Odin/SMR

Odin/SMR Level2 Completeness Analysis Document

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Chapter 1 | Introduction

1.1 Aim and scope of this document

Odin/SMR performs passive limb measurements of the atmosphere, mainly at wavelengths and frequencies around 0.6 mm and 500 GHz, respectively. From these measurements, profiles of O_3, ClO, N_2O, HNO_3, H_2O, CO, and isotopologues of H_2O, and O_3, that are species that are of interest for studying stratospheric and mesospheric chemistry and dynamics, can be derived. Odin/SMR has been in operation for approximately 18 years, and thus, the Level2 dataset can potentially be applied for scientifically interesting trend analysis.

A new Odin/SMR Level2 product dataset (version 3.0.0, see Murtagh et al. (2020)) has been generated, and this document presents a completeness analysis of this dataset. A completeness analysis is typically a description of how many scans that have been measured and successfully processed during the complete mission.

1.2 Document structure

Chapter 2 describes the Odin/SMR Level2 data products, and Chapter 3 describes the completeness analysis.

Chapter 2 | Odin/SMR Level2 data products

2.1 The Odin mission

The Odin satellite was launched on the 20th of February 2001, into a sun-synchronous 18:00 hour ascending node orbit, carrying two co-aligned limb sounding instruments: OSIRIS (Optical spectrograph and infrared imaging system) and SMR (Sub-millimetre radiometer) (Murtagh et al., 2002). Originally, Odin was used for both atmospheric and astronomical observations, but since 2007 only its aeronomy mission is active. Odin is a Swedish-led project, in cooperation with Canada, France and Finland. Both of Odin's instruments are still functional, and the present operation of the satellite is partly performed as an ESA third party mission.

2.2 The SMR instrument

The Odin/SMR package is highly flexible (Frisk et al., 2003). In short, the four main receiver chains can be tuned to cover frequencies in the ranges 486–504 GHz and 541–581 GHz, but the maximum total instantaneous bandwidth is only 1.6 GHz. This bandwidth is determined by the two auto-correlation spectrometers (ACs) used for atmospheric observations. The two ACs can be coupled to any of the four front-ends, but only two or three front-ends are used simultaneously. The ACs cover 400 or 800 MHz per front-end, depending on configuration. In the configuration applied for atmospheric sounding, the channels of the ACs have a spacing of 1 MHz, while the frequency resolution is only 2 MHz. To cover all molecular transitions of interest a number of "observation modes" have been defined. Each observation mode makes use of two or three frequency bands. Single sideband operation is obtained by tunable Martin–Pupplet interferometers. The nominal sideband suppression is better than 19 dB across the image band.

Odin/SMR also has a receiver chain around the 118 GHz oxygen transition that was heavily used during Odin's astronomy mission. For the atmospheric mission, this front-end was planned to be used for retrieving temperature profiles, but a technical problem (drifting LO frequency) and the fact that the analysis requires treatment of Zeeman splitting have given these data low priority.

The main reflector of Odin/SMR has a diameter of 1.1 m, giving a vertical resolution at the tangent point of about 2 km. The vertical scanning of the two instruments' line-of-sight is achieved by a rotation of the satellite platform, with a rate matching a vertical speed of the tangent altitude of 750 m/s. Measurements are performed during both upward and downward scanning. The lower end of the scan is typically at about 7 km, the upper end varies between 70 and 110 km, depending on observation mode. In correspondence, the

Table 2.1: Odin/SMR Level2 data (version 3.0.0) products by frequency mode.

Frequency mode	**Product**
01	"ClO / 501 GHz / 20 to 55 km" "N2O / 502 GHz / 15 to 50 km" "O3 / 501 GHz / 20 to 50 km"
02	"H2O / 545 GHz / 15 to 30 km" "HNO3 / 545 GHz / 20 to 50 km" "O3 / 545 GHz / 20 to 85 km" "O3-668 / 545 GHz / 25 to 45 km" "Temperature / 545 GHz / 15 to 65 km"
08	"H2O / 488 GHz / 20 to 70 km" "H2O-181 / 488 GHz / 20 to 60 km" "O3 / 488 GHz / 20 to 60 km"
13	"H2O - 557 GHz - 45 to 100 km" "O3 - 557 GHz - 45 to 90 km" "Temperature - 557 (Fmode 13) - 45 to 90 km"
19	"H2O - 557 GHz - 45 to 100 km" "O3 - 557 GHz - 45 to 90 km" "Temperature - 557 (Fmode 19) - 45 to 90 km"
21	"NO - 551 GHz - 45 to 115 km" "O3 - 551 GHz - 45 to 90 km" "Temperature - 551 GHz - 45 to 65 km"
14, 22, 24	"CO - 576 GHz"

horizontal sampling ranges from 1 scan per 600 km to 1 scan per 1000 km. Measurements are in general performed along the orbit plane, providing a latitude coverage between 82.5°S and 82.5°N. Since the end of 2004 Odin is also pointing off-track during certain periods, e.g. during the austral summer season, allowing the latitudinal coverage to be extended towards the poles.

2.3 Odin/SMR Level2 data products

Odin/SMR data are categorized into main and science Level2 products. The main products are retrieved from the so called “stratospheric” observation mode of Odin/SMR, and this modes cover approximately 50 % of the Odin/SMR observation time. In this mode spectra in frequency bands around 501 and 544 GHz are collected. The science data products are derived from less frequently applied observation modes (typically applied a few days per month). Ozone, ClO, N_2O, and HNO_3 profiles are the main Odin/SMR Level2 products. ClO and N_2O profiles are retrieved from spectra covering transitions around 501 GHz, and HNO_3 from spectra around 544 GHz. Ozone can be retrieved from both the 501 and the 544 GHz band. Profiles of H_2O, CO, NO and isotopologues of H_2O, and O_3 are considered as science data products for Odin/SMR. Observations covering the science data products are performed on a less frequent basis than the main data products. Table 2.1 describes the Odin/SMR Level2 data products by frequency mode. It should be noted that these are the products that are covered by the present reprocessing project, and not all products that potentially can be derived from Odin/SMR observations.

Chapter 3 | Completeness analysis

Table 3.1 and Figure 3.1 to Figure 3.9 show the amount af available Level1B data and succesfully processed Level2 data for the considered FreqModes by month, from the start of the mission until the end of 2019 (Odin/SMR is to date still in operation and the end of 2019 is hence not the end of the mission).

The amount of available Level1B data varies during mission, and there are a number of reasons for this. During the first six years of the mission Odin/SMR was operated both in aeronomy and astronomy mode, and hence less aeronomy observations are available for these years compared to after 2008. Odin/SMR is powered by solar energy, and by batteries during during the solar eclipse season. During the most recent years Odin/SMR has both partly and completely been turned off during the summer months or solar eclipse season. Odin/SMR is a flexible instrument, as described in Sect. 2.1 but, in prinicipal, only two frequency modes (FreqModes) can be applied at a given time. The observation program, or how often the various FreqModes are used, has been varied during the mission.

FreqMode 1 and 2 are the most frequently applied modes, and about 5000-10000 scans have been observed each month (see Figure 3.1 and 3.2). Level2 processing generated in a result for the majority (89 and 81 %, respectively) of the available Level1B data. One of the main reason for the Level2 processing to not generate in a result is here that some scans do not cover a required altitude range, or that to few spectra are available within this range, i.e. not enough spread of the tangent altitude of individual spectra in a given scan. This can typically happen when the scanning pattern is switched.

The majority of FreqMode 2 Level2 data have a valid quality. A valid quality means here that the

- MinLmFactor [−]: The minimum value of the Levenberg - Marquardt factor during the OEM iterations, and the
- Residual [K]: The difference between the spectra matching retrieved state and used measurement spectra

are below specified thresholds (2 and 1.5 K, respectively). This is also true for FreqMode 1, except for data after summer of 2014 where a large fraction of the produced Level2 data have an unsatisfactory quality. Instrumental problems with this mode for the later part of the mission is discussed in Murtagh et al. (2020). Recommendations for Level2 data users are also found in Murtagh et al. (2020).

Level2 processing generated in a result for about 84 % of the FreqMode 8 observations. The fraction of valid Level2 data is high (98 %) for FreqMode 8. One reason for this high fraction of valid Level2 data is that the quality criteria is less strict for FreqMode 8, compared to most other modes (except 13 and 19). These mode showed considerable sideband leakage, and a correction has been applied Murtagh et al. (2020).

For the water vapor modes around 557 GHz (FreqMode 13 and 19) the Level2 processing generates in a result for about 82 % of the scans. The fraction of Level2 data with a

Table 3.1: Odin/SMR Level1B and Level2 data count by frequency mode. Level2 data are further categorized into two classes: "All-Level2" and "Ok-Level2", where "Ok-Level2" means that the Level2 processing produced a result with a valid quality. Column "succes rate - Level2" and "succes rate - Ok Level2" describes the fraction of "Level2 count - All" over "Level1B count" and "Level2 count - ok" over "Level2 count - All".

Frequency mode	**Level1B count**	**Level2 count**		**Succes rate** [%]	
		All	Ok	Level2	Ok Level2
01	1924043	1711616	1494160	89.0	87.3
02	1907511	1541197	1463753	80.8	95.0
08	400901	335727	329448	83.7	98.1
13	359696	294299	269568	81.8	91.6
14	365195	218611	201758	59.9	92.2
19	400037	332057	235699	83.0	71.0
21	344476	299992	276128	87.1	92.0
22	93374	56768	56452	60.8	99.4
24	15794	12873	12655	81.5	98.3

valid quality is 92 and 71 % for FreqMode 13 and 19, respectively. Issues with FreqMode 13 and 19 observations are discussed in Murtagh et al. (2020).

Level2 processing of the FreqMode 21 (NO mode) generated in a result for about 87 % of the scans. Most of this data (92 %) have a satisfactory quality.

FreqMode 14, 22, 24 are deployed for CO observations. The frontend used for these observations have been unstable (drifting in frequency, see further in Grieco et al. (2020)), and that can result in that the CO signature is not covered in observed spectra of some of the scans. This gives that the fraction of level2 data produced is lower for those modes. However, the data are valid for a high percentage (above 92 %) for the Level2 data actually produced.

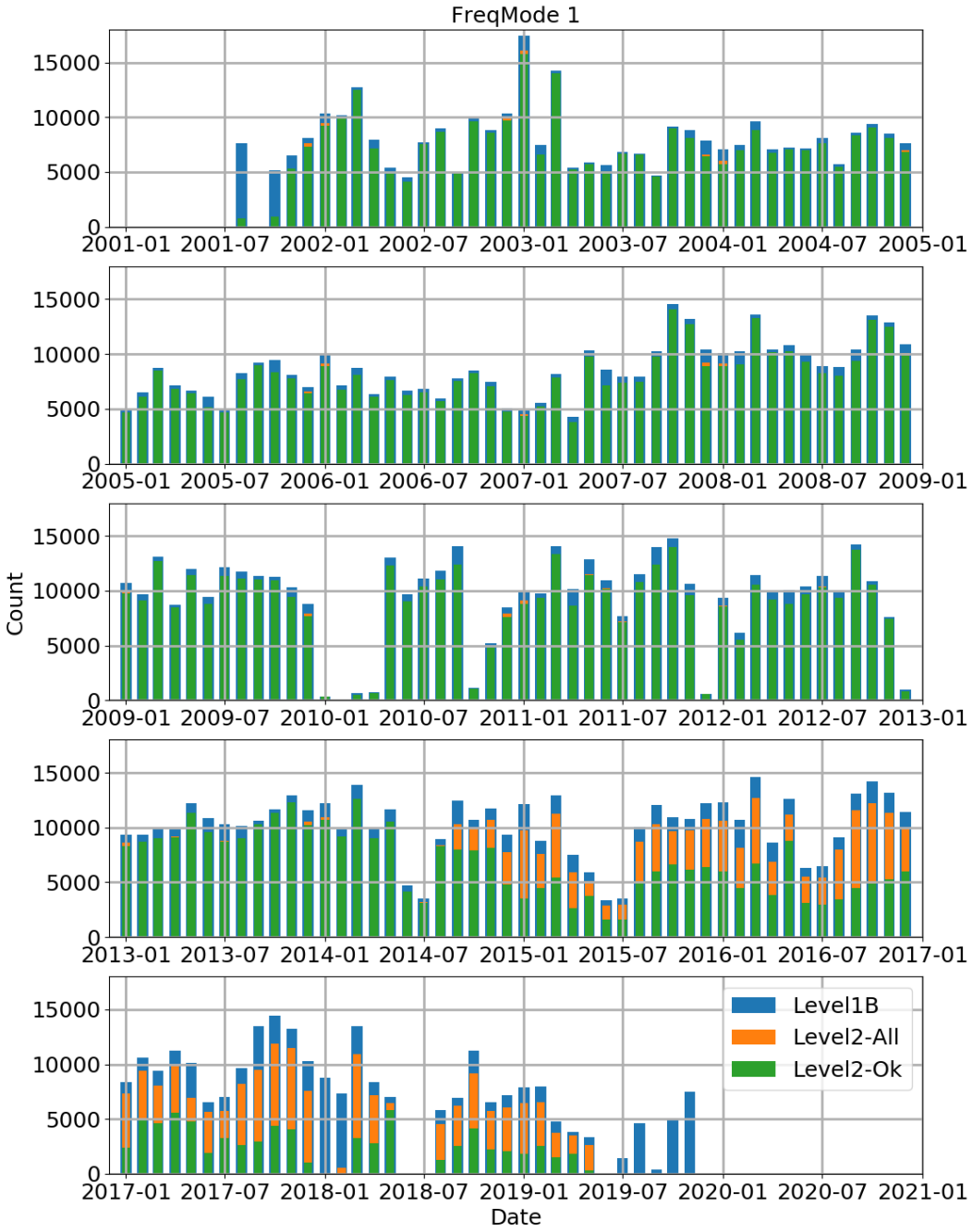

Figure 3.1: Number of available Level1b and succesfully processed Level2 scans by month for FreqMode 1, during the complete Odin/SMR mission.

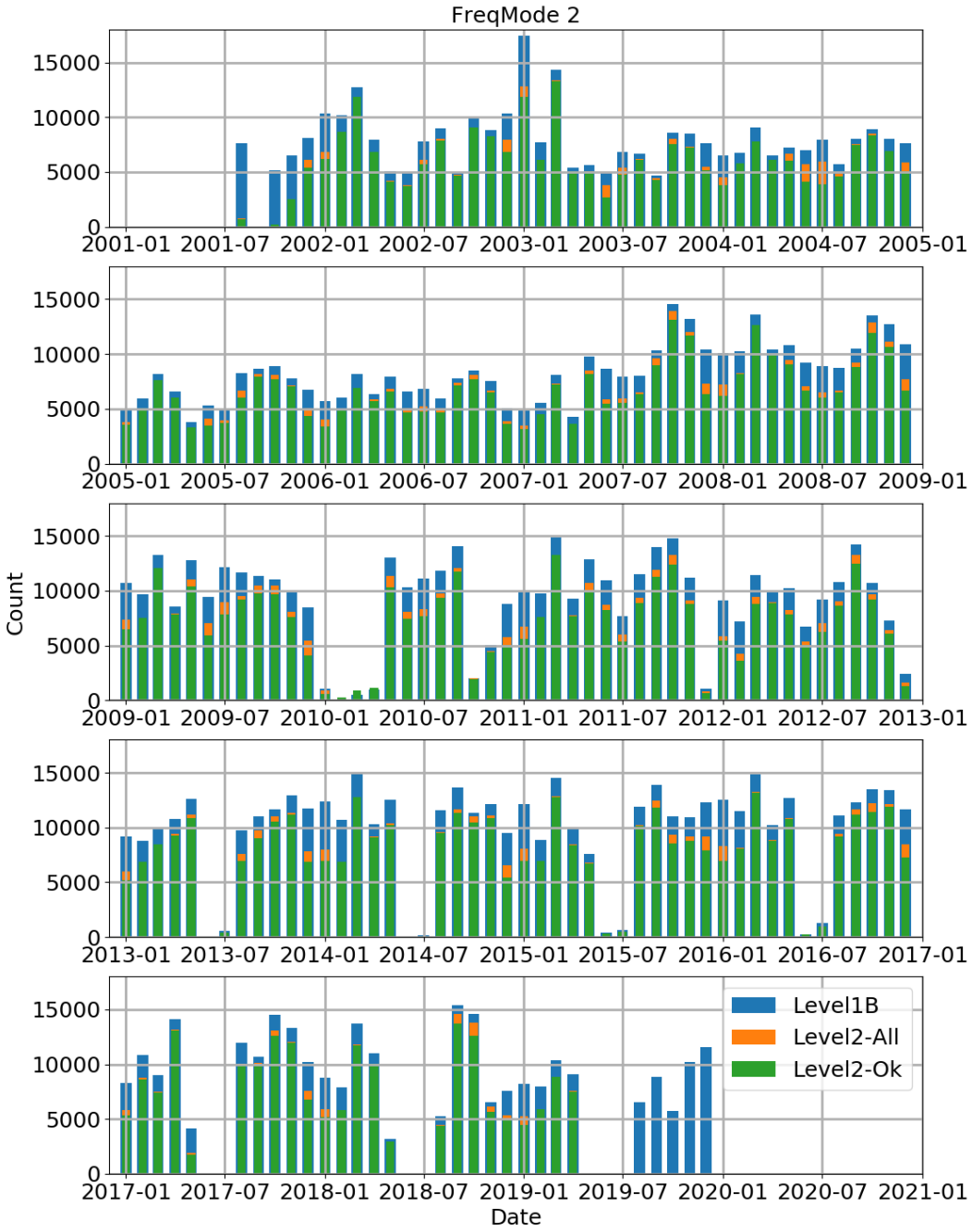

Figure 3.2: As Figure 3.1 but for FreqMode 2.

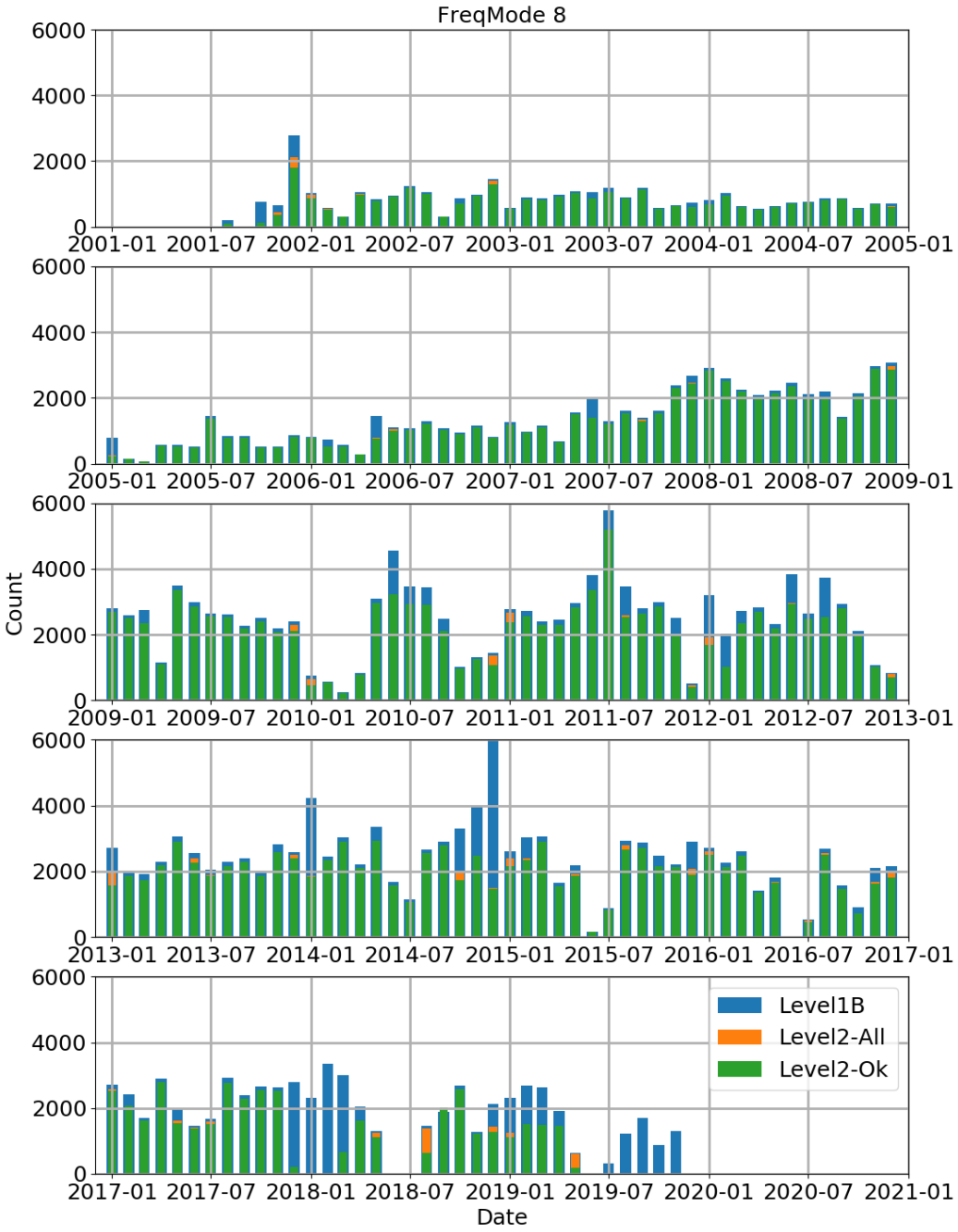

Figure 3.3: As Figure 3.1 but for FreqMode 8.

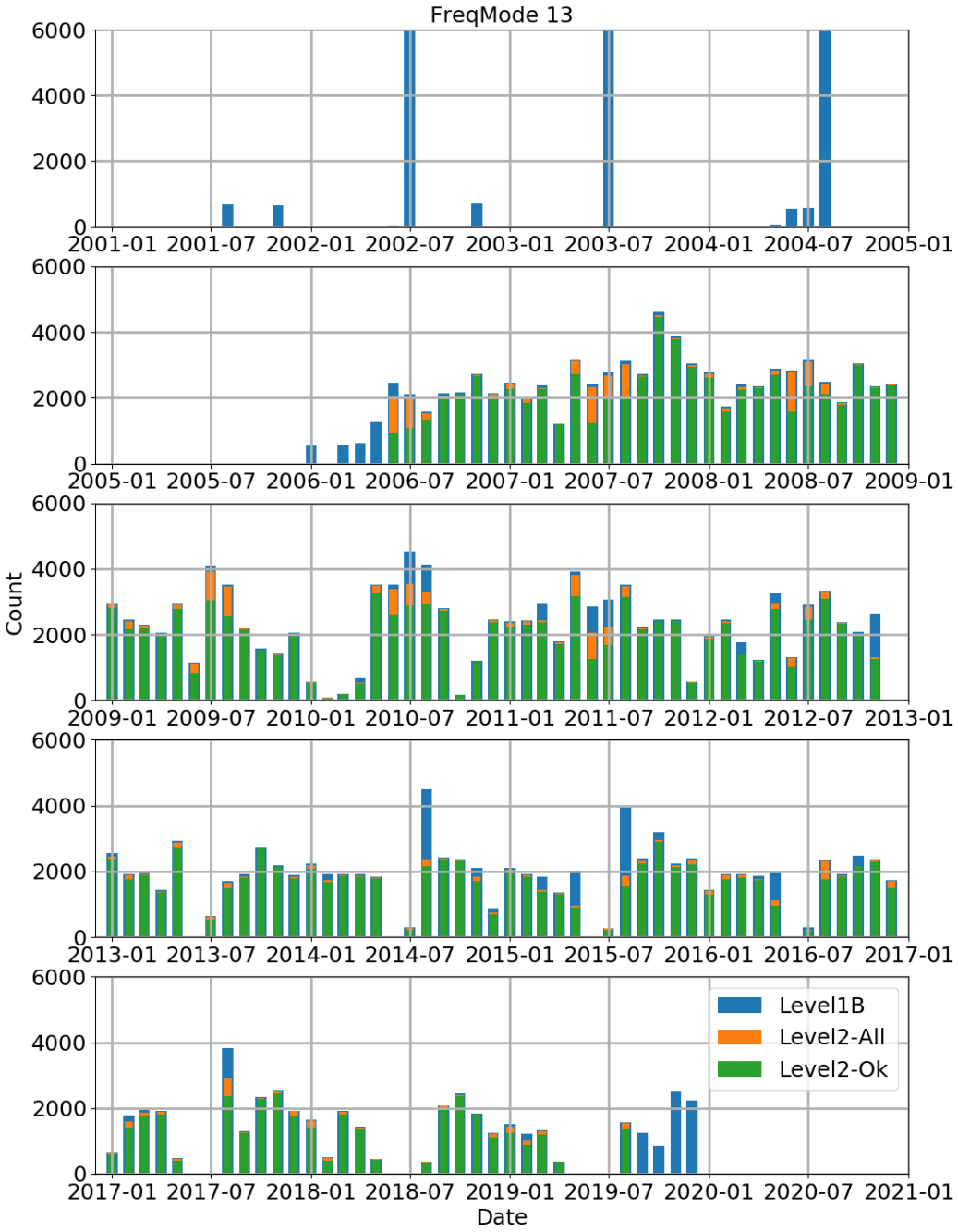

Figure 3.4: As Figure 3.1 but for FreqMode 13.

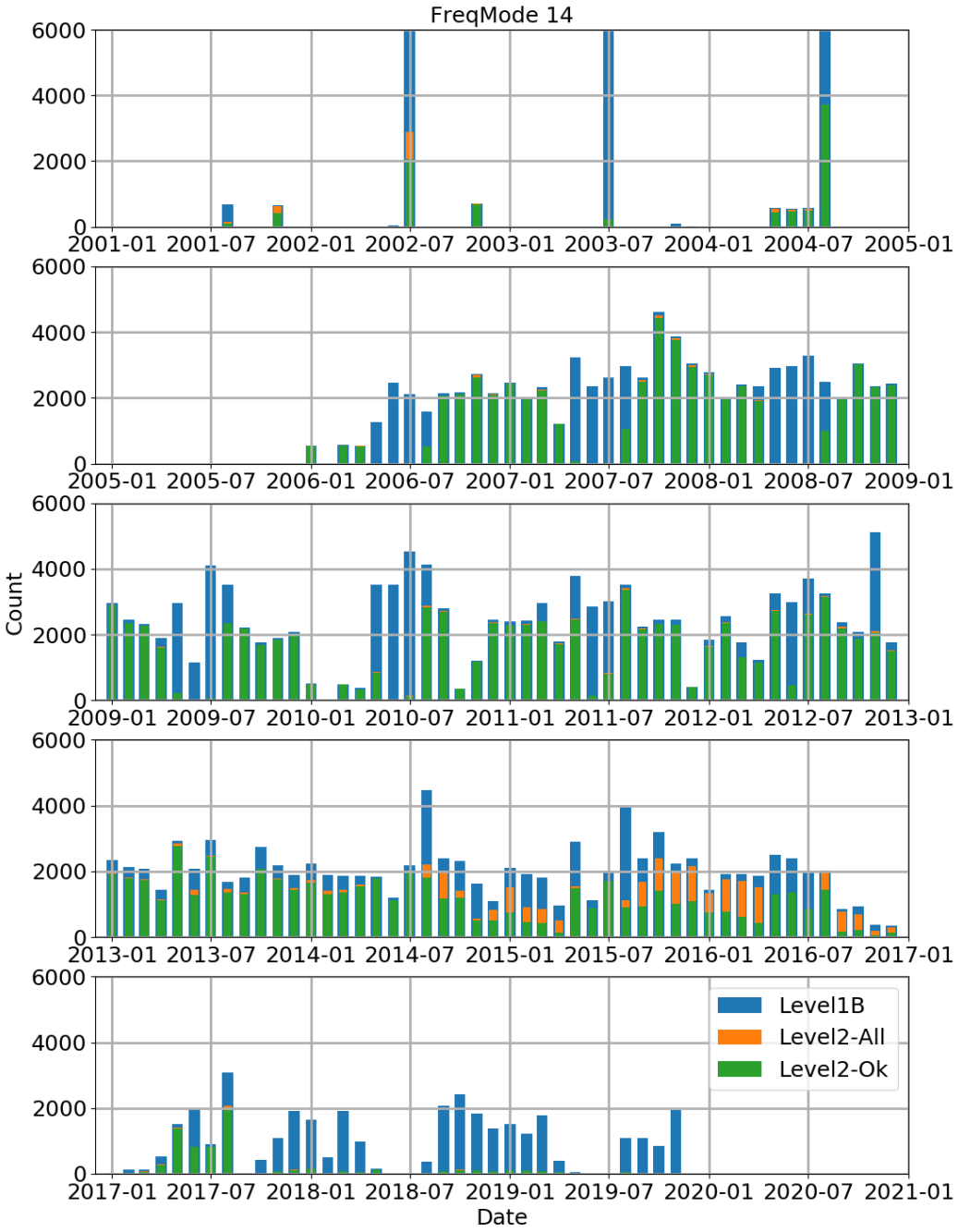

Figure 3.5: As Figure 3.1 but for FreqMode 14.

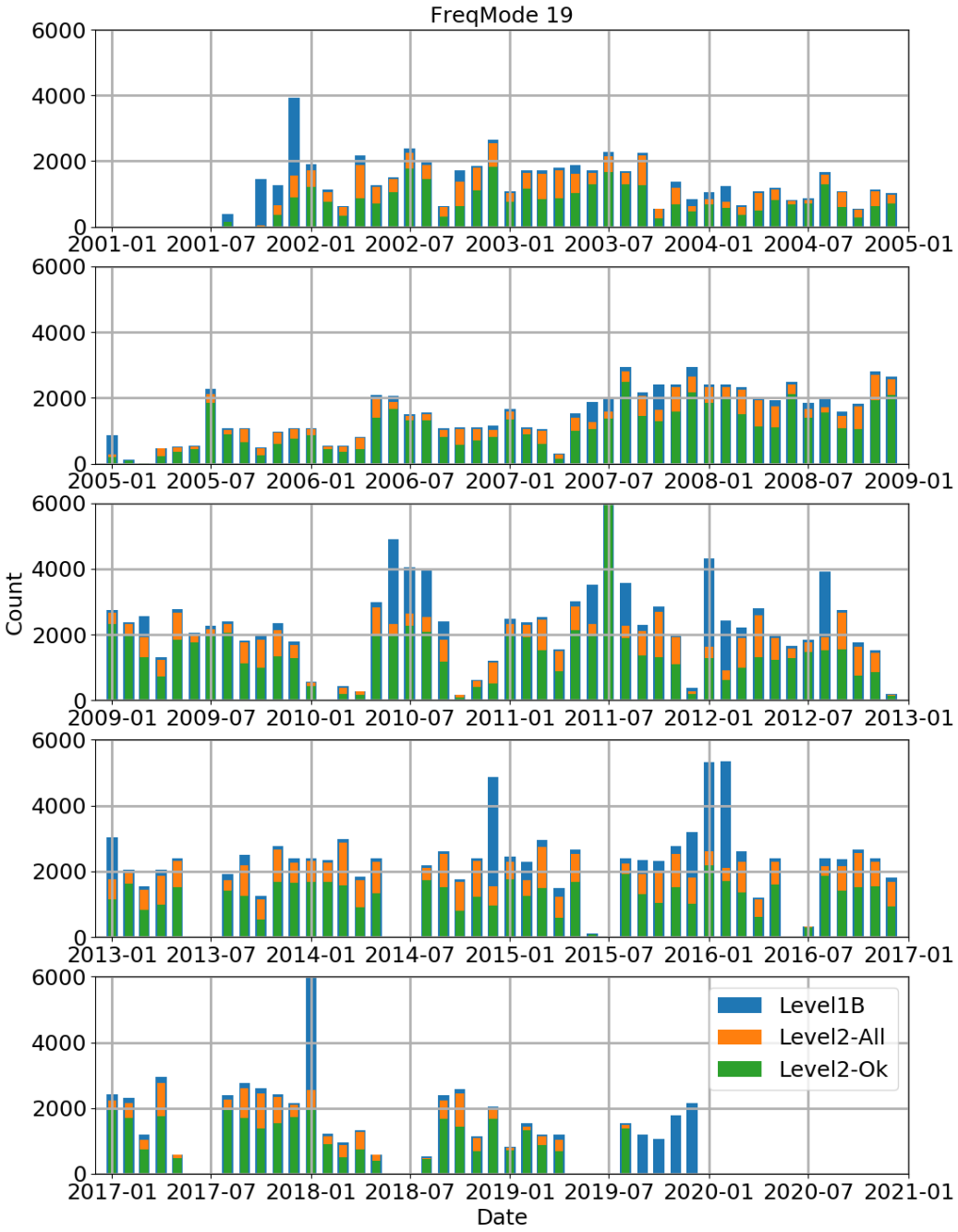

Figure 3.6: As Figure 3.1 but for FreqMode 19.

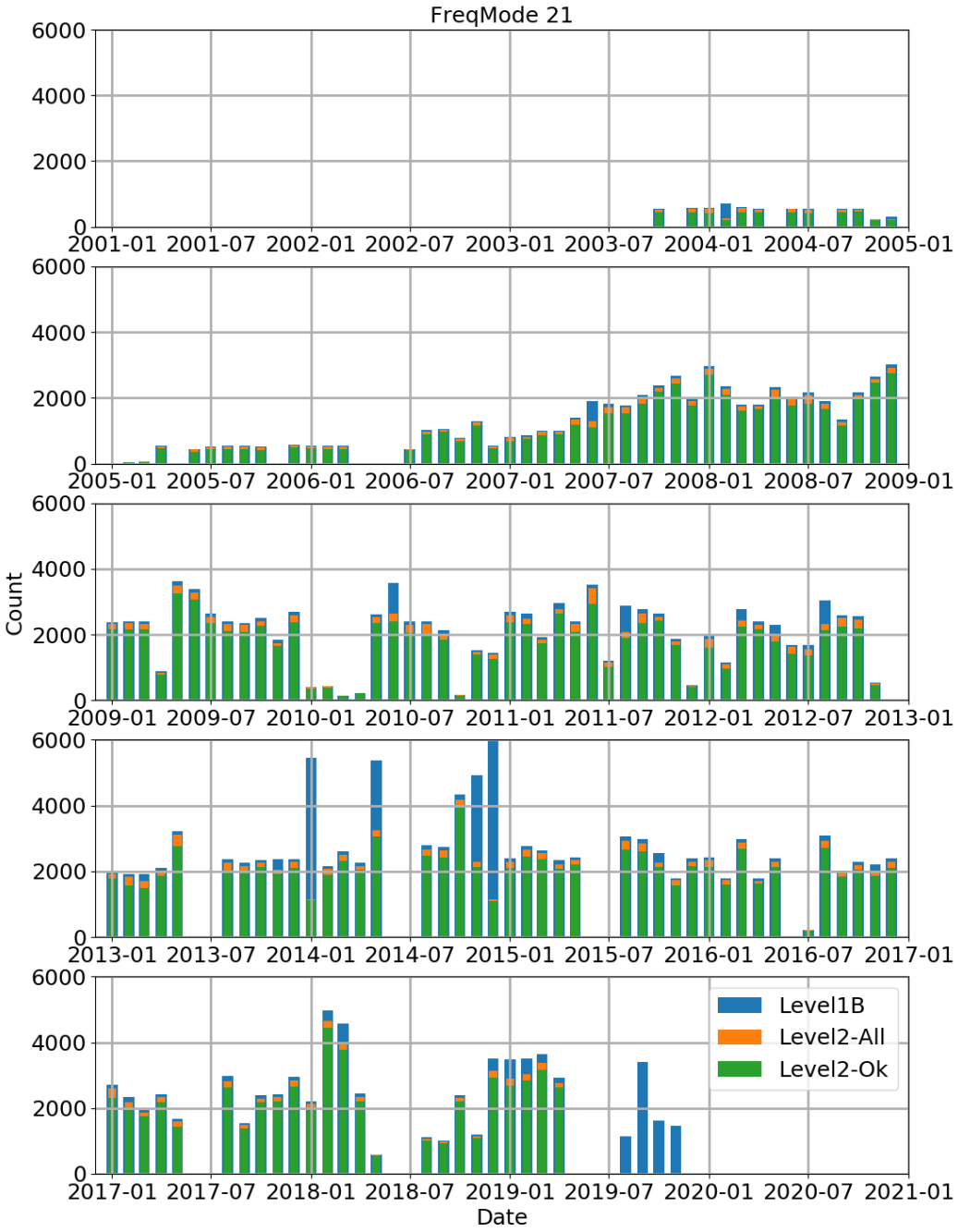

Figure 3.7: As Figure 3.1 but for FreqMode 21.

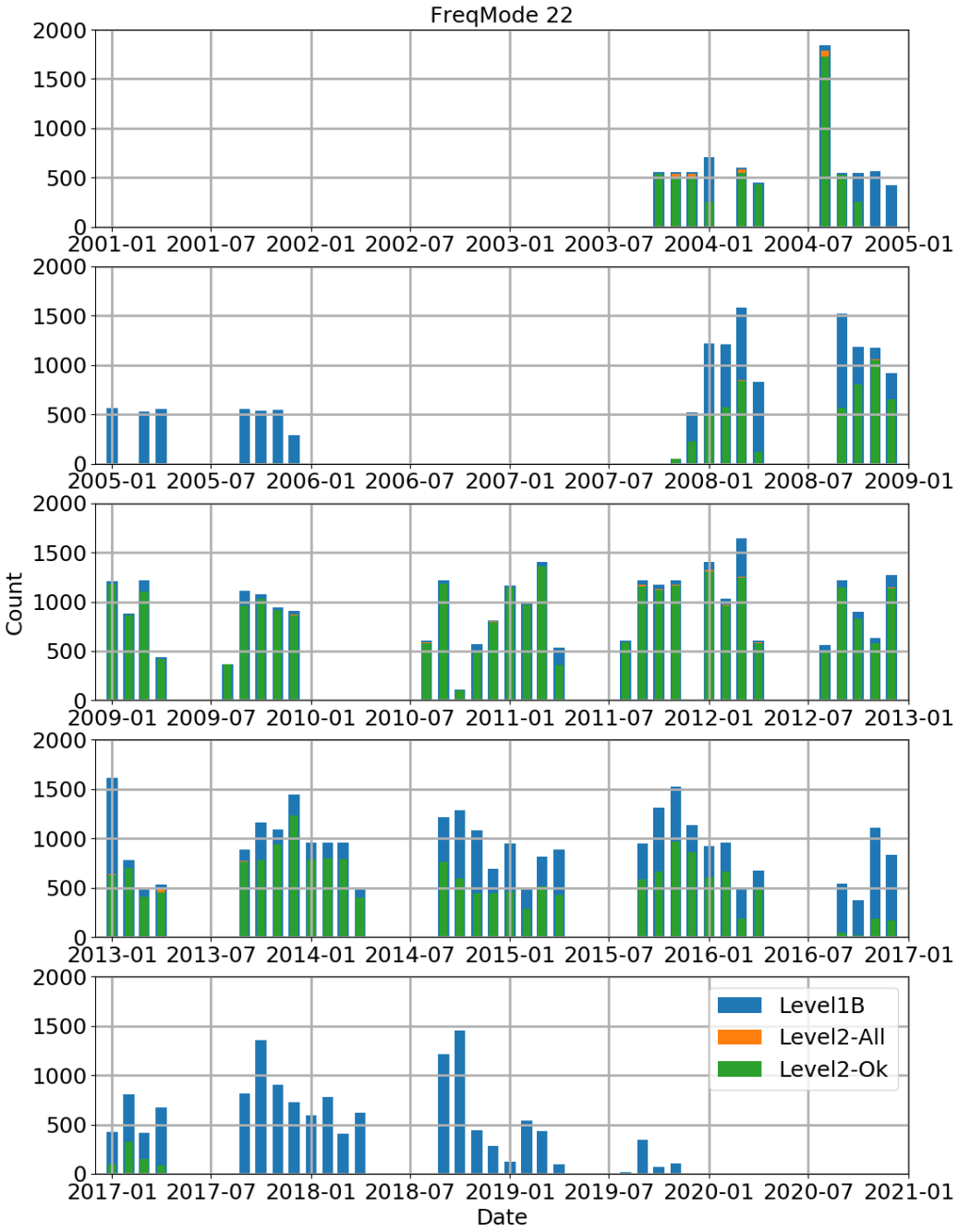

Figure 3.8: As Figure 3.1 but for FreqMode 22.

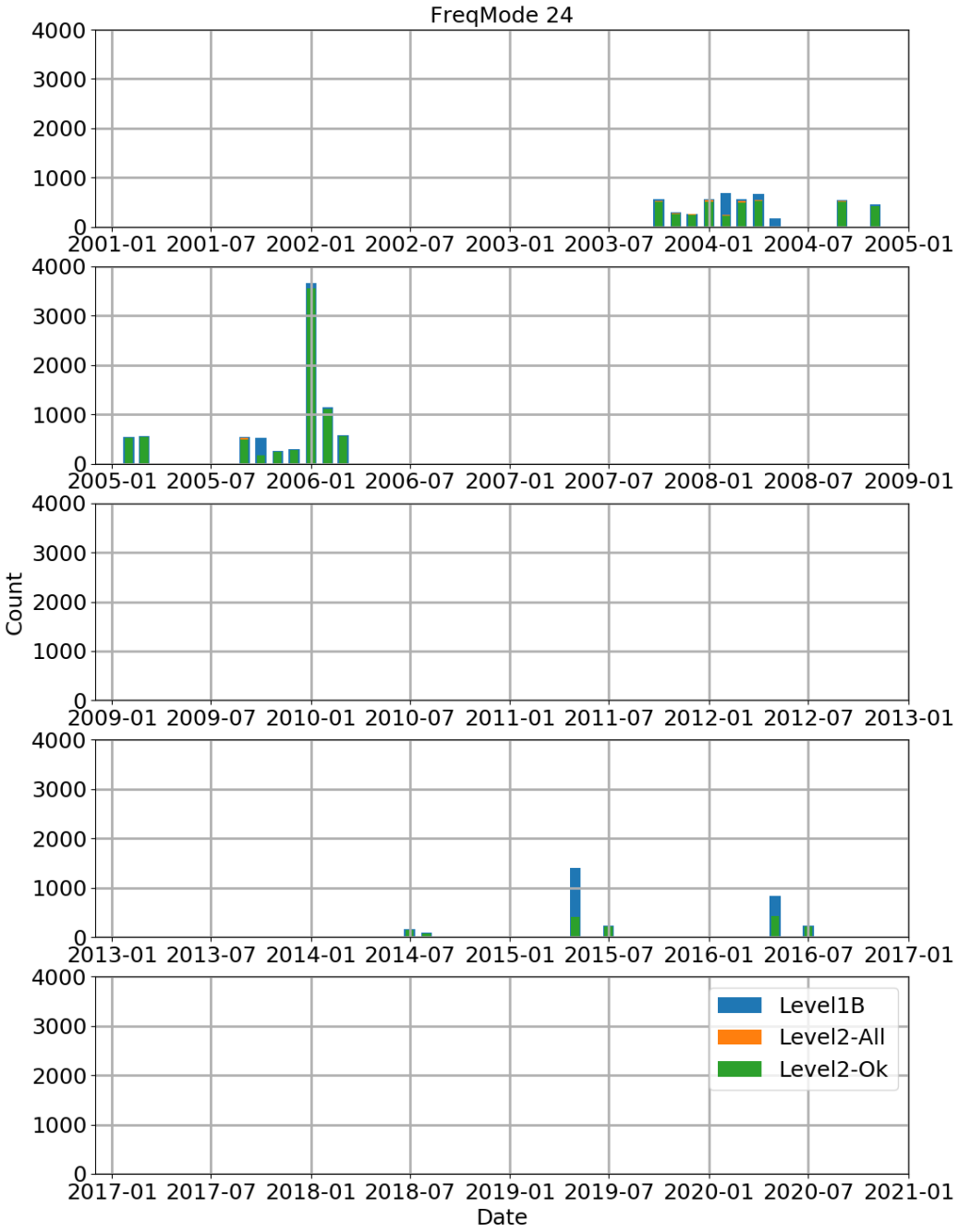

Figure 3.9: As Figure 3.1 but for FreqMode 24.

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