P-07-113

Forsmark site investigation

Hydro monitoring program

Report for October 2006 – March 2007

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May 2007

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ISSN 1651-4416
SKB P-07-113

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Keywords: AP PF 400-05-120, AP PF 400-07-021, Groundwater, Borehole, Instrumentation, Measurement methods, Monitoring, HMS, Forsmark.

Abstract

This document reports data obtained within the hydro monitoring program, which is one of the activities performed within the site investigation at Forsmark. The objective of the groundwater monitoring is to support the hydrogeological characterization of the area and to document the groundwater conditions before a possible excavation.

Data presented in this report are collected during the period of October 2006 until March 2007 and include groundwater levels in surface boreholes and groundwater pressure in some boreholes situated in the SFR-tunnel. Meteorological and hydrological data and some service parameters have also been collected within this activity, but are not presented in this report.

The data collecting system in HMS (Hydro Monitoring System) consists of two measurement stations (computers) which communicate with and collect data from a number of dataloggers. The computers are connected to the SKB Ethernet LAN. All data are collected by means of different transducers connected to different types of data loggers: Minitroll, LevelTroll, Mitec and Datataker.

In order to calibrate registrations from the data loggers, manual levelling of all sections is made, normally once every month. The logger data are converted to water levels using calibration constants. All collected data are quality checked once every three months. During this work, obviously erroneous data are removed and calibration constants are corrected so that the monitored data correspond with the manual levelling. At these occasions the status of the equipment is also controlled and service might be initiated.

Diagrams of groundwater levels for the period of October 2006 – March 2007 (one data point per section and twenty-four hours) are presented in Appendix 2. The original data are stored in the primary data base Sicada. The data in this data base may then be used for further analysis.

There are no nonconformities with respect to the activity plan or the method description.

Sammanfattning

Denna rapport redovisar data erhållna inom programmet för grundvattenmonitering vilket är en av aktiviteterna inom platsundersökningen i Forsmark. Syftet med grundvattenmoniteringen är att stödja den hydrogeologiska karakteriseringen av platsen och att dokumentera grundvattenförhållanden före en eventuell tunneldrivning för ett djupförvar.

Data presenterade i rapporten är insamlade under perioden oktober 2006 till och med mars 2007 och består av grundvattennivå i ytborrhål samt grundvattentryck i några borrhål belägna i SFR-tunneln. Inom ramen för platsundersökningarna insamlas även meteorologiska och ythydrologiska data, men dessa presenteras inte i denna rapport.

Datainsamlingssystemet i HMS (Hydro Monitoring System) består av två mätstationer (datorer) vilka kommunicerar med och samlar in data från ett antal dataloggrar. Datorerna är förbundna med SKB:s nätverk. Alla data samlas in med hjälp av givare förbundna med olika typer av dataloggrar: Minitroll, LevelTroll, Mitec och Datataker.

För att kunna kalibrera registreringarna från dataloggrarna utförs, vanligtvis en gång i månaden, manuell nivåregistrering (lodning) i alla sektioner. Loggerdata omvandlas till vattennivåer genom applicering av kalibreringskonstanter. Alla insamlade data kvalitetskontrolleras en gång i kvartalet. Under detta arbete tas uppenbart felaktiga data bort och kalibreringskonstanterna korrigeras så att automatiskt registrerade data överensstämmer med manuella nivåregistreringar. Vid dessa tillfällen kontrolleras utrustningens status och service kan initieras.

Diagram över grundvattennivåerna för perioden oktober 2006 – mars 2007 (en datapunkt per sektion och 24 timmar) visas i Appendix 2. Originaldata lagras i primärdatabasen Sicada. Data från denna databas kan användas för vidare analyser.

Aktiviteten har utförts i överensstämmelse med aktivitetsplanen och metodbeskrivningen.

Contents

1 Introduction

This document reports data collected within the hydro monitoring program, which is one of the activities performed within the site investigation at Forsmark. The work was carried out in accordance with activity plans SKB AP PF 400-05-120 and SKB AP PF 400-07-021. In Table 1-1, controlling documents for this activity are listed. Both of the activity plans and the method description are SKB's internal controlling documents. The site investigation internal report presents the results from the quality check performed once every three months, see Chapter 4.4.

Data presented in this report were collected during October 2006 – March 2007. Groundwater levels from boreholes and some surface water levels are included in the data set.

The HMS (Hydro Monitoring System) is used to collect and store all data.

Original data from the reported activity are stored in the primary database Sicada, where they are traceable by the Activity Plan number (AP PF 400-07-021). Only data in SKB's databases are accepted for further interpretation and modelling. The data presented in this report are regarded as copies of the original data. Data in the databases may be revised, if needed. Such revisions will not necessarily result in a revision of the P-report, although the normal procedure is that major data revisions entail a revision of the P-report. Minor data revisions are normally presented as supplements, available at www.skb.se.

Table 1-1. Controlling documents.

Activity Plans	**Number**	**Version**
Platsundersökning Forsmark Moniteringsprogram för hydrogeologi, hydrologi och meteorologi 2006	AP PF 400-05-120	1.0
Platsundersökning Forsmark Moniteringsprogram för hydrogeologi, hydrologi och meteorologi 2007	AP PF 400-07-021	1.0
Method Descriptions	**Number**	**Version**
Metodbeskrivning för grundvattenmonitering vid SKB:s platsundersökningar	SKB MD 360.002	1.0
Site investigation Internal Reports (in Swedish)	**Number**	
Platsundersökning i Forsmark Kvalitetskontroll av yt- och grundvattenmonitering Period augusti – oktober 2006	PIR-06-37	
Platsundersökning i Forsmark Kvalitetskontroll av yt- och grundvattenmonitering Period oktober 2006 – januari 2007	PIR-07-08	
Platsundersökning i Forsmark Kvalitetskontroll av yt- och grundvattenmonitering Period januari – april 2007	in prep.	

2 Objective and scope

The objective of the part of the hydro monitoring program presented in this report is to determine baseline conditions of the natural variations of the groundwater levels prior to the potential excavation for a nuclear waste repository and to support the hydro-geological site characterisation.

Data collected within this activity are:

- Groundwater level in surface boreholes (including monitoring wells in soil).
- Groundwater pressure in boreholes situated in the SFR-tunnel.
- Water level, water temperature and electrical conductivity of surface waters measured in flumes at runoff stations, although not presented in this report.
- Meteorological data from SMHI (Swedish Meteorological and Hydrological Institute), although not presented in this report.

There are also some parameters that are used for monitoring the hardware performance and the environment in which the hardware is used. However, these parameters are not reported herein.

The following numbers of boreholes and monitoring wells in soil were included in the Forsmark monitoring system at the end of March 2007:

- 19 core-drilled surface boreholes.
- 36 percussion-drilled surface boreholes.
- 58 monitoring wells in soil.
- 4 core-drilled boreholes in the SFR-tunnel.

The locations of the boreholes are shown in Figure 2-1.

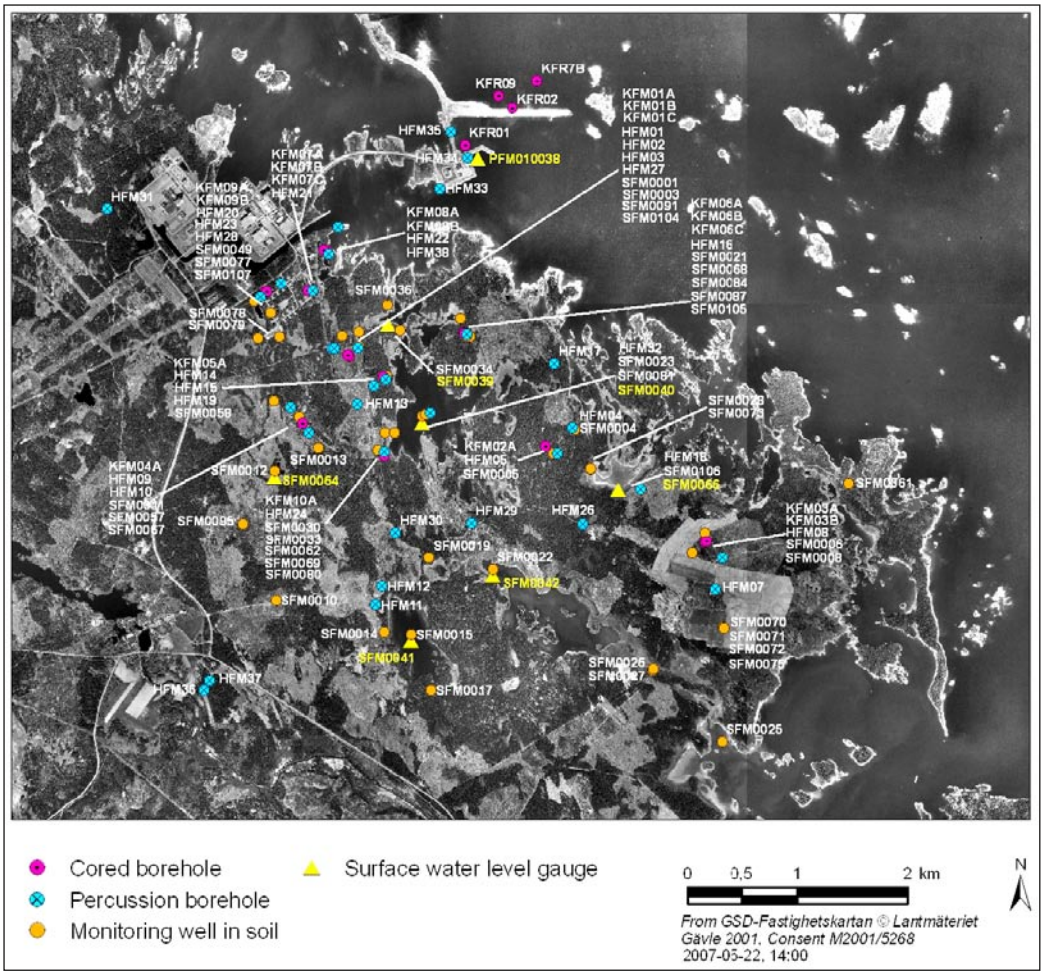


Figure 2-1. *Overview of the Forsmark site investigation area with boreholes of different categories and surface water level gauges.*

3 Equipment

3.1 Description

A drawing of the ground surface equipment used for percussion- and core-drilled boreholes is shown in Figure 3-1.

A drawing of the borehole equipment for permanent instrumentation in core-drilled boreholes is presented in Figure 3-2. Permanent instrumentation in percussion-drilled boreholes is shown in Figure 3-3.

In open boreholes, a transducer or data logger is submerged in the groundwater without any other equipment. Examples of open boreholes in Forsmark are monitoring wells in soil.
No drawing is presented.

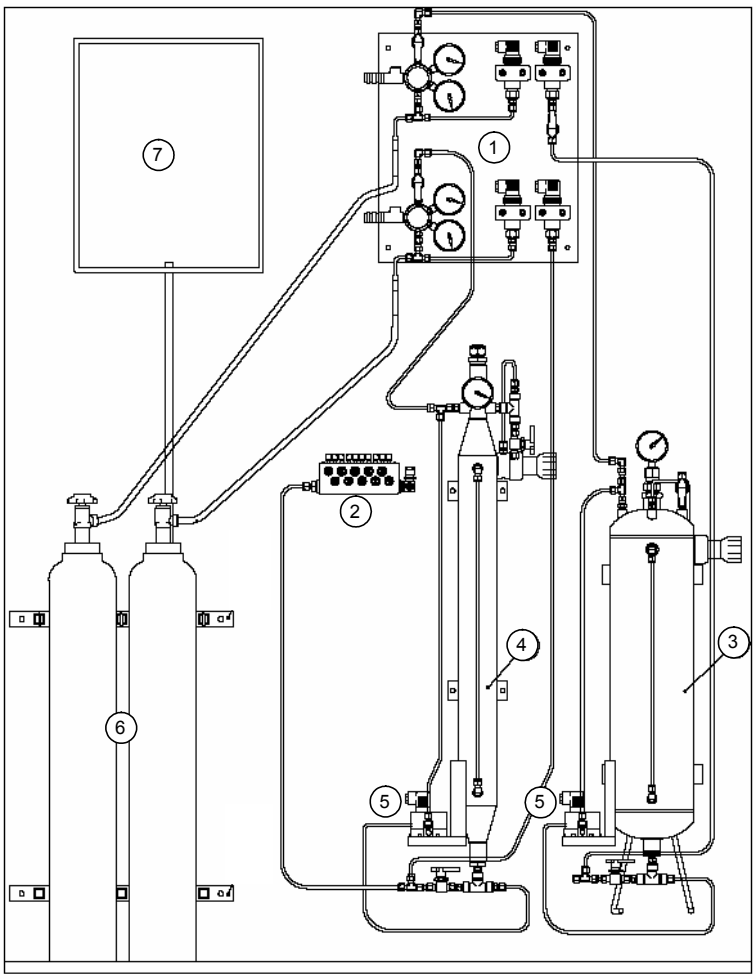


Figure 3-1. *Example of ground surface equipment for percussion- and core-drilled boreholes.*

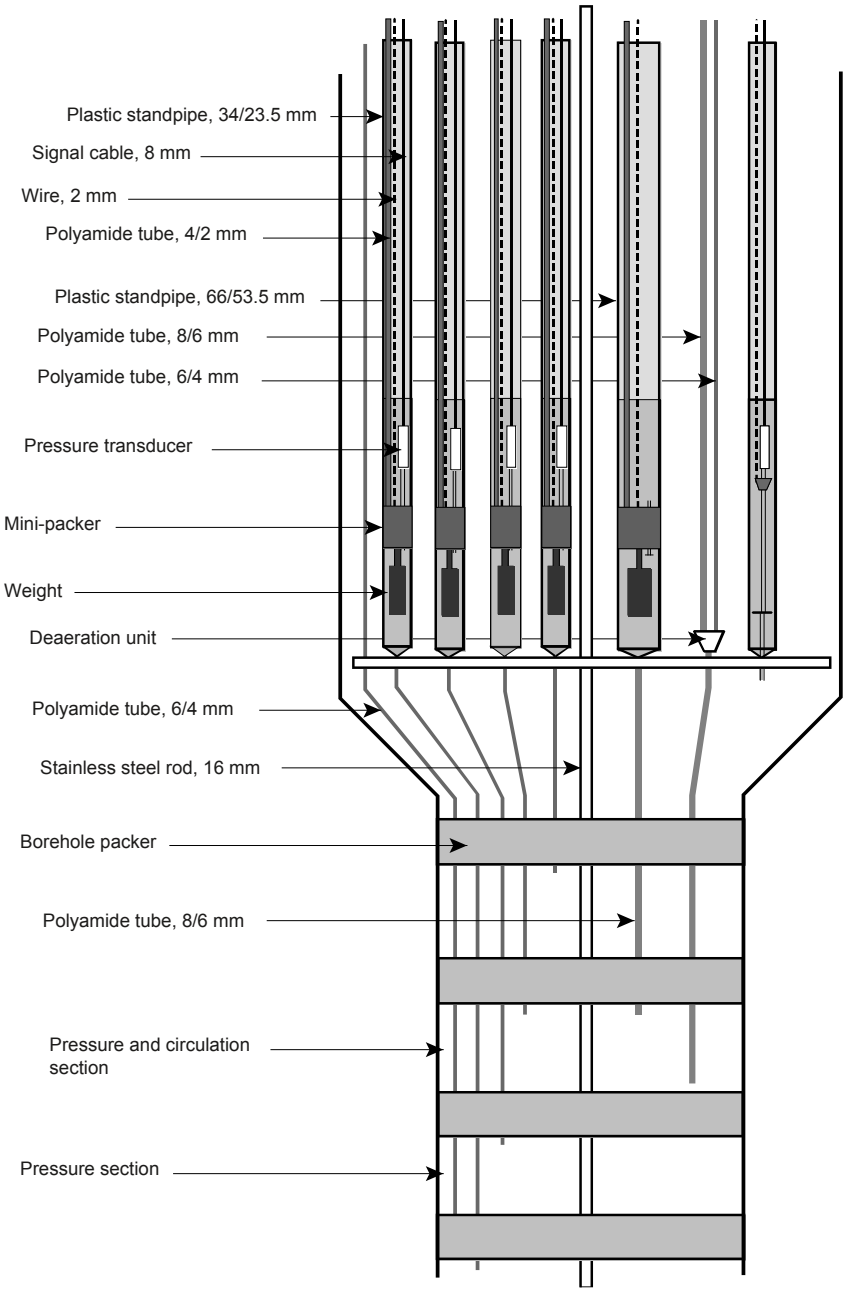


Figure 3-2. *Example of permanent instrumentation in core-drilled boreholes with a circulation section, i.e. a borehole section which enables circulation of fractures as well as water sampling.*

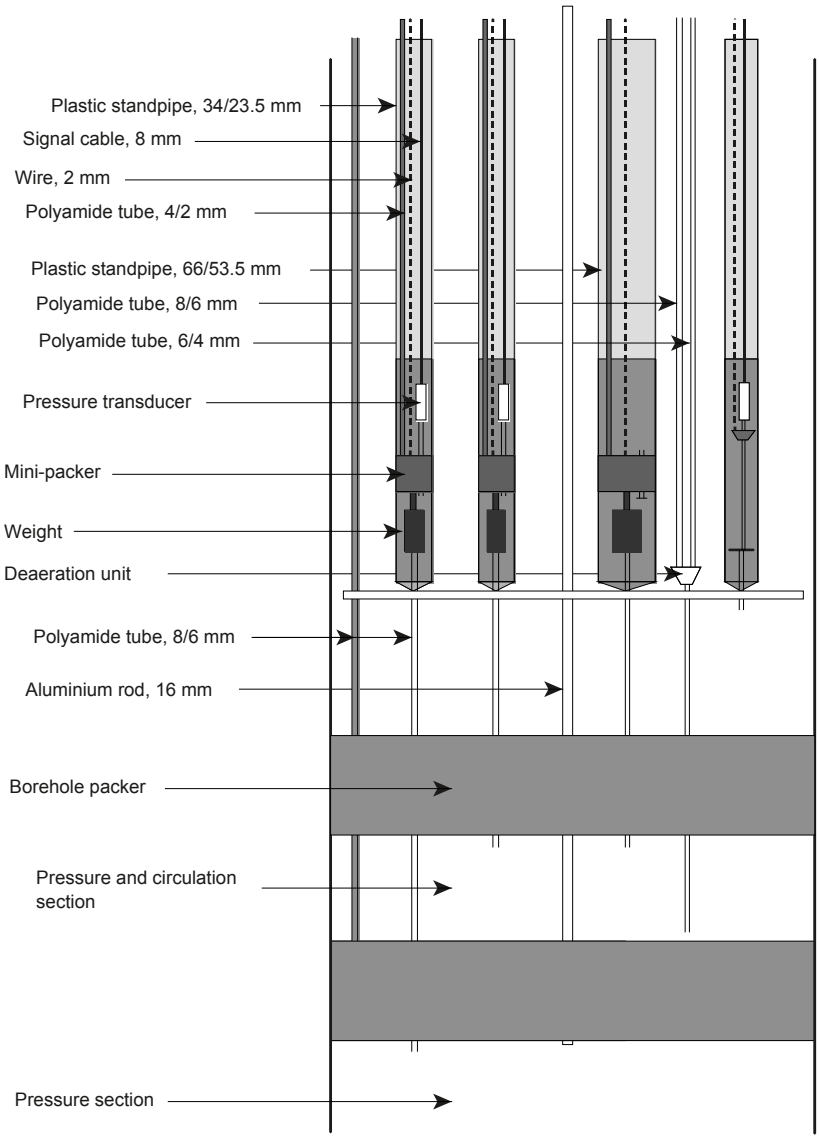


Figure 3-3. *Example of permanent instrumentation in percussion-drilled boreholes with a circulation section.*

3.2 Data collection

The data collection system, which is part of the Hydro Monitoring System (HMS), consists of two measurement stations (computers), which collect data from a number of data sources, see Figure 3-4. The computers are connected to the SKB Ethernet LAN.

The on-line system is designed to be able to handle short interruptions in the communication. Data can be stored for at least a couple of hours in the loggers. All data are finally stored in the measurement station. Tape backup is made of all data.

All data are collected by means of pressure transducers connected to different types of data loggers or by manual levelling. The following data loggers are used:

Minitroll: A single-channel data logger of stand-alone type where the transducer is integrated in the logger. The logger is submerged in the groundwater and has the capacity to store 80,000 data.

Leveltroll: The successor to Minitroll, which is no longer manufactured. It is a logger that in most respects is equal to Minitroll, but has the capacity to store 350,000 data.

Mitec: A data logger connected on-line by means of GSM telephony. A pressure transducer of the type Druck PTX is connected to the logger. Only the transducer is submerged in the groundwater. The logger has eight channels, but during monitoring in boreholes, only one channel is used for pressure monitoring and one for monitoring of the battery voltage.

Datataker: A data logger connected on-line by means of radio or network. The logger has 42 channels and is used only for monitoring in percussion- and core-drilled boreholes.

Monitored data that have been quality assured are transferred quarterly to the site characterization database, Sicada.

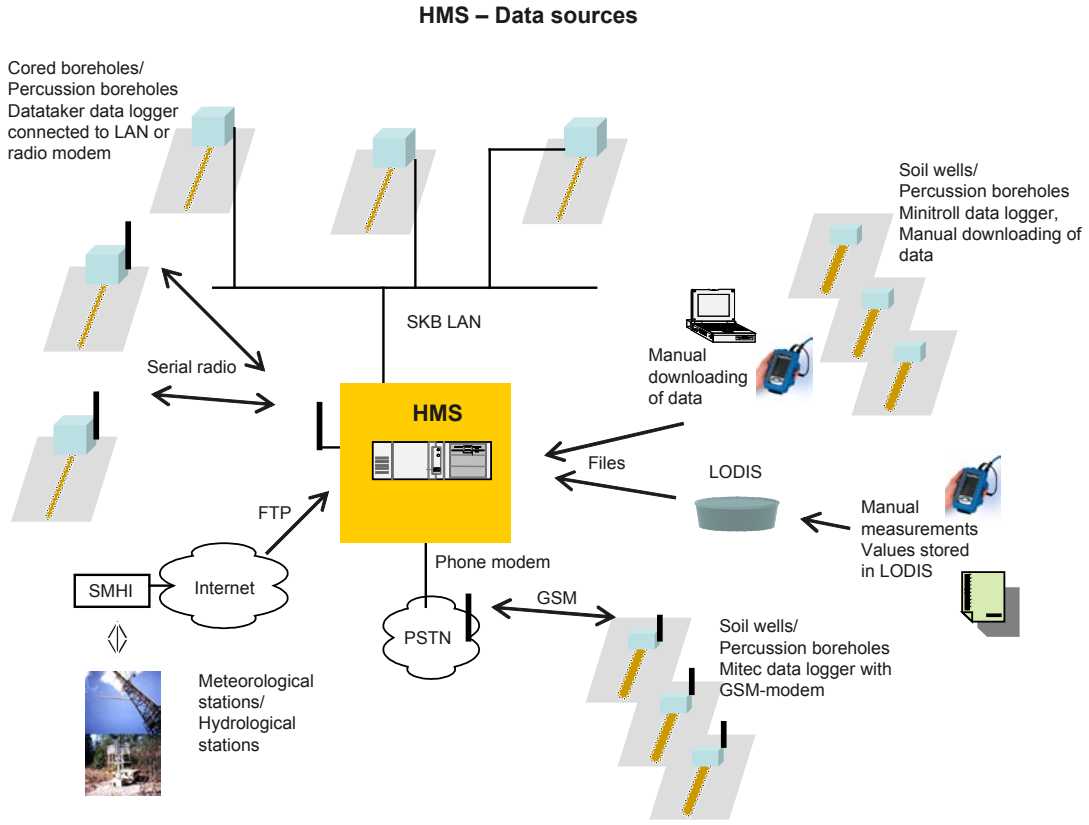


Figure 3-4. *HMS data sources.*

4 Execution

4.1 General

Data are collcted to the measurement system, HMS, as described in Chapter 3.

4.2 Field work

Manual levelling is generally carried out once a month. At the same time, the equipment is checked and maintenance is performed.

All data from stand-alone type loggers are manually dumped into a portable PC and then transmitted to the measurement station, normally once every three months.

4.3 Data handling

4.3.1 Calibration method

Manual levelling of all sections is made, normally once every month, in order to calibrate the registrations from the data loggers.

The logger data are converted to water levels by means of a linear calibration equation. It is also necessary to subtract the air pressure since all transducers give the absolute pressure. Converted logger data are compared with results from manual levelling. If the two differ, calibration constants are adjusted until an acceptable agreement is obtained.

4.3.2 Recording interval

For stand-alone and GSM-connected data loggers, measurements of the groundwater level are normally made with five minute intervals. For all other data loggers connected on-line, levels are normally measured once every ten minutes.

Measured values are not stored unless they differ from the previously stored value by more than 0.1 m for percussion- and core-drilled boreholes, and 0.05 m for monitoring wells in soil. In addition to this, a value is stored every two hours.

4.4 Quality assurance

Once every week, a preliminary inspection of all collected data is performed. The purpose of this is to verify that all loggers are sending data and that all transducers are functioning.

Quarterly, all data collected are subject to a quality check. During this Q/A, obviously erroneous data are removed and calibration constants are corrected so that the monitored data correspond with the manual levelling data (see Section 4.3.1). At this occasion, the status of the equipment is also checked and service might be initiated.

4.5 Nonconformities

There are no nonconformities with respect to the activity plan or the method description.

5 Results

5.1 General

The quality assured data, according to Section 4.4, are stored in the primary data base SICADA where they are traceable by the activity plan numbers. The data in this data base may then be used for further analysis.

5.2 Groundwater levels

Monitored sections in percussion- and core-drilled boreholes are listed in Appendix 1.

Diagrams of groundwater levels and groundwater pressure are presented in Appendix 2.
All levels in the diagrams are given as metres above sea level in the national elevation system (RT90-RHB70).

In the diagrams, daily values are presented for each section. The data point shown is the first stored data point after midnight. When registrations are missing, manually levelled data, if available, are inserted.

Boreholes included in the monitoring system in Forsmark:

- Core-drilled boreholes (19): KFM01A, KFM01B, KFM01C, KFM02A, KFM03A, KFM03B, KFM04A, KFM05A, KFM06A, KFM06B, KFM06C, KFM07A, KFM07B, KFM07C, KFM08A, KFM08B, KFM09A, KFM09B, KFM10A.
- Percussion-drilled boreholes (36): HFM01 – HFM05, HFM07 – HFM24, HFM26 – HFM38.
- Monitoring wells in soil (51): SFM0001, SFM0003 – SFM0006, SFM0008, SFM0010 – SFM0015, SFM0017, SFM0019, SFM0021 – SFM0023, SFM0025 – SFM0028, SFM0030, SFM0033 – SFM0034, SFM0036, SFM0049, SFM0057 – SFM0058, SFM0061 – SFM0062, SFM0067 – SFM0073, SFM0075, SFM0077 – SFM0081, SFM0084, SFM0087, SFM0091, SFM0095, SFM0104 – SFM0107.
- Surface water level gauges (7): SFM0038 (=PFM010038) – SFM0042, SFM0064, SFM0066.
- SFR boreholes (4): KFR01, KFR02, KFR7B, KFR09.

5.2.1 General comments

Results from monitoring in boreholes are presented in diagrams. Level data and pressure data from all sections in each borehole are presented for the period of October 2006 until March 2007.

The symbols used in the diagrams are:

The lowest section =	Section 1	○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○
	Section 2	+ + + + + + + + + +
	Section 3	× × × × × × × × × ×
	Section 4	□ □ □ □ □ □ □ □ □ □ □
	Section 5	◇ ◇ ◇ ◇ ◇ ◇ ◇
	Section 6	△ △ △ △ △ △ △ △ △ △
	Section 7	◁ ◁ ◁ ◁ ◁ ◁ ◁ ◁ ◁ ◁
	Section 8	▽ ▽ ▽ ▽ ▽ ▽ ▽ ▽ ▽ ▽
	Section 9	▷ ▷ ▷ ▷ ▷ ▷ ▷ ▷ ▷ ▷
	Section 10	× × × × × × × × × ×

Sometimes it is difficult to differentiate registrations from individual sections in the diagrams. However, since the main purpose of this report is to present an overall view of the long-term changes, it was not found advantageous to show more detailed diagrams from individual sections. Detailed diagrams during test periods are presented in reports from the different tests.

Due to failures in the mechanical or electronic equipment, data are sometimes missing for longer or shorter periods. This is not commented on below. For more comments on the diagrams, see Site investigation Internal Reports, Table 1-1.

Remarks are given when the registration for some reason has a deviating appearance. When registrations are missing, manually levelled data, if available, are inserted.

In many boreholes, the groundwater level shows large and rapid variations. This is often due to nearby drilling. Also, many borehole sections are influenced by other activities such as pumping, water sampling, tracer tests etc.

Packers may deflate due to leakage, which can be difficult to discover. If a section in a borehole suddenly shows a pressure that is close to the pressure in a neighbouring section, the reason might be deflated packers.

5.2.2 Comments on some of the diagrams

The groundwater in many of the monitoring wells in soil has been reported to be frozen in February and March 2007.

HFM05 and HFM36: The boreholes have been used as drilling water wells during the reported period.

HFM14: No measurement has been performed during the reported period due to other activities in the borehole.

HFM34: After installation of packers in the borehole in July 2006, section 1 is reported to be dry.

KFM01A and KFM06A: The anomalous behaviour for section one in both of the boreholes is caused by low transmisivity and/or poor communication between the standpipe and the section, in combination with a relatively large difference between the stand-pipe level and the pressure in the borehole section. When the mini-packer is released, in connection to the monthly levellings, a sudden jump to the level in the standpipe occurs. Thereafter, when the mini-packer is inflated again, the pressure is slowly approaching the actual pressure in the borehole section.

SFM0005: The borehole is reported to be dry from the beginning of July to the end of October 2006.

SFM0006: From July to November 2006 the borehole is reported to be dry.

SFM0070: The borehole is reported to be dry at the levelling occasions in August through October 2006.

Appendix 1

Monitored sections

Borehole	Section no	Start date	Stop date	Secup (m)	Seclow (m)	Circ Section	Z Secup (m.a.s.l.)	Z SecMid (m.a.s.l.)
HFM01	1	2003-06-16	2003-09-08	0.00	200.20		1.73	–96.89
	1	2005-08-11	2006-10-25	0.00	200.20		1.73	–96.89
	1	2006-10-26		46.50	200.20		–43.91	–119.90
	2	2006-10-26		33.50	45.50	x	–31.10	–37.02
	3	2006-10-26		0.00	32.50		1.73	–14.15
HFM02	1	2002-12-10	2003-01-23	0.00	100.00		3.05	–46.90
	1	2003-01-23	2004-03-15	0.00	100.00		3.05	–46.90
	1	2004-03-18		49.00	100.00		–45.90	–71.38
	2	2004-03-18		38.00	48.00	x	–34.91	–39.91
	3	2004-03-18		0.00	37.00		3.05	–15.43
HFM03	1	2003-01-30	2003-03-05	0.00	26.00		3.15	–9.84
	1	2004-03-18		19.00	26.00		–15.83	–19.32
	2	2004-03-18		0.00	18.00		3.15	–5.84
HFM04	1	2002-12-10	2003-12-10	0.00	221.70		3.87	–106.58
	1	2003-12-10	2004-02-23	0.00	221.70		3.87	–106.58
	1	2004-03-02		66.90	221.70		–62.81	–139.61
	2	2004-03-02		57.90	65.90	x	–53.83	–57.82
	3	2004-03-02		0.00	56.90		3.87	–24.46
HFM05	1	2004-05-12		0.00	200.10		7.67	–92.09
HFM07	1	2003-02-17	2003-02-21	0.00	122.50		5.78	–55.27
	1	2003-02-21	2003-12-10	0.00	122.50		5.78	–55.27
	1	2003-12-10		0.00	122.50		5.78	–55.27
HFM08	1	2003-02-27	2003-03-14	0.00	143.50		7.13	–64.49
	1	2003-03-17	2003-07-09	101.50	143.50		–94.02	–114.72
	2	2003-03-17	2003-07-09	82.00	100.50		–74.69	–83.87
	3	2003-03-17	2003-07-09	0.00	81.00		7.13	–33.29
	1	2004-03-05	2005-02-08	0.00	143.50		7.13	–64.49
	1	2005-02-09		117.00	143.00		–109.31	–122.09
	2	2005-02-09		0.00	116.00		7.13	–50.78
HFM09	1	2003-08-20	2003-10-27	0.00	50.25		5.15	–18.26
	1	2003-10-27		0.00	50.25		5.15	–18.26
HFM10	1	2003-12-16	2004-11-02	0.00	150.00		4.99	–65.40
	1	2004-11-04		100.00	150.00		–88.51	–111.42
	2	2004-11-04		0.00	99.00		4.99	–41.54
HFM11	1	2003-09-09	2003-09-30	0.00	182.35		7.56	–59.14
	1	2004-01-22	2005-03-15	0.00	182.35		7.56	–59.14
	1	2005-03-16		54.00	182.35		–32.67	–77.75
	2	2005-03-16		0.00	53.00		7.56	–12.36
HFM12	1	2003-09-30	2003-10-03	0.00	209.55		7.03	–69.52
	1	2004-01-22	2005-03-15	0.00	209.55		7.03	–69.52
	1	2005-03-18		57.50	209.50		–35.83	–89.04
	2	2005-03-18		0.00	56.50		7.03	–14.38

Borehole	Section no	Start date	Stop date	Secup (m)	Seclow (m)	Circ Section	Z Secup (m.a.s.l.)	Z SecMid (m.a.s.l.)
HFM13	1	2003-10-03	2004-11-08	0.00	175.60		5.69	–70.91
	1	2004-12-16		159.00	173.00	x	–132.64	–138.63
	2	2004-12-16		101.00	158.00		–82.41	–107.18
	3	2004-12-16		0.00	100.00		5.69	–37.81
HFM14	1	2003-10-13	2003-10-15	0.00	150.50		3.91	–62.22
	1	2003-11-10	2004-01-21	0.00	150.50		3.91	–62.22
	1	2004-01-21		0.00	150.50		3.91	–62.22
HFM15	1	2003-11-03	2004-01-21	0.00	99.50		3.88	–31.08
	1	2004-01-23	2005-01-31	0.00	99.50		3.88	–31.08
	1	2005-02-04		85.00	95.00	x	–55.70	–59.11
	2	2005-02-04		0.00	84.00		3.88	–25.65
HFM16	1	2003-11-26	2004-09-29	0.00	132.50		3.21	–62.93
	1	2004-09-29	2005-11-17	0.00	132.50		3.21	–62.93
	1	2005-11-28		68.00	132.00		–64.67	–96.55
	2	2005-11-28		54.00	67.00	x	–50.69	–57.18
	3	2005-11-28		0.00	53.00		3.21	–23.20
HFM17	1	2003-12-10		0.00	210.65		3.75	–100.94
HFM18	1	2004-05-04	2005-12-07	0.00	180.65		5.04	–70.75
	1	2005-12-07		42.00	180.00		–30.53	–87.64
	2	2005-12-07		28.00	41.00		–18.75	–24.22
	3	2005-12-07		0.00	27.00		5.04	–6.49
HFM19	1	2004-02-13	2004-04-29	151.00	185.20		–117.64	–130.83
	2	2004-02-13	2004-04-29	111.00	150.00		–86.76	–101.84
	3	2004-02-13	2004-04-29	0.00	110.00		3.66	–42.31
	1	2004-05-07	2004-09-29	0.00	185.20		3.66	–72.42
	1	2005-01-25		168.00	182.00	x	–130.75	–136.13
	2	2005-01-25		104.00	167.00		–81.32	–105.69
	3	2005-01-25		0.00	103.00		3.66	–39.47
HFM20	1	2004-06-03	2005-02-18	0.00	301.00		2.97	–147.33
	1	2005-03-03		131.00	301.00		–127.84	–212.74
	2	2005-03-03		101.00	130.00		–97.85	–112.34
	3	2005-03-03		49.00	100.00		–45.88	–71.36
	4	2005-03-03		0.00	48.00		2.97	–20.95
HFM21	1	2004-06-09	2004-06-14	38.00	202.00		–28.03	–94.29
	2	2004-06-09	2004-06-14	0.00	37.00		3.98	–11.68
	1	2004-06-14	2006-09-26	0.00	202.00		3.98	–79.41
	1	2006-09-30		107.00	202.00		–84.14	–120.20
	2	2006-09-30		33.00	106.00		–23.84	–54.02
	3	2006-09-30		22.00	32.00	x	–14.62	–18.82
	4	2006-09-30		0.00	21.00		3.98	–4.94
HFM22	1	2004-09-13	2004-09-16	0.00	222.00		1.54	–86.49
	1	2004-10-20		0.00	222.00		1.54	–86.49
HFM23	1	2005-09-05		0.00	211.50		4.25	–66.08
HFM24	1	2005-12-06	2006-11-28	18.03	151.35		–11.74	–69.40
HFM26	1	2006-03-15		0.00	202.70		2.73	–74.36
HFM27	1	2005-12-06	2006-04-24	12.03	127.50		–8.69	–61.88
	1	2006-04-27		59.00	128.00		–52.03	–83.68
	2	2006-04-27		46.00	58.00	x	–40.09	–45.60
	3	2006-04-27		25.00	45.00		–20.70	–29.96

Borehole	Section no	Start date	Stop date	Secup (m)	Seclow (m)	Circ Section	Z Secup (m.a.s.l.)	Z SecMid (m.a.s.l.)
	4	2006-04-27		0.00	24.00		2.44	–8.66
HFM28	1	2006-03-16		0.00	151.20		4.27	–70.65
HFM29	1	2006-03-15		0.00	199.70		4.47	–84.10
HFM30	1	2006-05-18		0.00	200.75		3.13	–81.56
HFM31	1	2006-05-22		0.00	200.75		6.07	–86.83
HFM32	1	2006-01-26		98.00	202.65		–96.27	–147.51
	2	2006-01-26		32.00	97.00		–30.95	–63.24
	3	2006-01-26		26.00	31.00	x	–24.97	–27.46
	4	2006-01-26		0.00	25.00		0.97	–11.50
HFM33	1	2006-05-18		0.00	140.20		2.62	–55.84
HFM34	1	2006-06-13	2006-07-03	0.00	200.75		2.45	–82.92
	1	2006-07-05		91.00	200.75		–75.12	–119.83
	2	2006-07-05		22.00	90.00		–16.35	–45.52
	3	2006-07-05		0.00	21.00		2.45	–6.52
HFM35	1	2006-08-17		182.00	201.00		–137.33	–143.97
	2	2006-08-17		151.00	181.00		–115.43	–126.09
	3	2006-08-17		34.00	150.00		–26.57	–71.87
	4	2006-08-17		0.00	33.00		1.90	–12.10
HFM36	1	2006-09-05		0.00	152.55		8.41	–53.52
HFM37	1	2006-09-05		0.00	191.75		11.39	–74.10
HFM38	1	2006-06-28	2007-02-26	0.00	200.75		2.21	–74.85
KFM01A	1	2003-06-17	2003-12-16	132.00	1,001.49		–128.22	–558.63
	2	2003-06-17	2003-12-16	110.00	131.00		–106.34	–116.78
	3	2003-06-17	2003-12-16	0.00	109.00		3.13	–51.12
	1	2004-02-24	2004-05-07	0.00	1,001.49		3.13	–493.66
	1	2004-06-04	2004-10-25	0.00	1,001.49		3.13	–493.66
	1	2004-11-26		431.00	1,001.49		–424.77	–705.14
	2	2004-11-26		374.00	430.00		–368.37	–396.09
	3	2004-11-26		205.00	373.00		–200.75	–284.12
	4	2004-11-26		131.00	204.00		–127.22	–163.50
	5	2004-11-26		109.00	130.00	x	–105.34	–115.79
	6	2004-11-26		0.00	108.00		3.13	–50.62
KFM01B	1	2004-10-14		142.00	500.00		–135.77	–308.47
	2	2004-10-14		101.00	141.00		–95.80	–115.31
	3	2004-10-14		0.00	100.00		3.09	–45.92
KFM01C	1	2006-06-22		238.00	450.00		–177.03	–255.79
	2	2006-06-22		59.00	237.00		–41.96	–109.26
	3	2006-06-22		0.00	58.00		2.91	–19.19
KFM02A	1	2004-03-29	2004-04-28	0.00	1,002.44		7.35	–492.20
	1	2004-05-12	2004-10-22	0.00	1,002.44		7.35	–492.20
	1	2005-04-11	2005-05-17	0.00	1,002.44		7.35	–492.20
	1	2005-06-13		889.00	1,002.00		–876.80	–932.66
	2	2005-06-13		519.00	888.00		–509.90	–693.08
	3	2005-06-13		490.00	518.00	x	–481.04	–494.97
	4	2005-06-13		443.00	489.00		–434.23	–457.14
	5	2005-06-13		411.00	442.00	x	–402.36	–417.80
	6	2005-06-13		241.00	410.00		–232.98	–317.18
	7	2005-06-13		133.00	240.00		–125.31	–178.66
	8	2005-06-13		0.00	132.00		7.35	–58.46

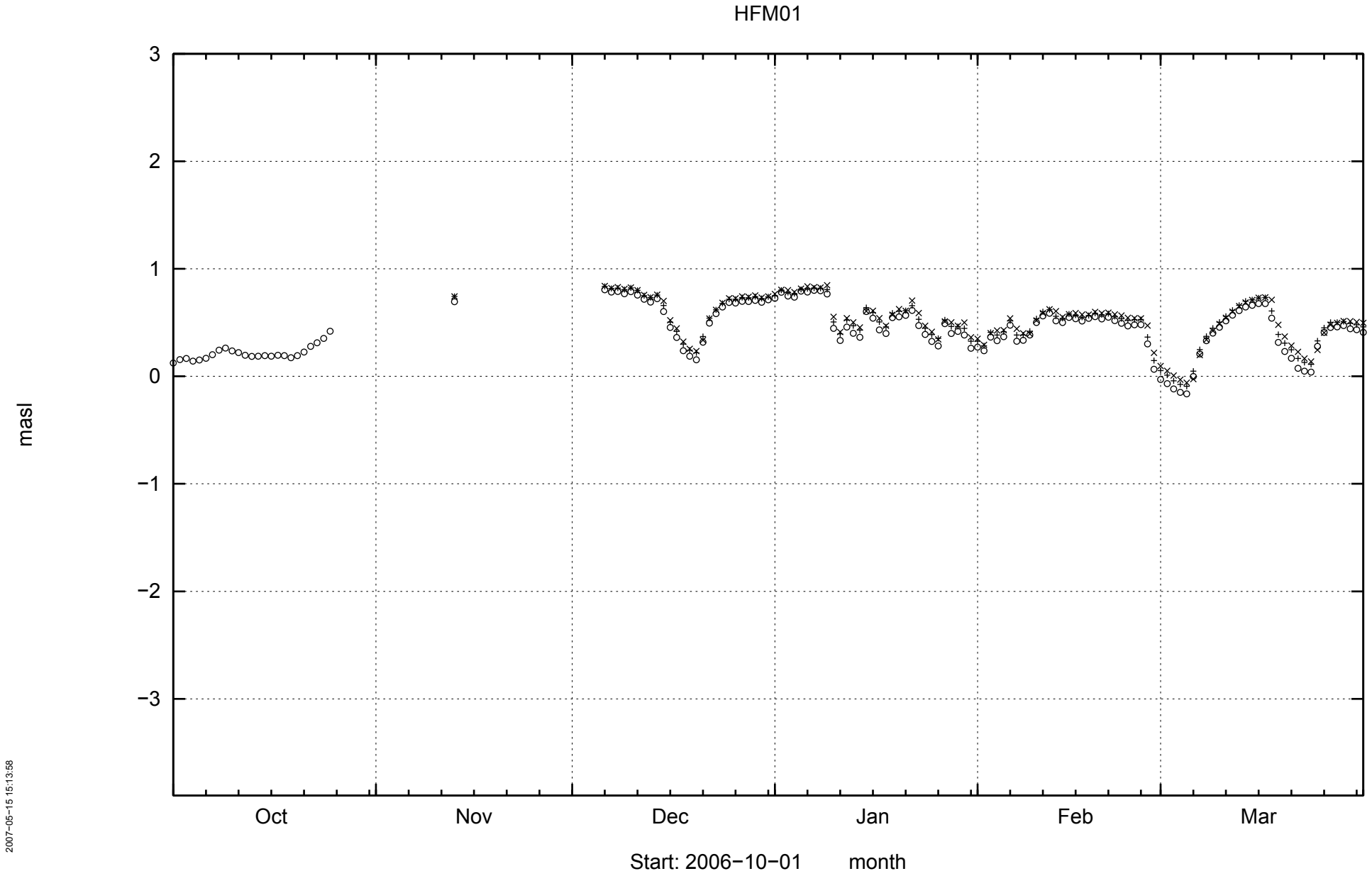
Borehole	Section no	Start date	Stop date	Secup (m)	Seclow (m)	Circ Section	Z Secup (m.a.s.l.)	Z SecMid (m.a.s.l.)
KFM03A	1	2003-12-15	2004-01-28	0.00	1,001.19		8.29	–490.66
	1	2004-08-06	2004-11-15	0.00	1,001.19		8.29	–490.66
	1	2005-05-09		969.50	994.50	x	–956.73	–969.13
	2	2005-05-09		820.50	968.50		–808.79	–882.28
	3	2005-05-09		651.00	819.50		–640.30	–724.04
	4	2005-05-09		633.50	650.00	x	–622.90	–631.10
	5	2005-05-09		472.50	632.50		–462.70	–542.31
	6	2005-05-09		402.50	471.50		–393.00	–427.35
	7	2005-05-09		351.50	401.50		–342.21	–367.11
	8	2005-05-09		0.00	350.50		8.29	–166.53
KFM03B	1	2005-01-27		52.00	102.00		–43.34	–68.24
	2	2005-01-27		0.00	51.00		8.47	–16.94
KFM04A	1	2004-02-24	2004-04-07	0.00	1,001.42		8.77	–420.65
	1	2004-06-30	2006-01-17	0.00	1,001.42		8.77	–420.65
	1	2006-06-27	2006-08-28	169.00	1,001.42		–139.99	–487.98
	2	2006-06-27	2006-08-28	0.00	168.00		8.77	–64.76
	1	2006-12-20		496.00	1,001.00		–416.85	–613.74
	2	2006-12-20		391.00	495.00		–330.90	–373.85
	3	2006-12-20		246.00	390.00		–207.20	–269.10
	4	2006-12-20		230.00	245.00	x	–193.32	–199.83
	5	2006-12-20		186.00	229.00		–154.92	–173.74
	6	2006-12-20		164.00	185.00		–135.59	–144.83
	7	2006-12-20		0.00	163.00		8.77	–62.55
KFM05A	1	2004-06-11		0.00	1,002.71		5.53	–419.89
	1	2005-08-30		699.00	1,002.44		–581.43	–704.29
	2	2005-08-30		490.00	698.00		–410.57	–495.72
	3	2005-08-30		273.00	489.00		–229.88	–320.33
	4	2005-08-30		254.00	272.00	x	–213.75	–221.40
	5	2005-08-30		115.00	253.00		–94.20	–153.86
	6	2005-08-30		0.00	114.00		5.53	–43.82
KFM06A	1	2005-10-18		827.00	1,000.64		–690.52	–759.54
	2	2005-10-18		749.00	826.00		–627.66	–658.83
	3	2005-10-18		738.00	748.00	x	–618.71	–622.78
	4	2005-10-18		363.00	737.00		–308.26	–464.36
	5	2005-10-18		341.00	362.00	x	–289.65	–298.54
	6	2005-10-18		247.00	340.00		–209.59	–249.29
	7	2005-10-18		151.00	246.00		–126.95	–167.98
	8	2005-10-18		0.00	150.00		4.10	–61.02
KFM06B	1	2005-09-05	2005-12-21	0.00	100.30		4.13	–45.71
	1	2006-01-09		51.00	100.00		–46.55	–70.89
	2	2006-01-09		27.00	50.00		–22.71	–34.13
	3	2006-01-09		0.00	26.00		4.13	–8.79
KFM06C	1	2006-06-07		873.00	1,000.64		–688.89	–735.58
	2	2006-06-07		667.00	872.00		–534.94	–611.65
	3	2006-06-07		647.00	666.00	x	–519.89	–527.04
	4	2006-06-07		541.00	646.00		–439.09	–479.36
	5	2006-06-07		531.00	540.00	x	–431.37	–434.84
	6	2006-06-07		402.00	530.00		–330.76	–380.97
	7	2006-06-07		351.00	401.00		–290.04	–310.06
	8	2006-06-07		281.00	350.00		–233.15	–261.36
	9	2006-06-07		187.00	280.00		–155.52	–194.07
	10	2006-06-07		0.00	186.00		4.09	–76.03

Borehole	Section no	Start date	Stop date	Secup (m)	Seclow (m)	Circ Section	Z Secup (m.a.s.l.)	Z SecMid (m.a.s.l.)
KFM07A	1	2005-05-16	2005-10-10	271.00	1,001.55		–230.05	–534.19
	2	2005-05-16	2005-10-10	0.00	270.00		3.33	–113.30
	1	2005-11-09	2006-06-26	271.00	1,001.00		–230.05	–533.97
	2	2005-11-09	2006-06-26	100.35	270.00		–83.28	–156.60
	1	2007-02-05		973.00	1,001.00		–799.66	–809.94
	2	2007-02-05		962.00	972.00	x	–791.51	–795.22
	3	2007-02-05		226.00	961.00		–191.67	–499.24
	4	2007-02-05		191.00	225.00		–161.62	–176.23
	5	2007-02-05		149.00	190.00		–125.41	–143.10
	6	2007-02-05		0.00	148.00		3.33	–60.47
KFM07B	1	2006-05-03	2006-12-18	0.00	298.93		3.36	–117.39
	1	2007-01-12		203.00	300.00		–160.23	–199.63
	2	2007-01-12		75.00	202.00		–57.83	–108.74
	3	2007-01-12		0.00	74.00		3.36	–26.90
KFM07C	1	2007-02-14		302.00	500.00		–297.03	–395.52
	2	2007-02-14		161.00	301.00		–156.82	–226.42
	3	2007-02-14		111.00	160.00		–107.11	–131.46
	4	2007-02-14		0.00	110.00		3.35	–51.43
KFM08A	1	2005-05-21	2005-05-31	0.00	1,001.19		2.49	–409.93
	1	2006-01-24	2006-05-16	506.00	1,001.19		–414.10	–596.64
	2	2006-01-24	2006-05-16	100.55	505.00		–84.11	–252.53
	1	2006-10-18		0.00	1,001.19		2.49	–409.93
KFM08B	1	2005-04-18	2006-02-02	0.00	200.54		2.25	–82.94
	1	2006-02-21		113.00	200.00		–93.68	–130.24
	2	2006-02-21		71.00	112.00		–58.14	–75.52
	3	2006-02-21		0.00	70.00		2.25	–27.57
KFM09A	1	2006-09-14		551.00	799.67		–445.62	–536.77
	2	2006-09-14		301.00	550.00		–248.28	–348.20
	3	2006-09-14		0.00	300.00		4.29	–123.11
KFM09B	1	2006-09-26		451.00	616.45		–353.72	–414.32
	2	2006-09-26		201.00	450.00		–159.18	–257.66
	3	2006-09-26		0.00	200.00		4.30	–77.66
KFM10A	1	2006-08-31	2006-09-18	**	**		**	**
	2	2006-08-31	2006-09-18	**	**		**	**
	1	2007-02-19		441.00	500.16		–303.45	–321.01
	2	2007-02-19		430.00	440.00	x	–296.80	–299.83
	3	2007-02-19		353.00	429.00		–248.57	–272.72
	4	2007-02-19		153.00	352.00		–110.36	–181.24
	5	2007-02-19		0.00	152.00		4.51	–53.22
KFR01	1	1984-12-08		44.50	62.30		410.87*	402.80*
	2	1984-12-08		11.00	43.50		441.23*	426.50*
KFR02	1	1986-03-24		137.00	170.30		277.17*	260.52*
	2	1986-03-24		119.00	136.00		295.17*	286.67*
	3	1986-03-24		81.00	118.00		333.17*	314.67*
KFR7B	1	1985-10-02		8.00	21.10		366.23*	366.00*
KFR09	1	1985-10-02		0.00	80.24		422.45*	418.95*

* Measured in the local coordinate system “SFR T-U”.
** Data is not found in Sicada.

Appendix 2

Groundwater level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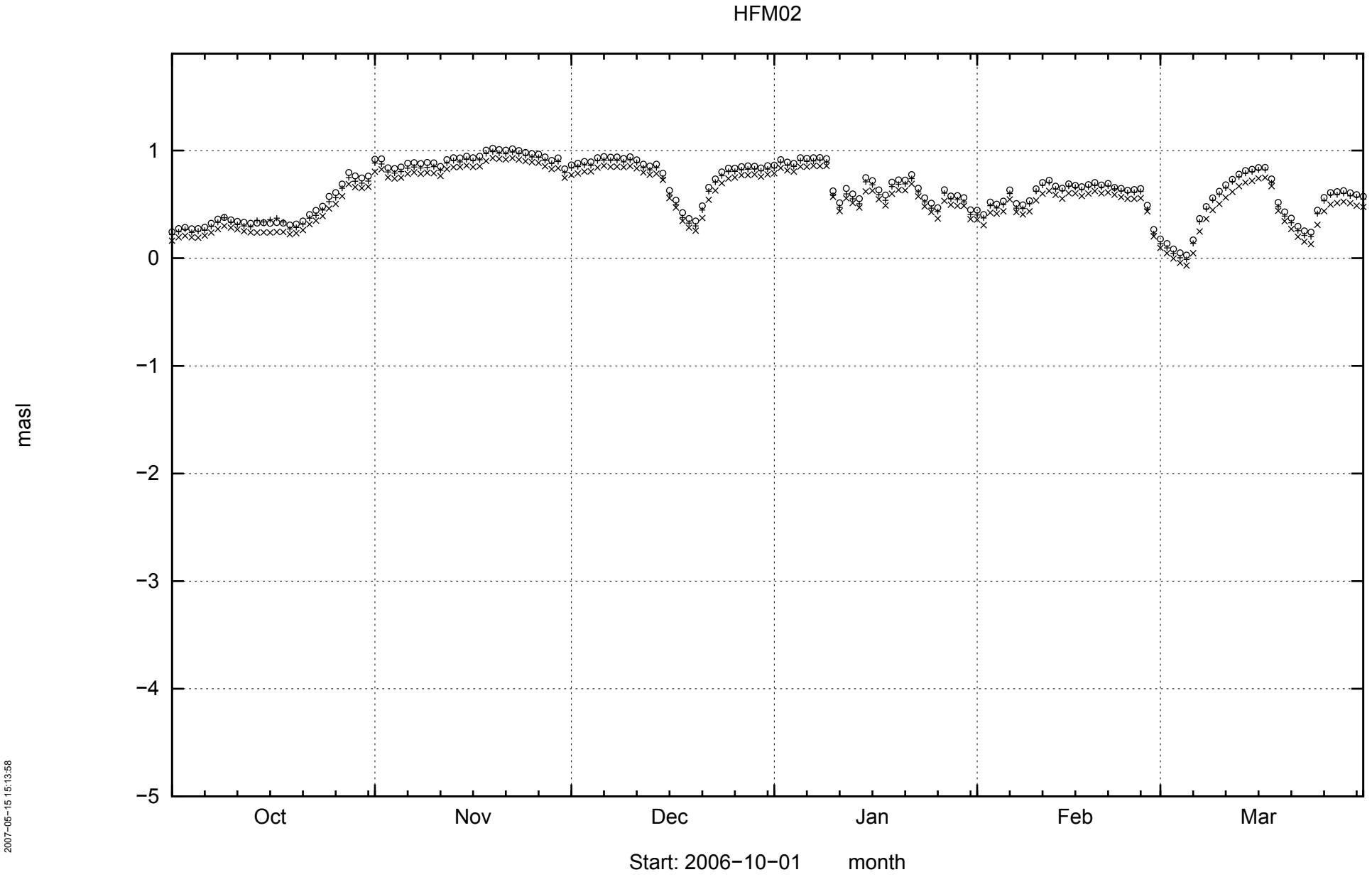
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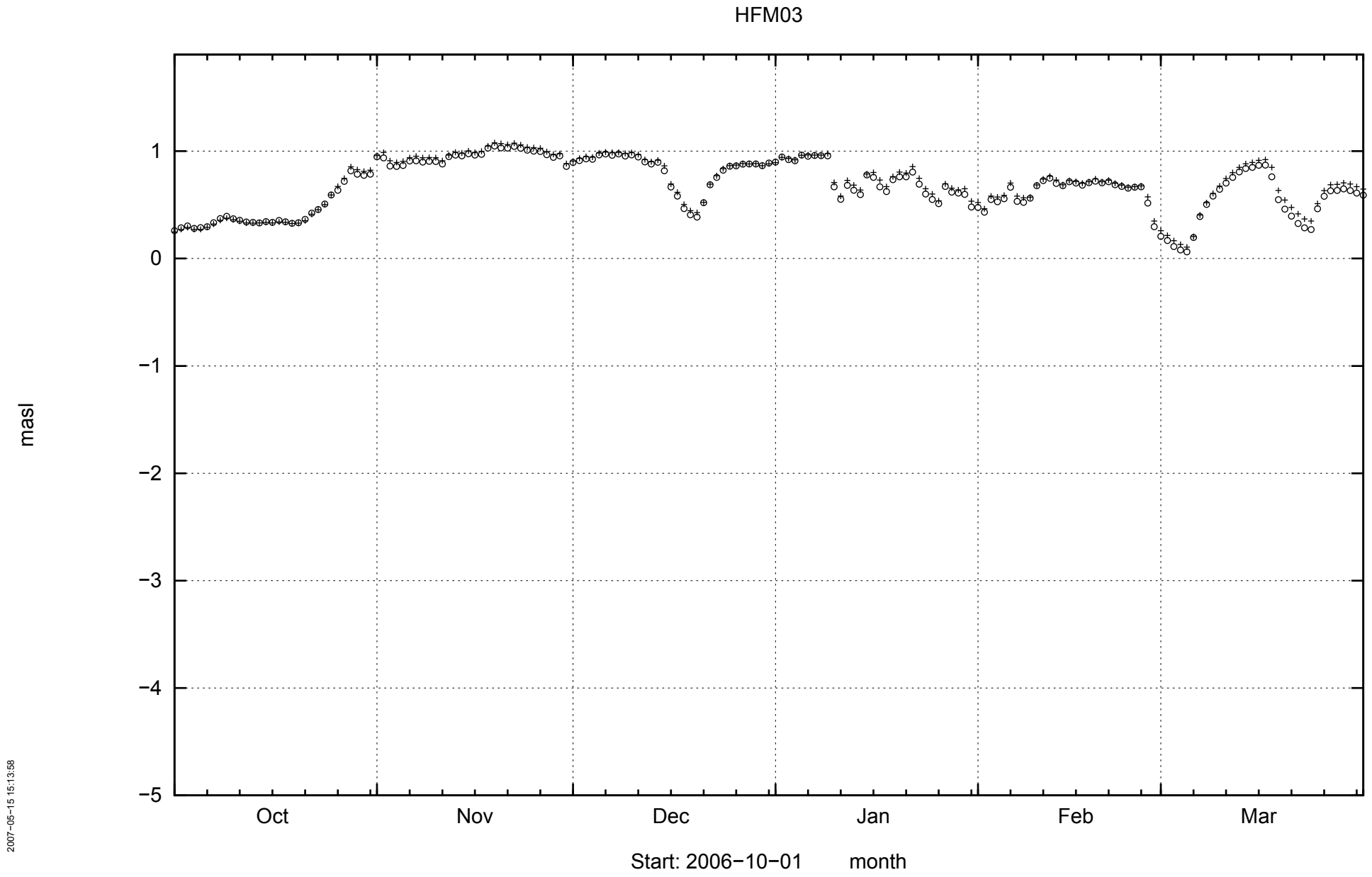
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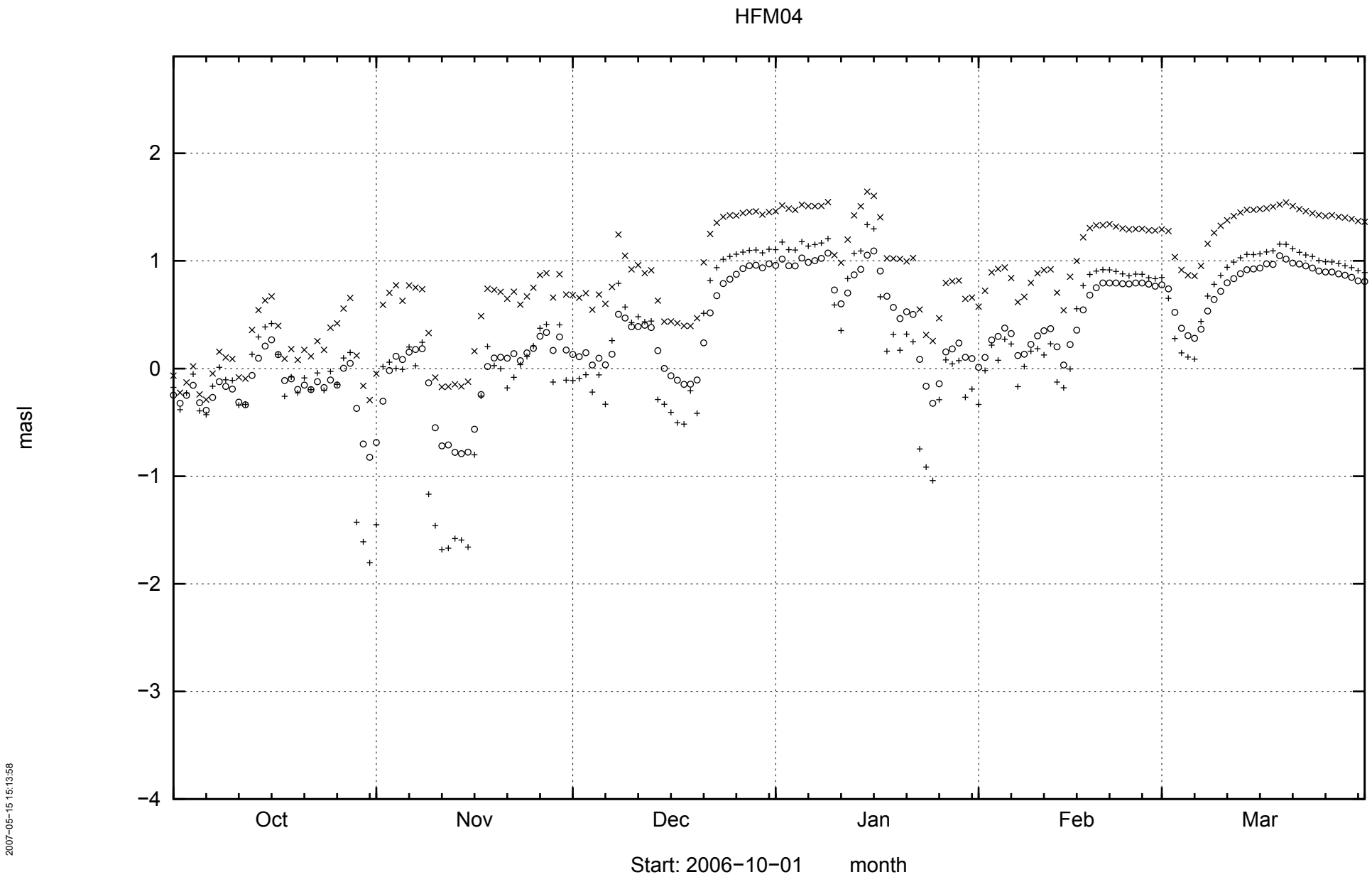
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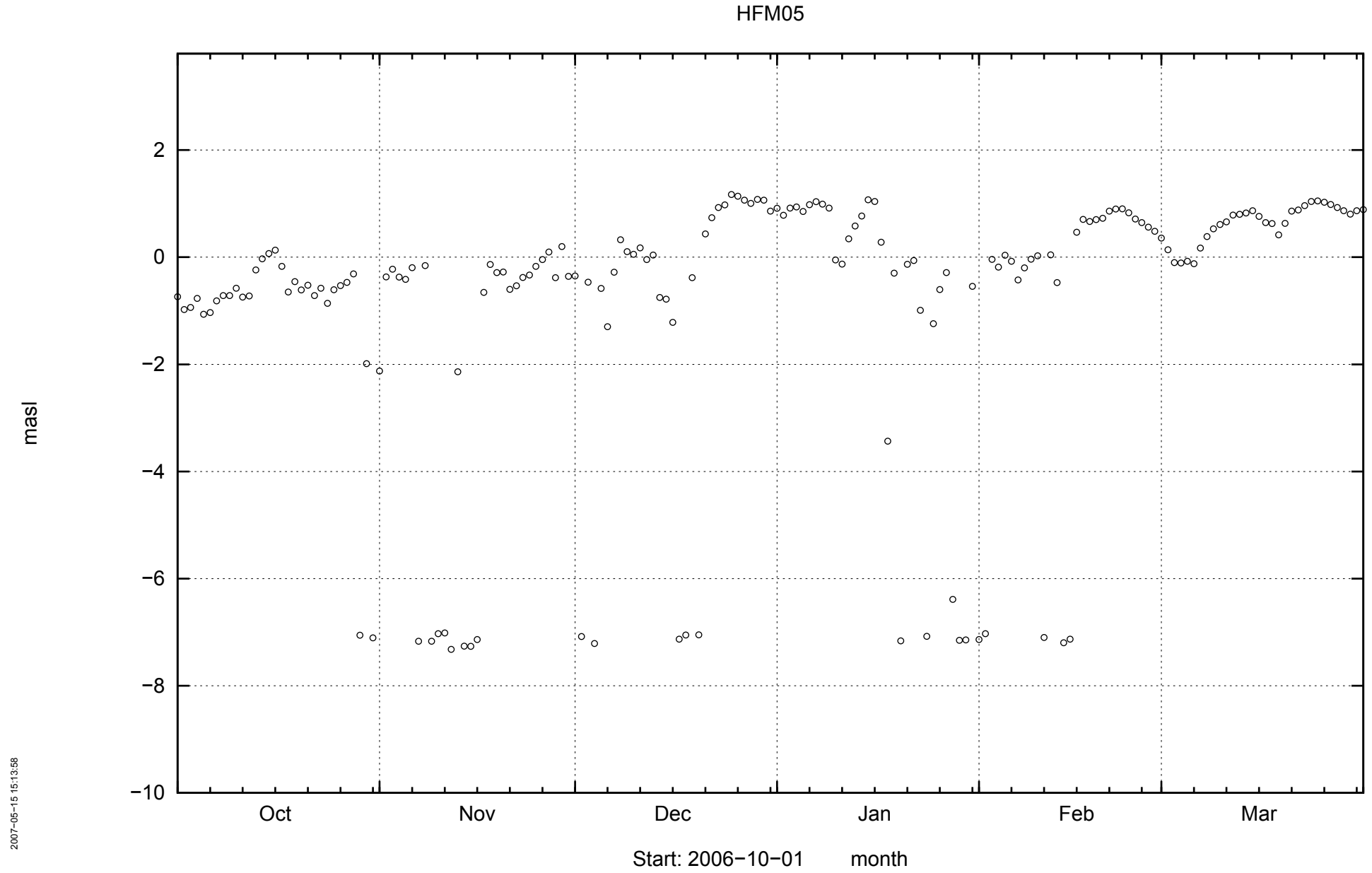
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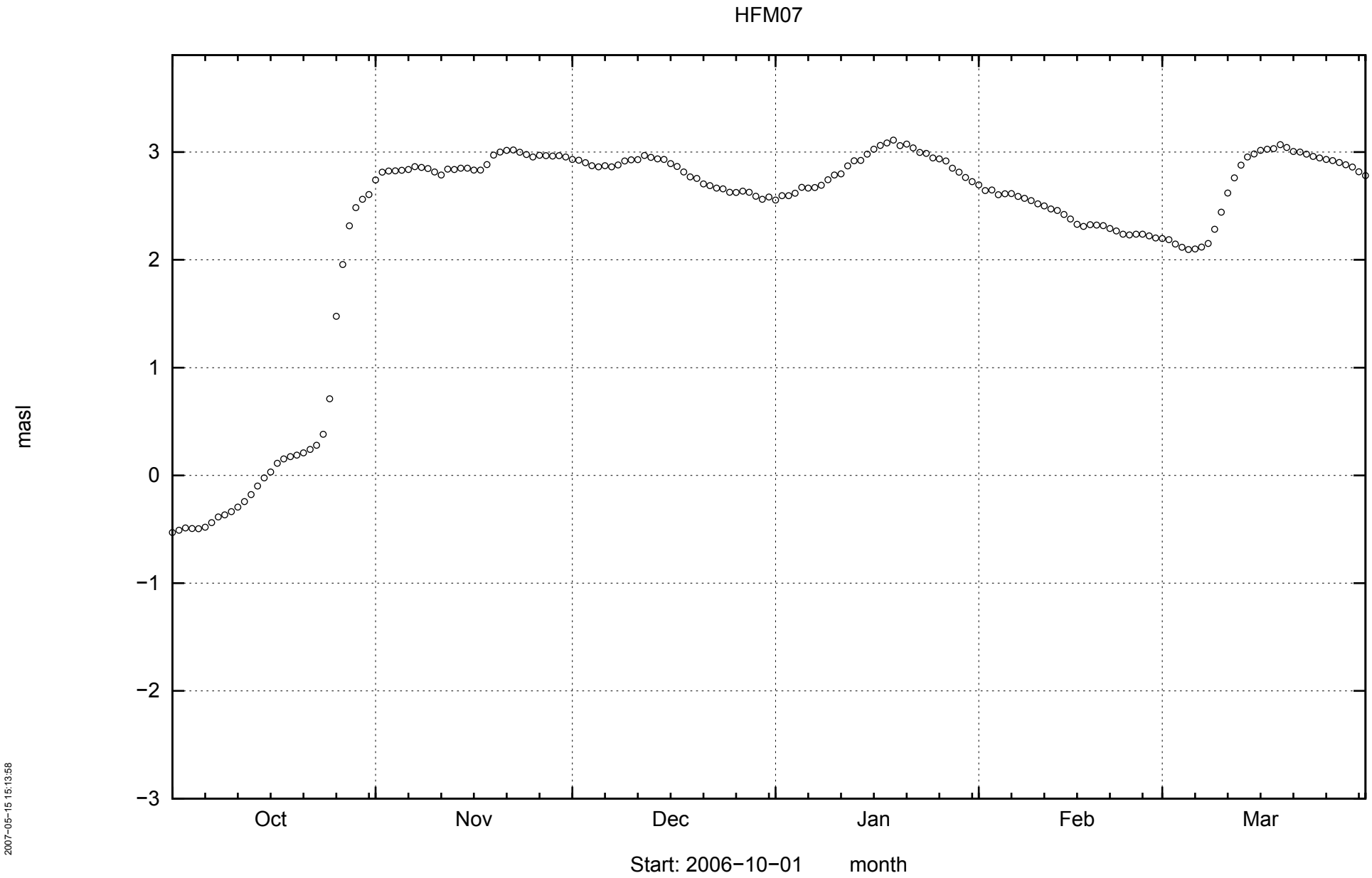
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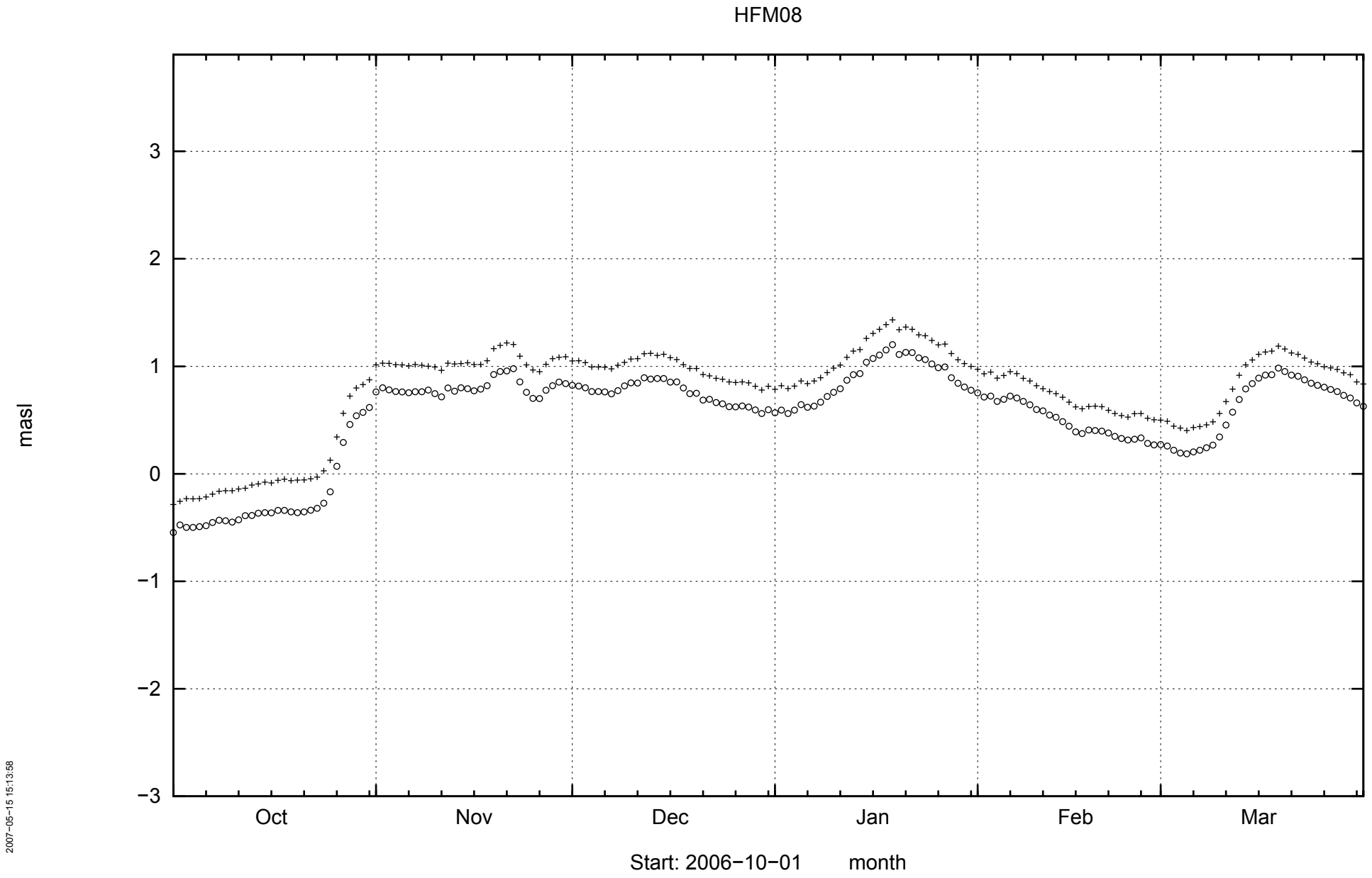
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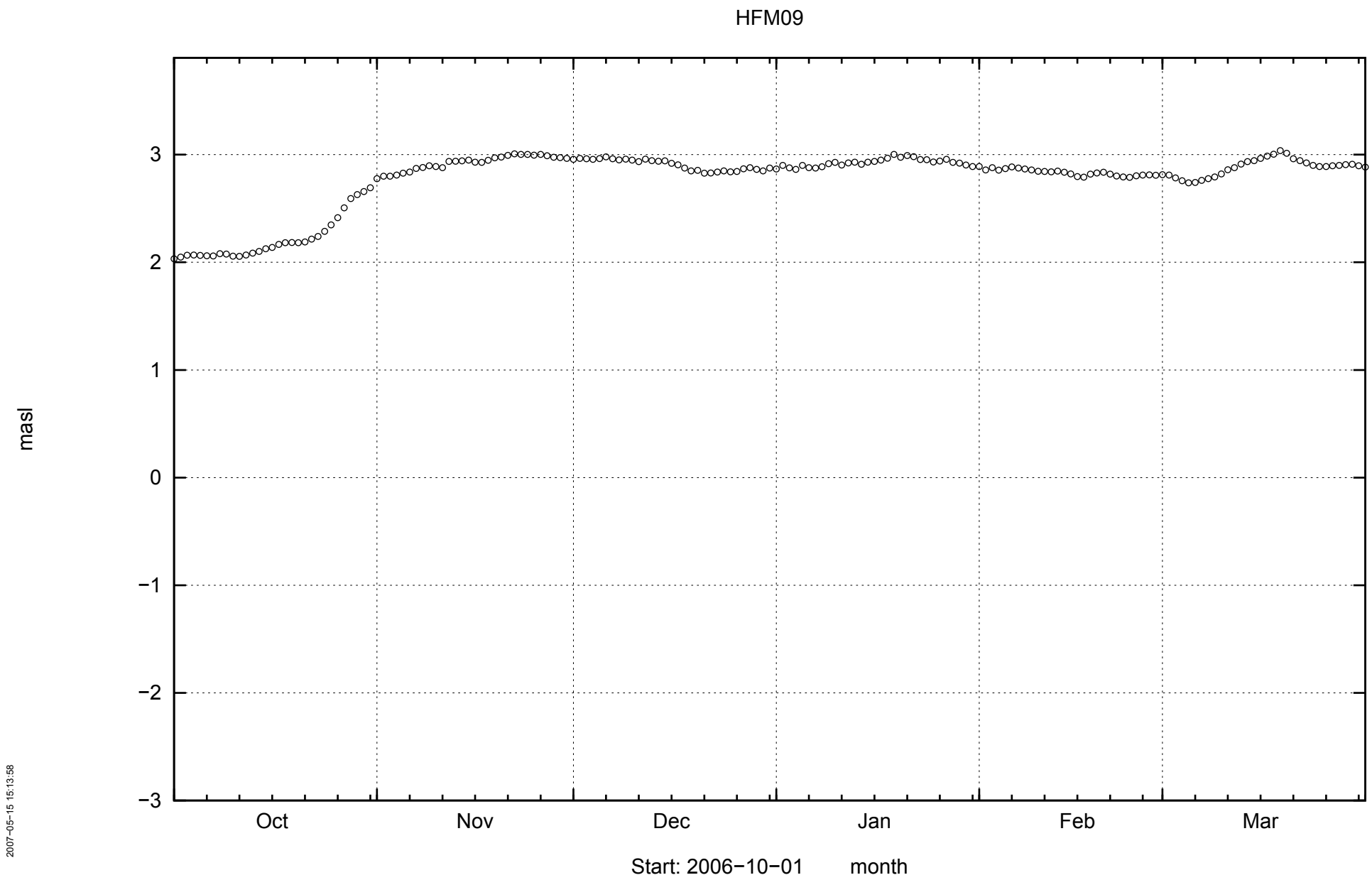
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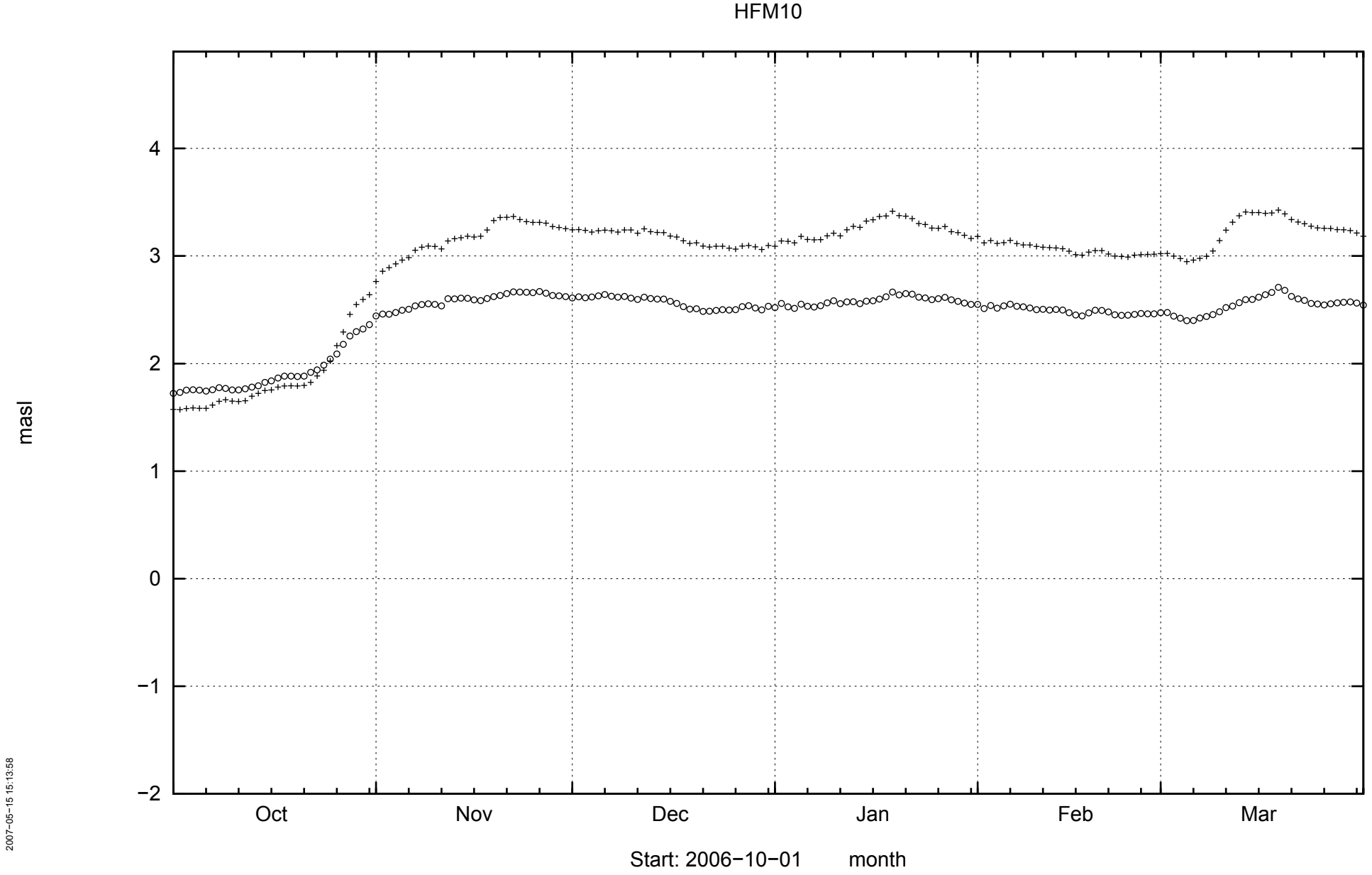
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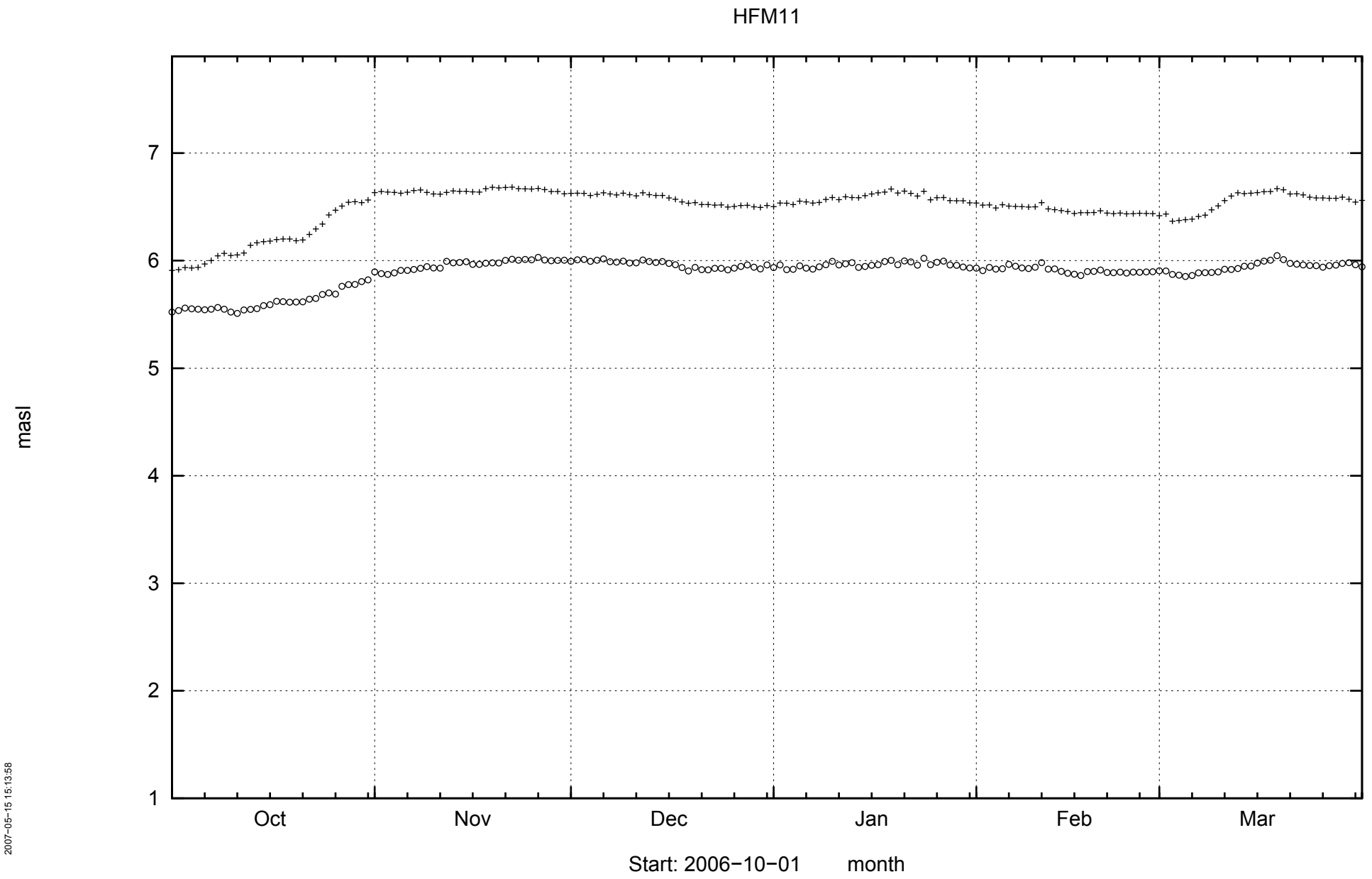
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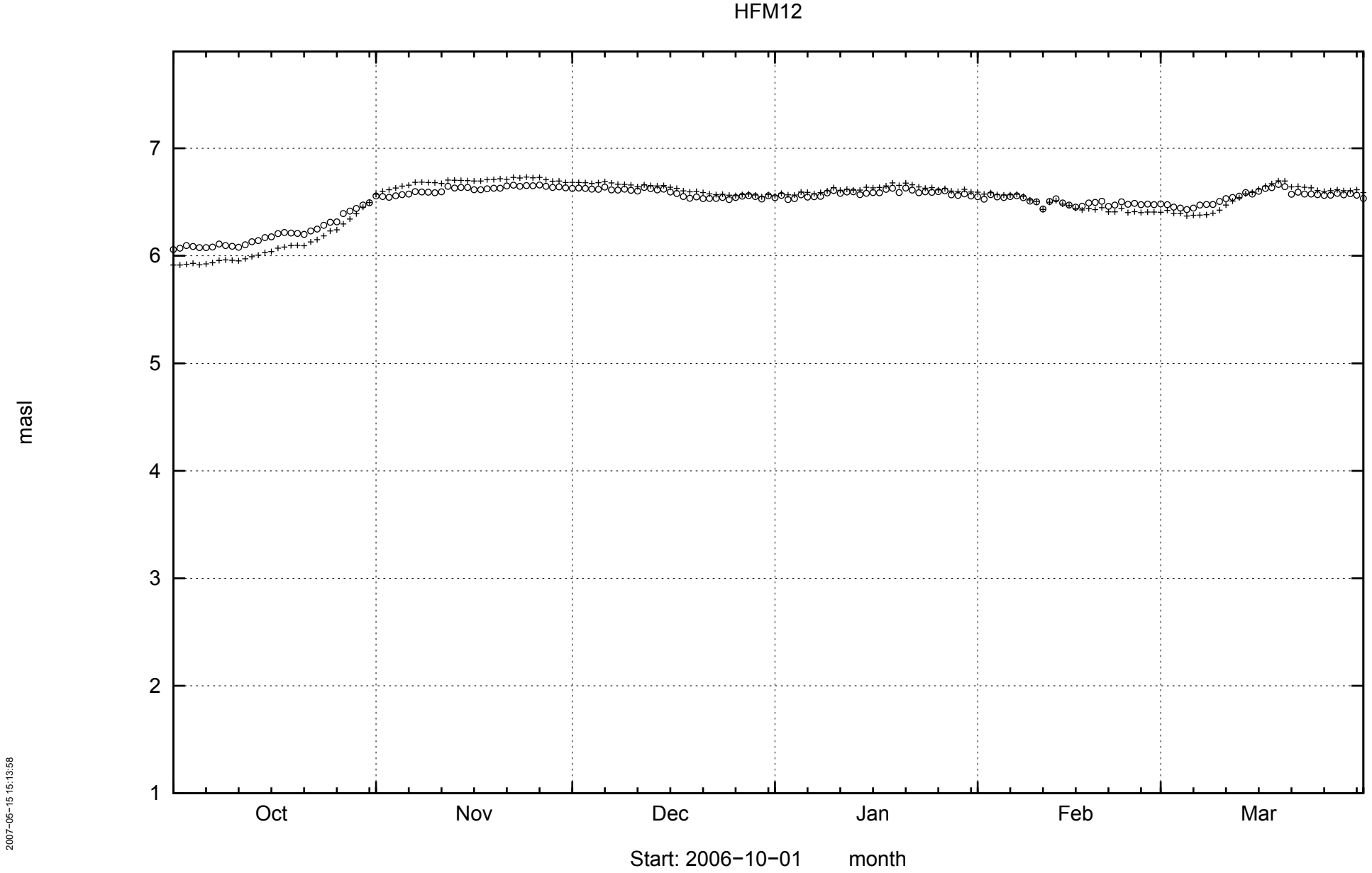
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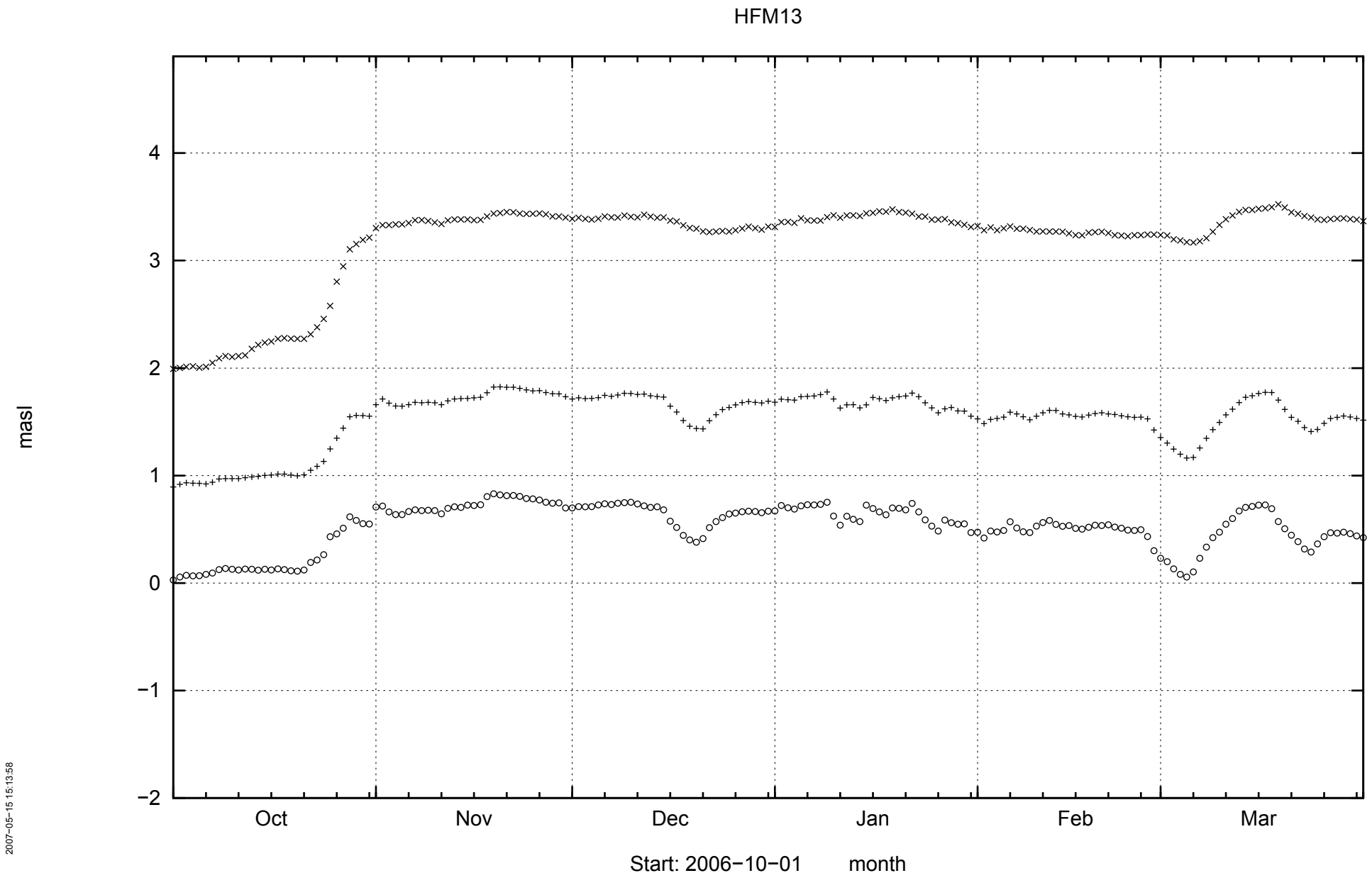
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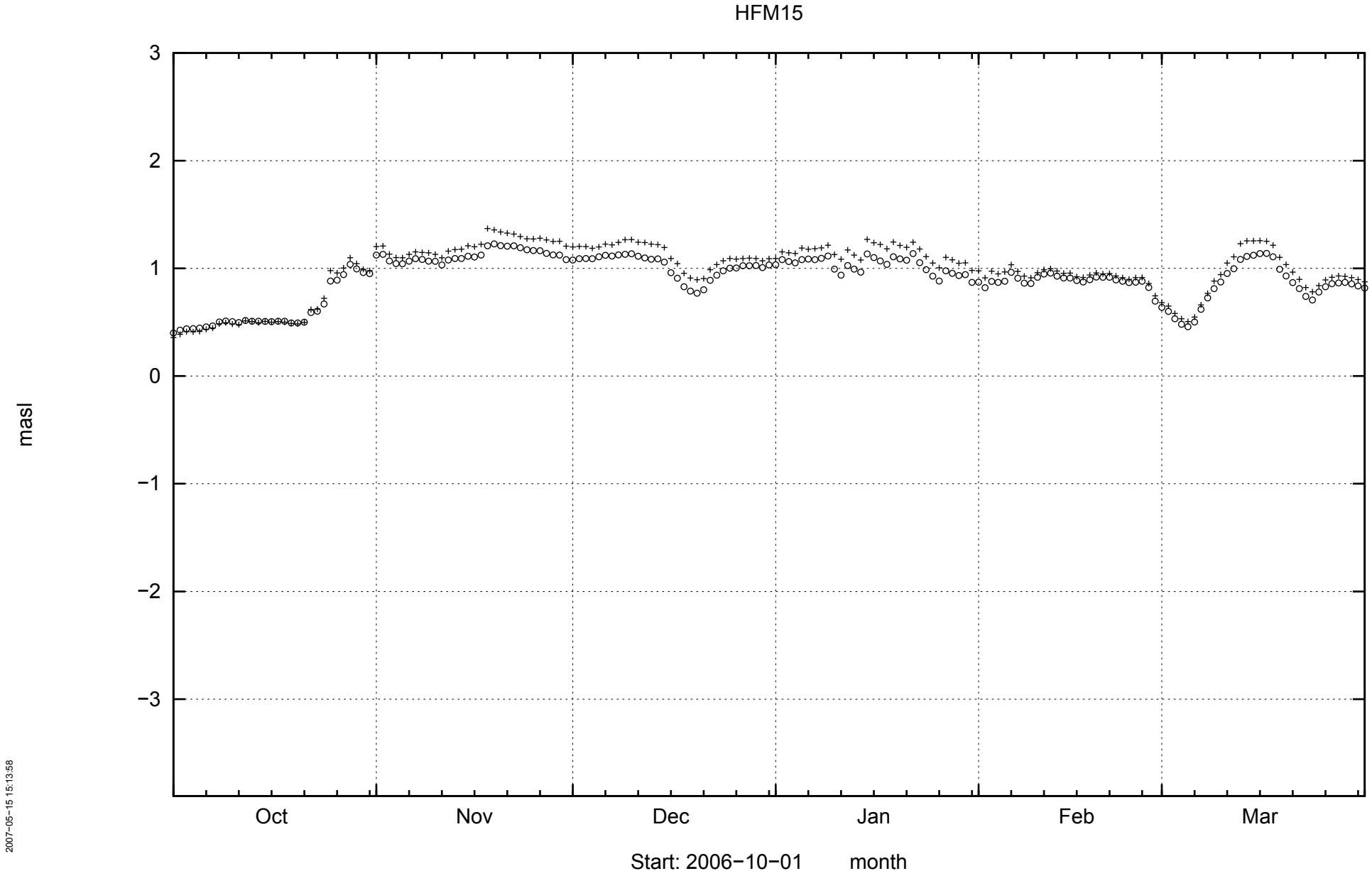
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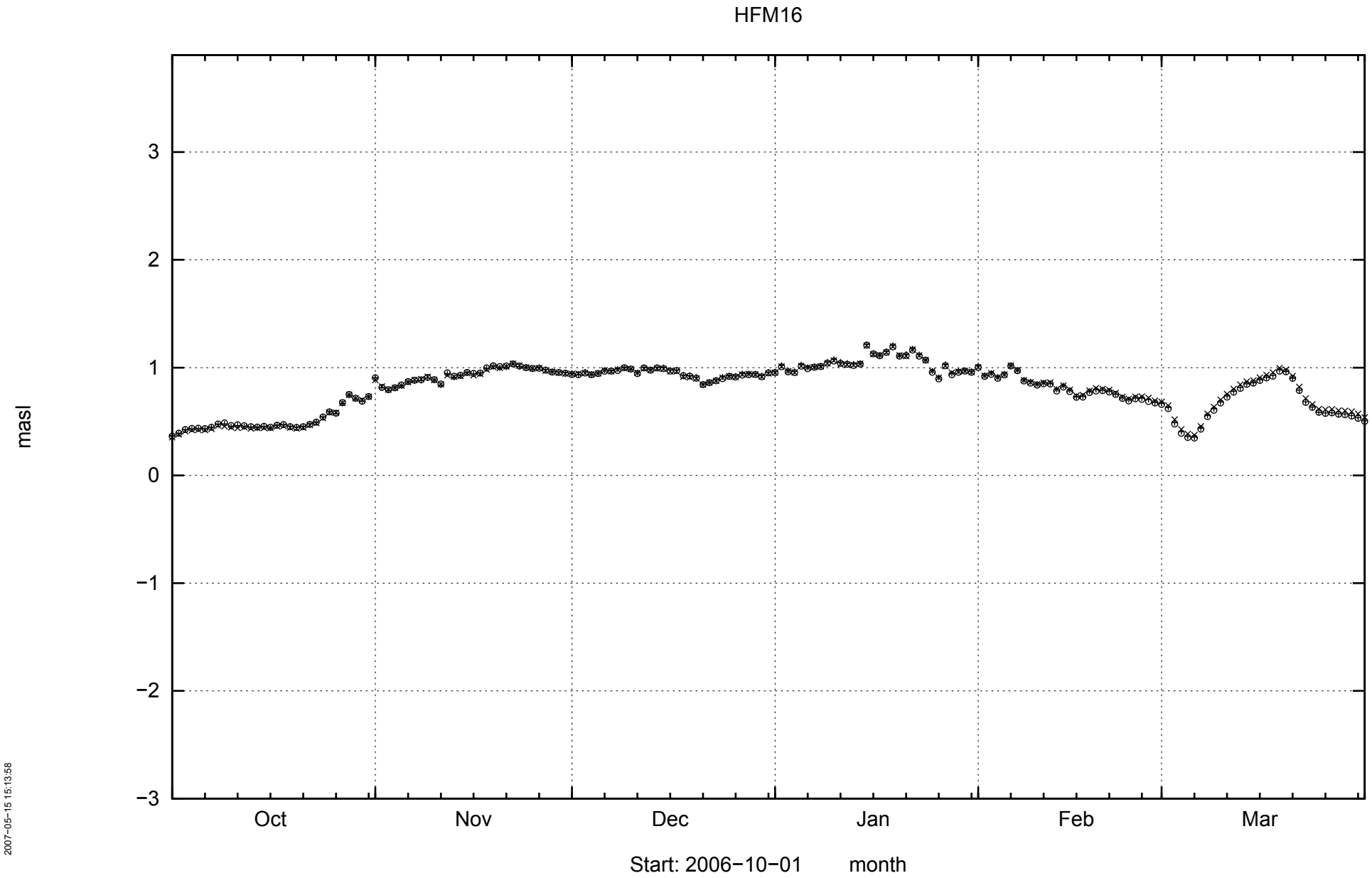
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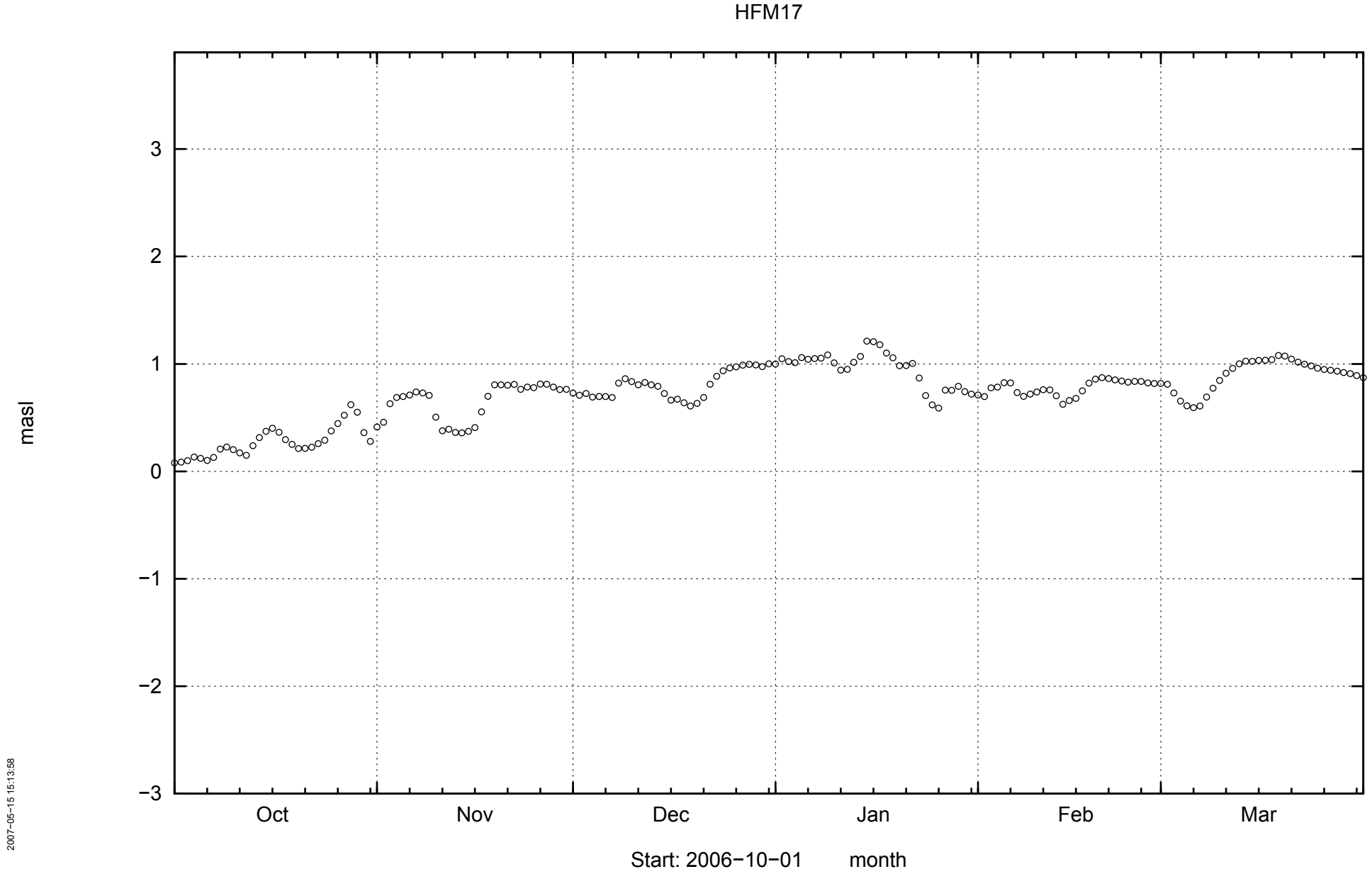
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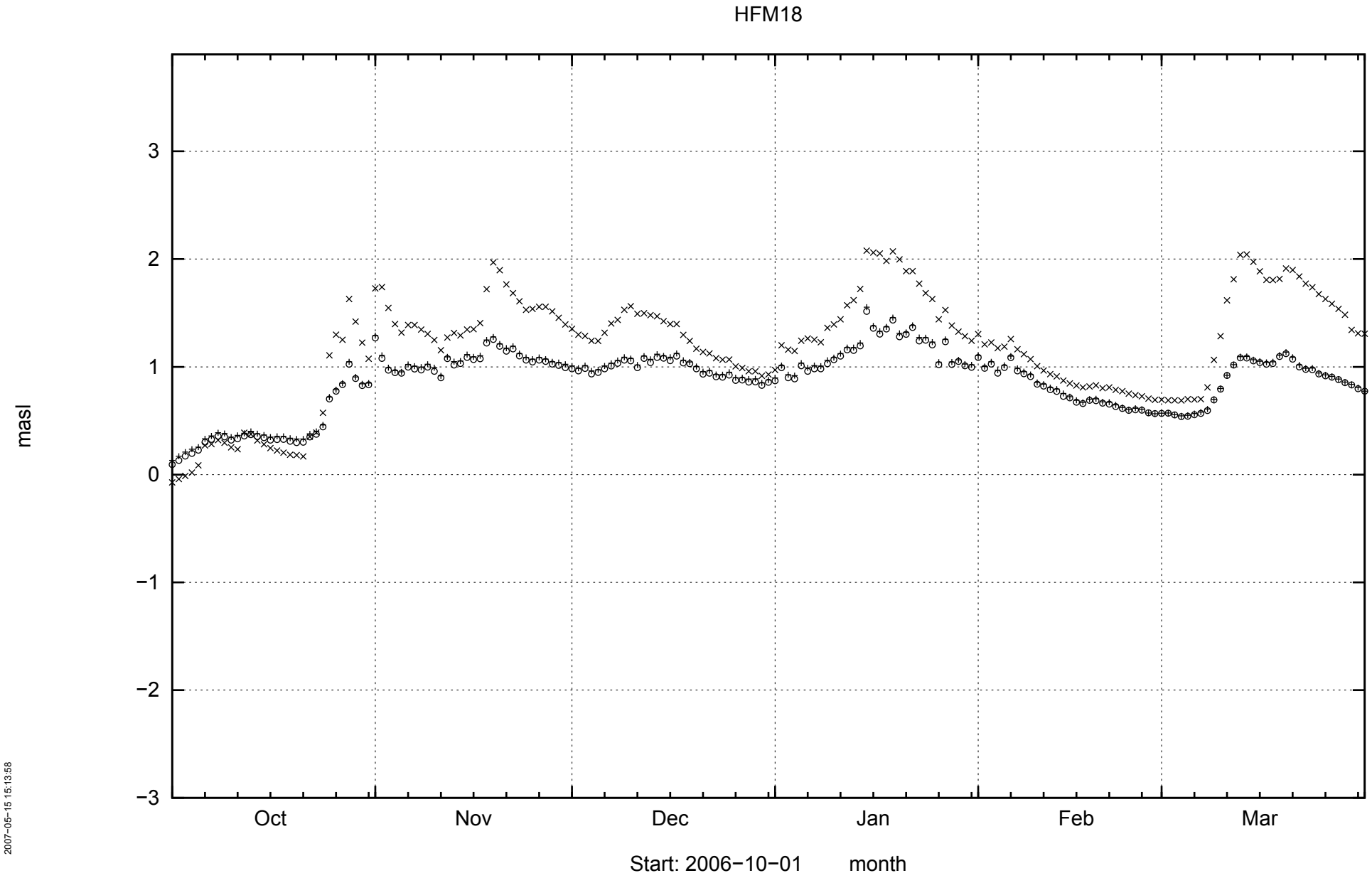
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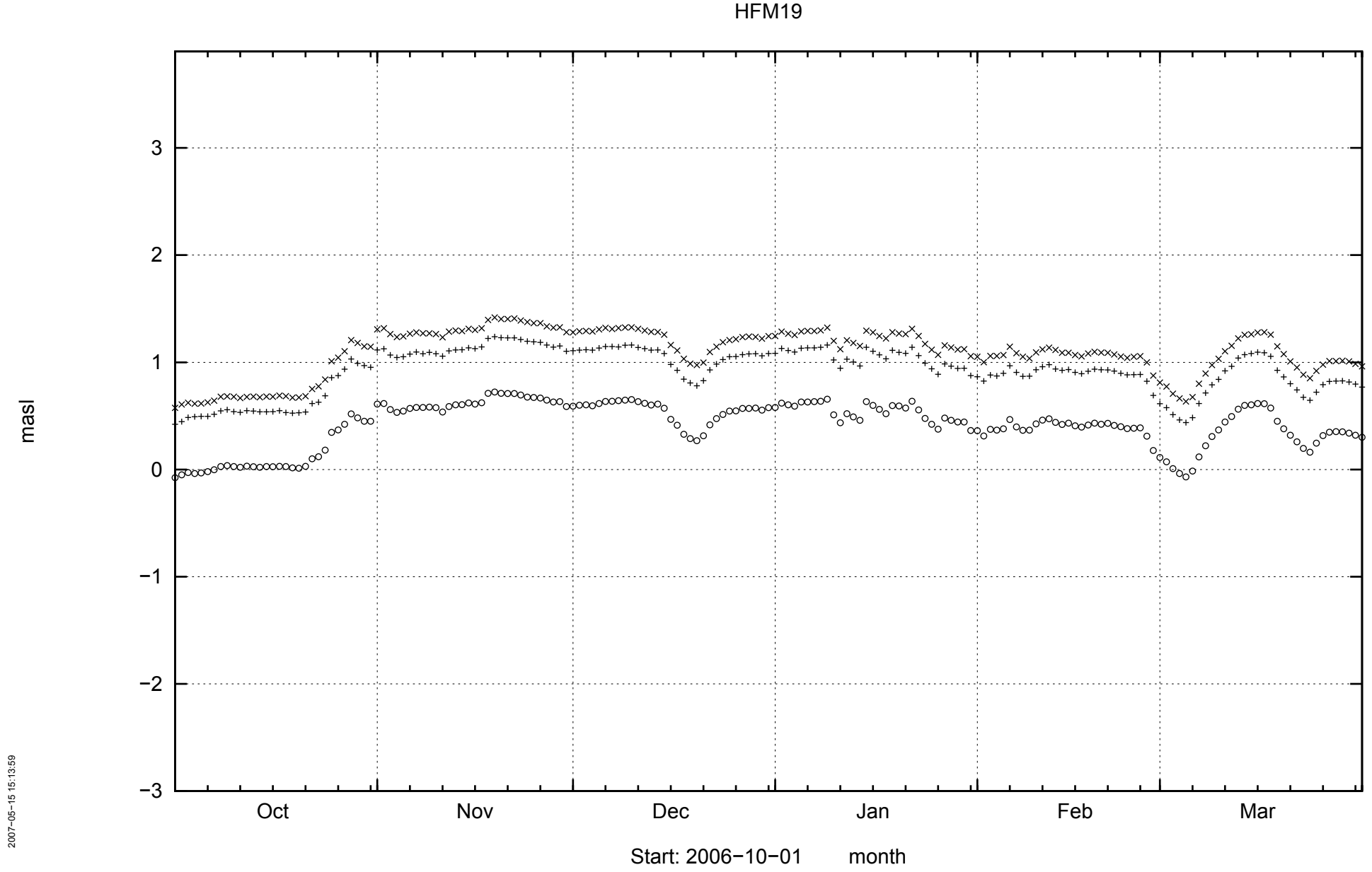
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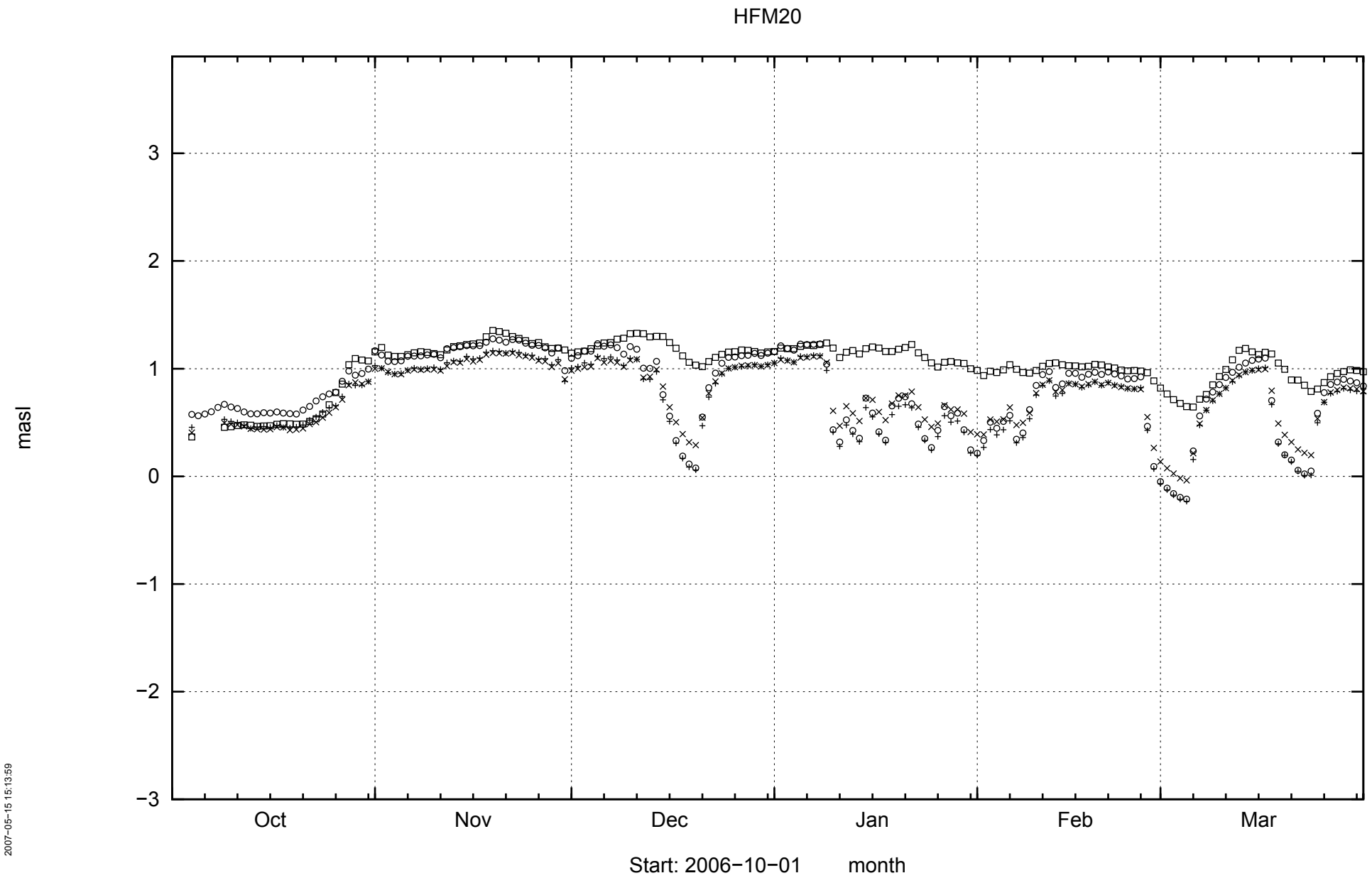
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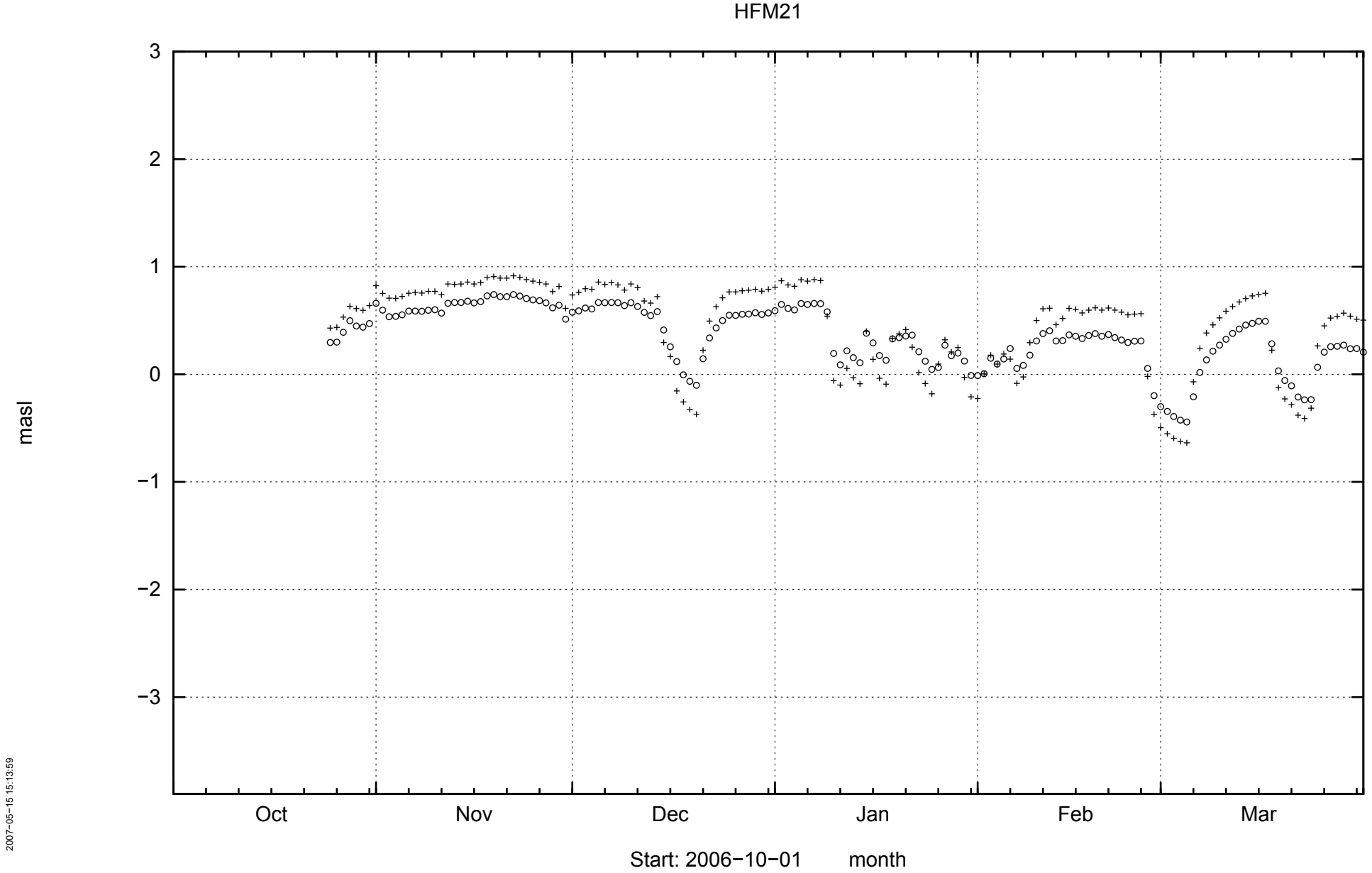
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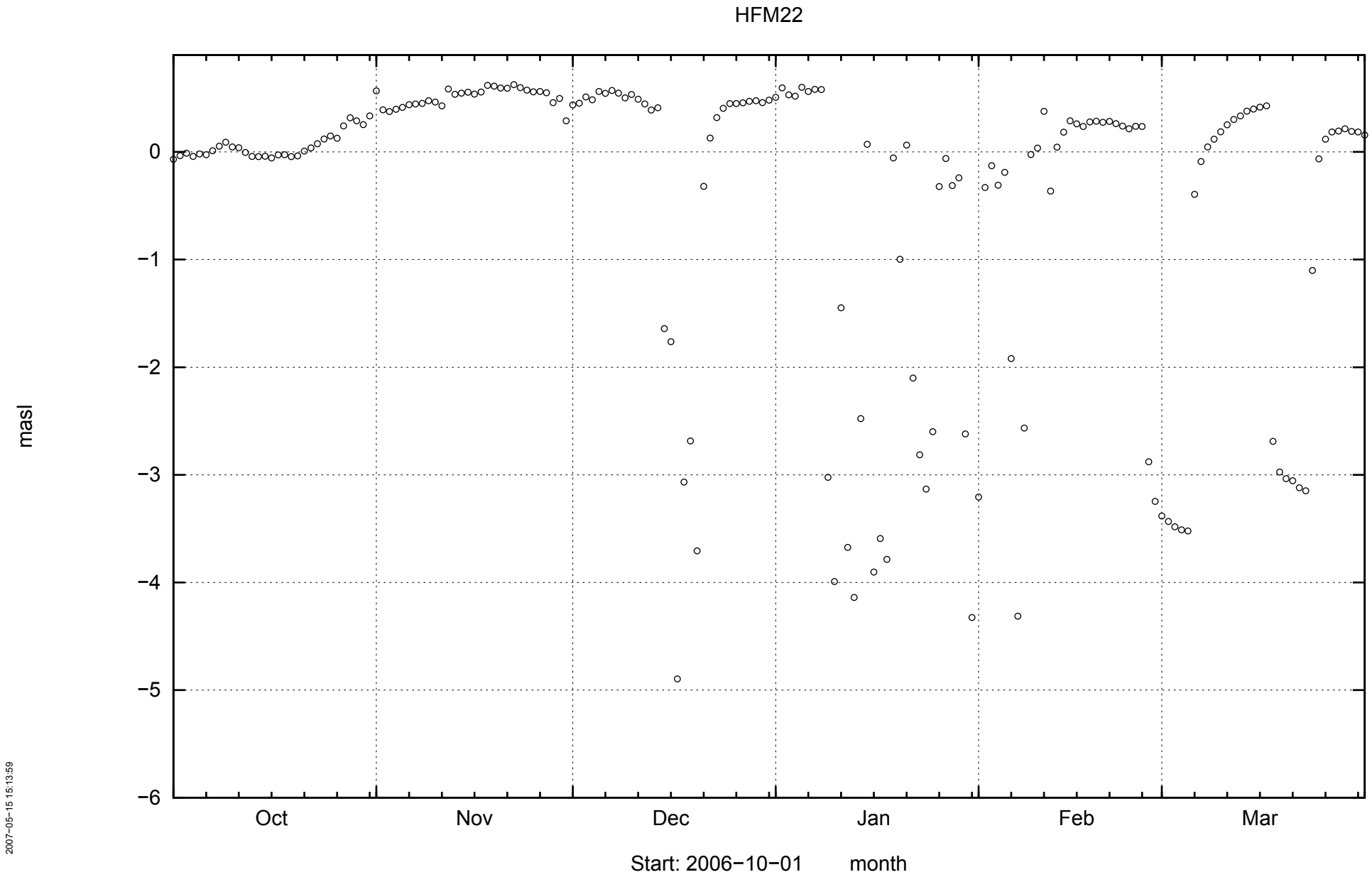
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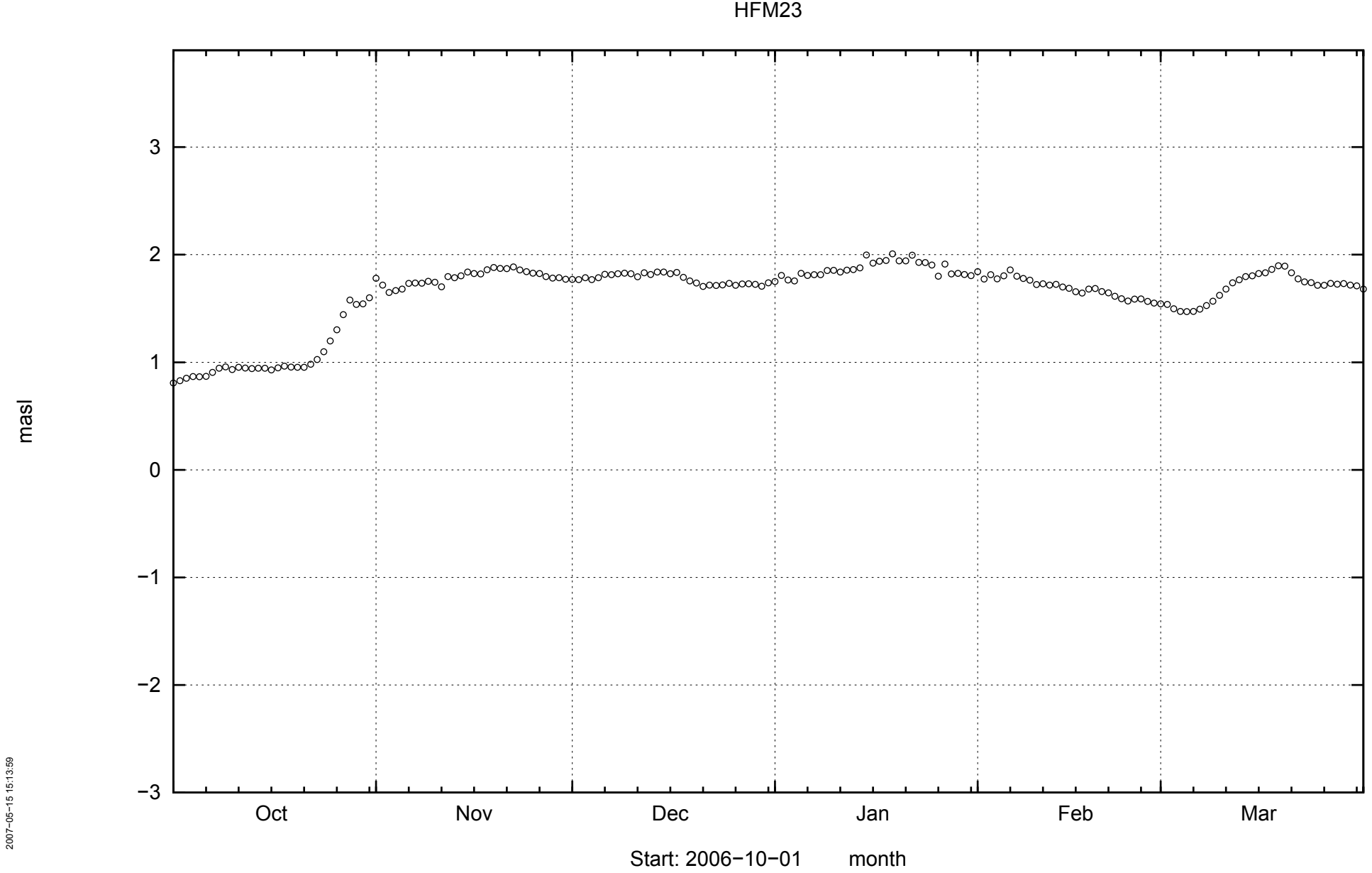
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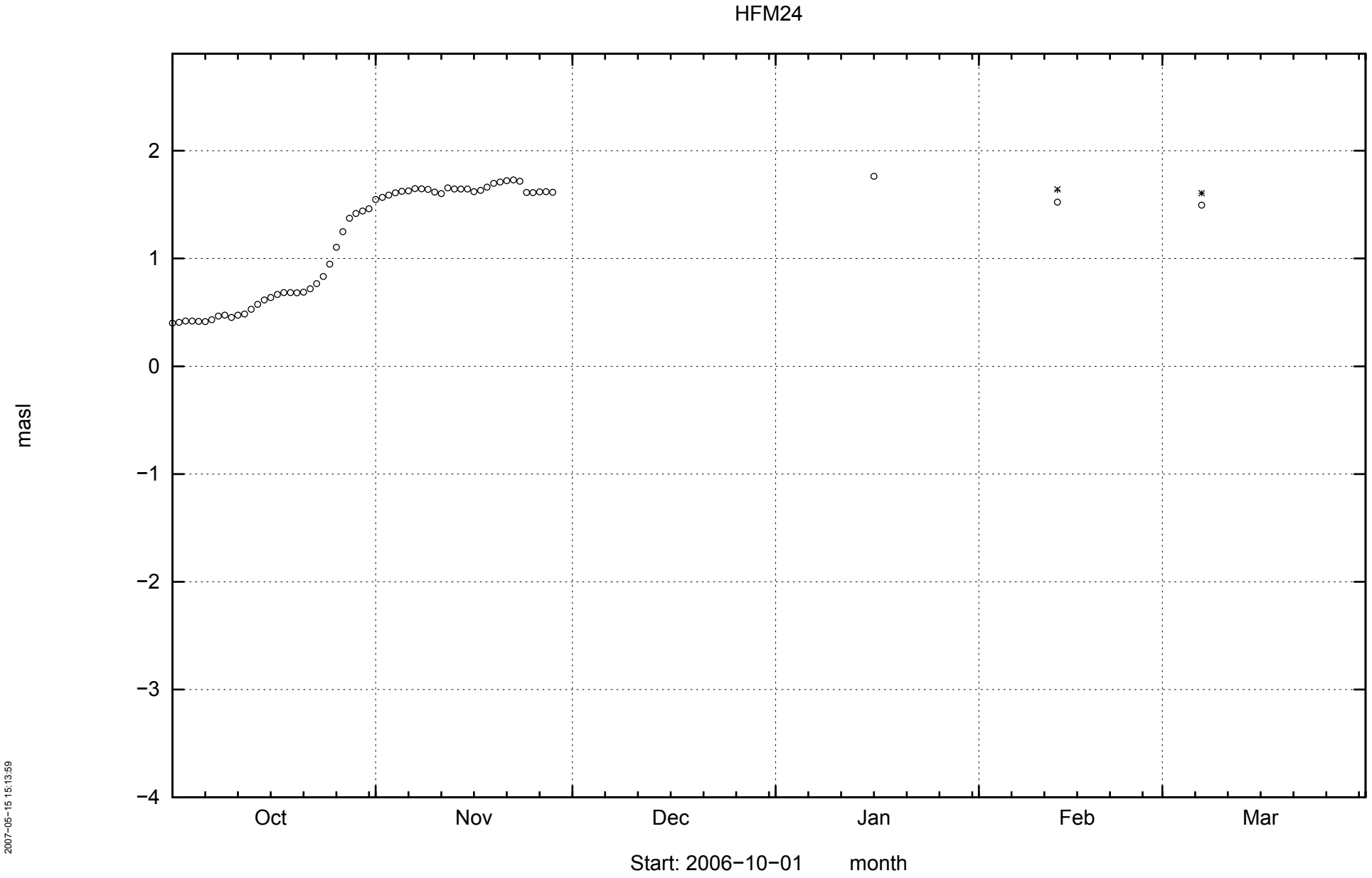
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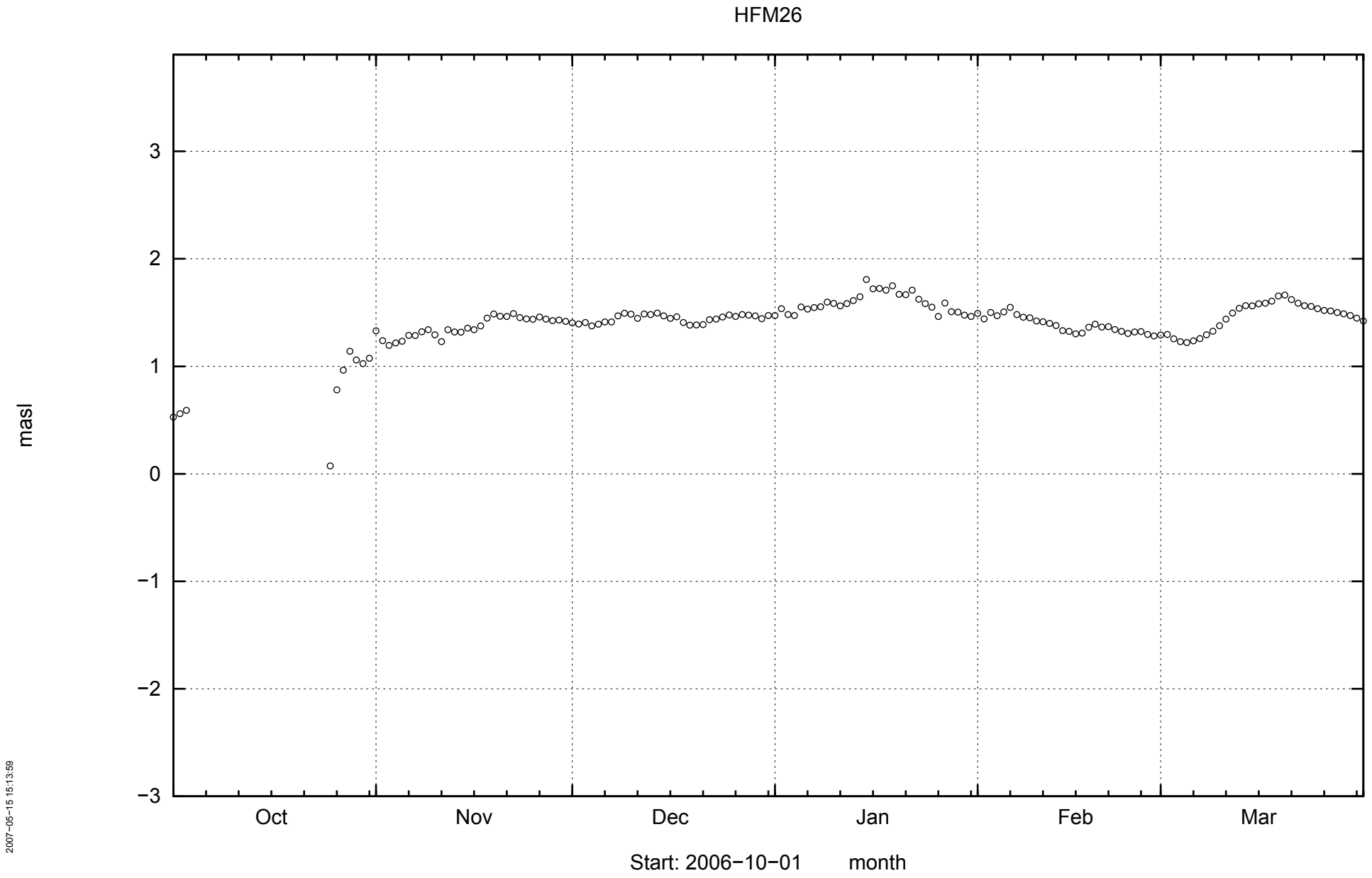
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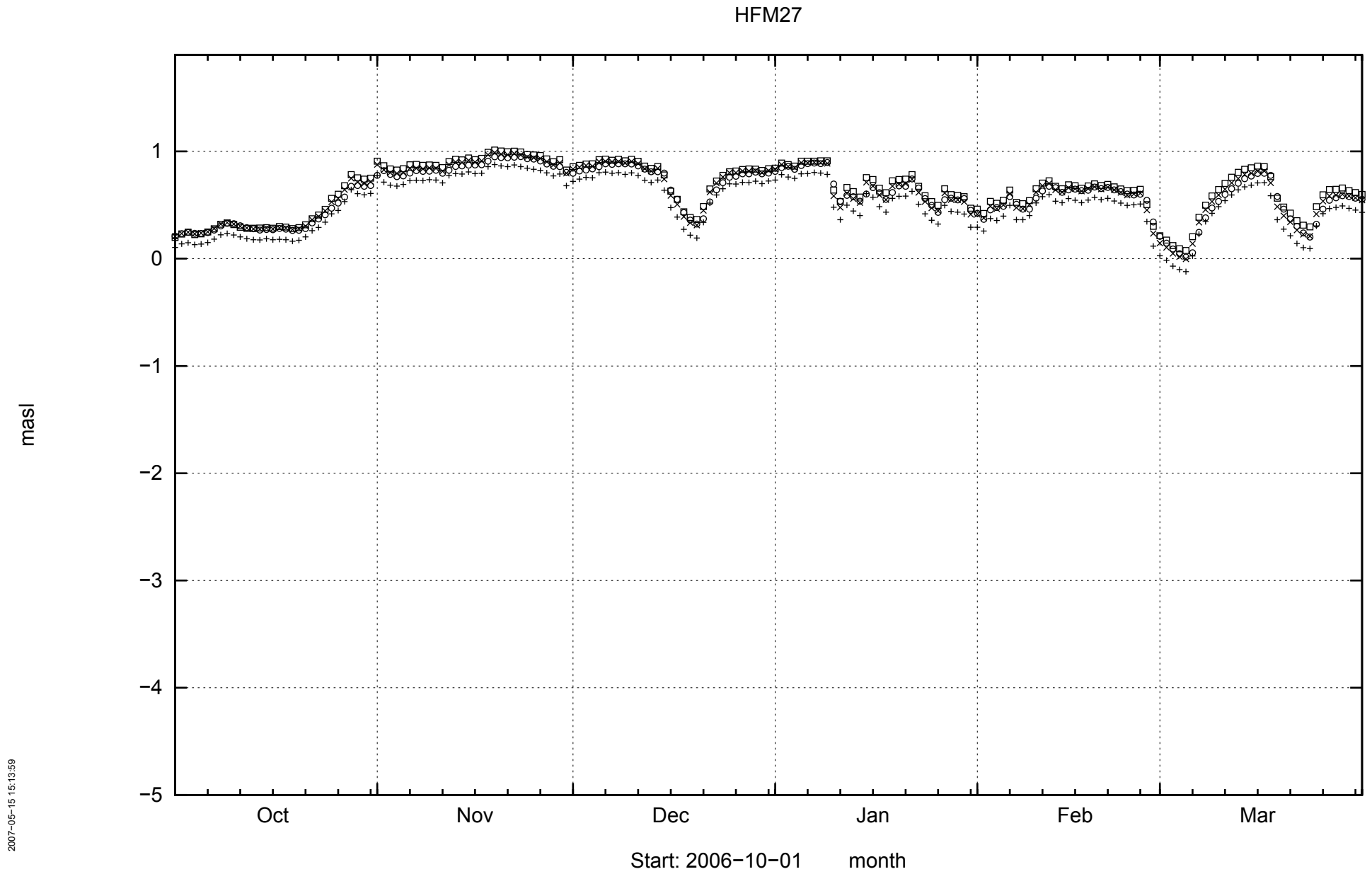
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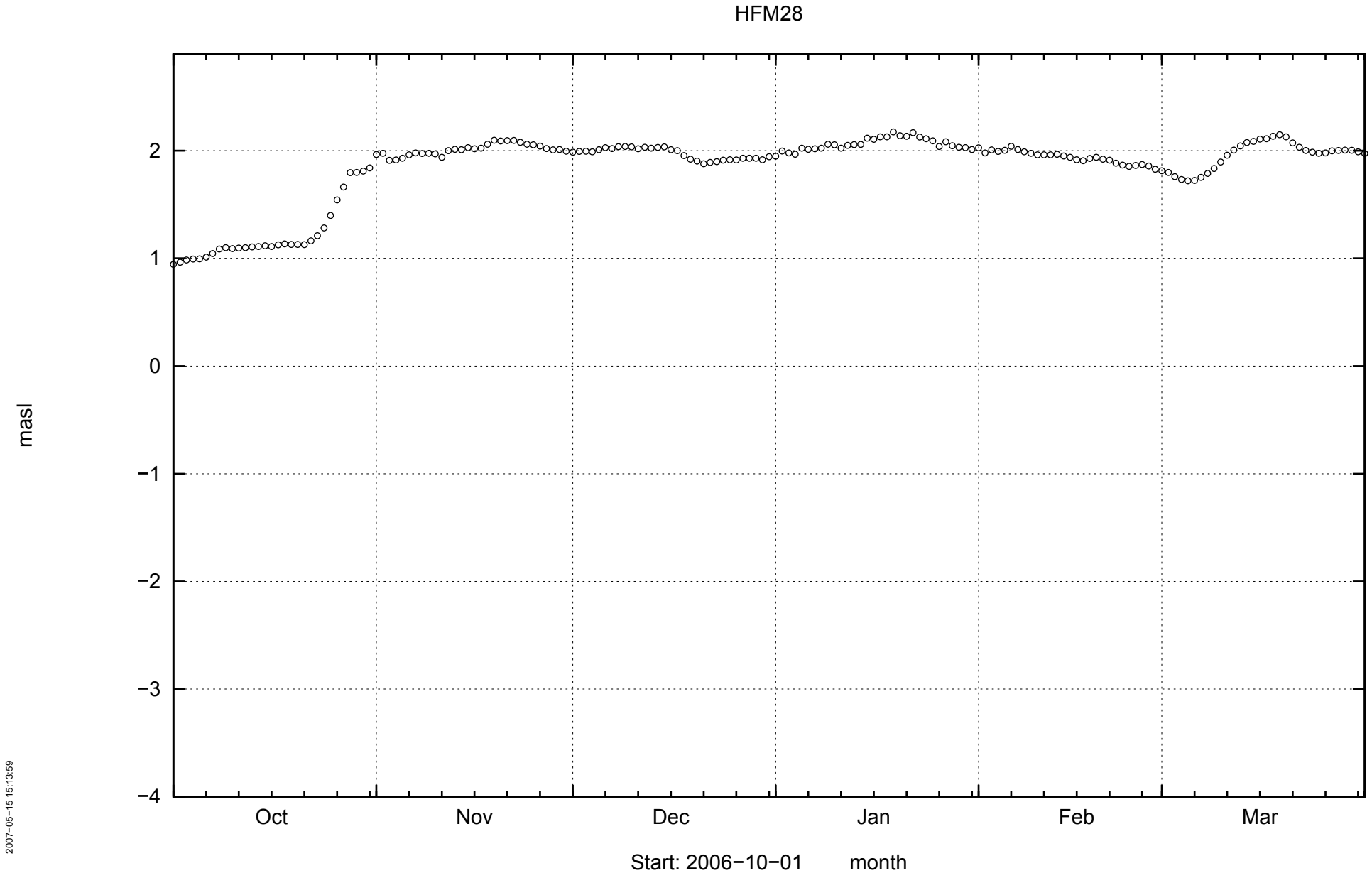
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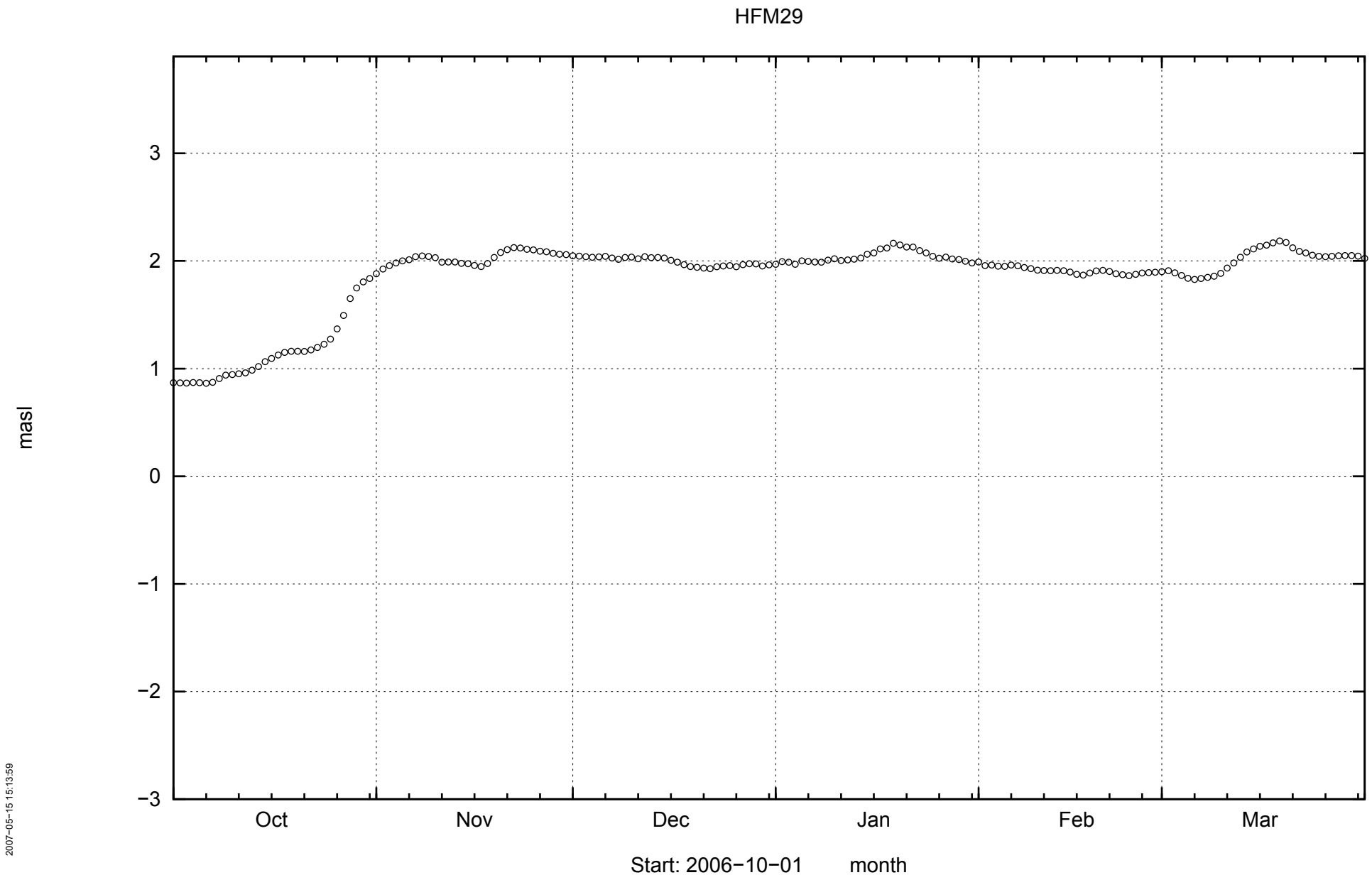
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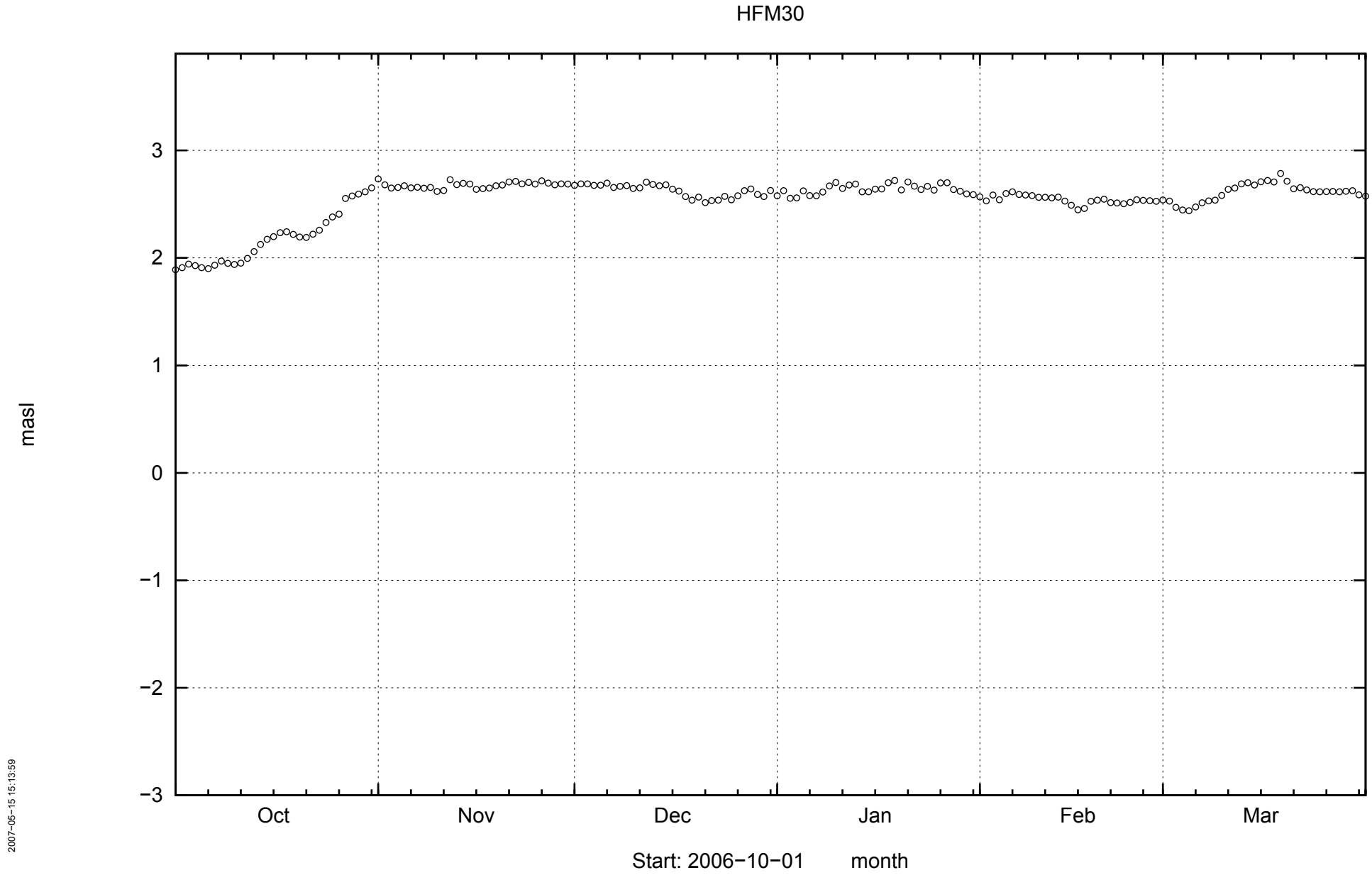
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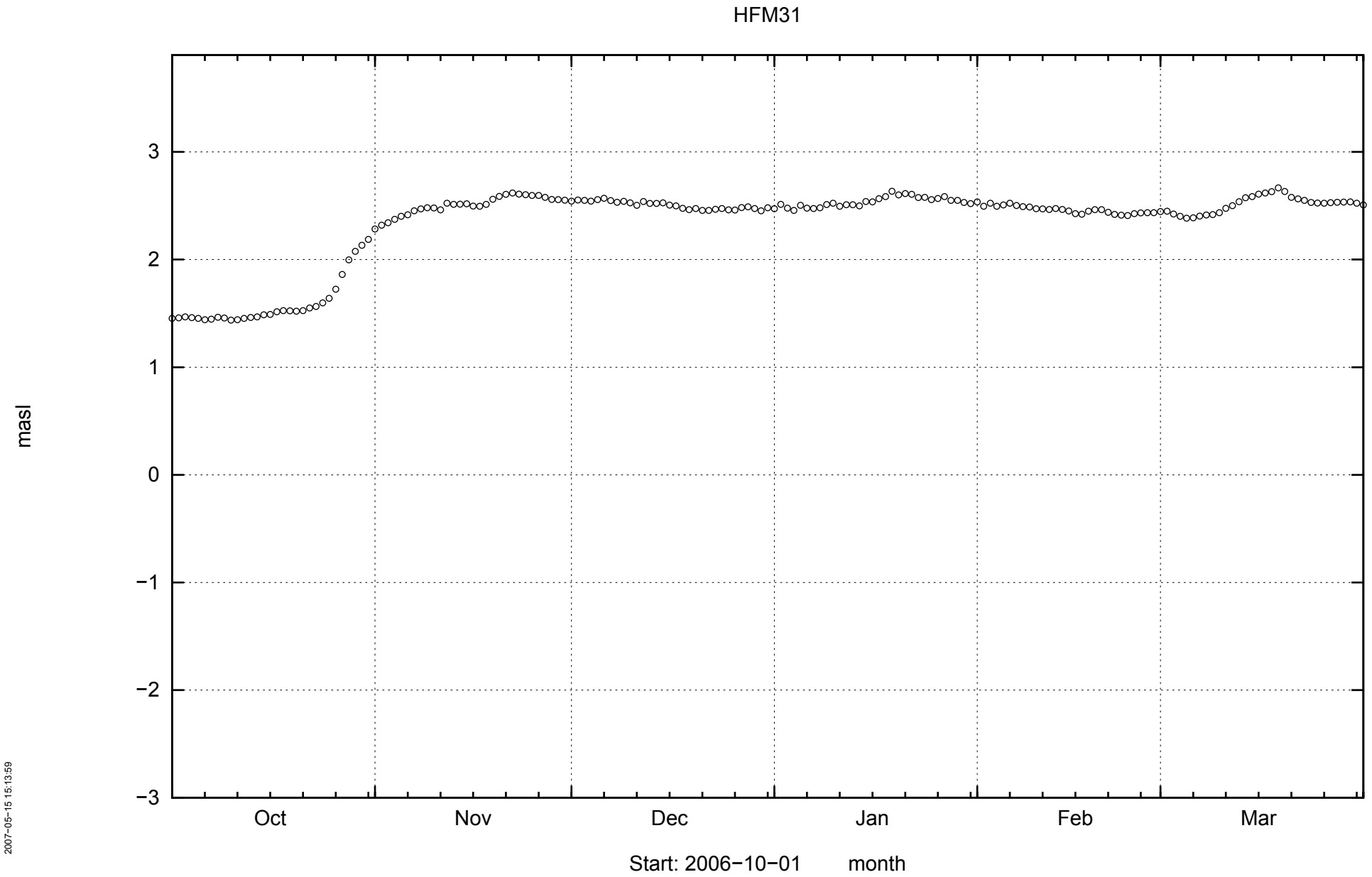
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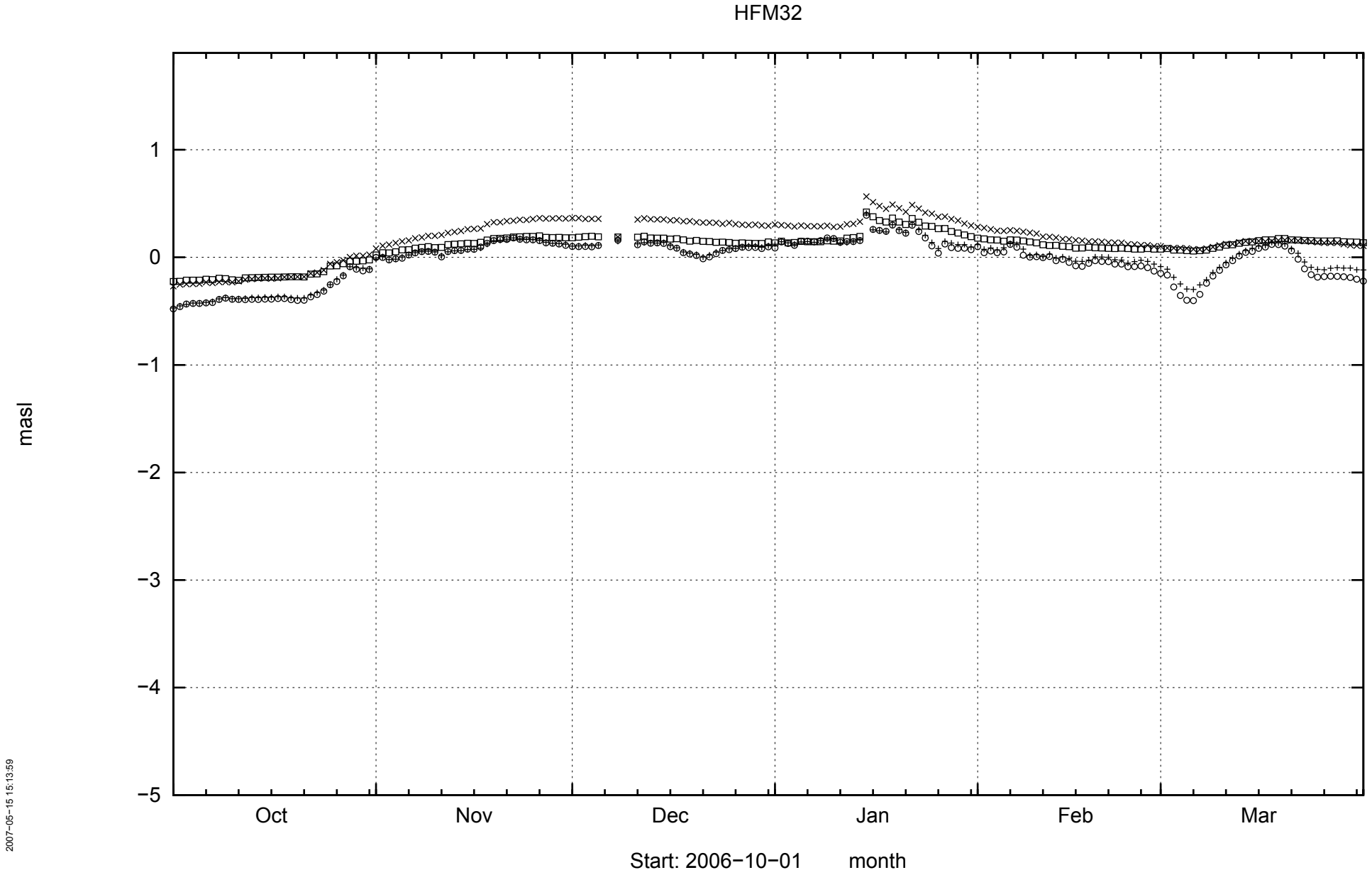
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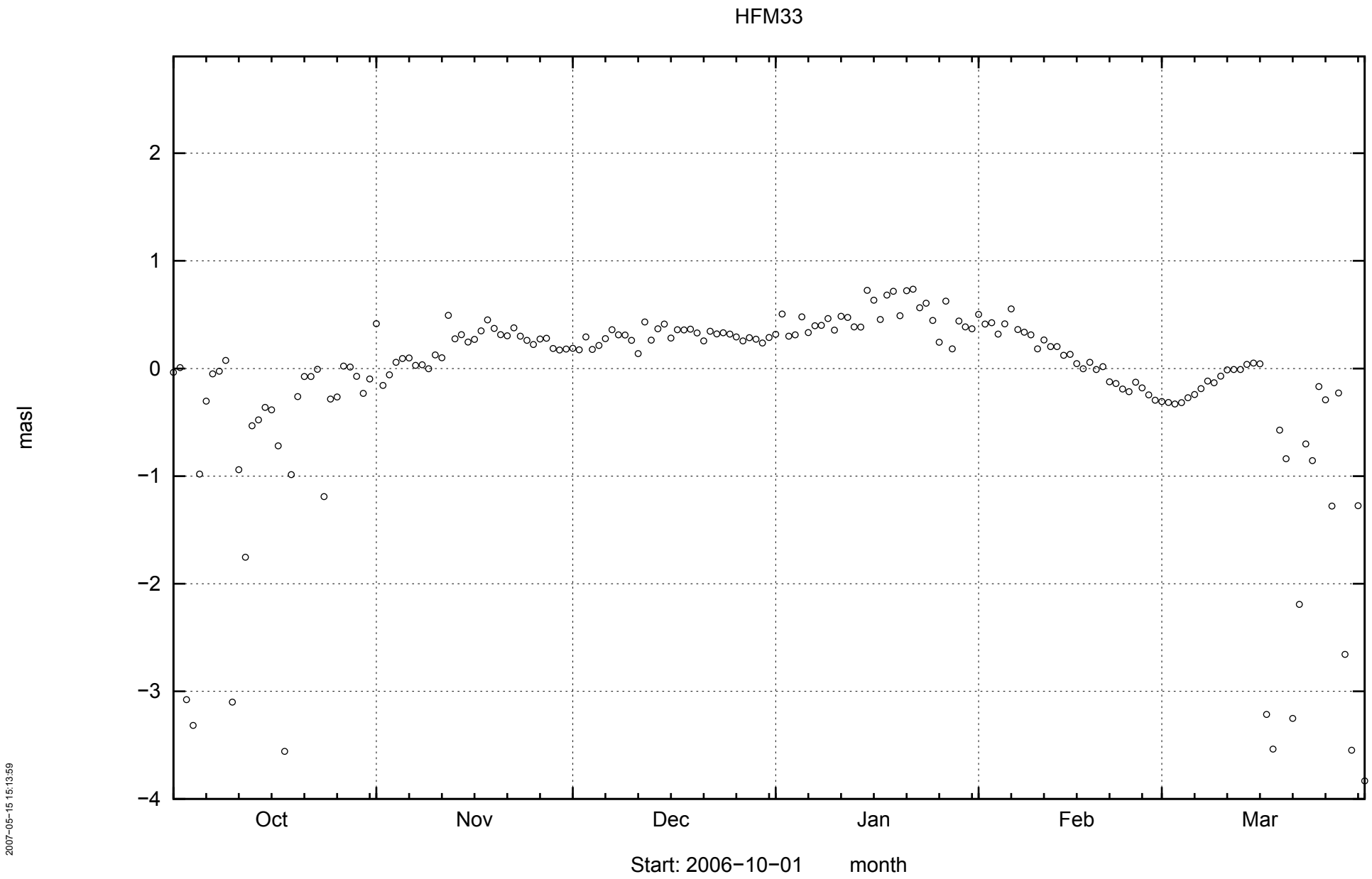
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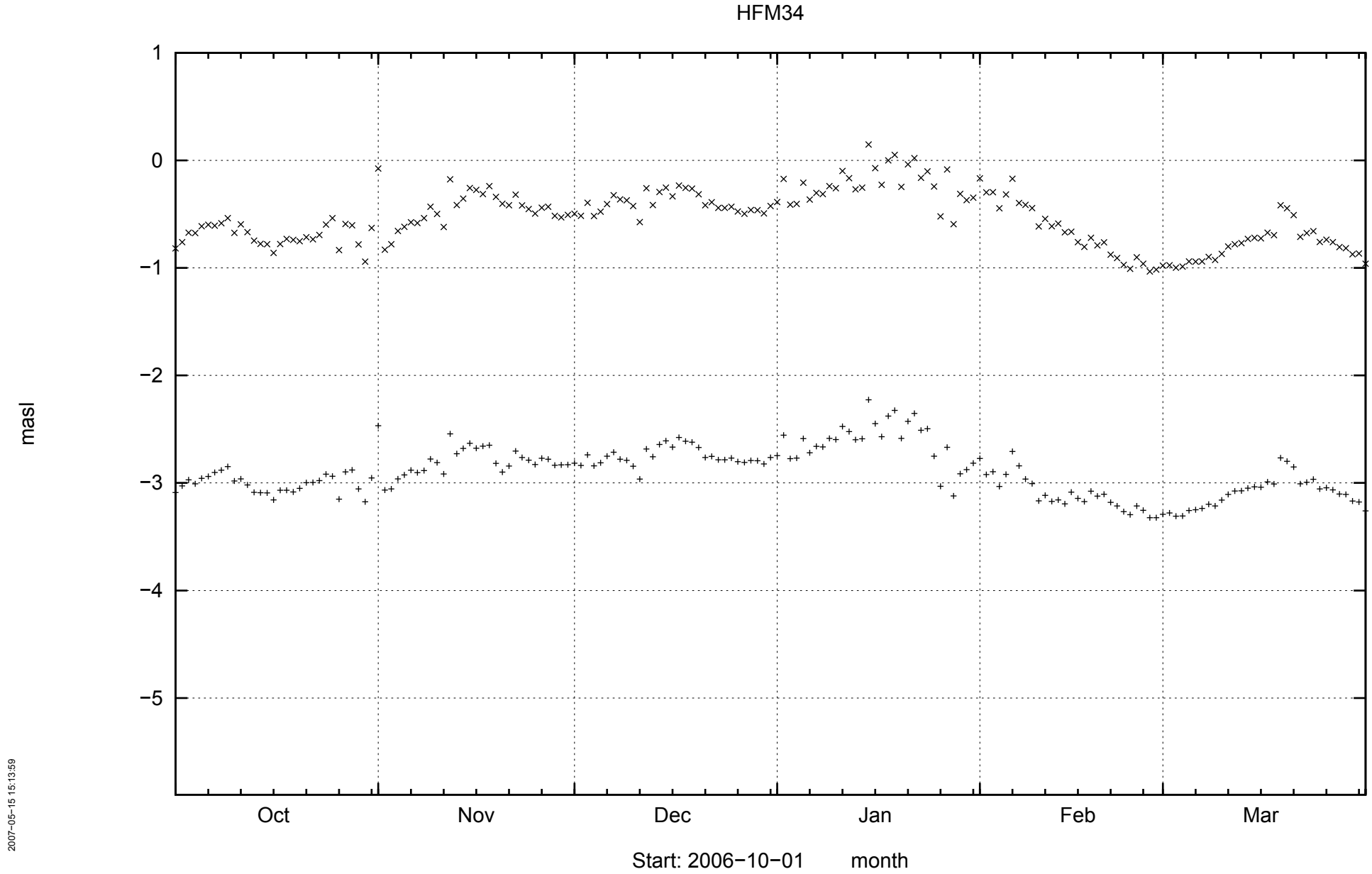
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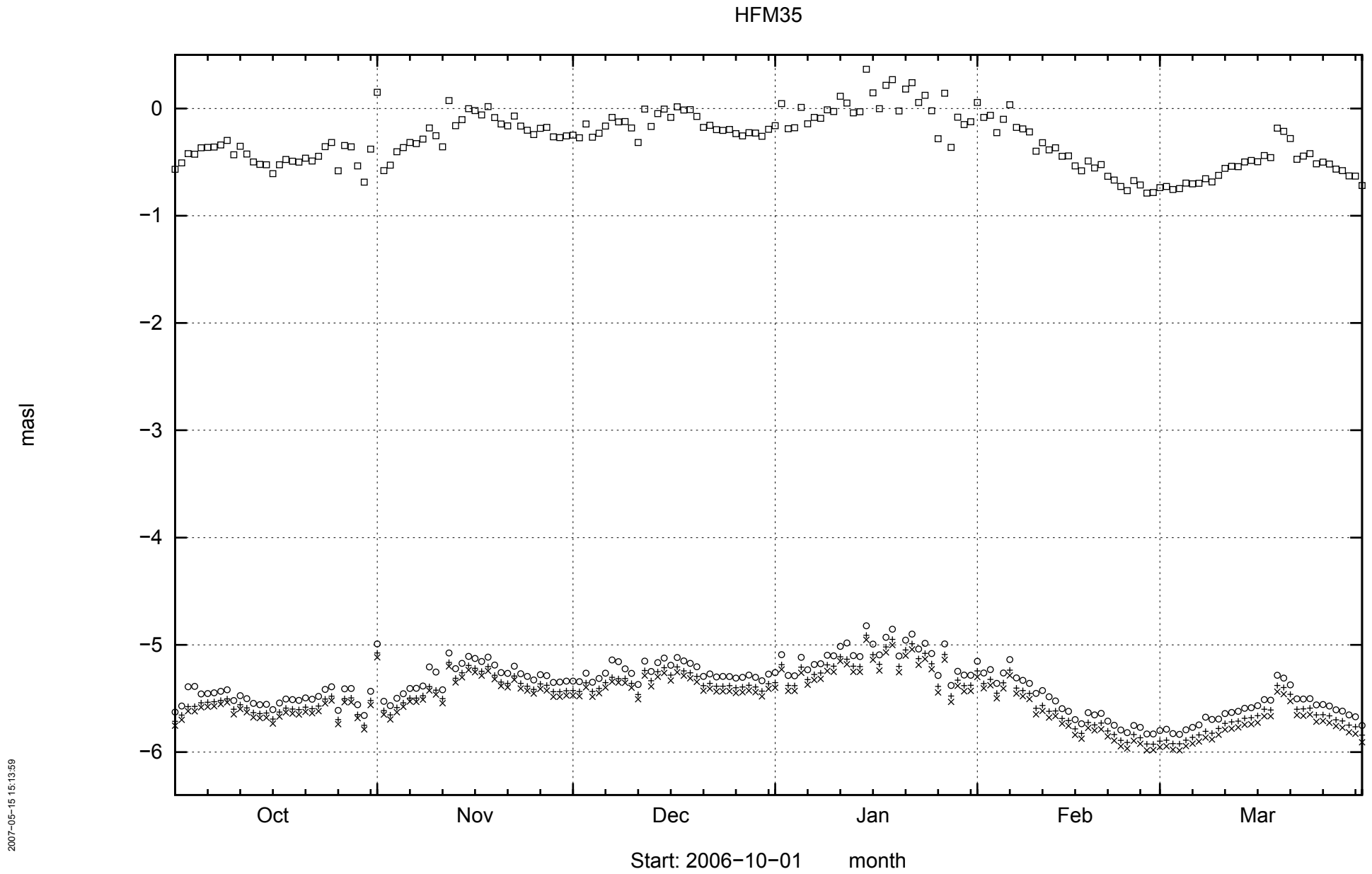
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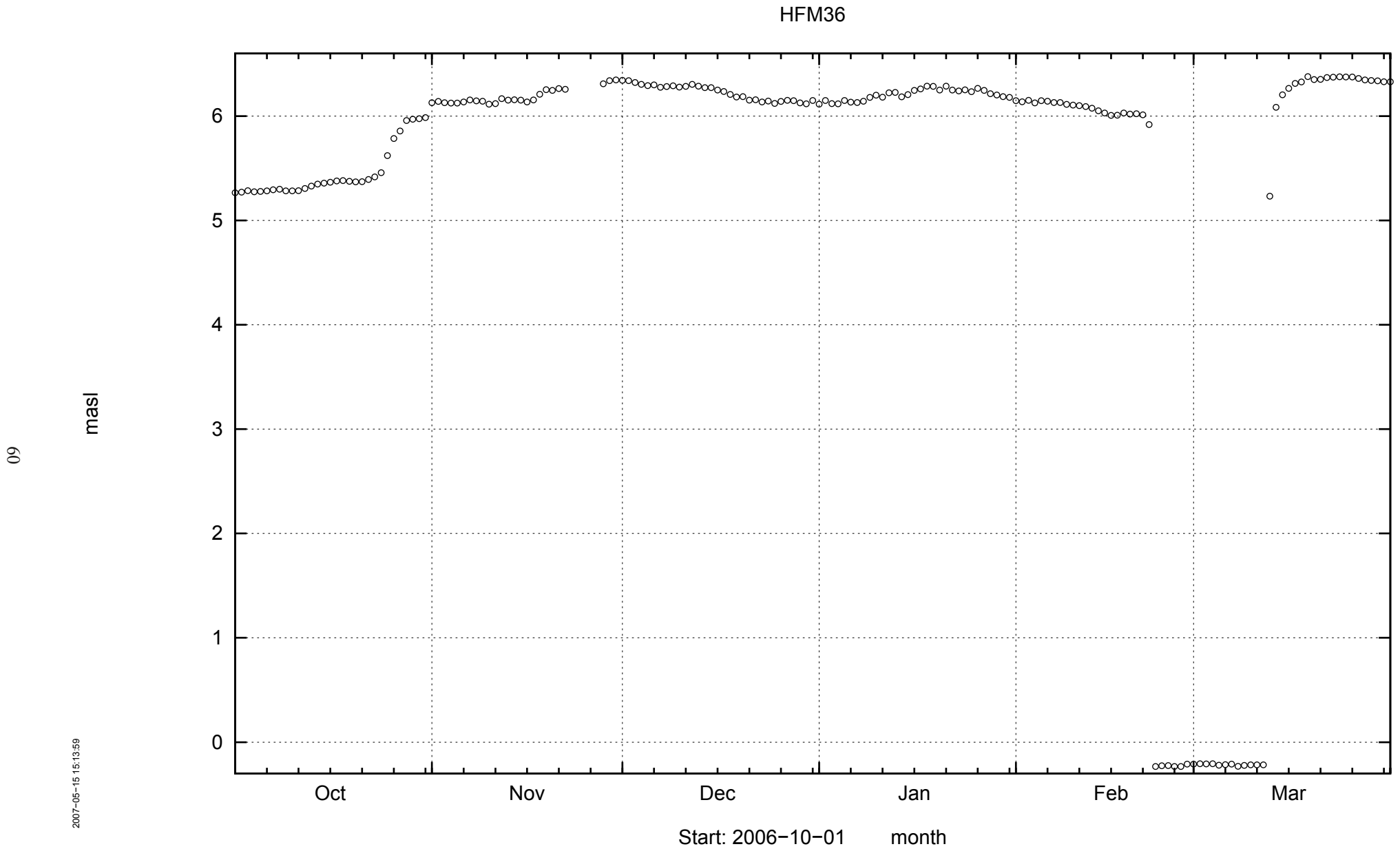
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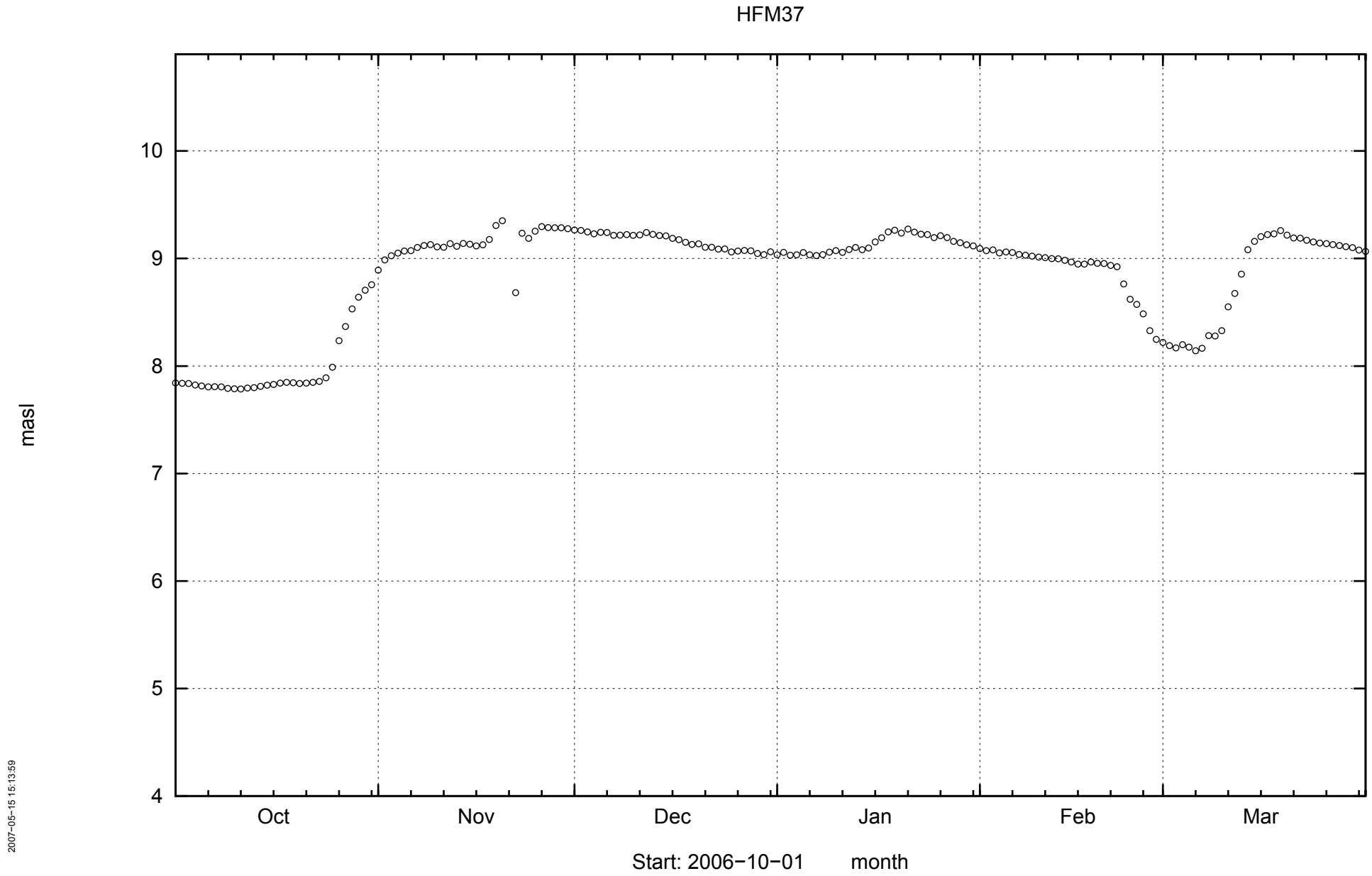
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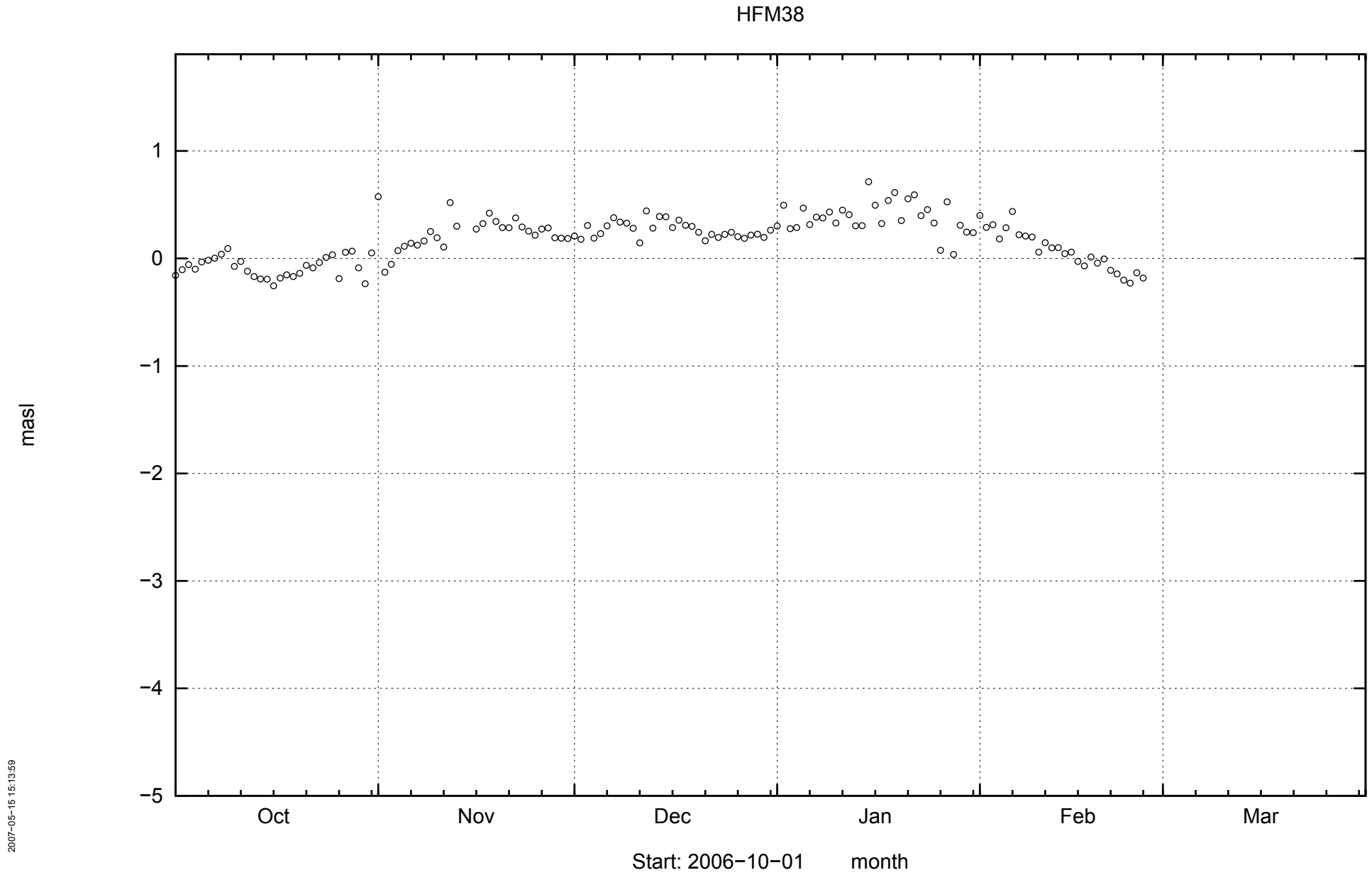
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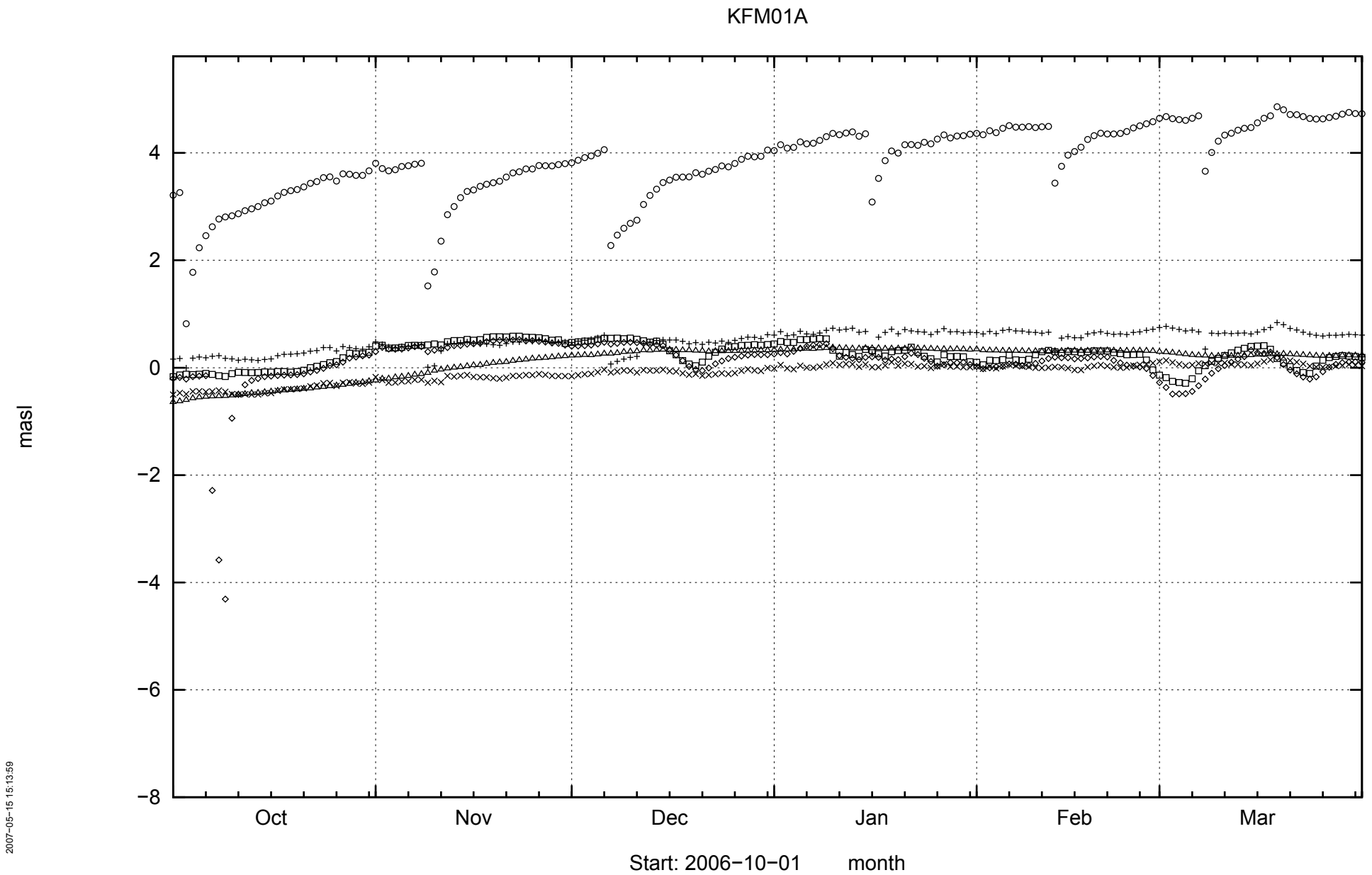
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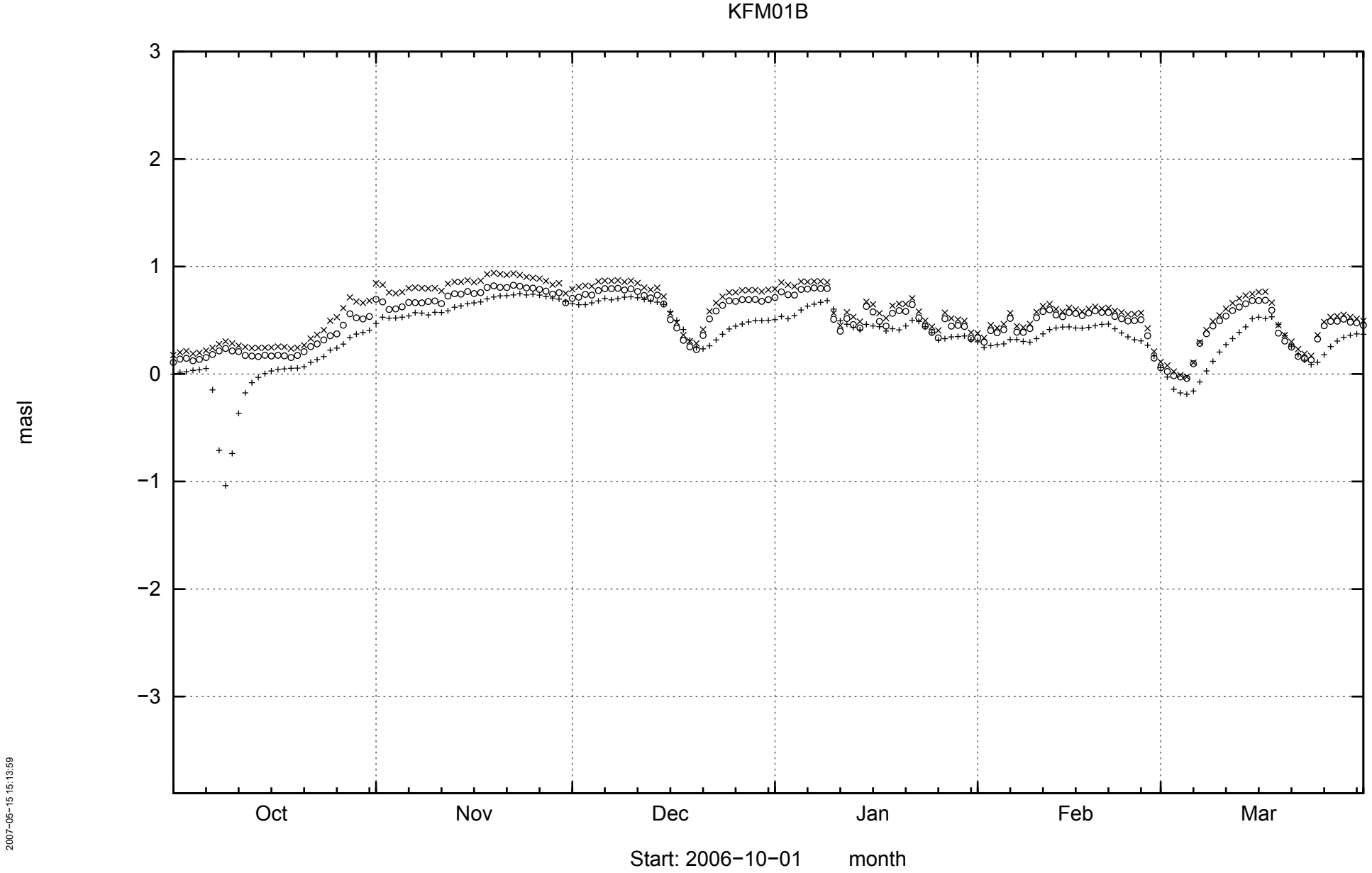
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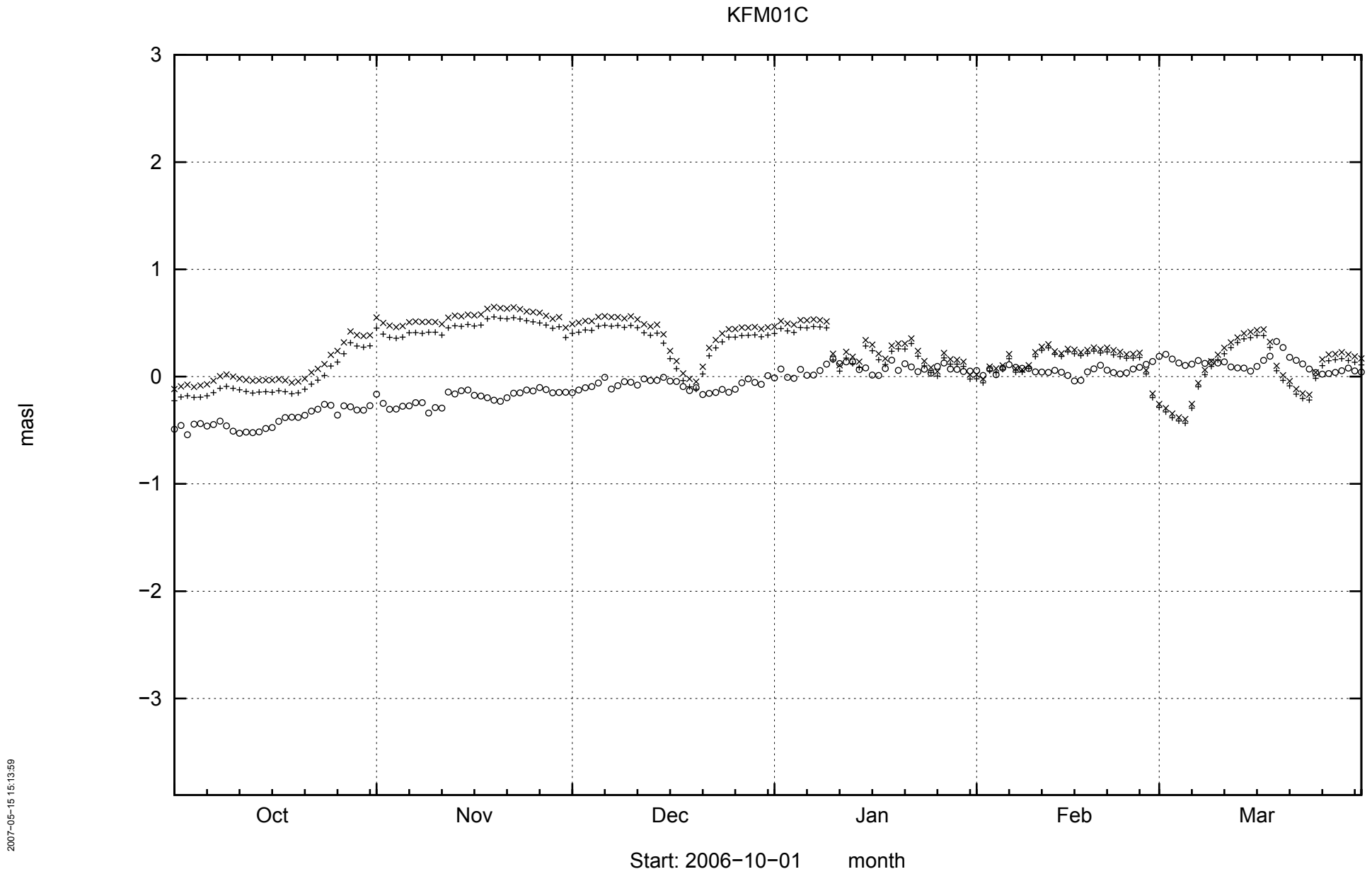
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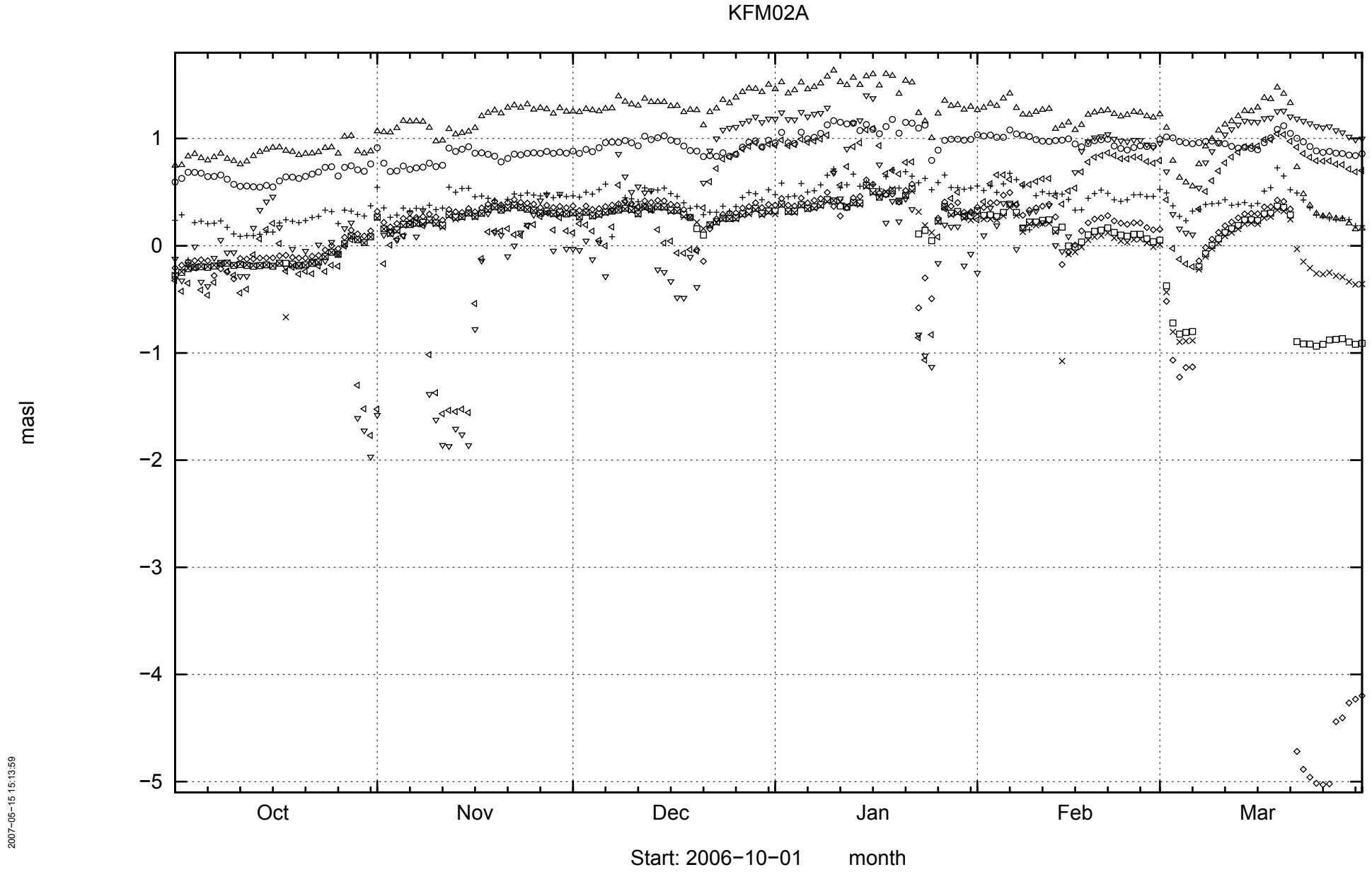
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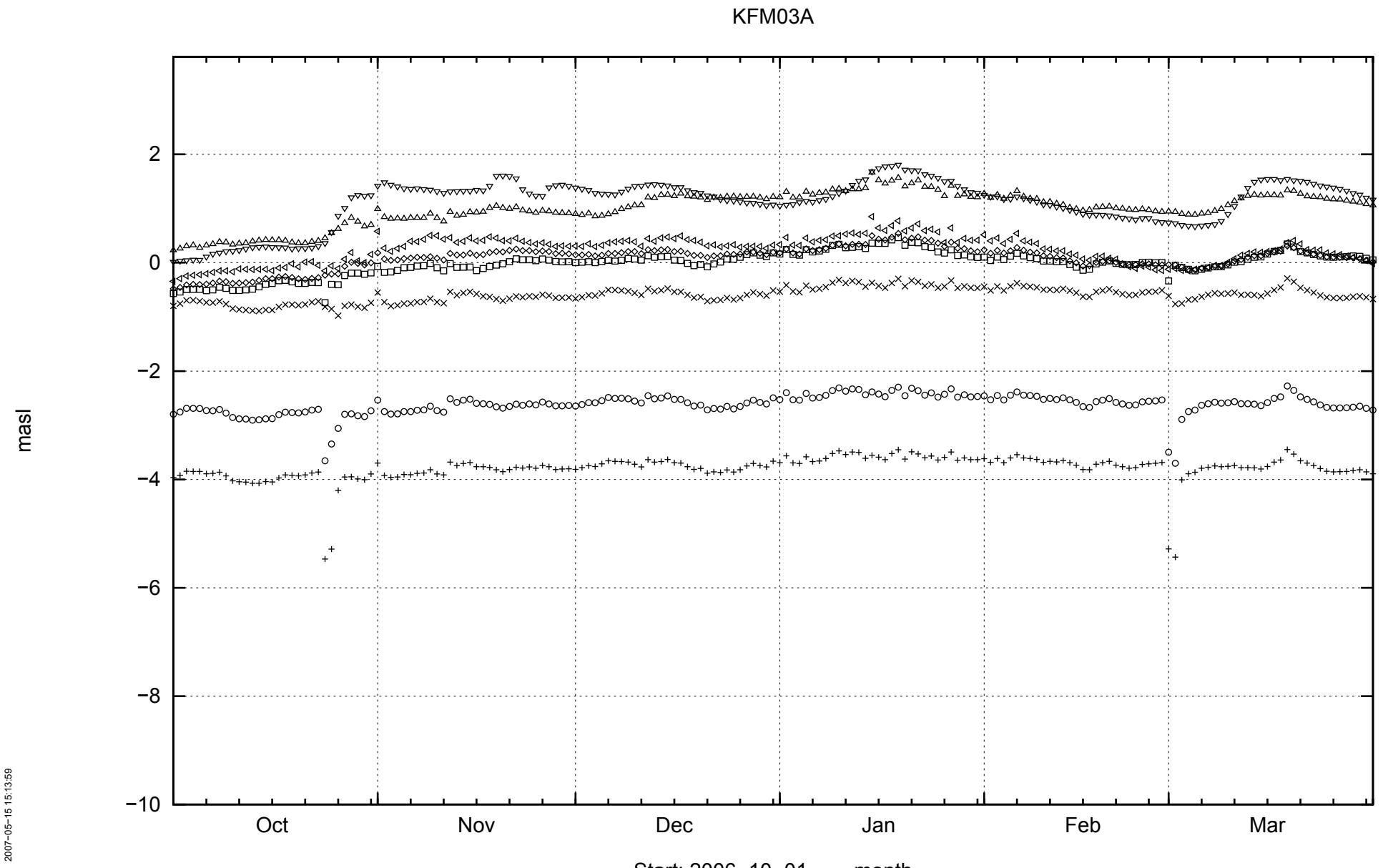
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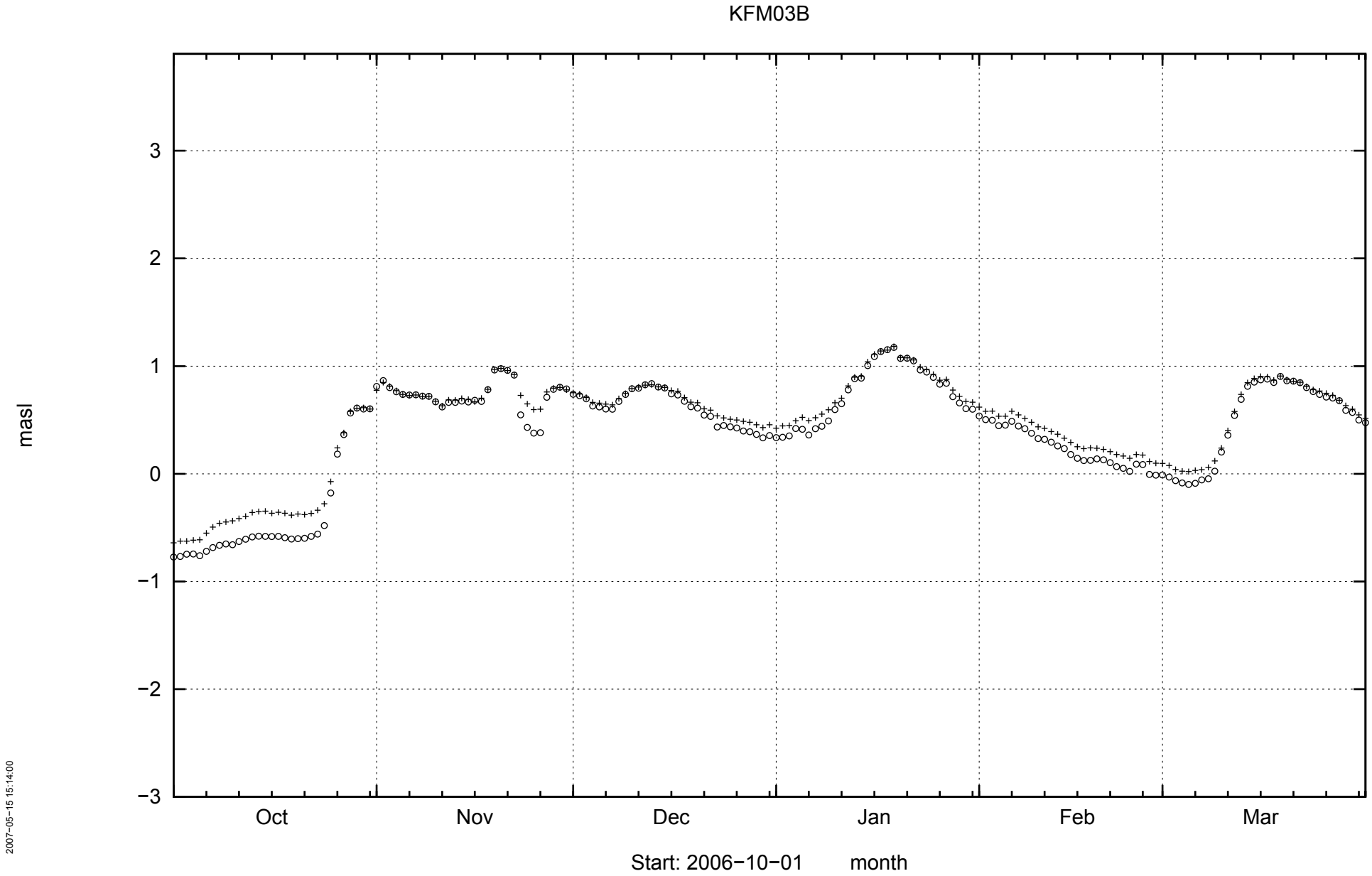
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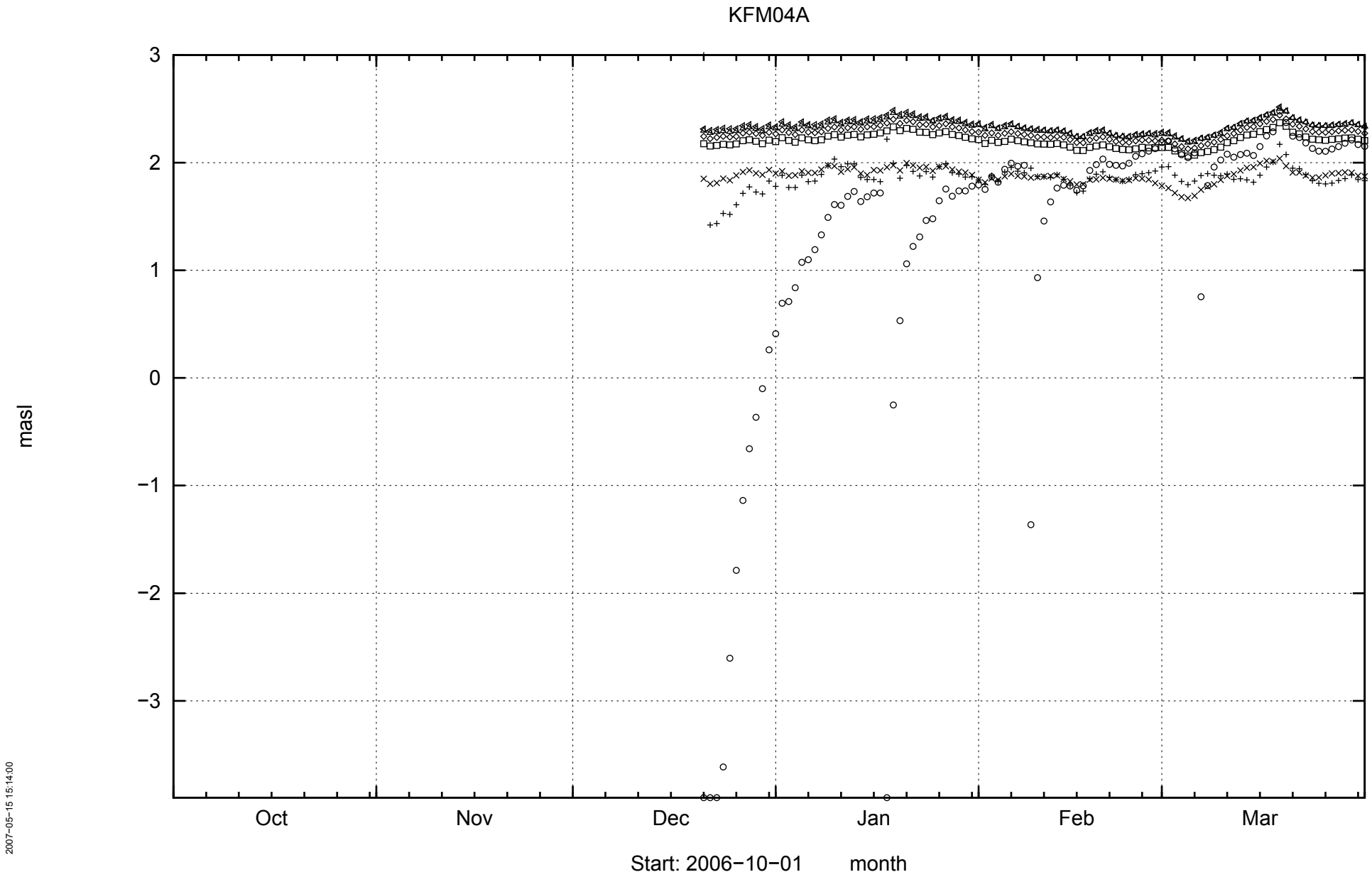
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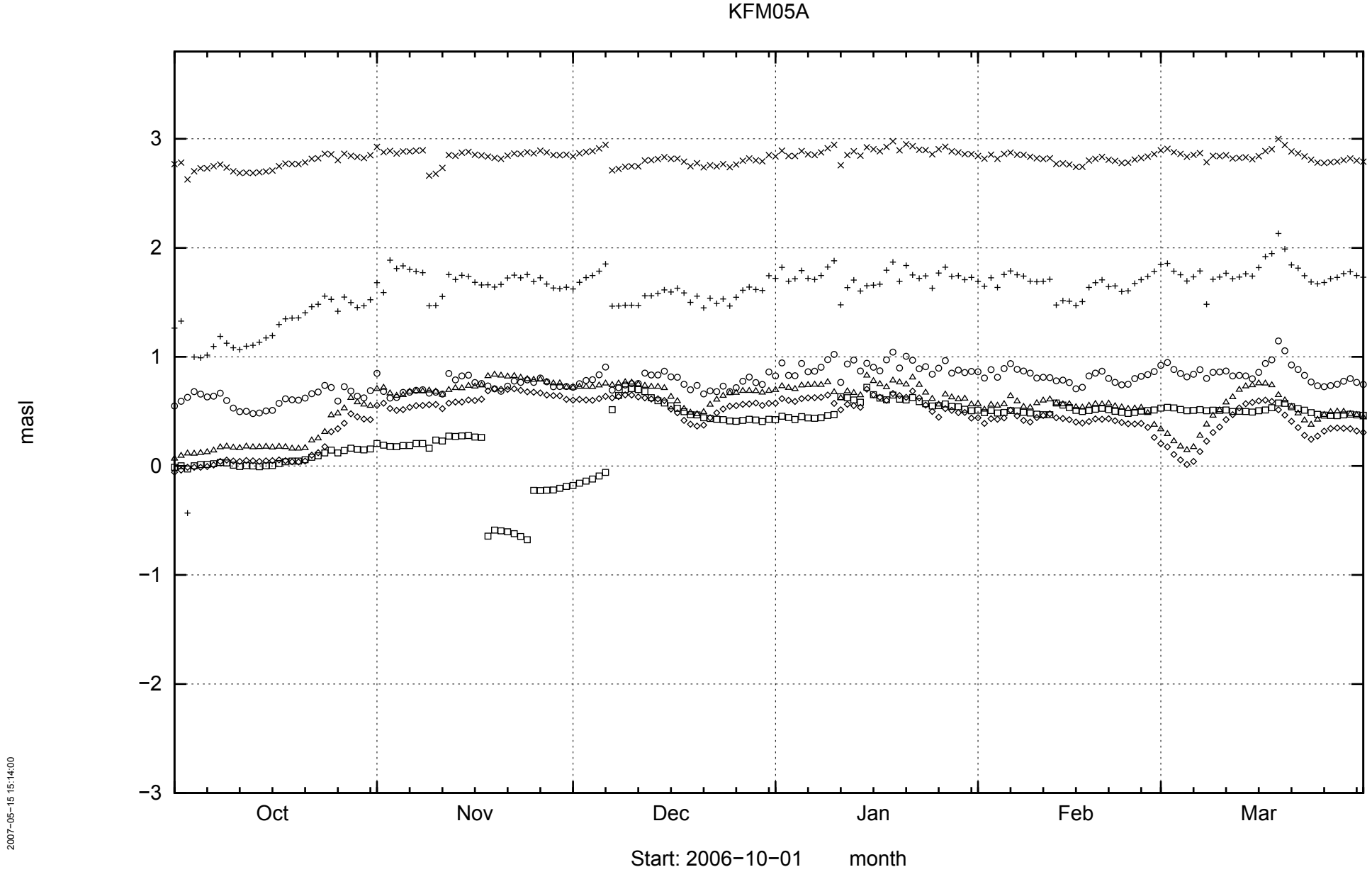
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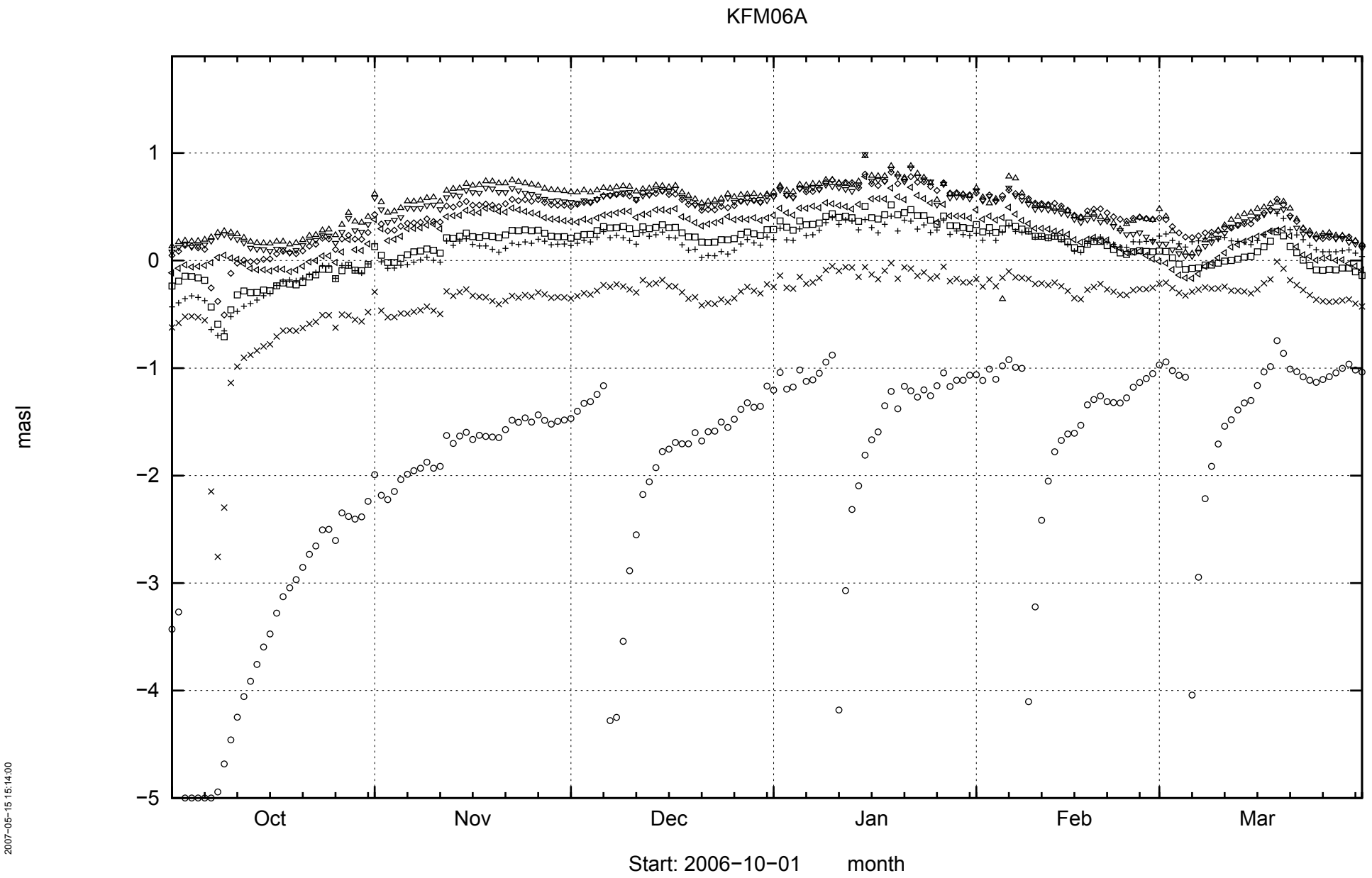
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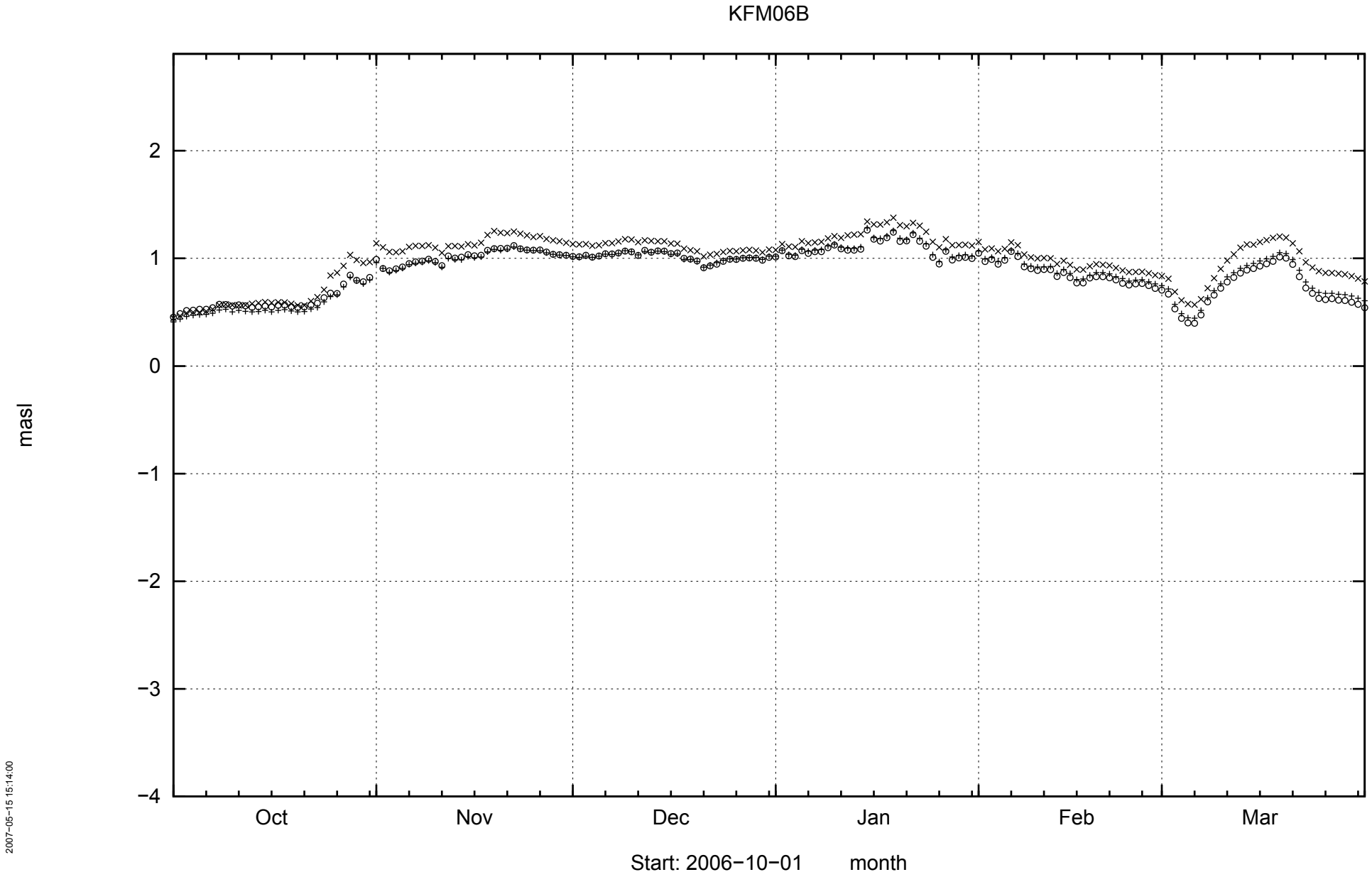
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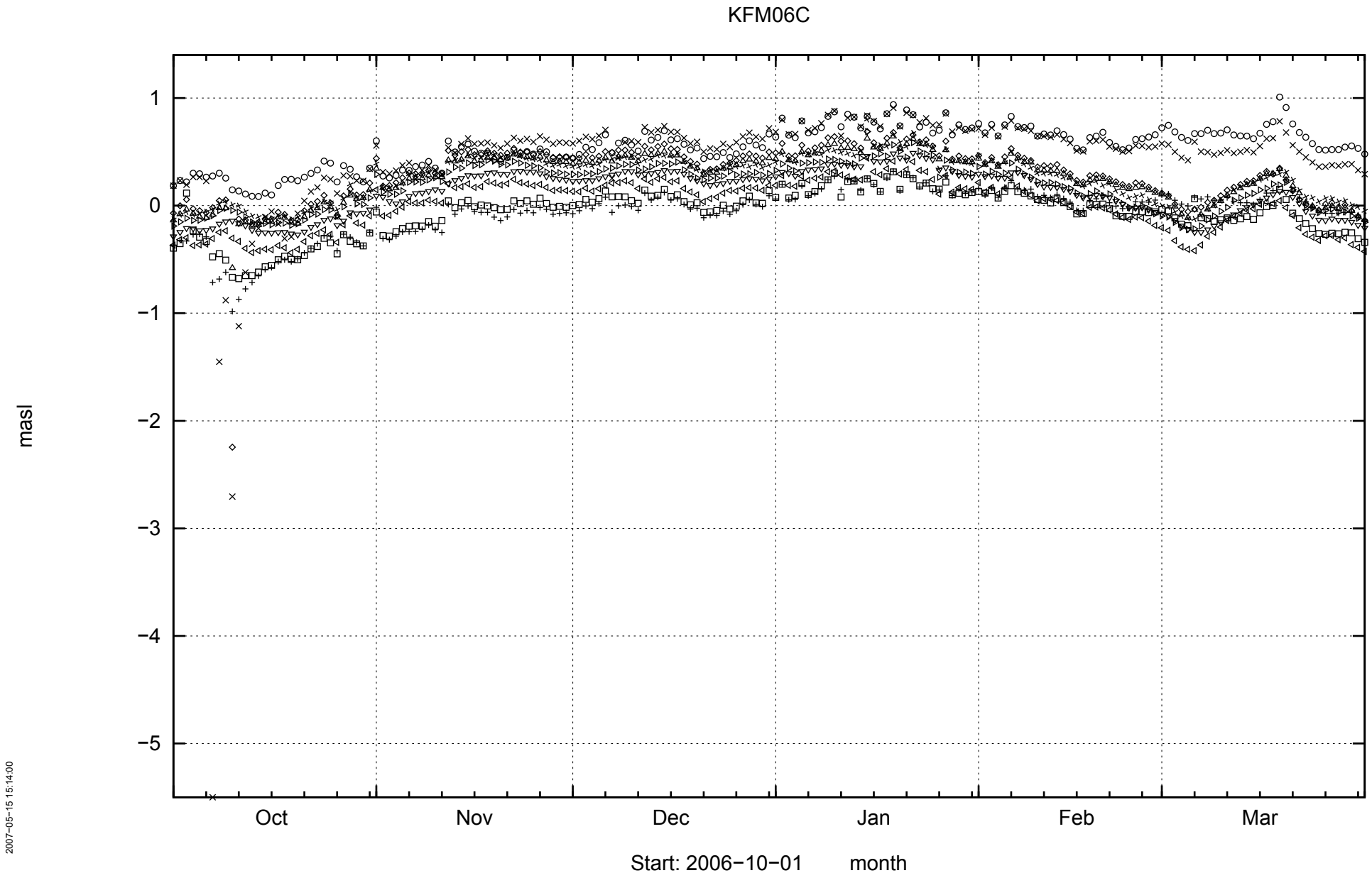
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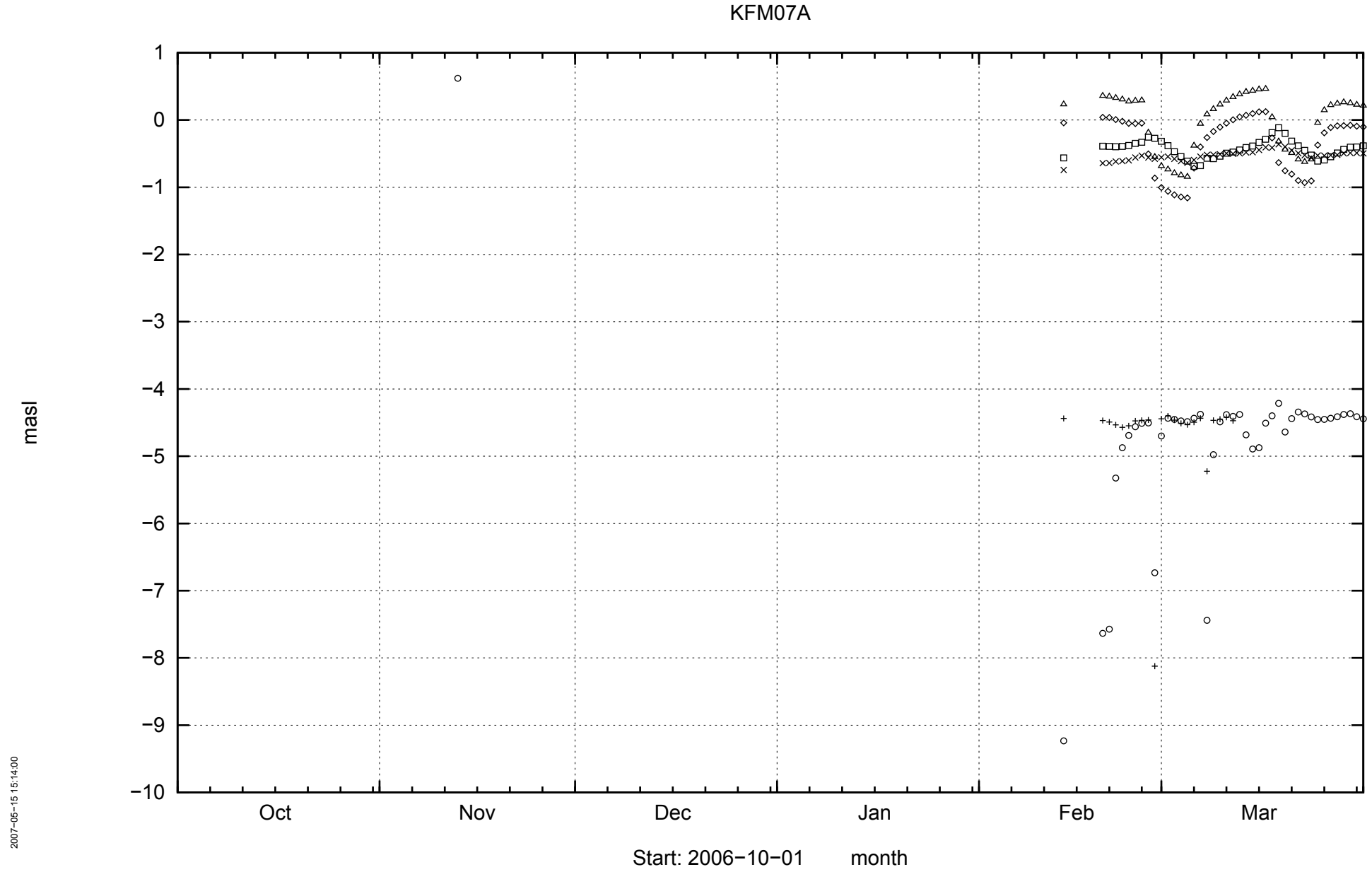
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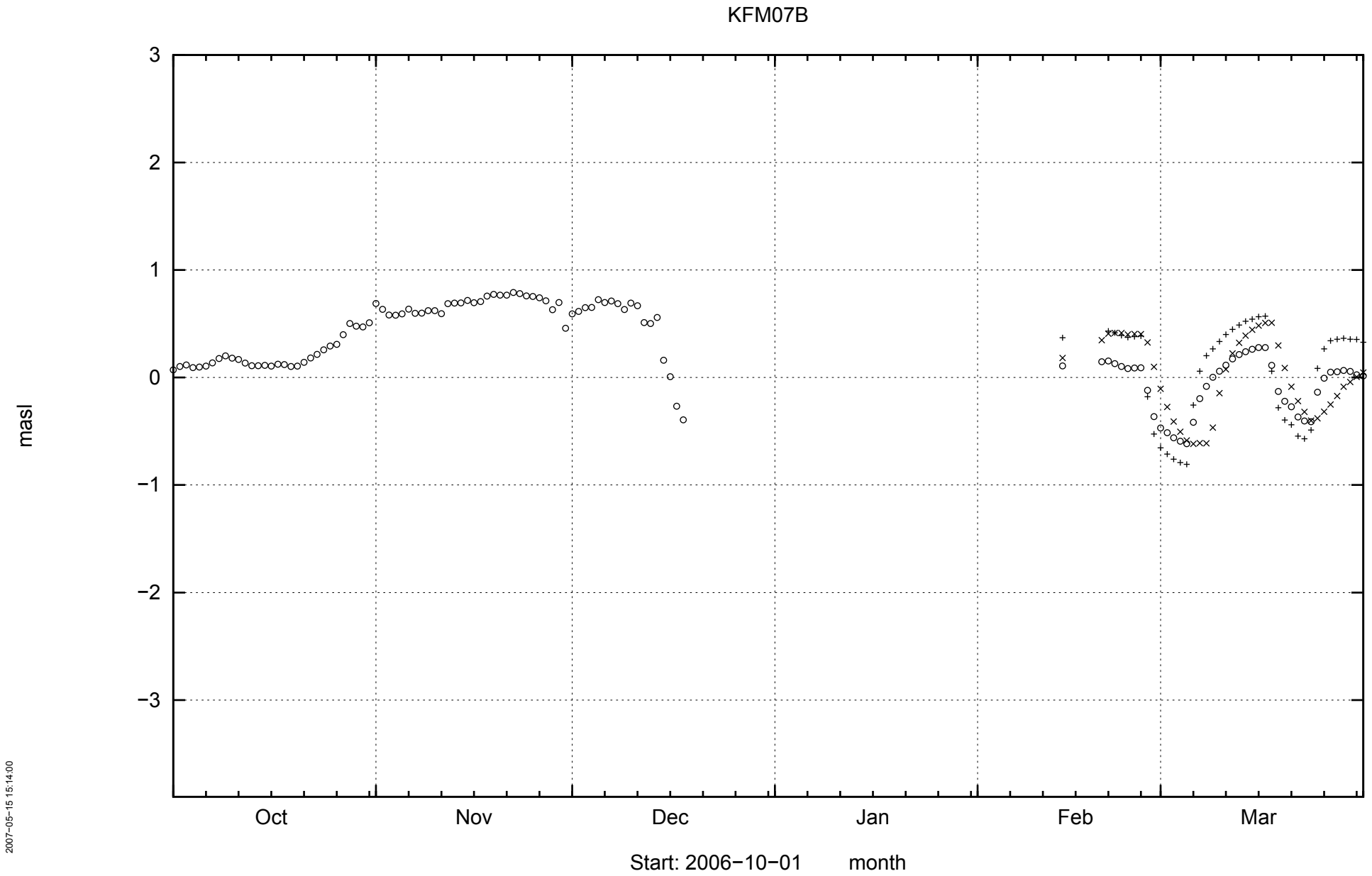
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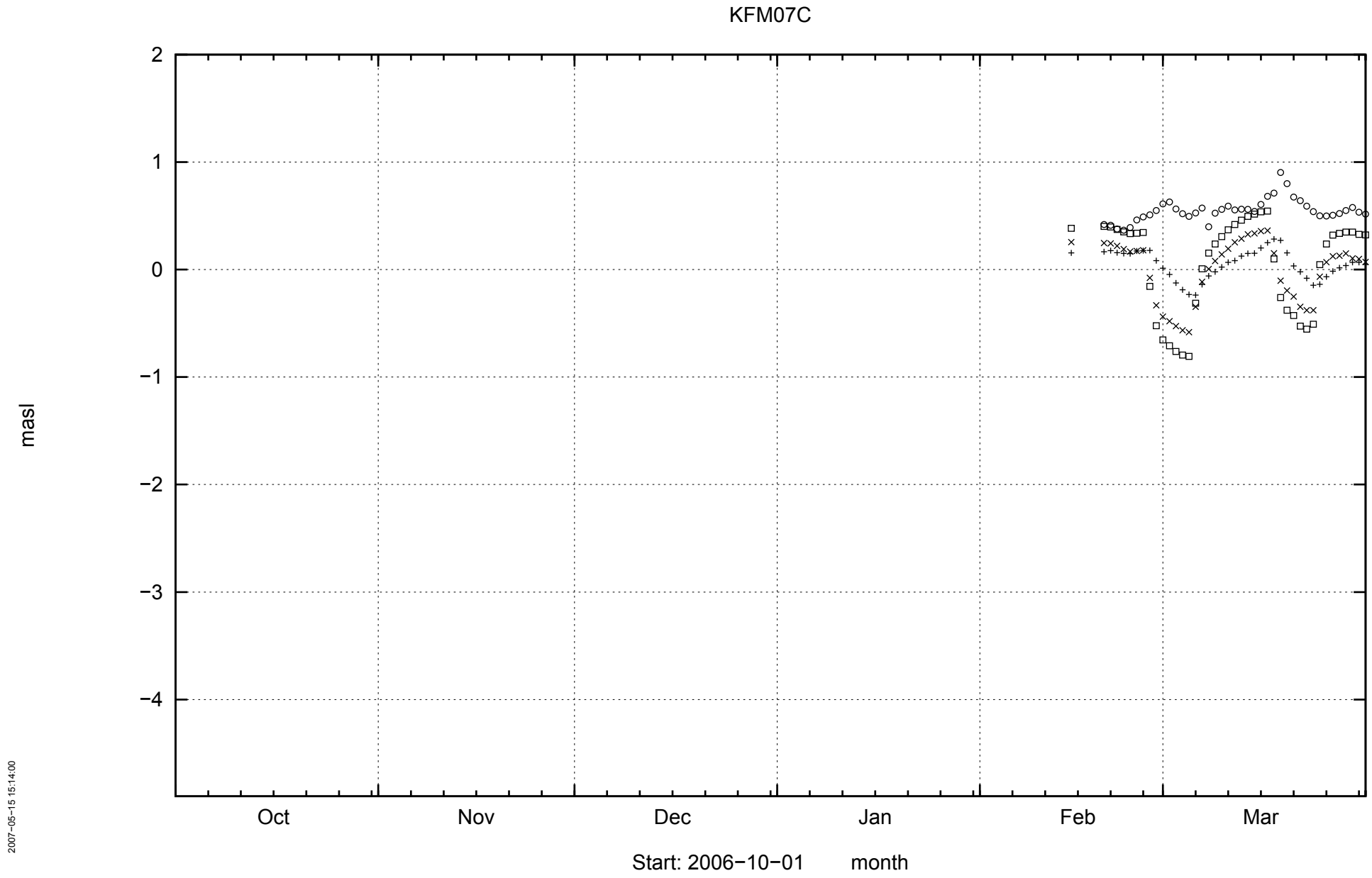
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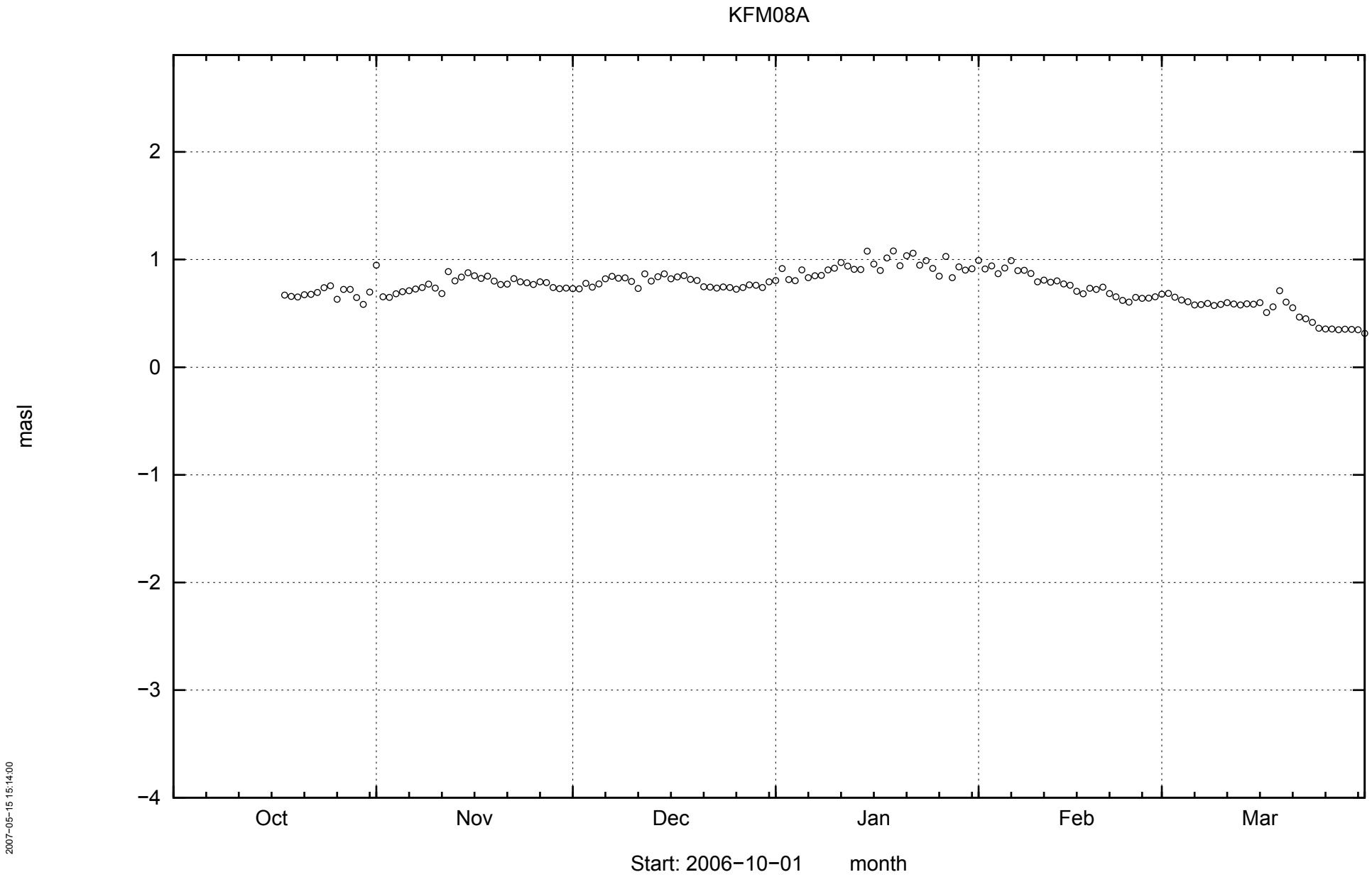
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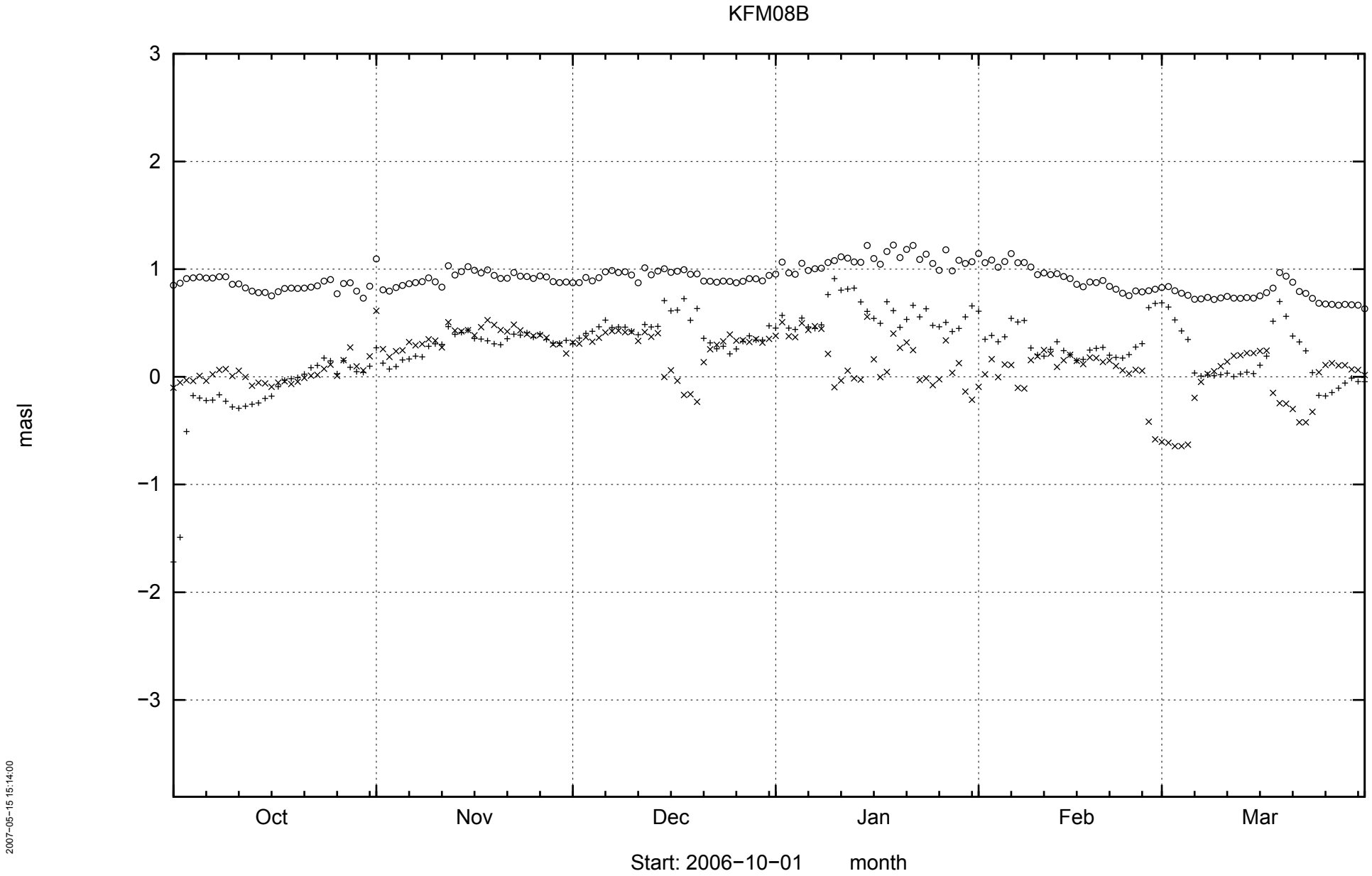
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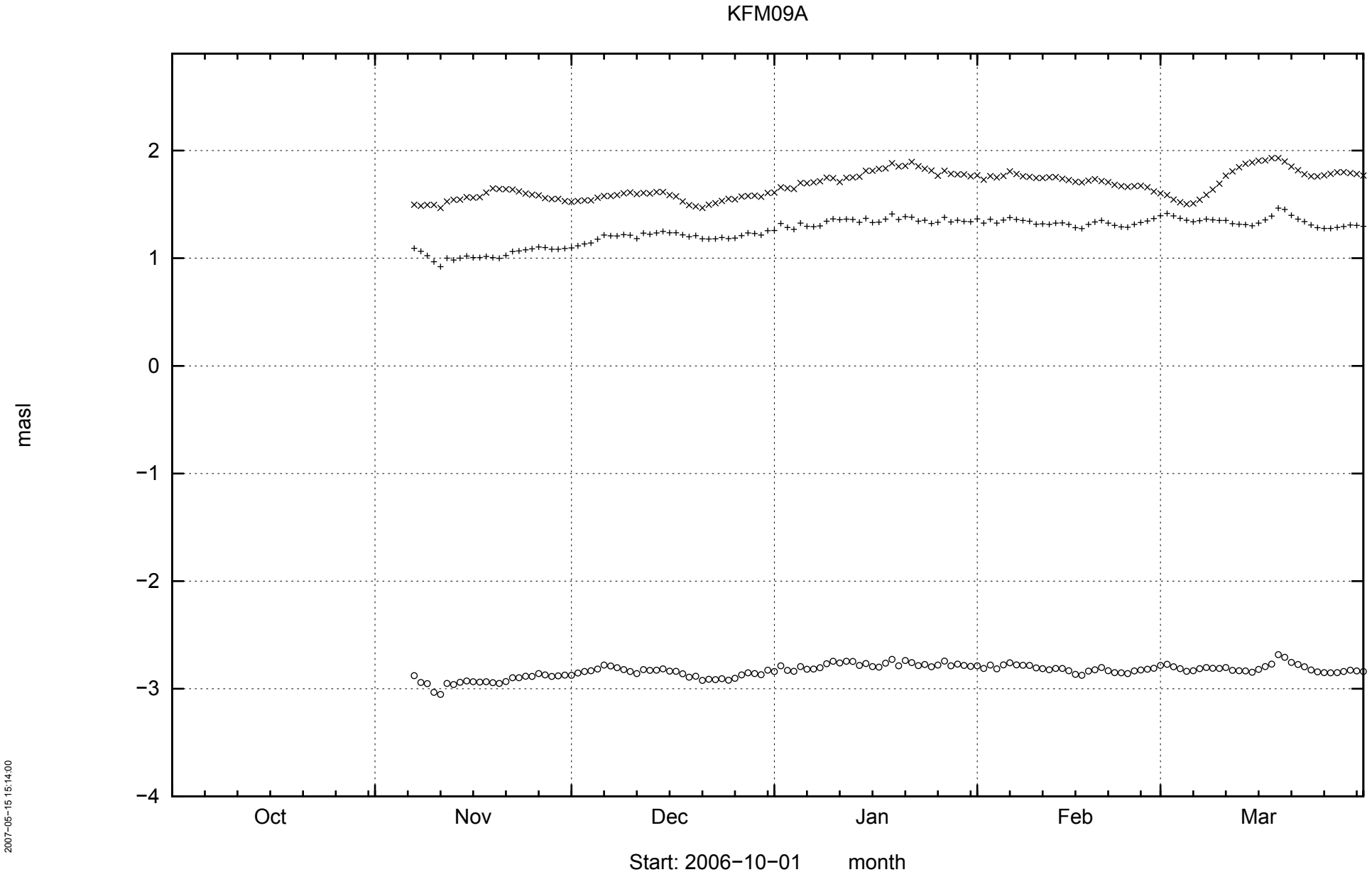
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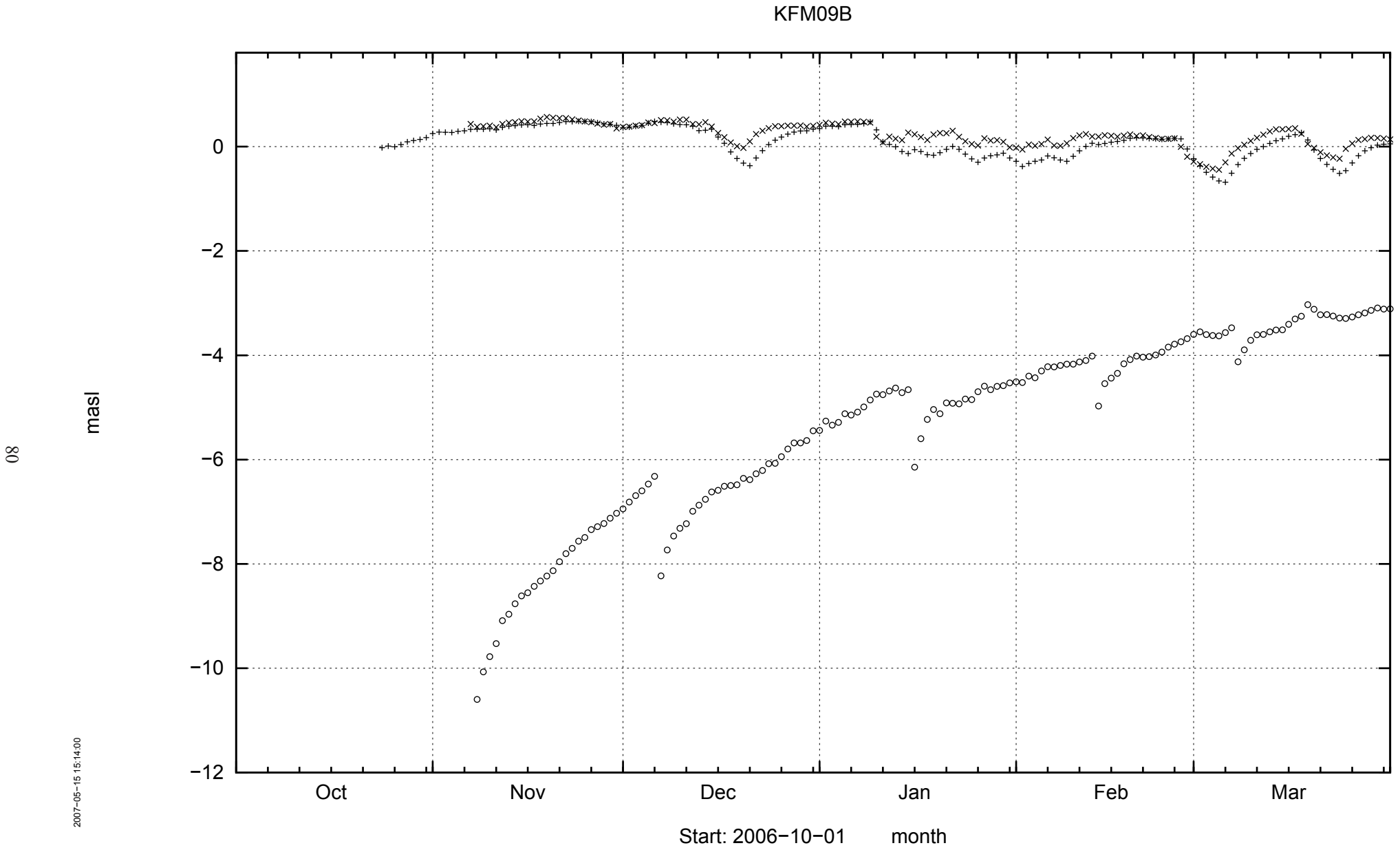
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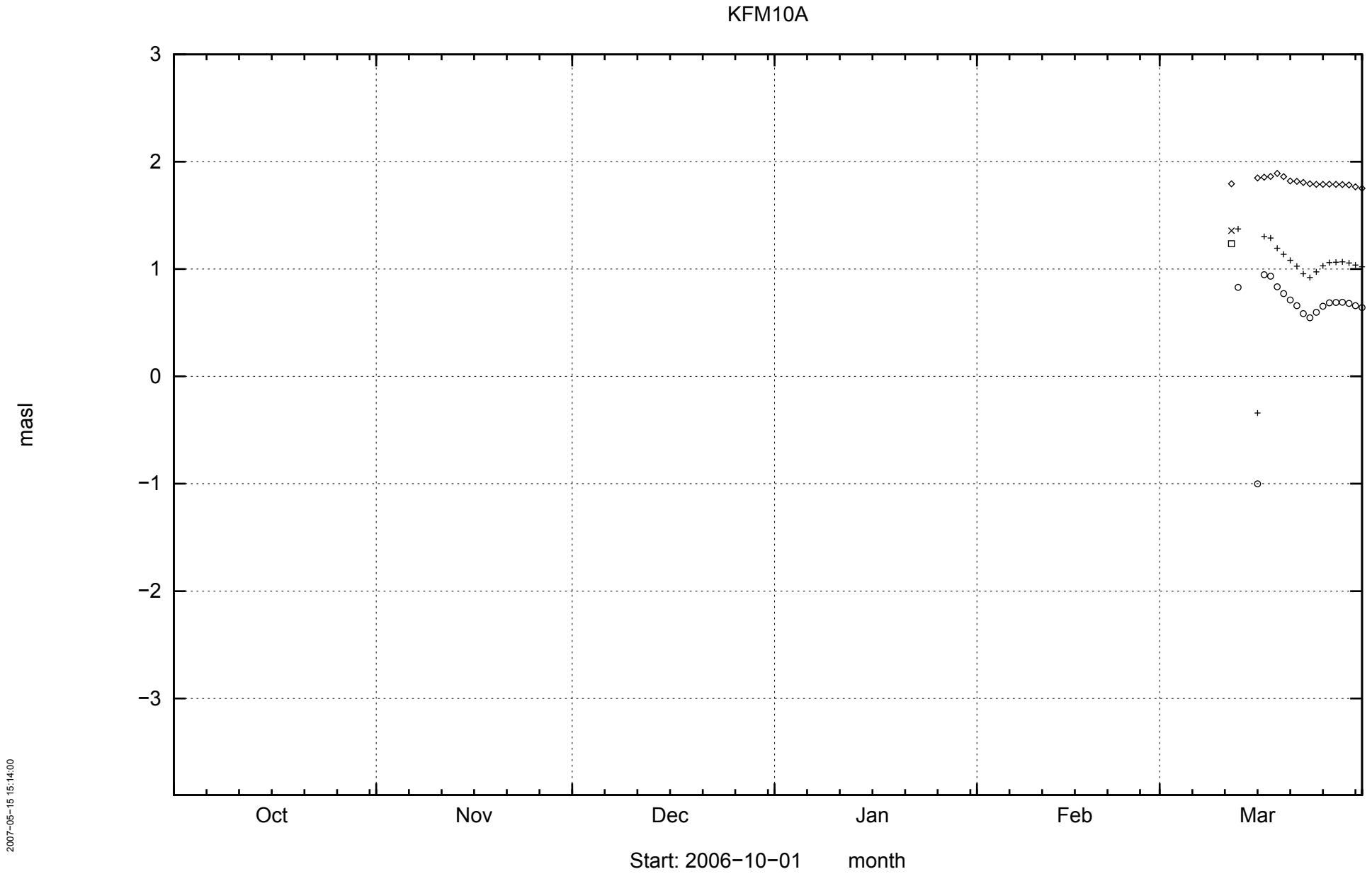
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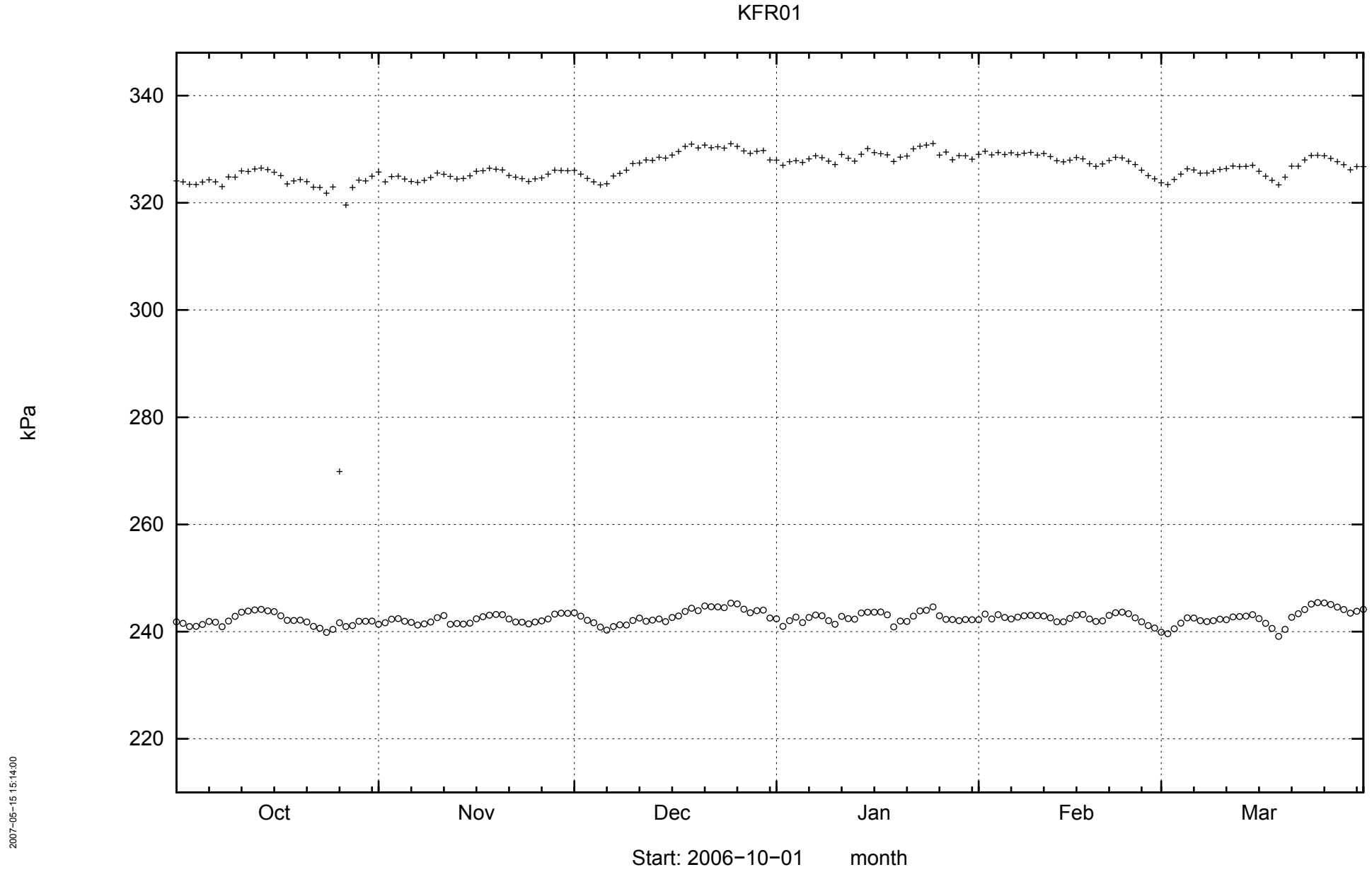
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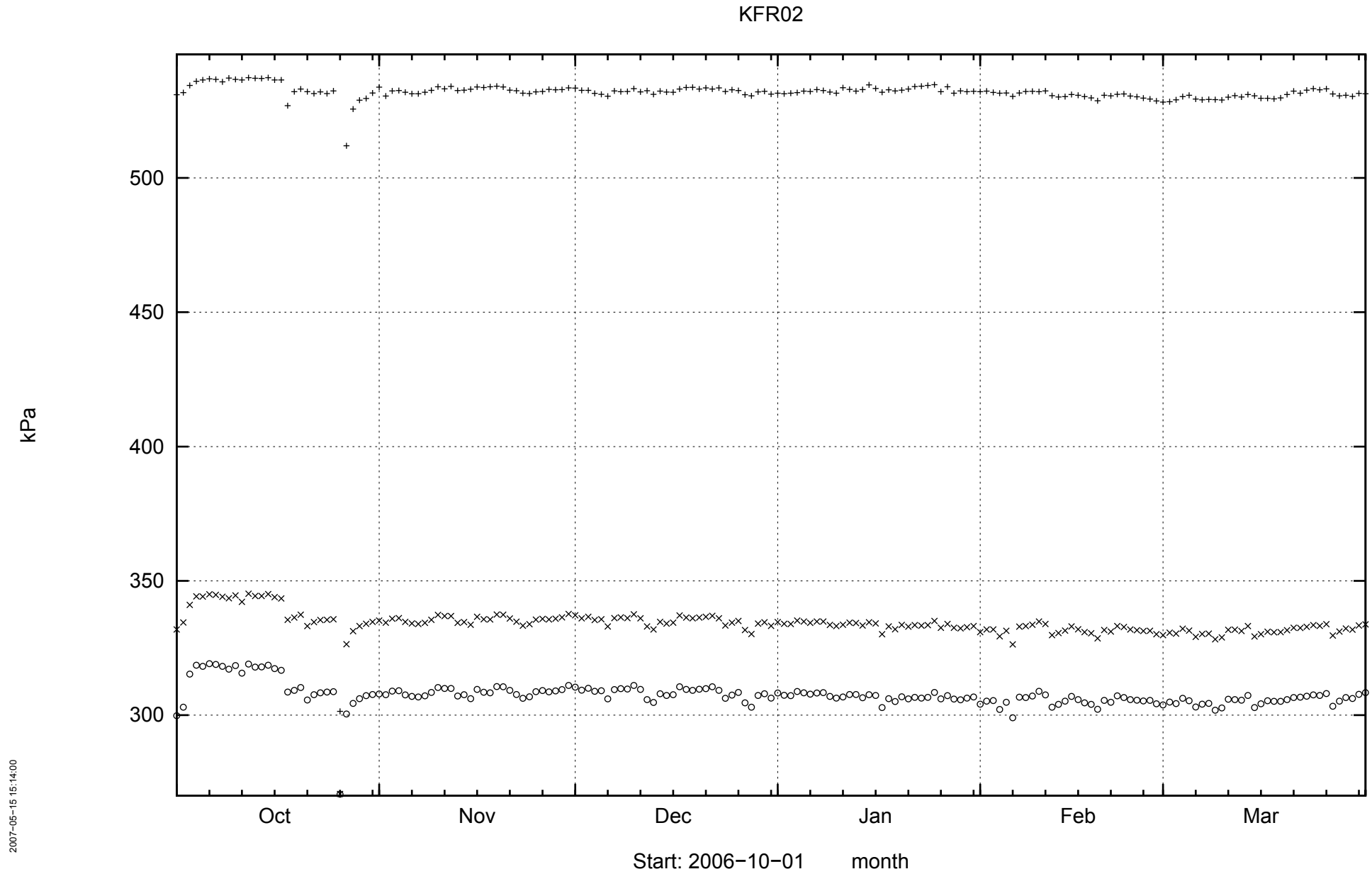
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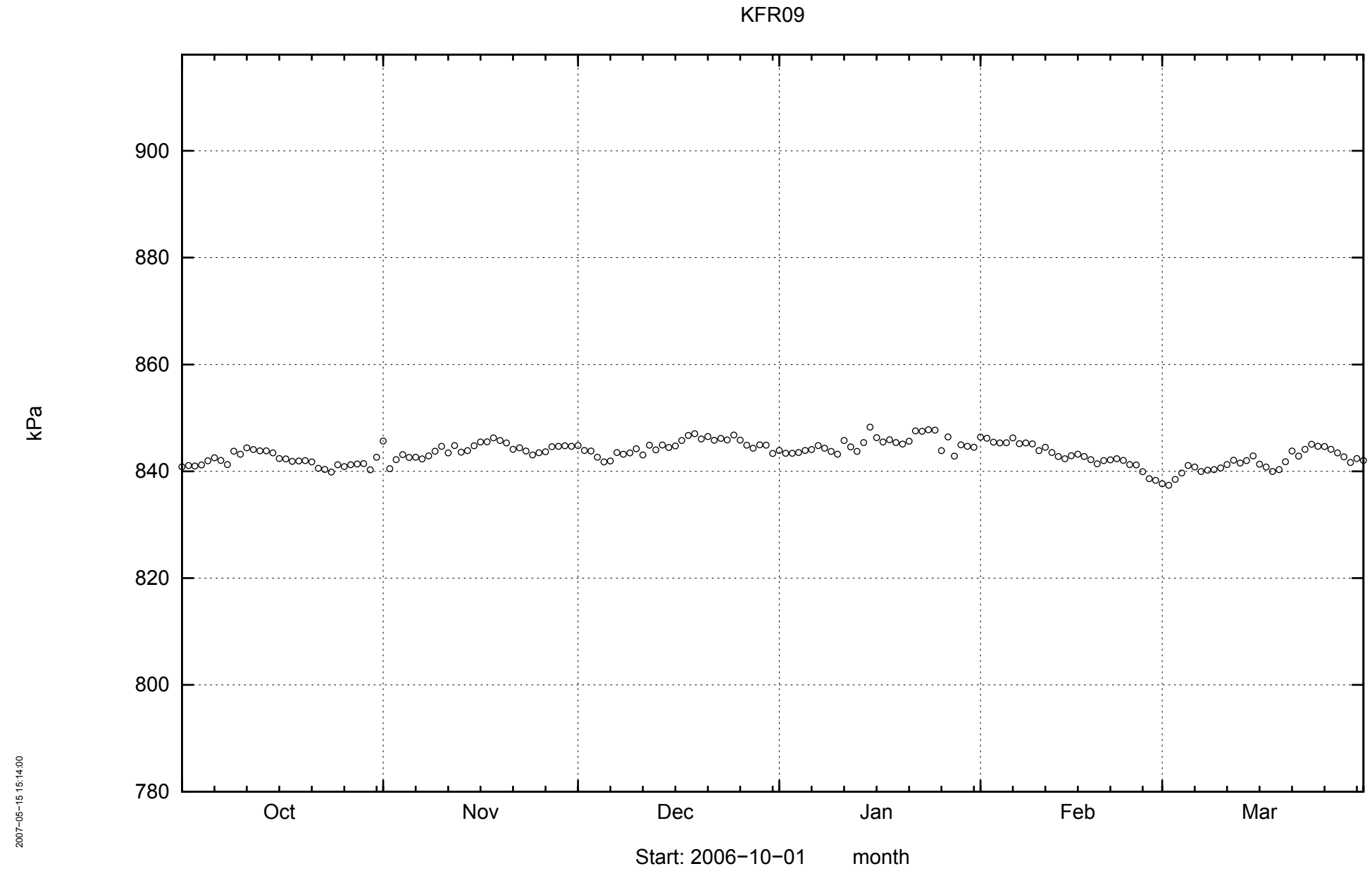
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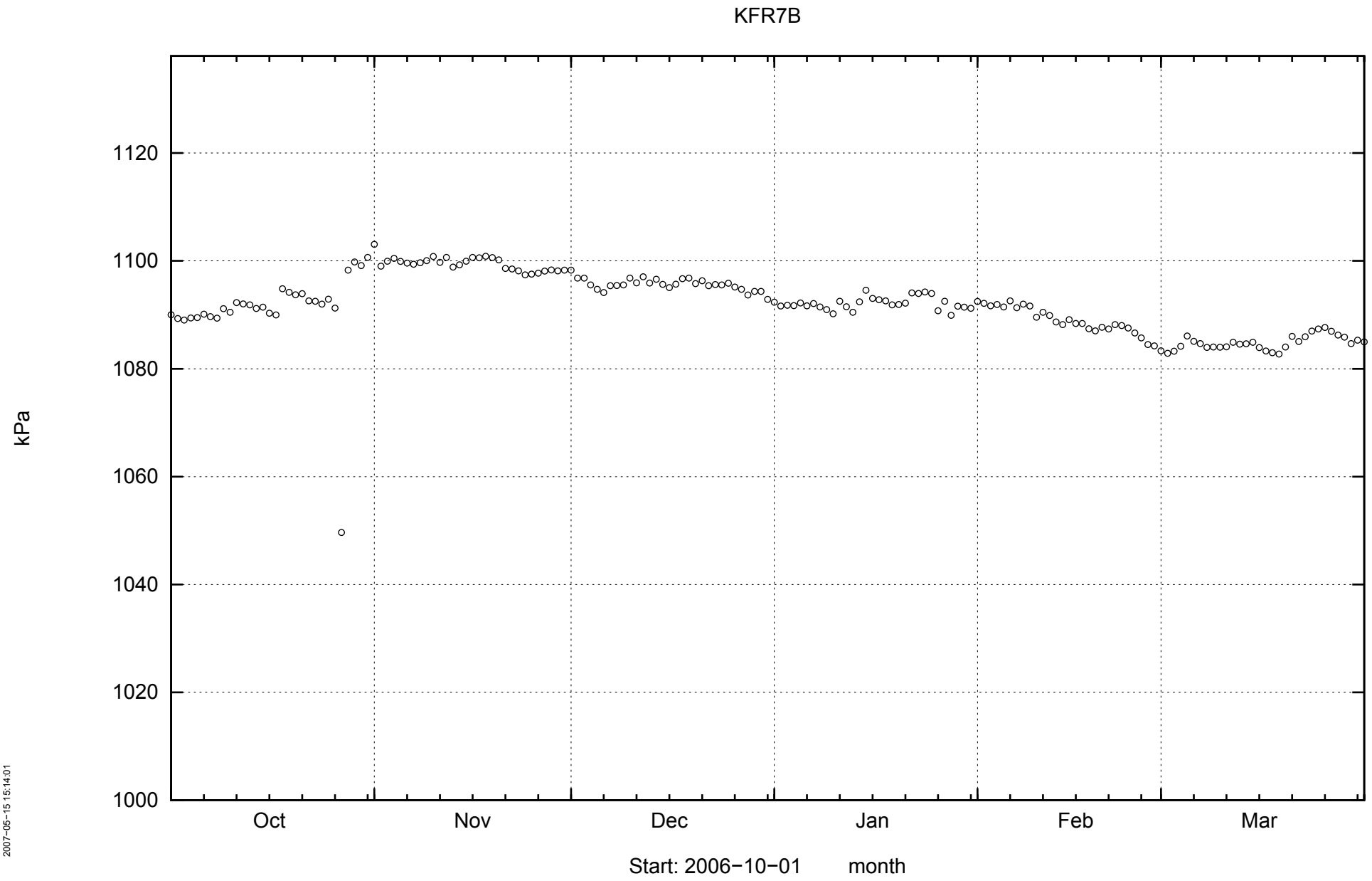
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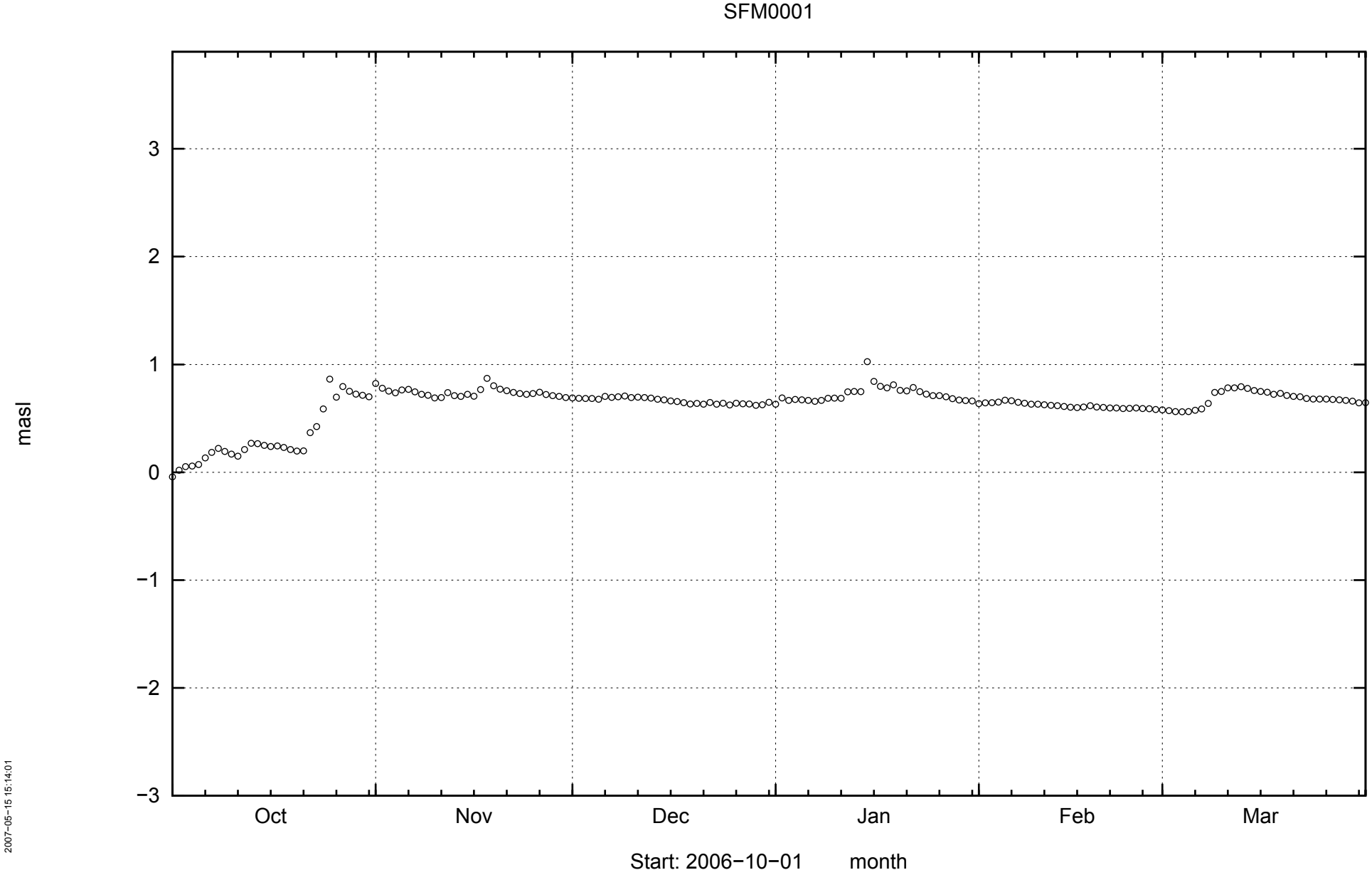
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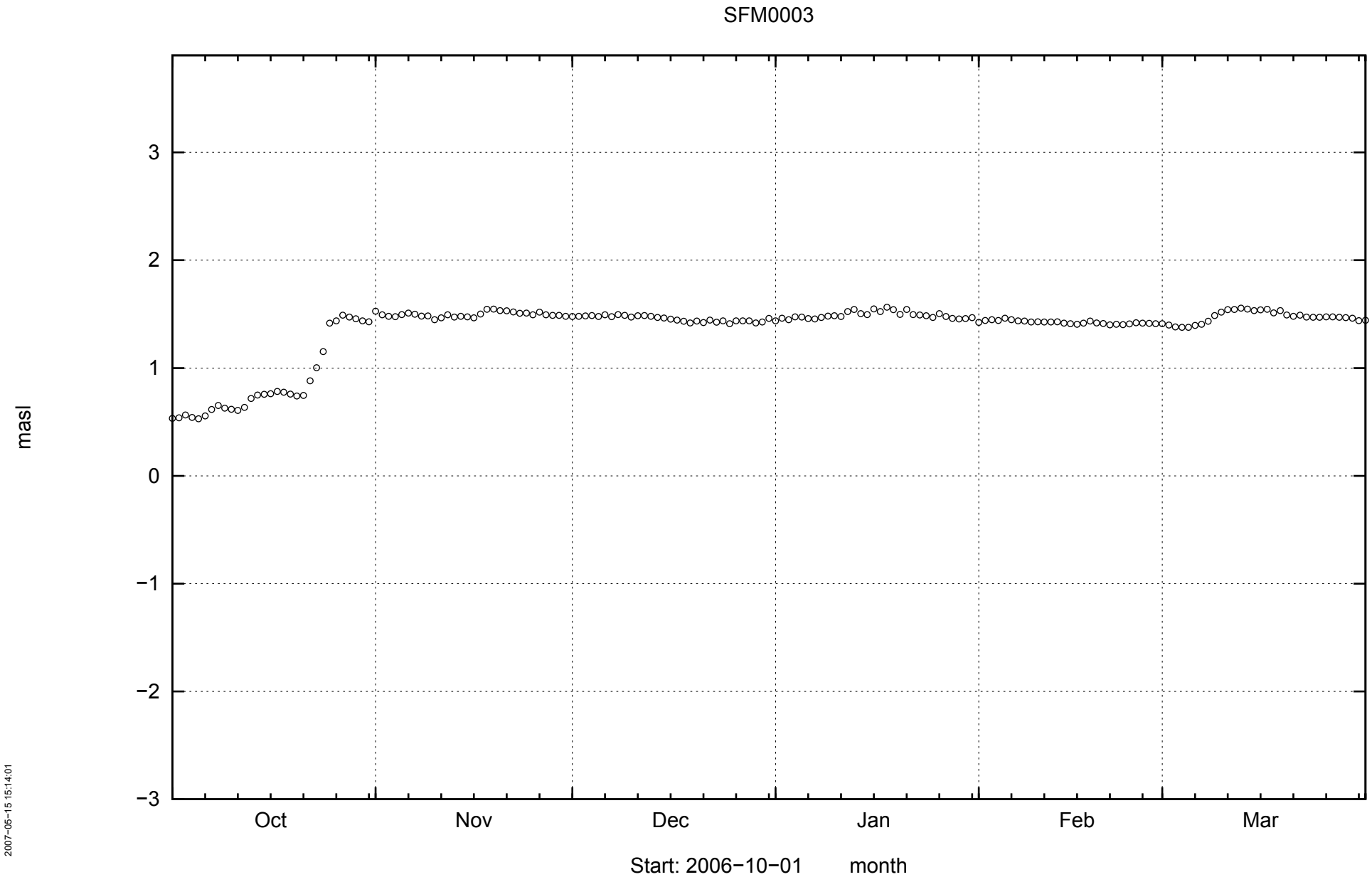
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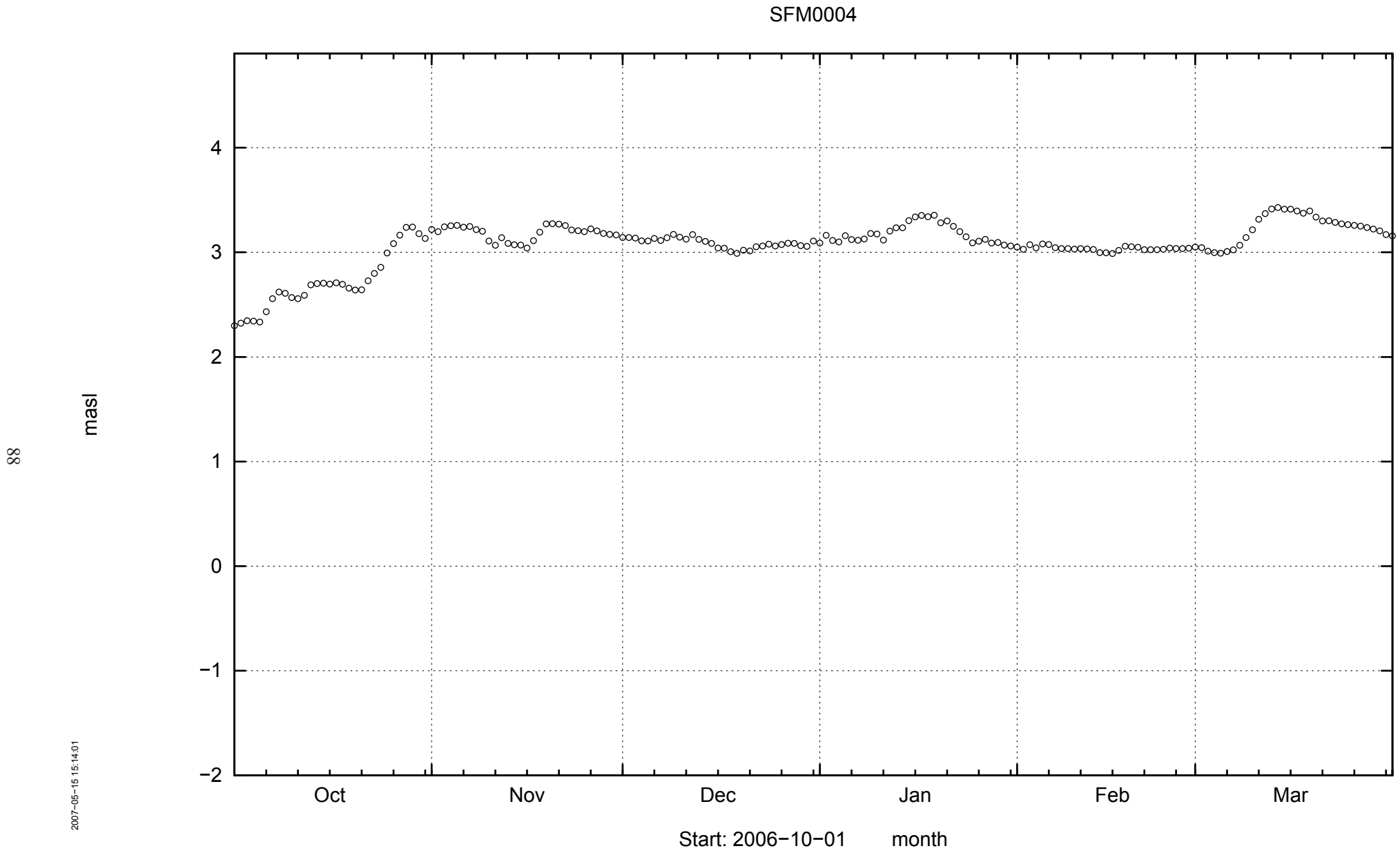
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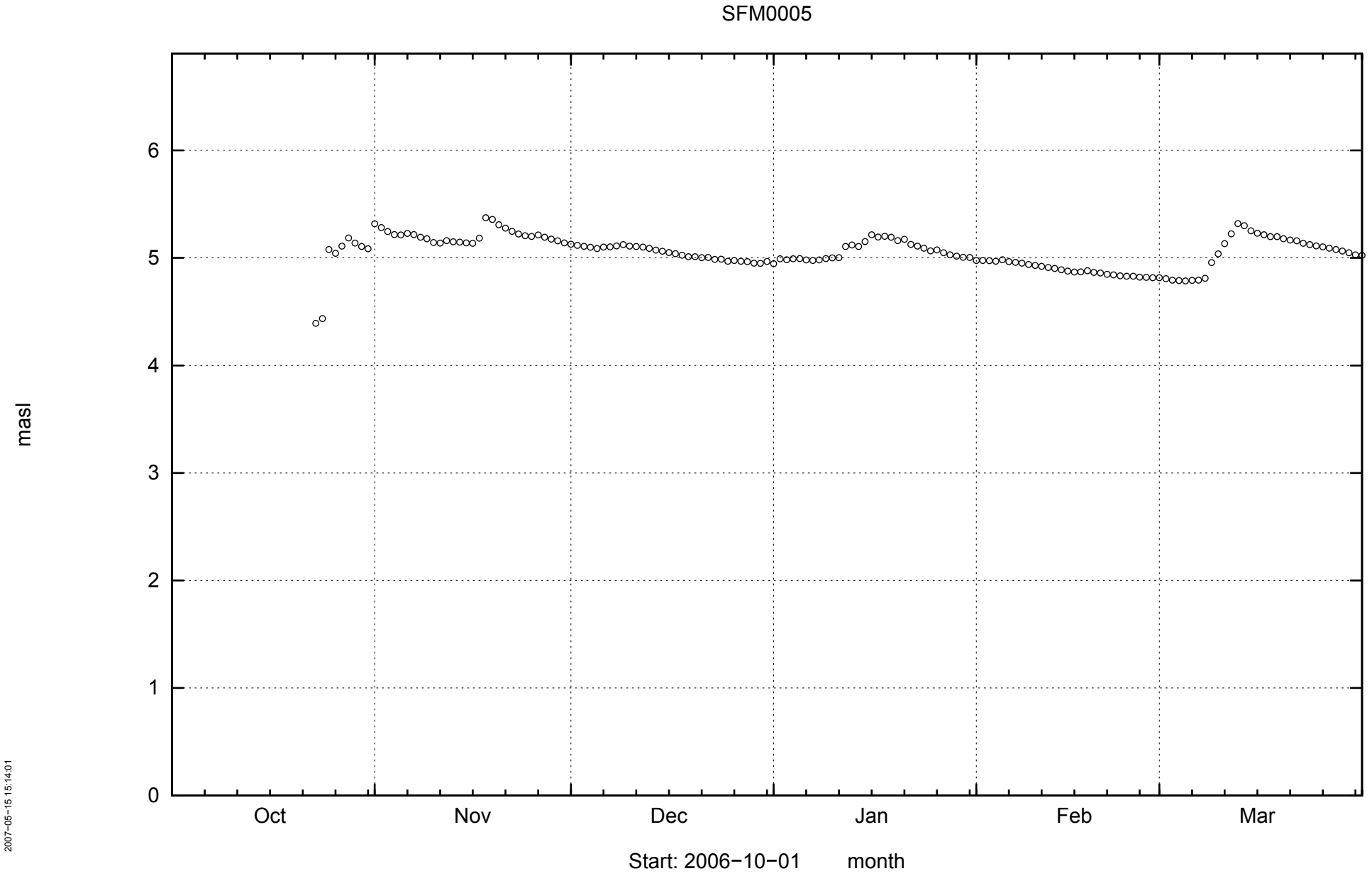
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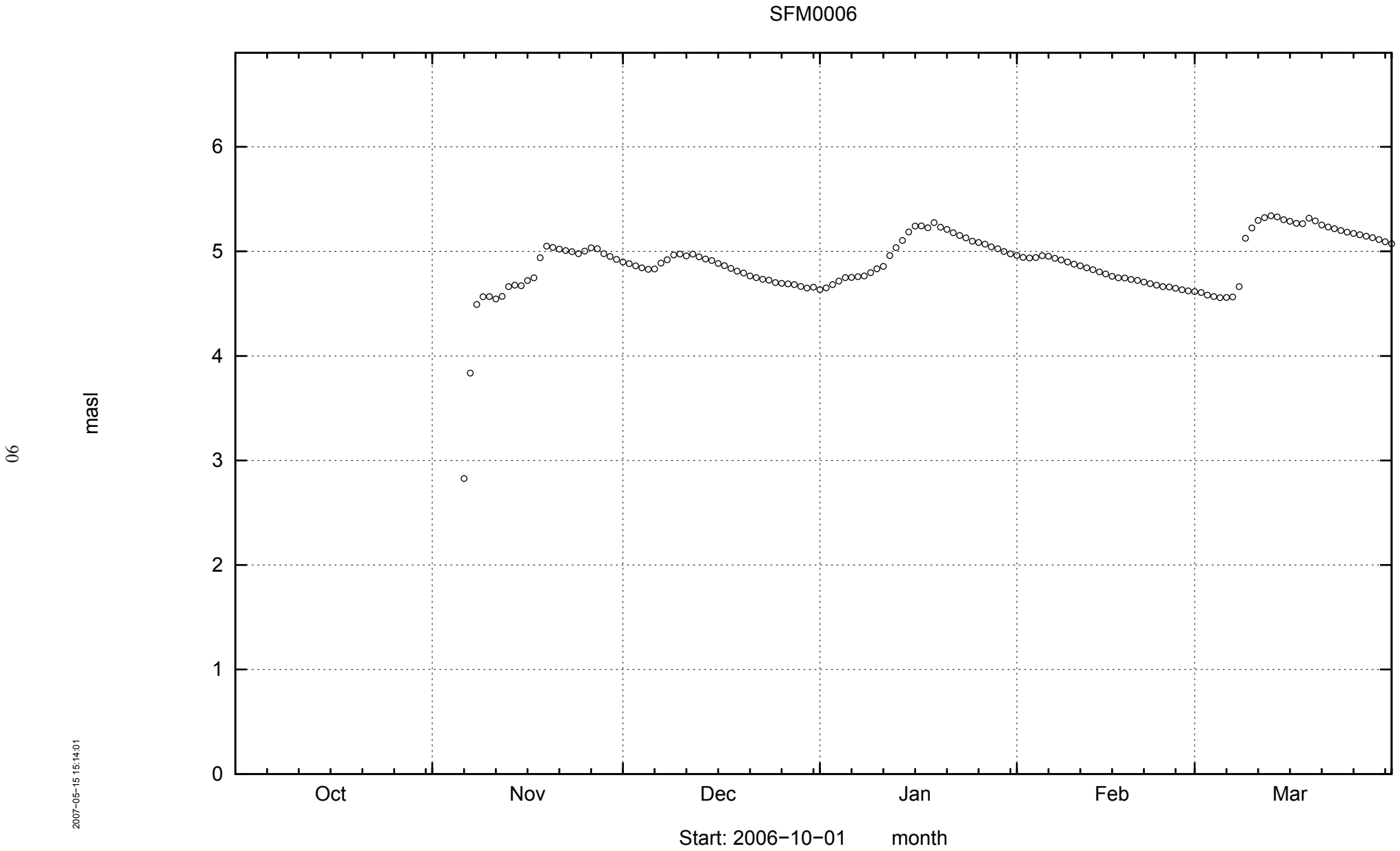
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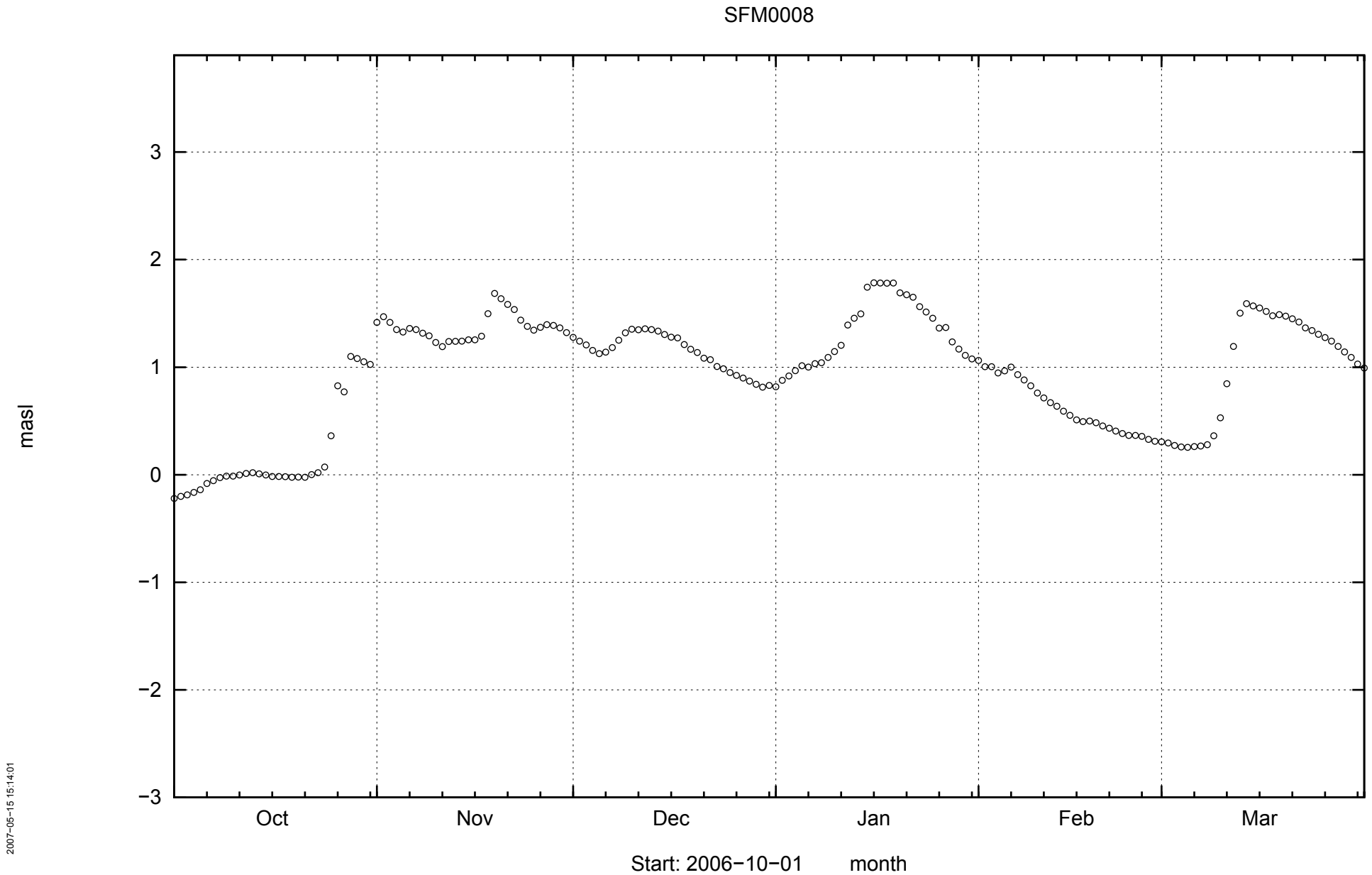
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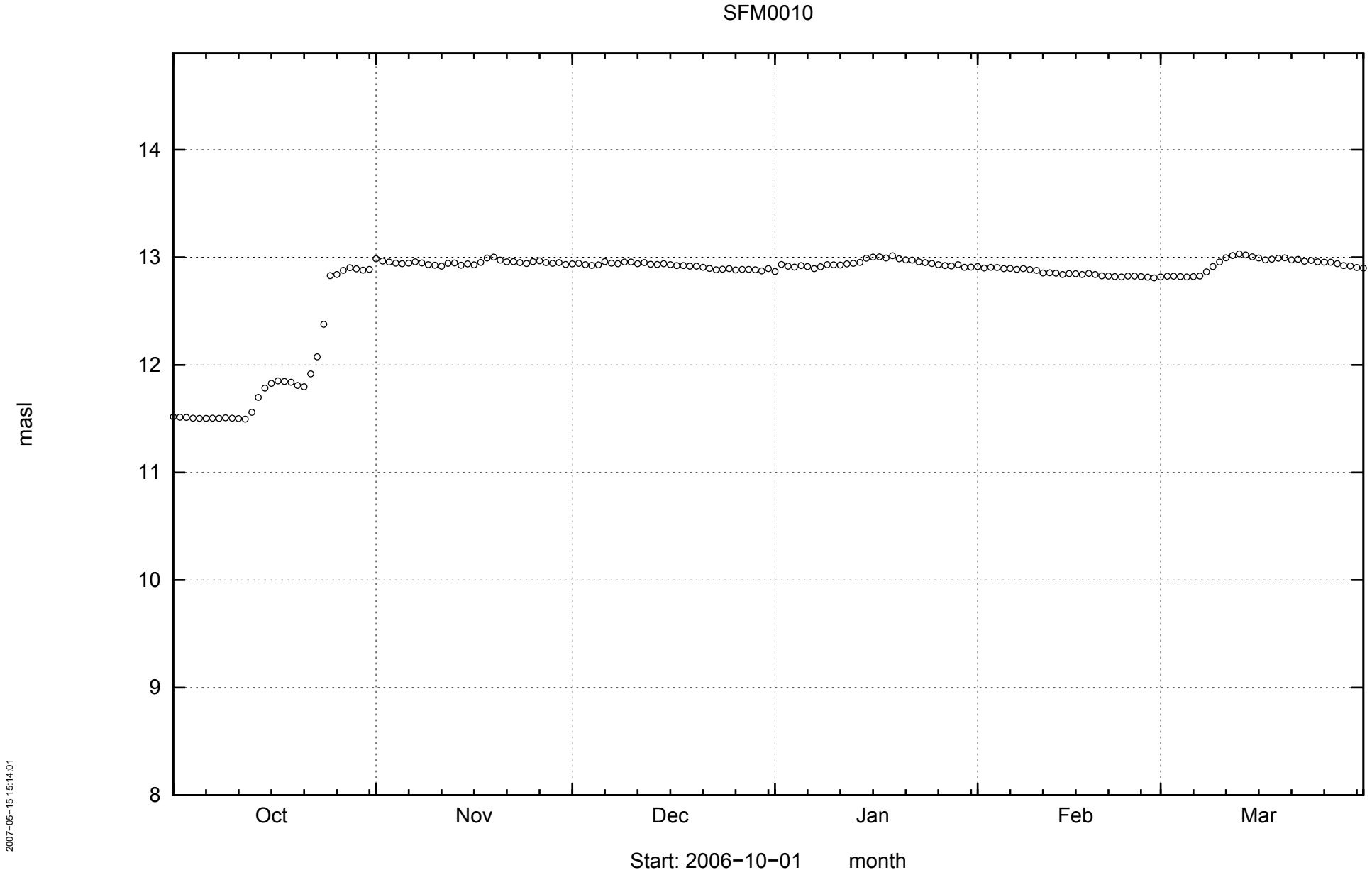
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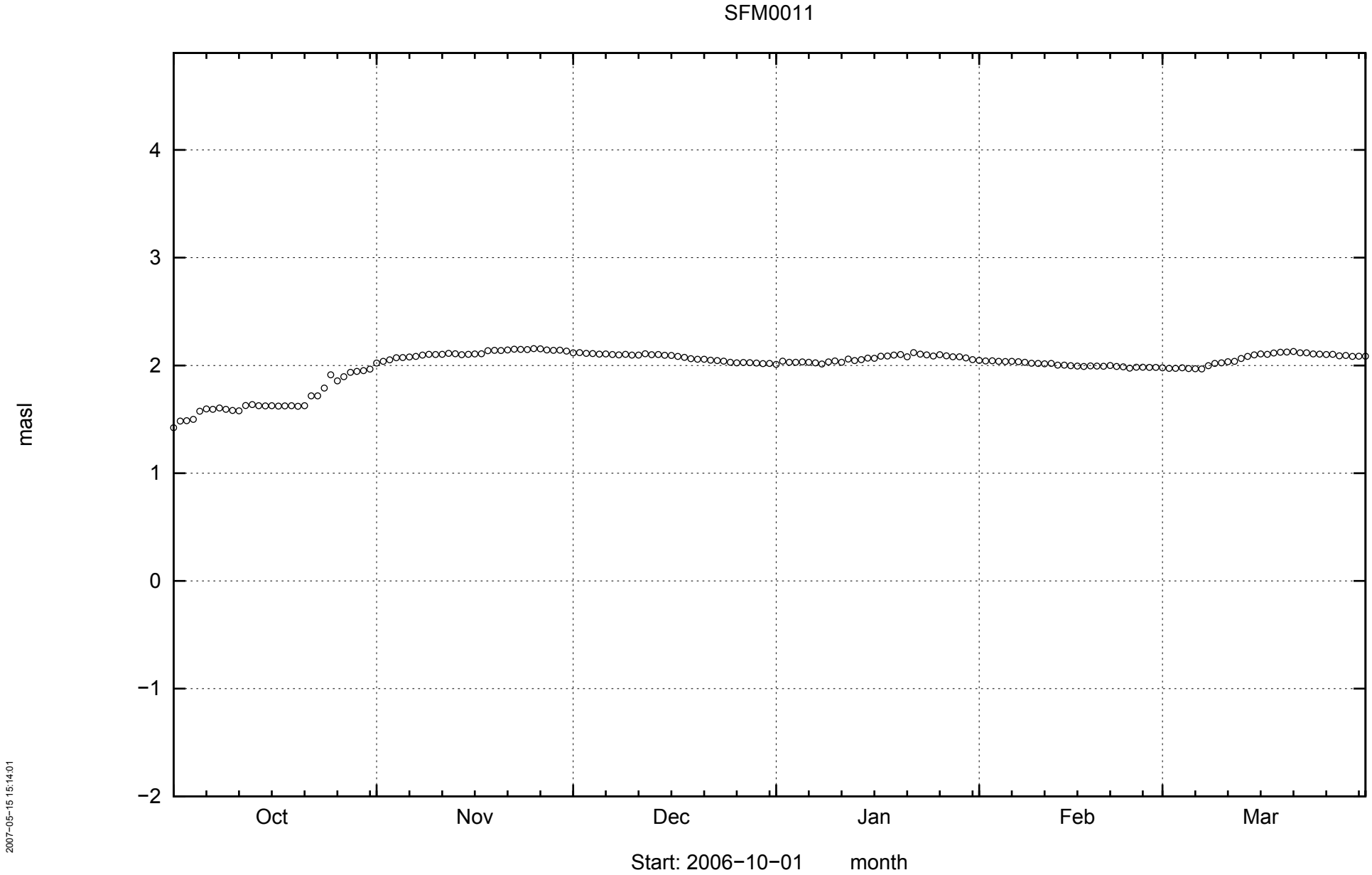
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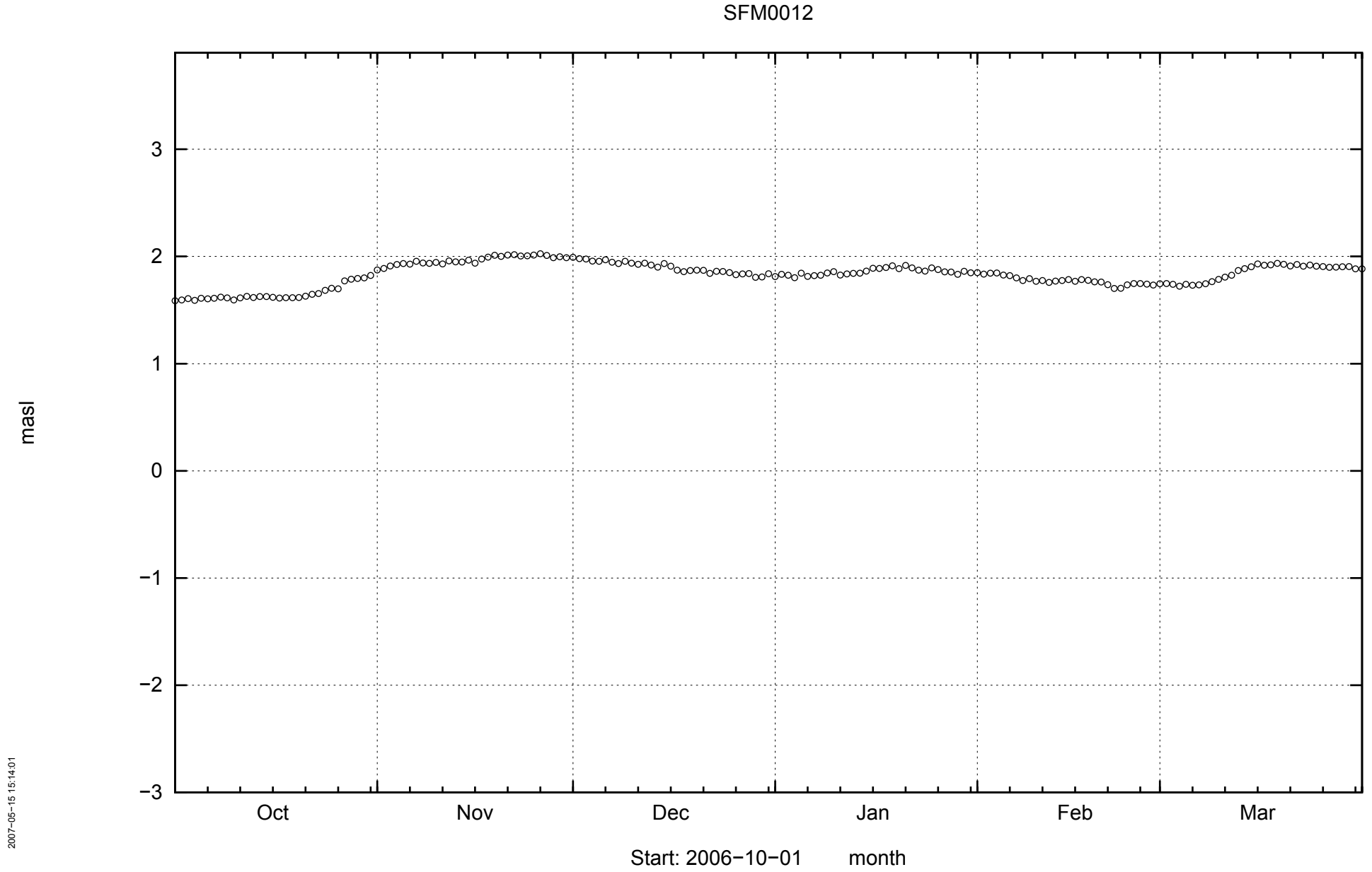
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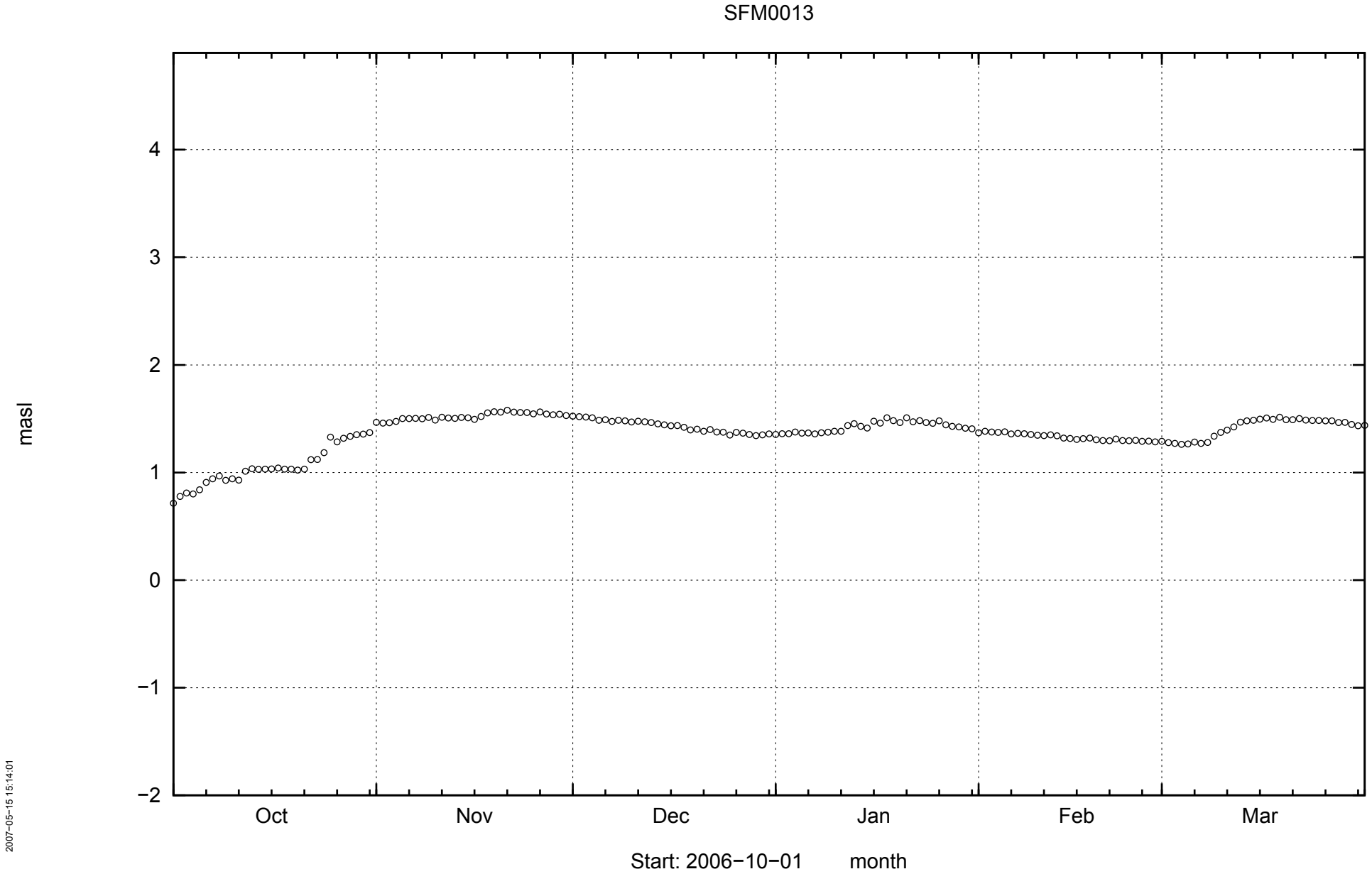
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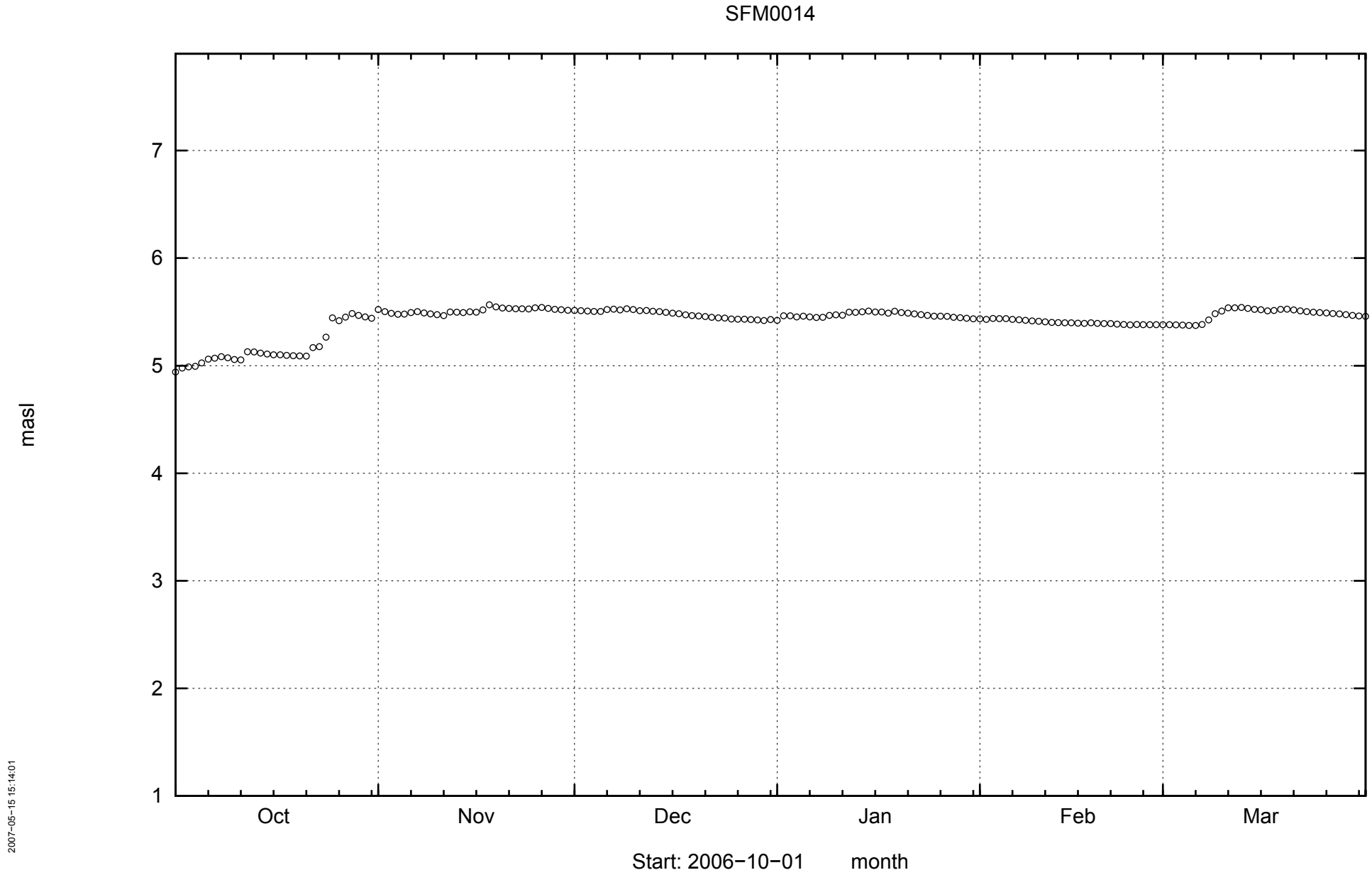
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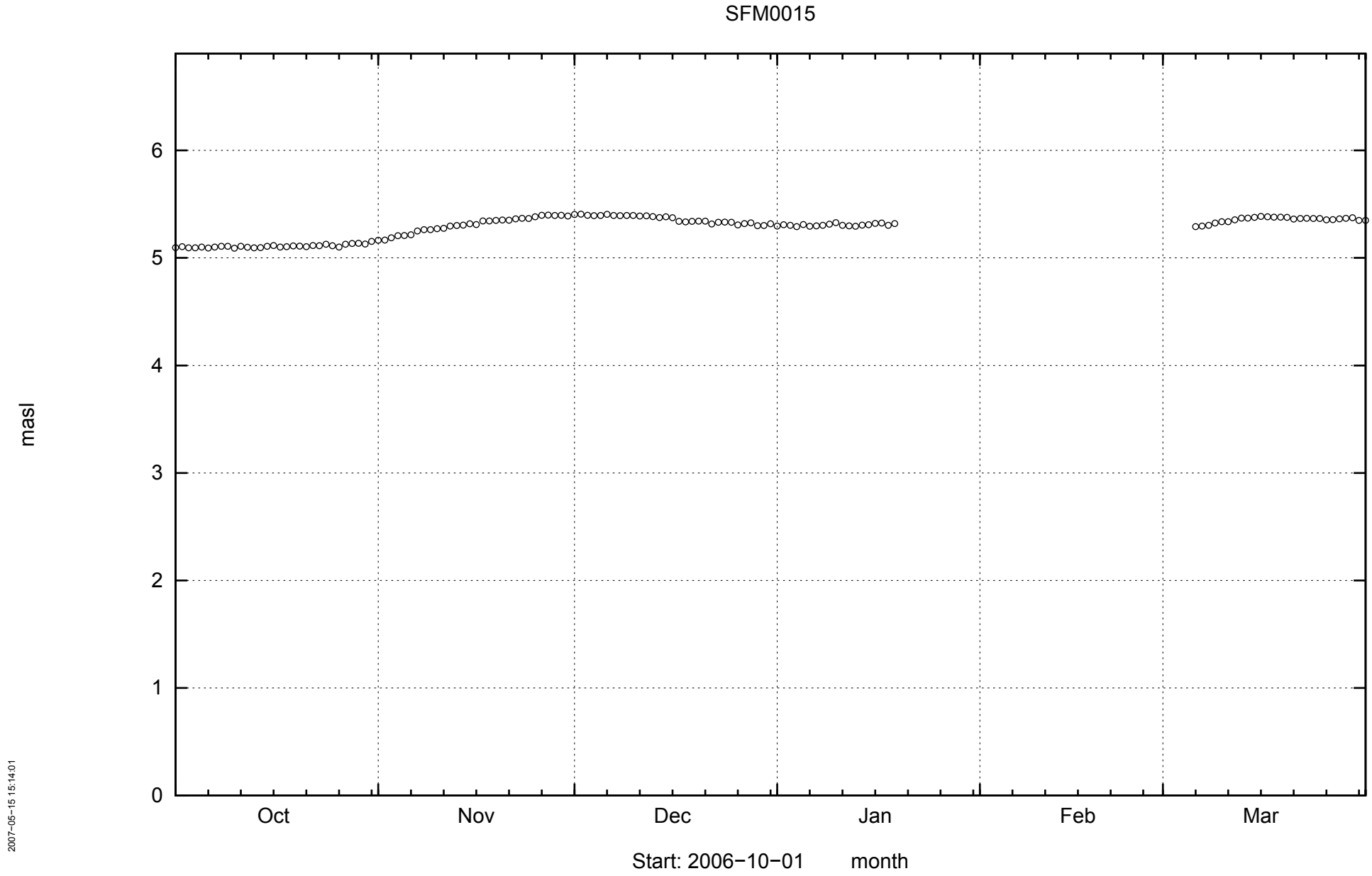
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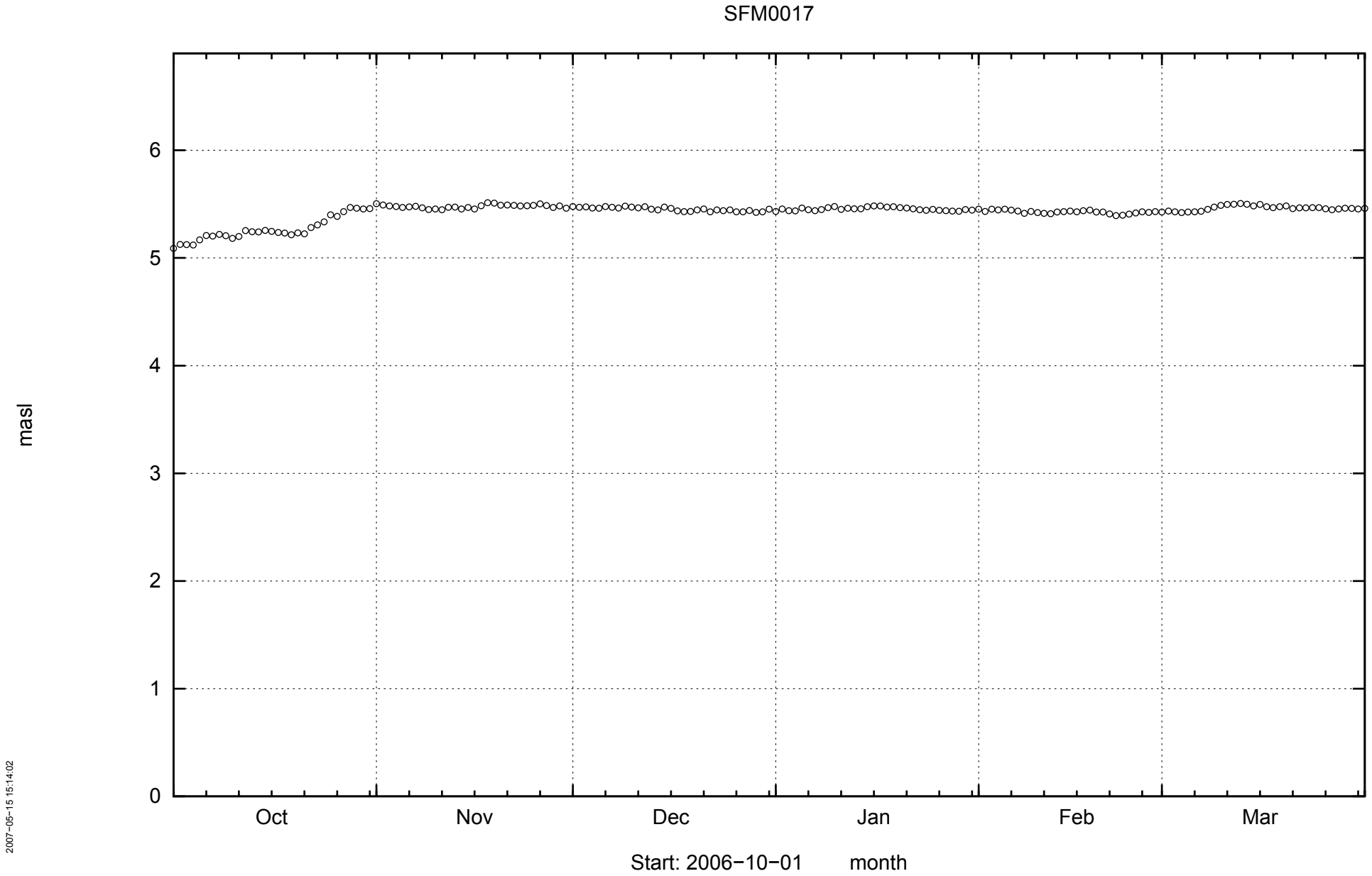
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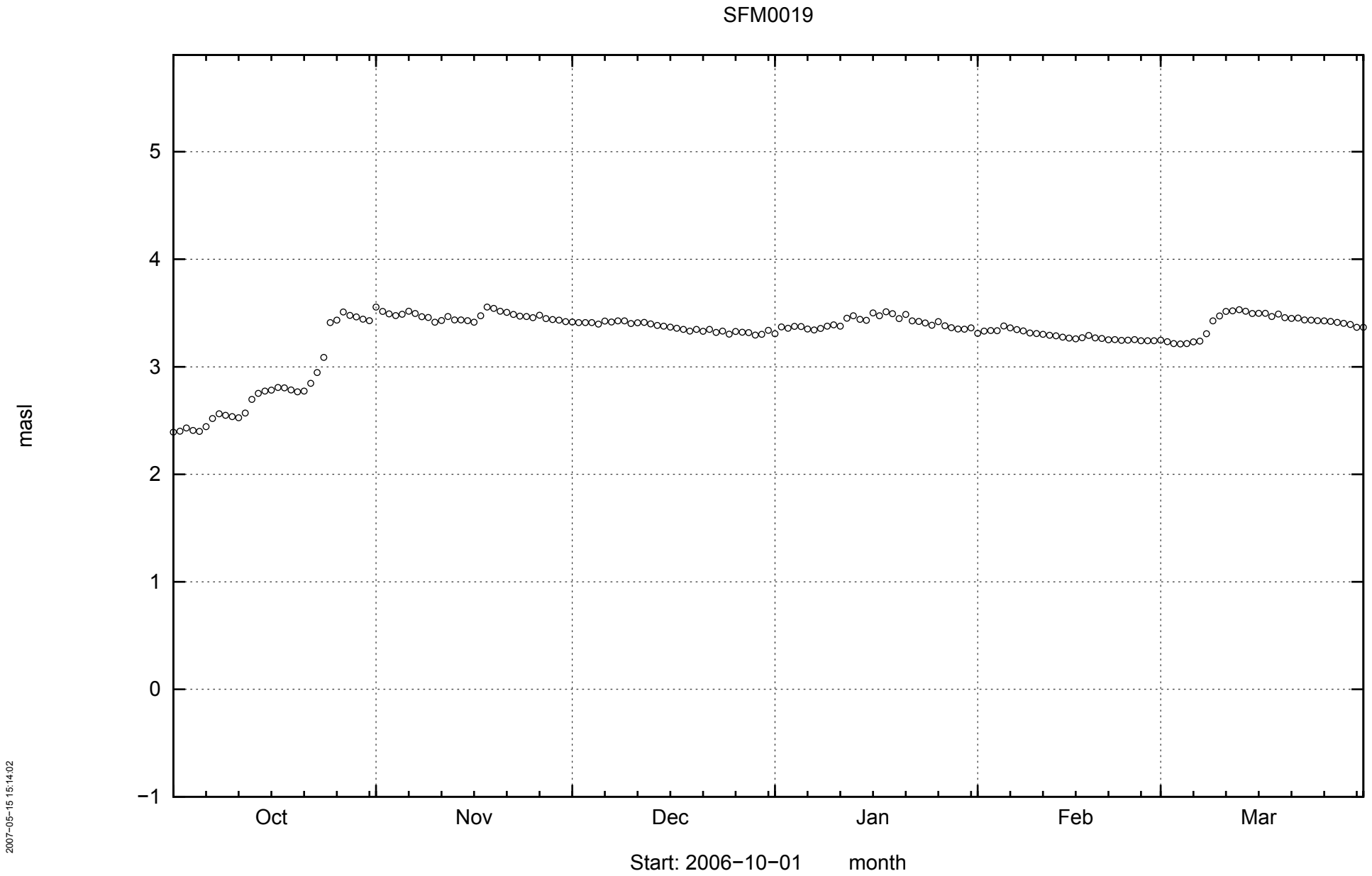
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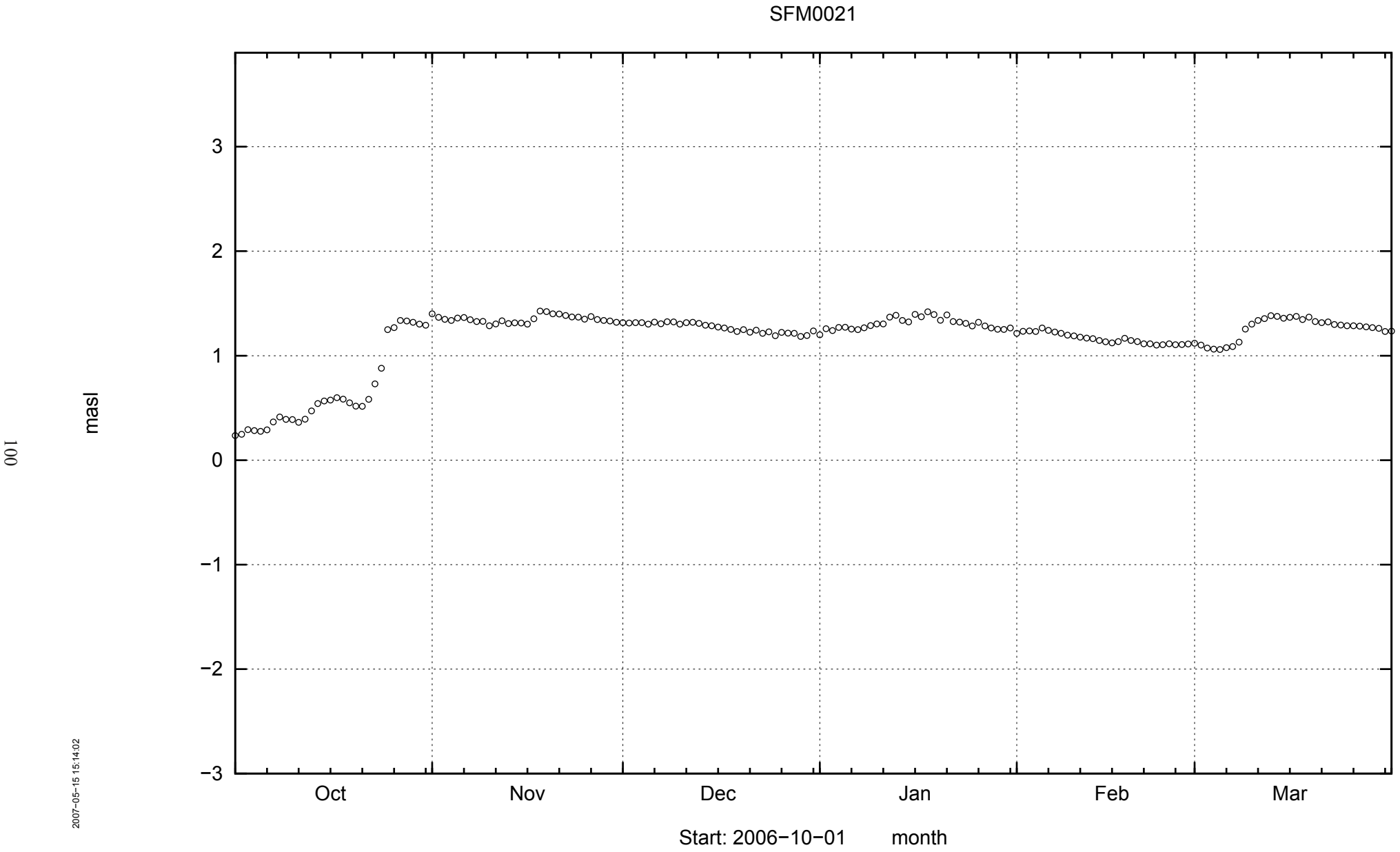
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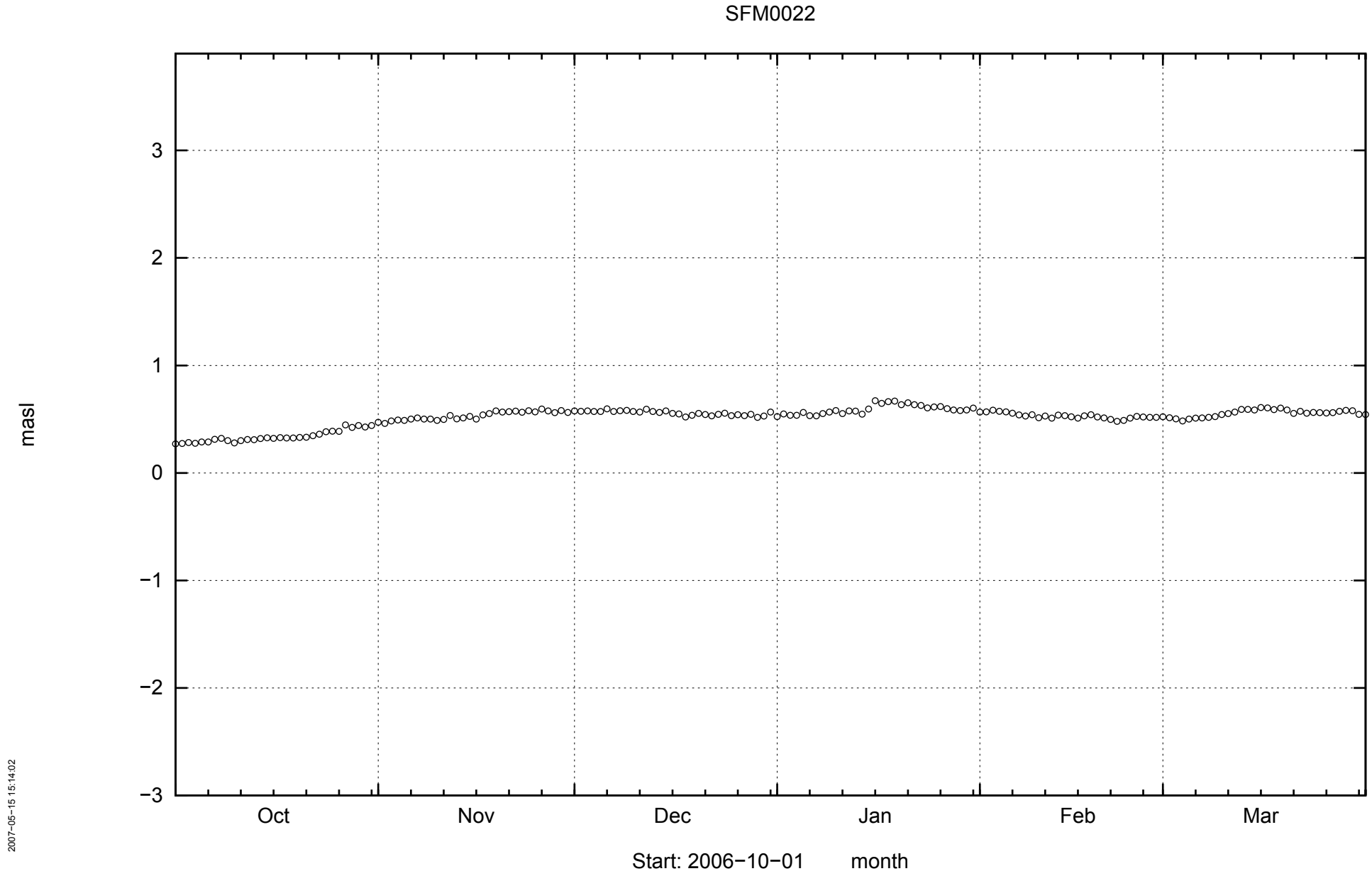
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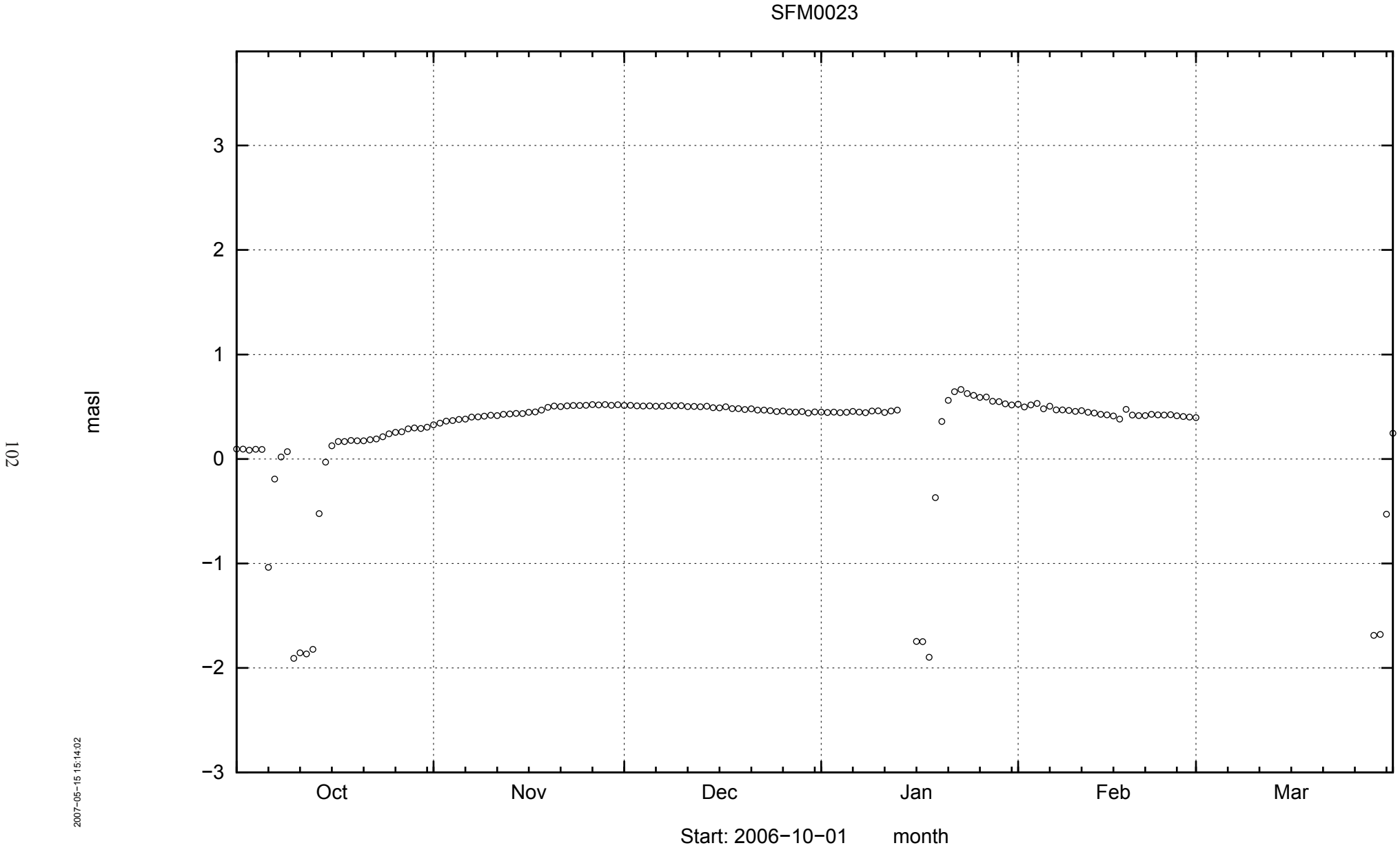
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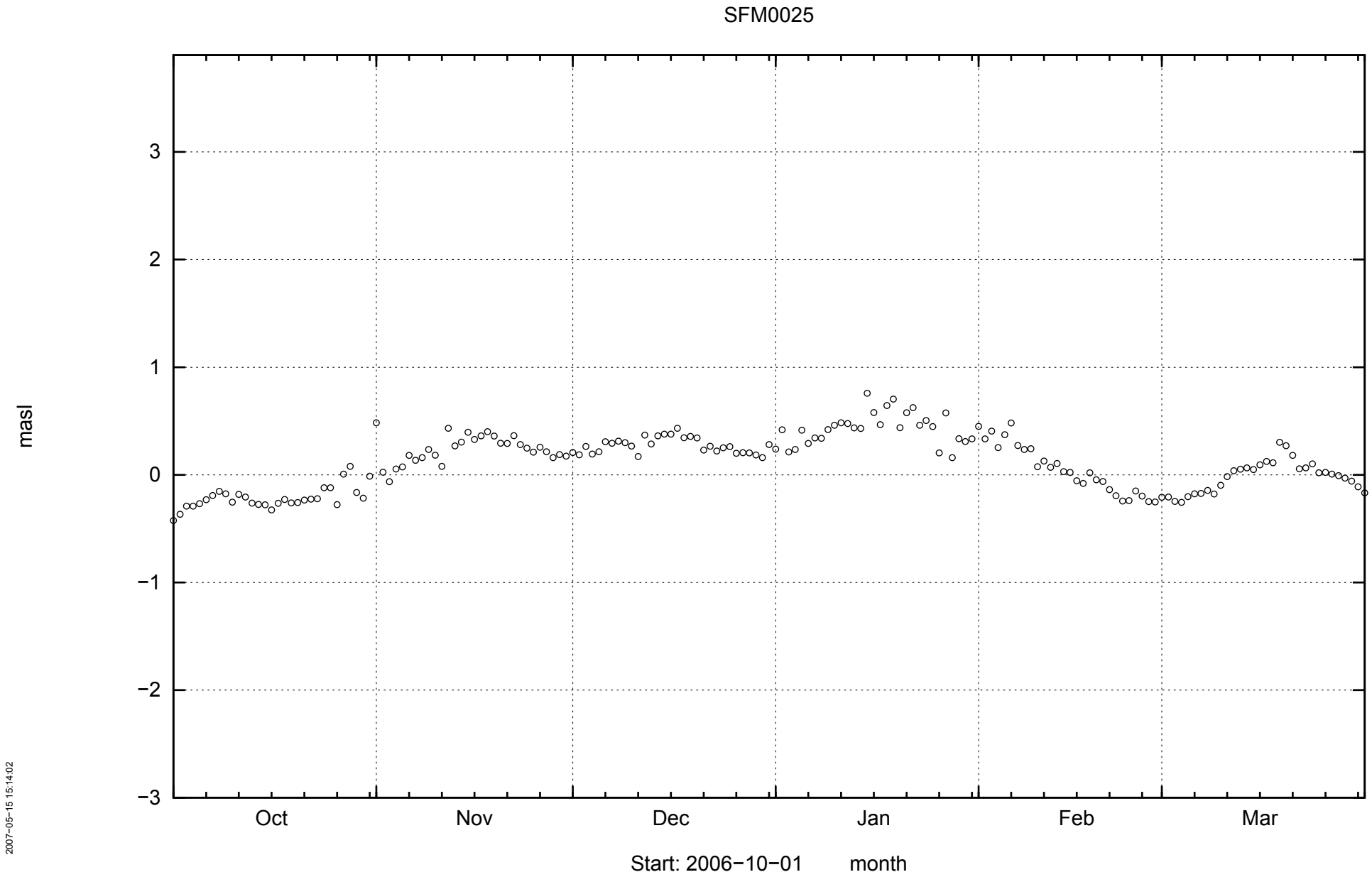
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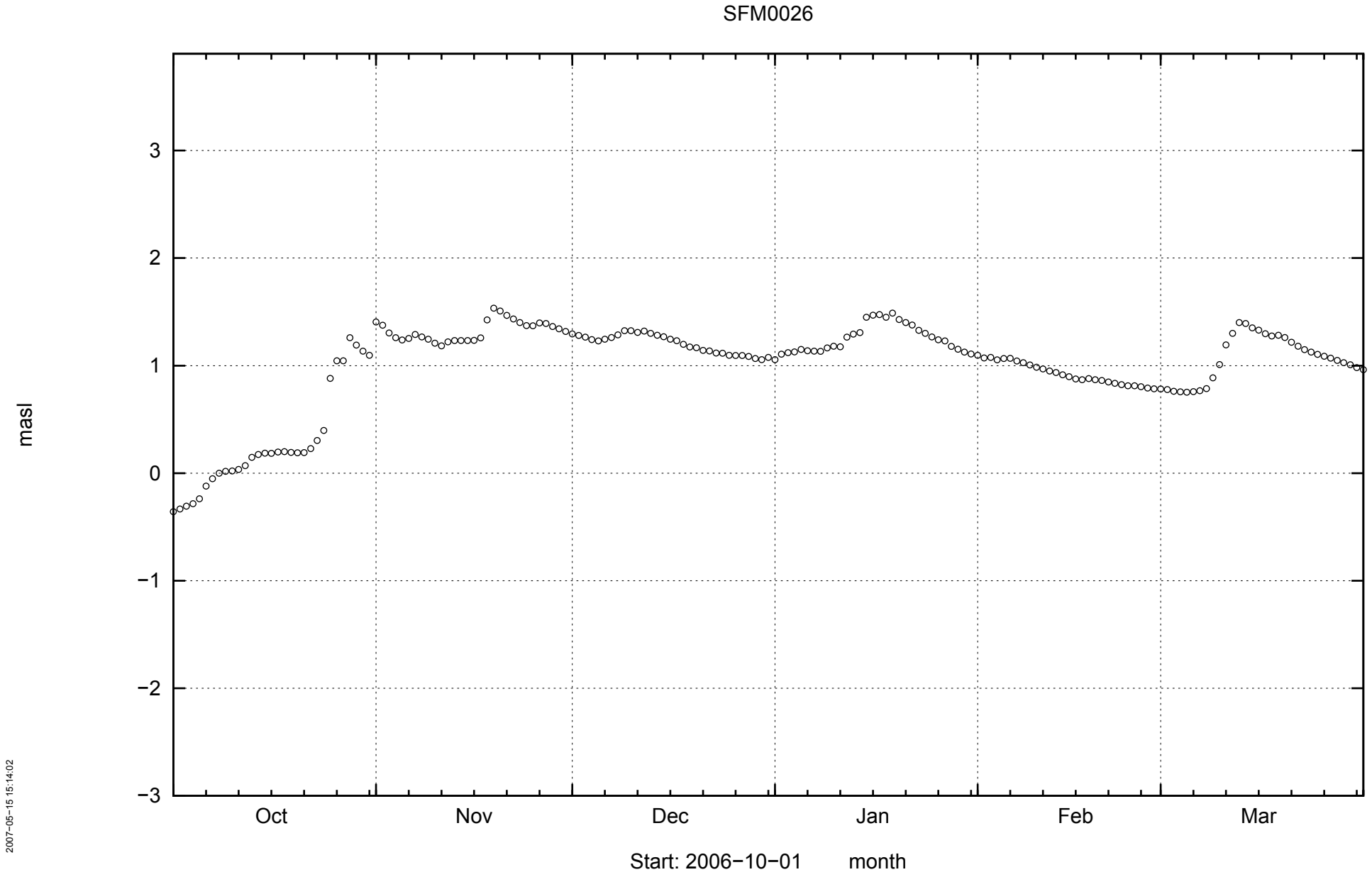
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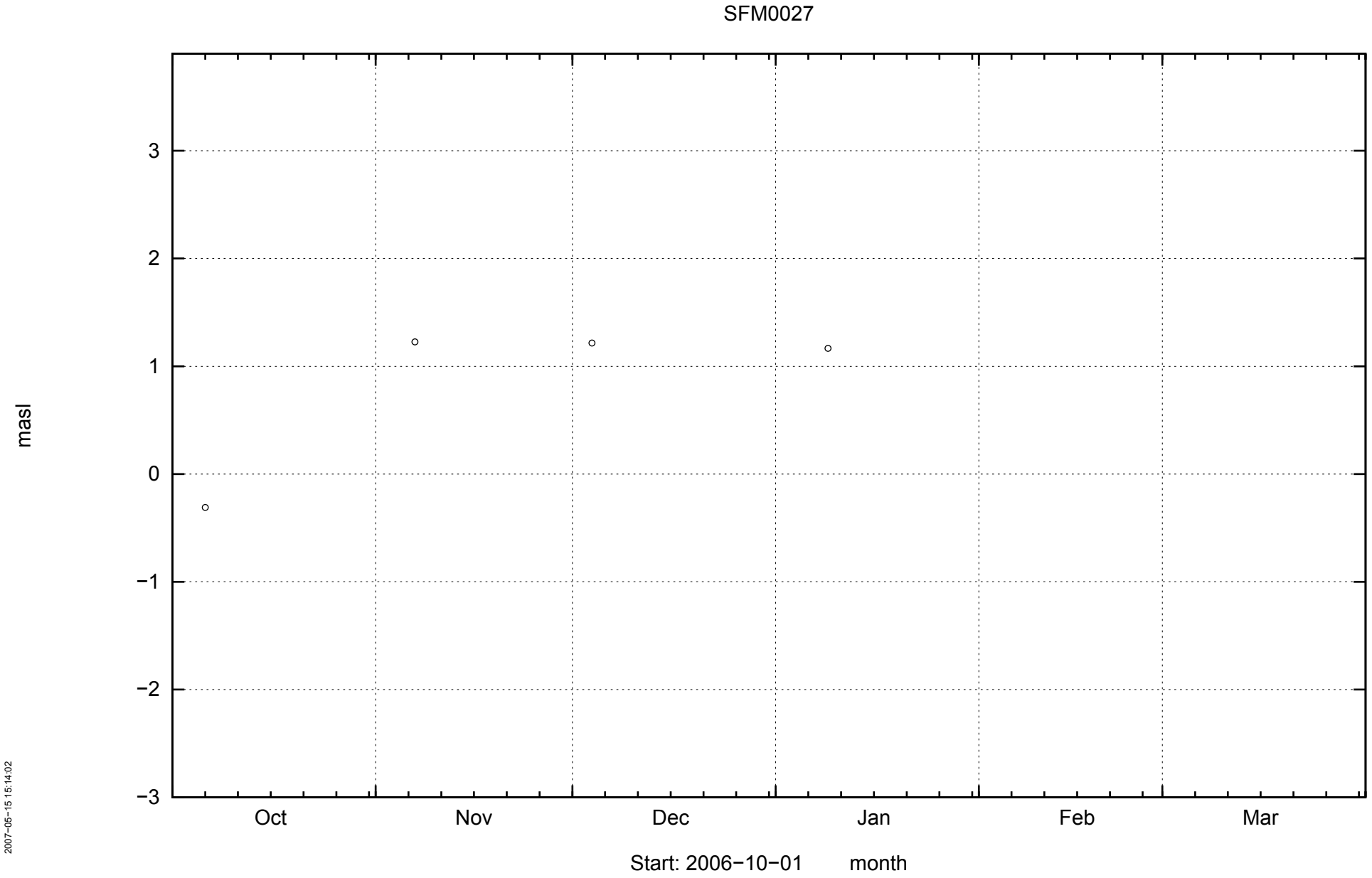
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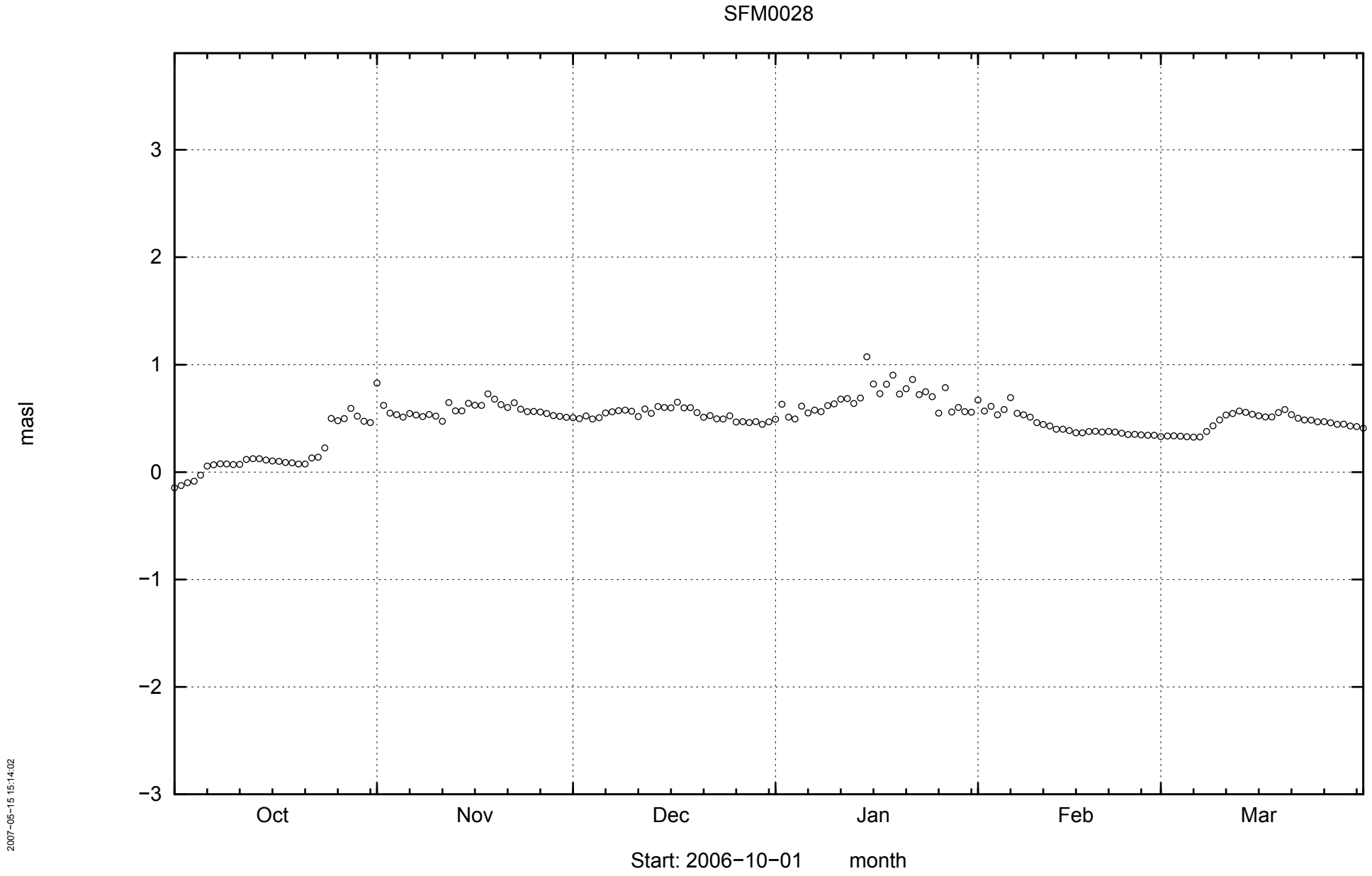
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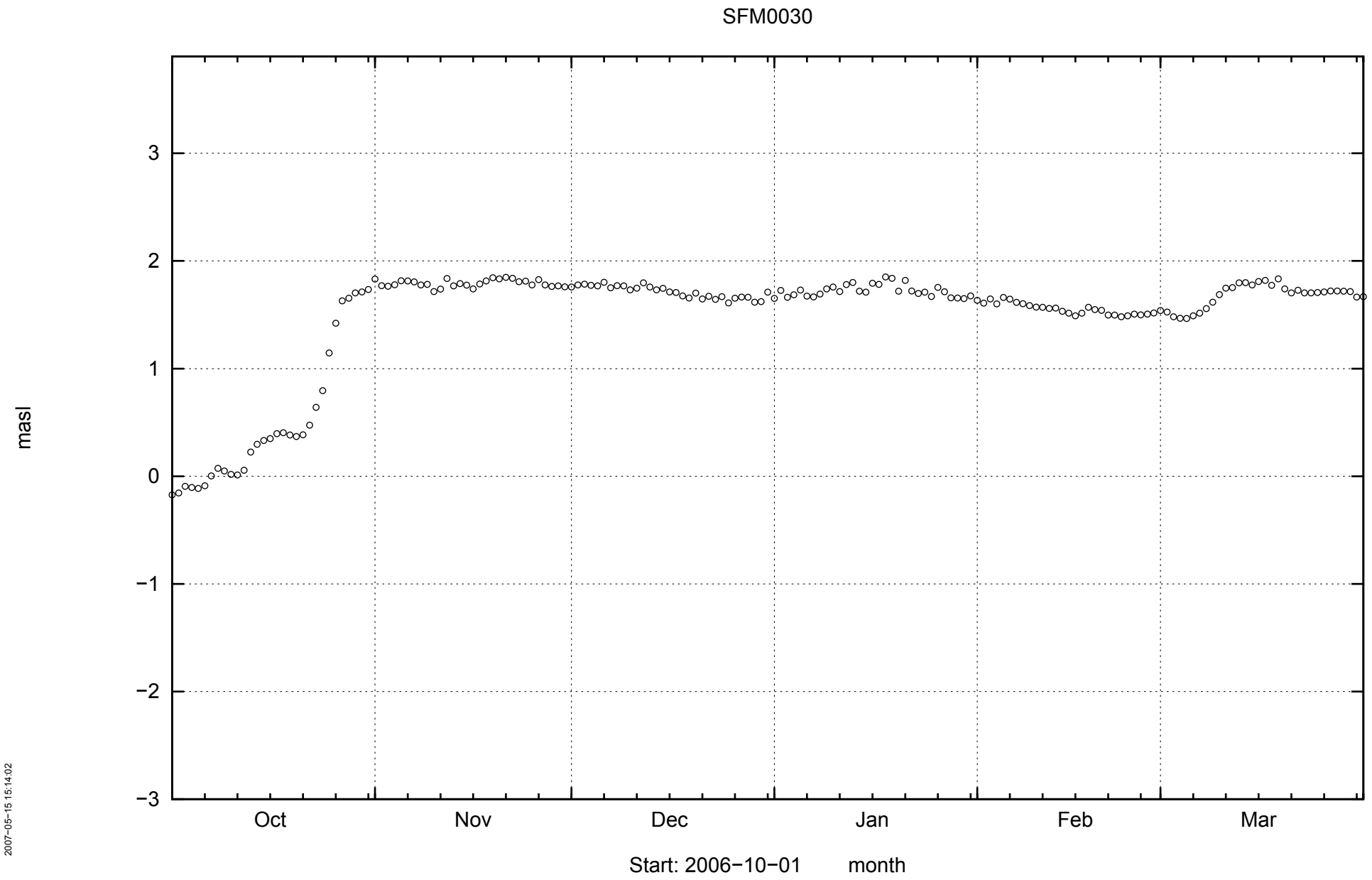
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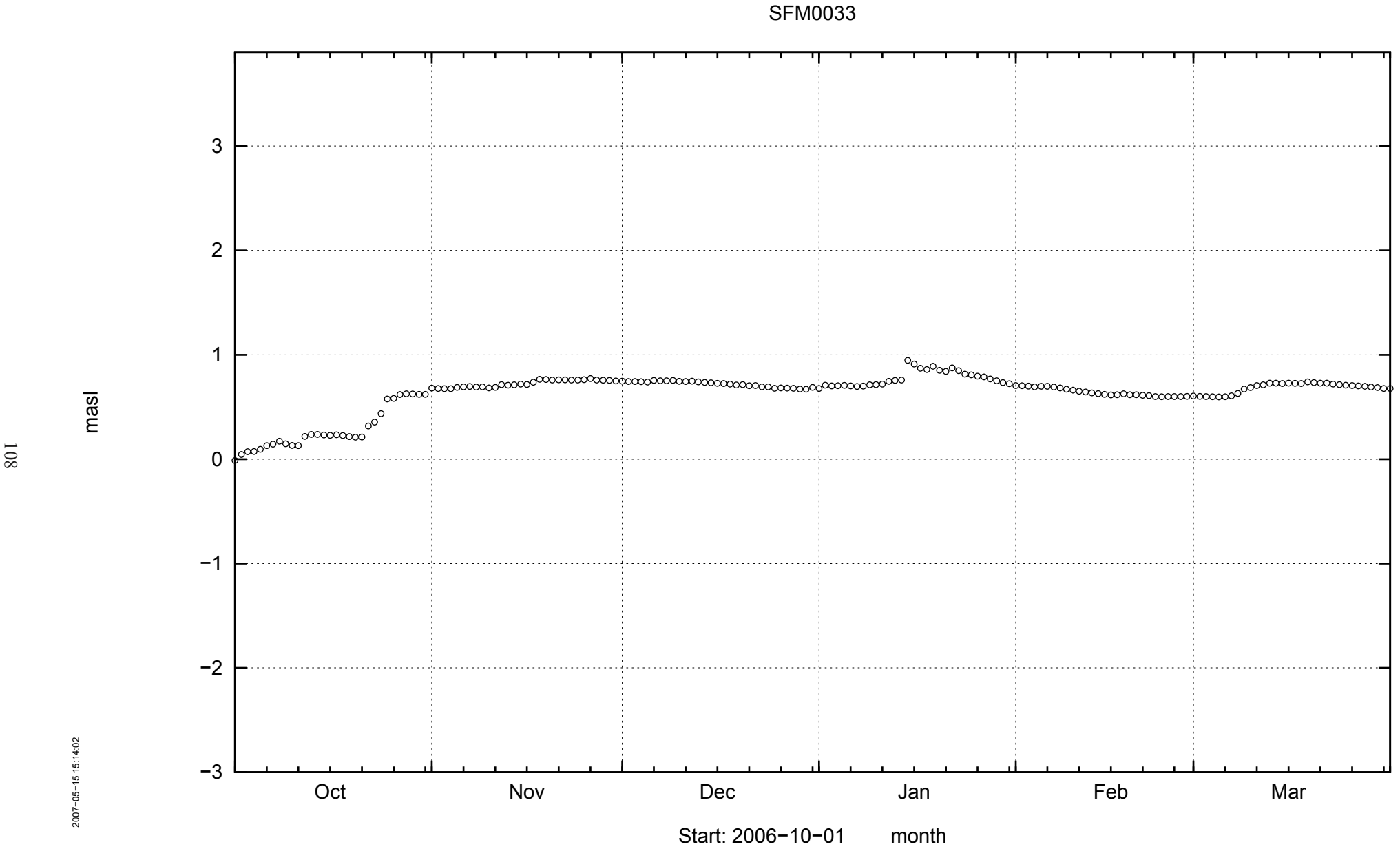
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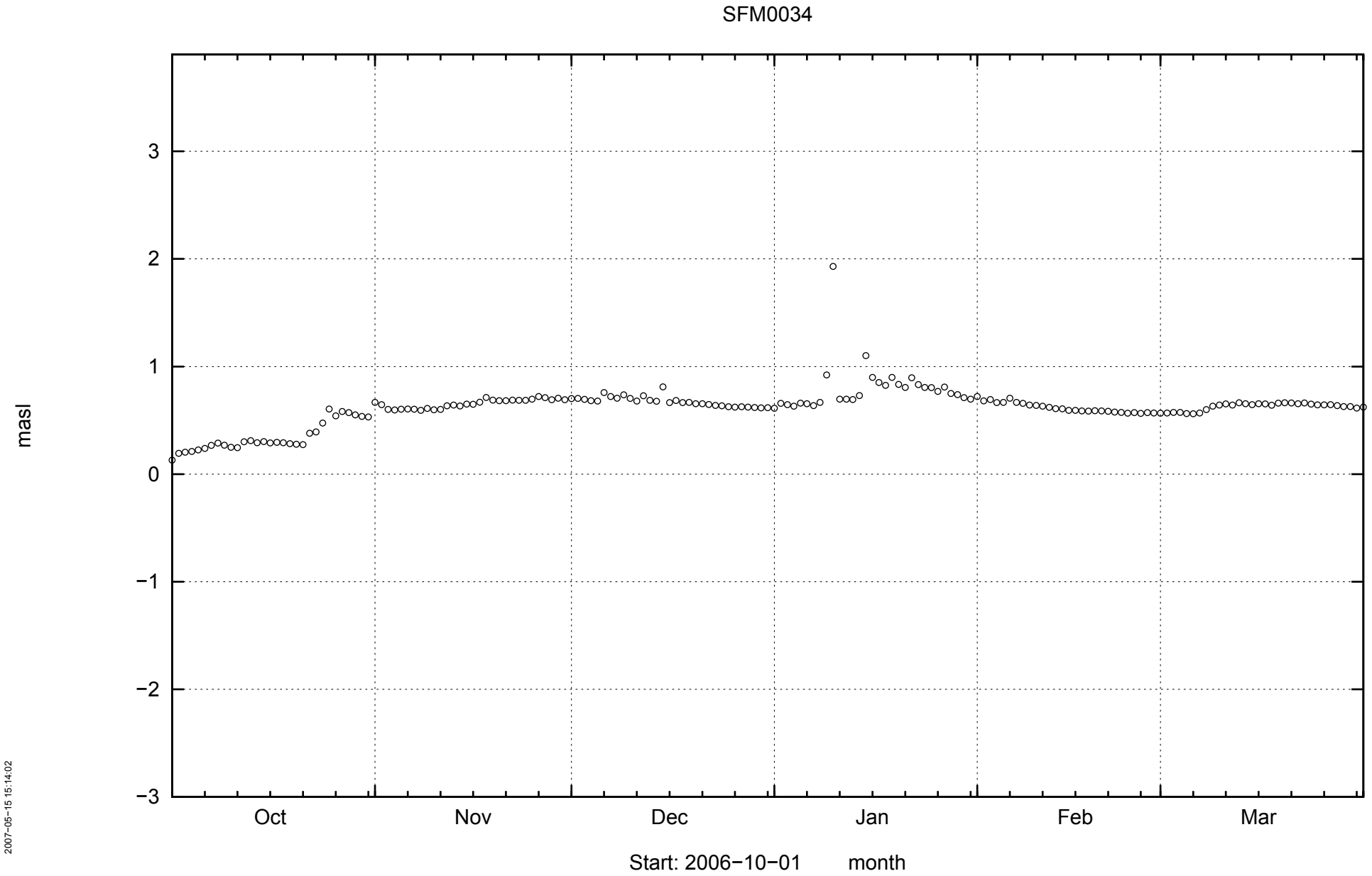
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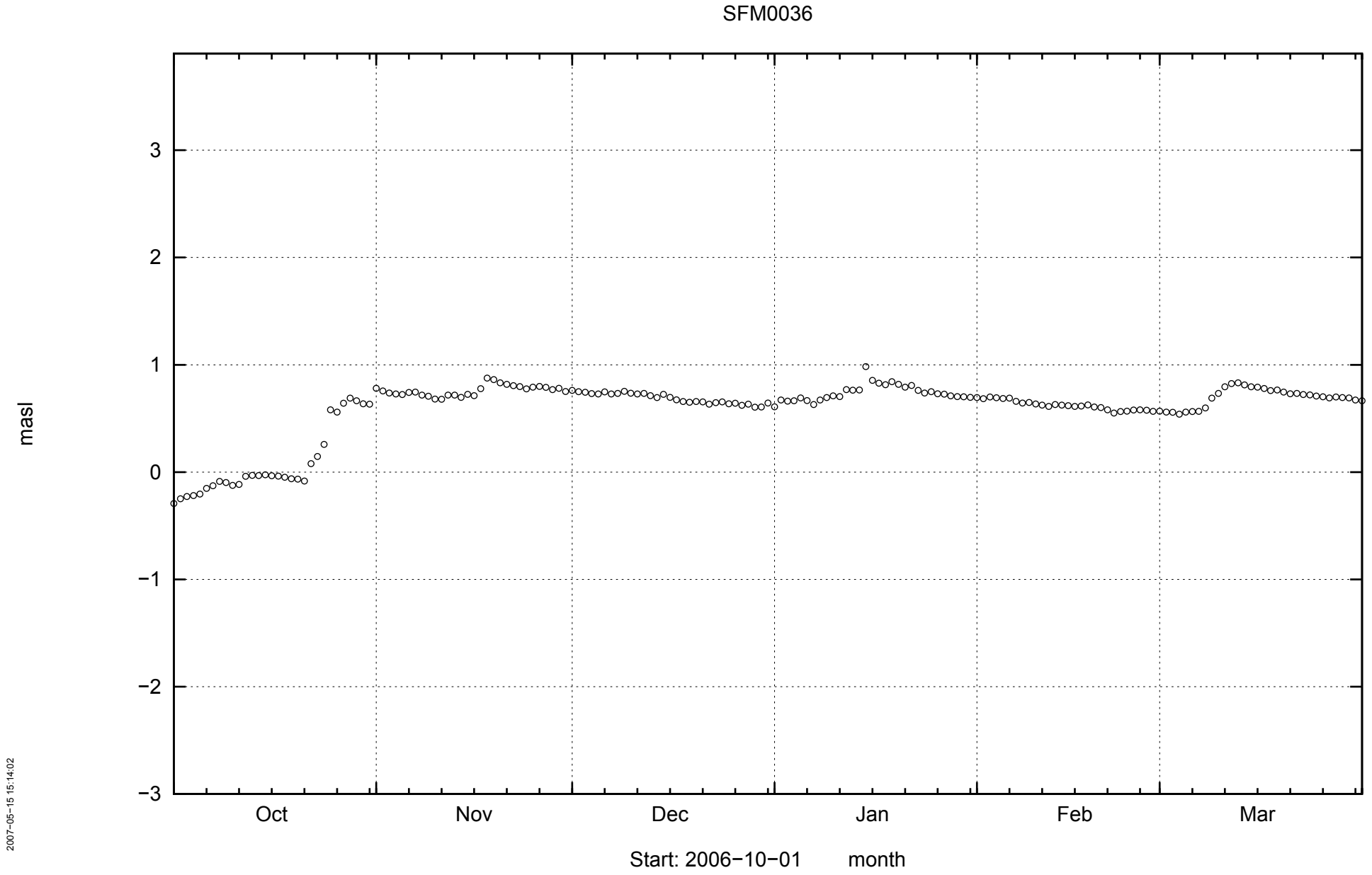
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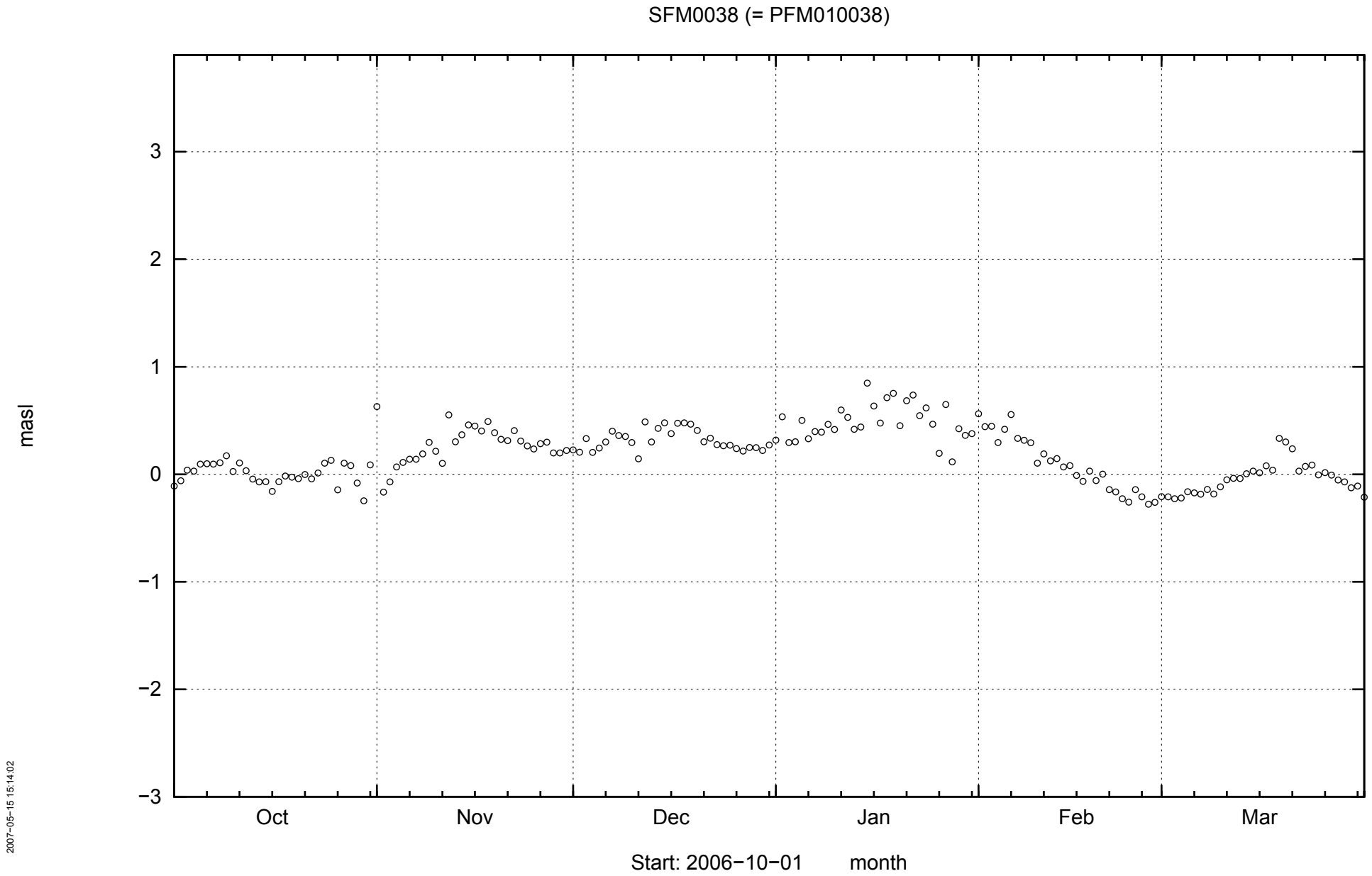
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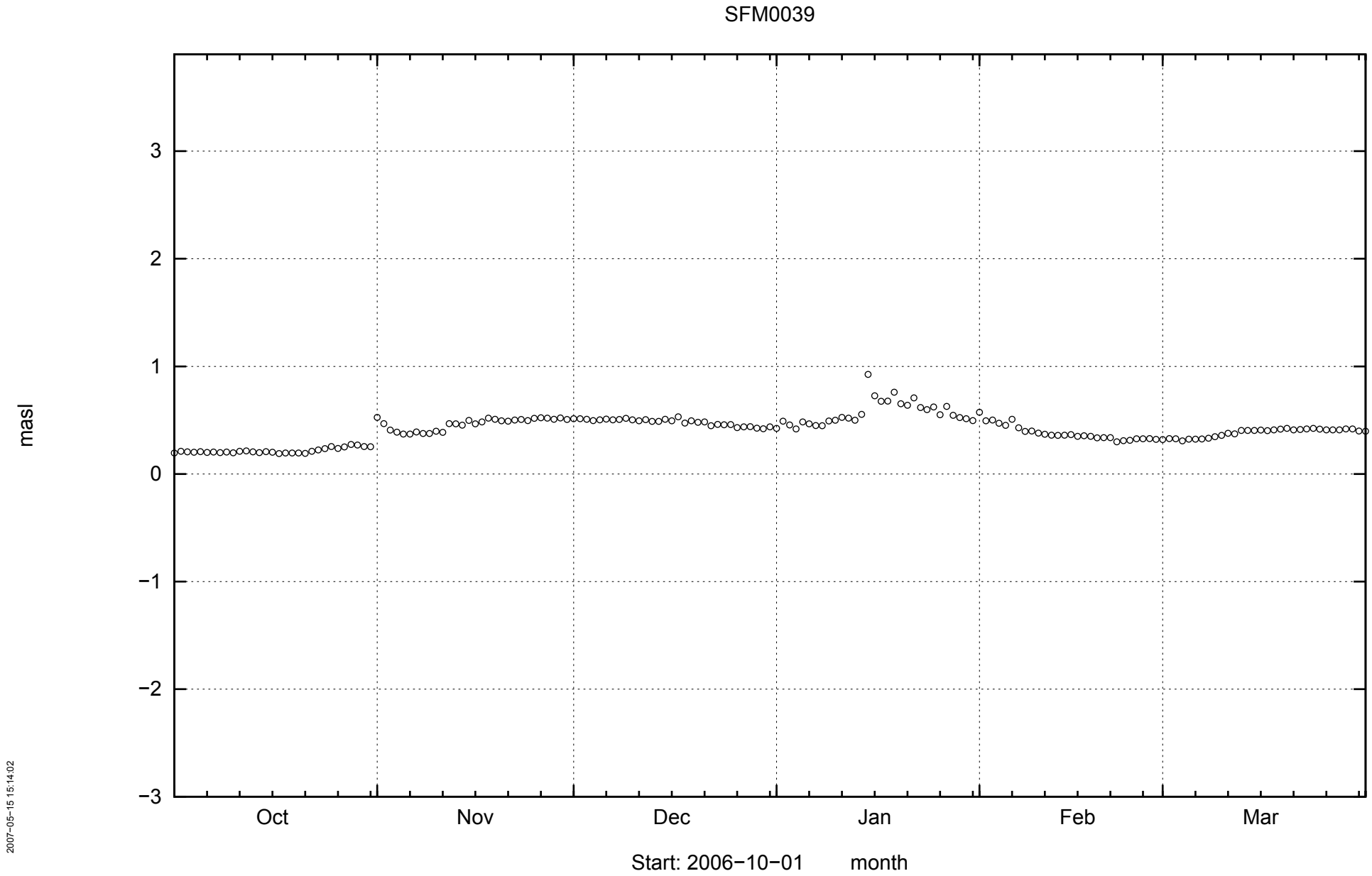
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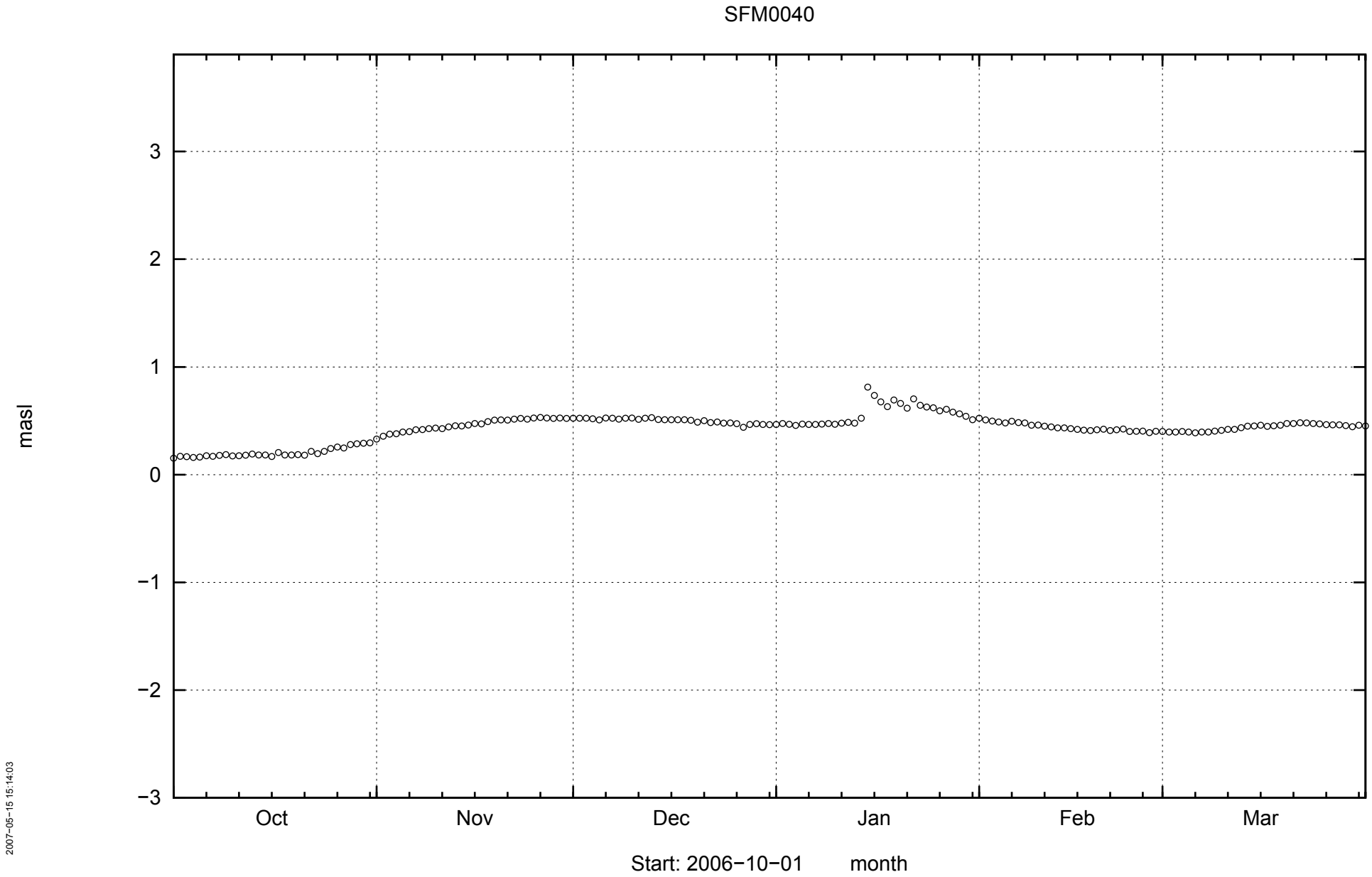
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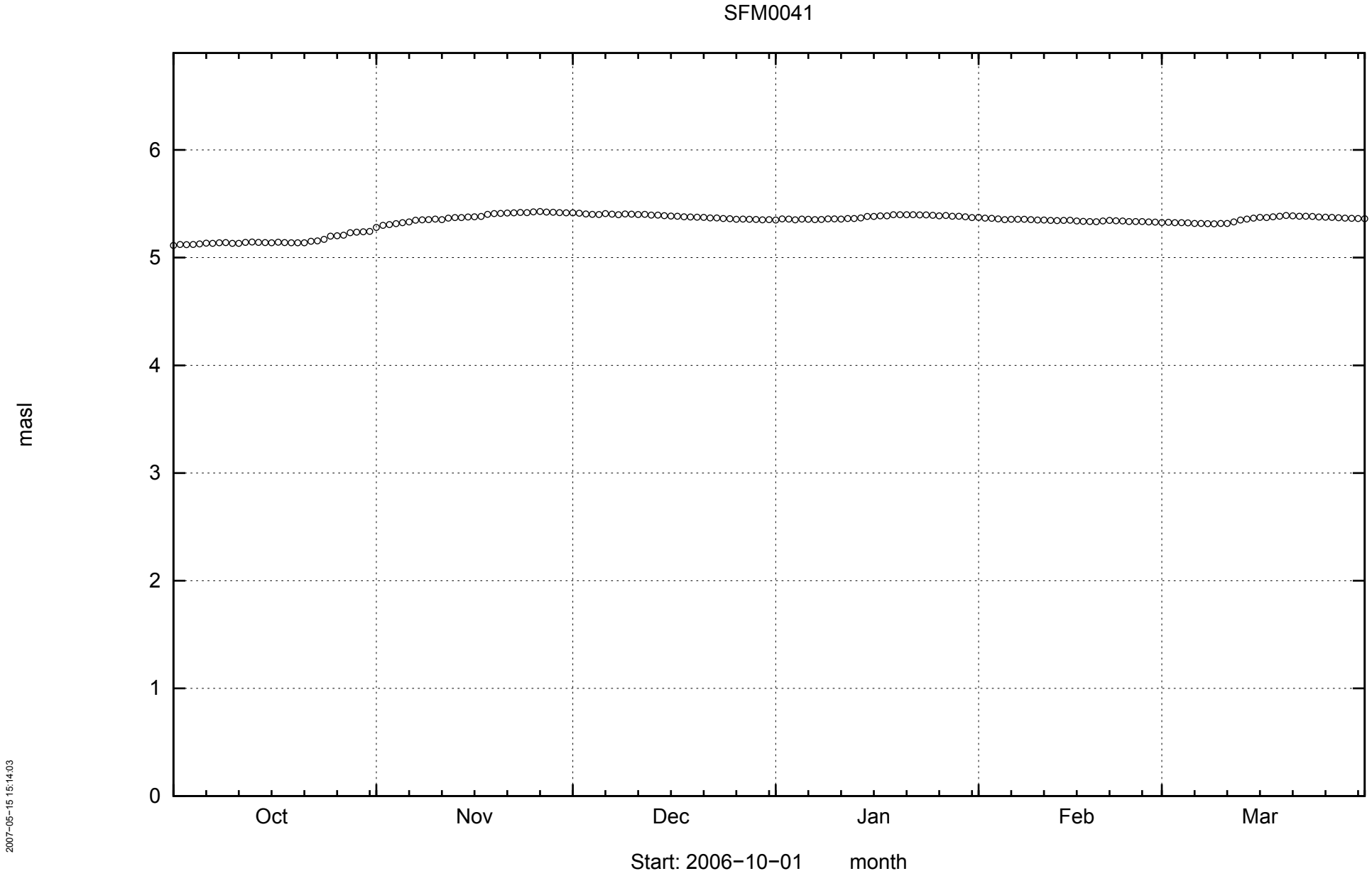
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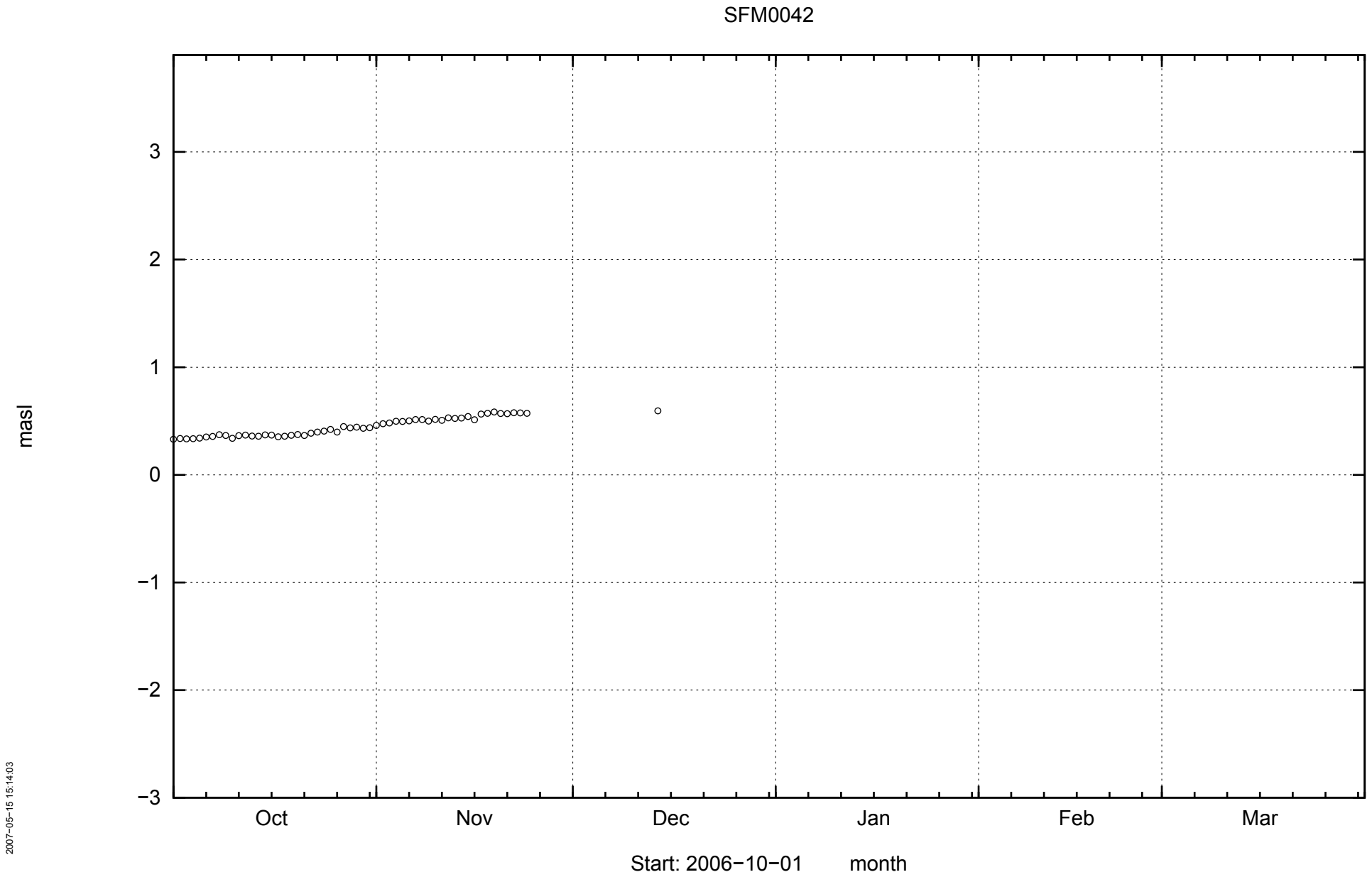
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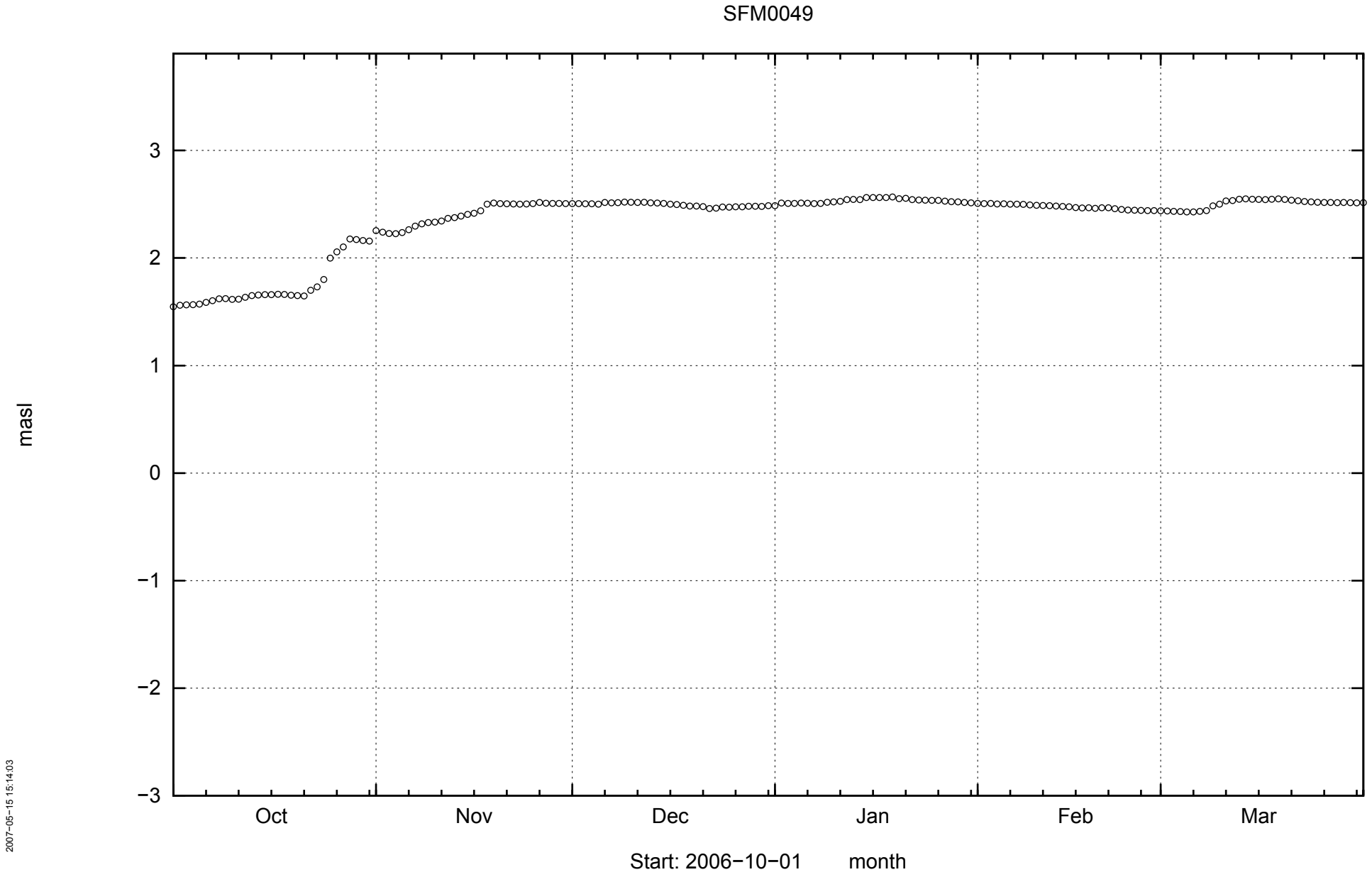
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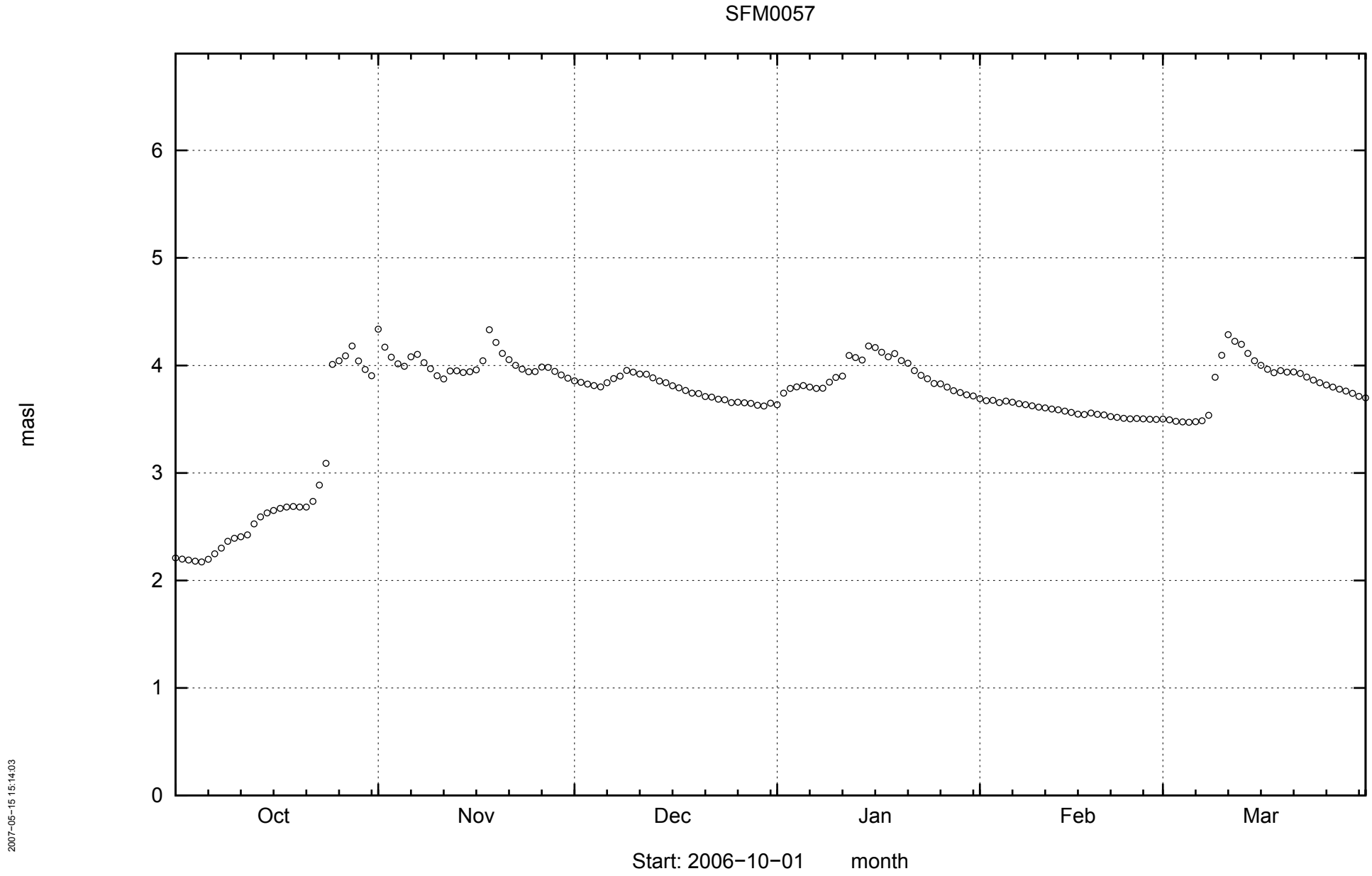
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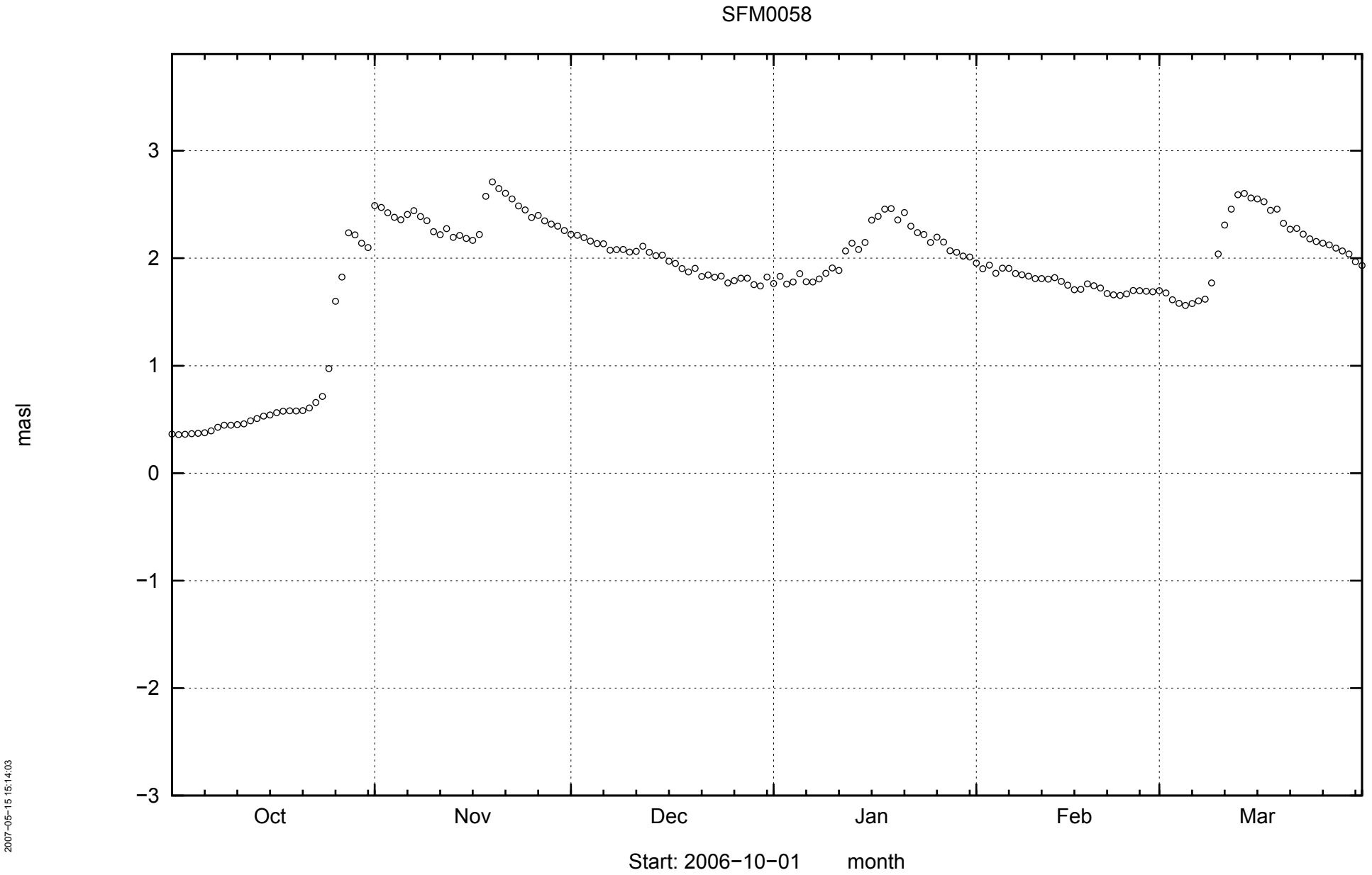
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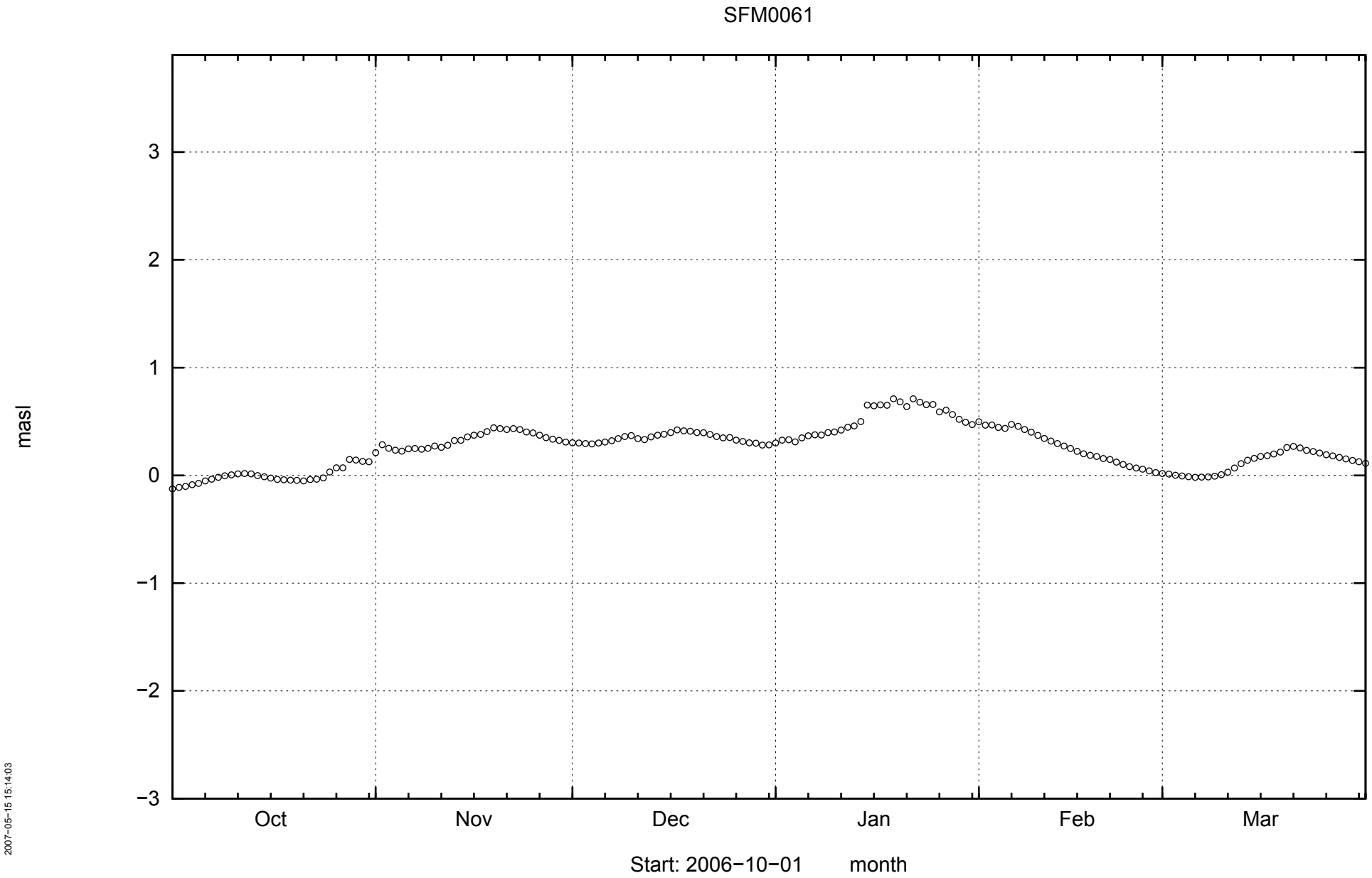
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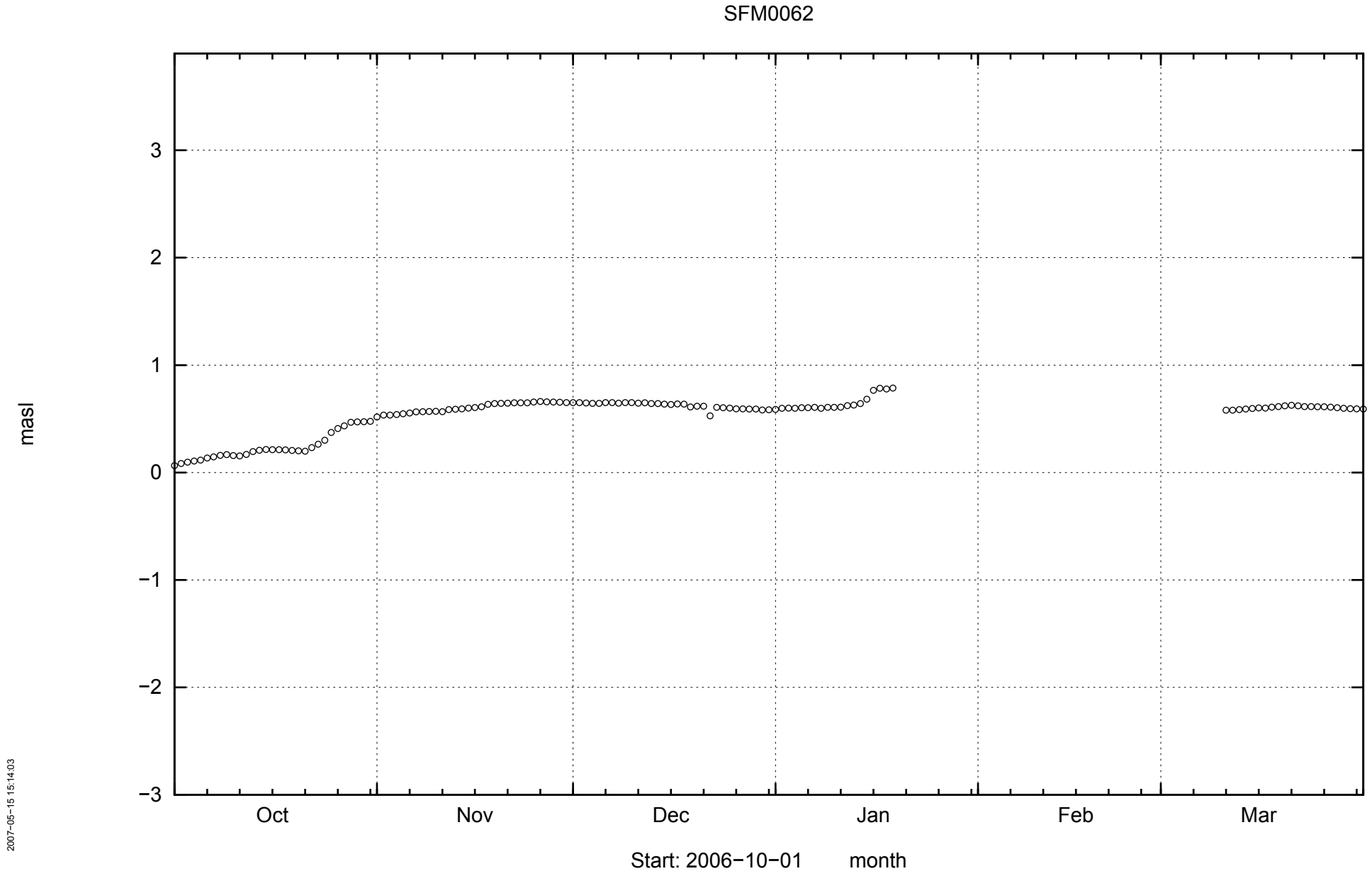
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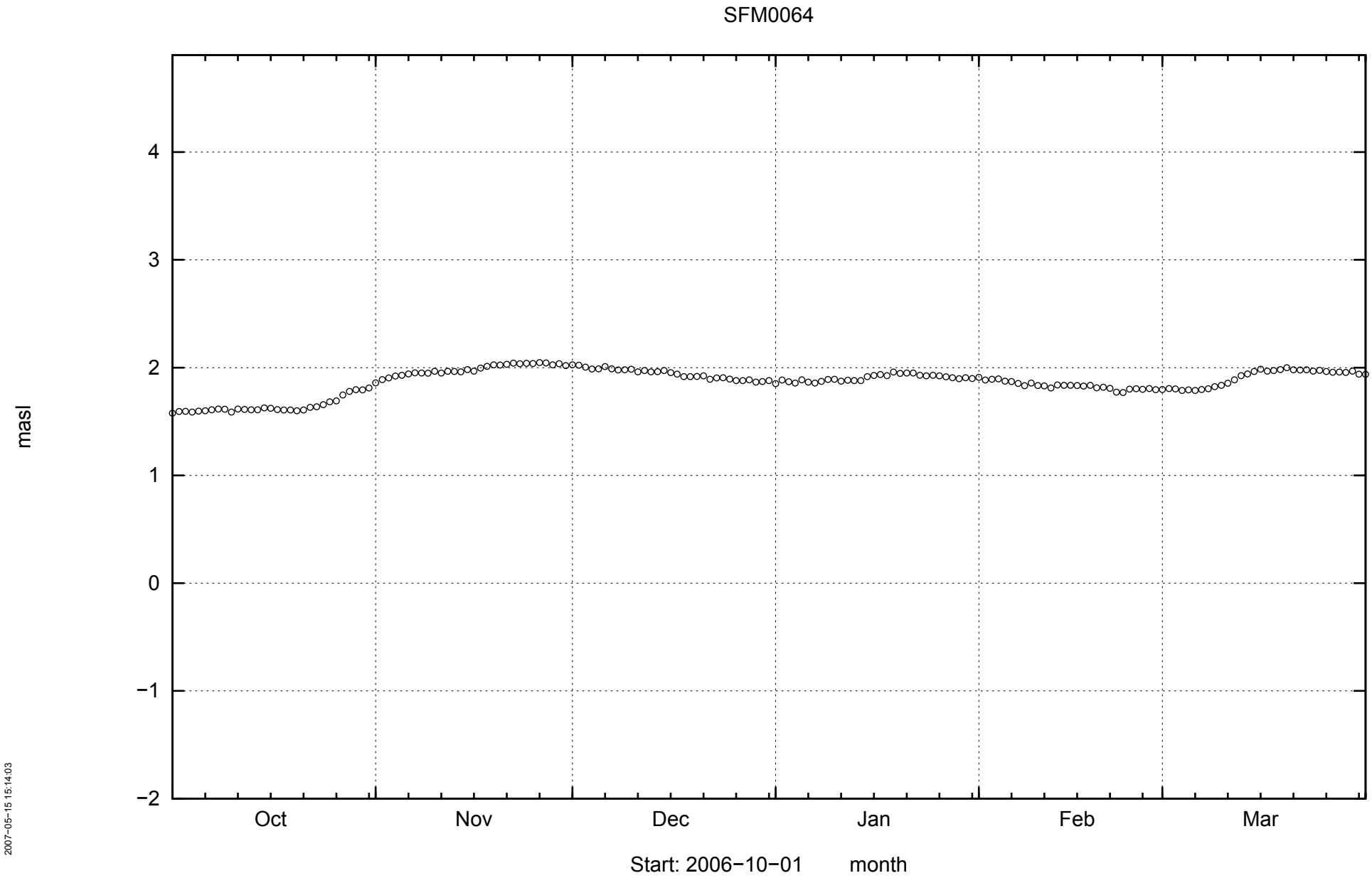
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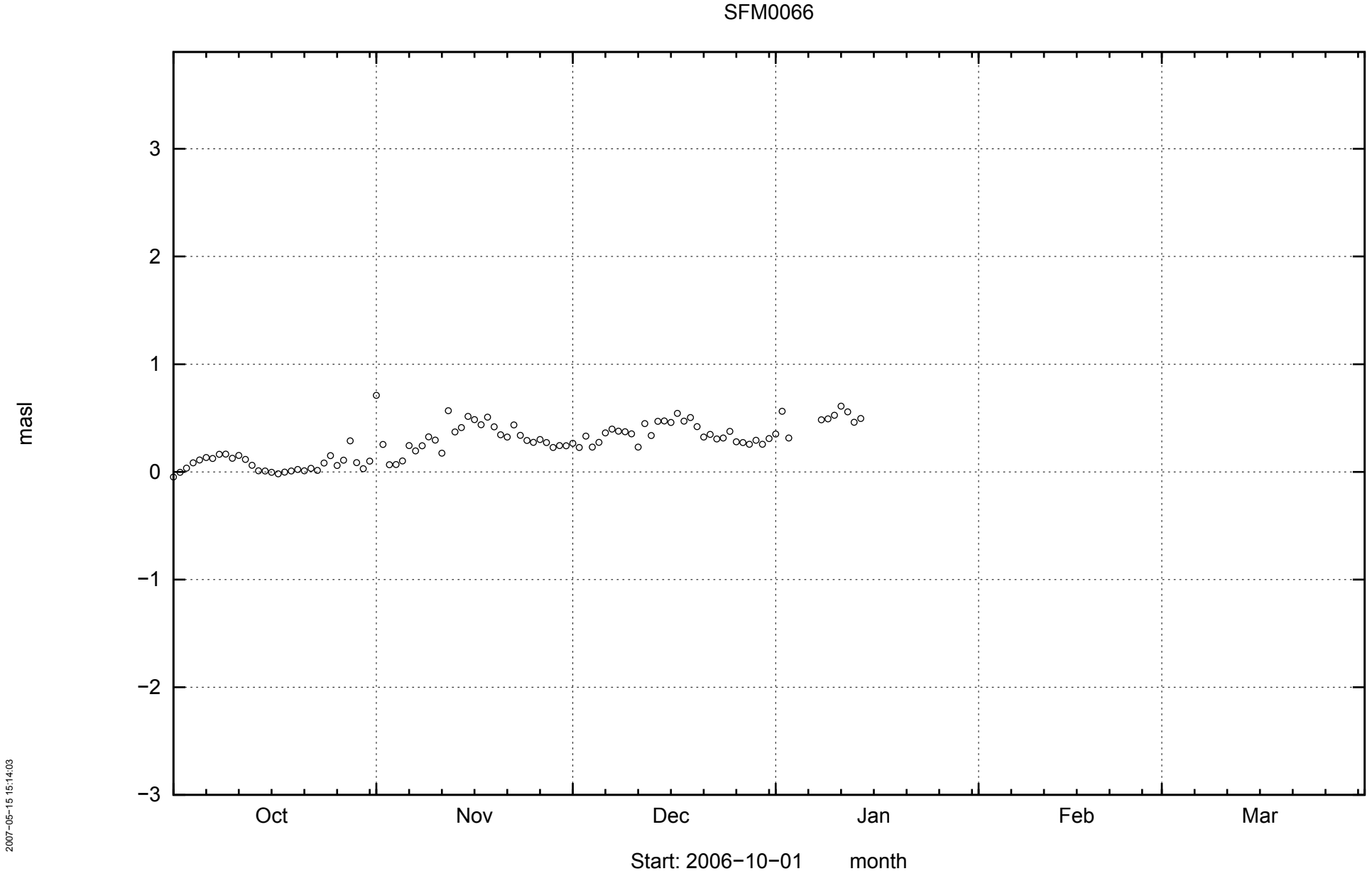
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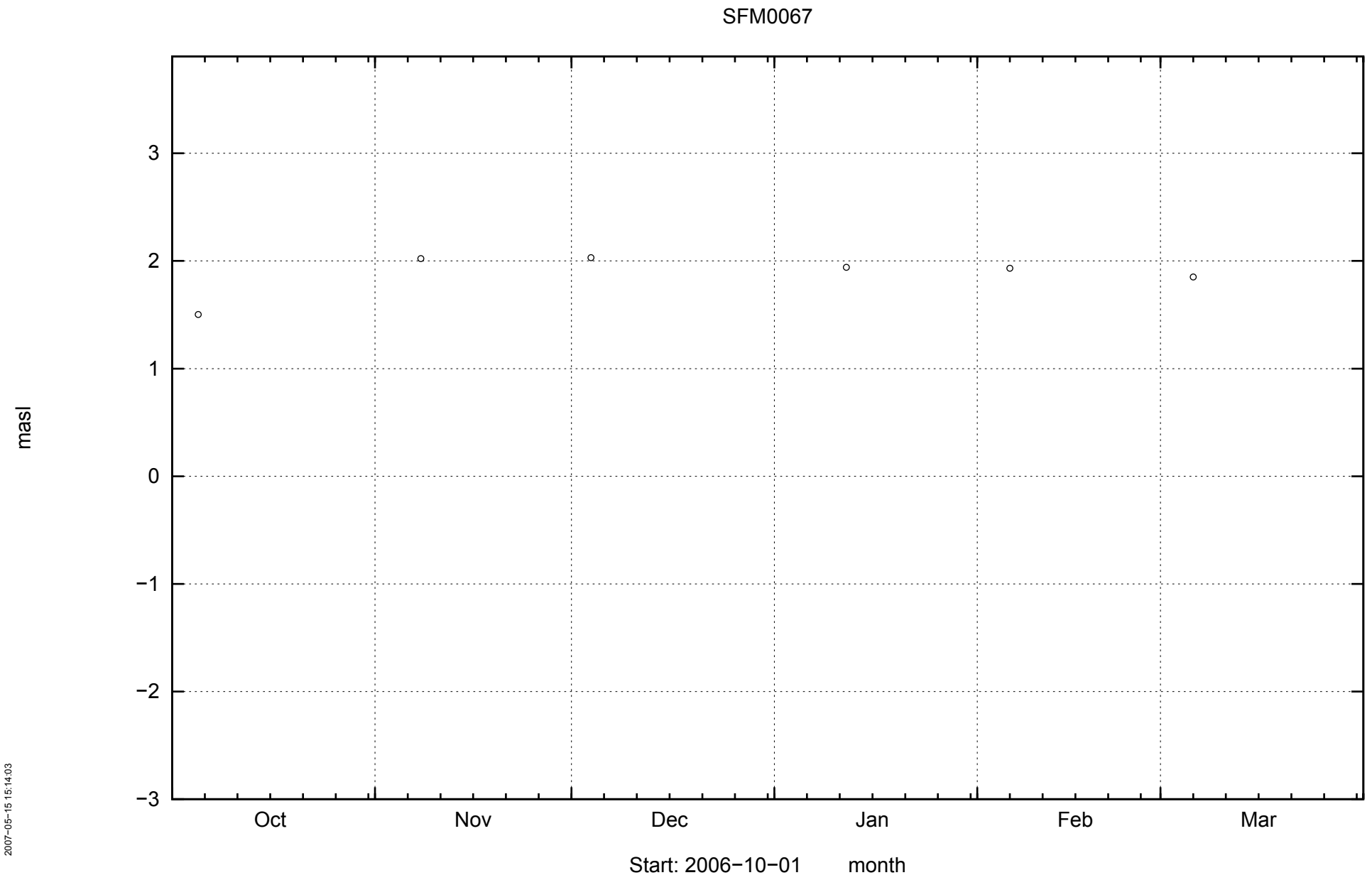
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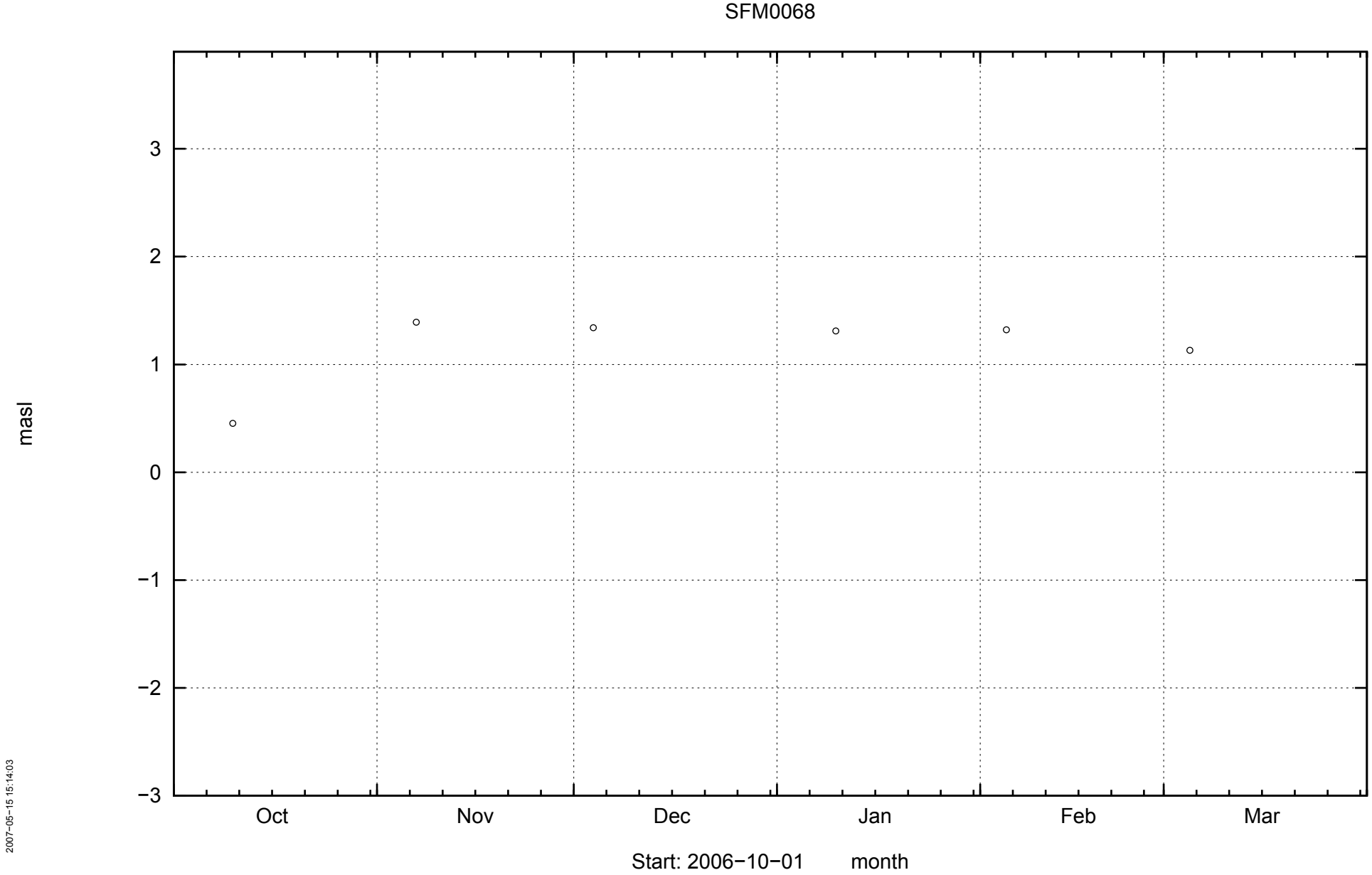
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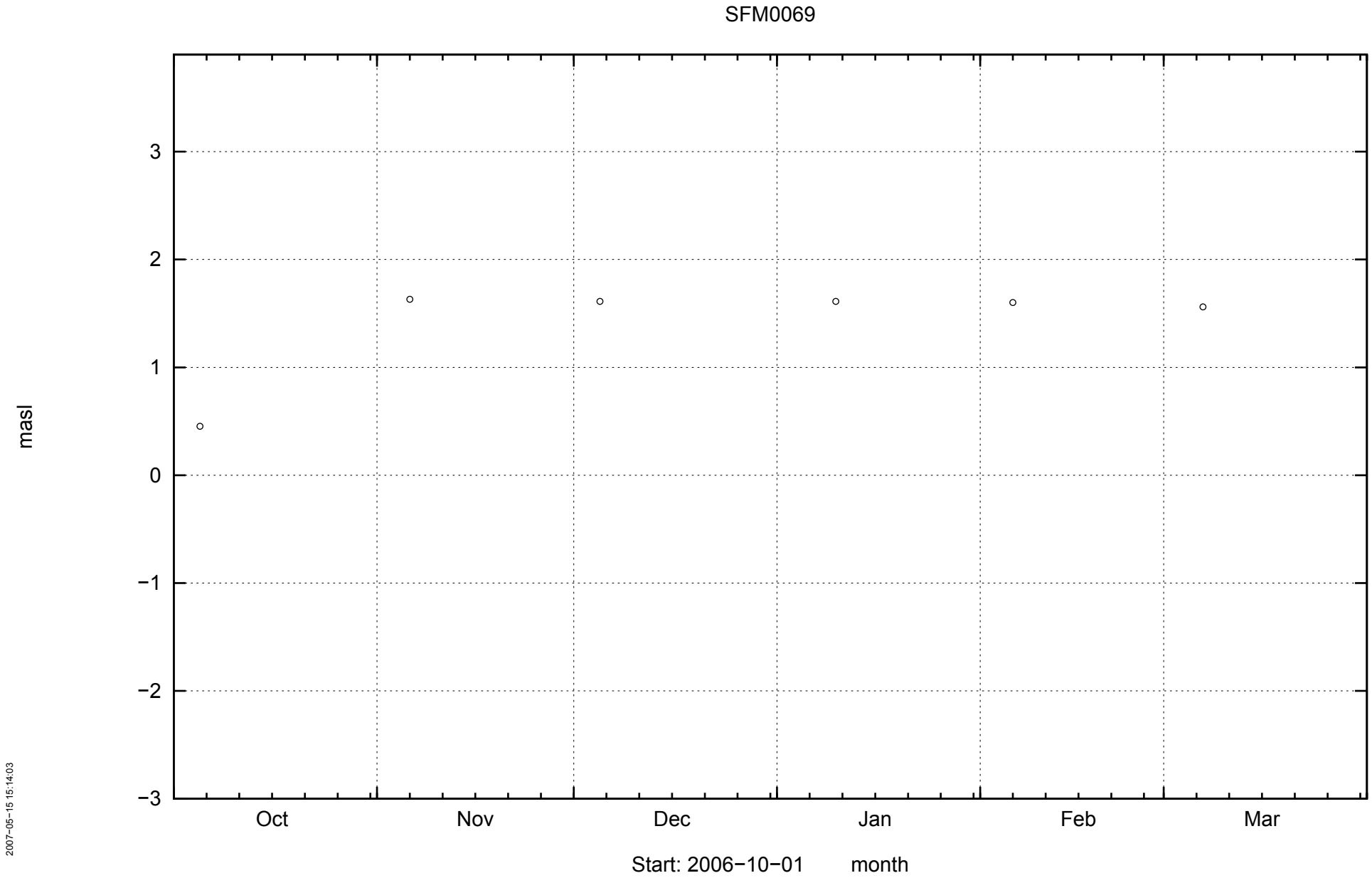
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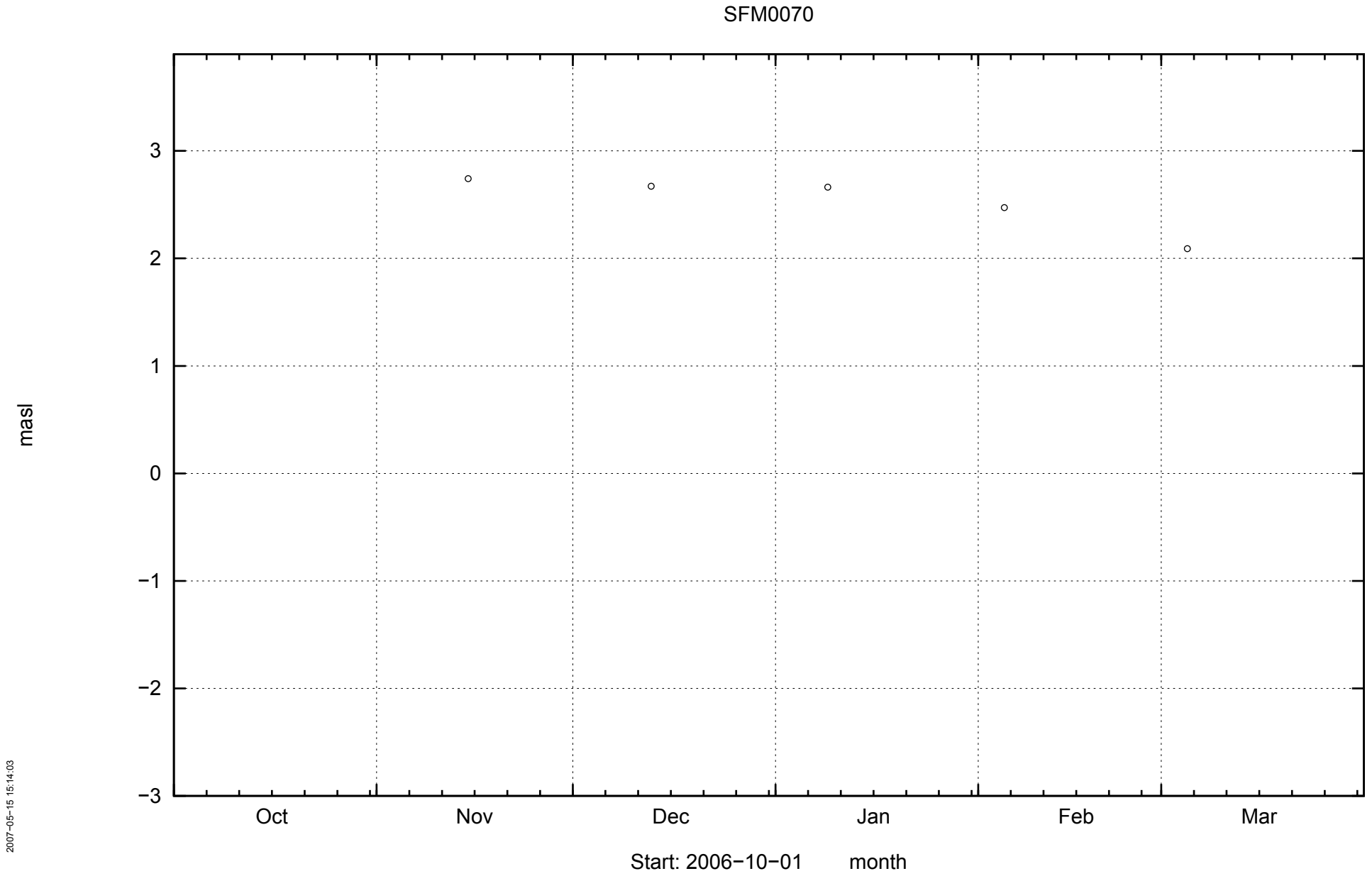
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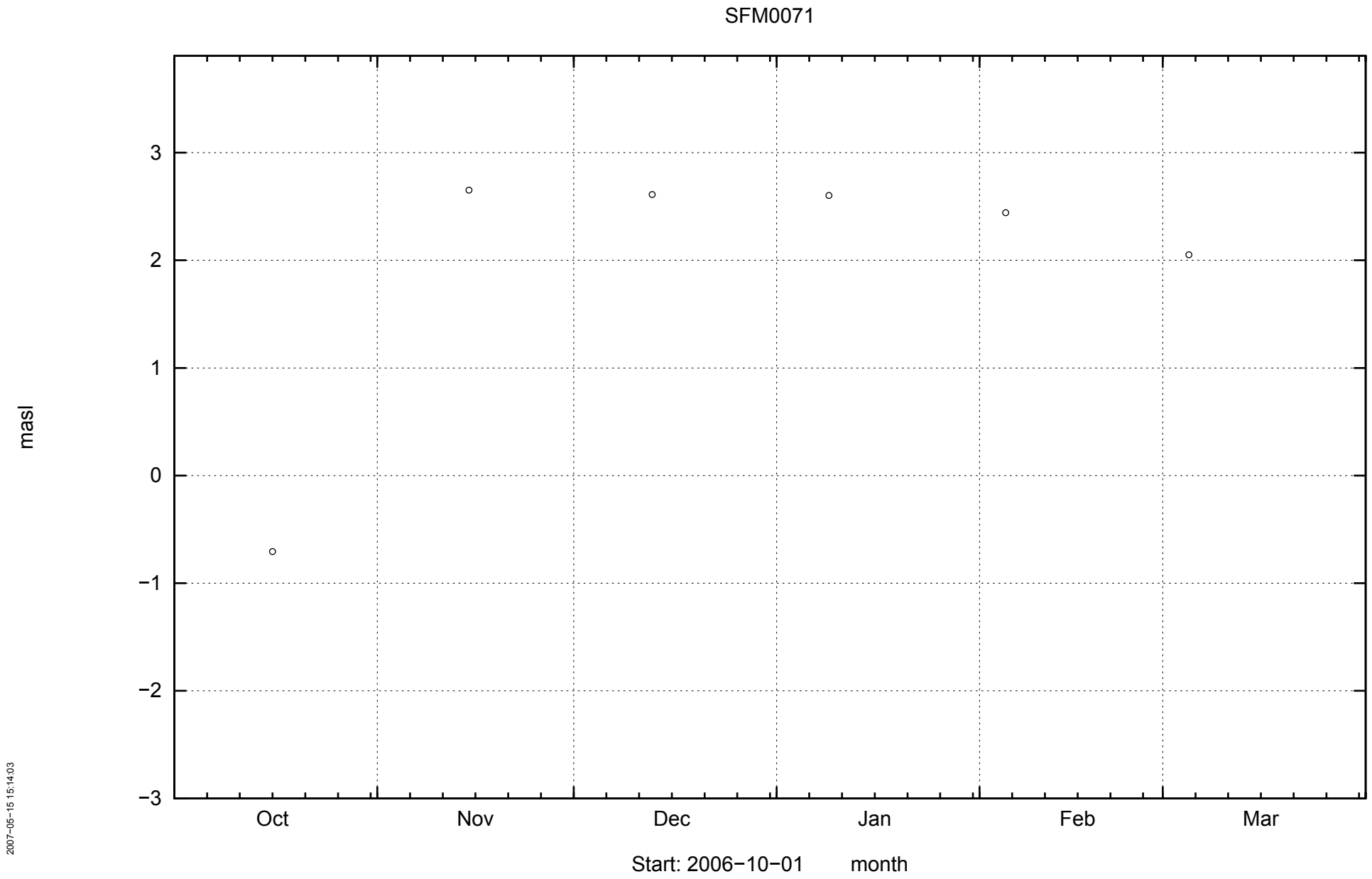
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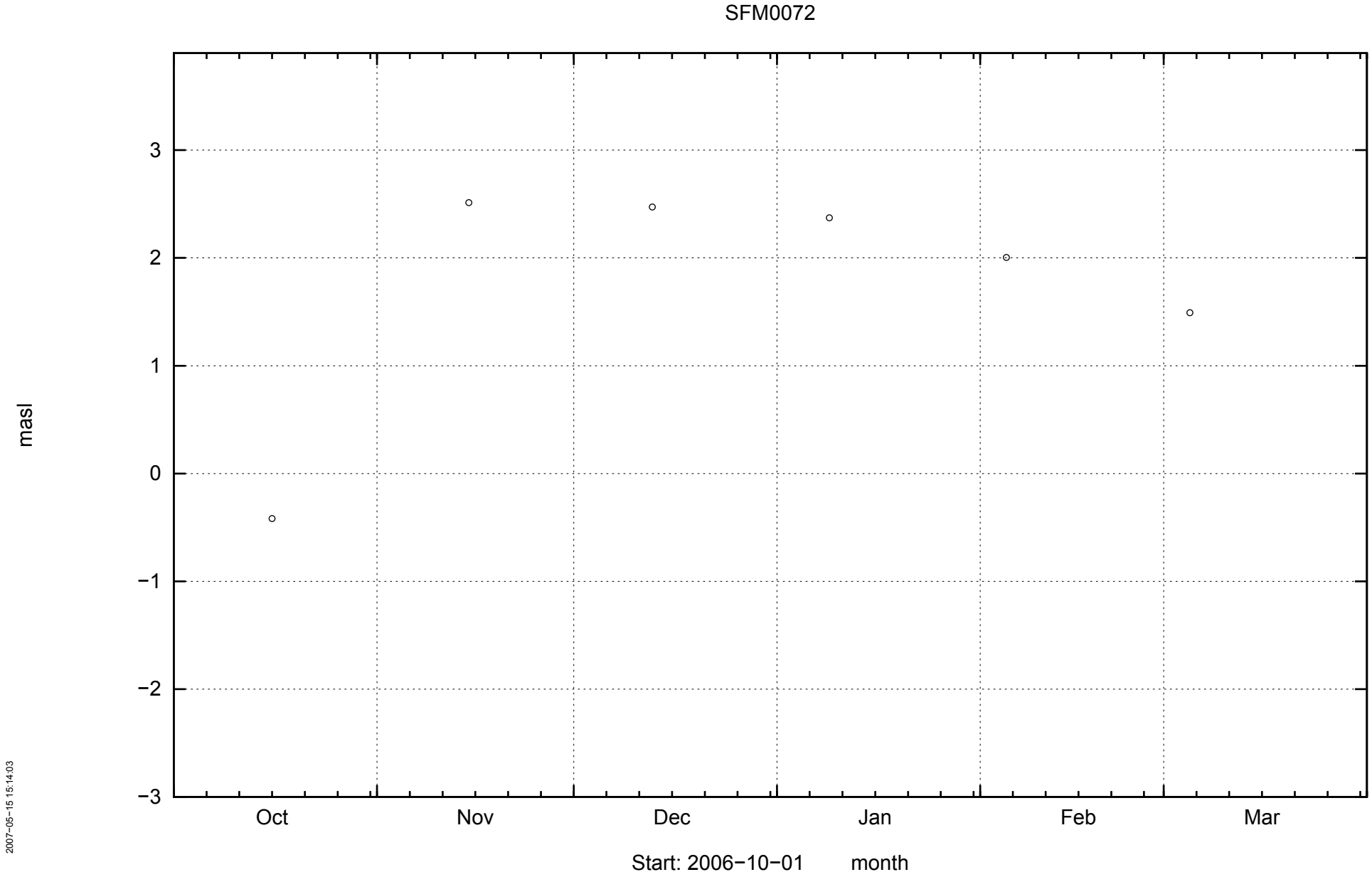
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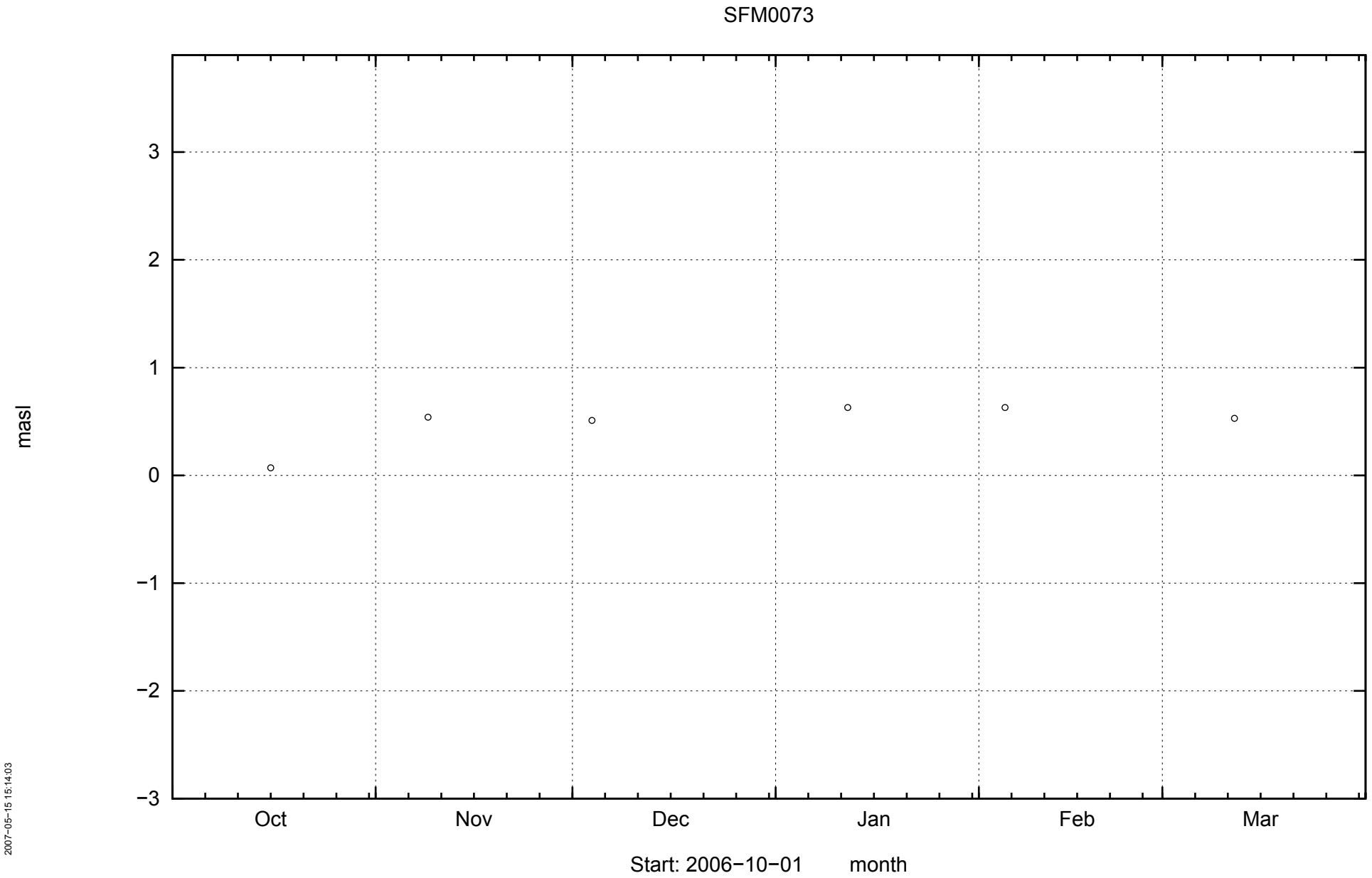
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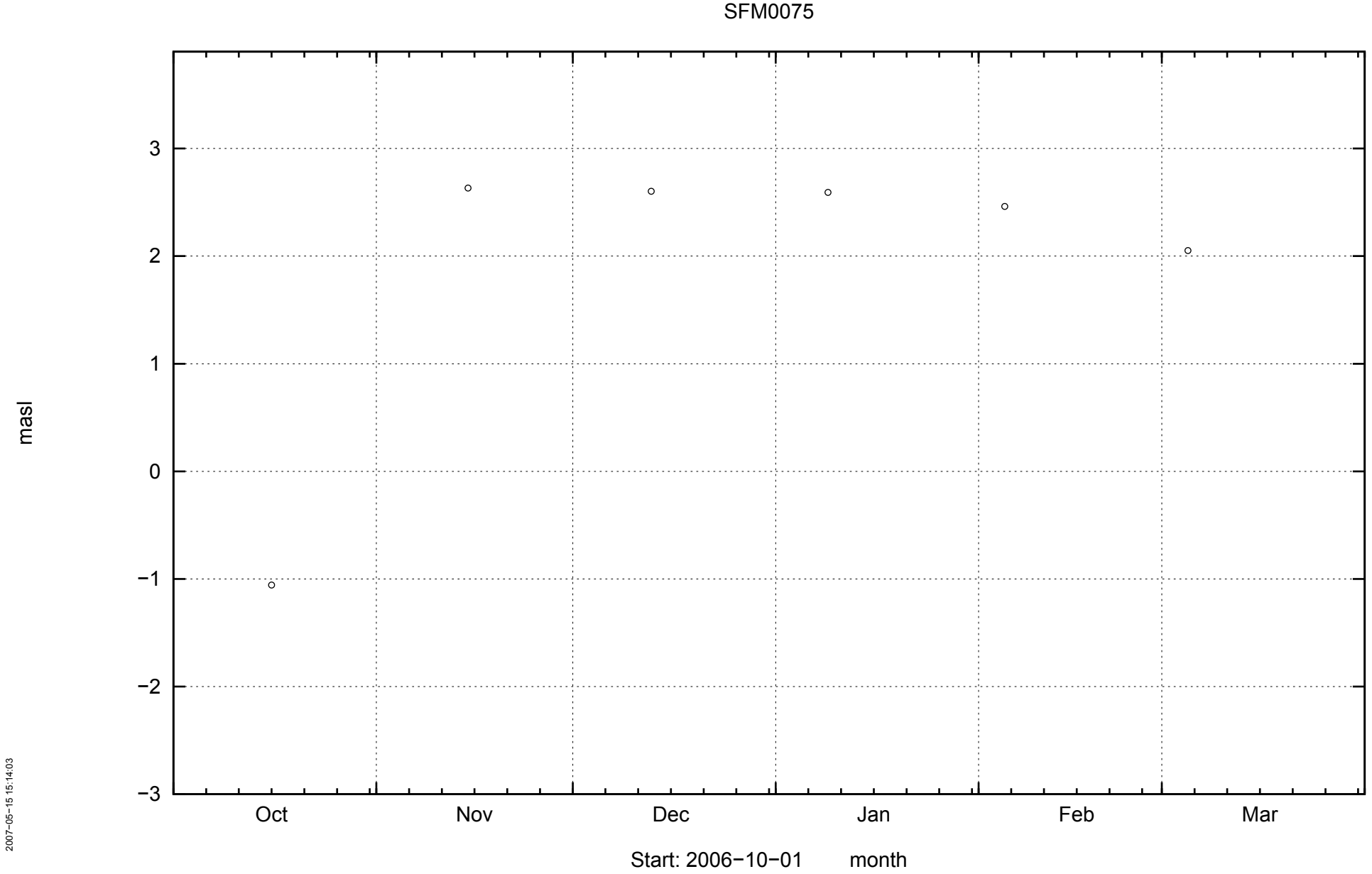
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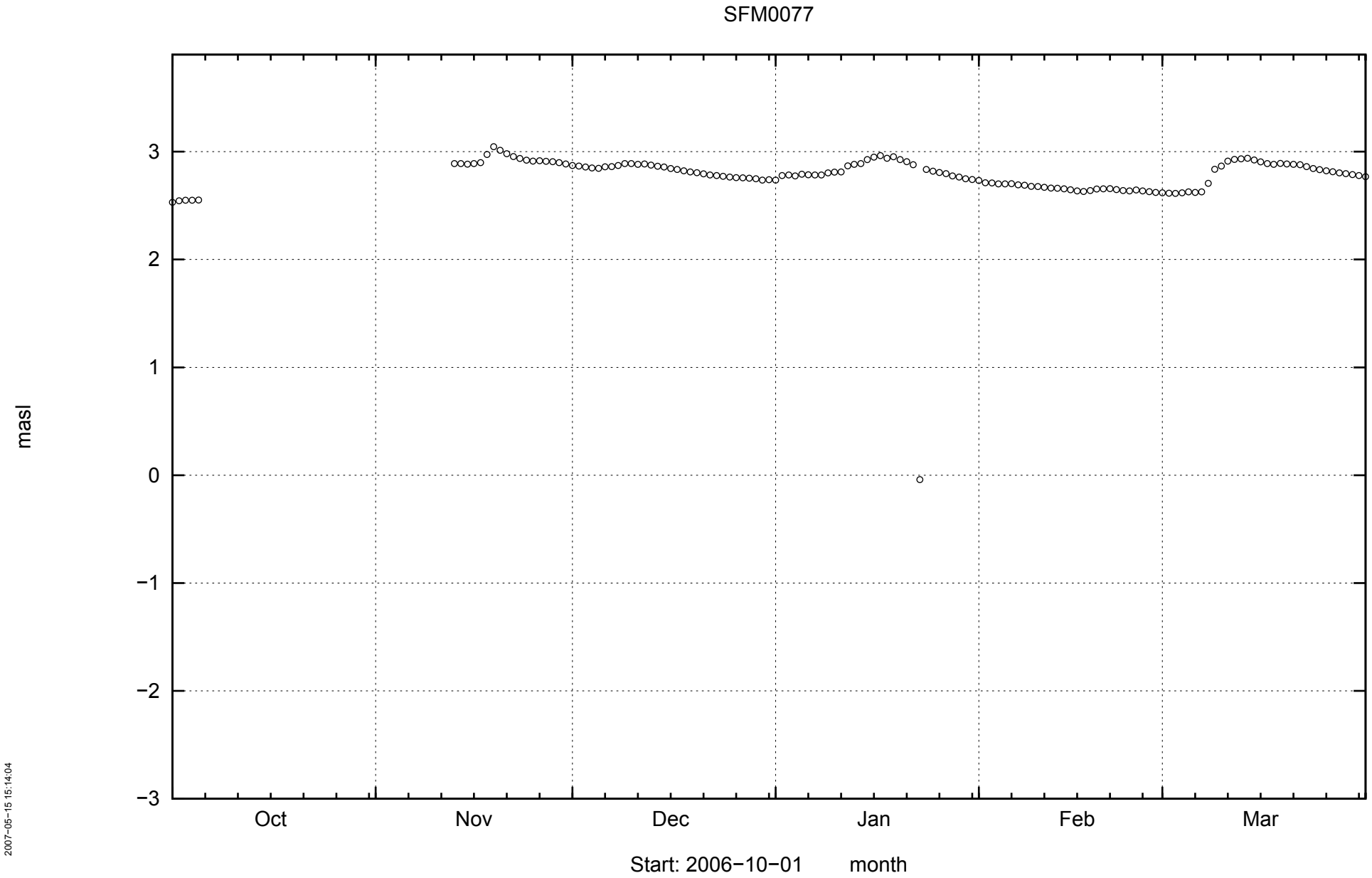
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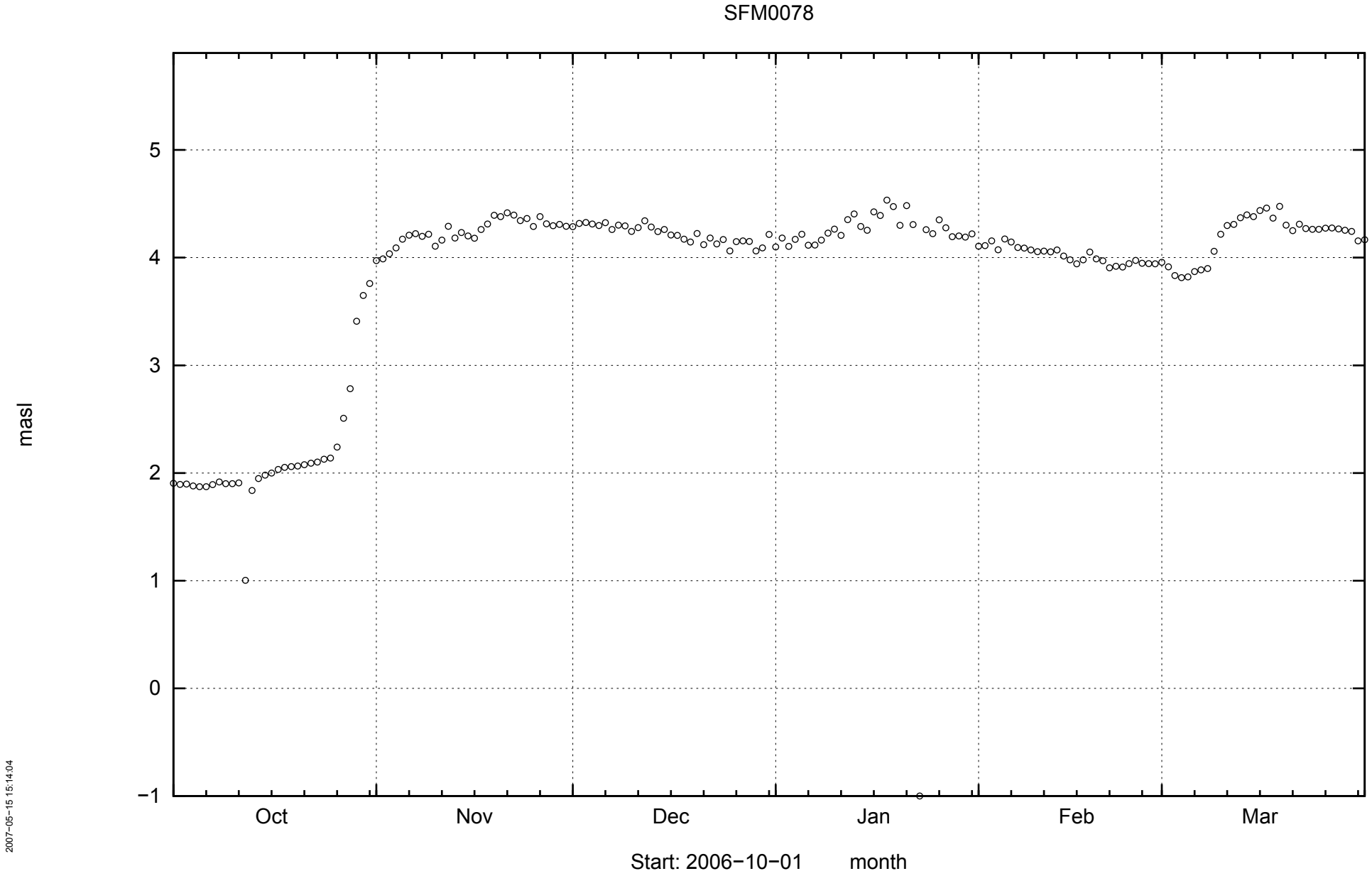
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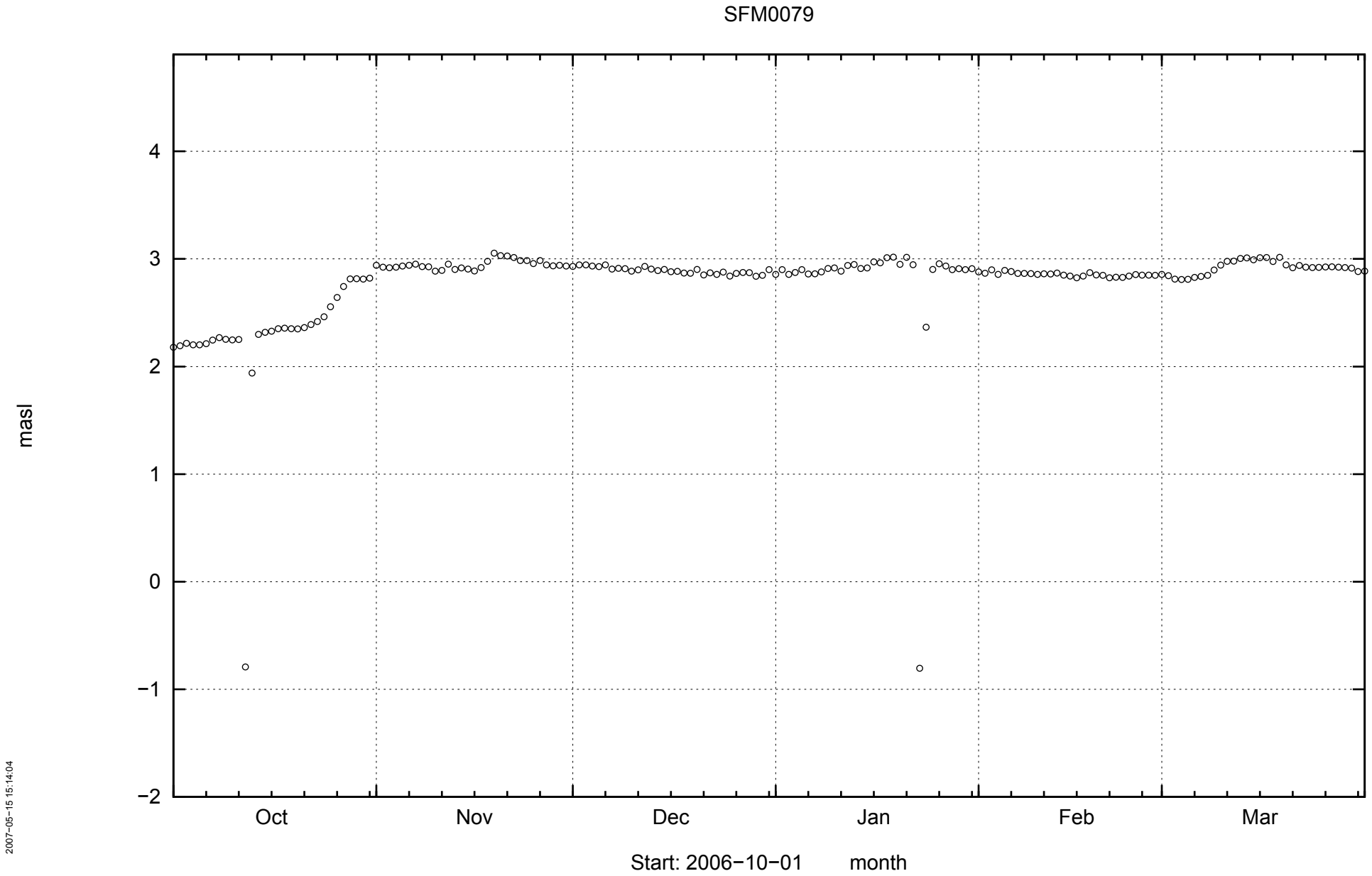
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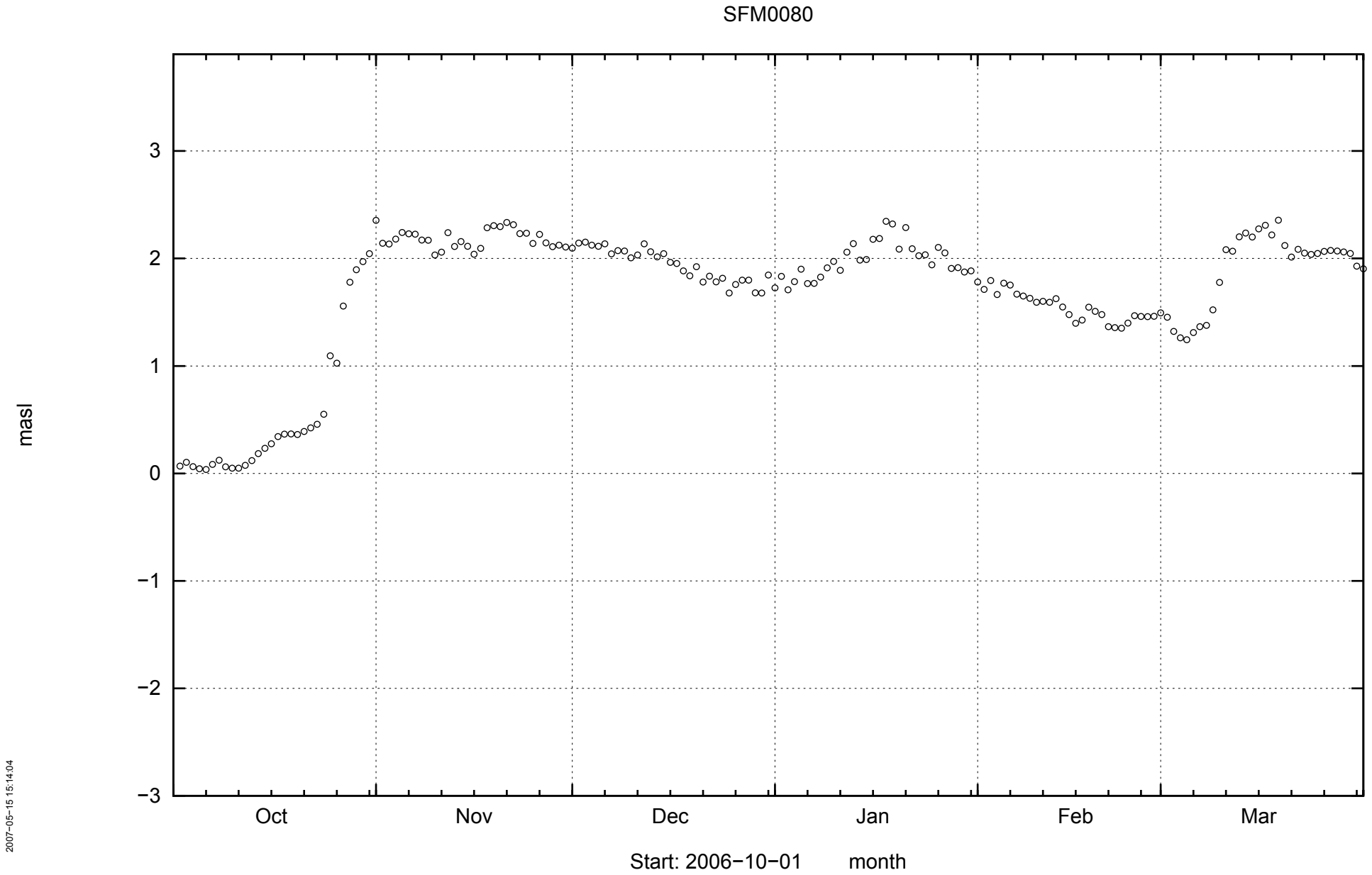
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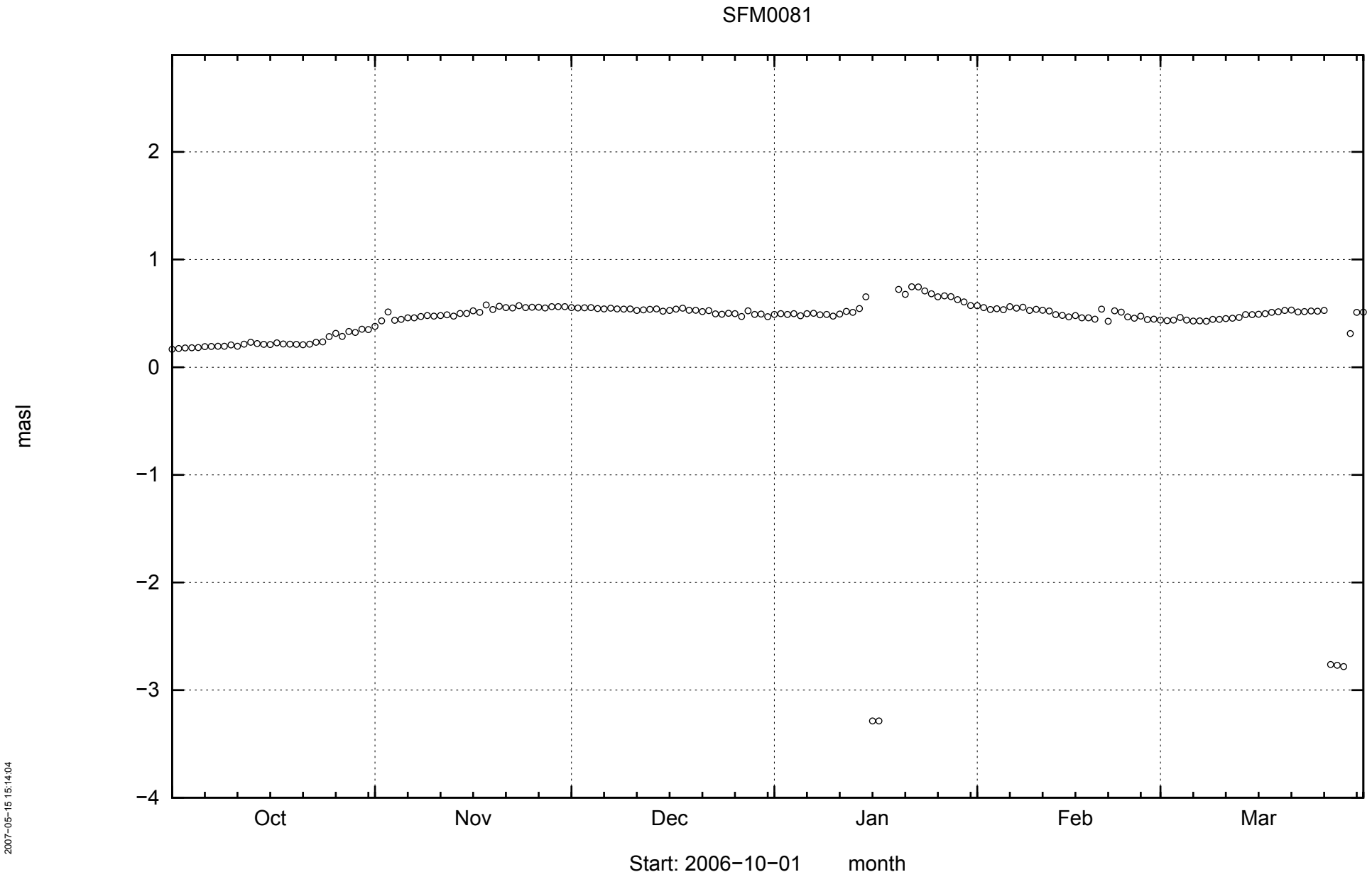
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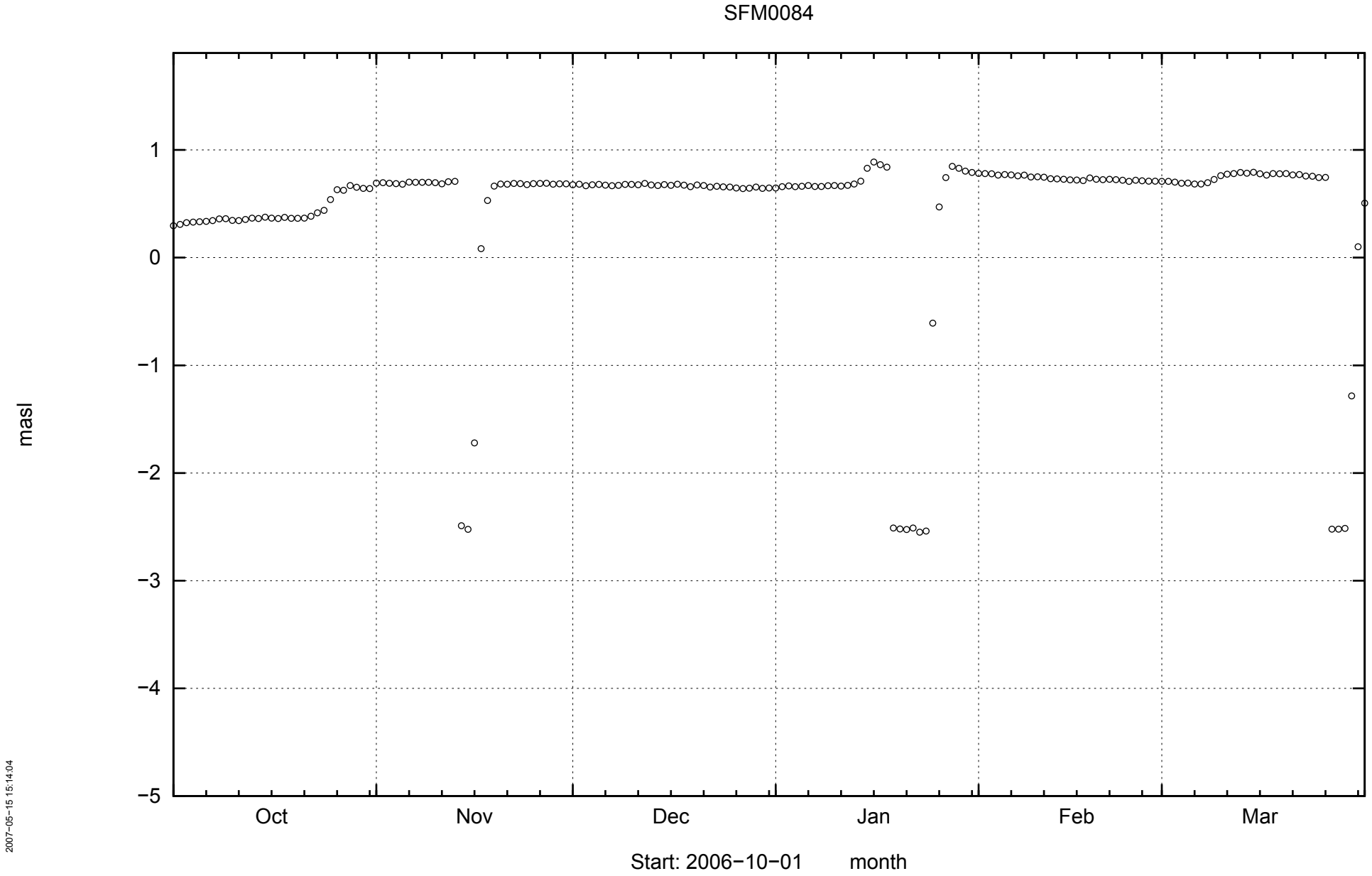
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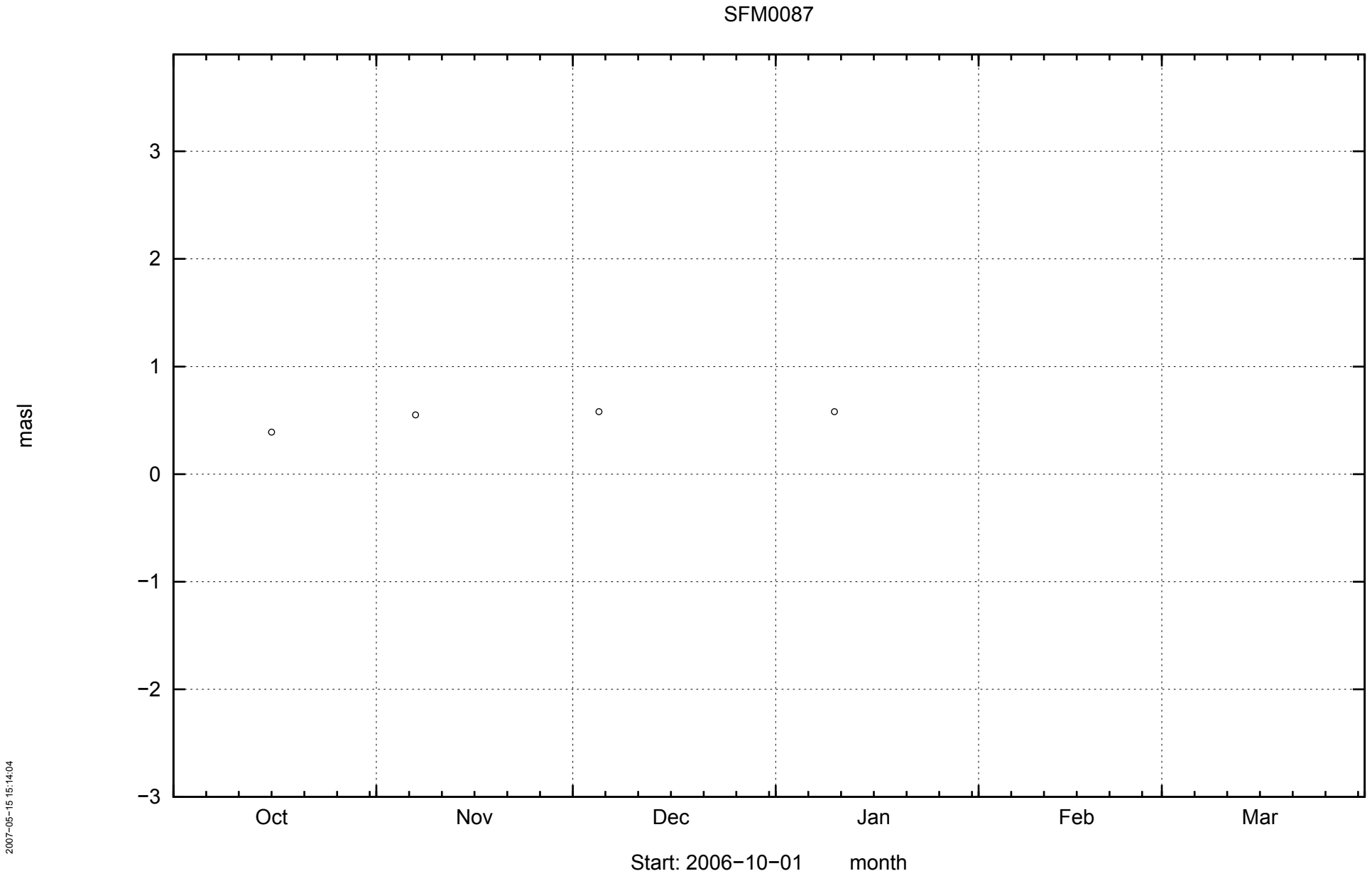
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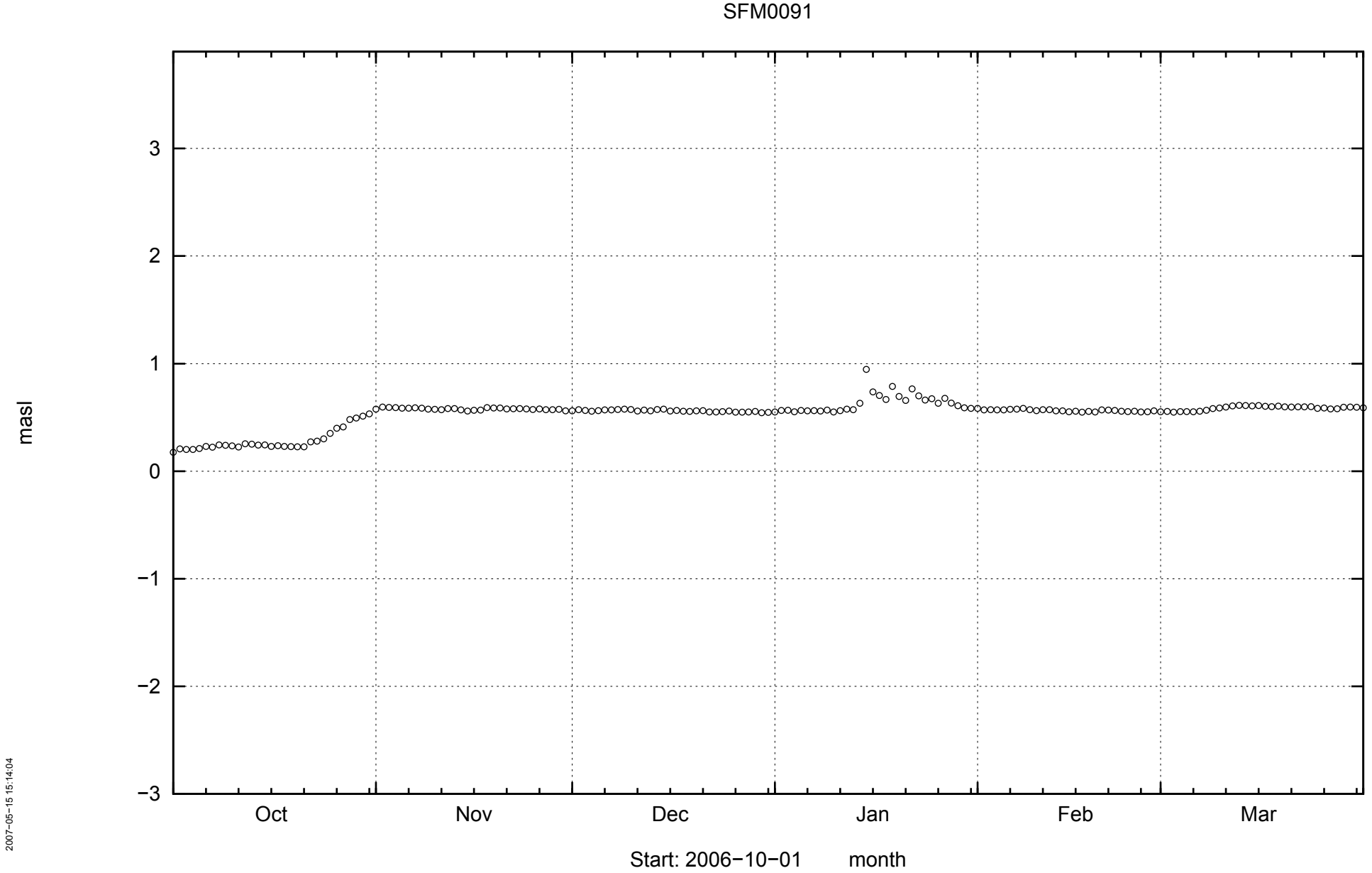
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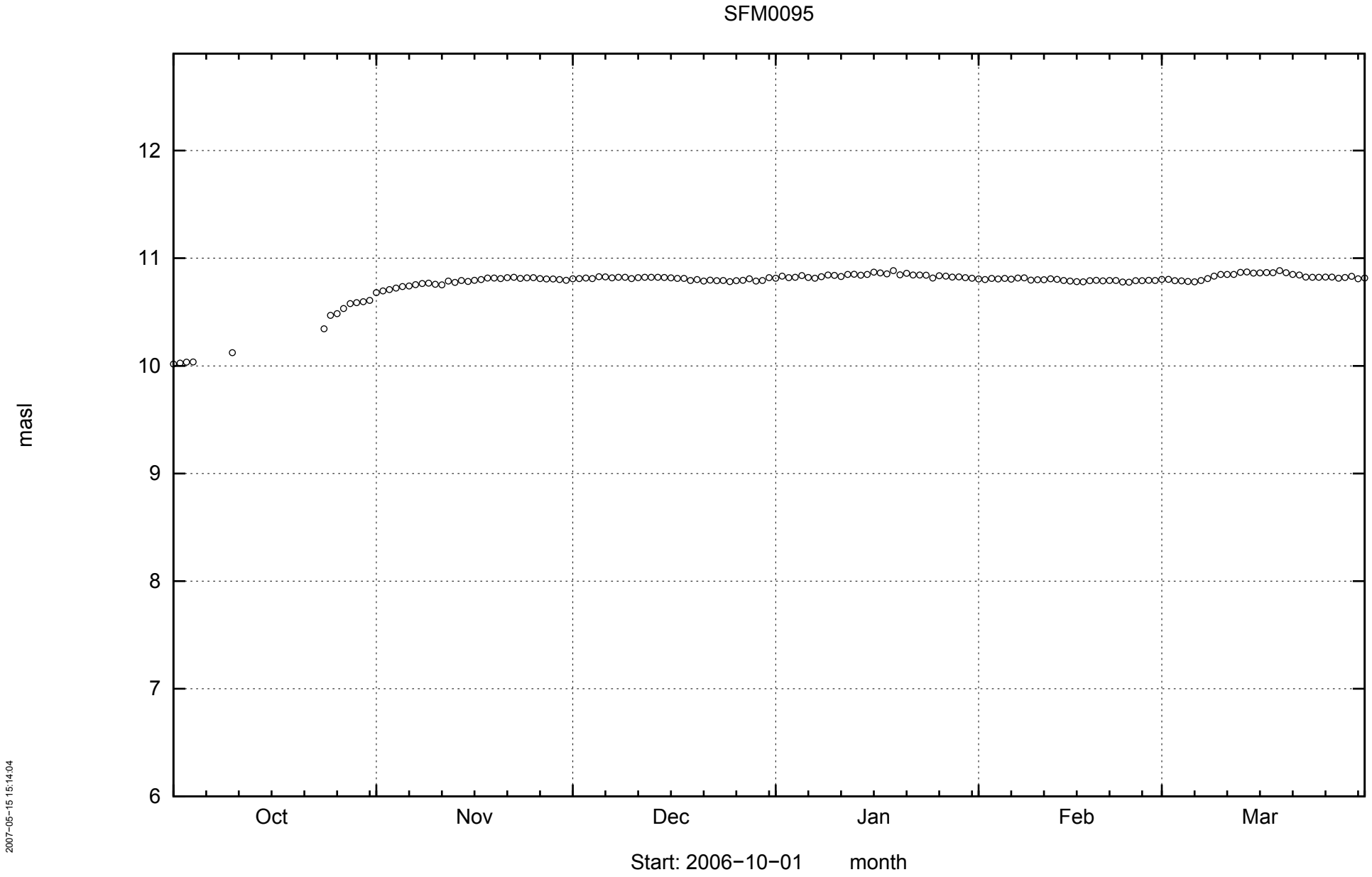
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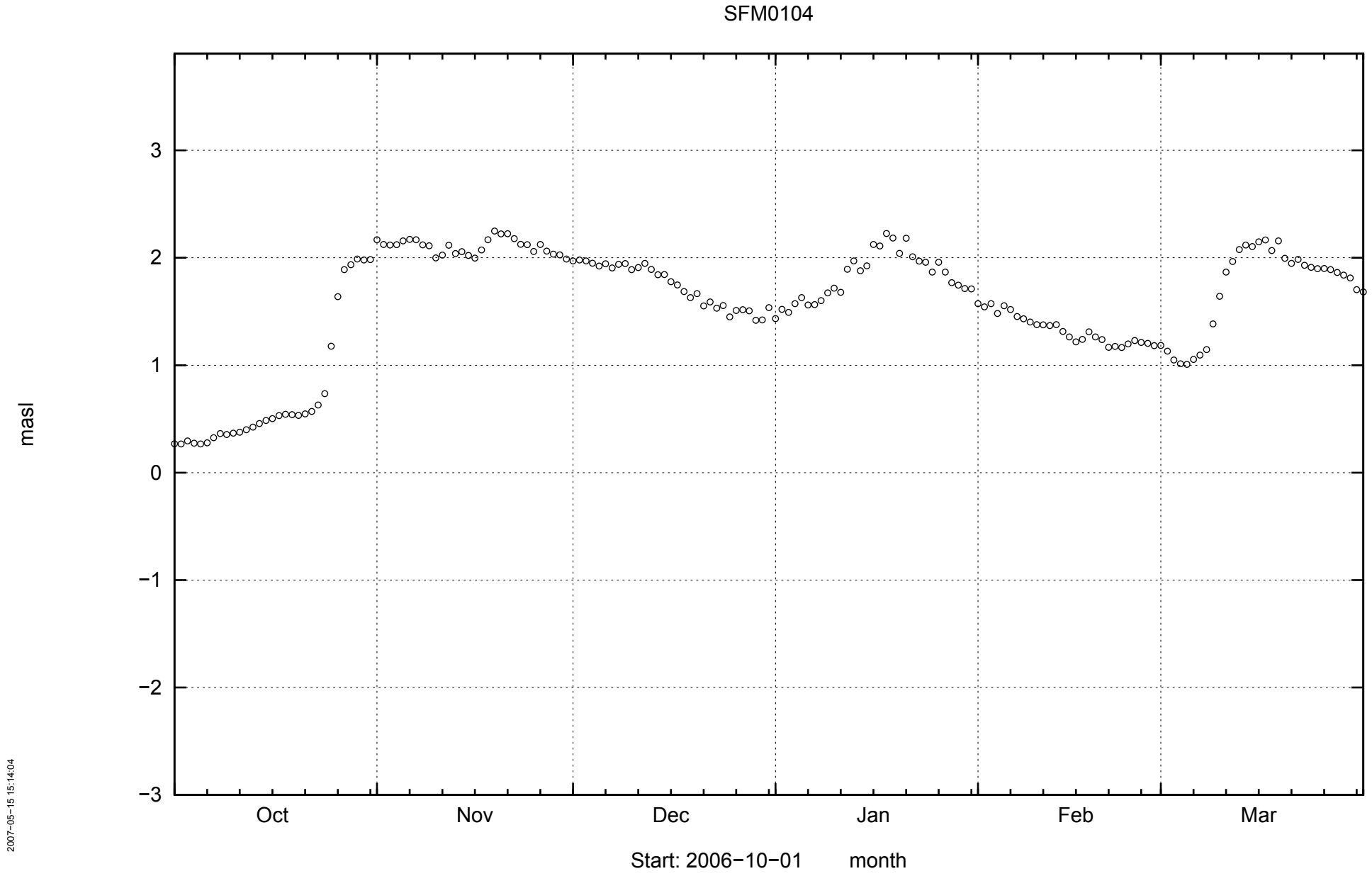
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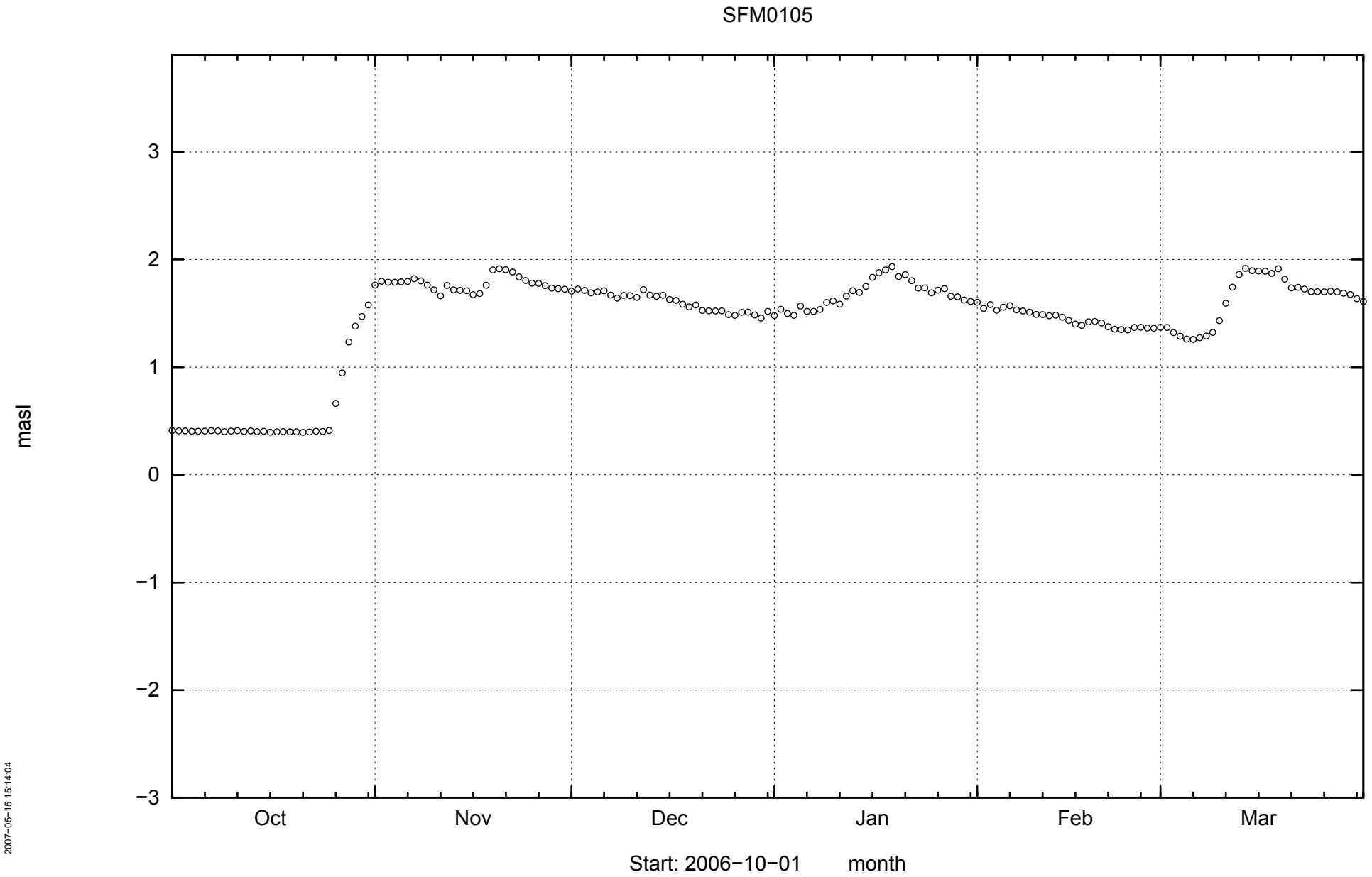
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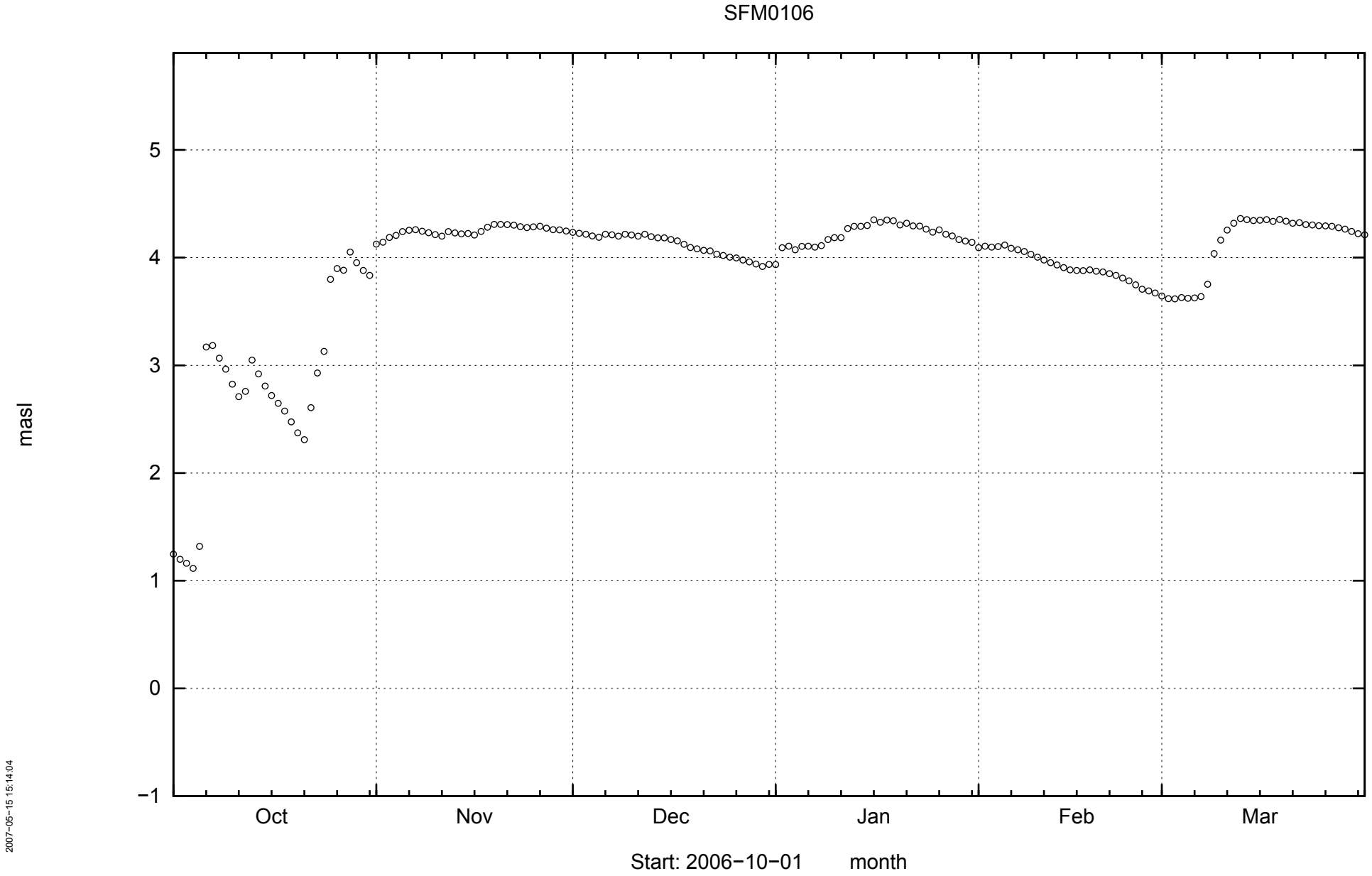
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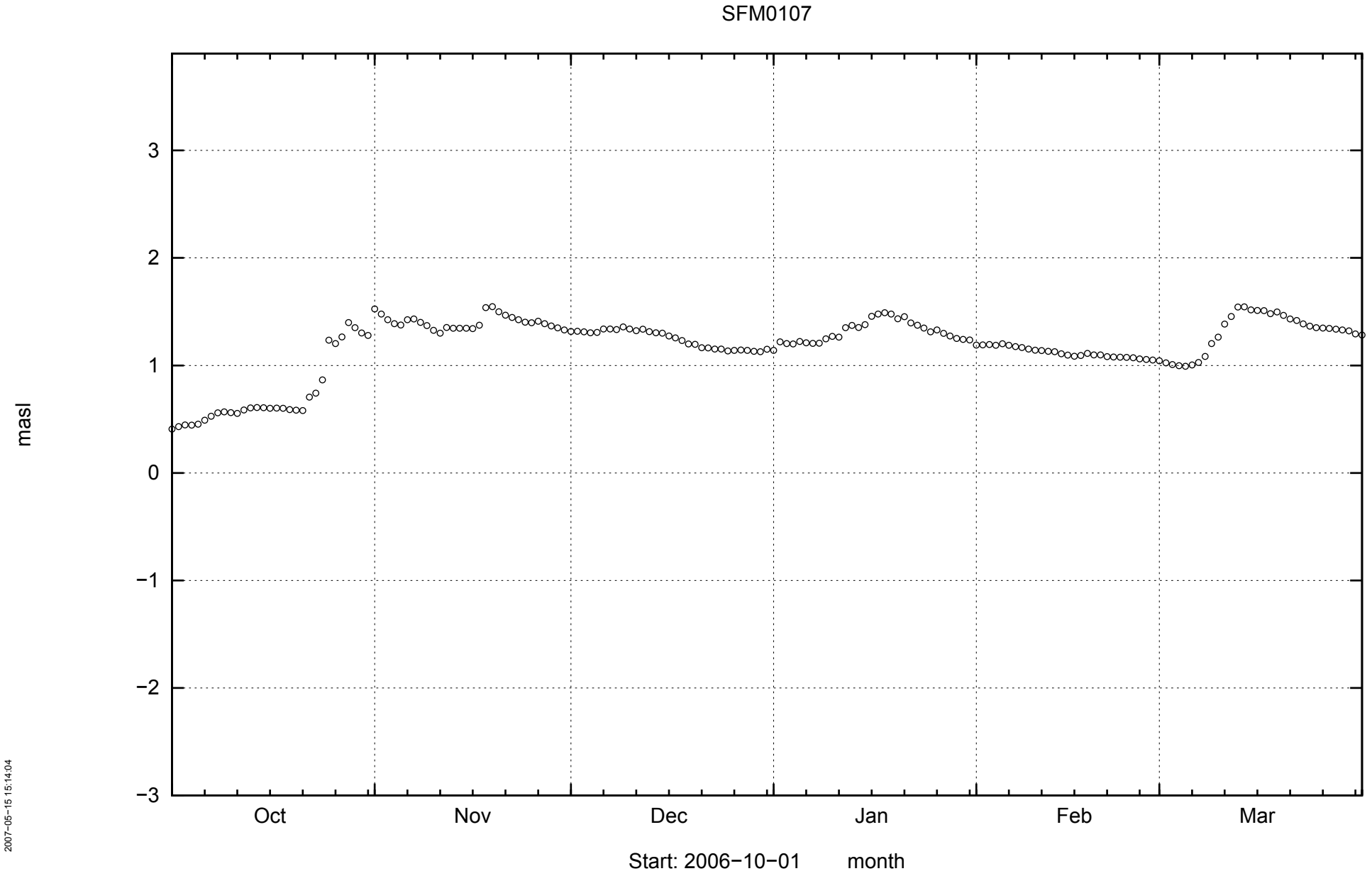
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