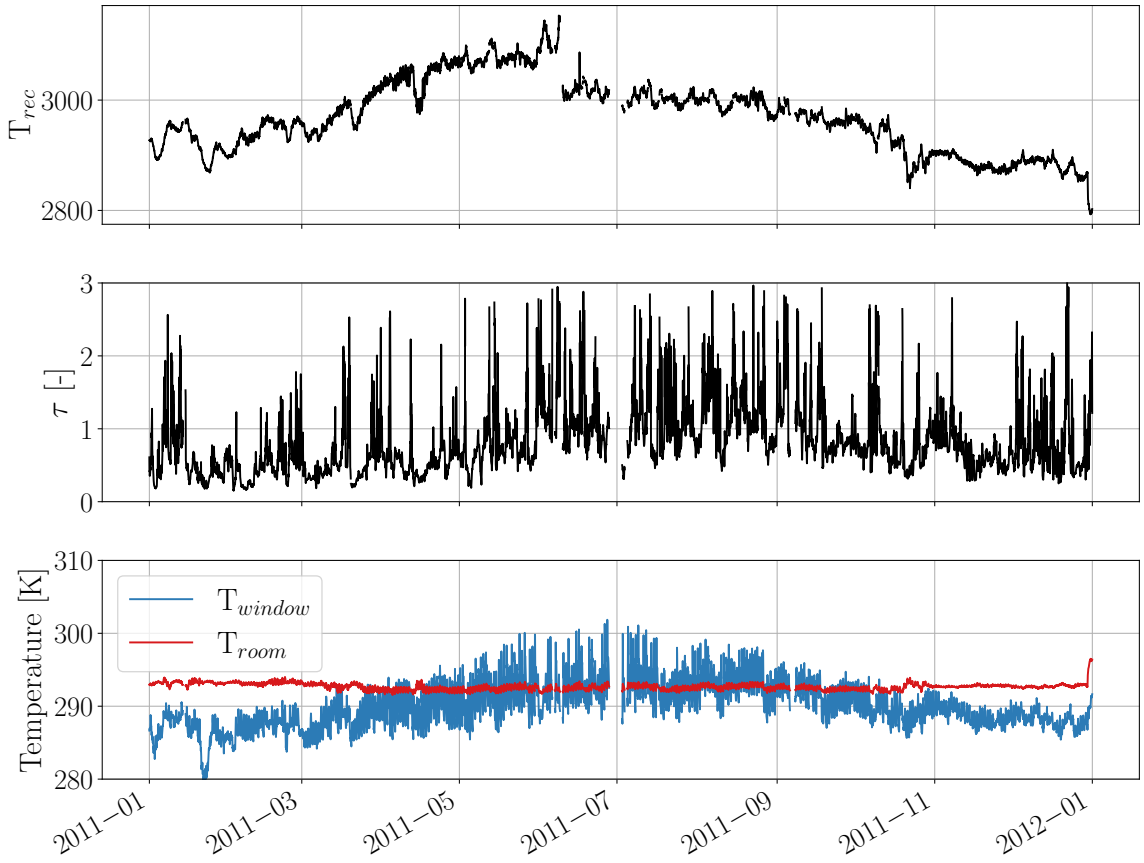


Figure 4.18: SOMORA, 2011

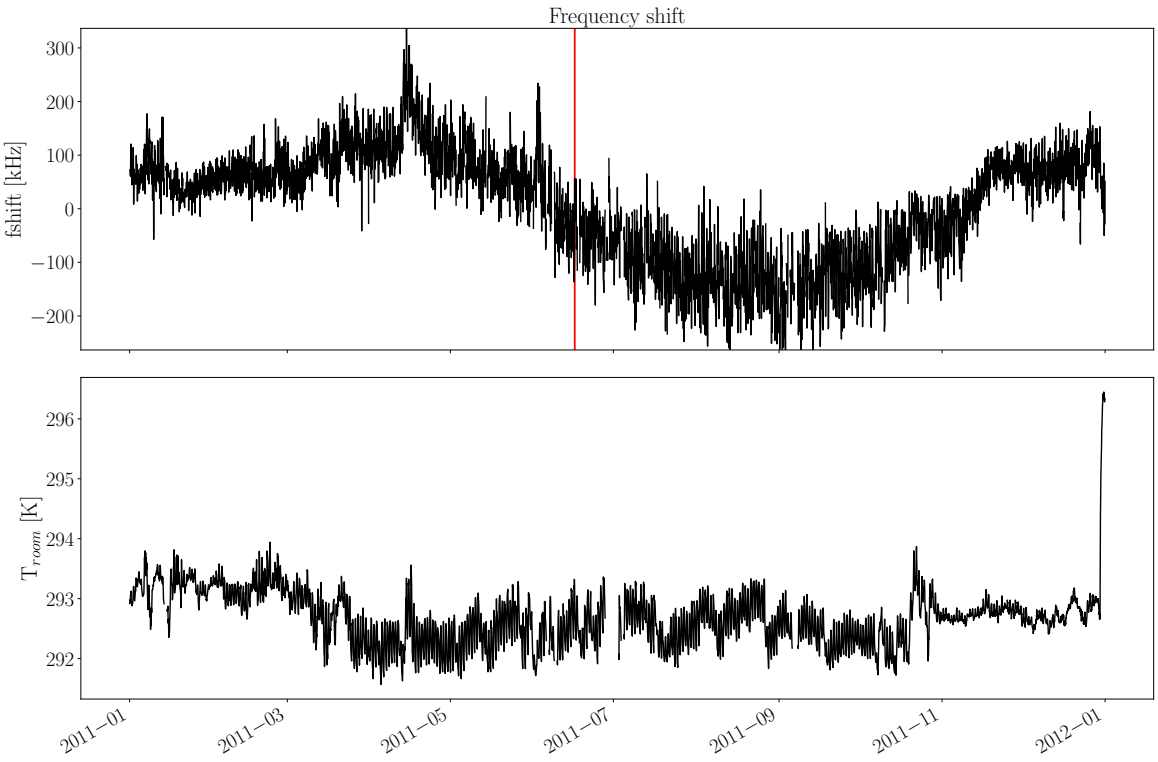


Figure 4.19: SOMORA, 2011

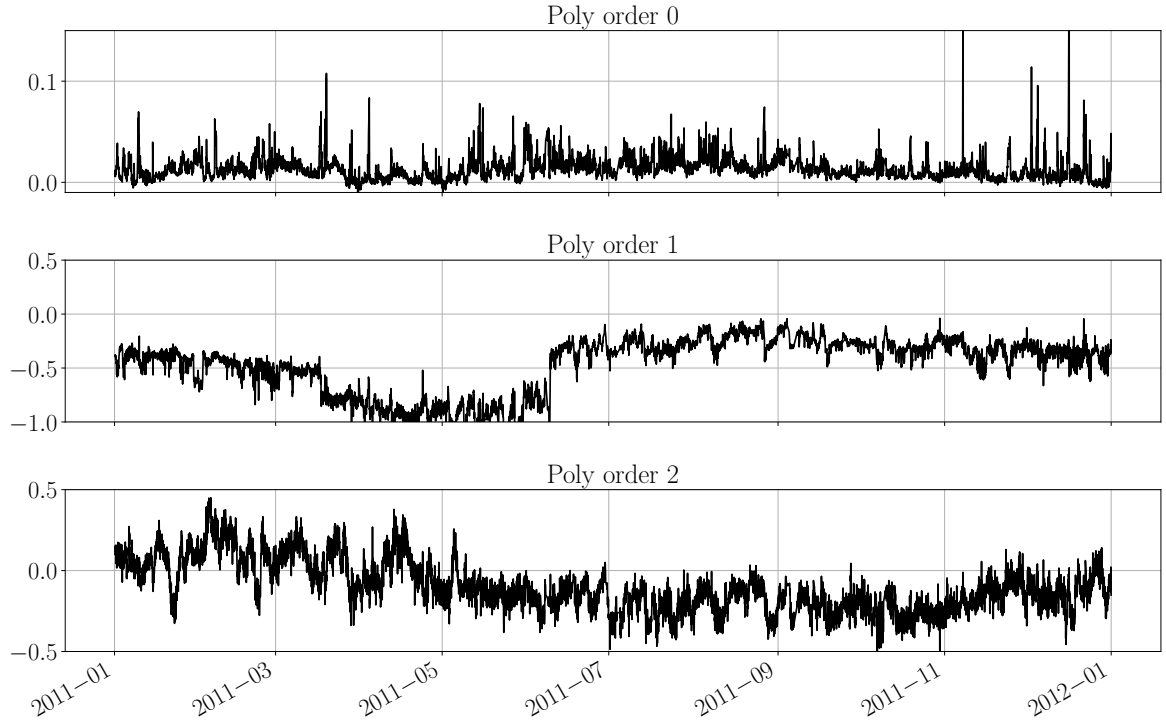


Figure 4.20: SOMORA, 2011

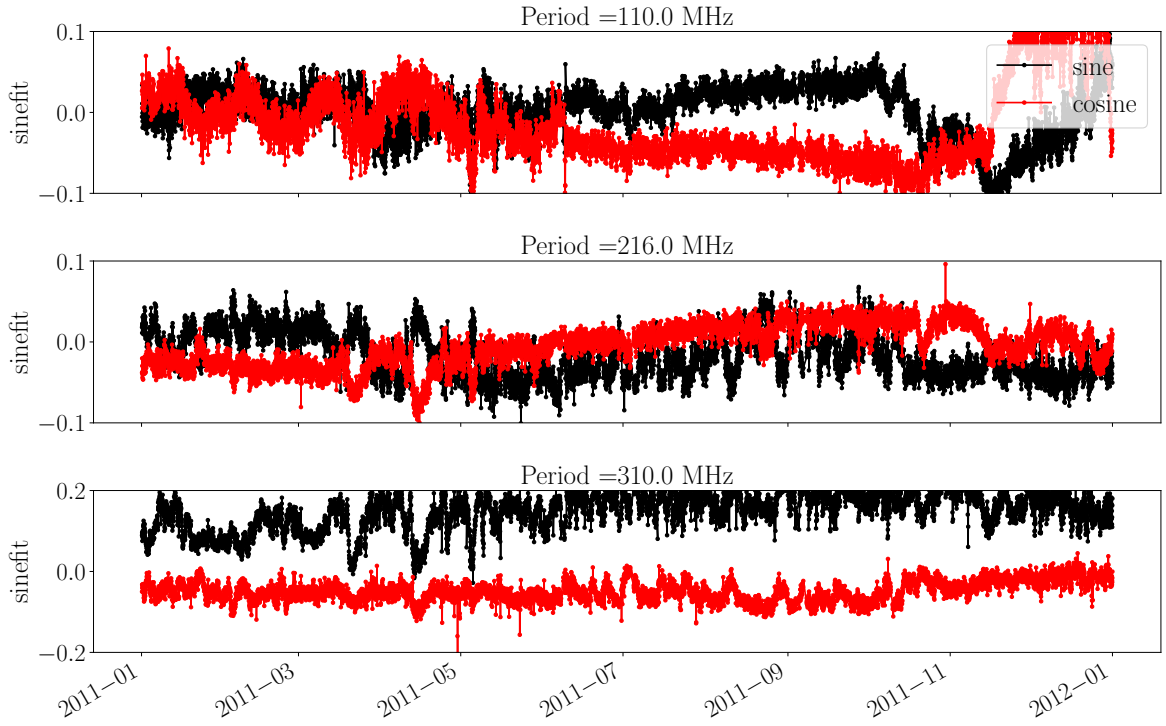


Figure 4.21: SOMORA, 2011

2012

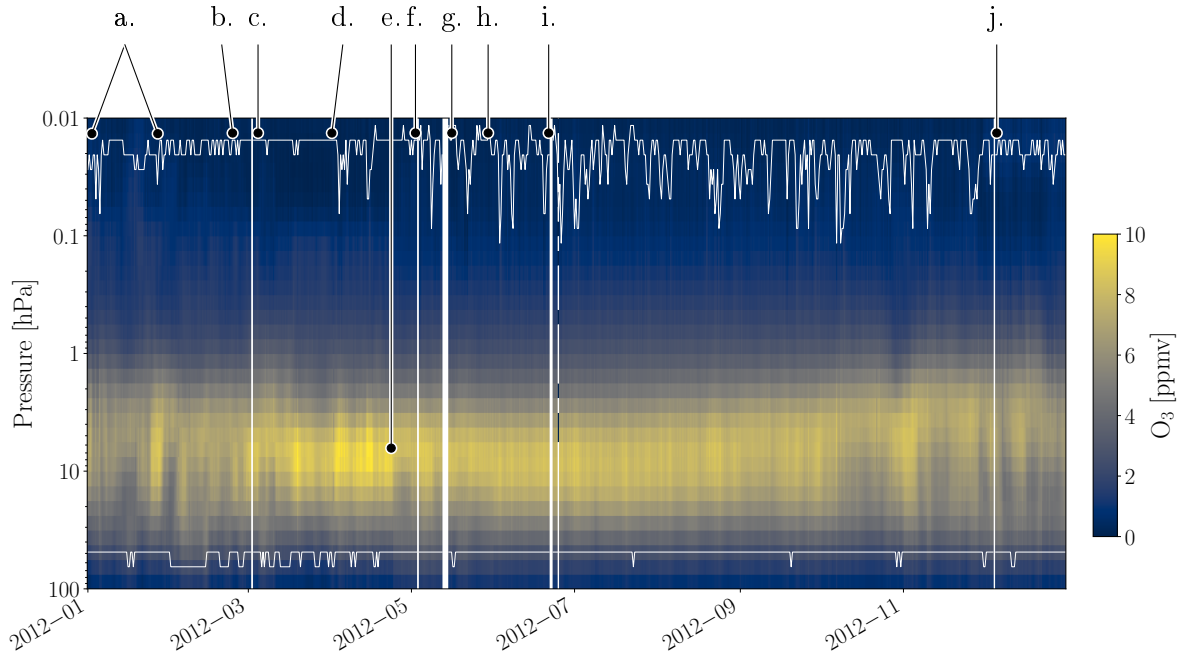


Figure 4.22: SOMORA, 2012

a. 28.10.11-18.01.12: Trec fluctuations are quite high for this period (unknown reasons). It might be due to room temperature fluctuations which were solved on the 18.01.12. The threshold for the Trec flucutations have been increased for this time period but the measurement look fine.

b. 28.02.12: cleaning of the cold load (icing problem). It reduced the quite large sine baselines present since November 2011.

c. 02.03.12: change of windows

d. 02.04.12: Windows update and restart of the spectrometer.

e. 24-27.04.12: cold load angle changed on 24.04 which produced a jump in ozone time series and baseline retrievals. From 24.04 to 27.04, the mirror angle was off -> data have been flagged for these days.

f. 03-04.05.12: some test were done during these days -> problem with the raw data.

g. 13-15.05.12: file writing problem solved on the 15.05 -> no FFTS raw data on 13-14.05.

h. 22.05.12: test of sideband effect done and change of IF attenuator which produced a jump in spectrometer counts (half) on this day. No other noticeable effect on the time series.

i. 22 and 25-26.06.06.12: no FFTS raw data on 22.06

j. 05-06.12: high Trec fluctuations (unknown reasons)

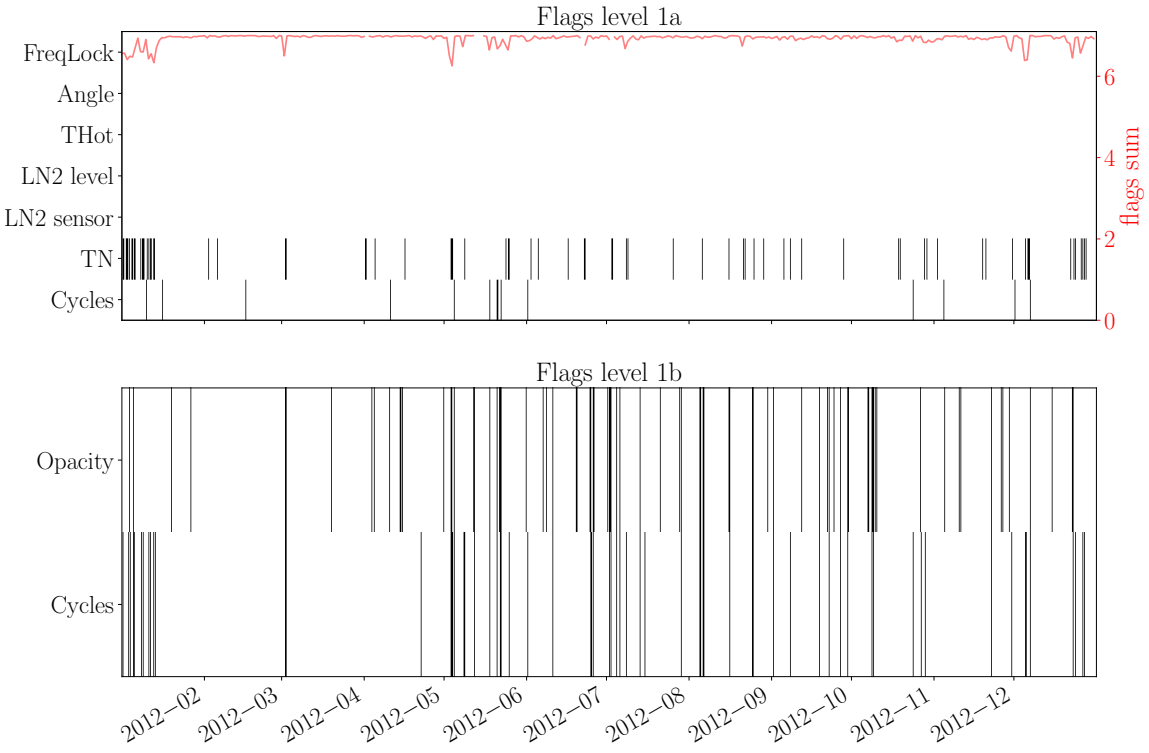


Figure 4.23: SOMORA, 2012

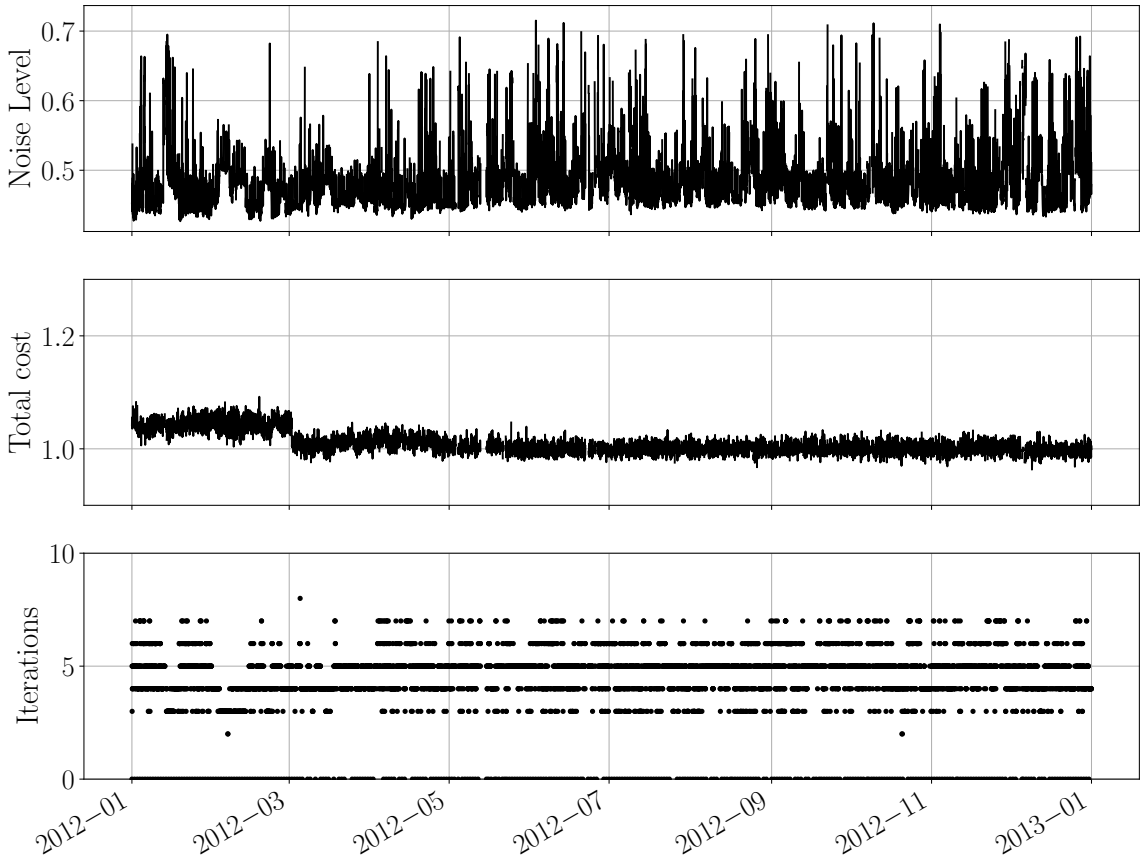


Figure 4.24: SOMORA, 2012

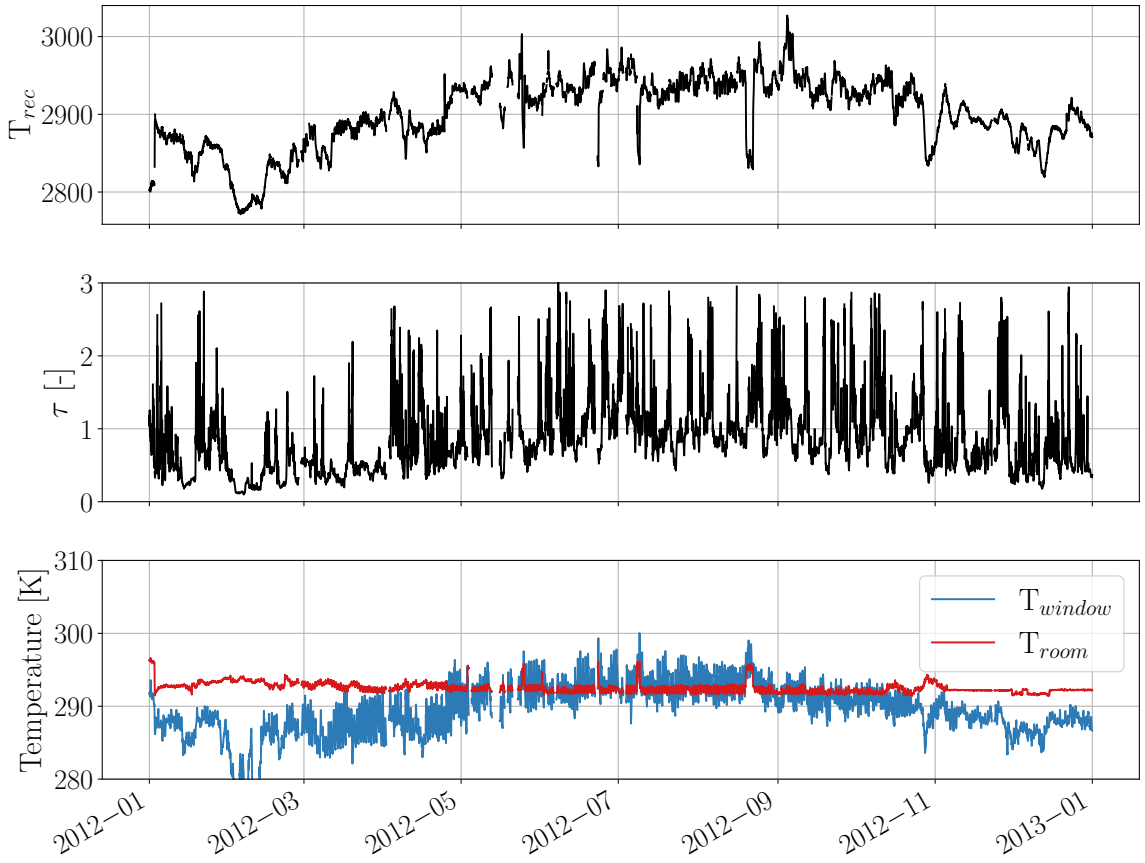


Figure 4.25: SOMORA, 2012

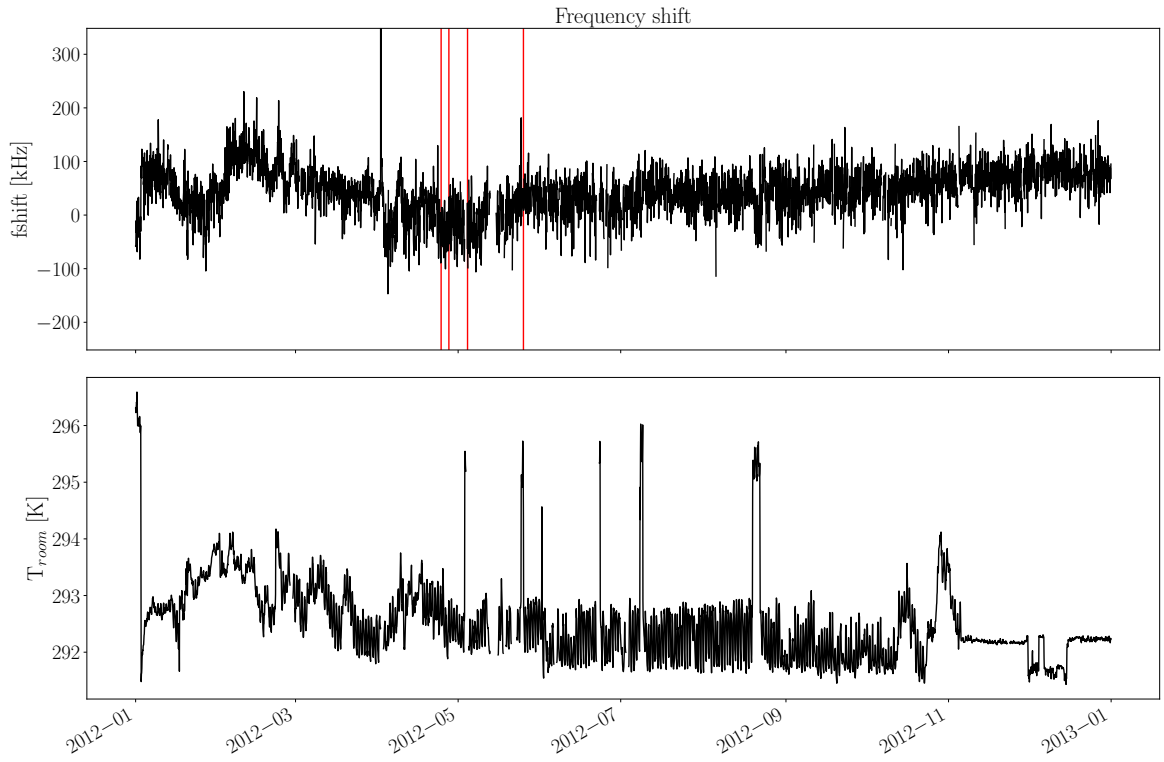


Figure 4.26: SOMORA, 2012

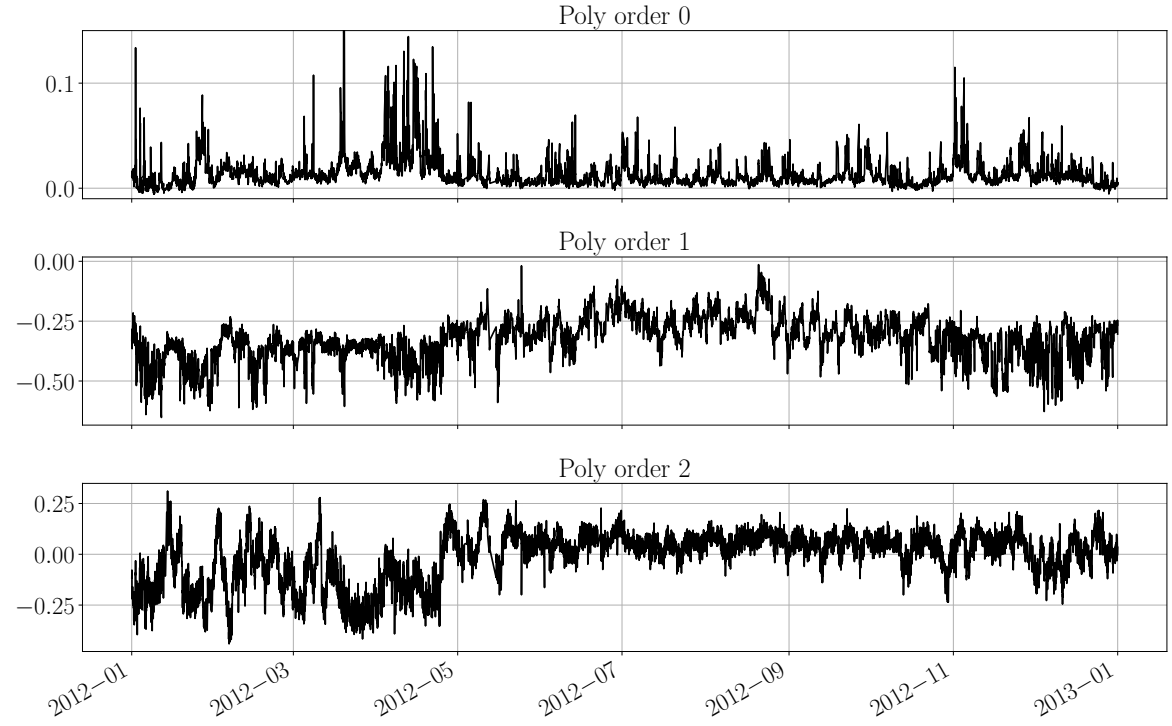


Figure 4.27: SOMORA, 2012

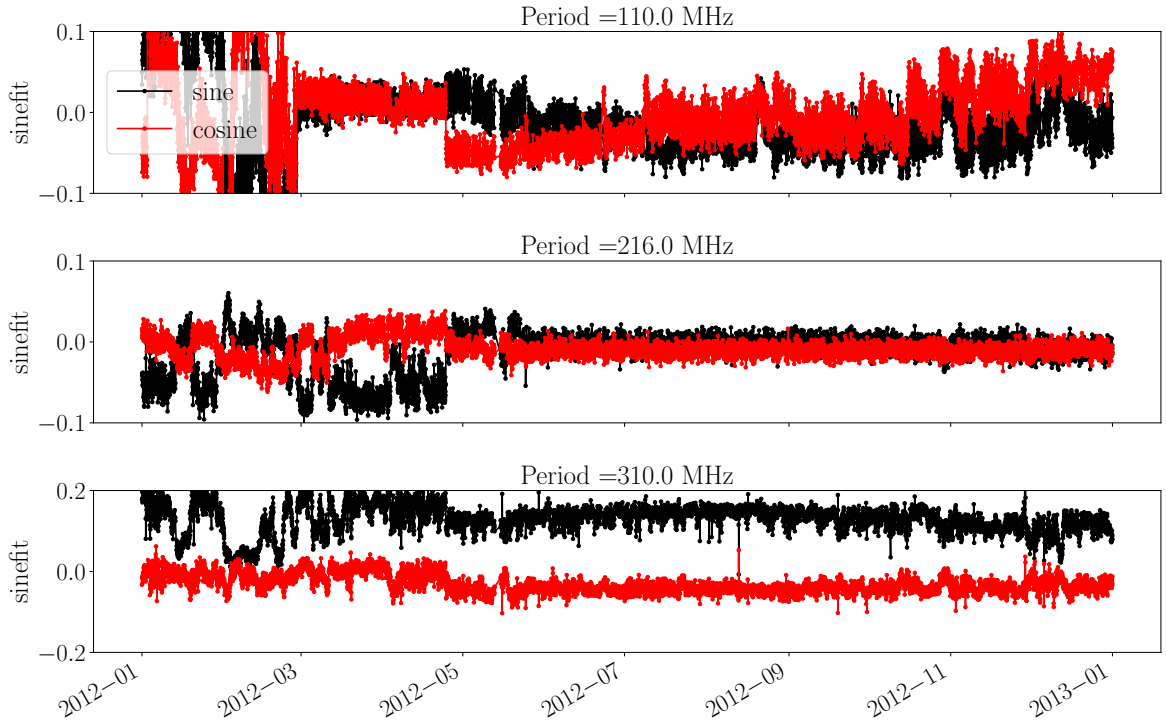


Figure 4.28: SOMORA, 2012

2013

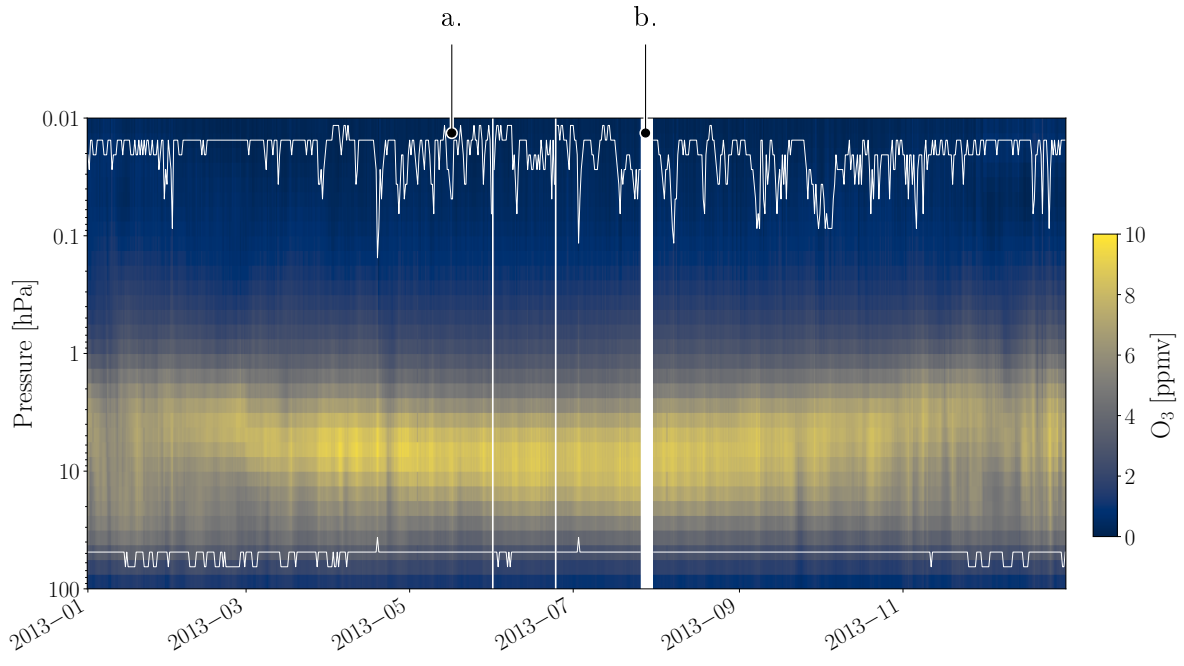


Figure 4.29: SOMORA, 2013

a. 17.05.13: cleaning of cold load, no noticeable effect on time series.

b. 26.07-06.08.13: lock errors combined with empty LN2 on 30-31.07. The lock problems were due to defective harmonic mixer and lasted until 06.08 but were flagged in the calibration routine. The problem was solved by changing attenuators between the mixer and synthesizer on 06.08.

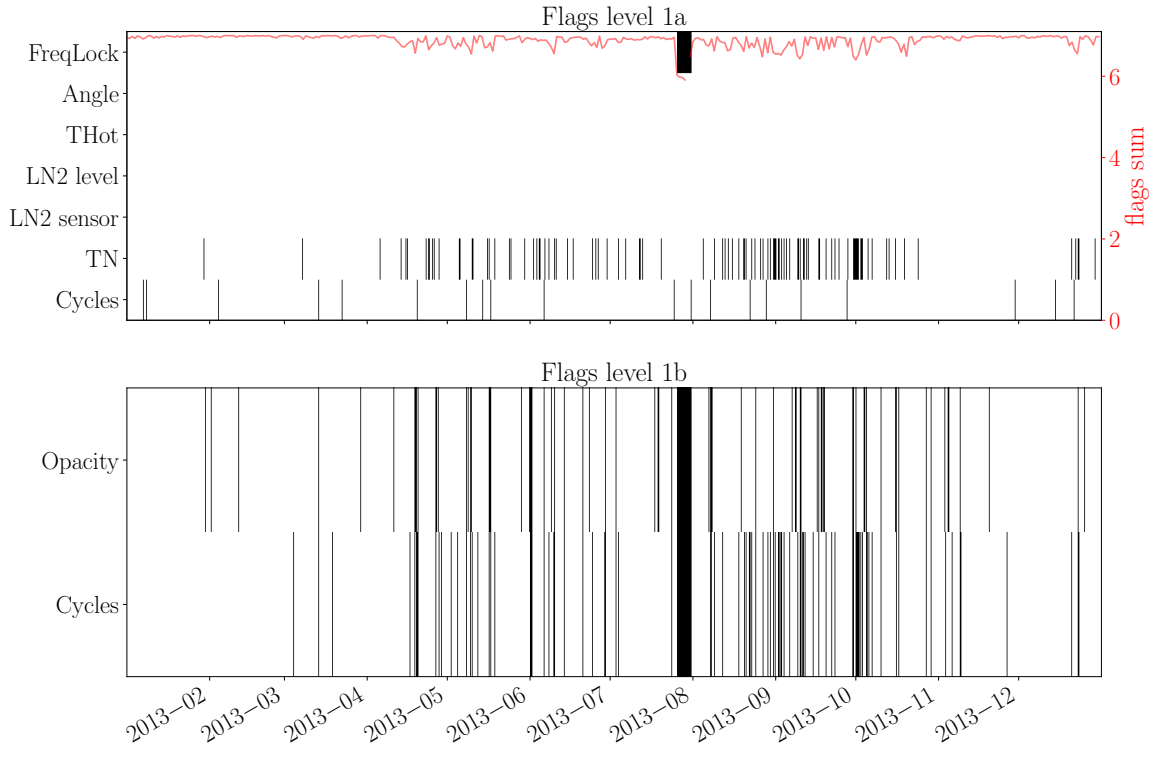


Figure 4.30: SOMORA, 2013

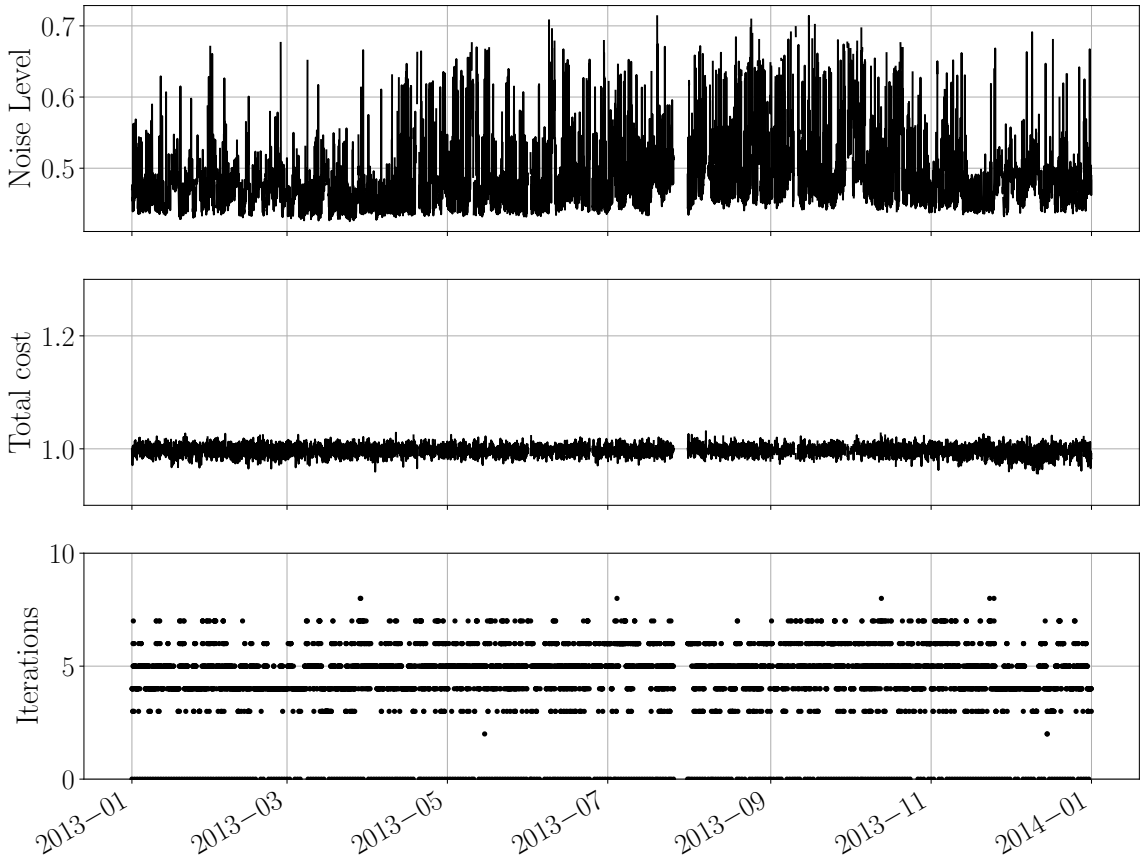


Figure 4.31: SOMORA, 2013

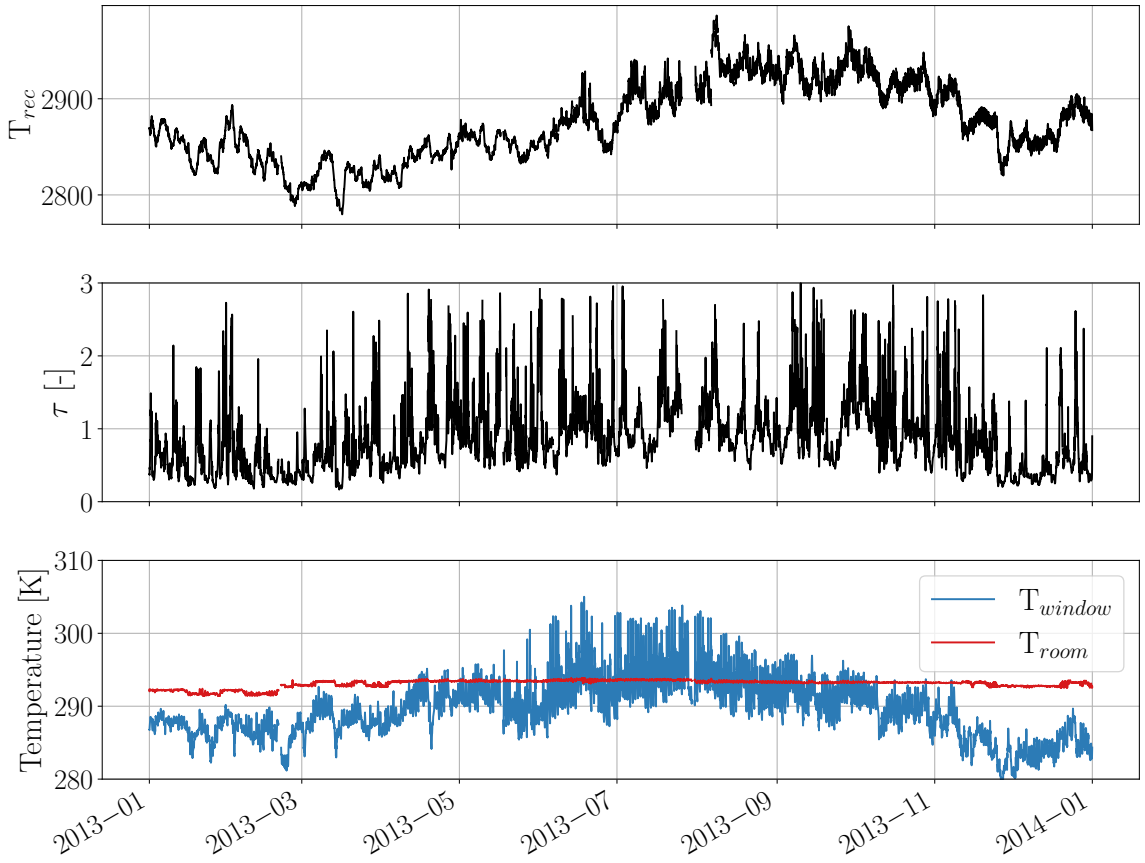


Figure 4.32: SOMORA, 2013

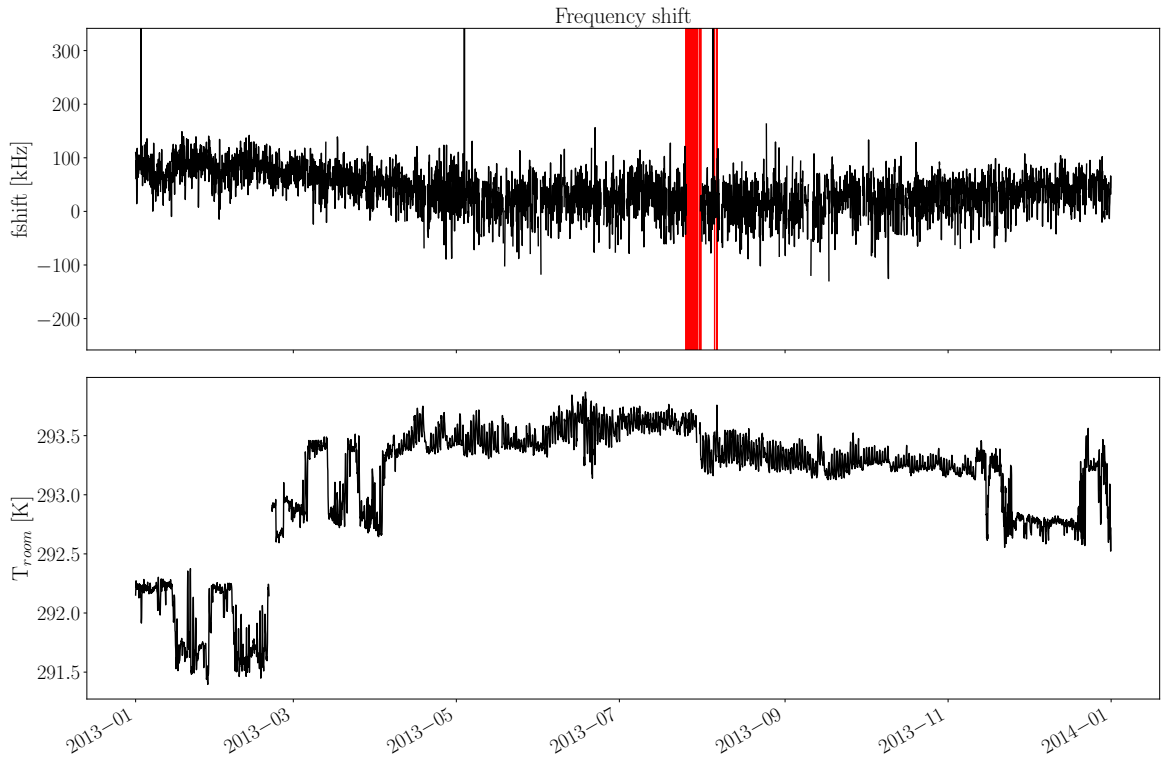


Figure 4.33: SOMORA, 2013

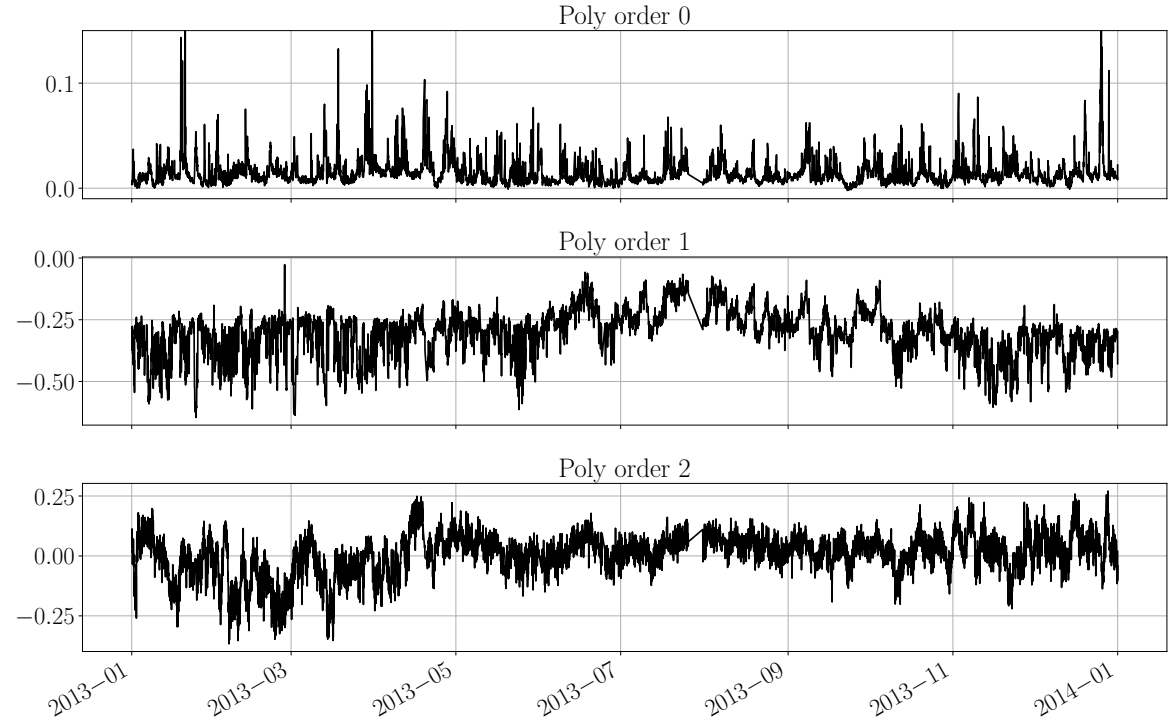


Figure 4.34: SOMORA, 2013

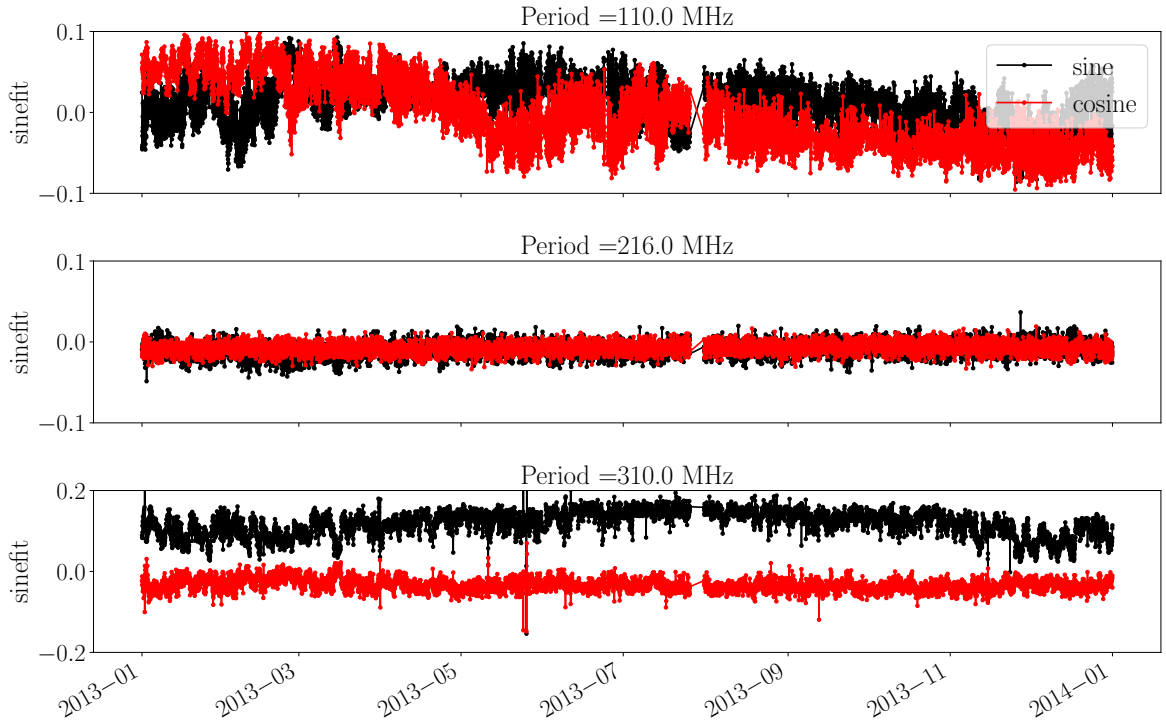


Figure 4.35: SOMORA, 2013

2014

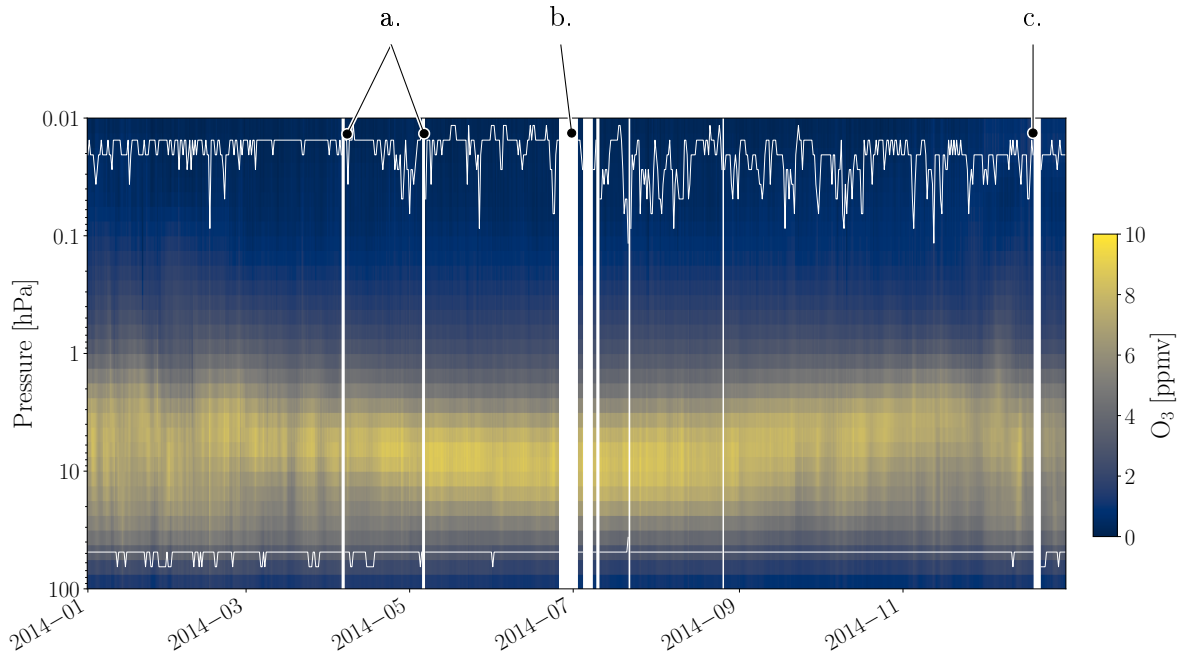


Figure 4.36: SOMORA, 2014

a. 06.04.14 and 06.05.14: unknow retrieval error

b. 26.06-03.07.14: lock errors on the whole period. Relocked on 03.07 but lock problems lasted until 11.07 and removal of 3dB attenuator between MIX and 4.6 GHz reference.

c. 20-22.12.14: spectrometer crash for unknown reasons.

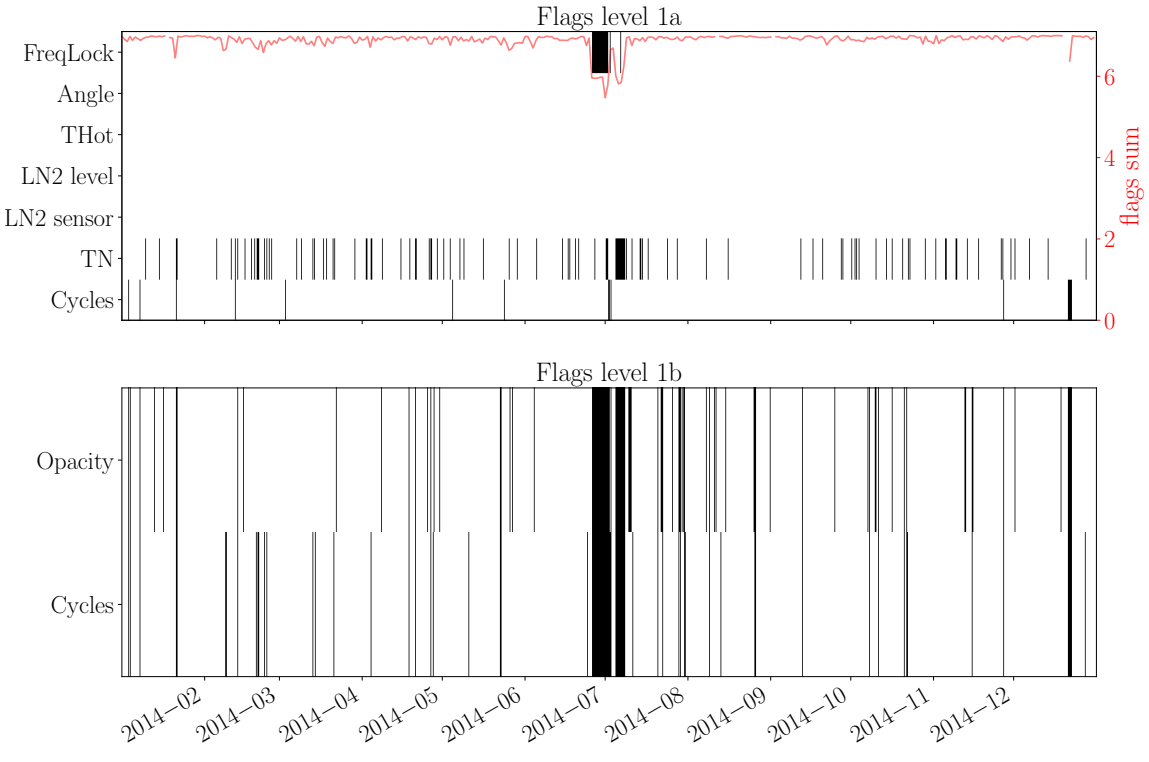


Figure 4.37: SOMORA, 2014

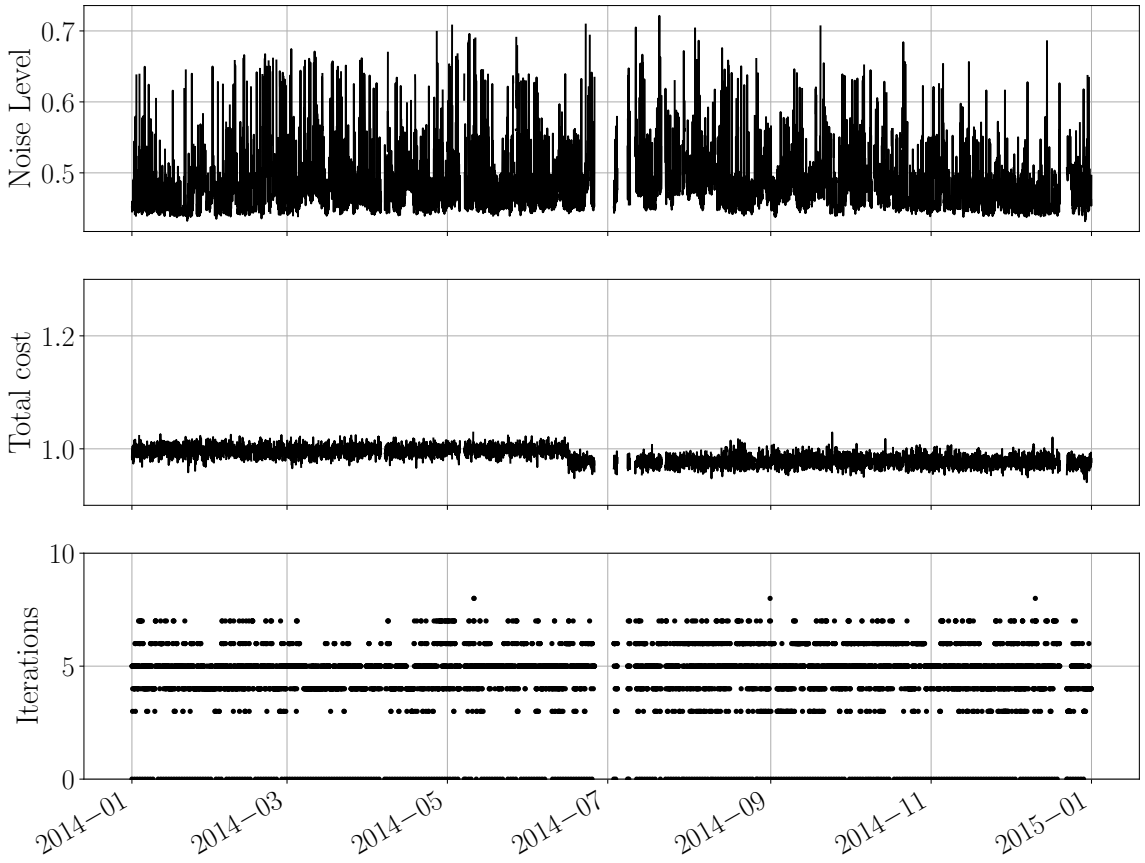


Figure 4.38: SOMORA, 2014

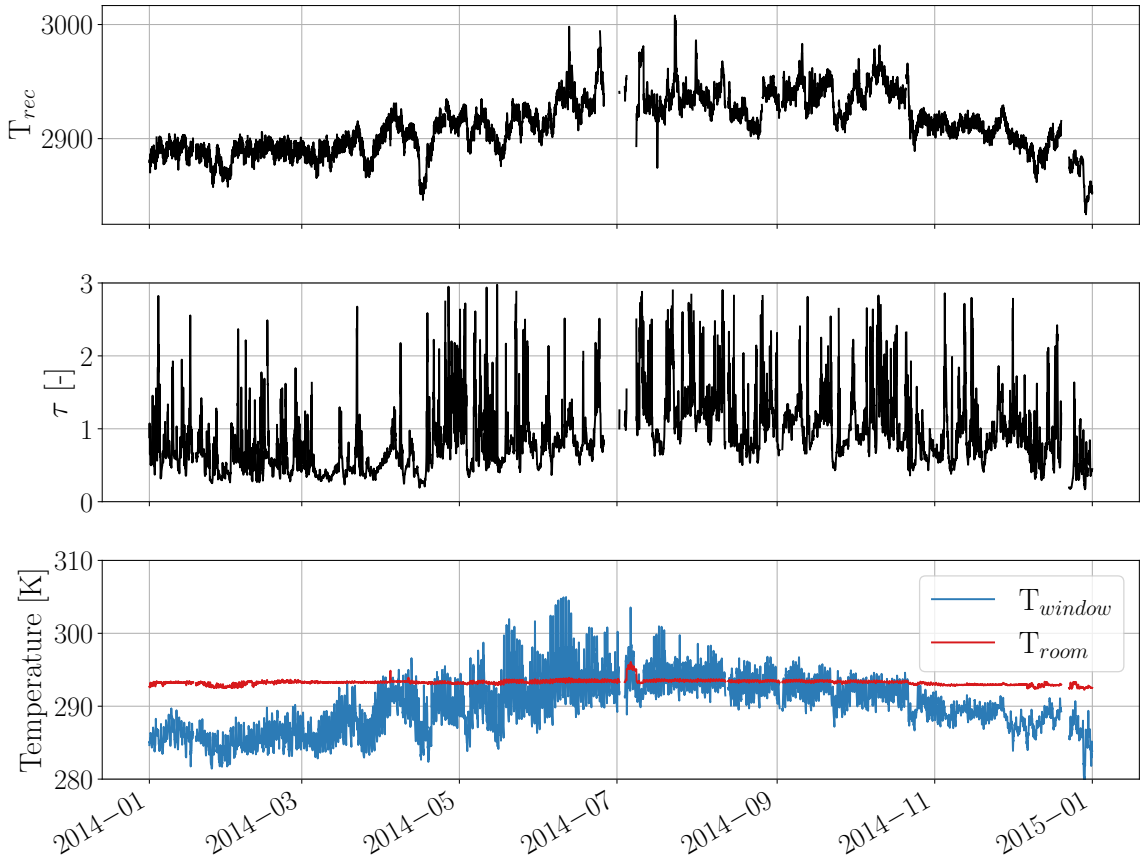


Figure 4.39: SOMORA, 2014

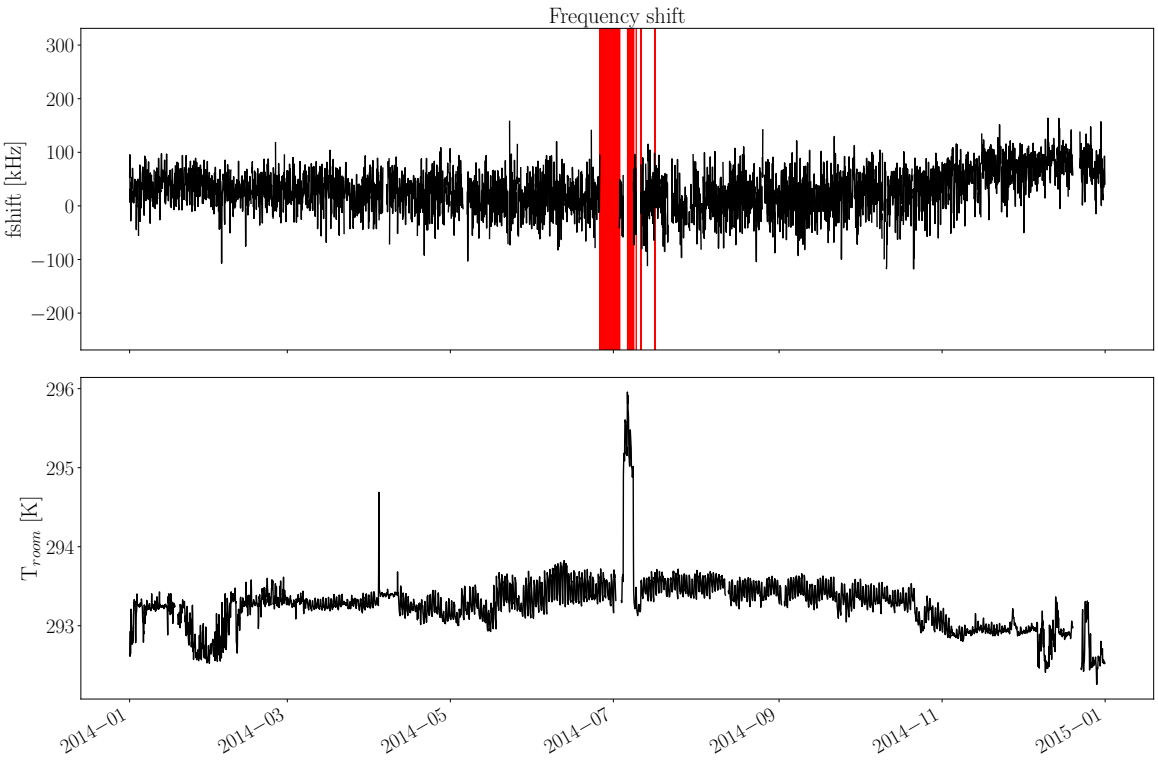


Figure 4.40: SOMORA, 2014

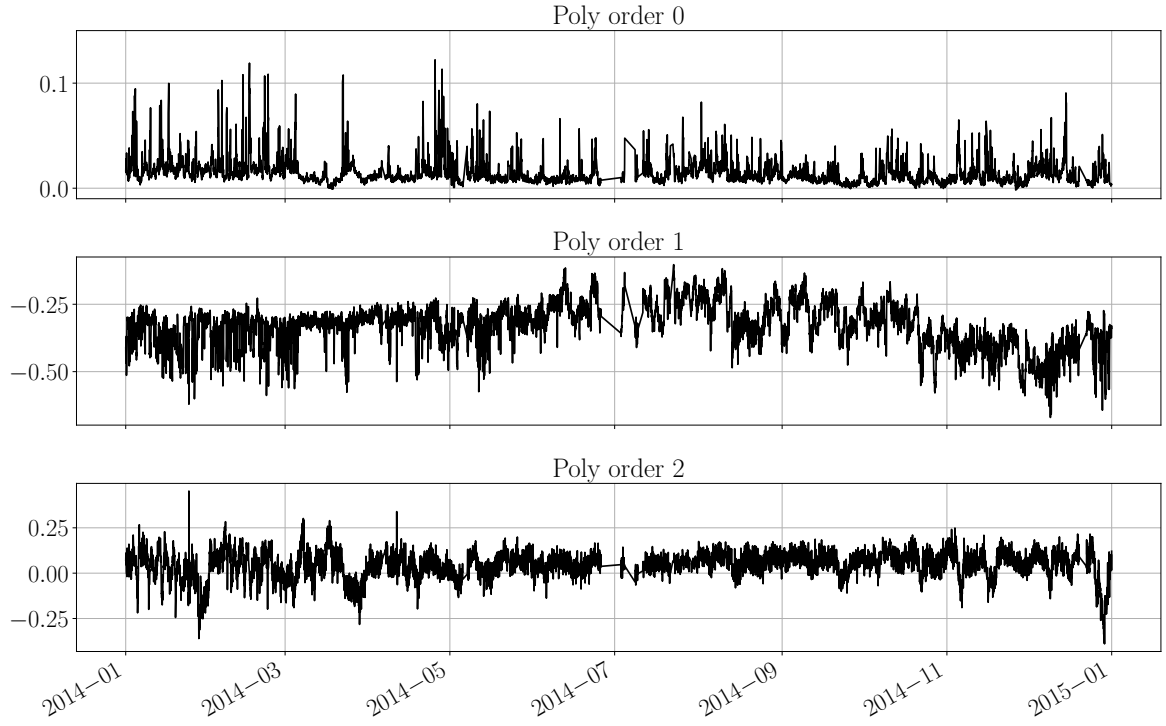


Figure 4.41: SOMORA, 2014

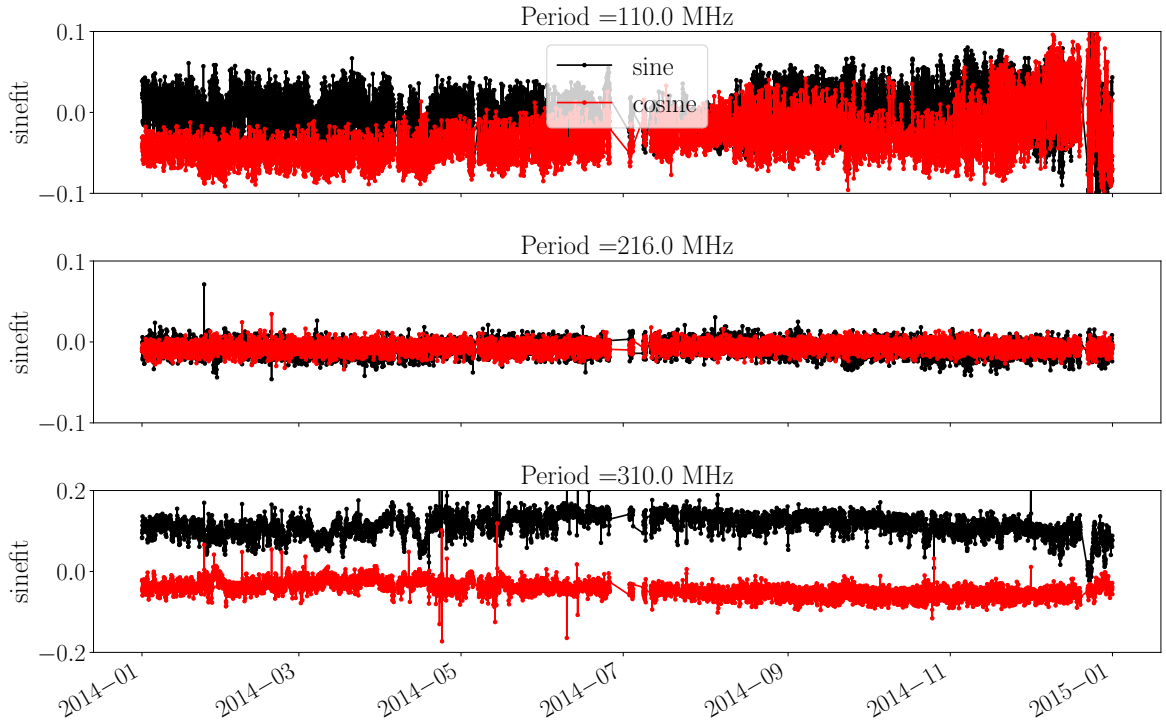


Figure 4.42: SOMORA, 2014

2015

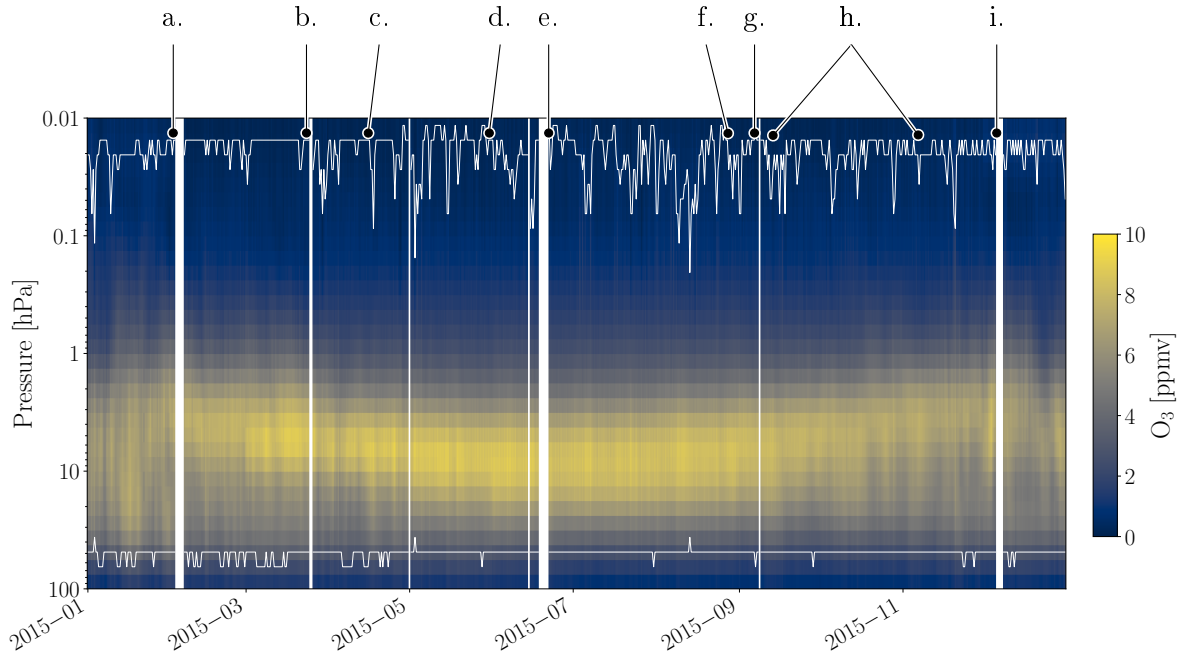


Figure 4.43: SOMORA, 2015

a. 03-05.02.15: measurement interruptions because of disk space problem

b. 25.03.15: unknown problem during calibration

c. 22.04.15: change of the window temperature sensor position

d. 24.05.15: problem with hot load blowers which resulted in a lower Thot (311 K to 297 K) and a jump of Trec. The blowers probably stayed out of order until 17.02.17 and Trec stayed higher as well during this period.

e. 18-22.06.15: measurement interruption because of labview errors. NI acquisition card damaged by a mouse nesting on the shelf !

f. 28.08.15: icing problem on the cold load -> cleaned without big effect on baselines.

g. 08.09.15: change of styrofoam window (yellow). Problem with the raw measurement after 12 UTC.

h. 23.09-10.11.15 higher Trec fluctuations during this period (?)

i. 06-07.12.15: measurement interruptions -> no FFTS raw files

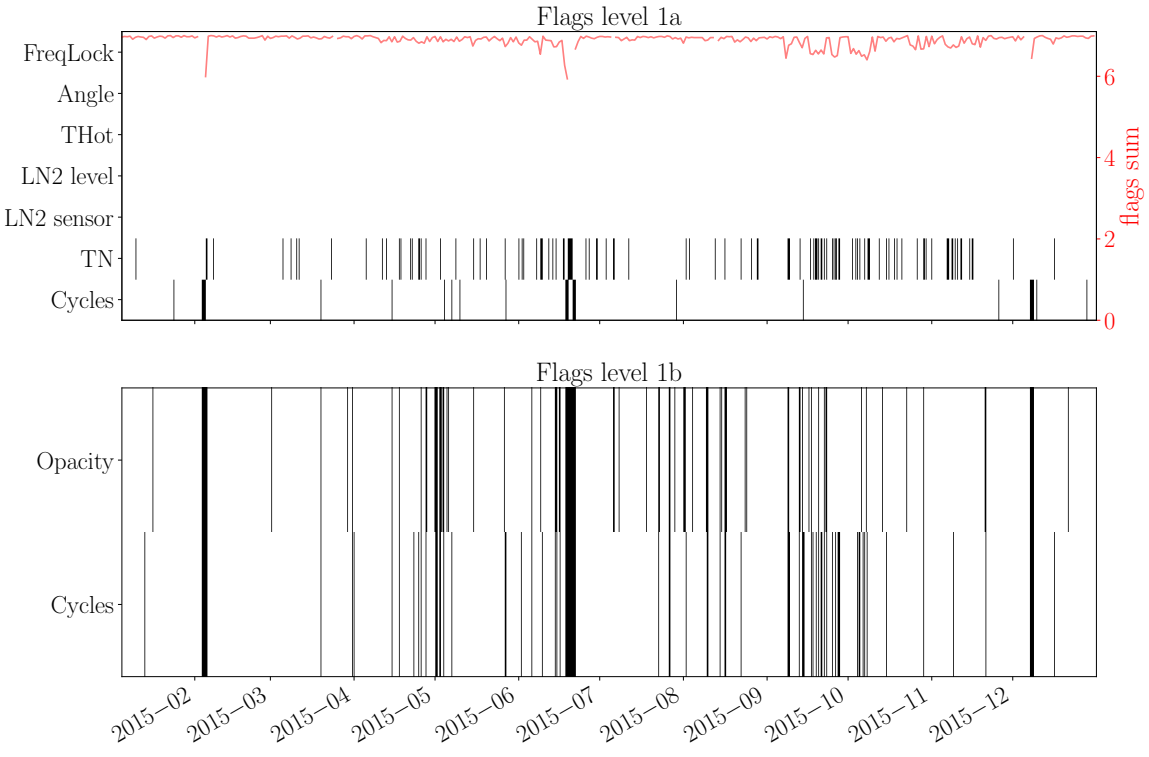


Figure 4.44: SOMORA, 2015

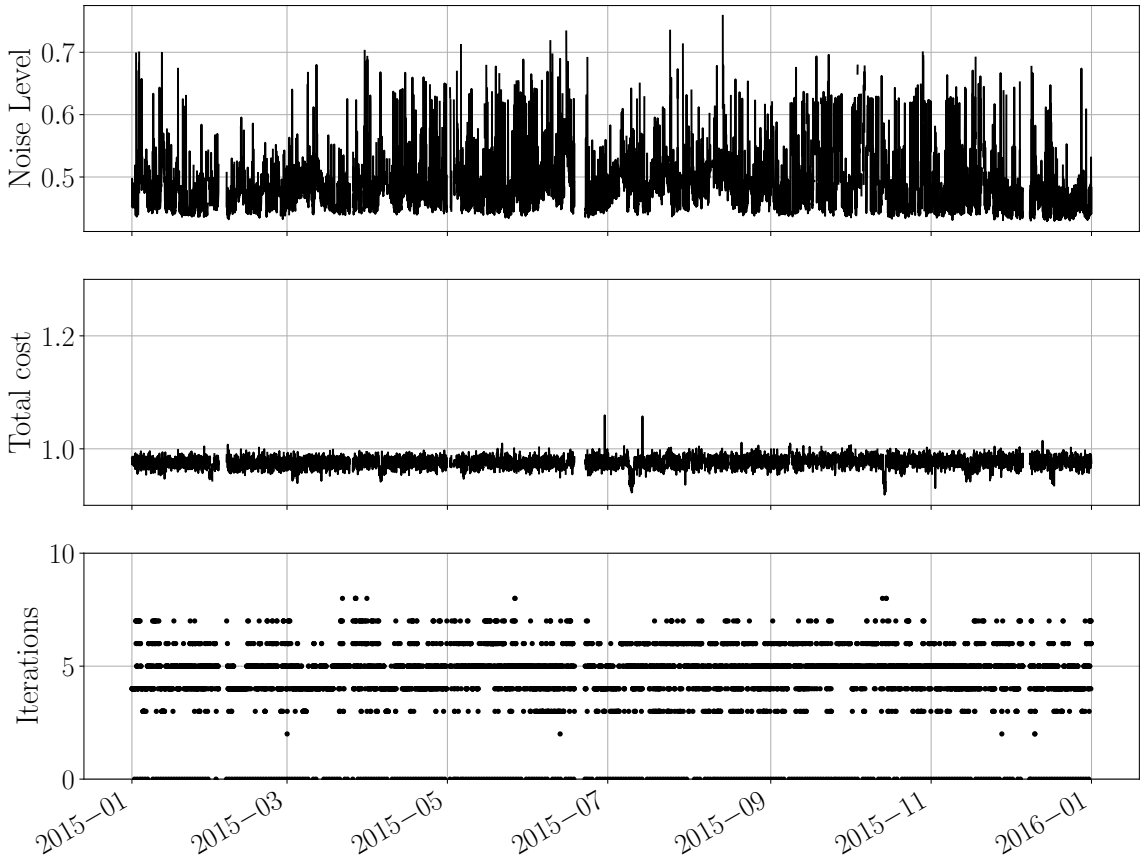


Figure 4.45: SOMORA, 2015

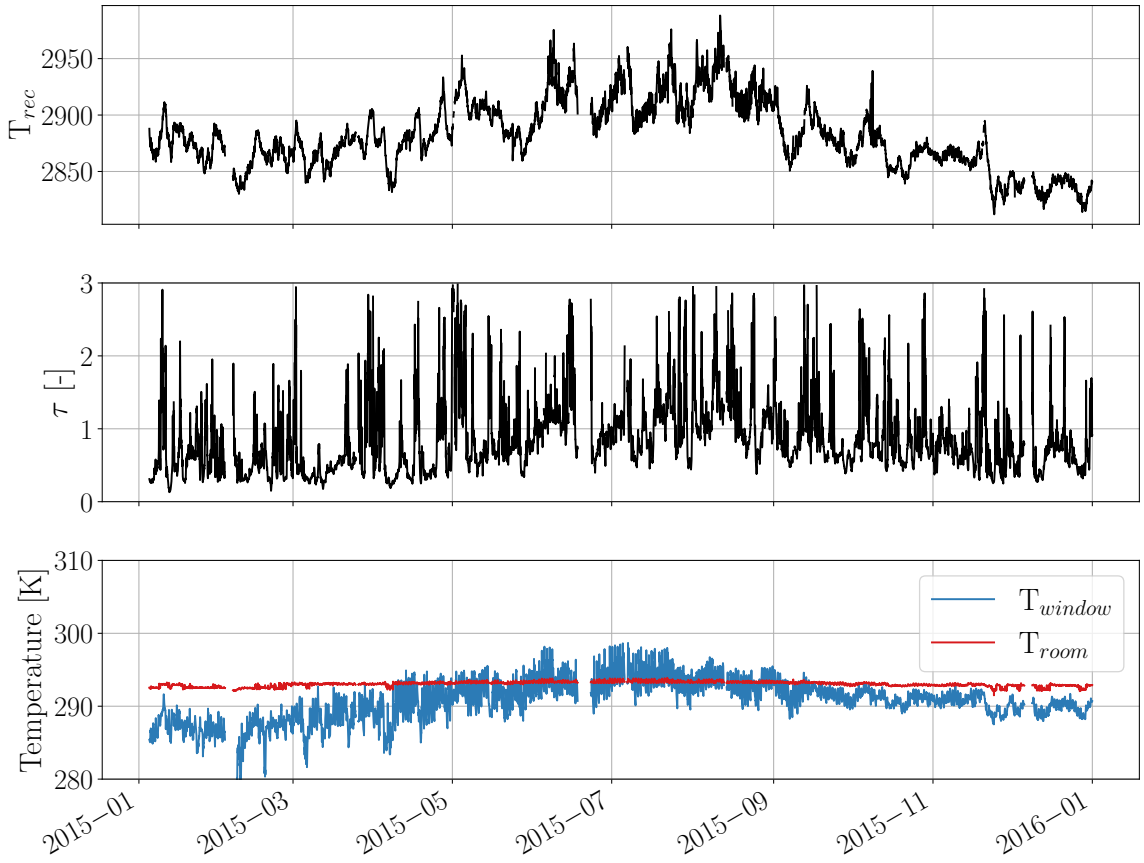


Figure 4.46: SOMORA, 2015

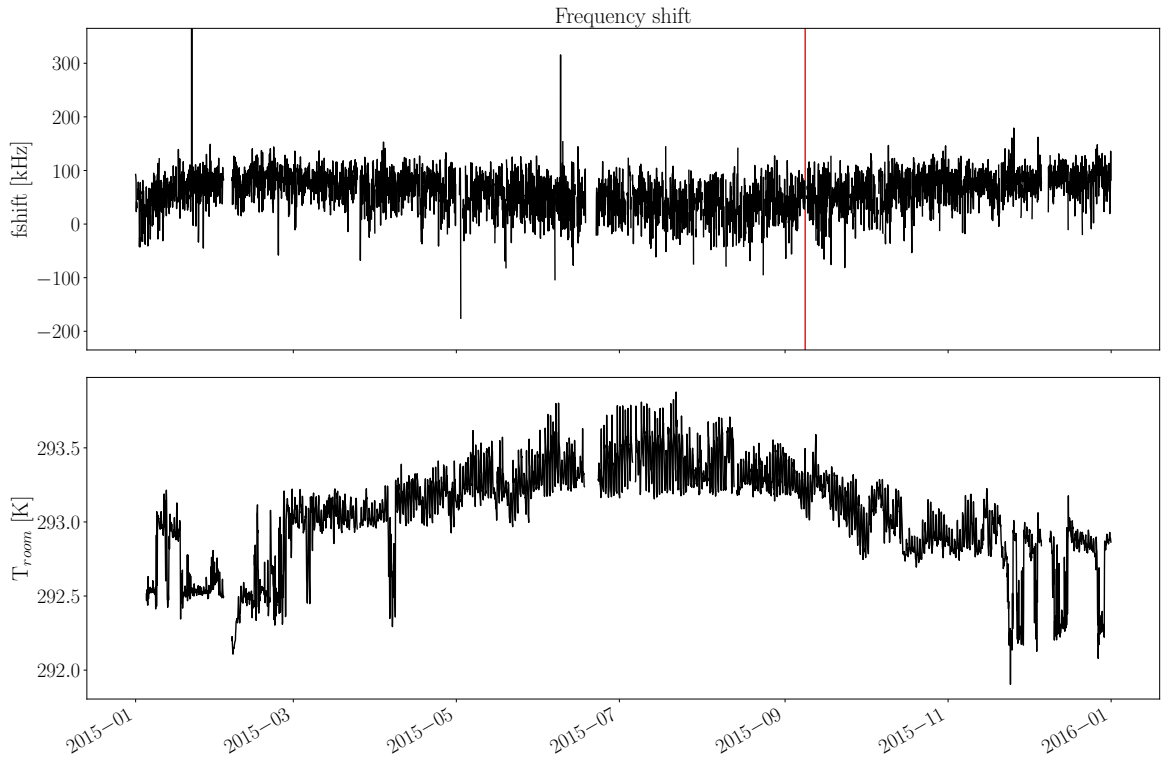


Figure 4.47: SOMORA, 2015

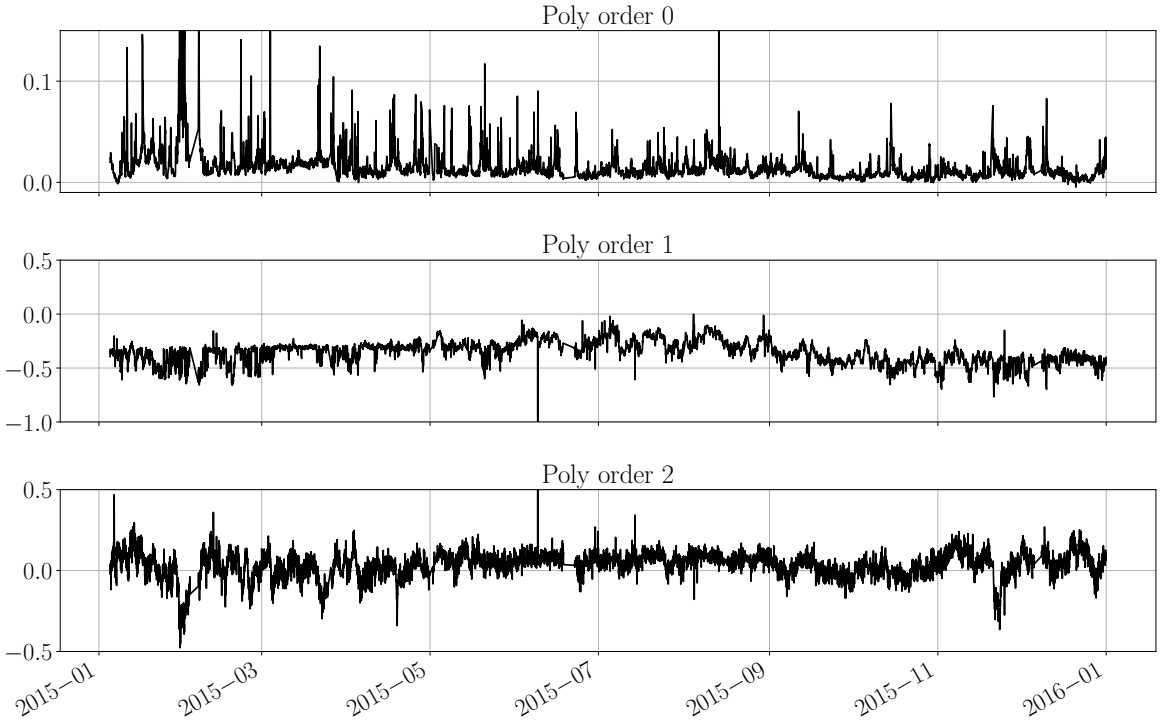


Figure 4.48: SOMORA, 2015

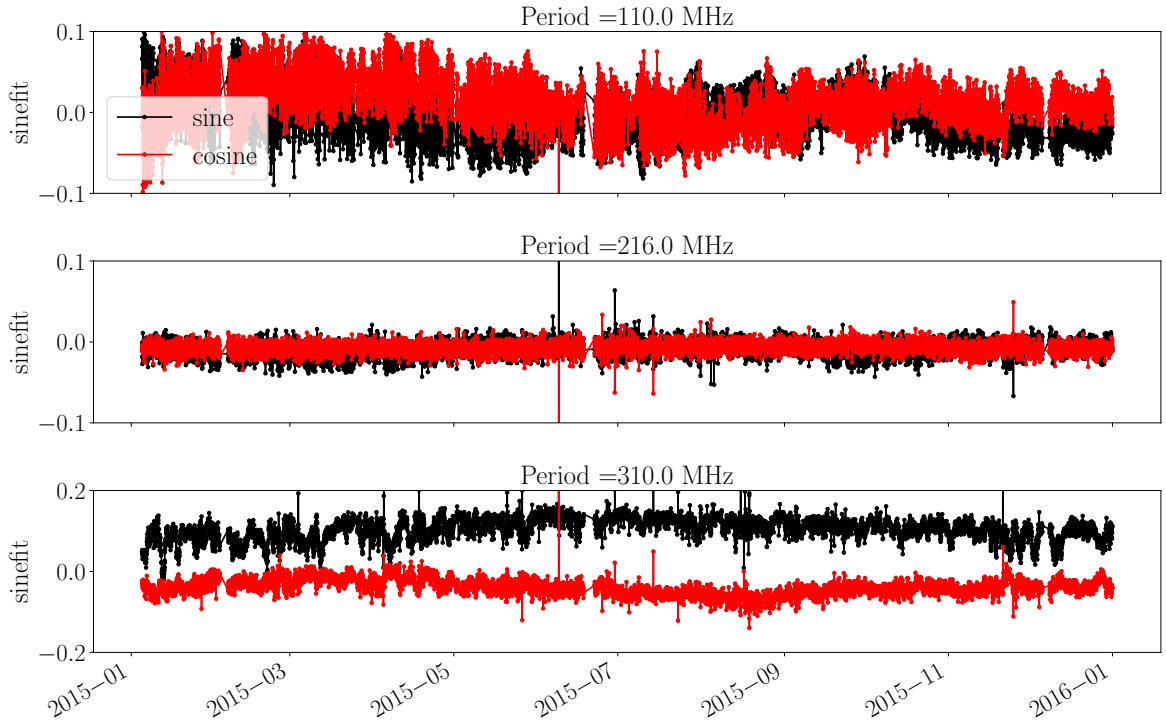


Figure 4.49: SOMORA, 2015

2016

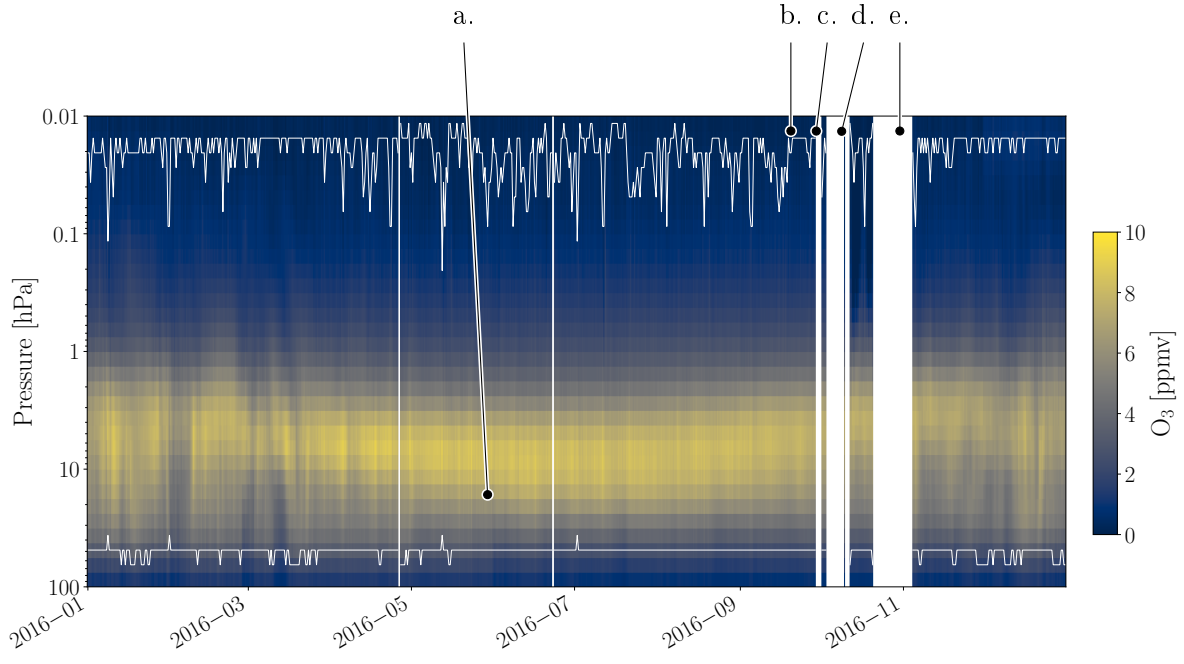


Figure 4.50: SOMORA, 2016

a. 24.05.15: Trec fluctuations and peak of Trec after every LN2 refill. Cleaning of the cold load and change of load cover on this day which we can notice on the ozone time series. It also ends the periods of variable sine baseline retrievals (Fig. 4.56).

b. 22.09.16: cleaning of the cold load, no noticeable effect on time series.

c. 29.09.16: begin of lock errors accompanied by a jump of Trec of $\approx$ 200 K.

d. 29.09-10.10.16: lock erros on most days in this periods. Some retrievals worked but the whole period is now flagged. On 10.10, some hardwares changes solved the lock errors until 20.10.

e. 20.10-03.11.16: some more lock problems which were finally solved on 04.11 after the front-end was sent at IAP for hardware upgrade. As a result, the whole period 29.09-03.11.16 is flagged.

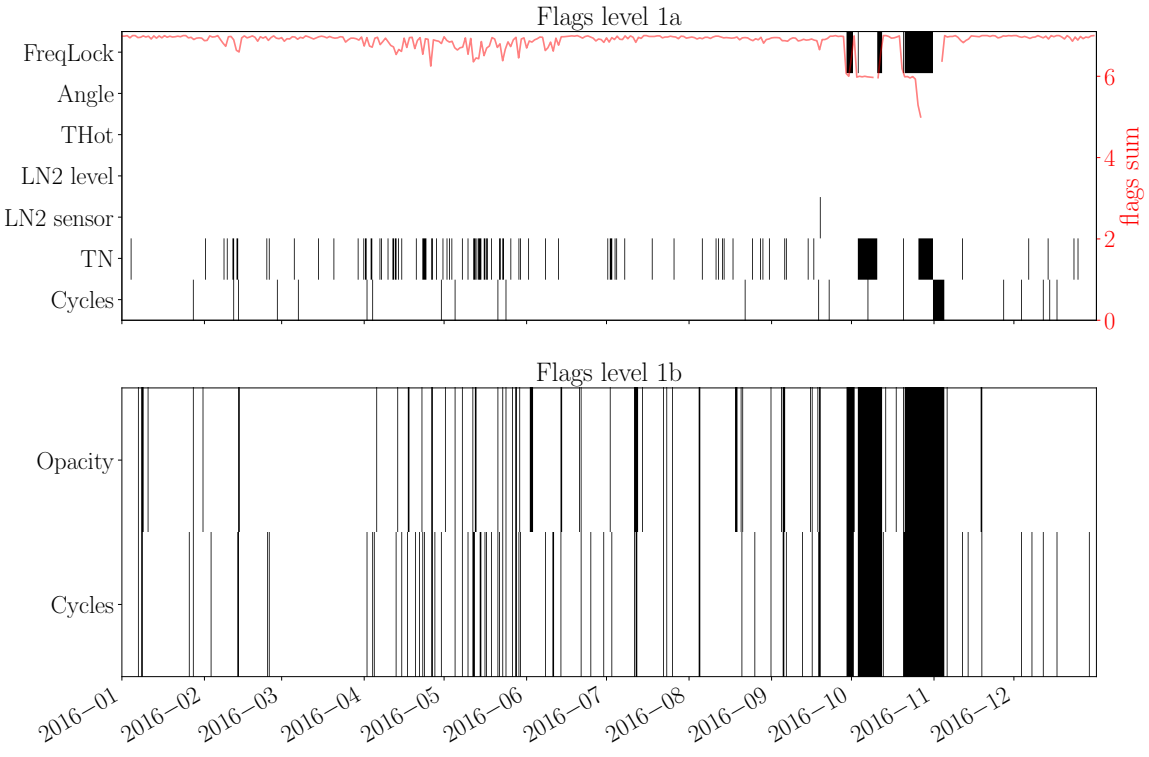


Figure 4.51: SOMORA, 2016

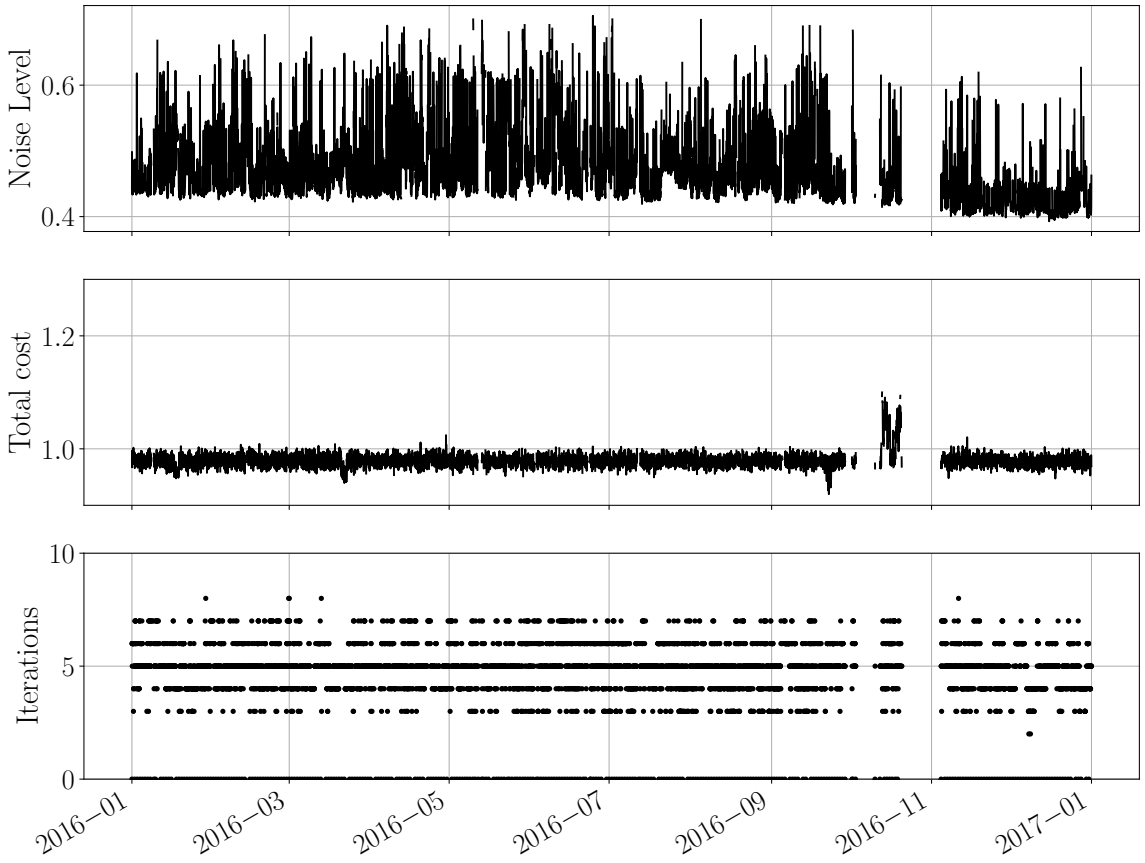


Figure 4.52: SOMORA, 2016

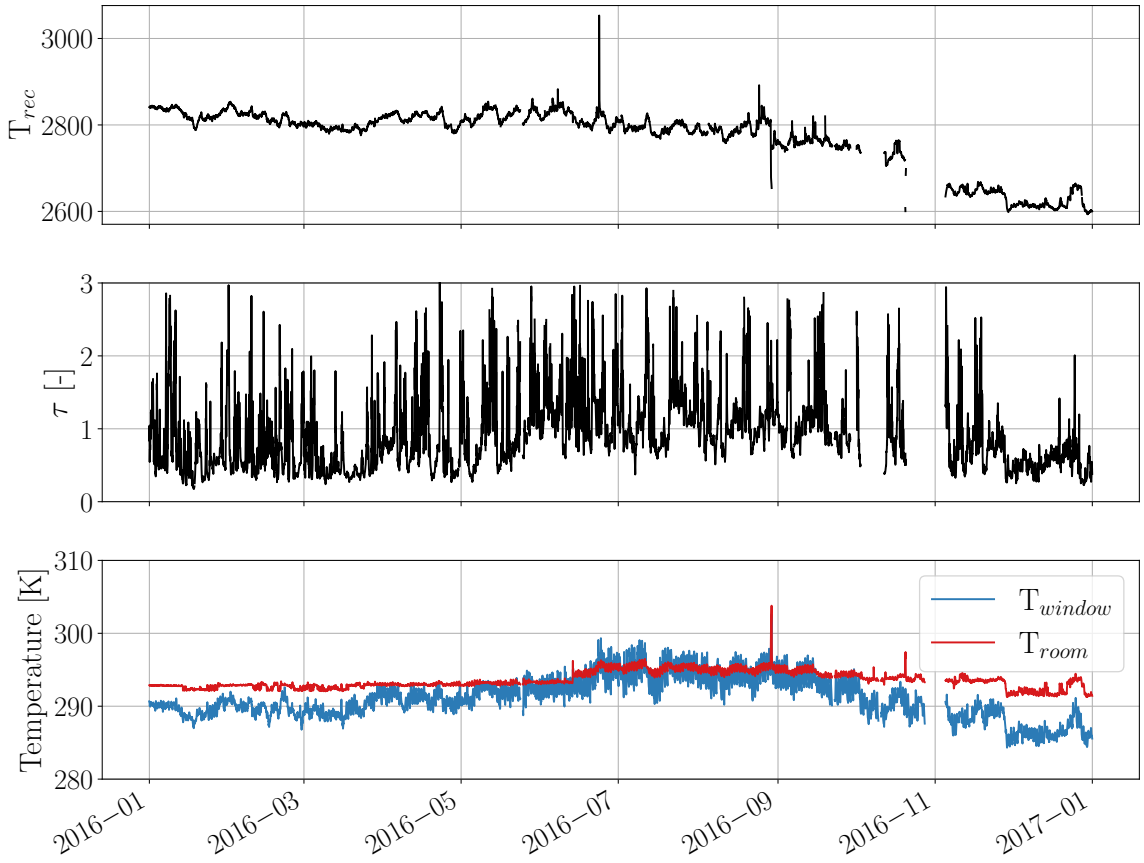


Figure 4.53: SOMORA, 2016

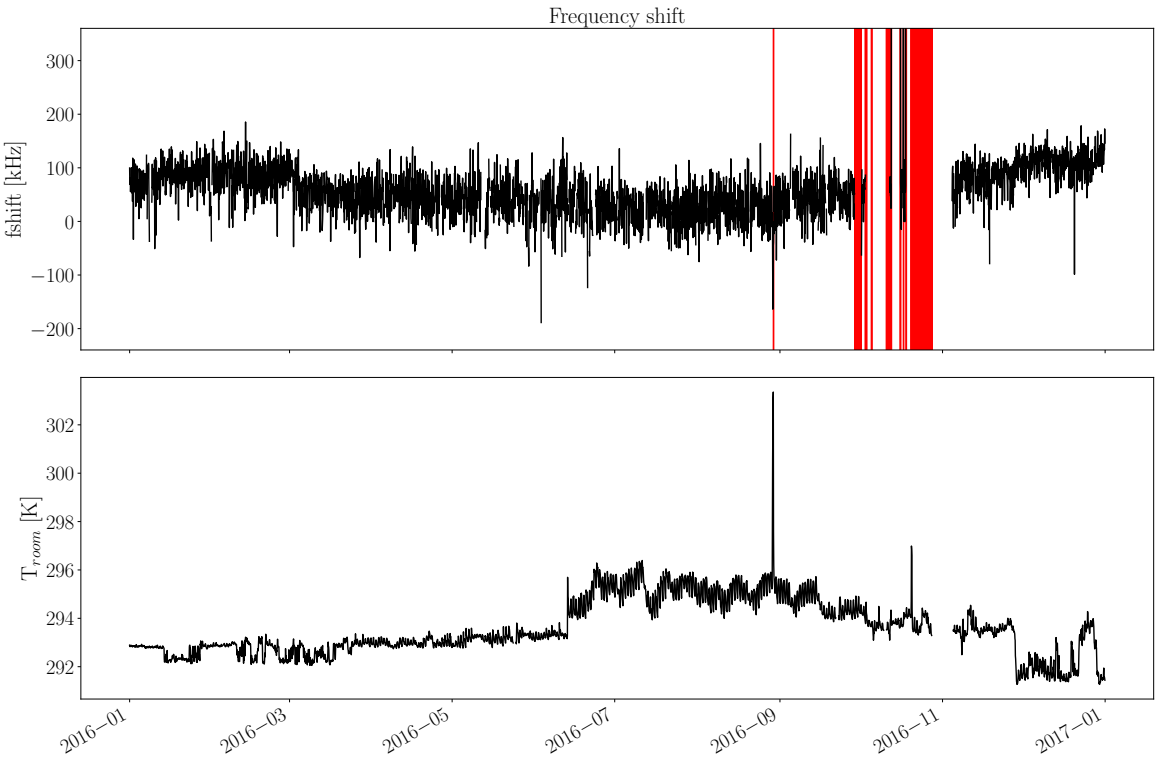


Figure 4.54: SOMORA, 2016

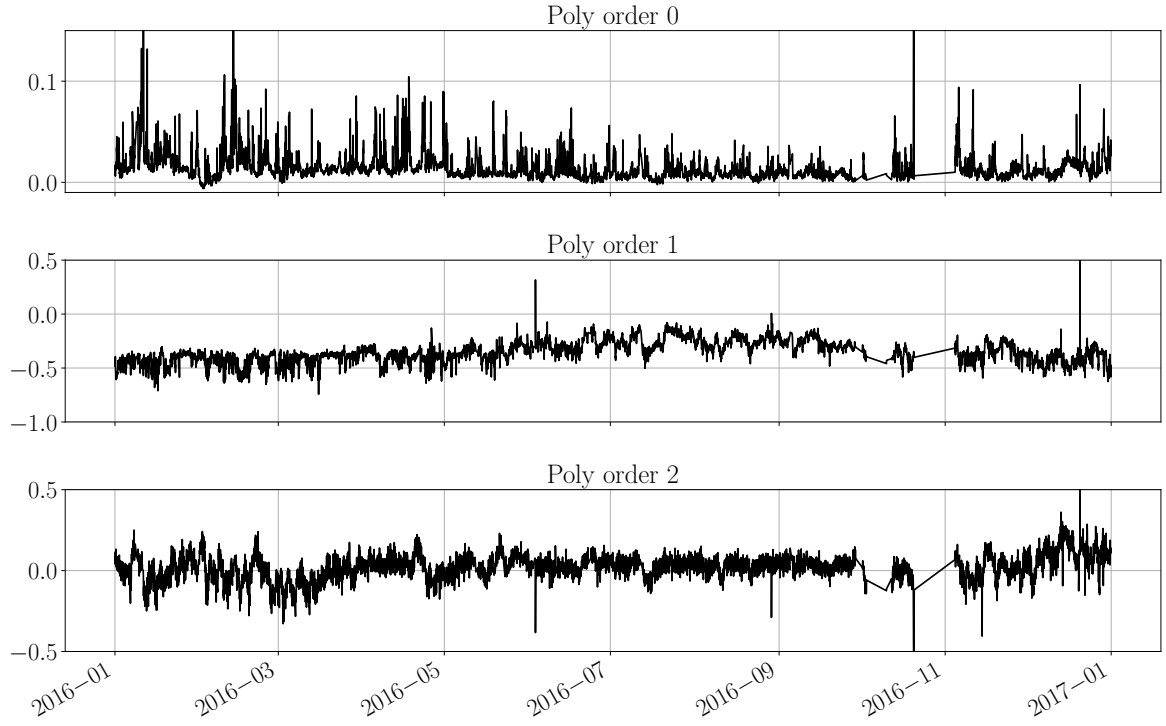


Figure 4.55: SOMORA, 2016

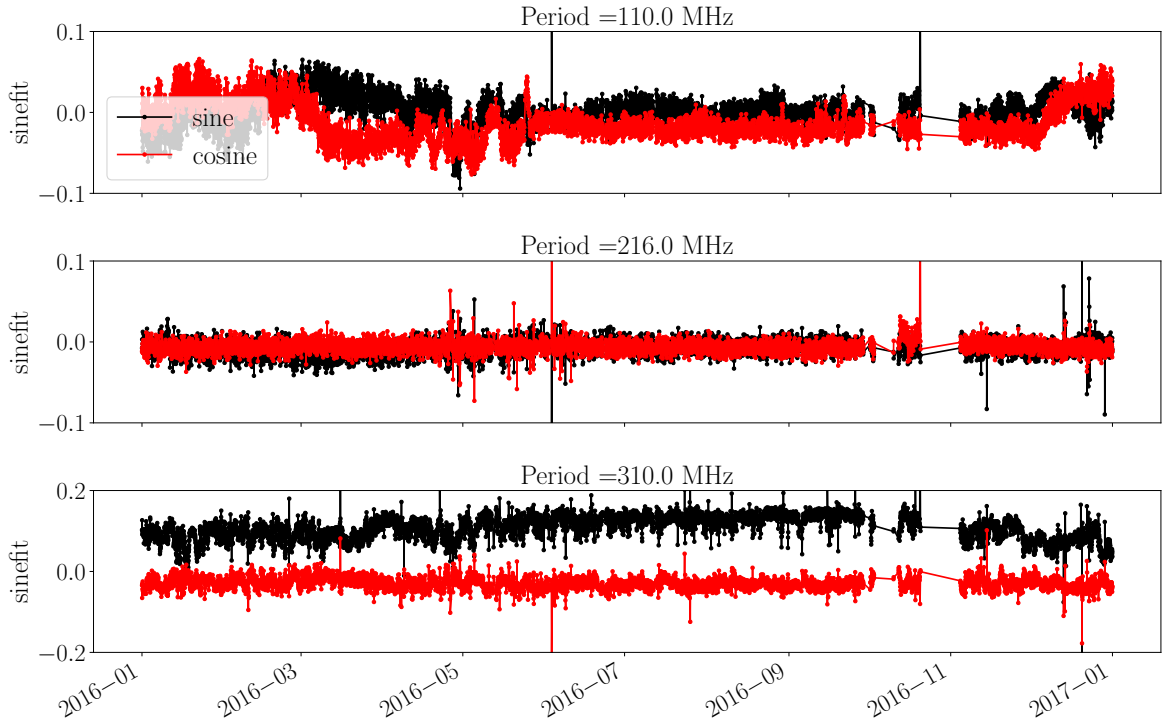


Figure 4.56: SOMORA, 2016

2017

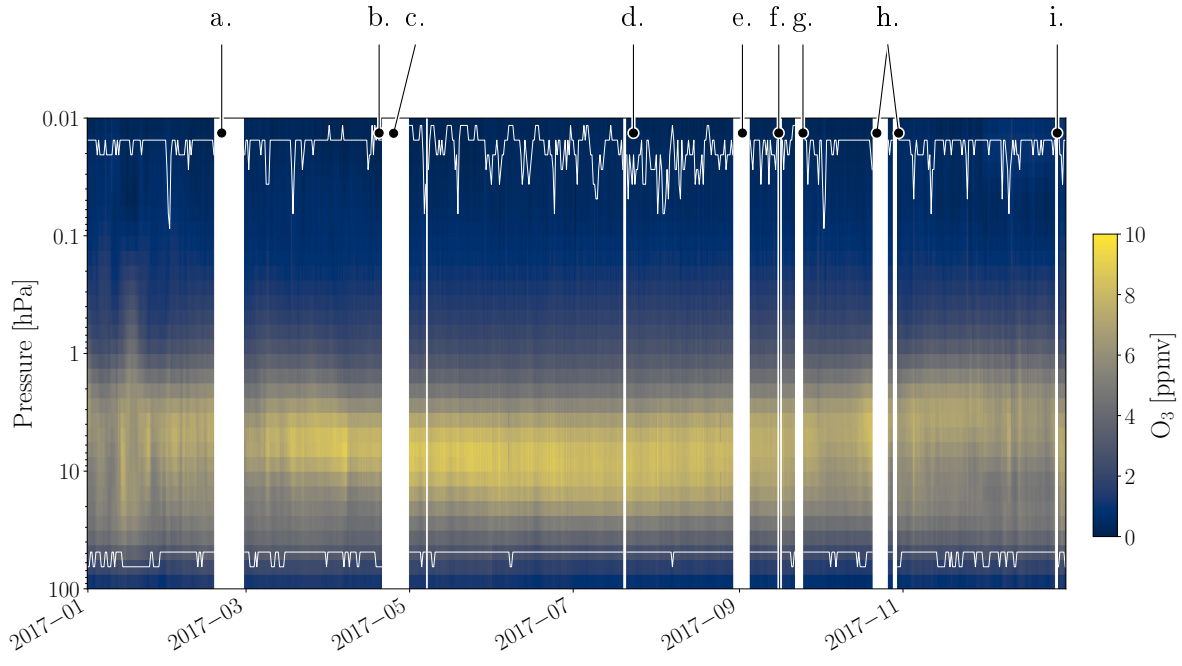


Figure 4.57: SOMORA, 2017

a. 17-28.02.17: hot load problem -> no data during this period. It also marks the end of the blowers problem on the hot load which lasted since 24.05.15. After the Note that Trec stayed very low until 08.03 after some change in water cooling temperature (Fig. 4.60) and then went back to normal. On 08.03, Thot also went back to normal (311 K) after 2 years of being around 297 K.

b. 21-23.04.17: no FFTS raw data

c. 20.04-01.05: LN2 empty due to delivery default -> no data during this period.

d. 20.07.17: unknown problem during calibration.

e. 30.08-05.09.17: alimentation problem, no FFTS raw data. On 05.09, cleaning of the cold load.

f. 14-16.09.17: very high Trec fluctuations, unknown reason.

g. 22-24.09.17: LN2 empty

h. 20-26.10.17 and 28-30.10.17: LN2 empty

i. 27-29.12.17: LN2 empty

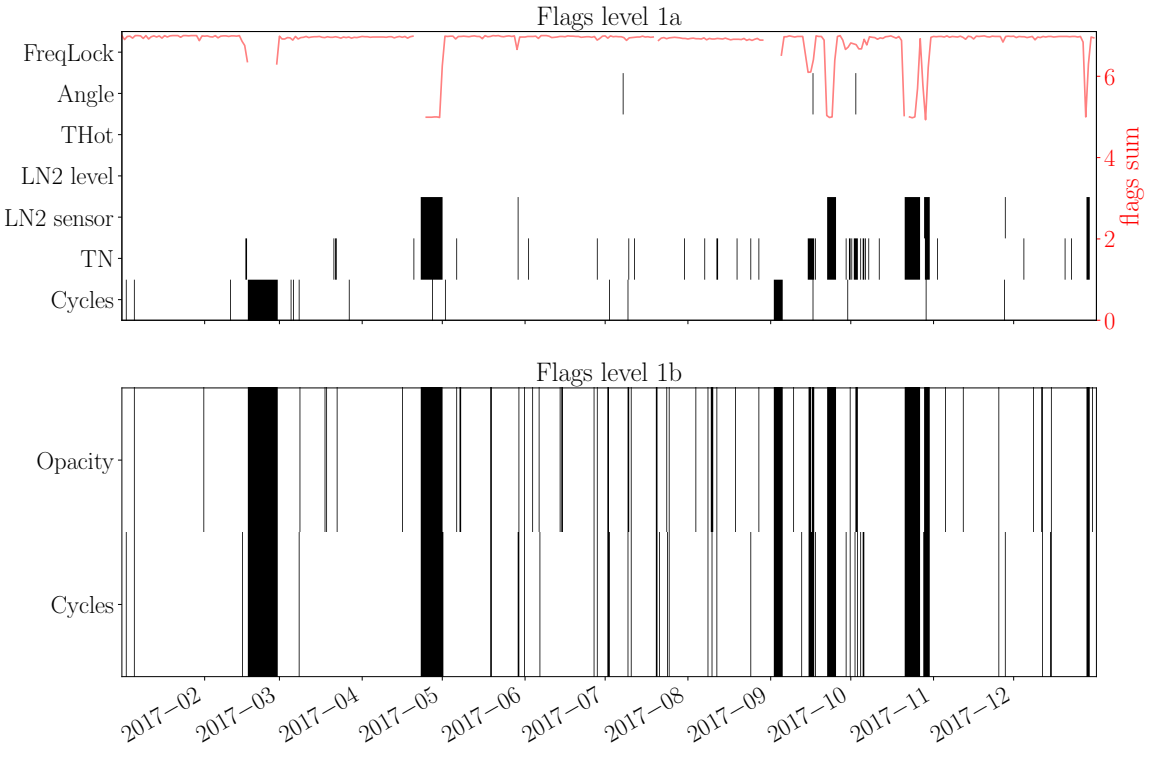


Figure 4.58: SOMORA, 2017

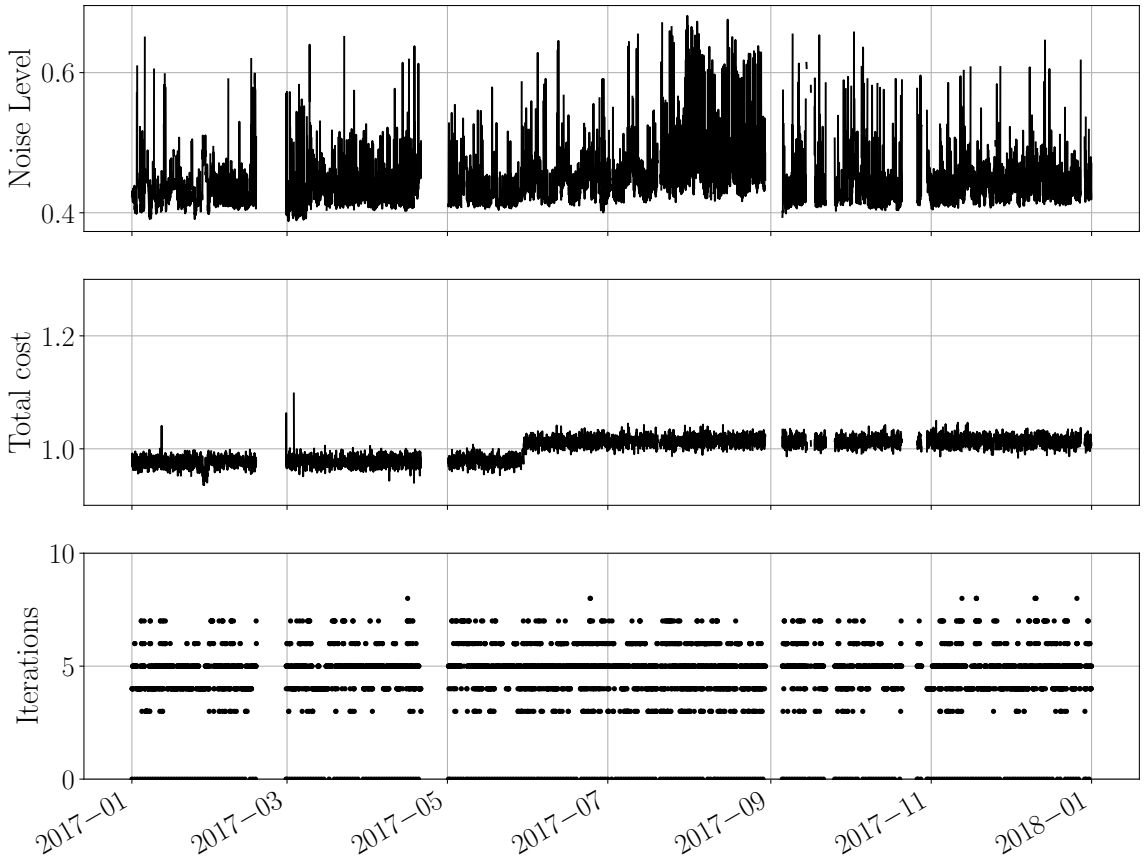


Figure 4.59: SOMORA, 2017

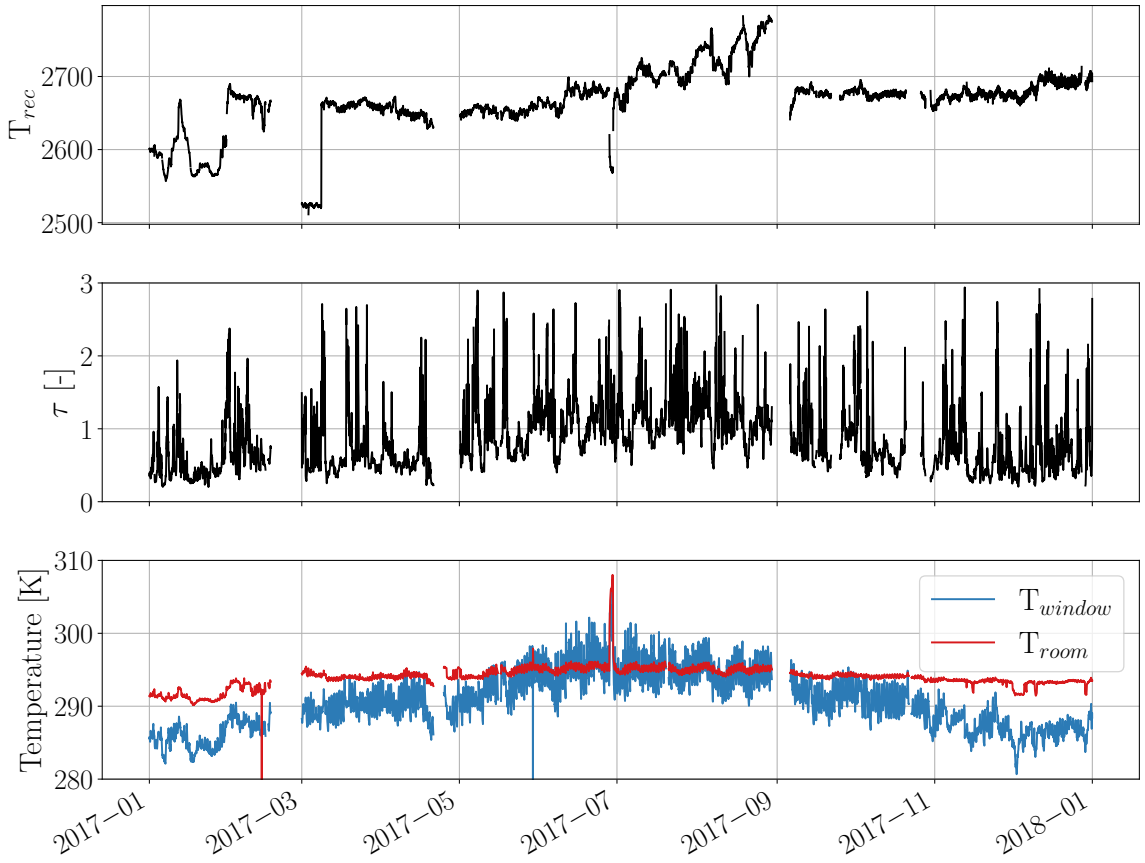


Figure 4.60: SOMORA, 2017

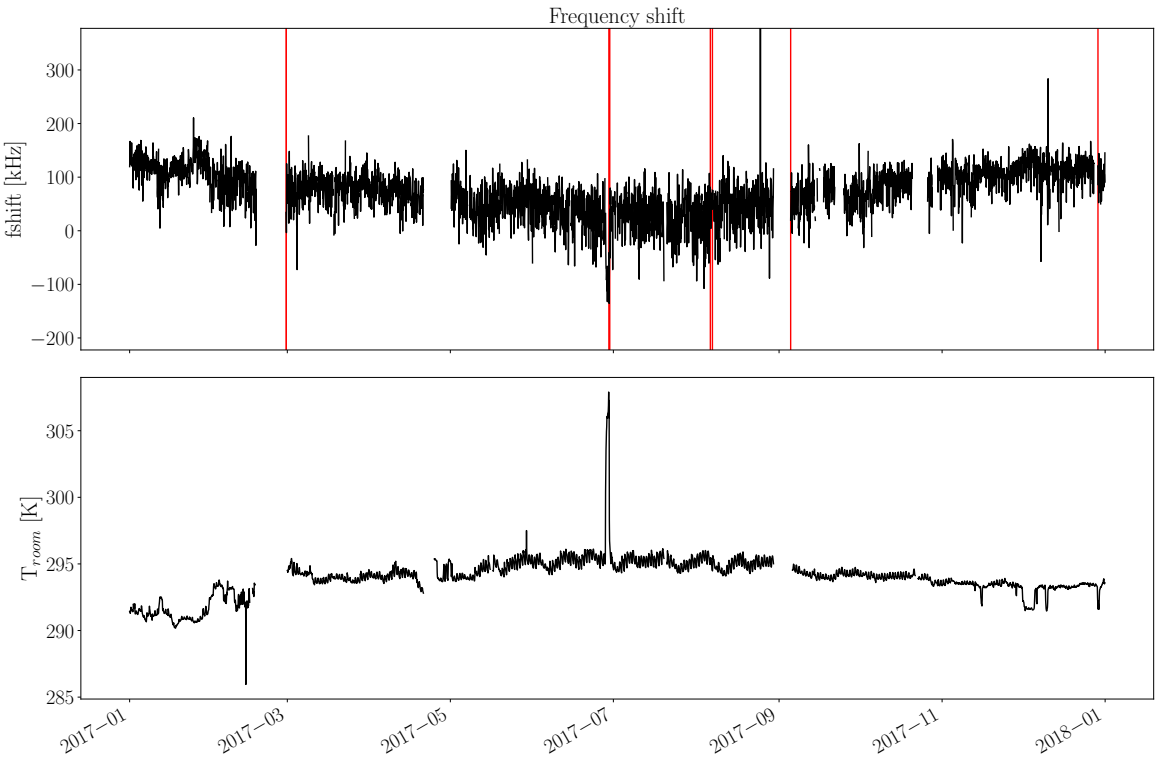


Figure 4.61: SOMORA, 2017

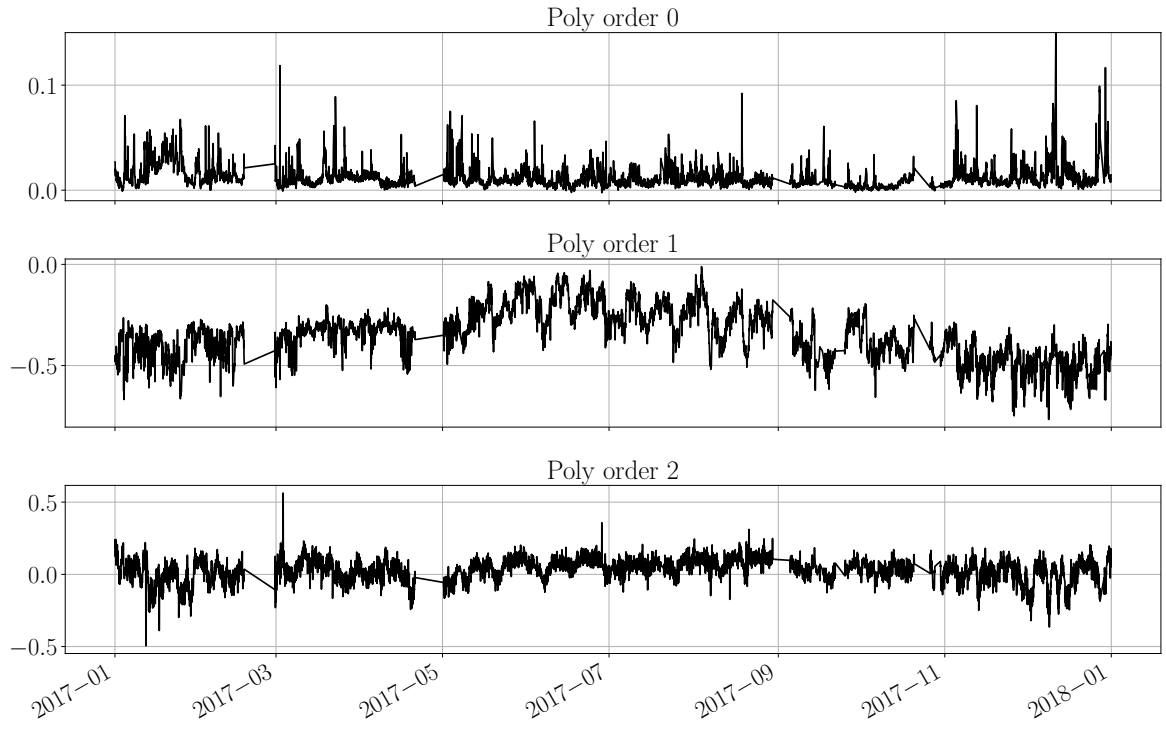


Figure 4.62: SOMORA, 2017

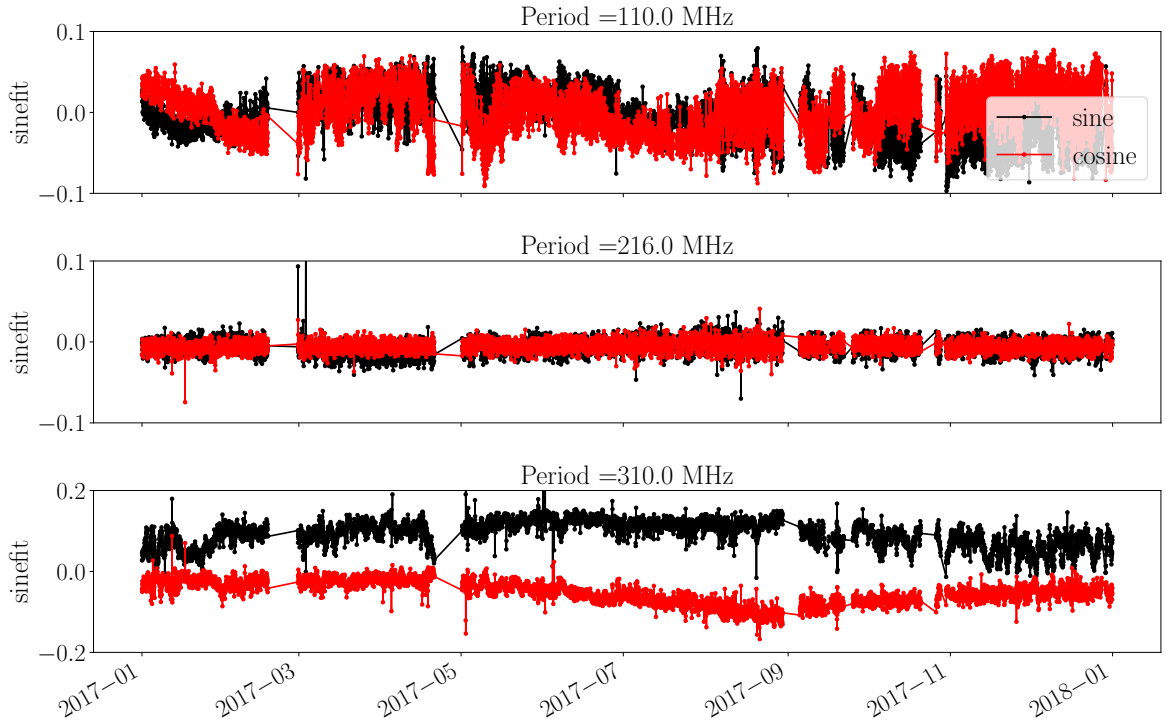


Figure 4.63: SOMORA, 2017

2018

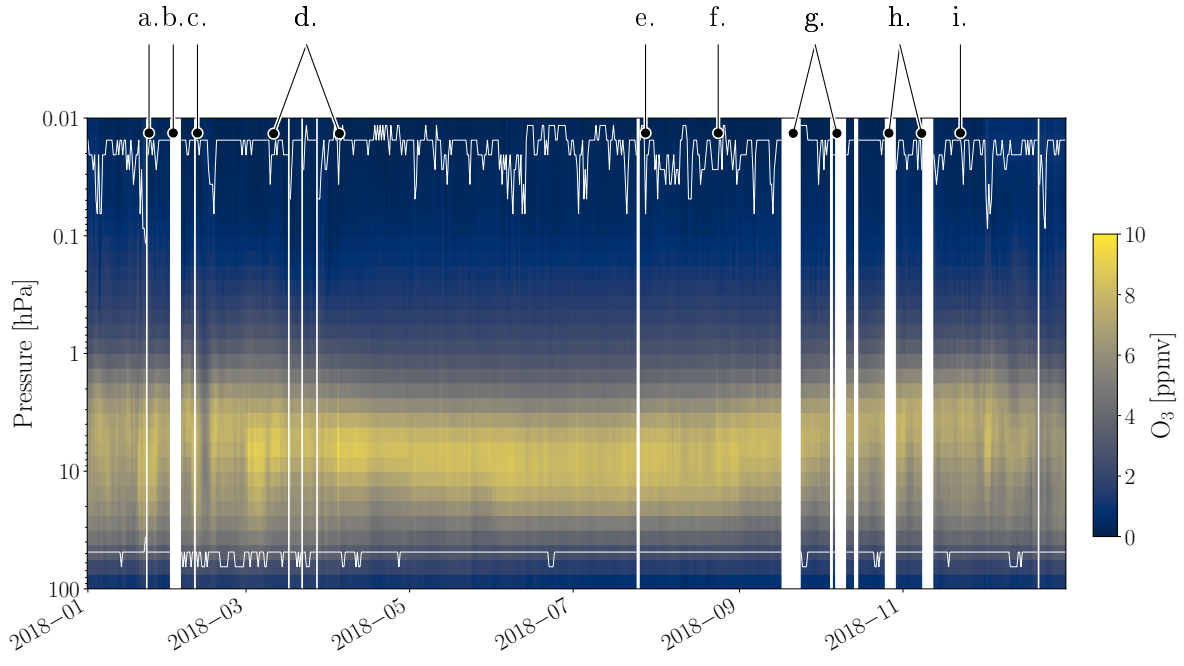


Figure 4.64: SOMORA, 2018

a. 15.01.18: climatisation problem

b. 31.01-06.02.18: LN2 empty

c. 05-11.02.18: Trec fluctuations quite high (unknown reasons). This entire period is therefore flagged in L2 data.

d. 14.03-06.04.18: high Trec fluctuations (seems to be due to cold load)

e. 25-26.07.18: main climatisation out of order -> peak in Troom which also induced some lock errors (Fig. 4.68). Troom remained unstable for some weeks.

f. 23.08.18: cleaning of the cold load. It resulted in a big jump of Trec (−250 K) and ends a period of strong disturbances on Trec and baselines that started around July 18. It is difficult to put a starting data on this event but to avoid removing too much good data, the L2 data are flagged between 25.07 to 23.08.

g. 17-24.09.18 and 13-15.10.18: measurement interruptions because of acquisition software -> no FFTS raw data.

h. 25-29.10.18 and 08-11.11.18: LN2 empty

i. 19.11-21.11.18: LN2 empty event on 19.11 that lead to jump in Trec (−50 K) and counts until 21.11.

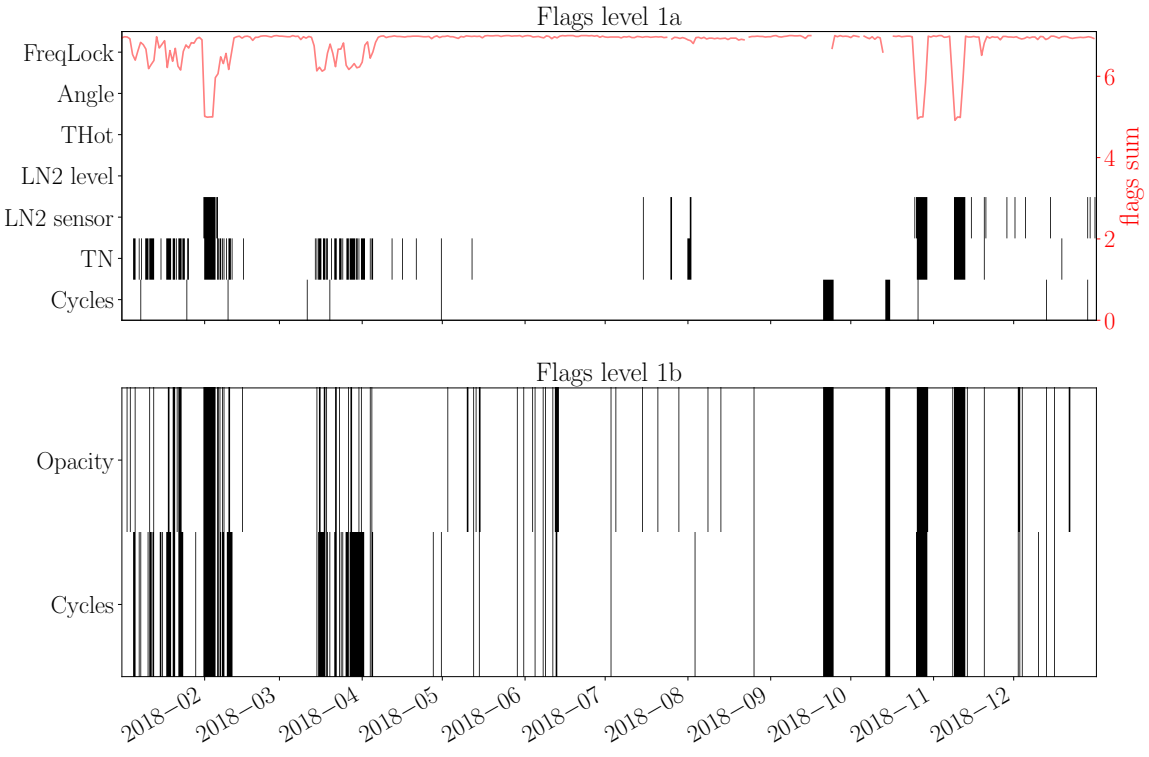


Figure 4.65: SOMORA, 2018

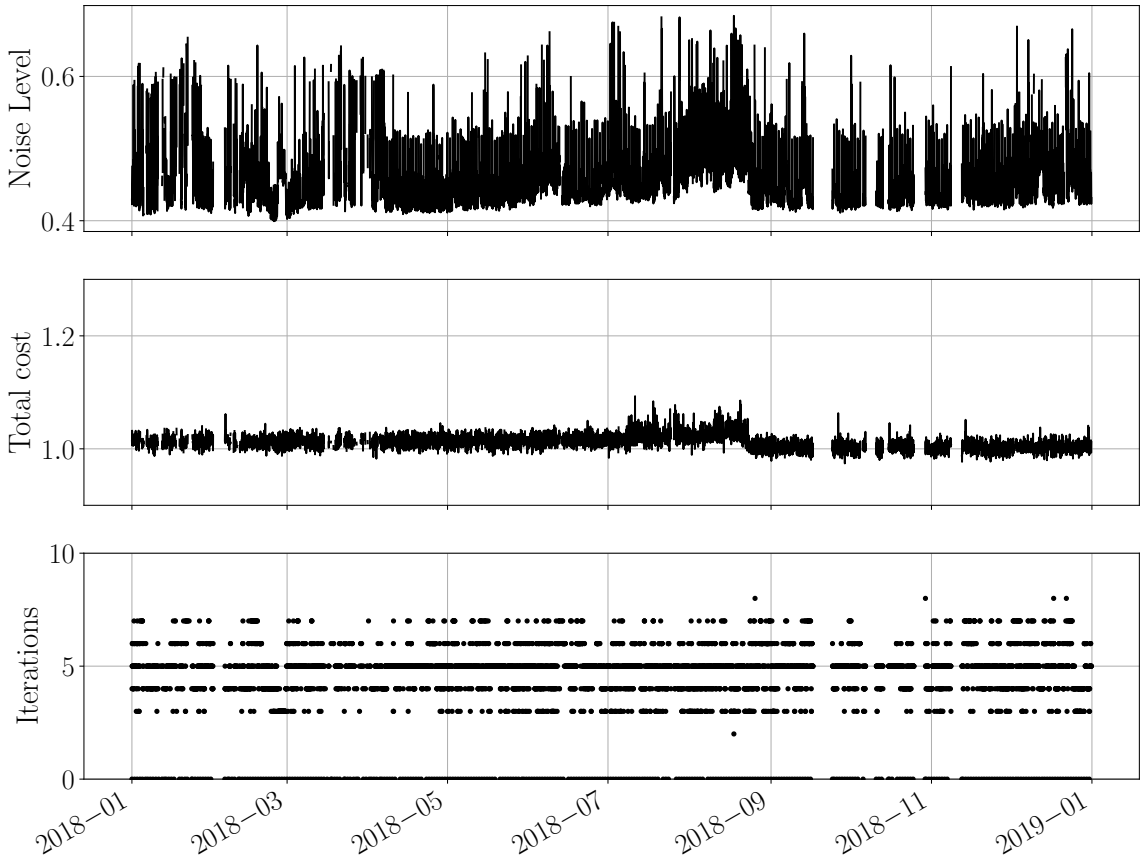


Figure 4.66: SOMORA, 2018

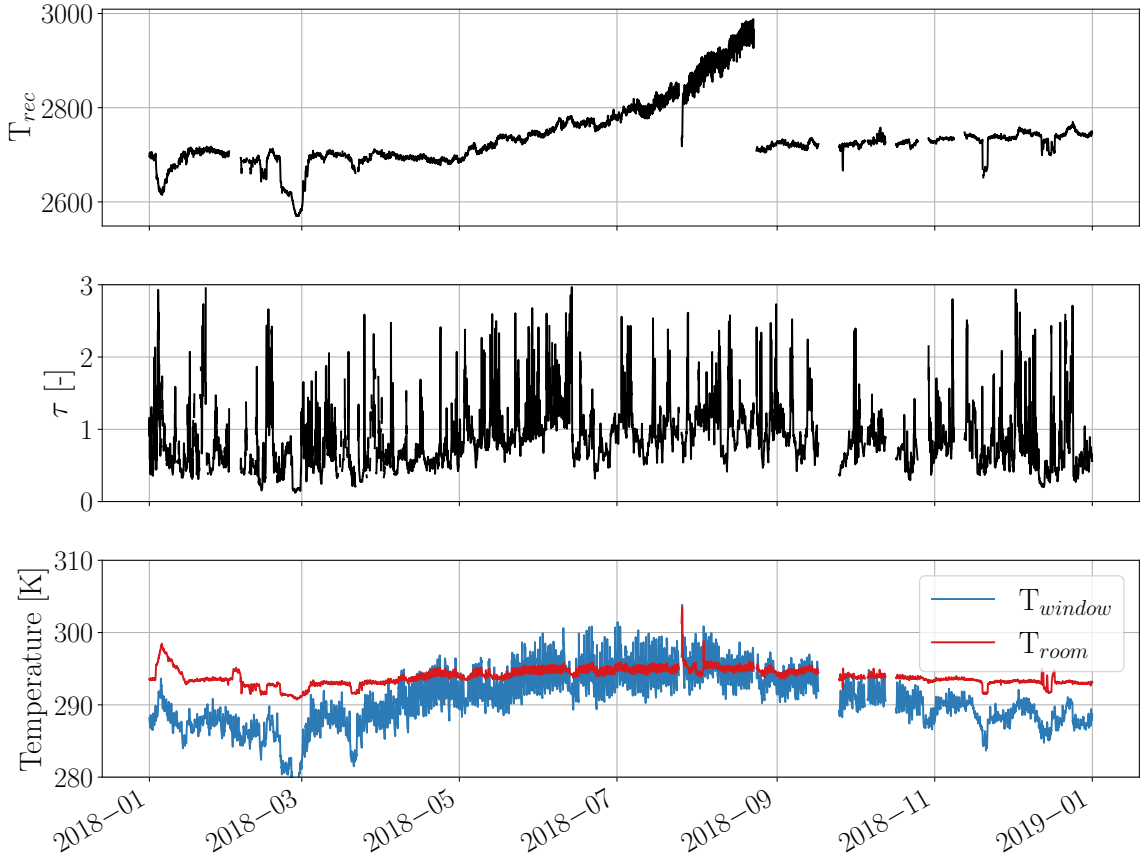


Figure 4.67: SOMORA, 2018

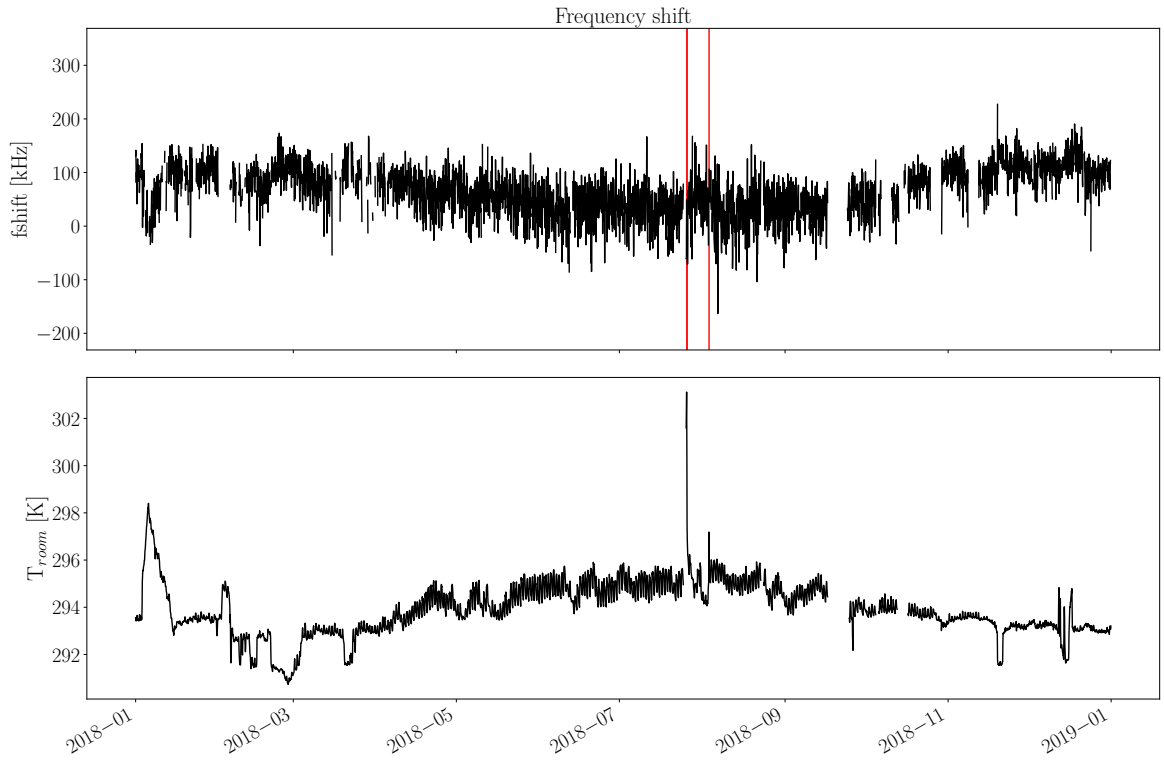


Figure 4.68: SOMORA, 2018

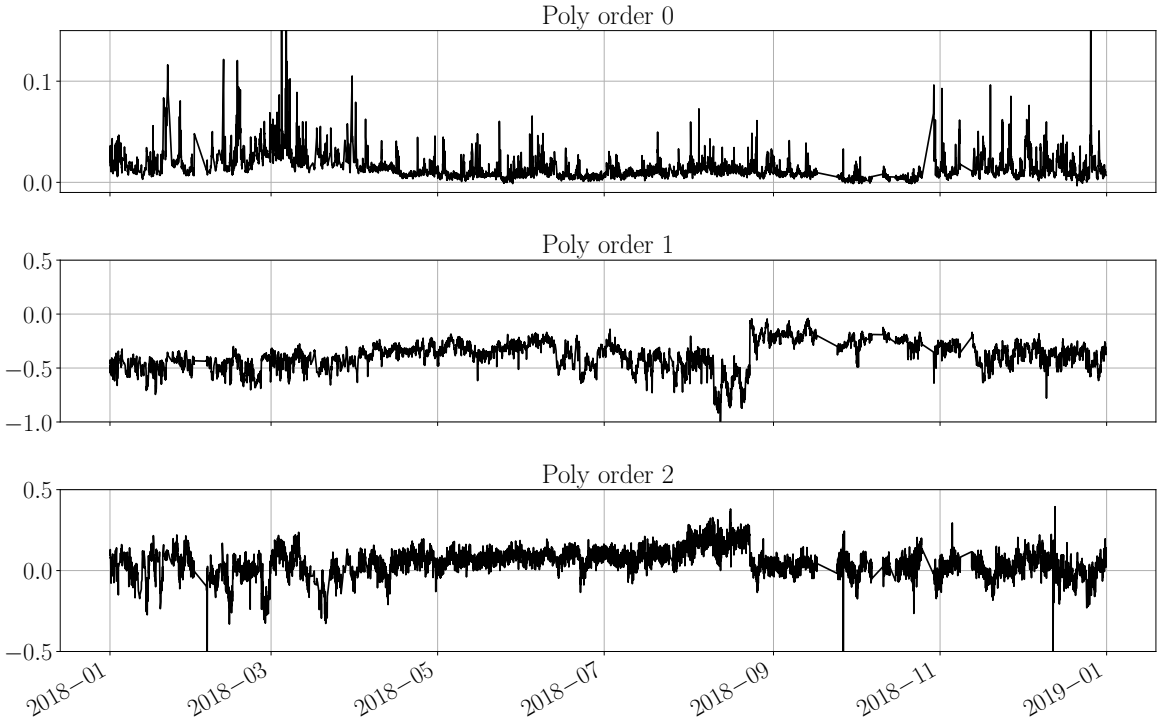


Figure 4.69: SOMORA, 2018

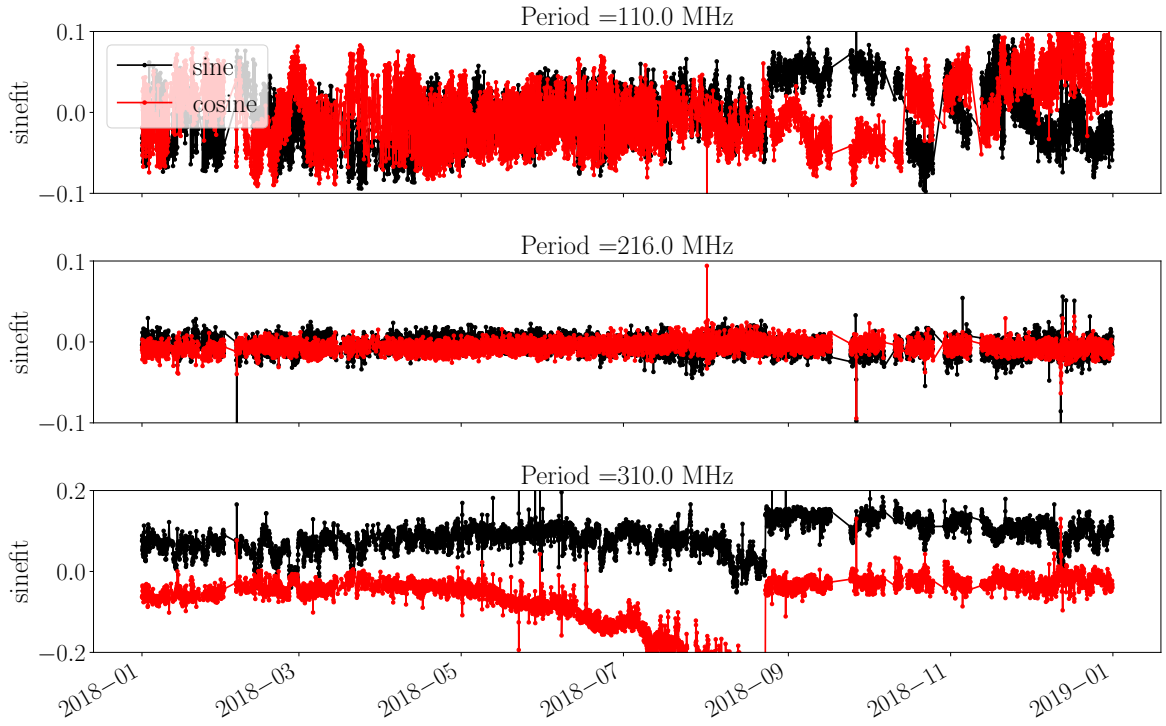


Figure 4.70: SOMORA, 2018

2019

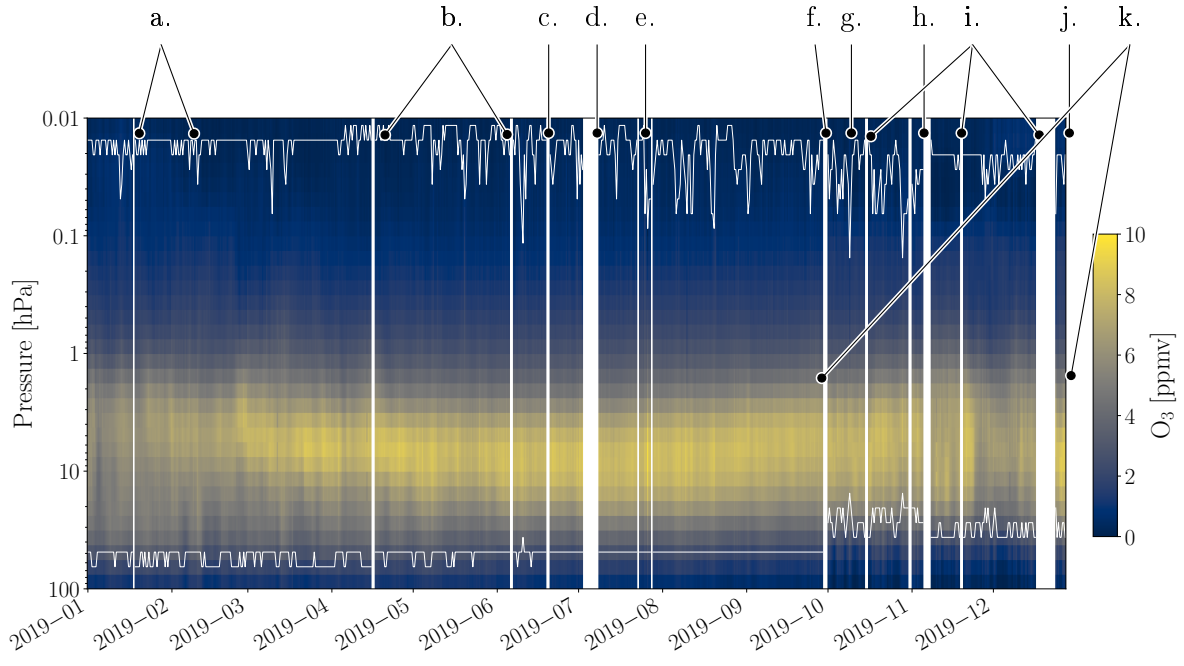


Figure 4.71: SOMORA, 2019

a. 17-18.01 and 25-26.02.19: LN2 empty and THot unstable on 25.02.

b. 16.04.19: unknown calibration problem

c. 18-20.06.19: LN2 empty and change in climatisation.

d. 02-08.07.19: LN2 empty and cleaning of the cold load on 15.07.

e. 22-23.07.19: LN2 empty followed by a gently increase in Trec remaining until the end of the year.

f. 27.09.19: cleaning of the cold load producing a small jump in Trec (Fig. 4.74). It marks the start of the problematic end-of-2019 period for SOMORA. Some features that can be seen on the plots later on are big baselines changes (polynomial and sinusodial)

g. 29.09-01.10.19: problem with the mirror.

h. 05-08.11.19: on 05.11 change of baseband converter attenuator resulting in a jump of Trec (+50 K) and counts ($x4$). It was reverted on the 08.11 but the data in this period are flagged.

i. 14-16.10.19, 18-19.11.19 and 16-24.12: LN2 empty. On 13-14.11.19, some hardware changes on the LN2 valves which lead to more Trec fluctuations at LN2 refill but faster recovery to stable position. This resulted in many "Relay open time overflow" flags so the threshold for this value was changed on 06.12.19 but this remained essentially until January 20.

j. 27.12.19-07.01.20: problems with the mirror, no good measurement for this period.

k. 27.09-31.12.19: in general, this whole period should be treated with care. There were many problems mostly related with the cold load or the mirror which resulted in significant changes in instrumental baseline. There are no L2 flags for this period but many missing data due to instrumental problems or retrieval failure.

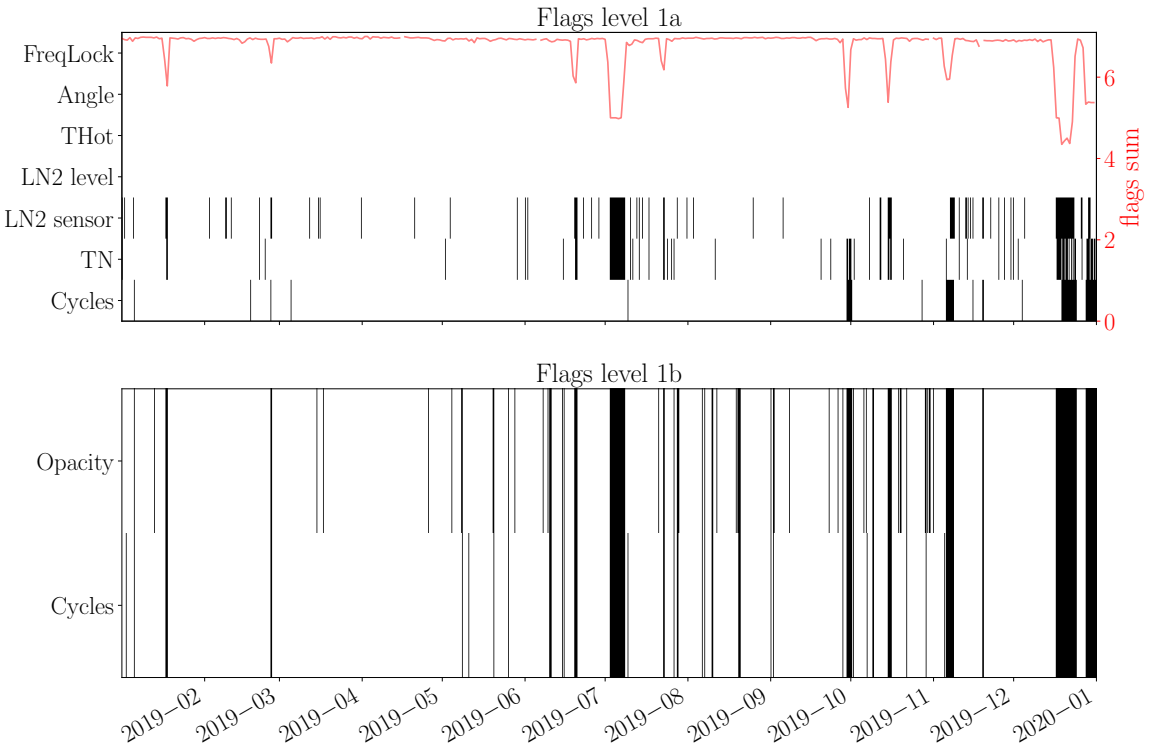


Figure 4.72: SOMORA, 2019

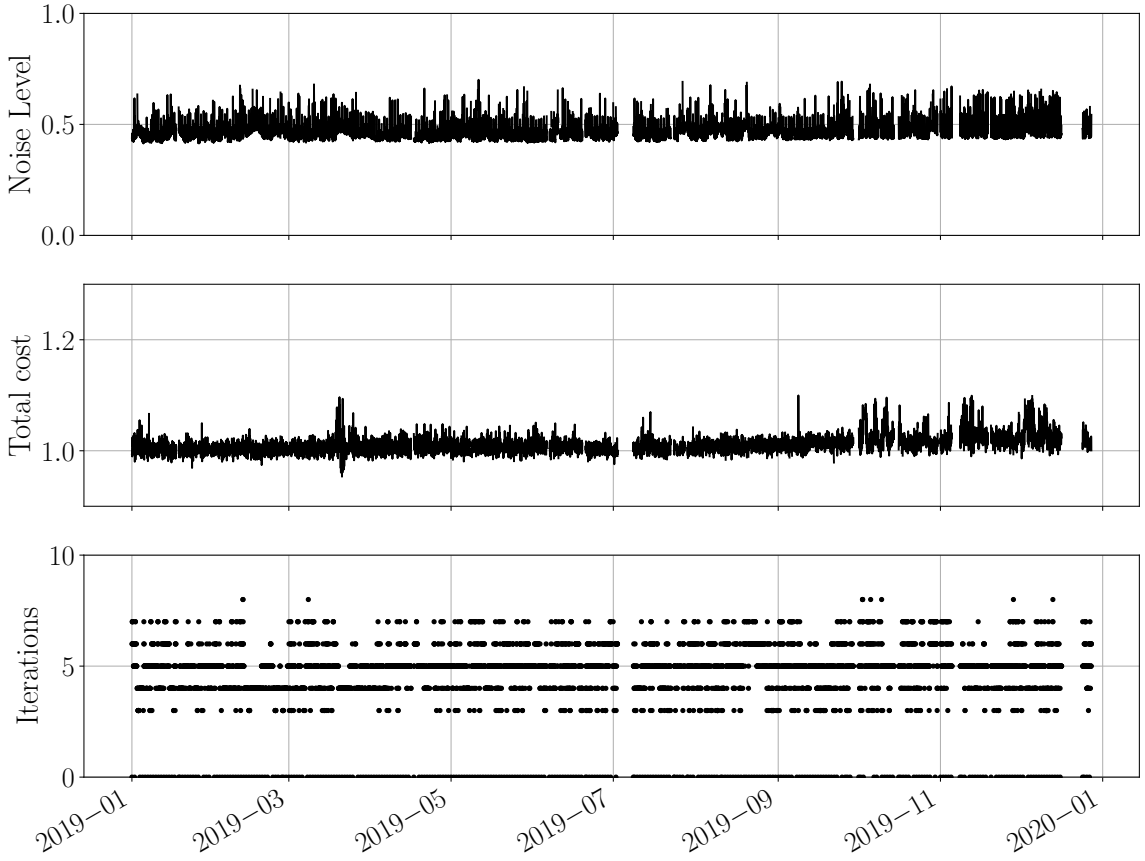


Figure 4.73: SOMORA, 2019

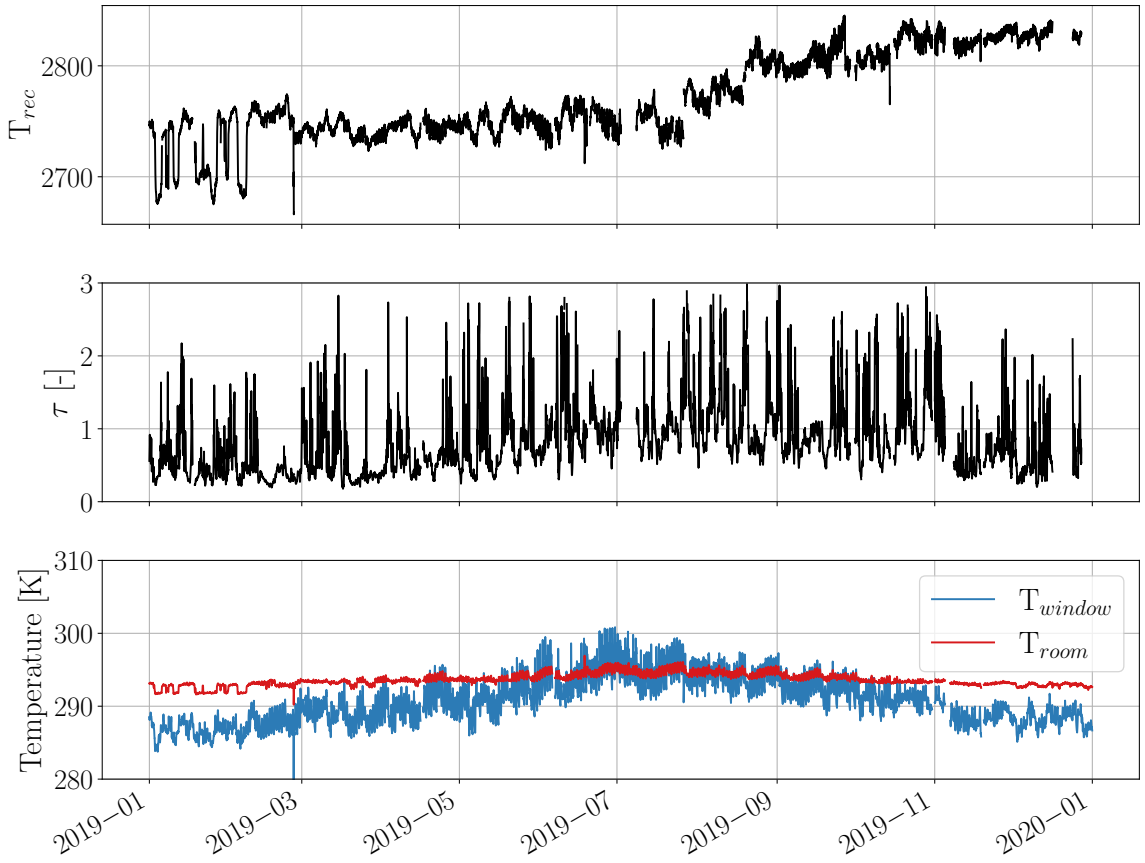


Figure 4.74: SOMORA, 2019

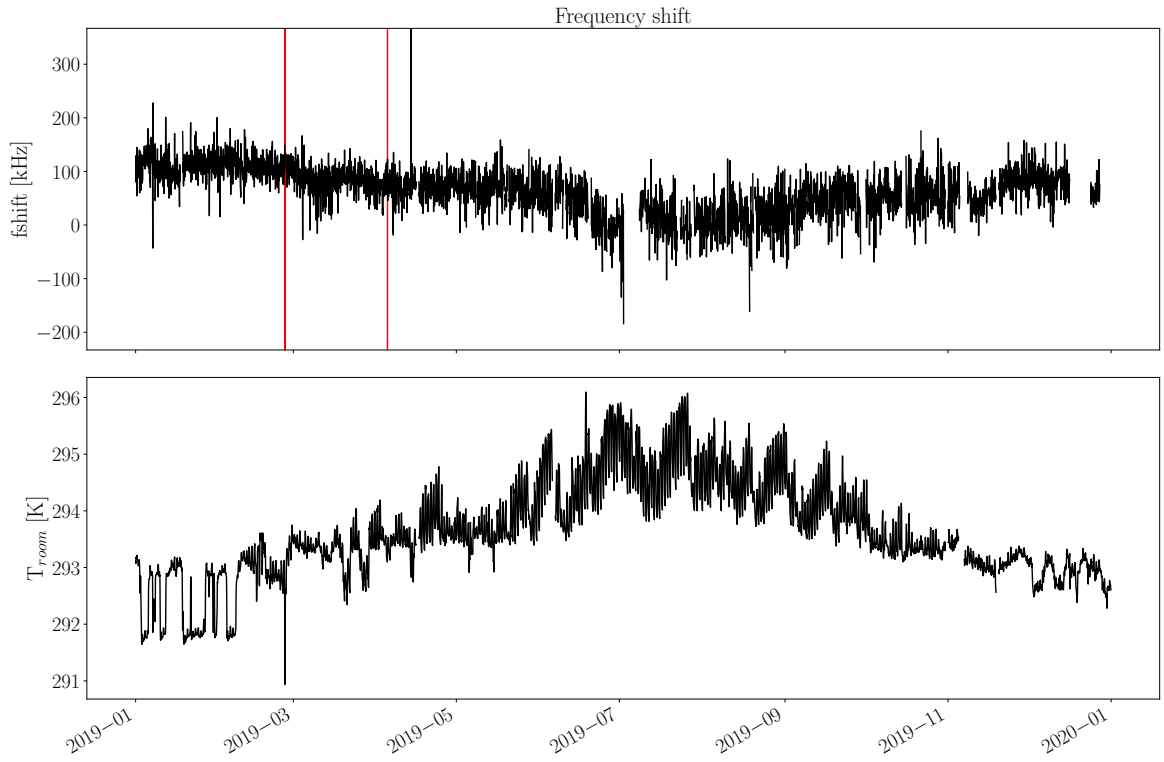


Figure 4.75: SOMORA, 2019

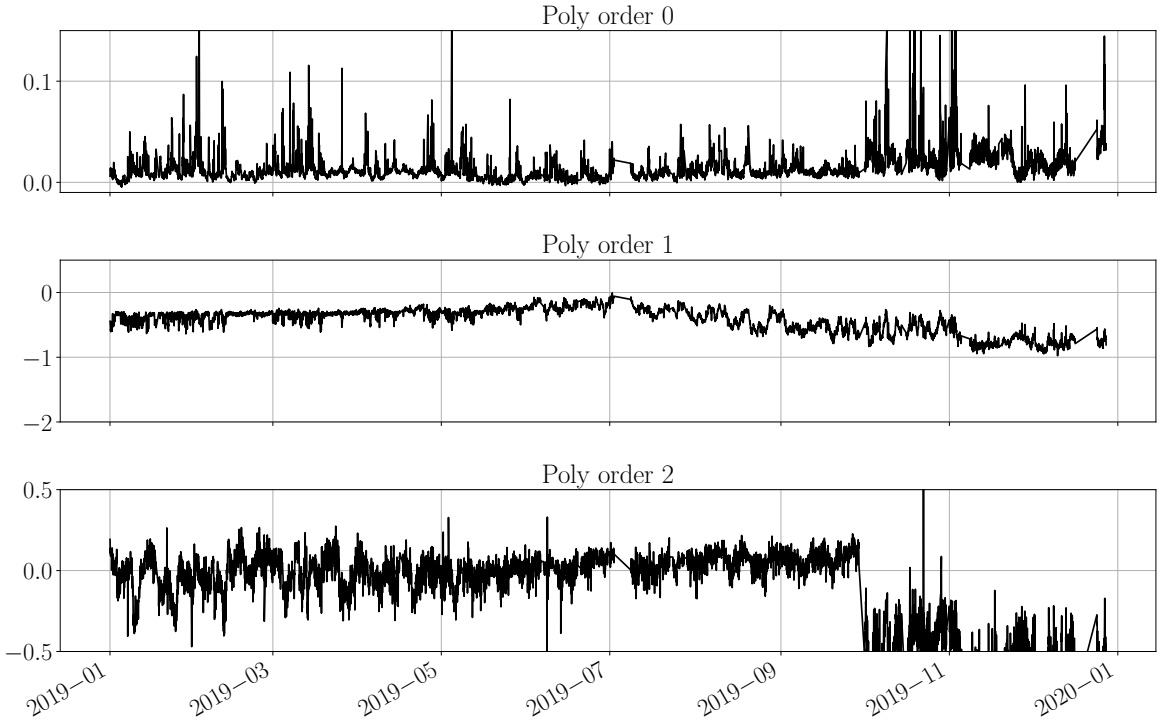


Figure 4.76: SOMORA, 2019

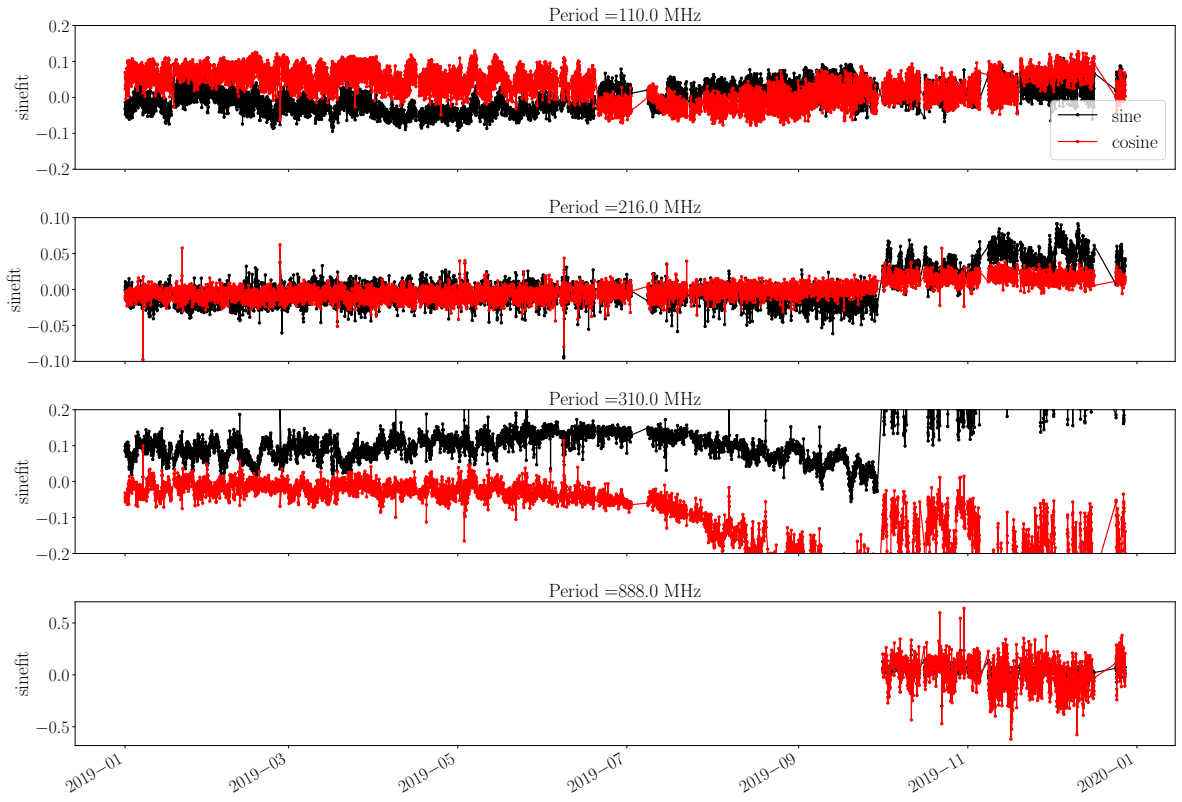


Figure 4.77: SOMORA, 2019

2020

This year was marked by significant hardware problem on SOMORA that began in September 2019.

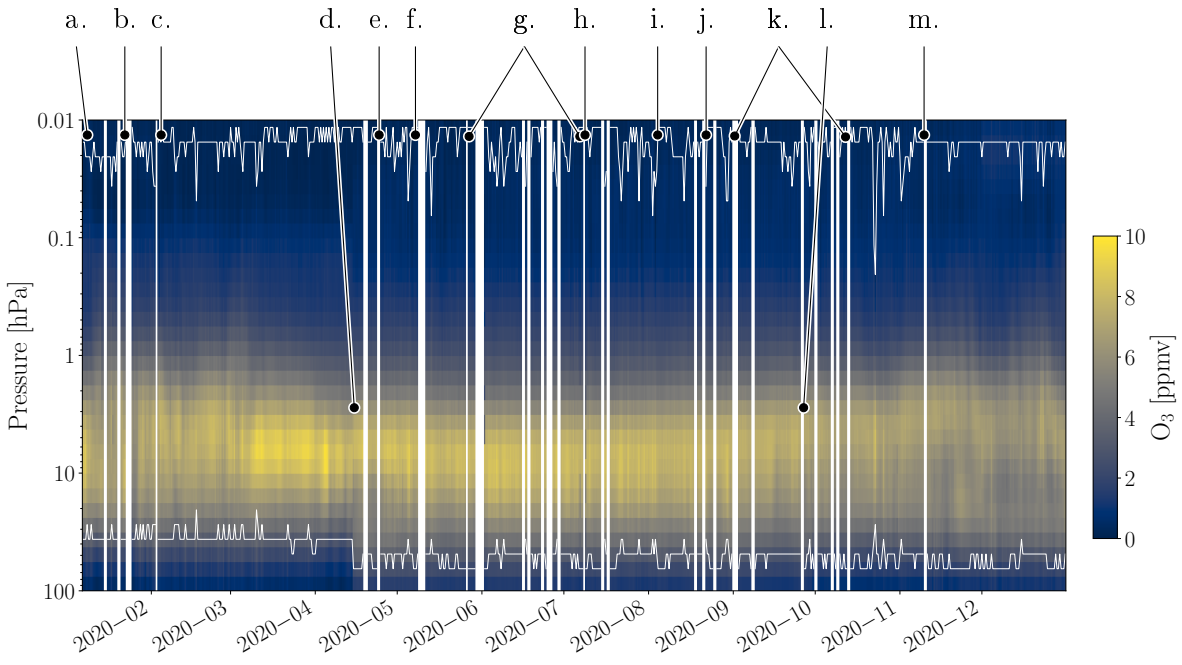


Figure 4.78: SOMORA, 2020

a. 27.12.19-07.01.20: problem with the mirror, no good measurements

b. 19-21.01.20: problem with the mirror and intervention at IAP between 24-26.01.20. Investigations of LO power decrease since September 19 (corresponding to the Trec increase ?). Front-end adjustment and optimal setting of the attenuator between LO and mixer. It resulted in a huge drop in Trec (−700 K !) as well as significant changes in instrumental baselines.

c. 04-07.02.20: problem with climatisation

d. 15.04 to 30.09.20: change of sine baselines which resulted in generally higher costs.

e. 19-20.04.20: problem with the mirror.

f. 08-11.05.20: LN2 empty

g. 18.05-23.06.20: many problems with the mirror during this period.

h. 07.07.20: change of window

i. 27.07.20: exchange of spectrometer with the spare model from IAP.

j. 14-21.08.20: on 14.08, change of hardware (FFT cards). On 17.08 acquisition stopped for unknown reason and resulted in jump in Trec (+200 K). On 18.06, a regulation valve for LN2 was added to lower LN2 refill time. This day also, some problem with the spectrometer. On 20.08, cleaning of the cold load. On 21.08, again test of different setup (FFT, Adlink card, etc...)

k. 01-02.09, 08.09 and 09.10.20: again some test and changes with different setup. The last change happened on 09.10.20 with a final setup composed of spare parts taken from IAP.

l. 30.09.20: again change in sine baselines.

m. 10.11.20: change of baseband converted from the LO to new signal generator. This resulted in jumps in Trec and counts and was the final step in the stabilization of SOMORA problems that lasted since September 2019.

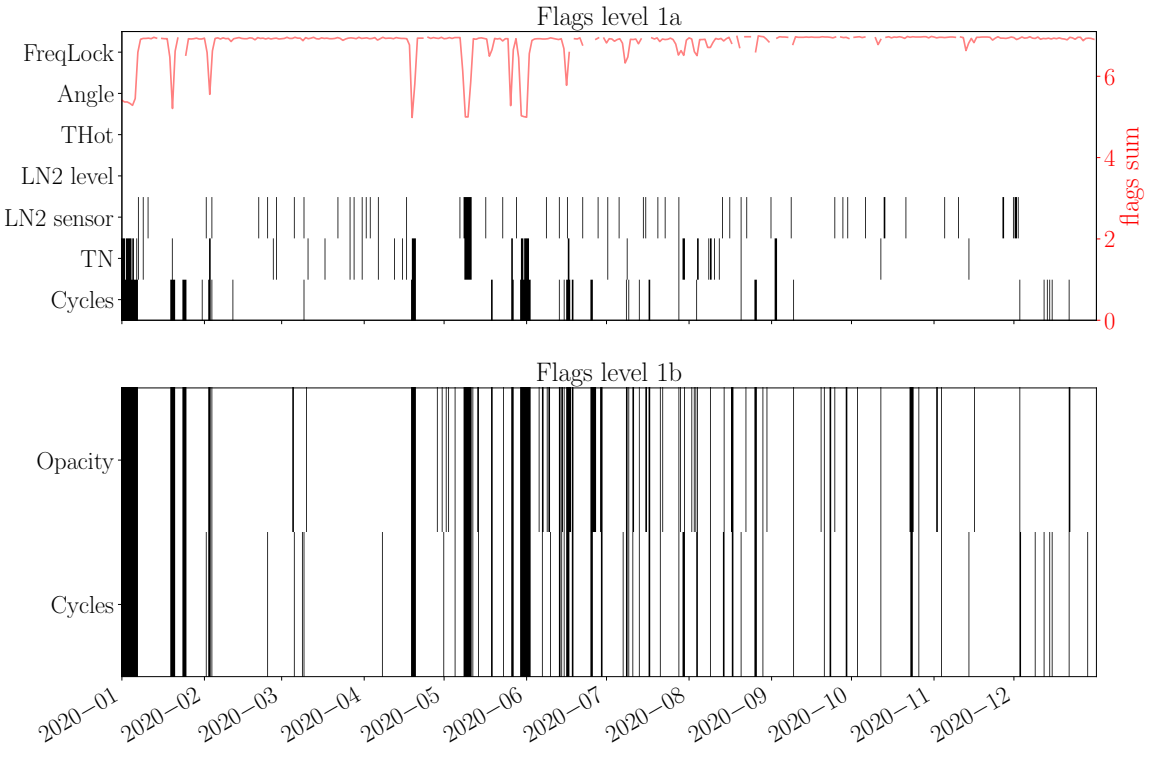


Figure 4.79: SOMORA, 2020

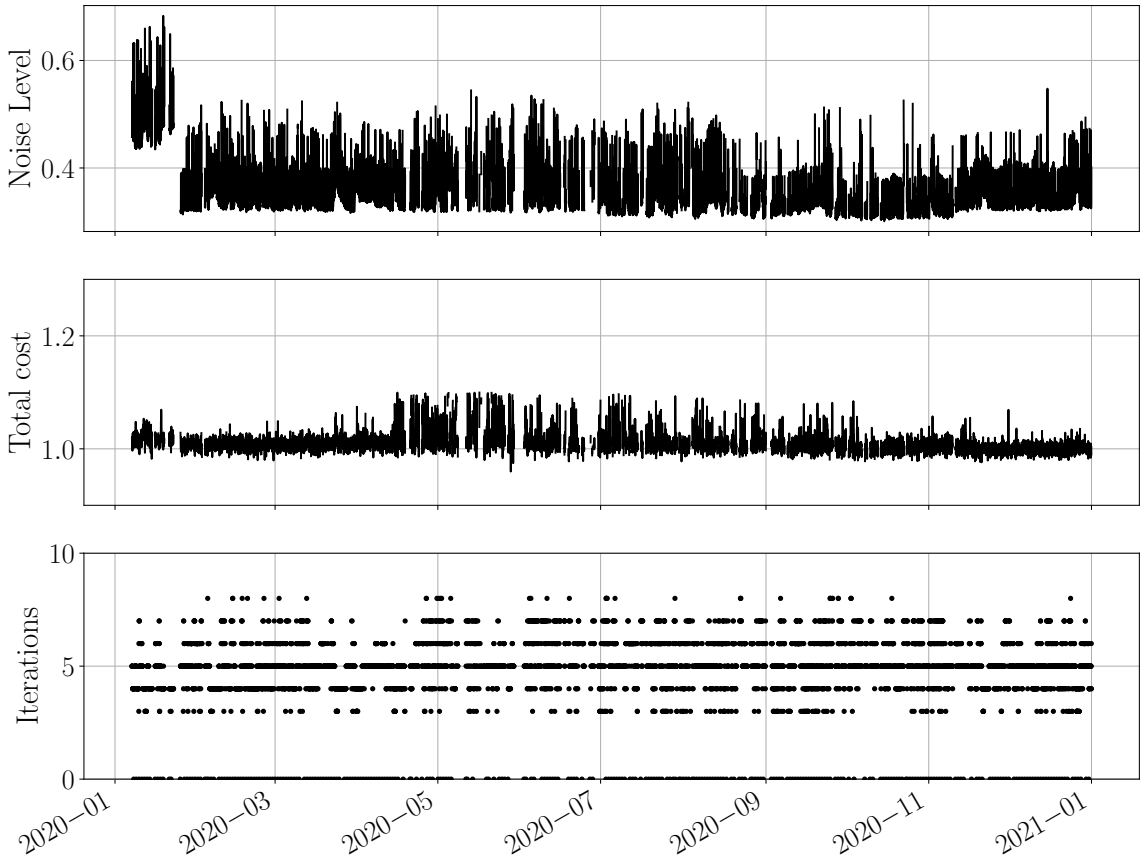


Figure 4.80: SOMORA, 2020

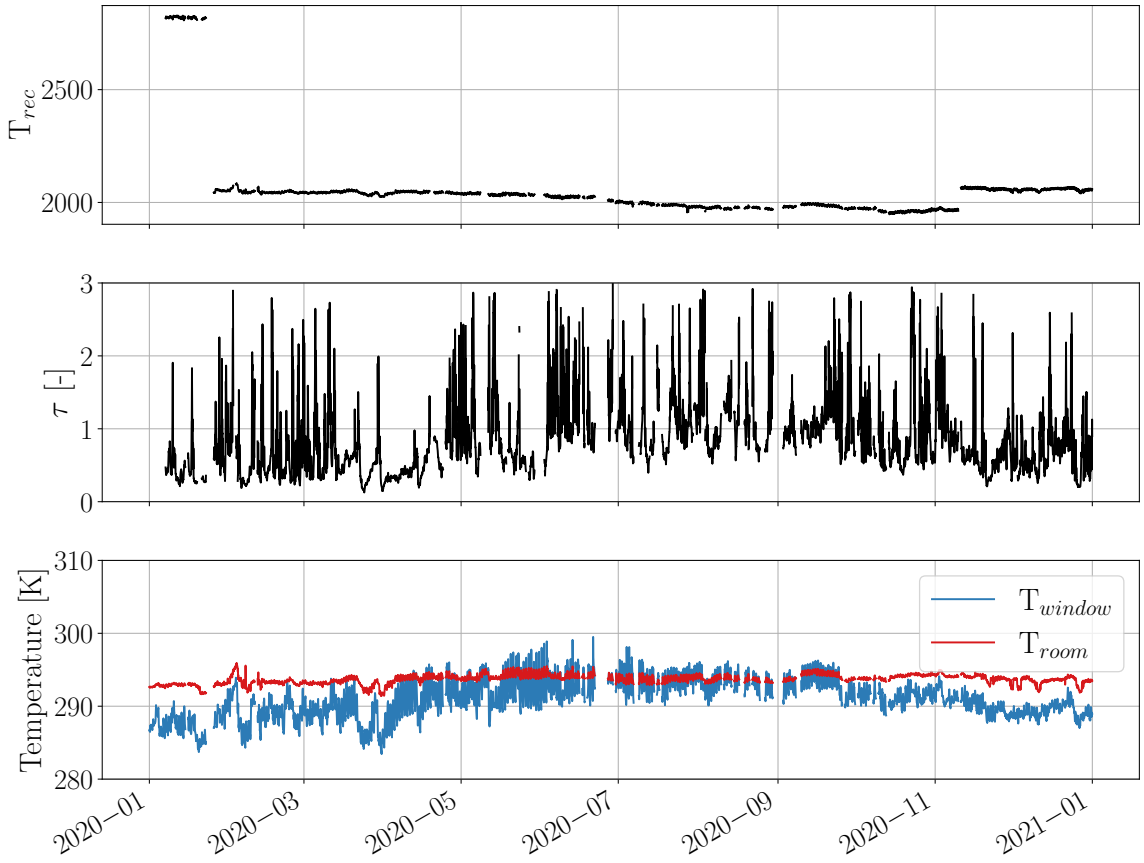


Figure 4.81: SOMORA, 2020

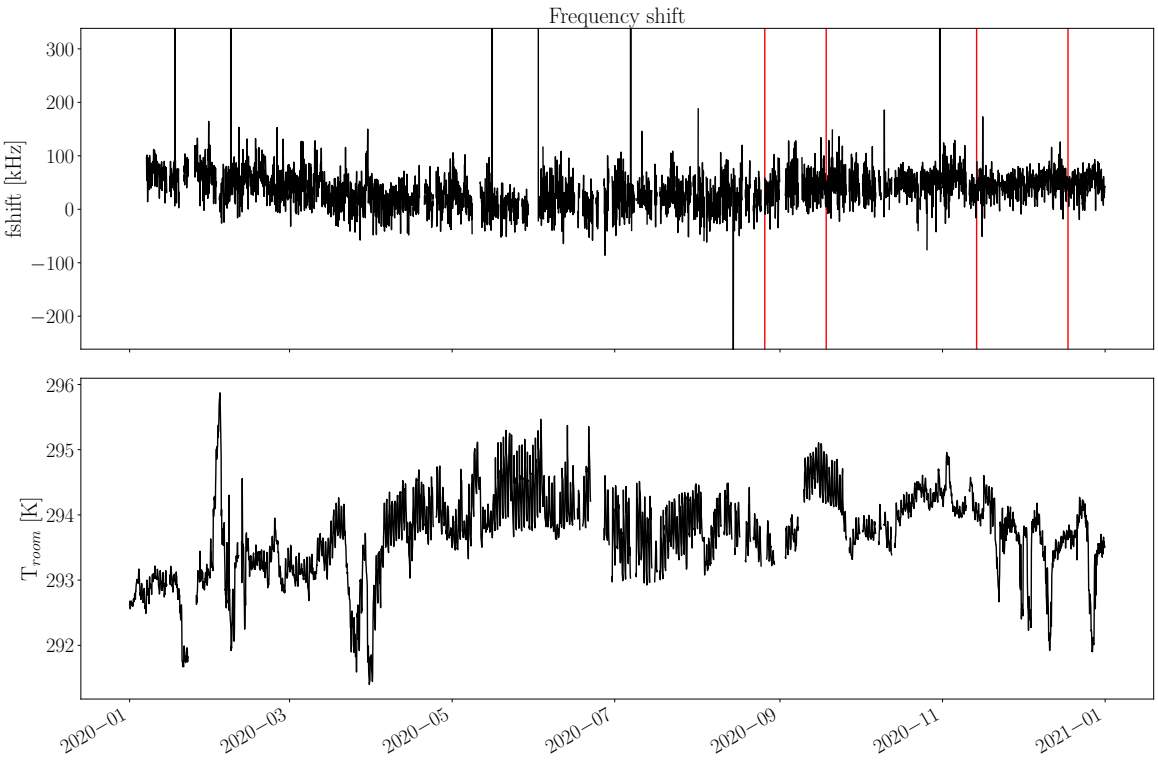


Figure 4.82: SOMORA, 2020

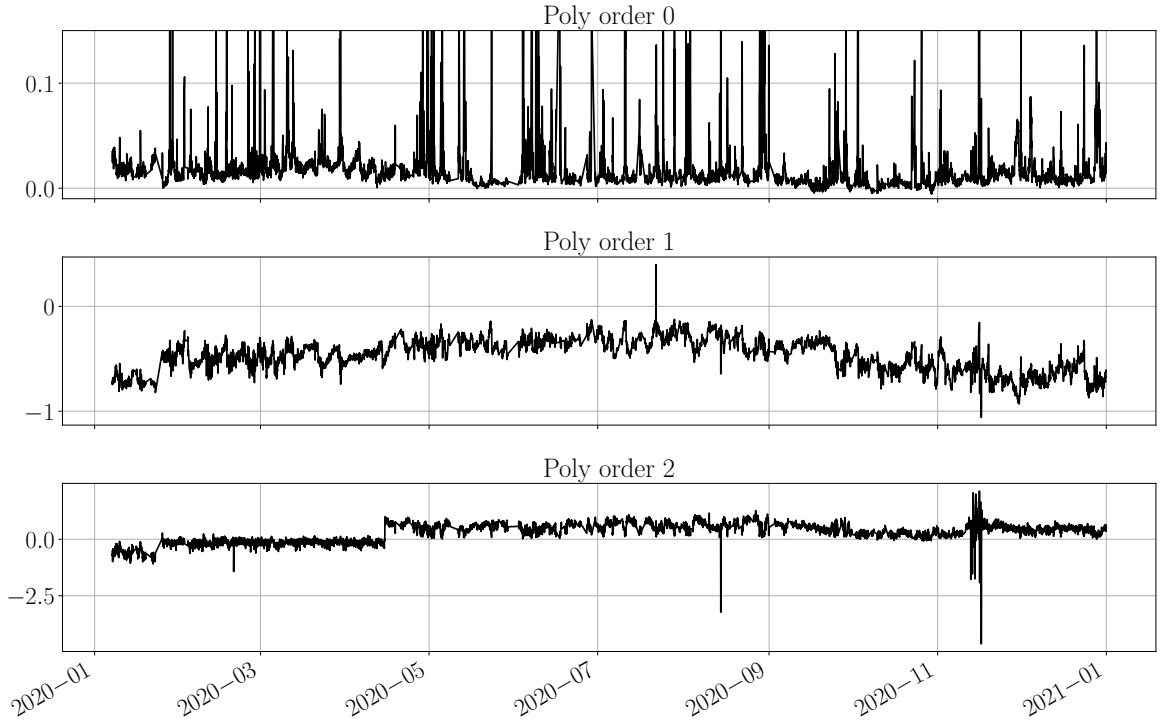


Figure 4.83: SOMORA, 2020

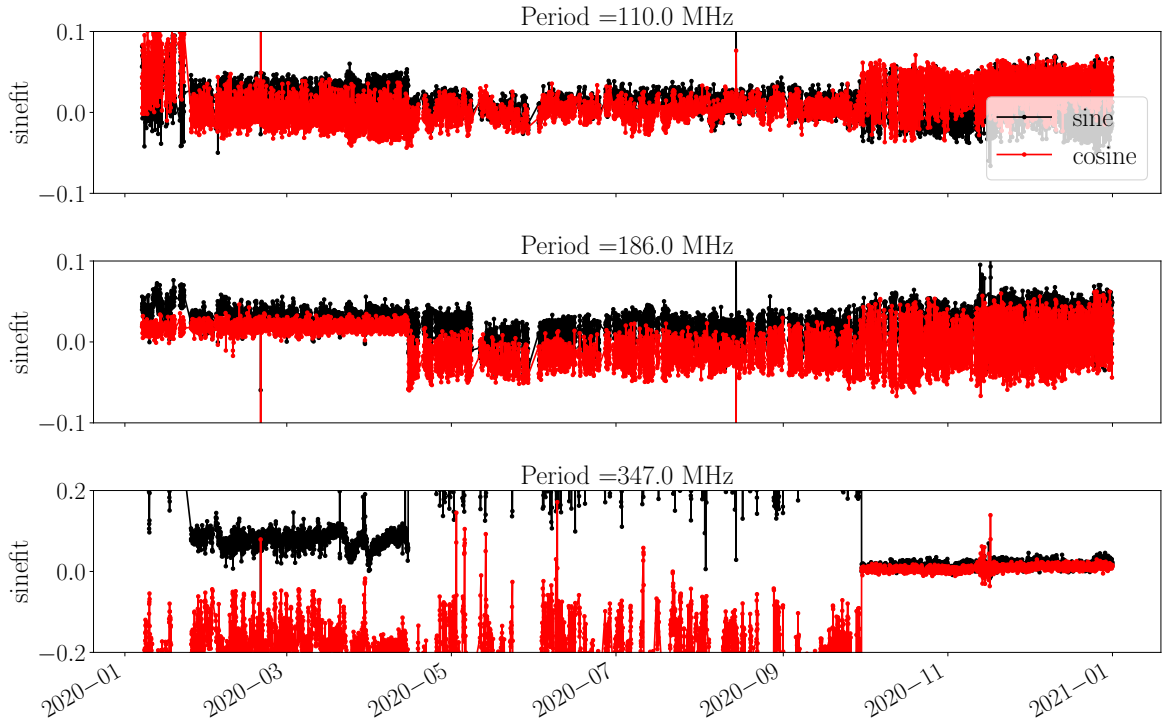


Figure 4.84: SOMORA, 2020

2021

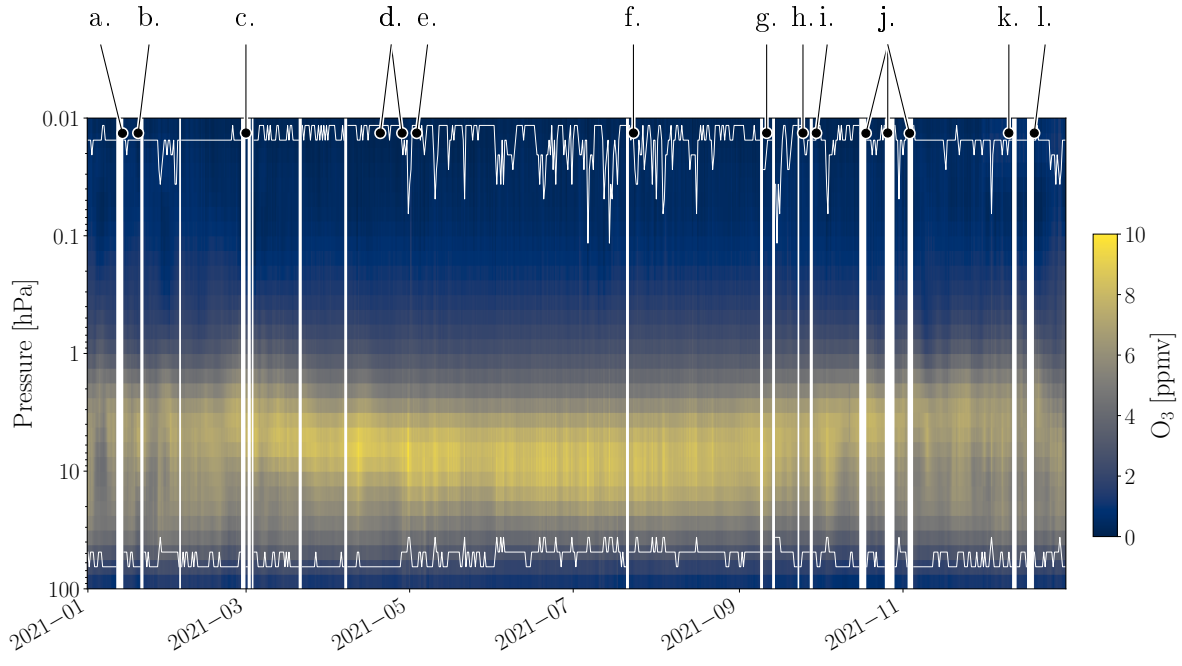


Figure 4.85: SOMORA, 2021

a. 11-14.01.21: empty LN2

b. 21.01.21: frequent ADC overload since November 2020. Change of the BBC output power.

c. 25.02-05.03.21: many tests to reduce the ADC overload problems which seems to be solved on 05.03.

d. 28.04-02.05.21: some regular problems (spectrometer ?) of unknown reason and lasting for a few hours seen during this period.

e. 11.05.21: measurement performed on front-end and changes in the external reference. It resulted in a small Trec jump (-15 K) and very slight increase of the FFT counts.

f. 21.07.21: calibrated data missing (was run at MCH)

g. 13-14.09.21: complete shutdown in prevision of main power cut on 14.09. The main climatisation does not work after this time and resulted in a premanent Troom decrease. At the same there were quite some lock problems which might have resulted in a small frequency shift (see Fig. 4.89).

h. 22-23.09.21: measurement interruptions due to power cut in Payerne

i. 27-28.09.21: pointing and antenna measurements done at IAP + cleaning of the cold load and installation of new cold load blowers. It resulted in a decrease of Trec -50 K and a slight increase of the FFT counts.

j. 16-18.10 + 26-28.10 + 03-04.11.21: LN2 empty because of leaking weld problem. It was repaired on 05.11.

k. 11-14.12.21: some problems during the LN2 refill since beginning of December 2021. Solved on 15.12 by turning the LN2 valve.

l. 17-20.12.21: measurement interruptions (LN2 empty ?)

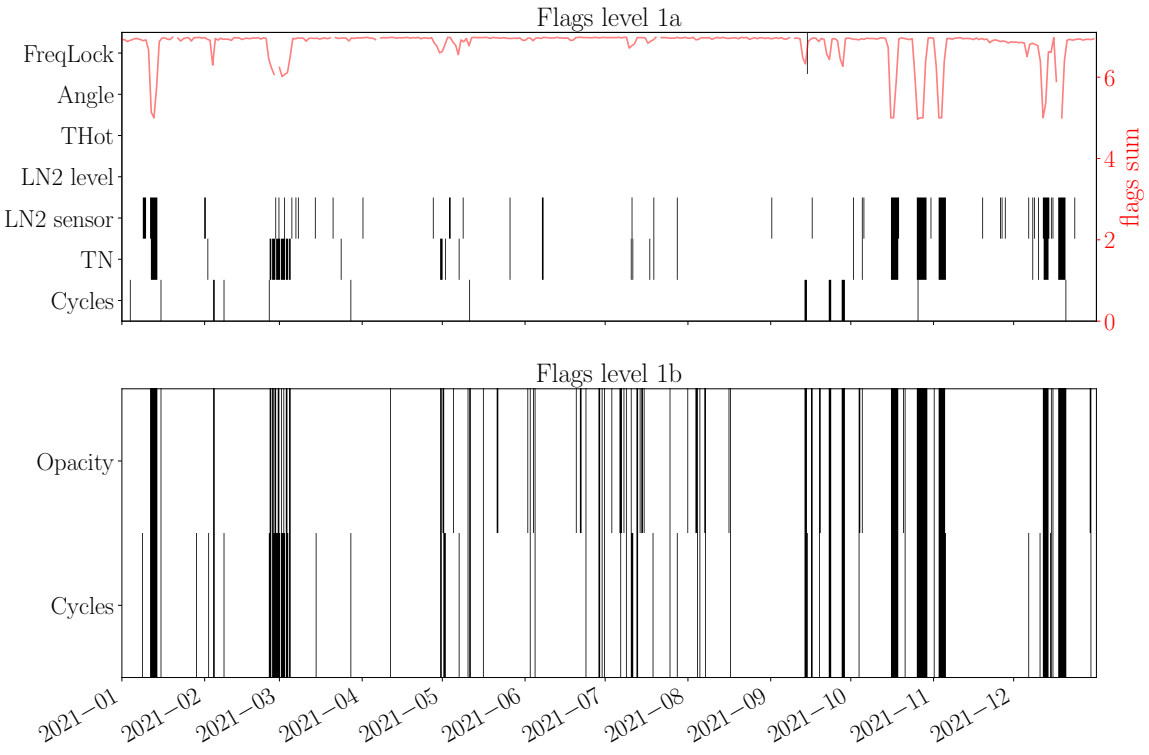


Figure 4.86: SOMORA, 2021

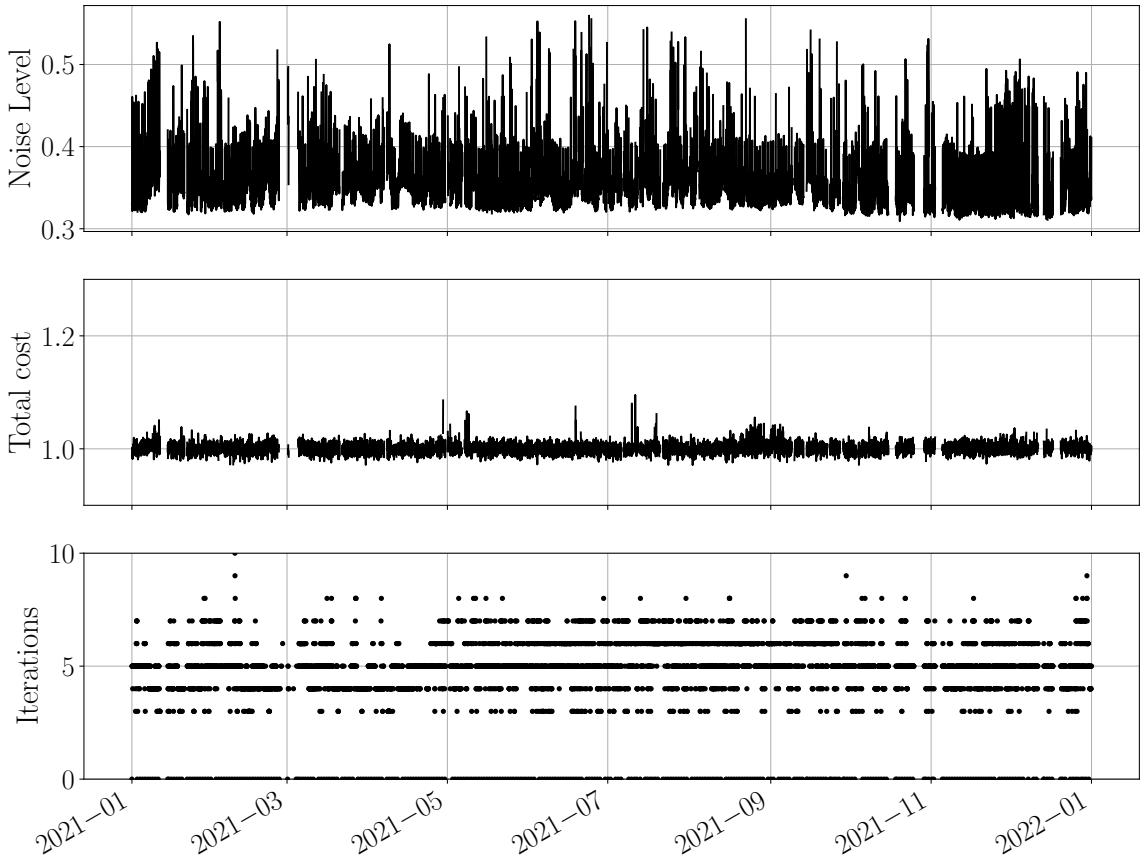


Figure 4.87: SOMORA, 2021

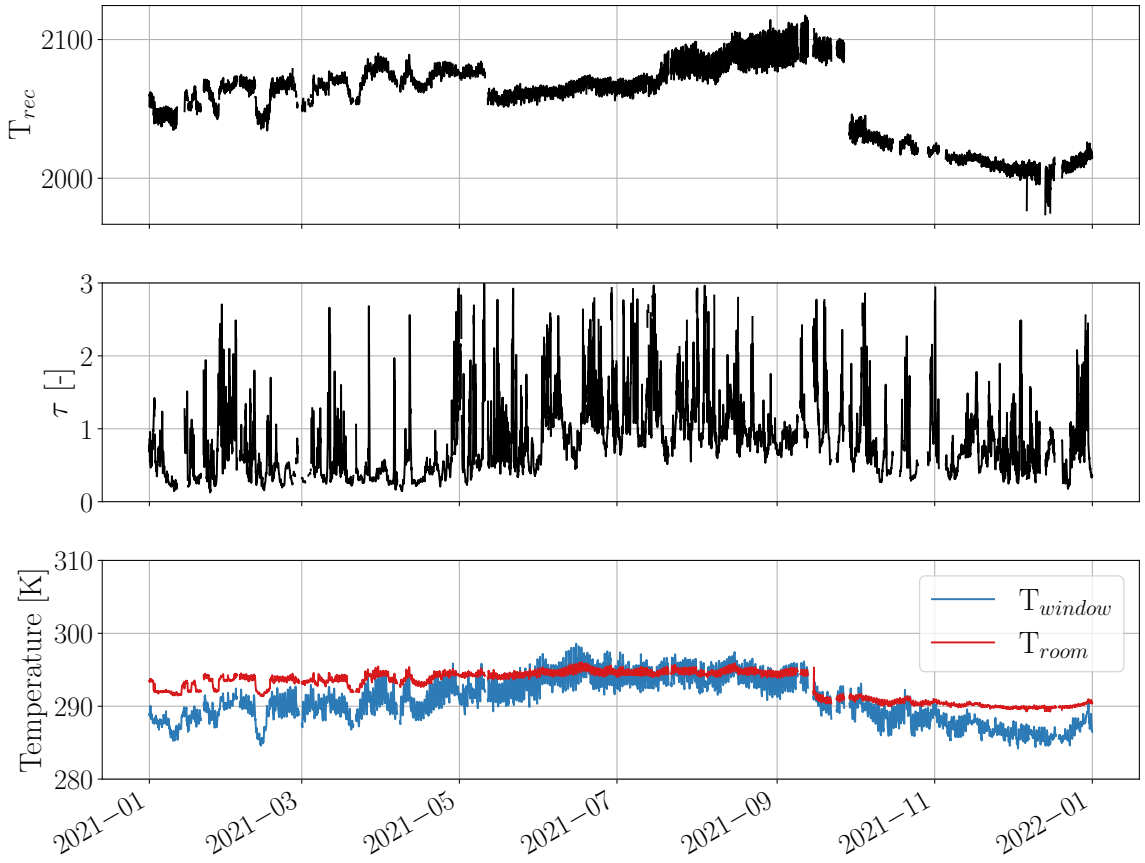


Figure 4.88: SOMORA, 2021

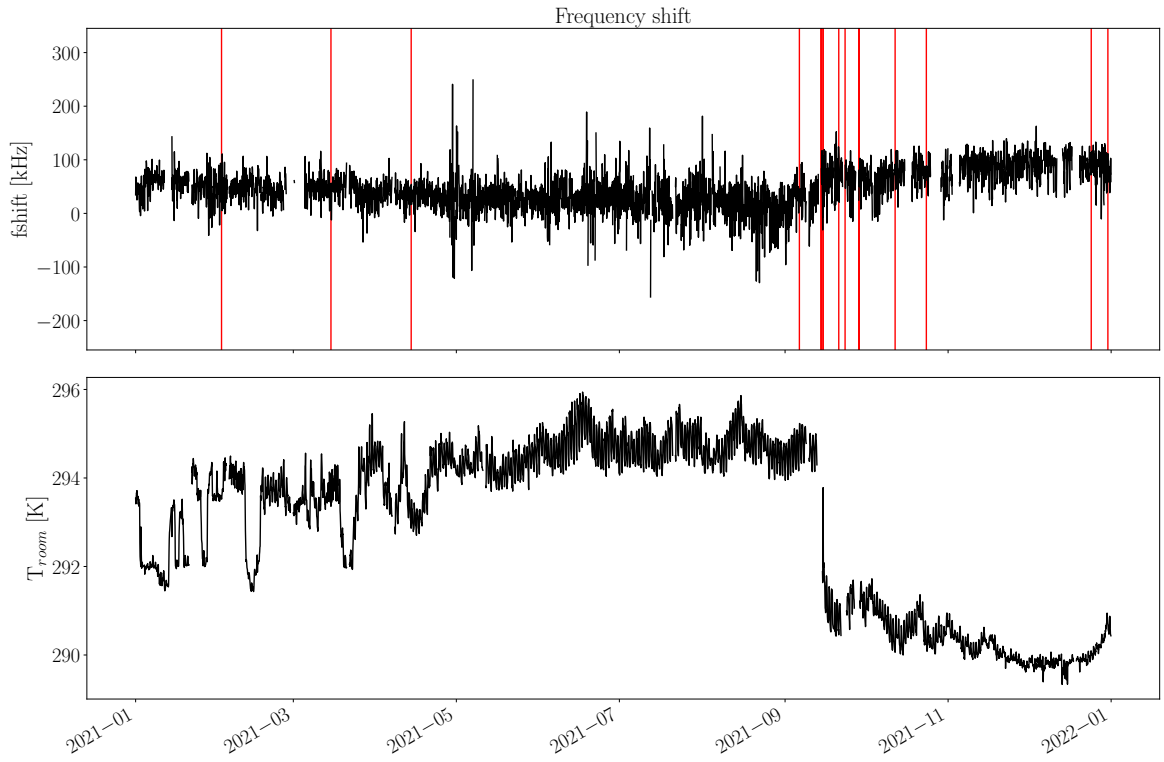


Figure 4.89: SOMORA, 2021

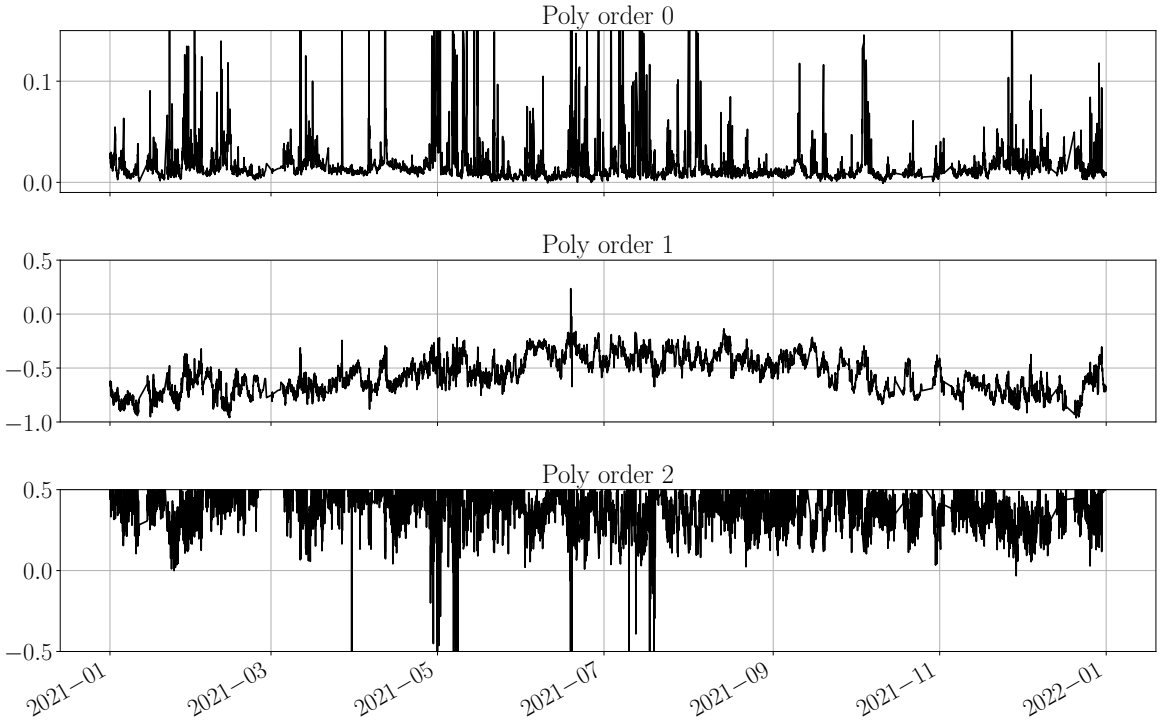


Figure 4.90: SOMORA, 2021

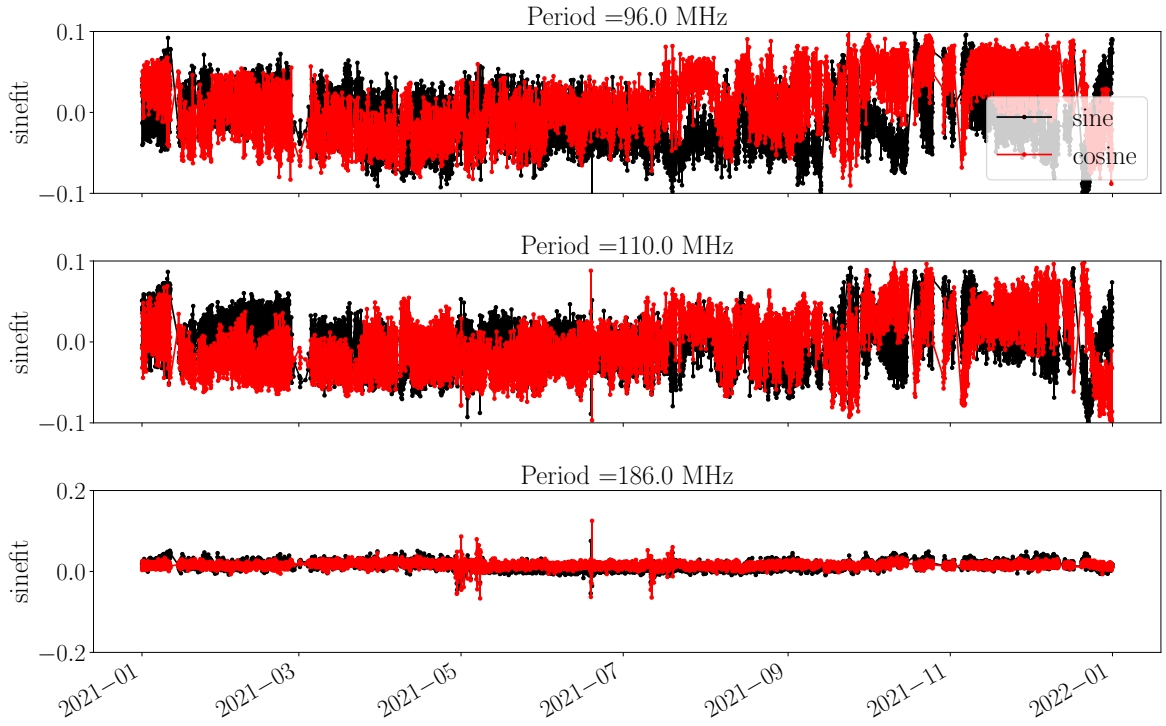


Figure 4.91: SOMORA, 2021

Acknowledgements

Thanks to Tobias Plüss for its wonderful image annotation package which can be downloaded here.