EUMETSAT

IASI L2 cloud parameter validation against spaceborne LIDAR measurements

Platform: M01,
GroundSegment: GS1

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1 INTRODUCTION

1.1 Purpose and scope

This report compiles validation statistics from the daily monitoring of the IASI L2 cloud products [RD 1] with *spaceborne* LIDAR measurements.
The IASI L2 products come from the operational ground segment GS1. The reference measurements are retrieved from CALIOP onboard CALIPSO [RD 3]. The collocation and statistics are computed with the MAP_GII visualization facility [RD 6].

This document is intended for internal monitoring purposes, to characterise and detect possible changes or trends in performances. It is also a public report to Users interested in IASI L2 cloud product uncertainties. In this respect, it is important to note that differences with CALIOP also include uncertainties of the CALIOP cloud products themselves as well as collocation uncertainties. These come from the representativeness of a point-like footprint of approx. 60m *vs* the 12-40 km footprint of IASI and from the spatial and temporal lags between CALIOP and IASI-L2 acquisitions.

1.2 Caliop Cloud Products

For this study 2 different Caliop cloud products have been combined in order to increase the accurracy of the reference dataset. 1) The Caliop 5km_Clay product and 2) the Caliop 1km_Clay product [RD 4]. In the longer scale product (5 km) contributions from strongly reflecting clouds are removed from the original signal to facilitate detection of very thin cloud layers and aerosols. This makes the identification of very thin Cirrus clouds in the 5km product more reliable compared to the 1km product, but on the other hand it also removes some of the mostly lower level clouds. In order to (re-)include those clouds, the respective 5 1km_Clay products are checked every time the 5km_Clay product reports clear conditions. In case that at least 1 out of 5 1km_Clay products reports a cloud the 5km_Clay product was updated with the cloud information of the respective 1Km_Clay products. This updated product normally gives an almost 5 % higher global cloud amount compared to the regular 5km_Clay product and is more sensitve to thin cirrus clouds compared to the 1km_Clay product. [RD 5]

1.2.1 Caliop Filtered Optical Depth

Caliop as Lidar is able to see even the thinnest clouds that passive sensors like IASI struggle to detect. It is therefore preferable to define a way that takes the different sensitivities of the two sensors into account. The filtered optical depth (FOD) method described in [RD 5] is a flexible way to establish a more *fair* comparison between IASI and Caliop using the optical depth product included in the 5km_Clay product of Caliop. Depending on the thickness, Caliop is able to report up to 10 different cloud layers before the signal saturates. Adding up those layer optical depths and defining a threshold for cloud detection, e.g. FOD = 0.1 provides the opportunity to remove those thin and transparent clouds IASI as sensor and not as retrieval is likely not sensitive enough to detect. Only if the threshold is reached the cloud mask is set to cloudy and the height of the layer first reaching the threshold will be treated as cloud top information. With this method very high and optical very thin clouds (e.g. cirrus) that are very hard to detect for IASI will be removed. Figure 1.1 shows the Hanssen Kuiper's skill Score (HKS, also True Skill Statistics TSS), the probability of detection (POD) and the false alarm rate (FAR) for different thresholds of FOD. POD and FAR are increasing with increasing FOD because an increasing FOD also means that more and

more clouds will be removed from the reference (Caliop). The HKS is a good measure for the sensitivity because it takes both scores POD and FAR into account and the peak (here at FOD=0.1) gives a good estimate of the sensitivity of IASI. For this validation a FOD of 0.1 is used, meaning that all cases where the sum of the layer optical depths is less than 0.1 are treated as clear even though it was reported cloudy in the first place.

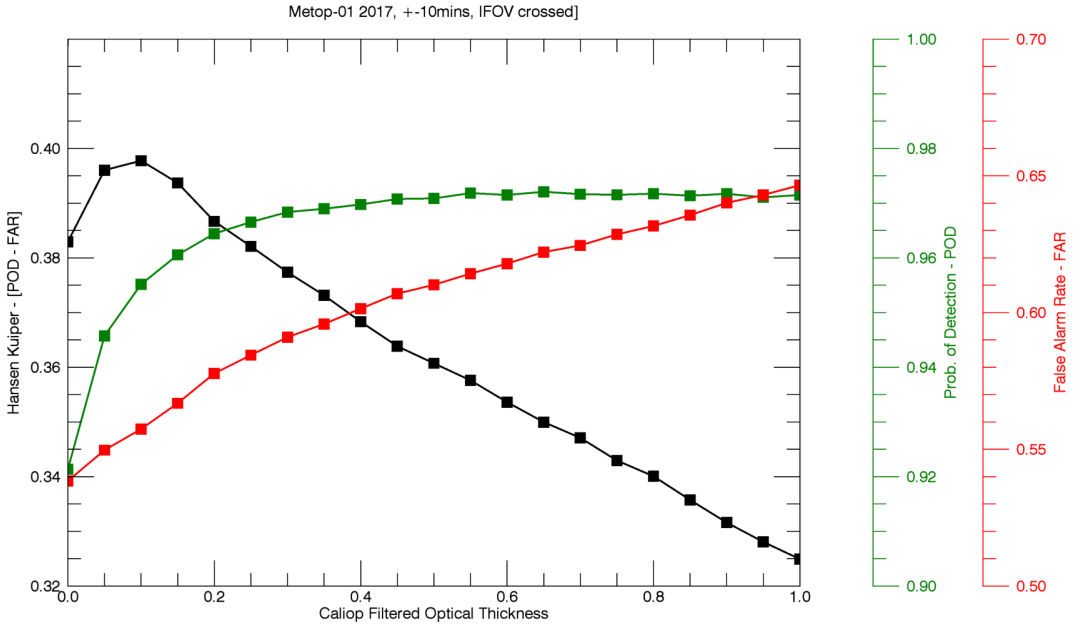

Figure 1.1: Hanssen Kuiper's skill Score, False Alarm Rate and Probability Of Detection as function of the filtered optical thickness (sum of the Caliop layer optical thickness).

1.3 Collocation criteria and data selection

Due to different orbits of Calipso (afternoon orbit with approx. 1 p.m. ECT) and the Metop satellites (morning orbits with approx. 10 a.m. ECT), collocations between the satellites are only possible in higher latitudes. Figure 1.2 shows an example of matchup maps between Calipso and Metop-B for the year 2017.

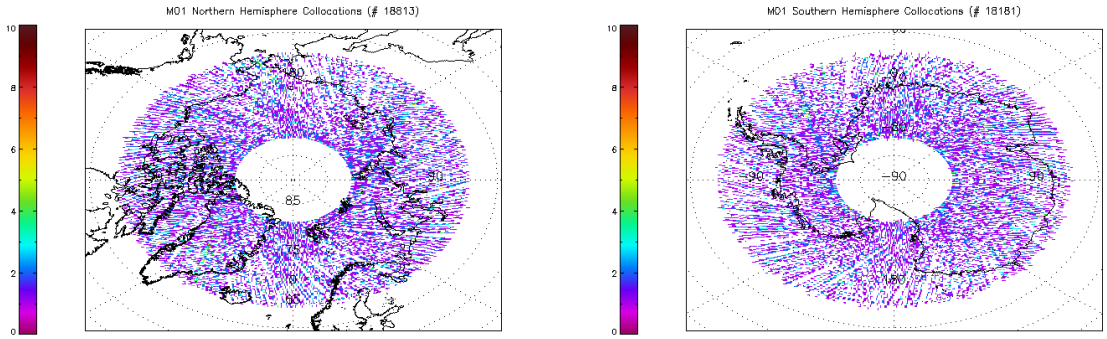

Figure 1.2: Northern (left) and southern hemisphere (right) matchups between Metop-B and Calipso! Due to different orbits the matchups within 10 mins are only possible at higher latitudes.

A collocation between IASI IFOV's and Caliop measurements is considered valid if the Caliop track is crossing right through the IASI-IFOV with a temporal difference of no more than 10 mins. The crossing is considered as optimal if it is along the major-axis of the ellipses that describes the IASI-IFOV based on the viewing geometry. Here; the length of the major-axis defines the maximum number of 5km Caliop Pixel that can theoretically lie inside the IASI-Pixel. This maximum number can be calculated and compared to the actual number. The ratio can be used as an indication if the Caliop track is crossing right through (capturing most of the space IASI would see) or if it only scratches the edge of the IASI-IFOV. Figure 1.3 shows 2 examples of the Caliop track (blue line) crossing through an IASI-IFOV. The bad example (left) only scratches the IASI-IFOV (green Ellipses), just one 5km Caliop Pixel (green square) is lying inside and the ratio between actual and maximum inside Caliop Pixel is 1:6 or 0.167 (see legend). This Collocation has been rejected because the ratio is below the defined threshold of 0.75. The good example on the right shows a ratio of 6:6 or 1.0 and is accepted as collocation. In a further step the matchup quality control retains products where the caliop products inside the IASI-IFOV are not homogenous, meaning all caliop products crossing the IASI IFOV must have the same cloud type, phase and report either cloudy or clear.

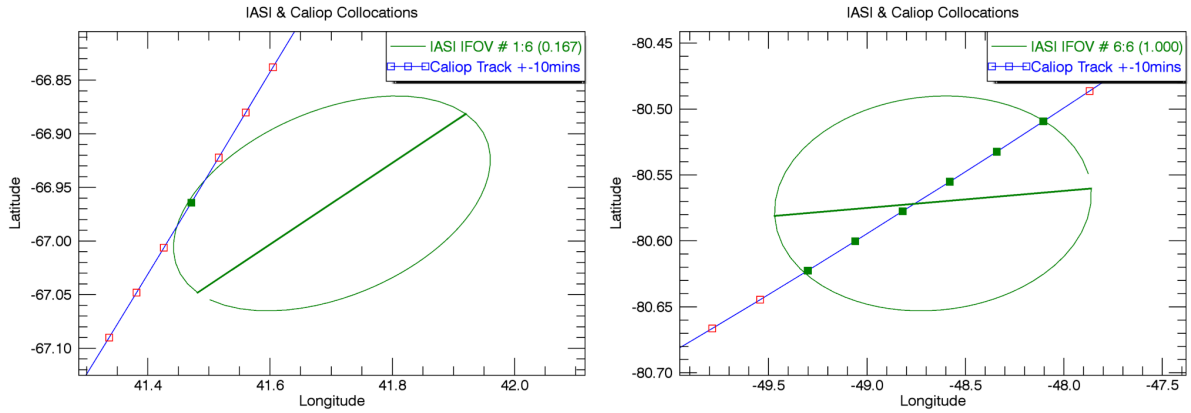

Figure 1.3: Bad example (left) and good example (right) between IASI L2 and Caliop

1.4 Reference Documents

ID	Title	Reference
[RD 1]	"IASI Level 2 Product Generation Specifications"	EPS.SYS.SPE.990013
[RD 2]	"IASI Level 2 Product Guide"	EUM/OPS-EPS/MAN/04/0033
[RD 3]	"CALIPSO-CALIOP"	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation - Cloud-Aerosol Lidar with Orthogonal Polarization
[RD 4]	"Overview of the CALIPSO mission and CALIOP data processing algorithms"	D. M. Winker; M.A. Vaughan; A. Omar; Y. Hu; K.A. Powell; Z. Liu; W.H. Hunt and S.A. Young; J. Atmos. Ocean. Tech.; 26; 2310-2323; doi:10.1175/2009JTECHA1281.1; 2009
[RD 5]	"On the optimal method for evaluating cloud products from passive satellite imagery using CALIPSO-CALIOP data: example investigating the CM SAF CLARA-A1 dataset"	K.G. Karlsson and E. Johansson; Atmos. Meas. Tech.; 6; 1271-1286; https://doi.org/10.5194/amt-6-1271-2013; 2013"
[RD 6]	"MAP_GII"	"IDL based Visualization Software"

1.5 Terminology

- M01 : Metop B
- M02 : Metop A
- M03 : Metop C
- Ground Segment 1 (GS1) : operational
- Ground Segment 2 (GS2) : validation
- Ground Segment 3 (GS3) : experiment
- Probability of detection (POD) : hit / (hit + missed)
- False Alarm Rate (FAR) : false alarms / (false alarms + correct negative)
- Hanssen-Kuiper Skill Score (HKS) : POD - FAR

2 GLOBAL

2.1 Matchups

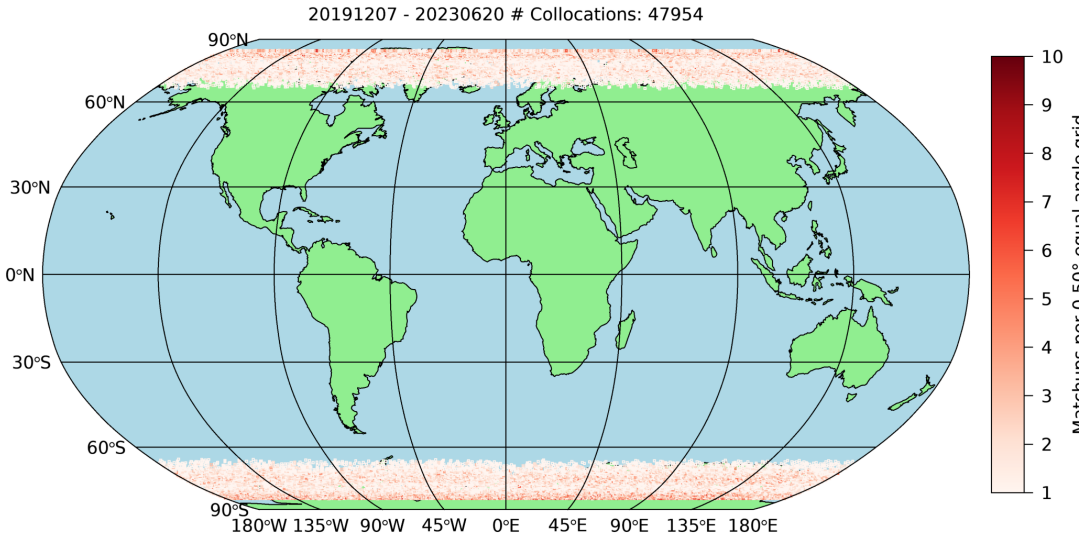

Figure 2.1: Global Matchups between Calipso and M01 IASI L2 from GS1

2.2 Cloud Mask

The Calipso Cloud products provide a binary cloud mask, clear or cloudy. In order to compare both masks, the IASI-L2 cloud mask was set to binary by setting CLDNES Flag values 1 and 2 to clear and values 3 and 4 to cloudy! The collocation homogeneity criteria (Section 1.3) makes sure that all caliop pixel crossing the IASI IFOV are either clear or cloudy and not mixed!

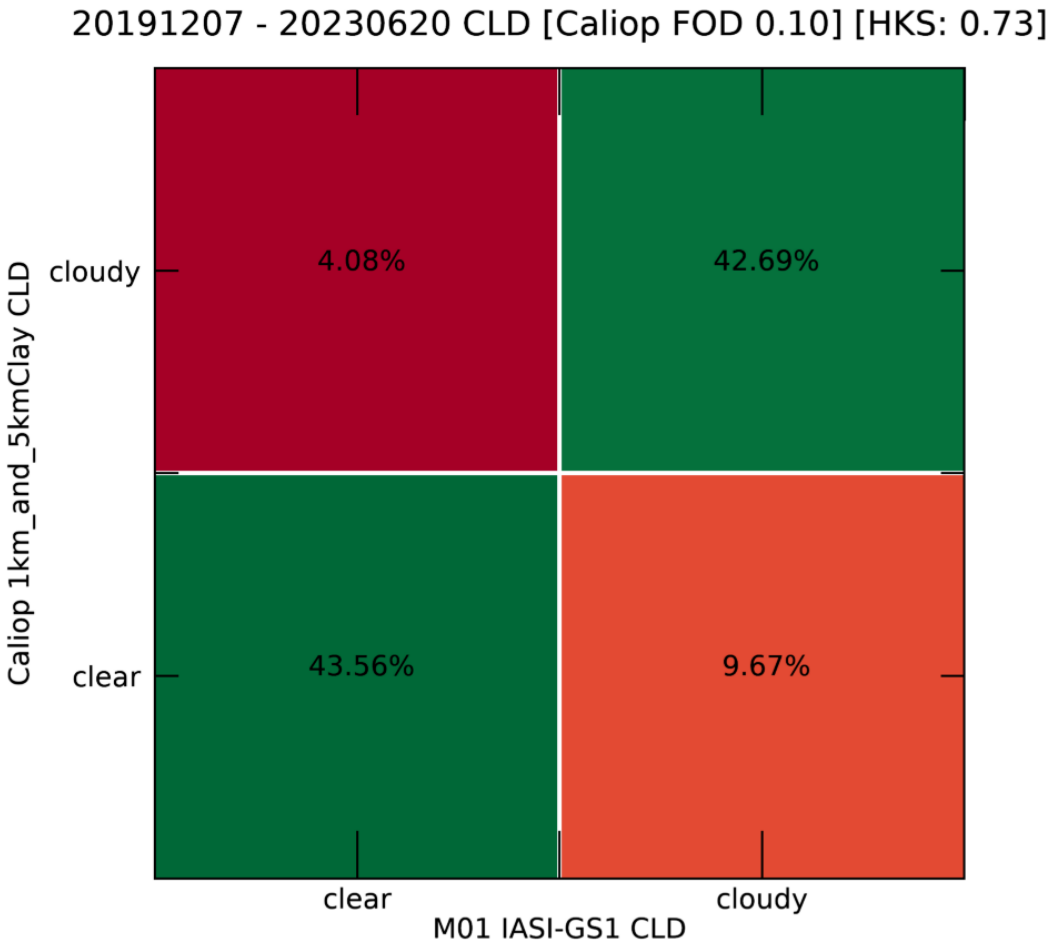

Figure 2.2: Long-Term Cloud Mask contingency table incl. Hanssen Kuiper's skill score. Global statistics with M01 IASI L2 from GS1

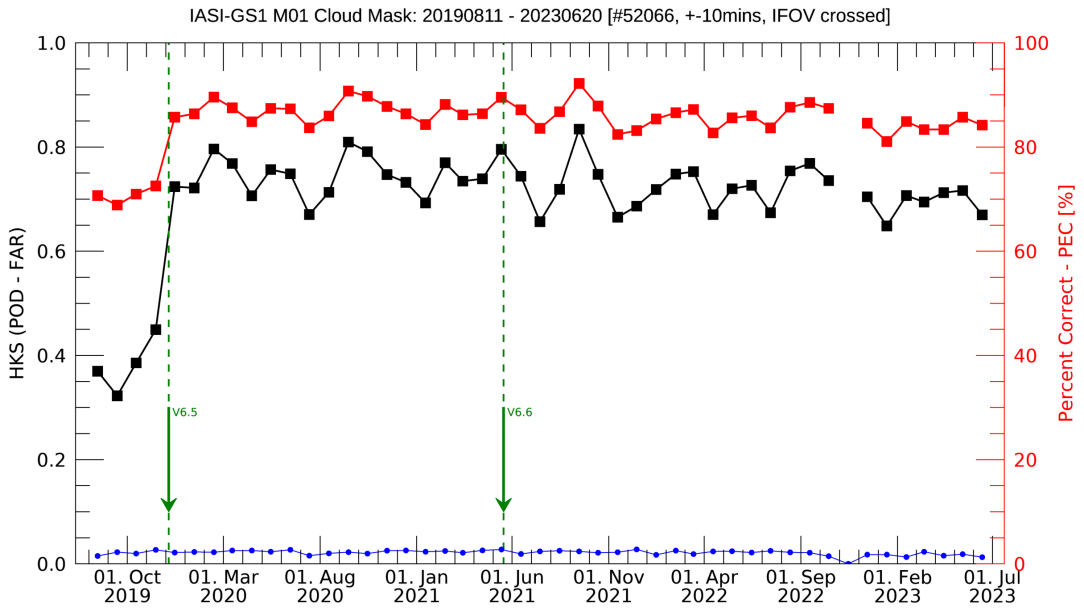

Figure 2.3: Long-Term Cloud Mask Time Serie for Hanssen Kuiper's skill score and Percent Correct, including fractional number of matchups per month (bottom blue) and #total-number-of-matchups (title). Global statistics with M01 IASI L2 from GS1.

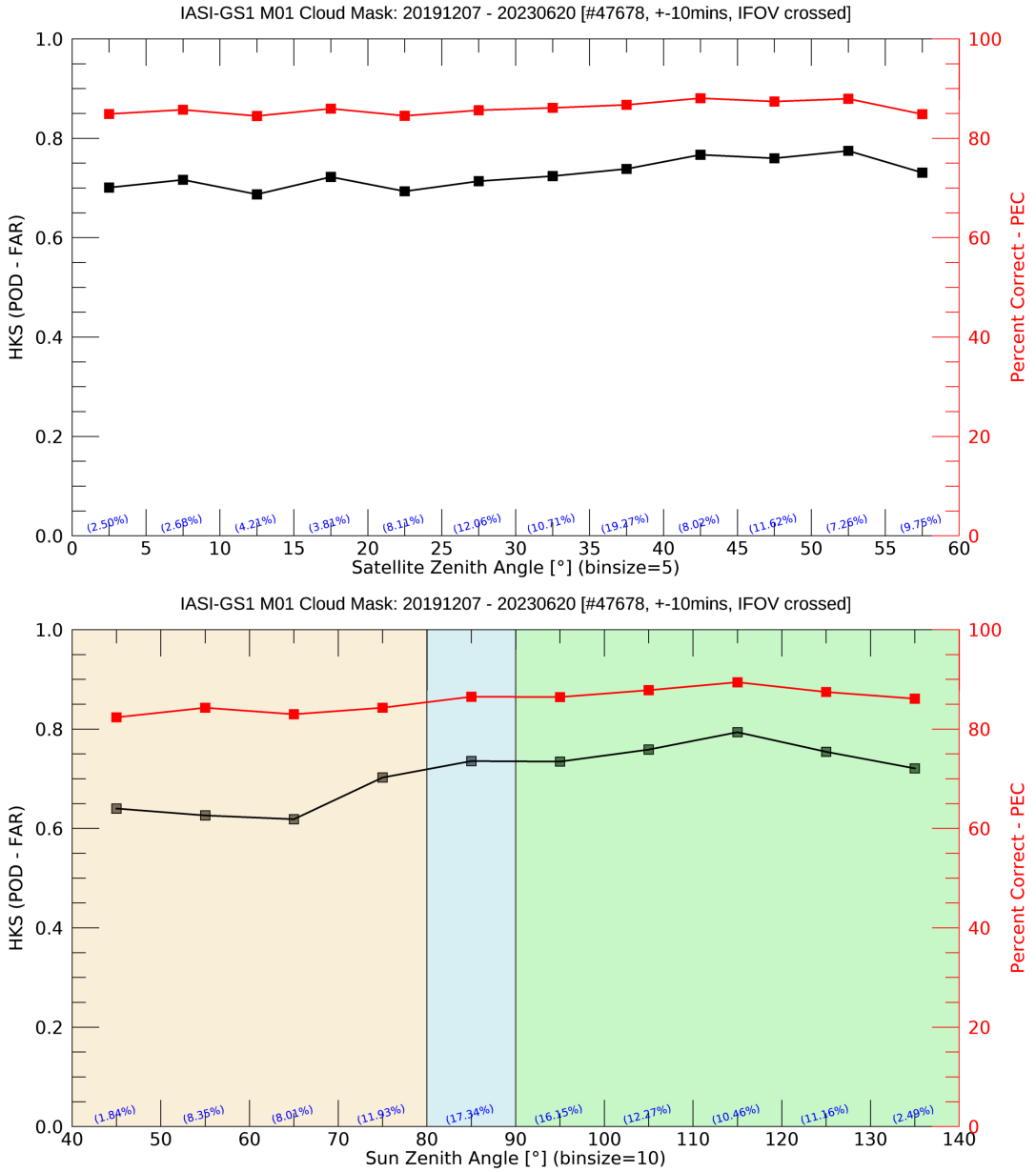

Figure 2.4: Satellite Zenith Angle (top) and Sun Zenith Angle (bottom) dependendencies on Cloud Mask differences between IASI L2 and Caliop, Global statistics with M01 IASI L2 from GS1

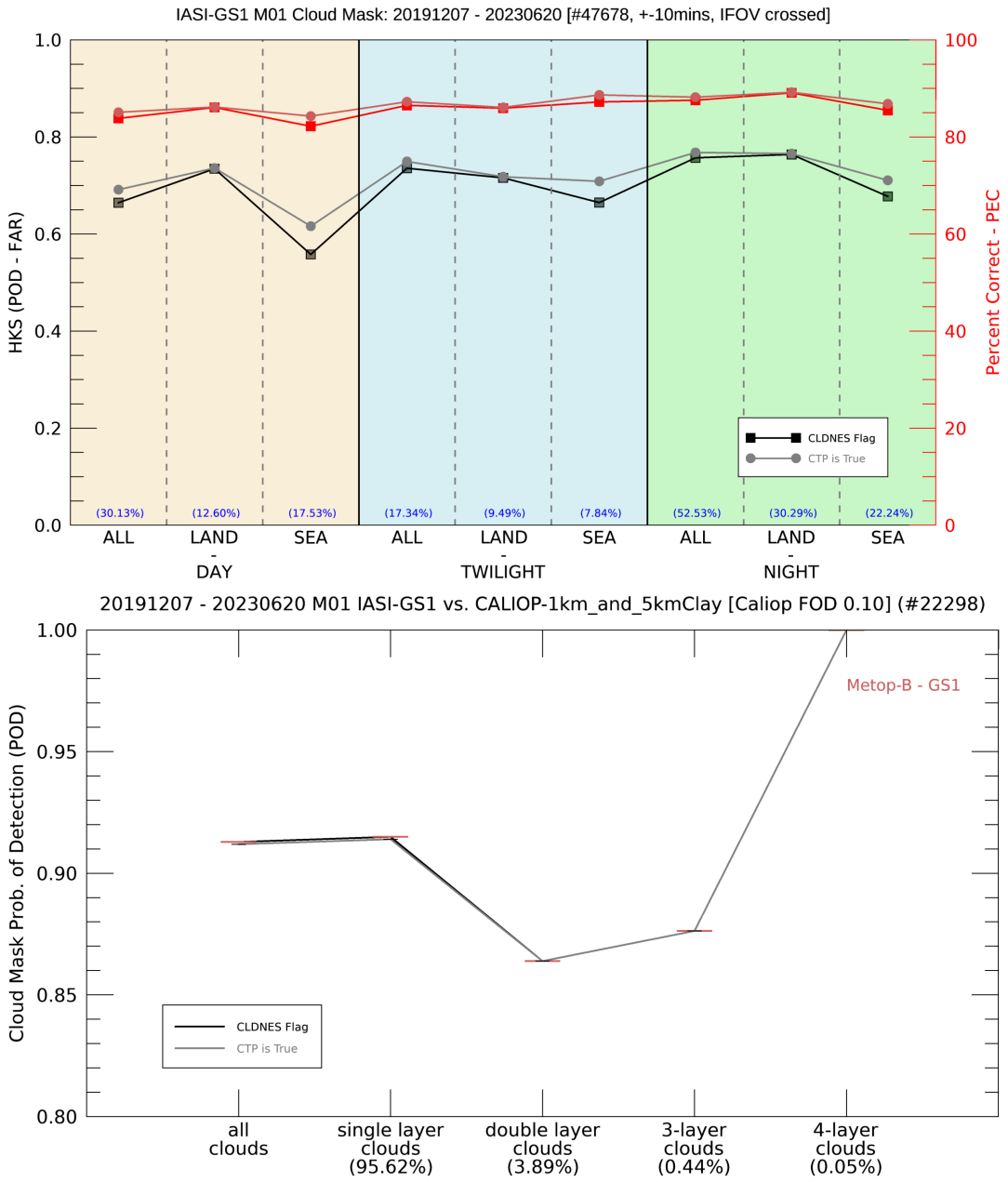

Figure 2.5: Cloud Mask dependencies on Daytime/Land/Sea (top) and number of Caliop Cloud layer (bottom) between IASI L2 and Caliop, Global statistics with M01 IASI L2 from GS1

2.3 Cloud Phase

The Calipso Cloud products provides 3 different states to describe the thermodynamic phase of clouds, 1: randomly oriented ice, 2: horizontally oriented ice and 3: water. The IASI-L2 provides the classification liquid, ice and mixed. In order to compare Caliop to the IASI-L2 cloud phase product both masks were set to a binary phase mask by combining the 2 ice phases of Caliop into a single *ice* class and removing the mixed statement from the IASI-L2 products. The homogeneity criteria (Section 1.3) makes sure that all caliop pixel crossing the IASI IFOV are either liquid or ice and not mixed!

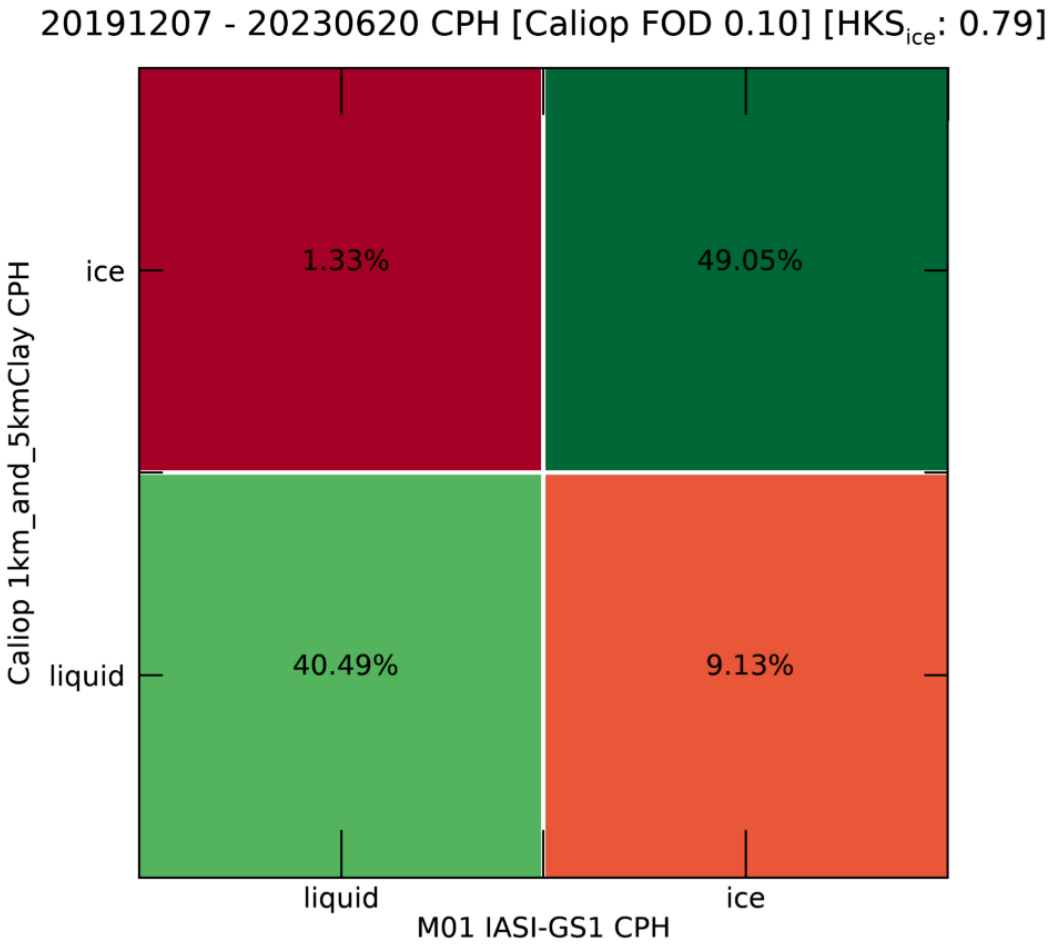

Figure 2.6: Long-Term Cloud Mask contingency table incl. Hanssen Kuiper's skill score. Global statistics with M01 IASI L2 from GS1

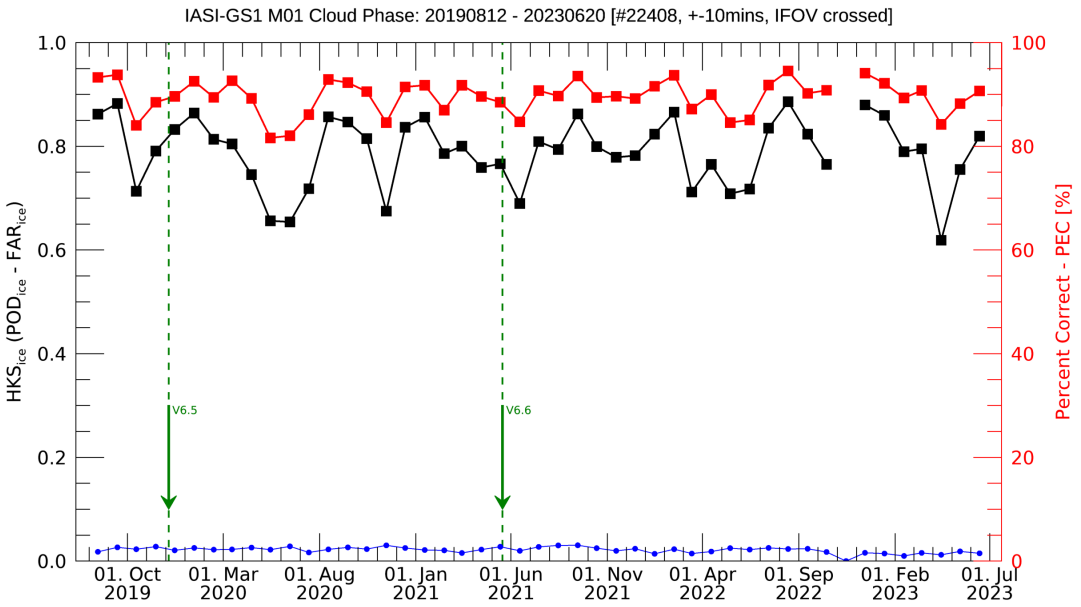

Figure 2.7: Long-Term Cloud Phase Time Serie for Hanssen Kuiper's skill score and Percent Correct, including fractional number of matchups per month (bottom blue) and #total-number-of-matchups (title). Global statistics with M01 IASI L2 from GS1.

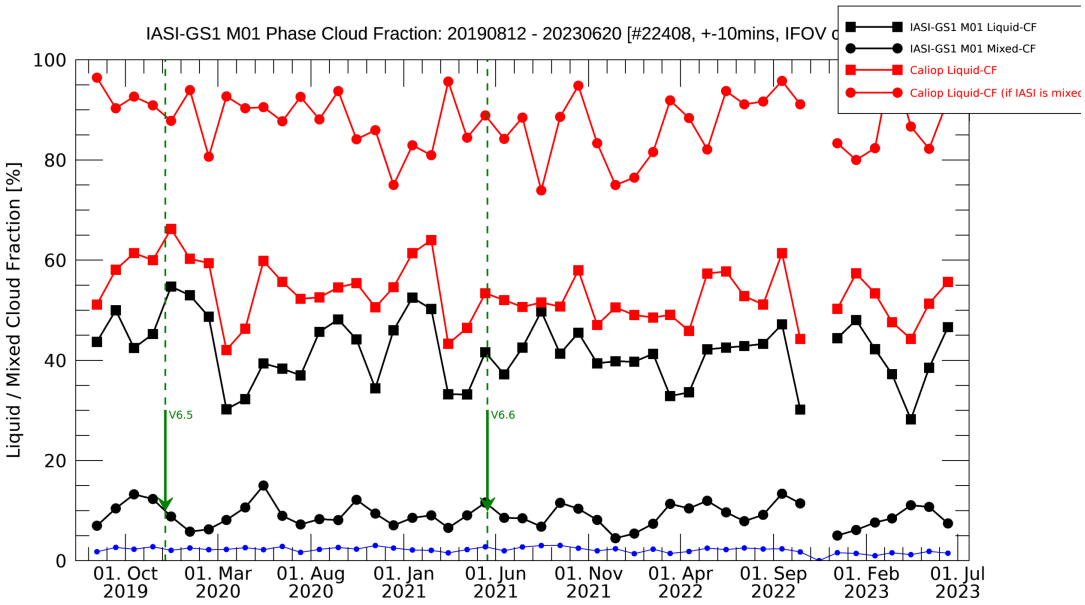

Figure 2.8: Long-Term Cloud Phase Time Serie for Liquid and Mixed cloud fraction in percent, including fractional number of matchups per month (bottom blue) and #total-number-of-matchups (title). Global statistics with M01 IASI L2 from GS1.

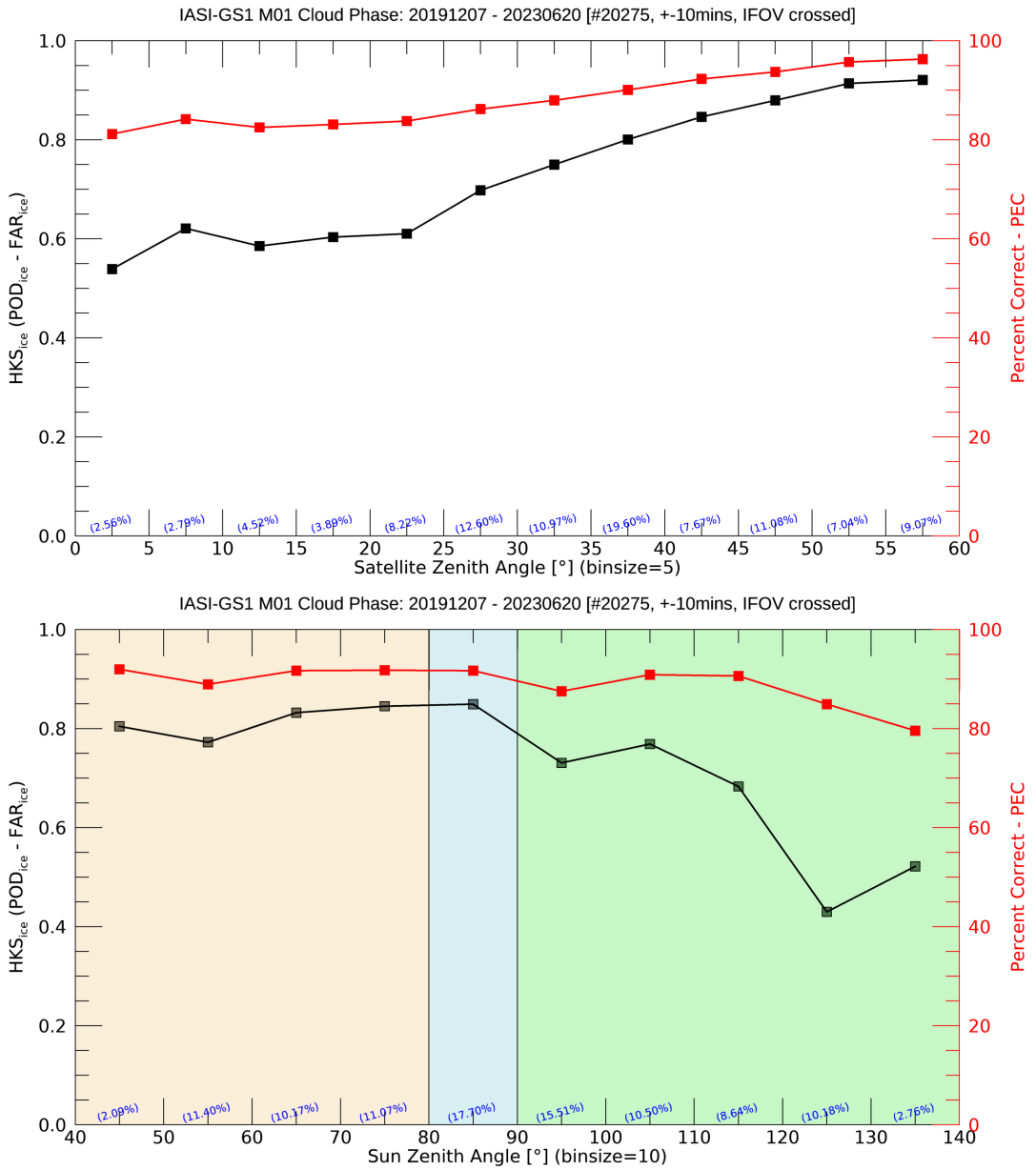

Figure 2.9: Satellite Zenith Angle (top) and Sun Zenith Angle (bottom) dependencies on Cloud Phase differences between IASI L2 and Caliop, Global statistics with M01 IASI L2 from GS1

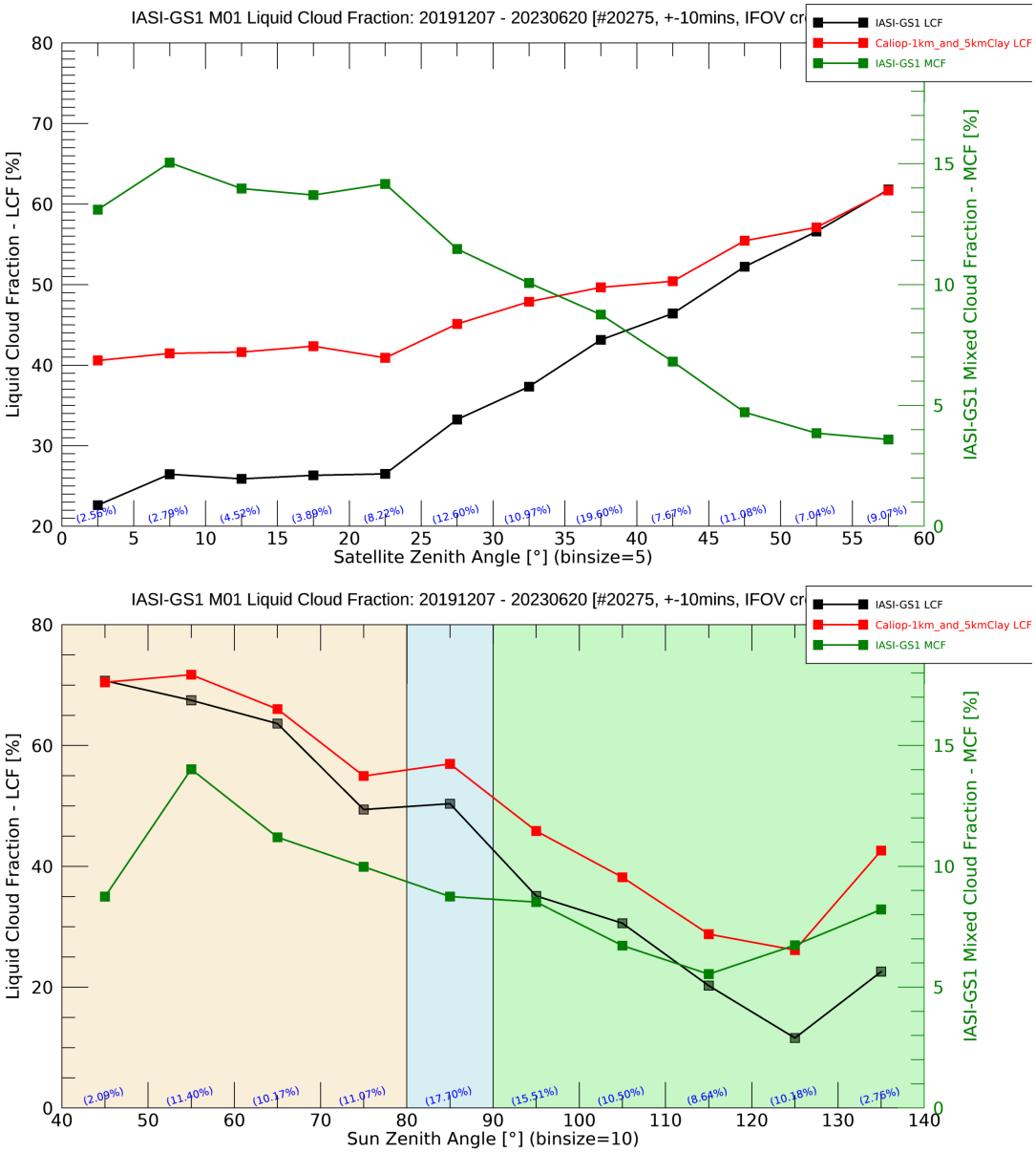

Figure 2.10: Satellite Zenith Angle (top) and Sun Zenith Angle (bottom) dependencies on Liquid and Mixed Cloud Fraction for IASI L2 and Caliop, Global statistics with M01 IASI L2 from GS1

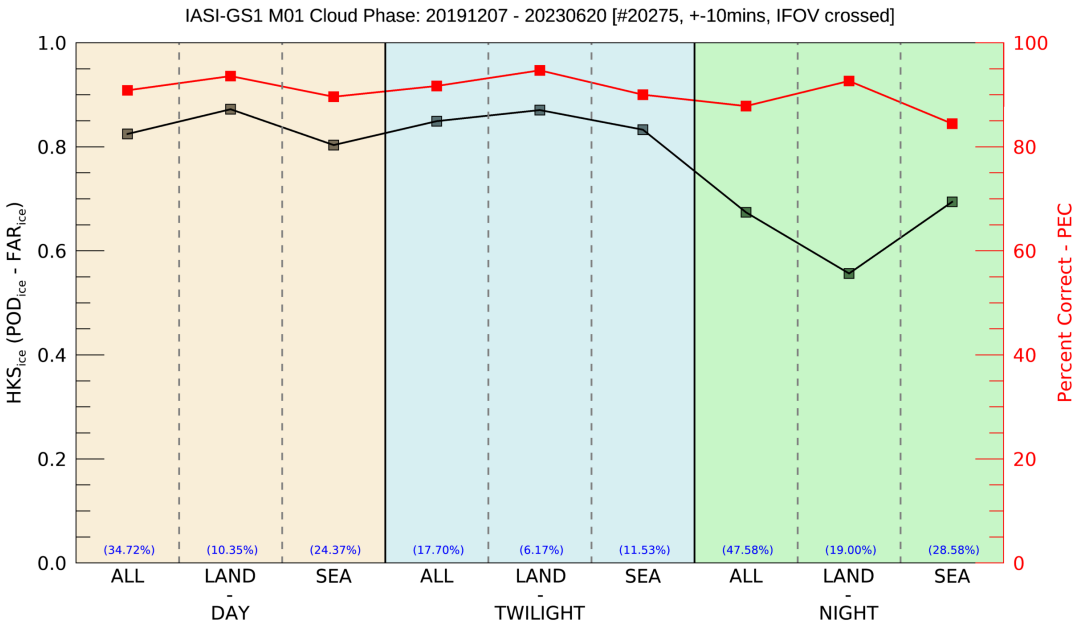

Figure 2.11: Cloud Phase dependencies on Daytime/Land/Sea between IASI L2 and Caliop, Global statistics with M01 IASI L2 from GS1

2.4 Cloud Top Pressure

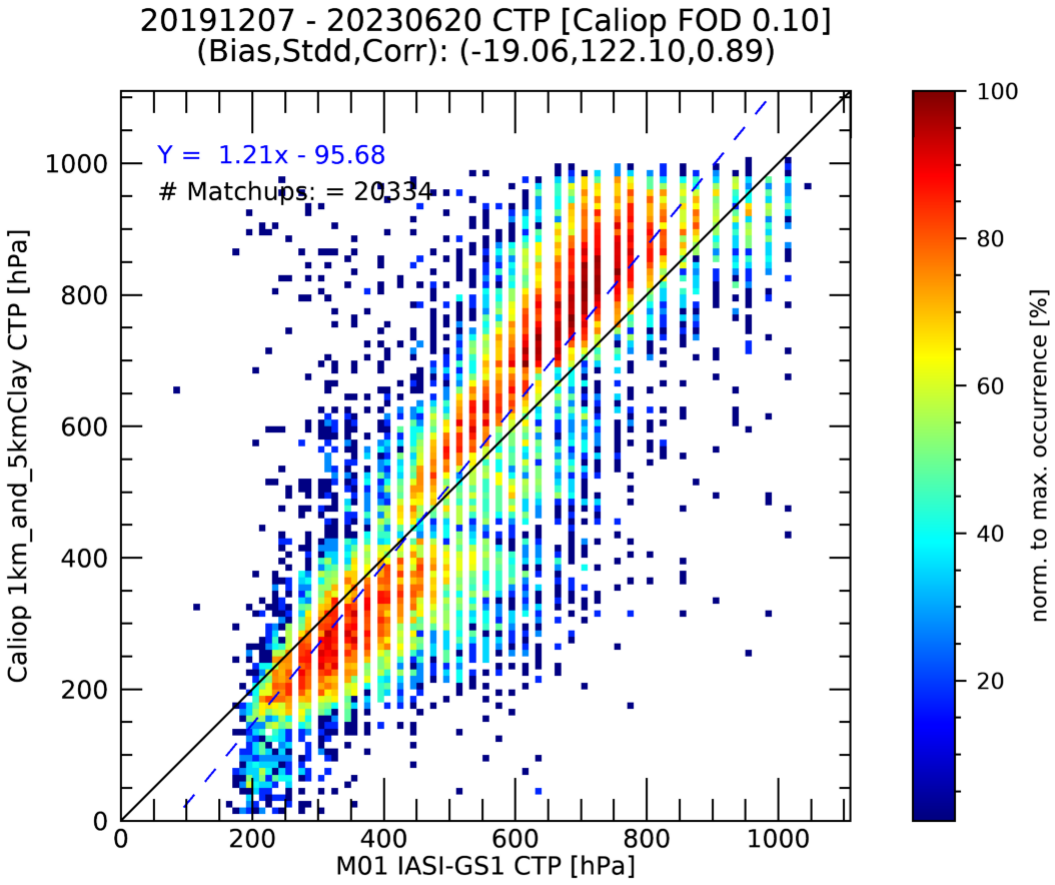

Figure 2.12: 2D Histograms for Cloud Top Pressure between IASI L2 and Caliop, Global statistics with M01 IASI L2 from GS1

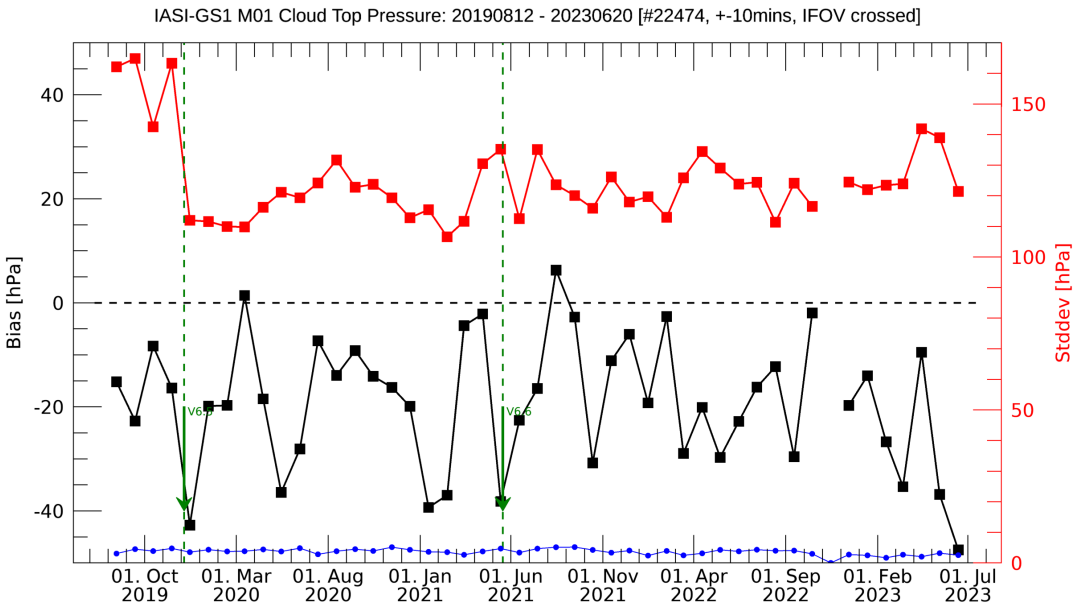

Figure 2.13: Long-Term Cloud Top Pressure Time Serie Bias and Standard Deviation of the differences, including fractional number of matchups per month (bottom blue) and #total-number-of-matchups (title). Global statistics with M01 IASI L2 from GS1.

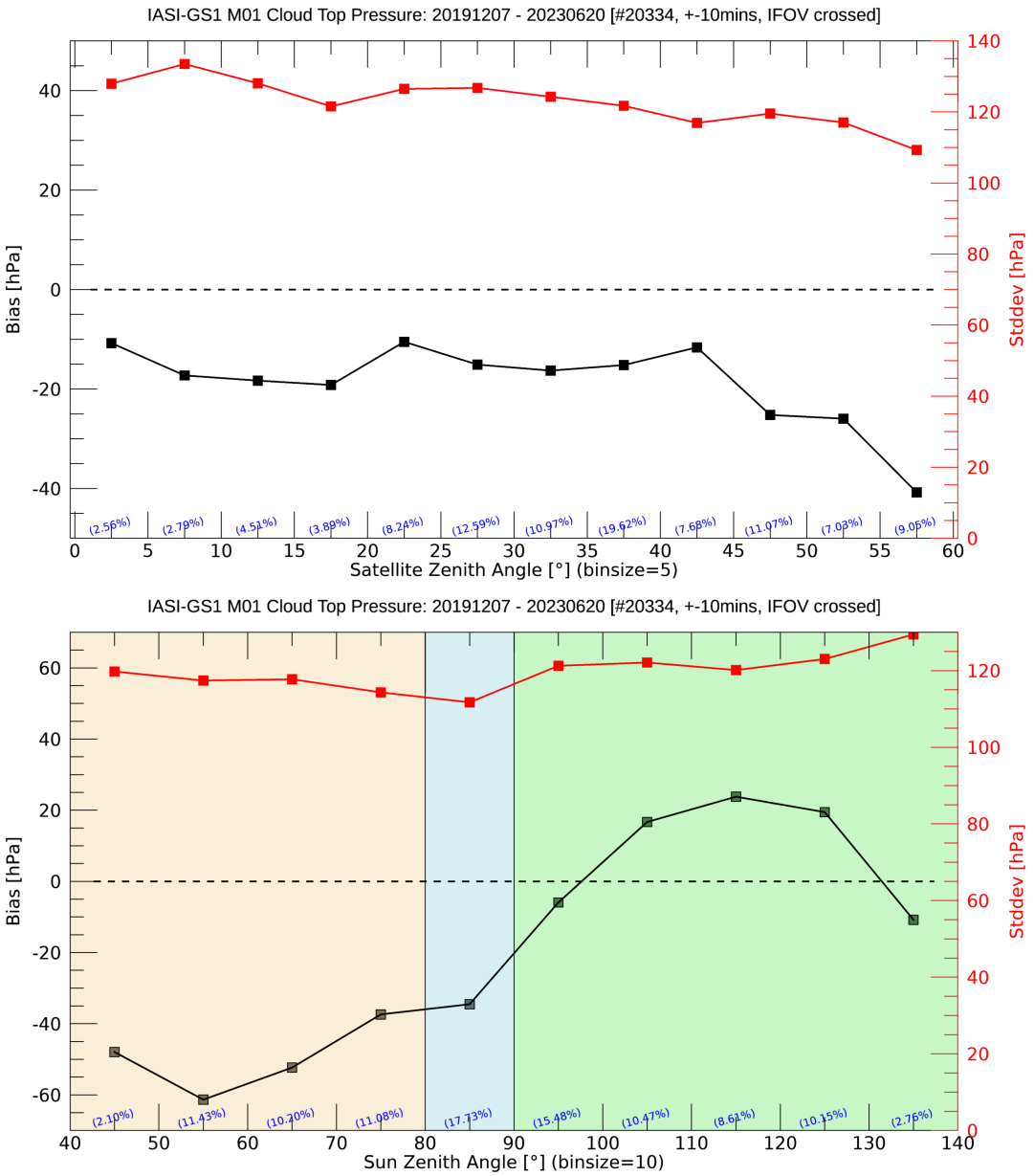

Figure 2.14: Satellite Zenith Angle (top) and Sun Zenith Angle (bottom) dependendencies on Cloud Top Pressure differences between IASI L2 and Caliop, Global statistics with M01 IASI L2 from GS1

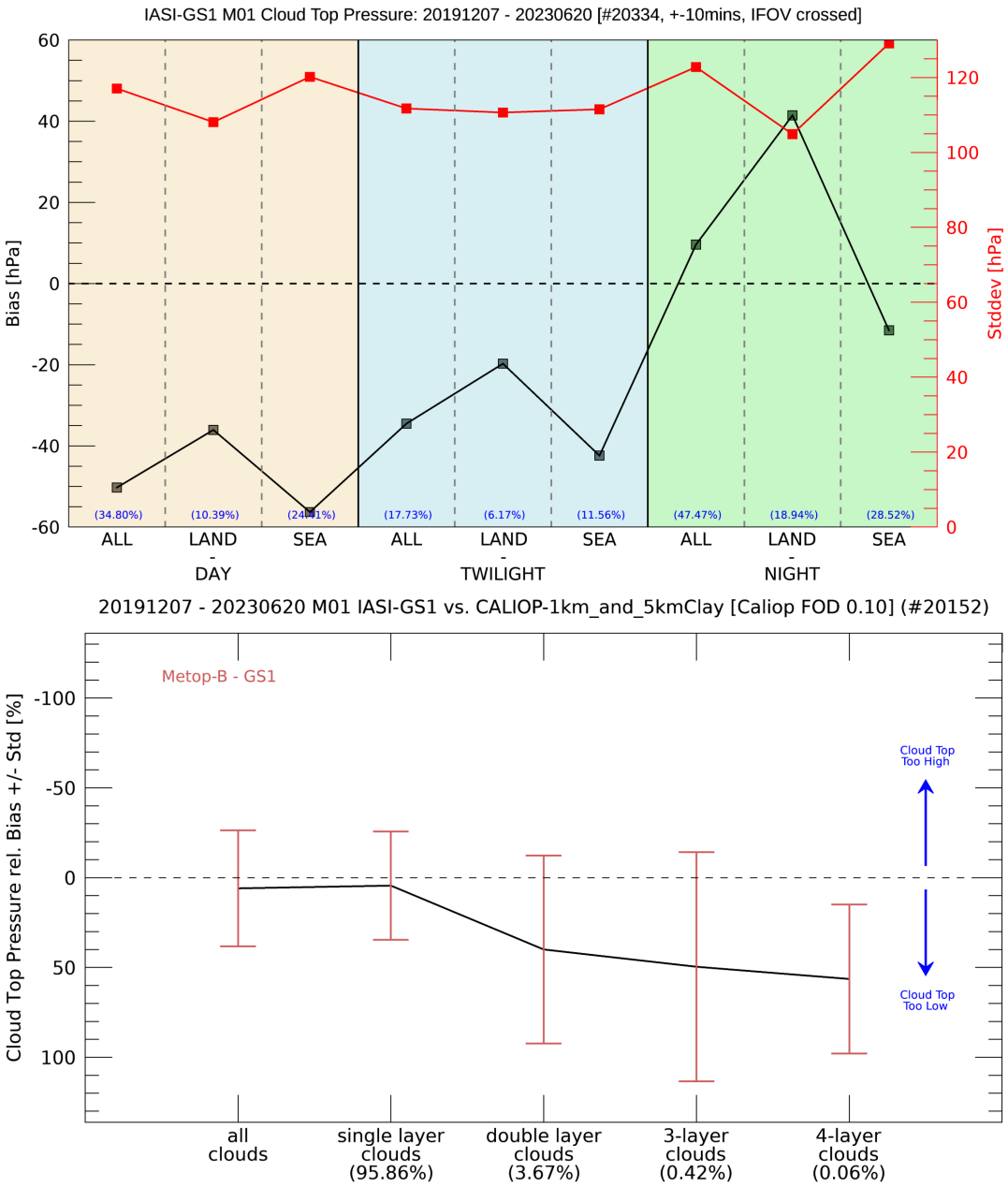

Figure 2.15: Cloud Top Pressure dependencies on Daytime/Land/Sea (top) and number of Caliop Cloud layer (bottom) between IASI L2 and Caliop, Global statistics with M01 IASI L2 from GS1

2.5 Cloud Top Temperature

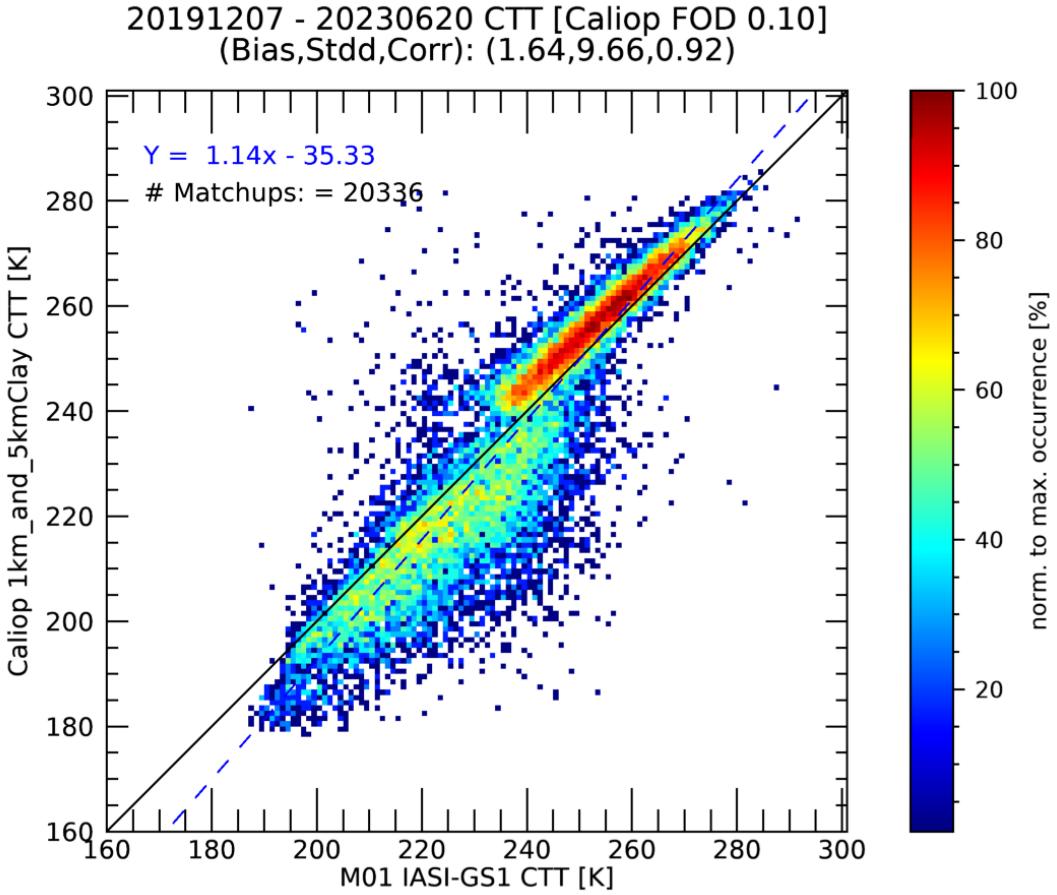

Figure 2.16: 2D Histograms for Cloud Top Temperature between IASI L2 and Caliop, Global statistics with M01 IASI L2 from GS1

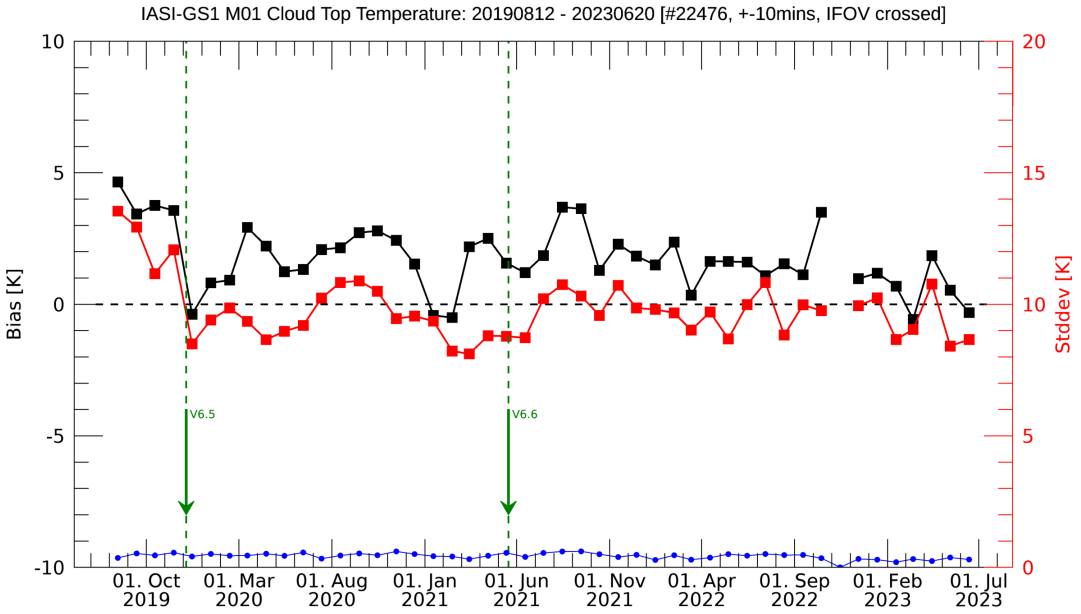

Figure 2.17: Long-Term Cloud Top Temperature Time Serie Bias and Standard Deviation of the differences, including fractional number of matchups per month (bottom blue) and #total-number-of-matchups (title). Global statistics with M01 IASI L2 from GS1.

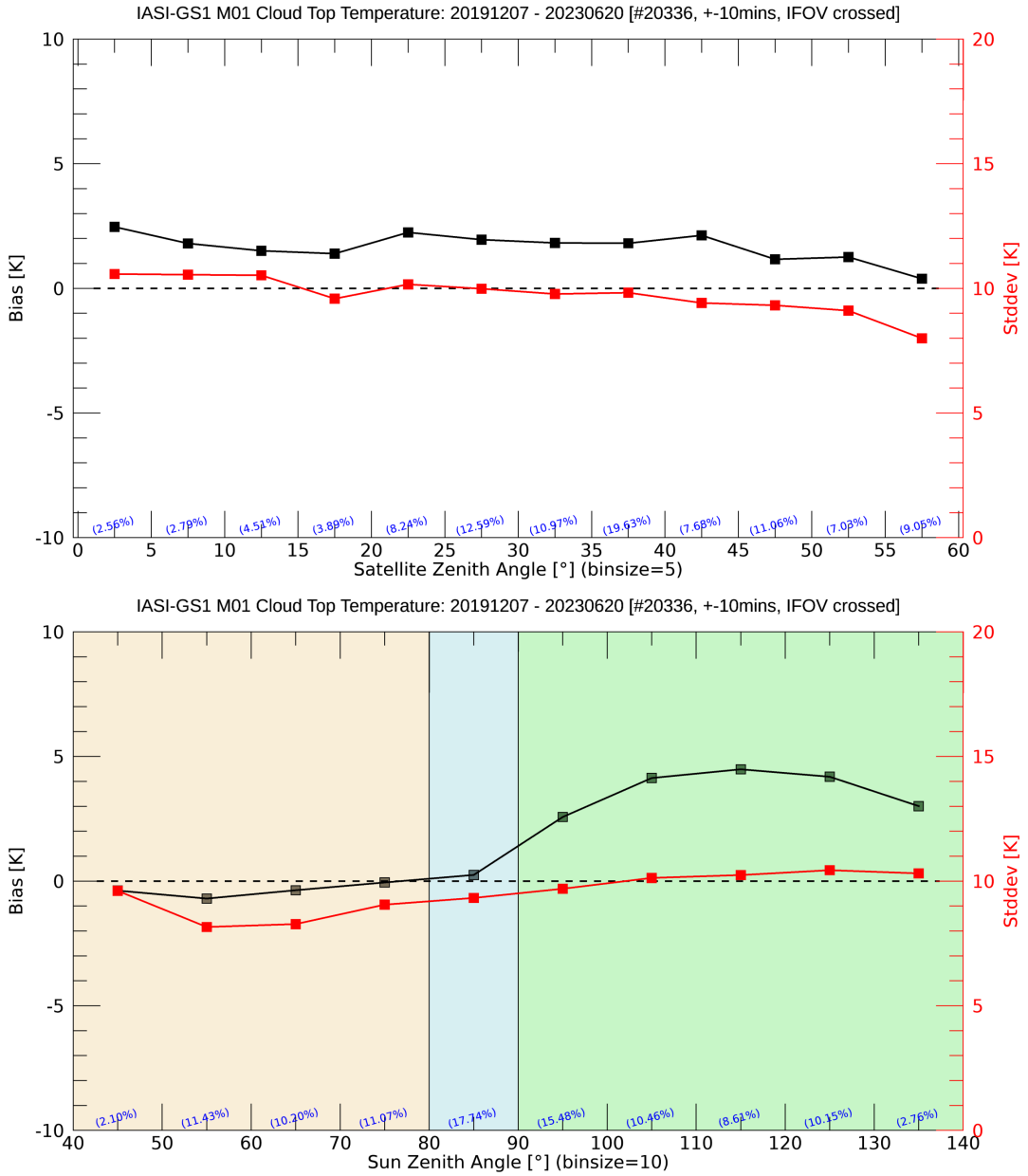

Figure 2.18: Satellite Zenith Angle (top) and Sun Zenith Angle (bottom) dependendencies on Cloud Top Temperature differences between IASI L2 and Caliop, Global statistics with M01 IASI L2 from GS1

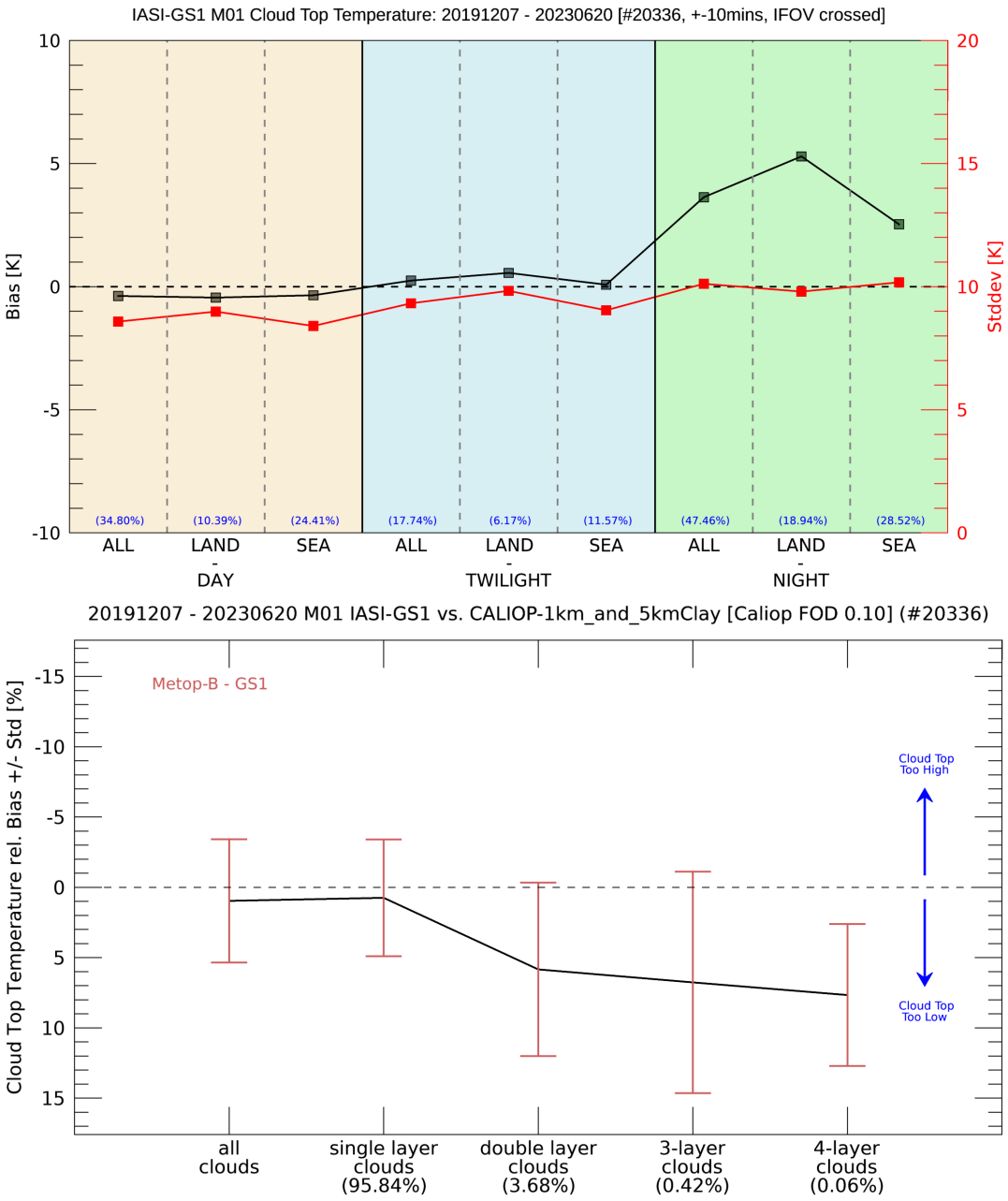

Figure 2.19: Cloud Top Temperature dependencies on Daytime/Land/Sea (top) and number of Caliop Cloud layer (bottom) between IASI L2 and Caliop, Global statistics with M01 IASI L2 from GS1

2.6 Cloud Type based statistics

The Caliop cloud products define 7 different cloud types (3 low, 2 mid and 2 high cloud types). In this section the performance of the IASI-L2 cloud top products are validated based on different cloud types!

2.6.1 Caliop Cloud Type Fraction Time Series

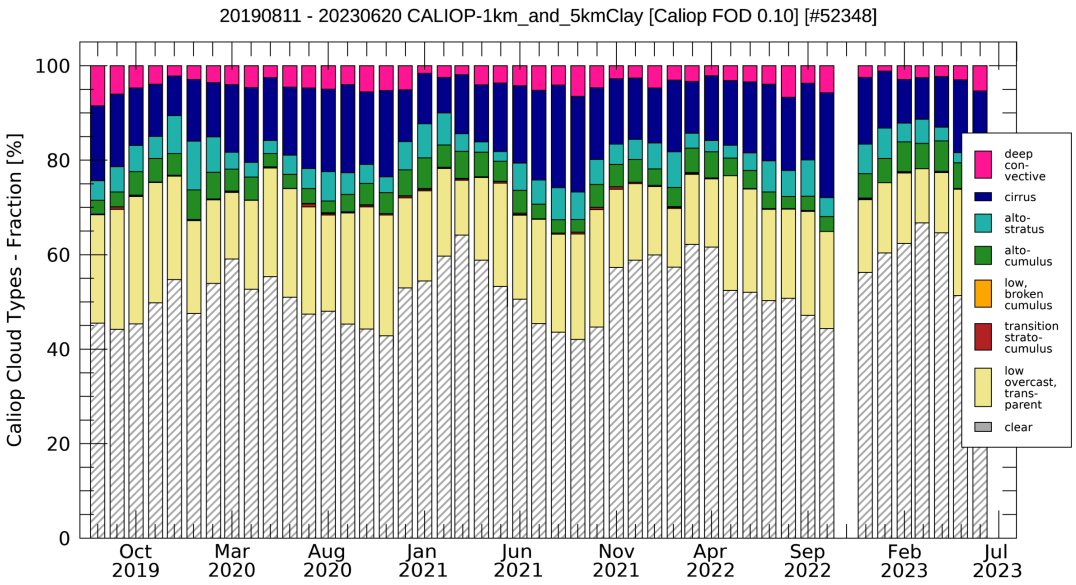

Figure 2.20: Long-Term Caliop Cloud Type Time Serie as fraction of cloud type appearance, including fractional number of matchups per month (bottom blue) and #total-number-of-matchups (title). Global collocations with M01 IASI L2 from GS1.

2.6.2 Cloud Mask

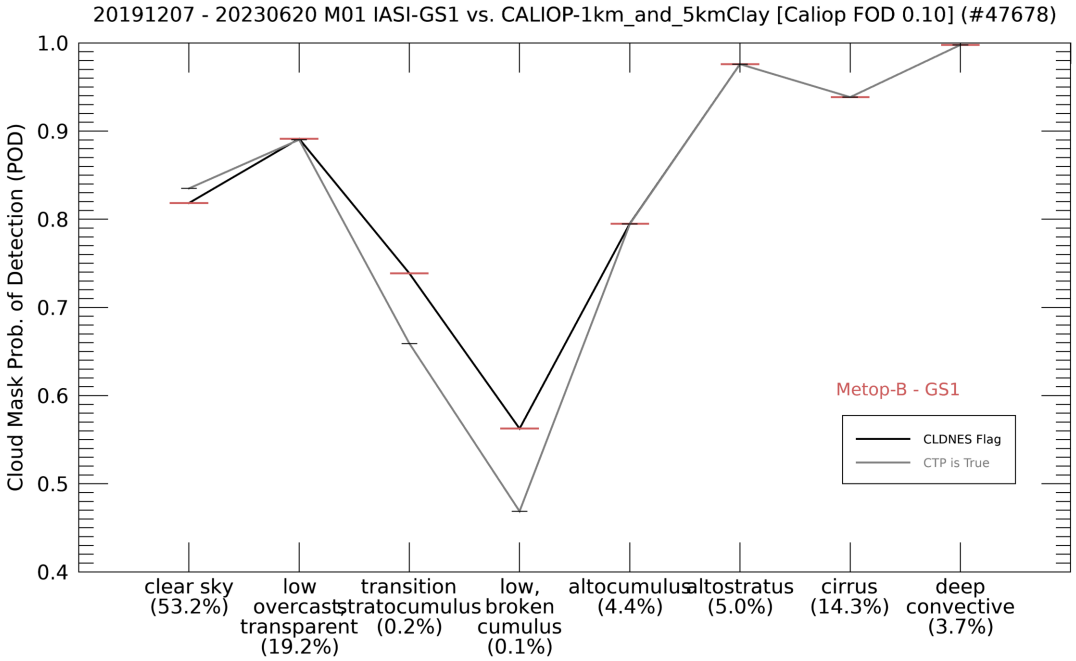

Figure 2.21: Cloud Type based statistics for Cloud Mask differences between IASI L2 and Caliop, Global statistics with M01 IASI L2 from GS1

2.6.3 Cloud Top Pressure

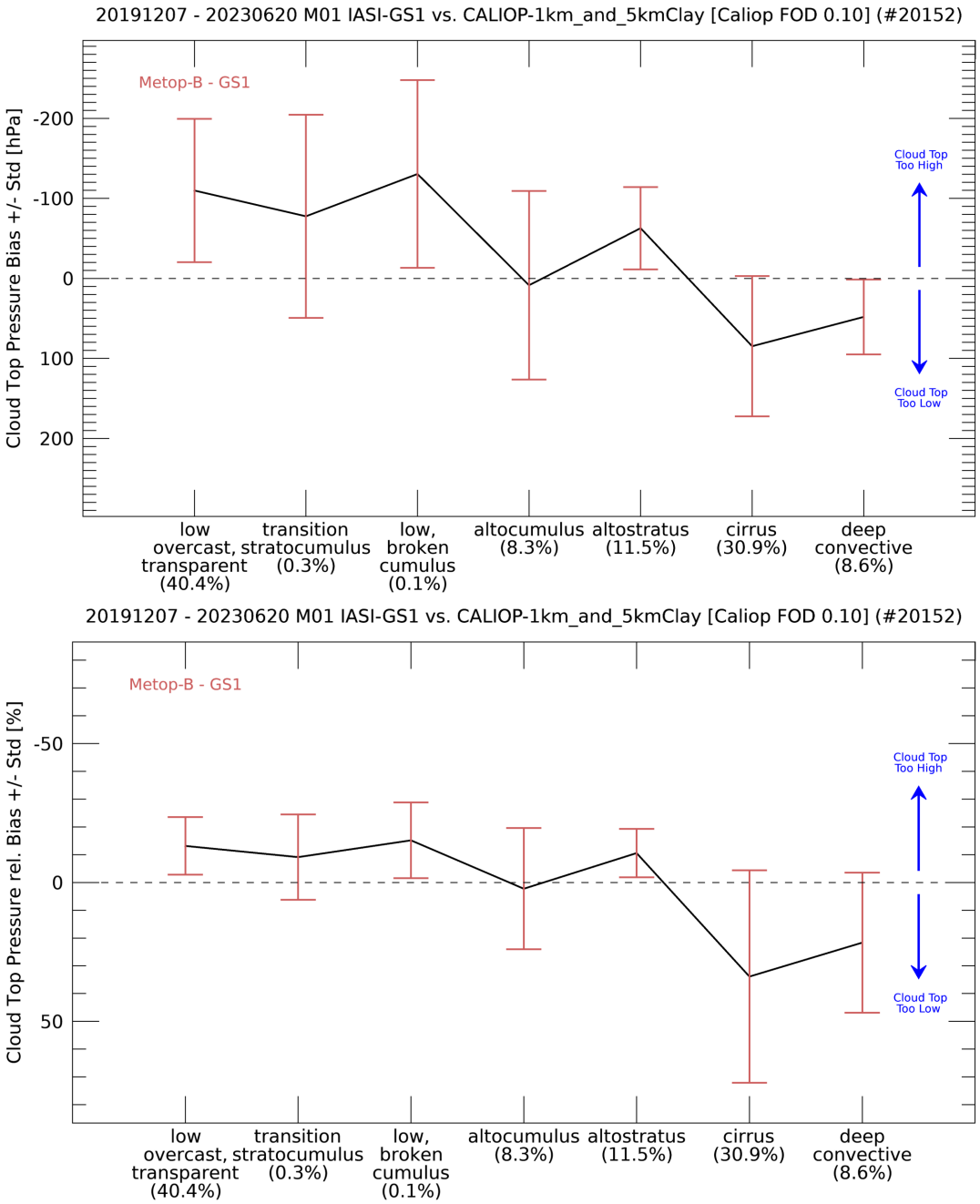

Figure 2.22: Cloud Type based statistics for Cloud Top Pressure absolute (top) and relative (bottom) differences between IASI L2 and Caliop, Global statistics with M01 IASI L2 from GS1

2.6.4 Cloud Top Temperature

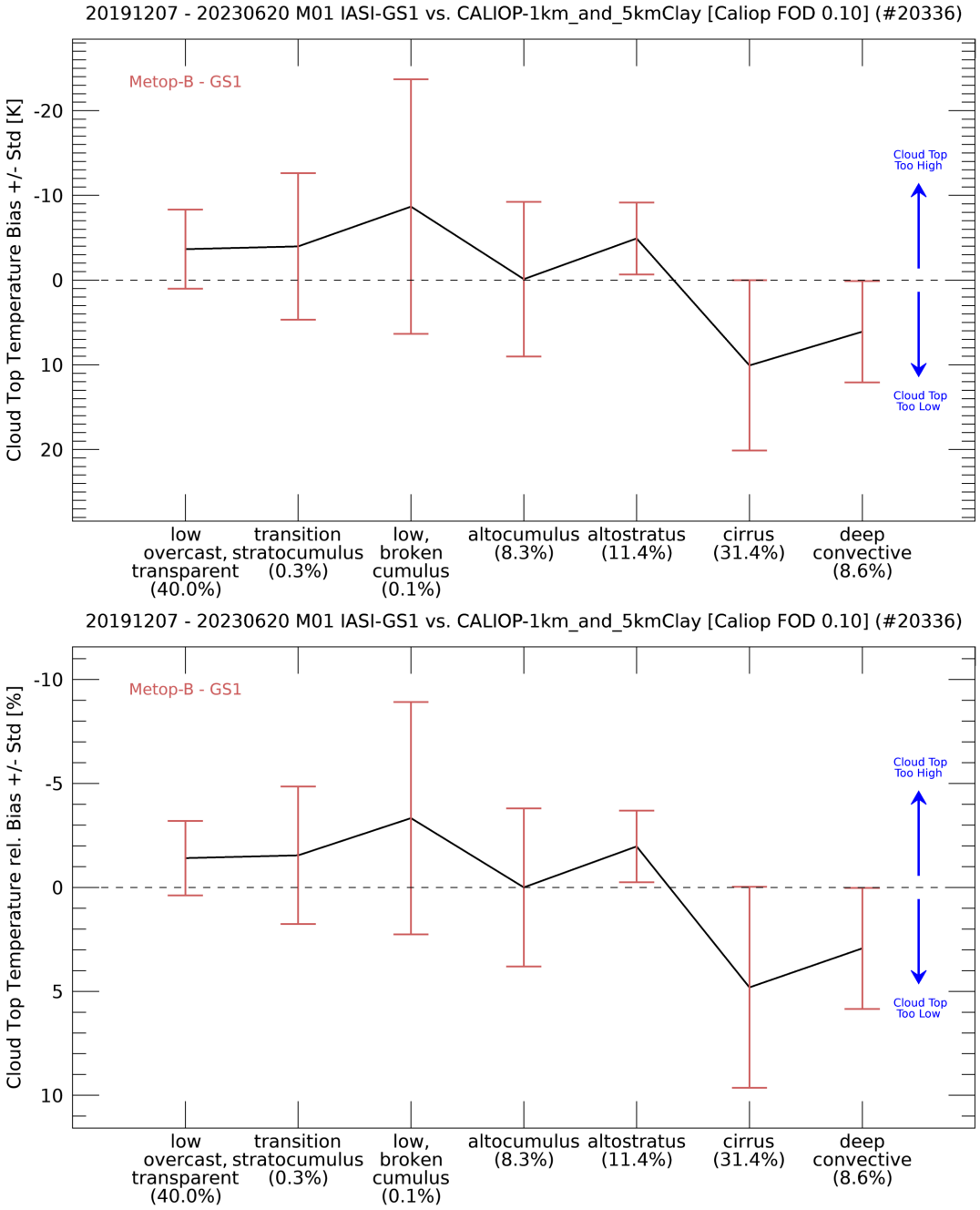

Figure 2.23: Cloud Type based statistics for Cloud Top Temperature absolute (top) and relative (bottom) differences between IASI L2 and Caliop, Global statistics with M01 IASI L2 from GS1

2.7 Cloud Phase vs Cloud Top Temperature

This section shows the liquid cloud fraction (LCF:= Fraction of clouds classified as liquid) for different cloud top temperatures (CTT, Binsize=10K). For CTT'S below -40 degree Celsius (*ice*) no liquid clouds should be present and the LCF should be 0%. In the transition zone between -40 degree celsius and 0 degree celsius (*supercooled*) the LCF should increase with increasing CTT and the LCF should eventually be 100% if the CTT's are greater 0 degree Celsius (*liquid*). Please note that mixed-typed cases have been removed from the IASI cloud phase product when compared to Caliop.

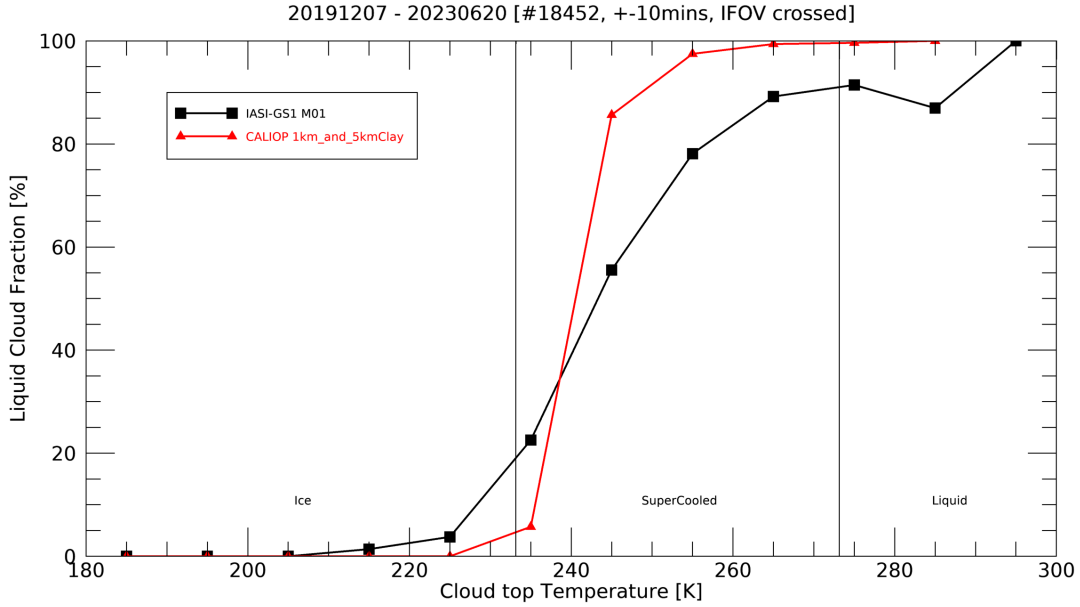

Figure 2.24: IASI (red) *vs* Caliop (black) Cloud Phase vs Cloud Top Temperature. Global statistics with M01 IASI L2 from GS1

3 NORTHERN HEMISPHERE

3.1 Matchups

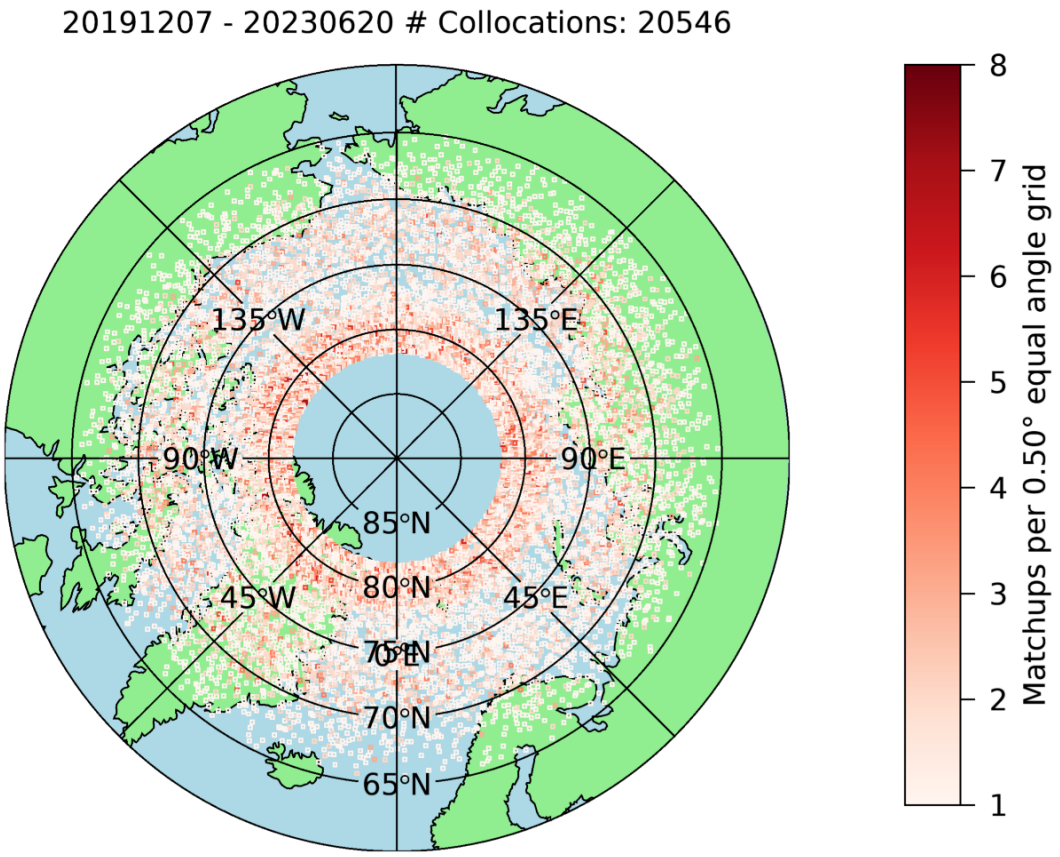

Figure 3.1: Northern Hemisphere Matchups between Calipso and M01 IASI L2 from GS1

3.2 Cloud Mask

The Calipso Cloud products provide a binary cloud mask, clear or cloudy. In order to compare both masks, the IASI-L2 cloud mask was set to binary by setting CLDNES Flag values 1 and 2 to clear and values 3 and 4 to cloudy! The collocation homogeneity criteria (Section 1.3) makes sure that all caliop pixel crossing the IASI IFOV are either clear or cloudy and not mixed!

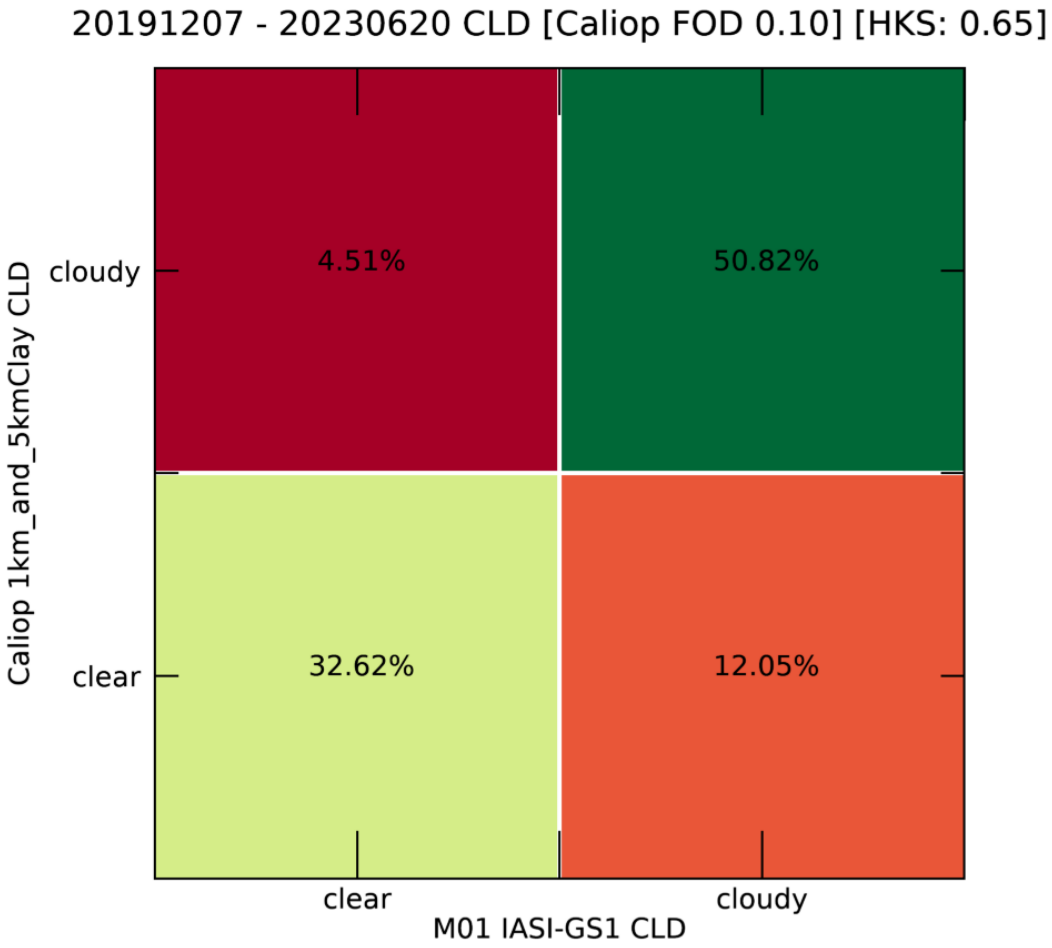

Figure 3.2: Long-Term Cloud Mask contingency table incl. Hanssen Kuiper's skill score. Northern Hemisphere statistics with M01 IASI L2 from GS1

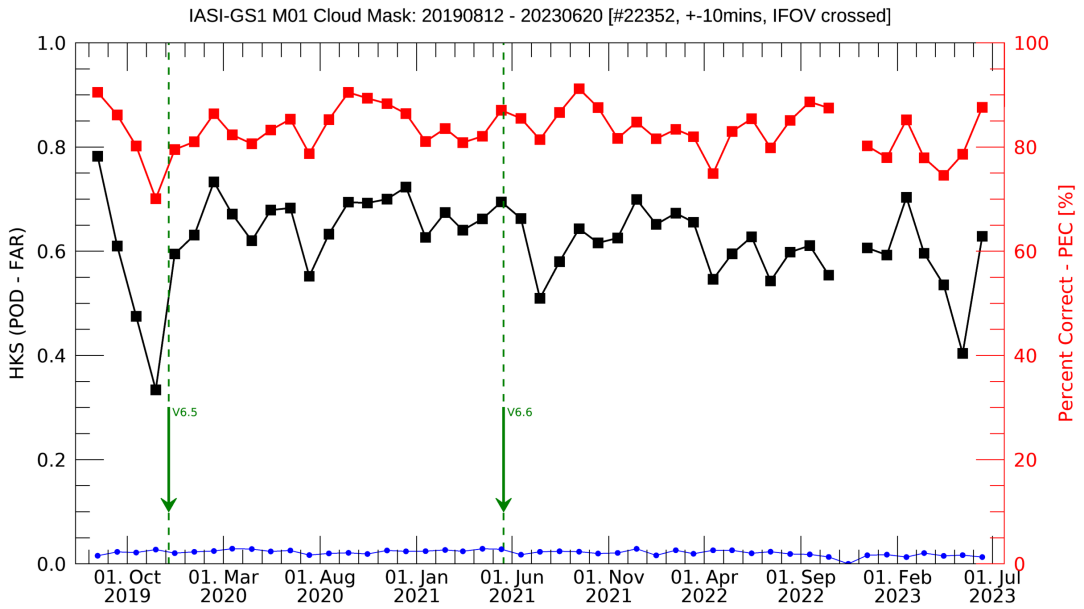

Figure 3.3: Long-Term Cloud Mask Time Serie for Hanssen Kuiper's skill score and Percent Correct, including fractional number of matchups per month (bottom blue) and #total-number-of-matchups (title). Northern Hemisphere statistics with M01 IASI L2 from GS1.

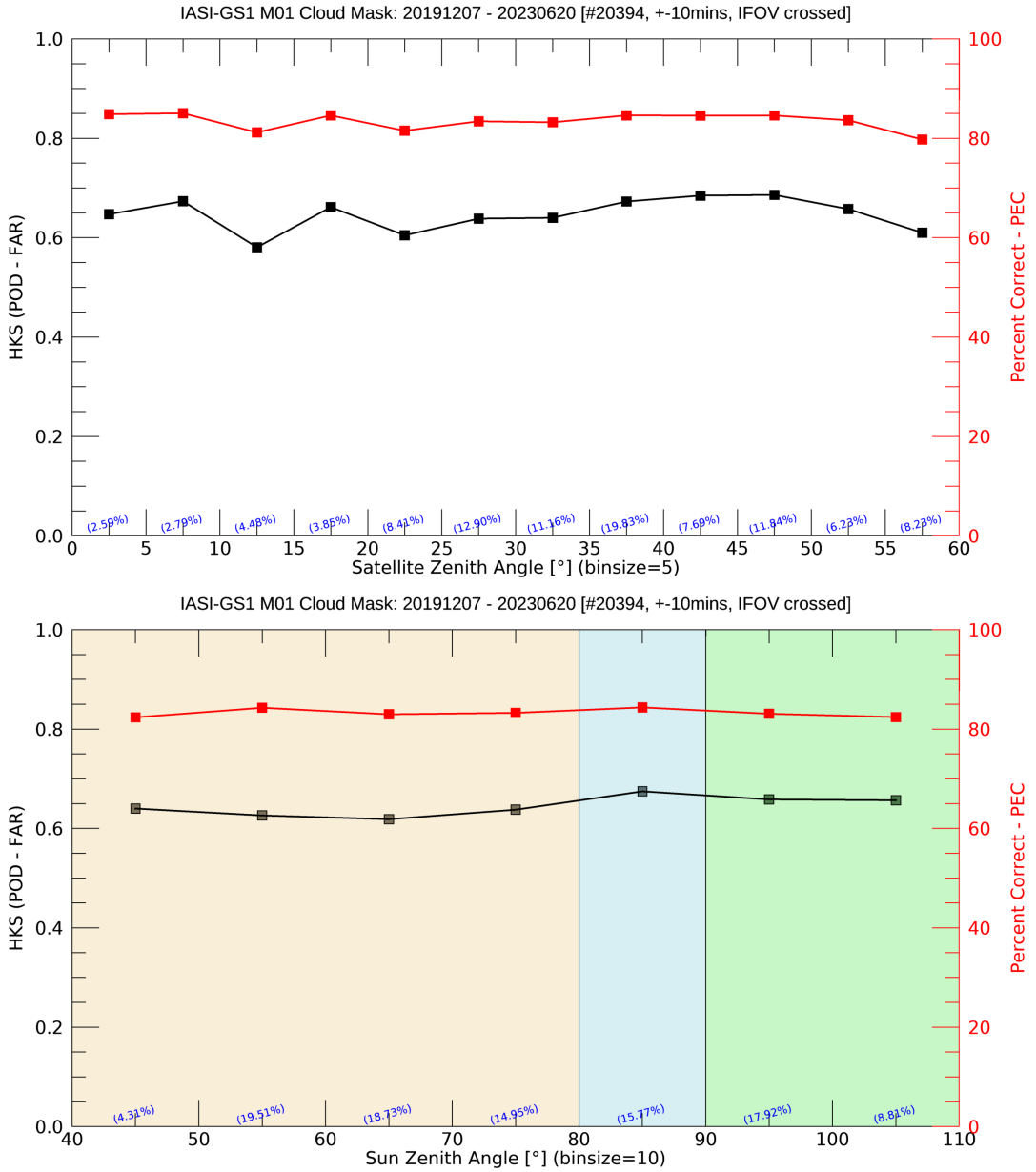

Figure 3.4: Satellite Zenith Angle (top) and Sun Zenith Angle (bottom) dependendencies on Cloud Mask differences between IASI L2 and Caliop, Northern Hemisphere statistics with M01 IASI L2 from GS1

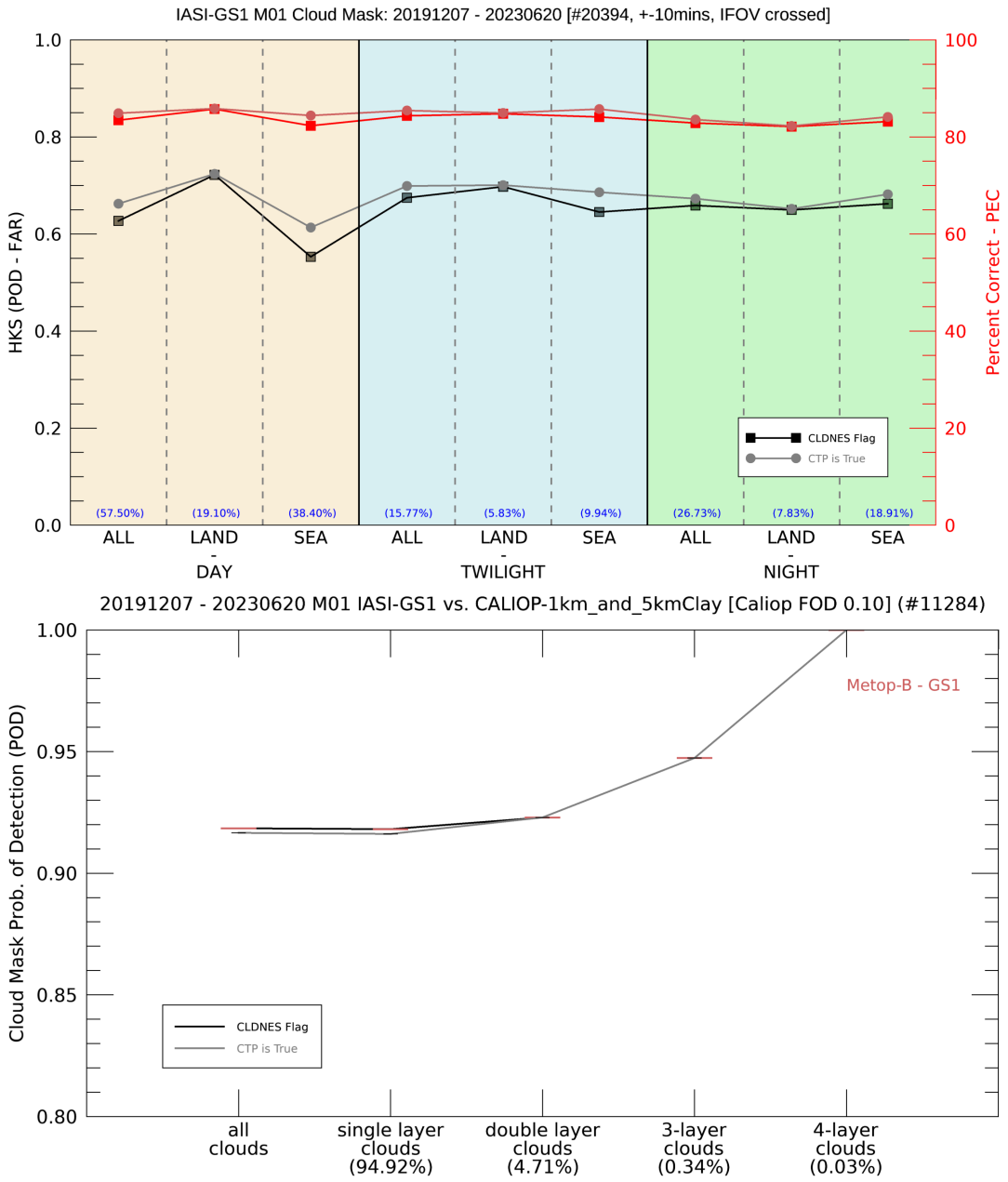

Figure 3.5: Cloud Mask dependencies on Daytime/Land/Sea (top) and number of Caliop Cloud layer (bottom) between IASI L2 and Caliop, Northern Hemisphere statistics with M01 IASI L2 from GS1

3.3 Cloud Phase

The Calipso Cloud products provides 3 different states to describe the thermodynamic phase of clouds, 1: randomly oriented ice, 2: horizontally oriented ice and 3: water. The IASI-L2 provides the classification liquid, ice and mixed. In order to compare Caliop to the IASI-L2 cloud phase product both masks were set to a binary phase mask by combining the 2 ice phases of Caliop into a single *ice* class and removing the mixed statement from the IASI-L2 products. The homogeneity criteria (Section 1.3) makes sure that all caliop pixel crossing the IASI IFOV are either liquid or ice and not mixed!

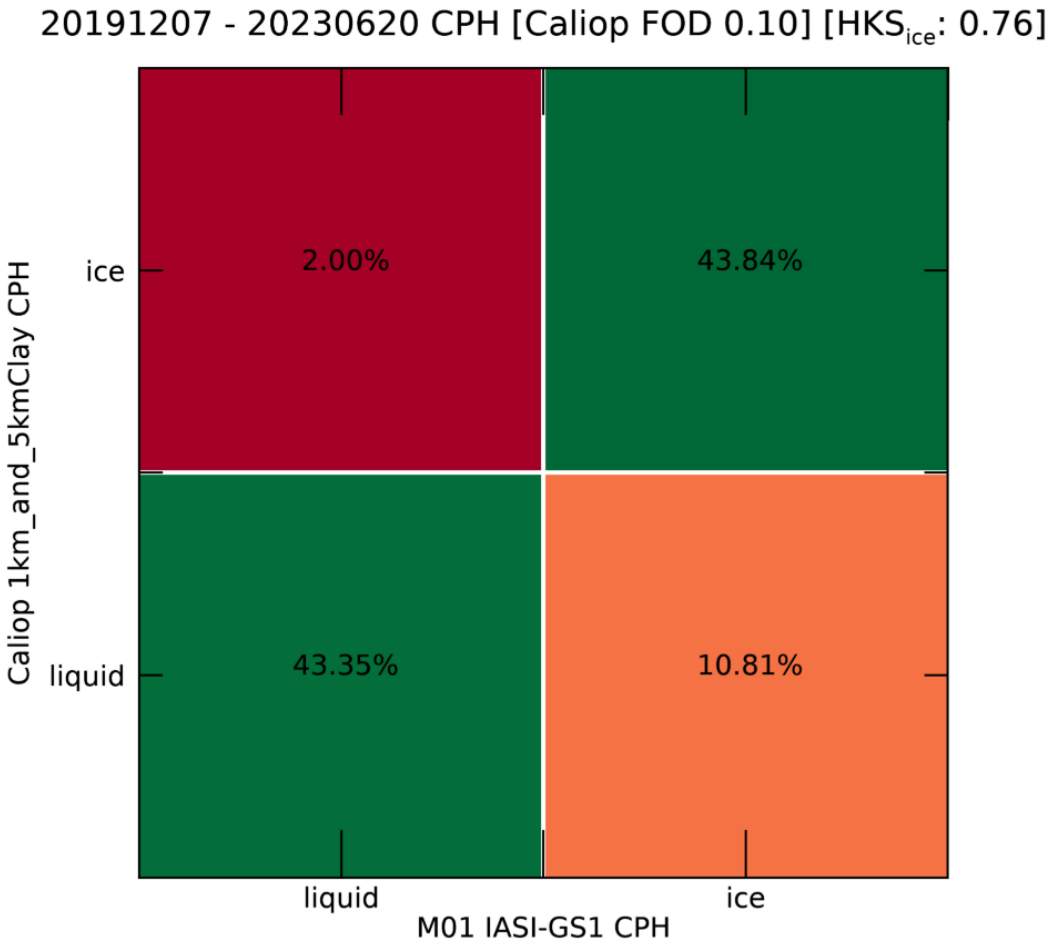

Figure 3.6: Long-Term Cloud Mask contingency table incl. Hanssen Kuiper's skill score. Northern Hemisphere statistics with M01 IASI L2 from GS1

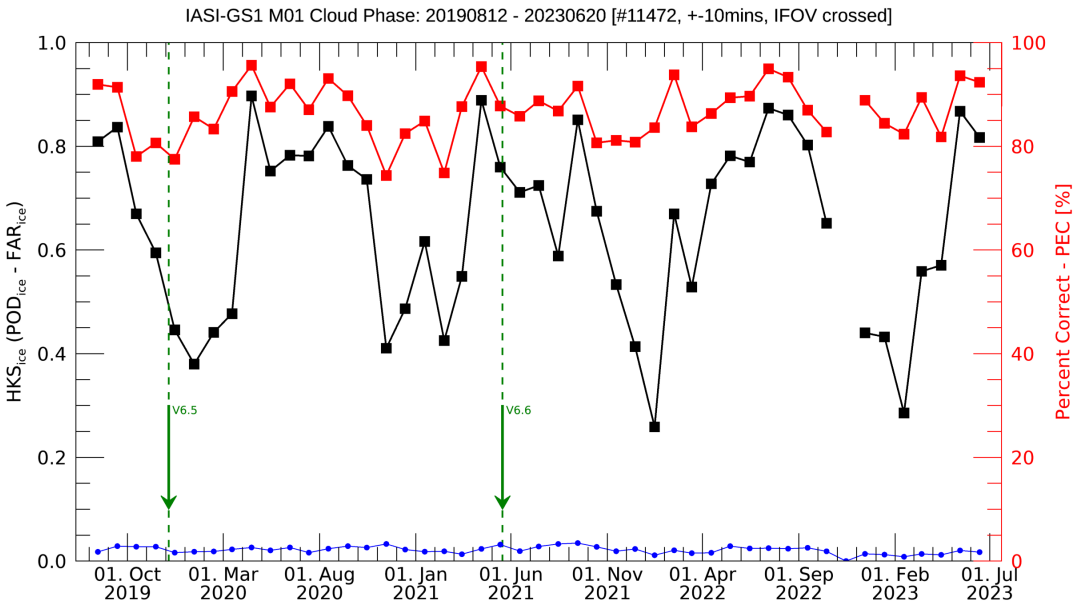

Figure 3.7: Long-Term Cloud Phase Time Serie for Hanssen Kuiper's skill score and Percent Correct, including fractional number of matchups per month (bottom blue) and #total-number-of-matchups (title). Northern Hemisphere statistics with M01 IASI L2 from GS1.

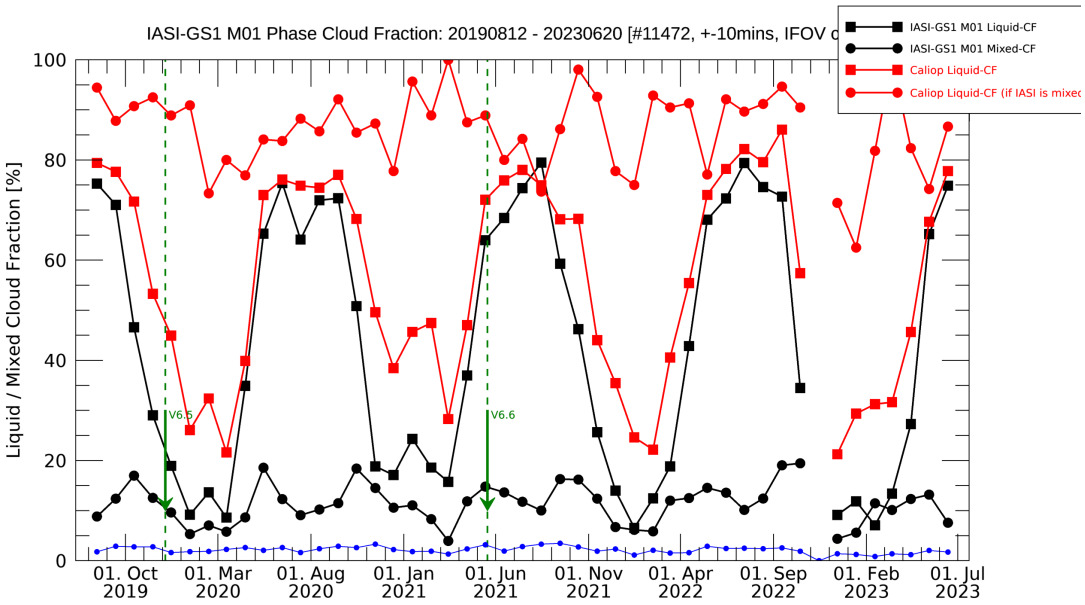

Figure 3.8: Long-Term Cloud Phase Time Serie for Liquid and Mixed cloud fraction in percent, including fractional number of matchups per month (bottom blue) and #total-number-of-matchups (title). Northern Hemisphere statistics with M01 IASI L2 from GS1.

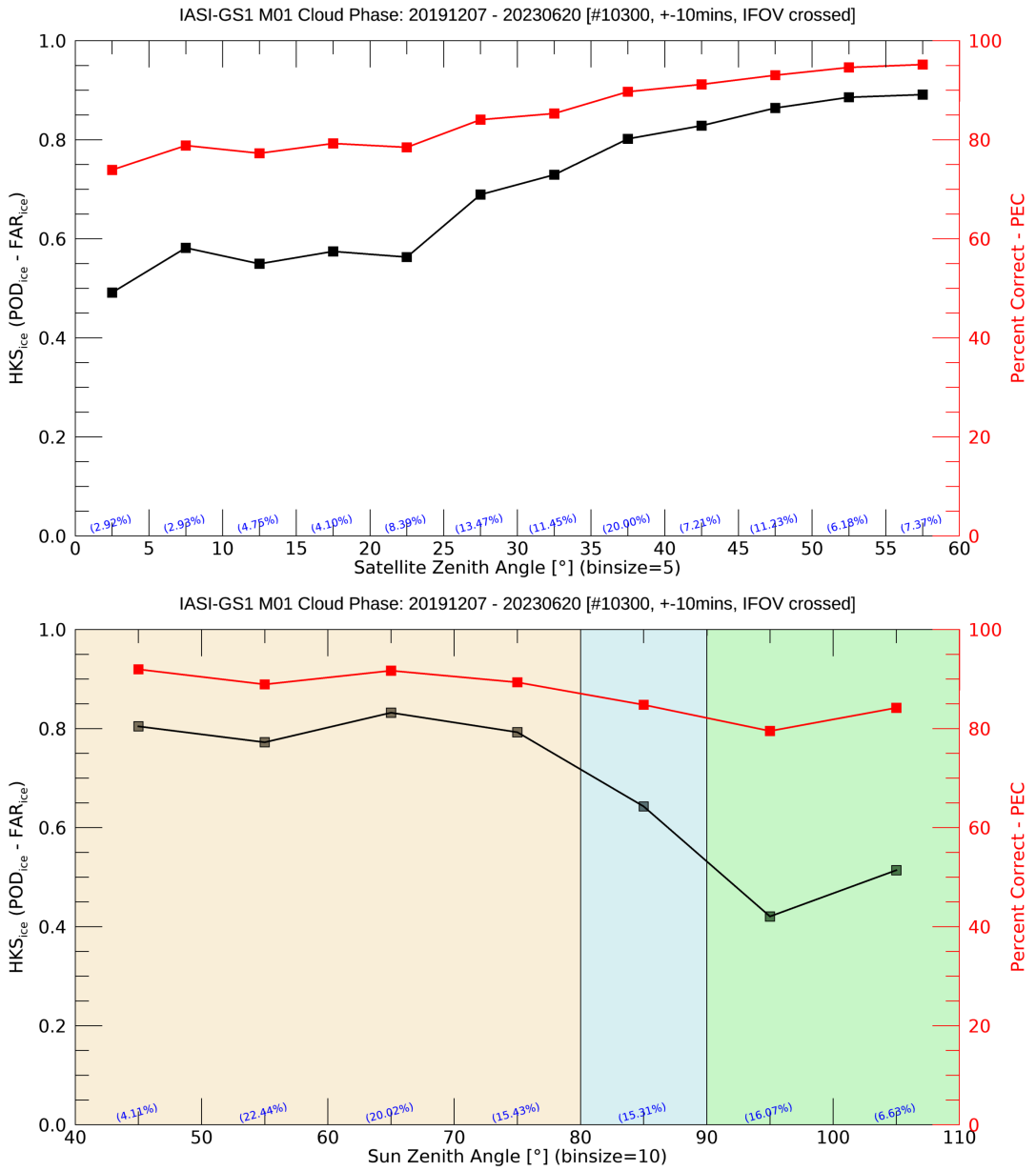

Figure 3.9: Satellite Zenith Angle (top) and Sun Zenith Angle (bottom) dependencies on Cloud Phase differences between IASI L2 and Caliop, Northern Hemisphere statistics with M01 IASI L2 from GS1

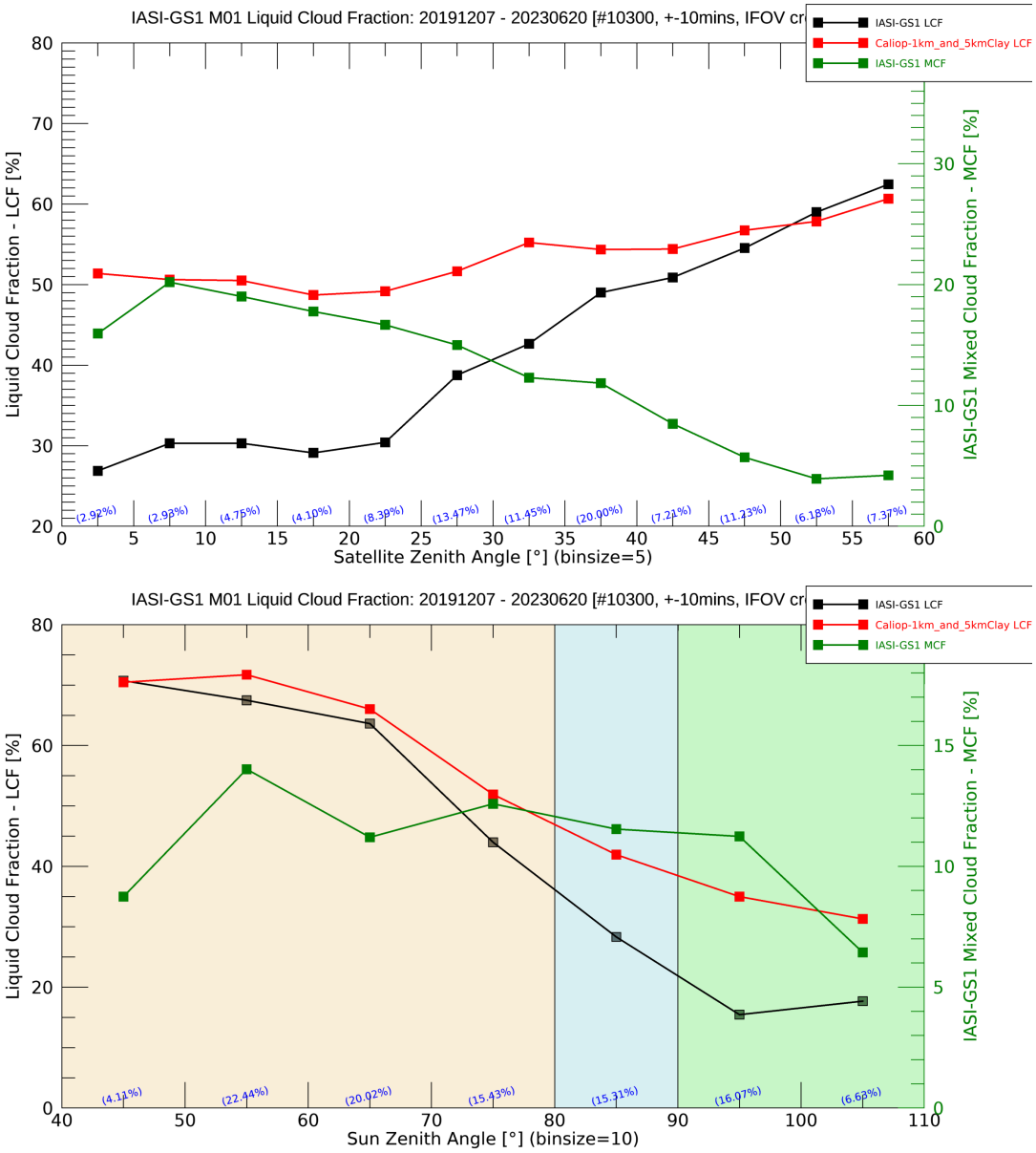

Figure 3.10: Satellite Zenith Angle (top) and Sun Zenith Angle (bottom) dependendencies on Liquid and Mixed Cloud Fraction for IASI L2 and Caliop, Northern Hemisphere statistics with M01 IASI L2 from GS1

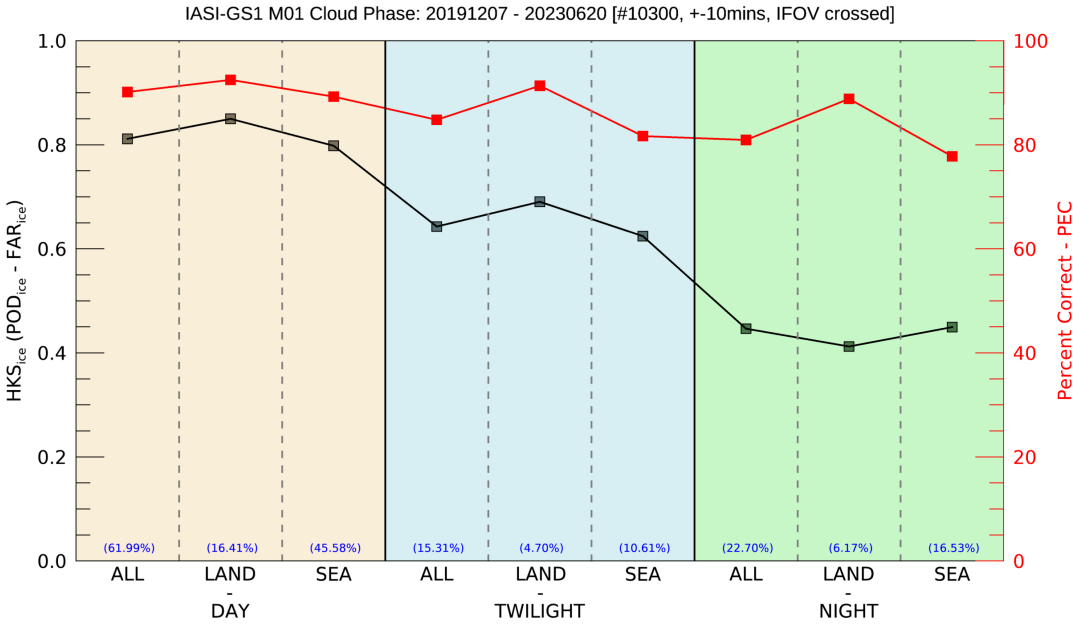

Figure 3.11: Cloud Phase dependencies on Daytime/Land/Sea between IASI L2 and Caliop, Northern Hemisphere statistics with M01 IASI L2 from GS1

3.4 Cloud Top Pressure

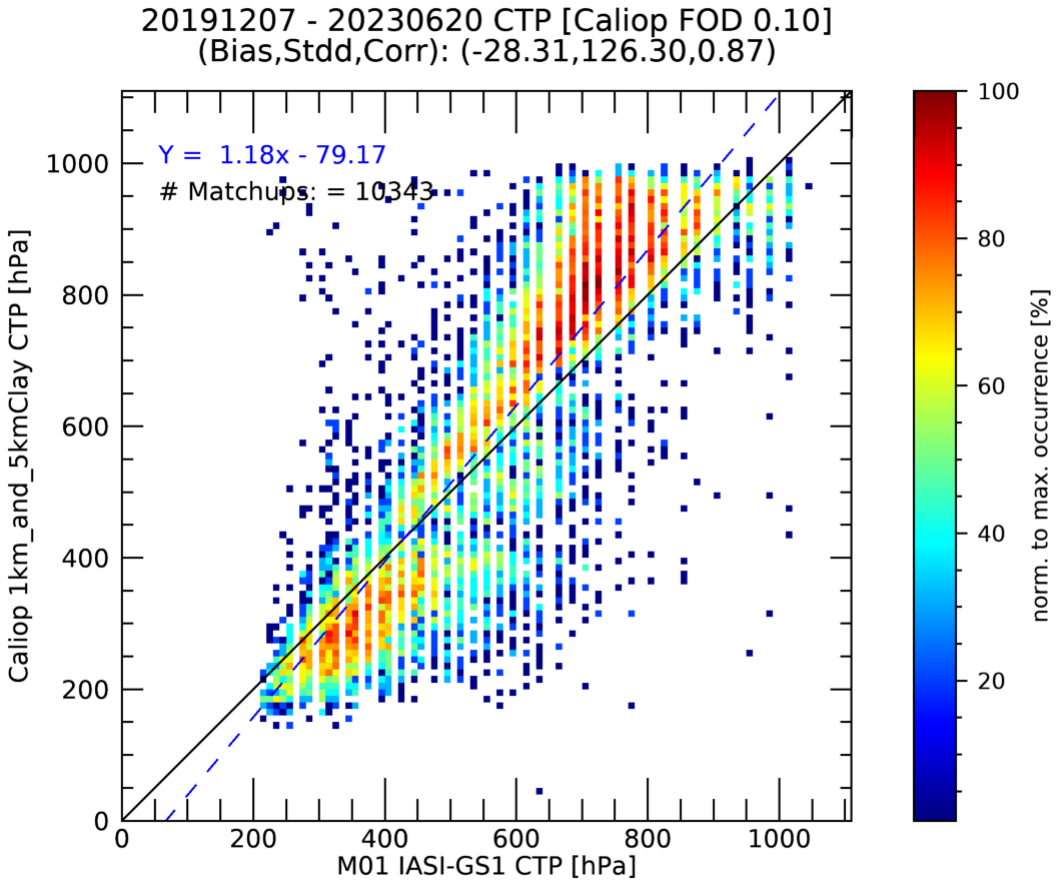

Figure 3.12: 2D Histograms for Cloud Top Pressure between IASI L2 and Caliop, Northern Hemisphere statistics with M01 IASI L2 from GS1

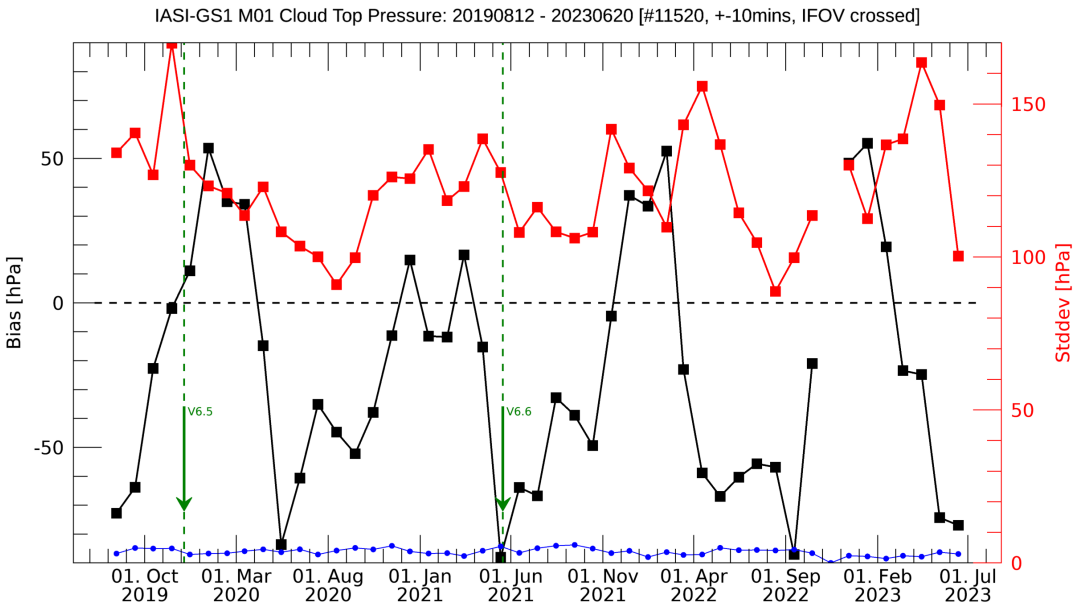

Figure 3.13: Long-Term Cloud Top Pressure Time Serie Bias and Standard Deviation of the differences, including fractional number of matchups per month (bottom blue) and #total-number-of-matchups (title). Northern Hemisphere statistics with M01 IASI L2 from GS1.

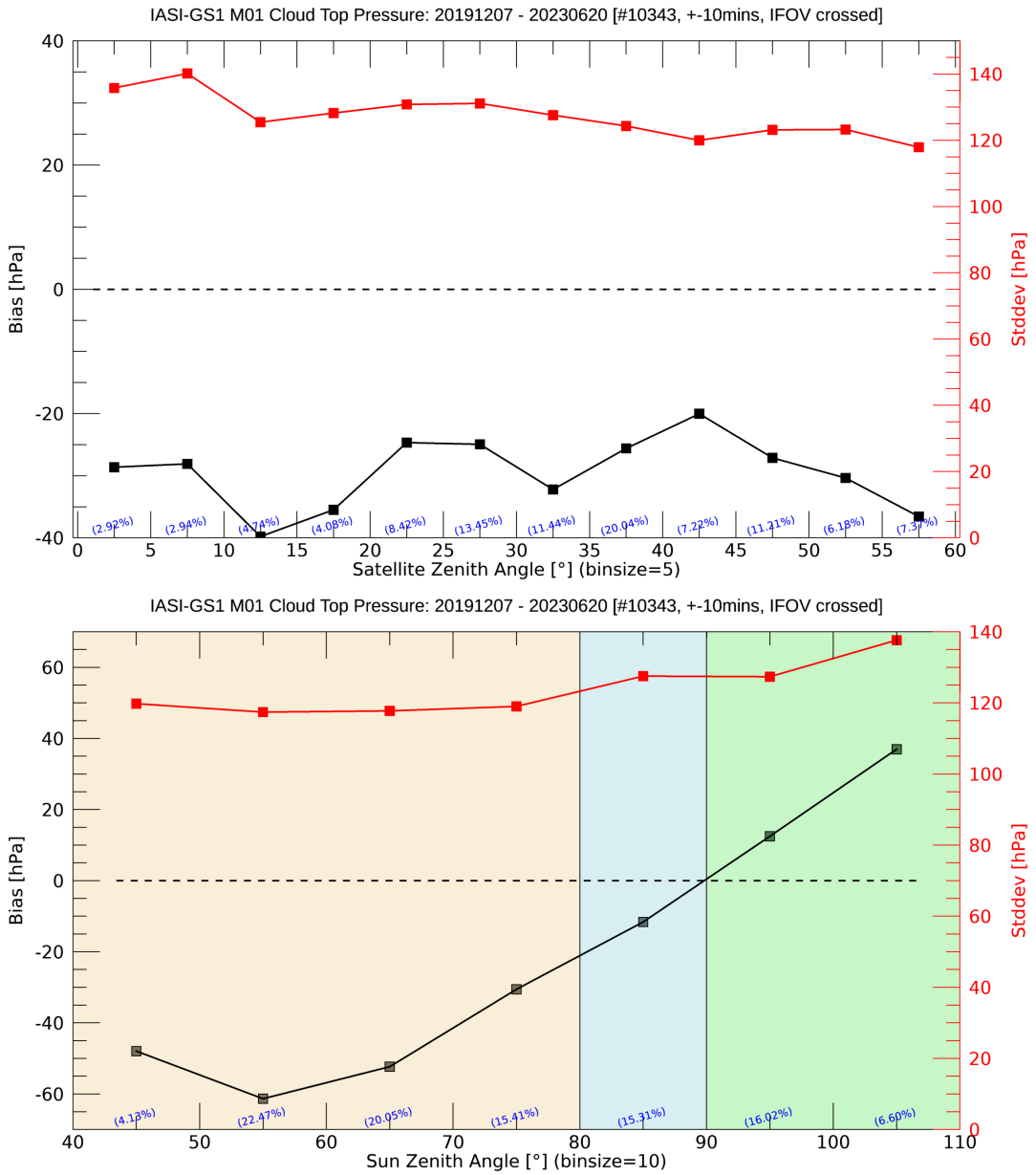

Figure 3.14: Satellite Zenith Angle (top) and Sun Zenith Angle (bottom) dependendencies on Cloud Top Pressure differences between IASI L2 and Caliop, Northern Hemisphere statistics with M01 IASI L2 from GS1

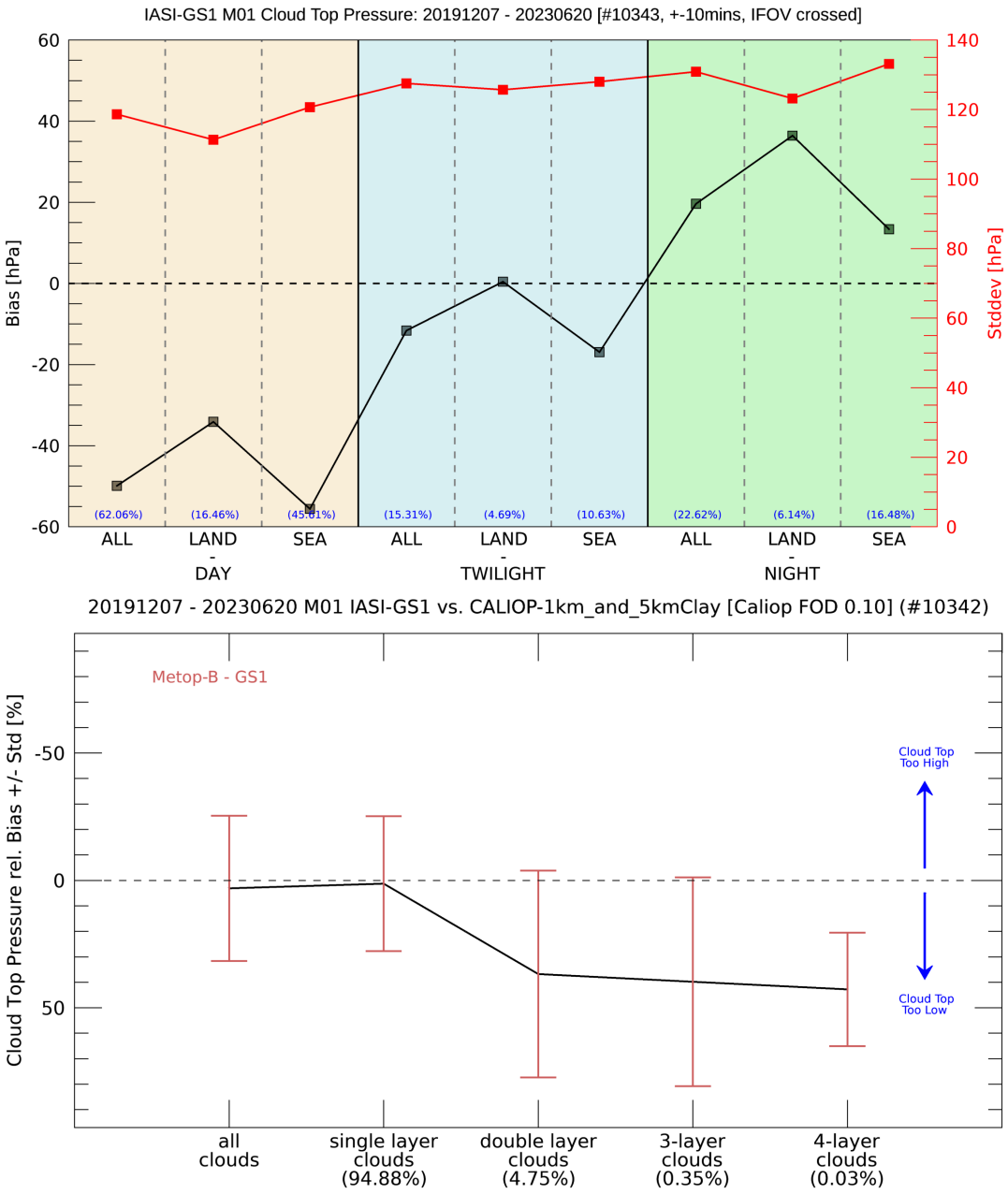

Figure 3.15: Cloud Top Pressure dependencies on Daytime/Land/Sea (top) and number of Caliop Cloud layer (bottom) between IASI L2 and Caliop, Northern Hemisphere statistics with M01 IASI L2 from GS1

3.5 Cloud Top Temperature

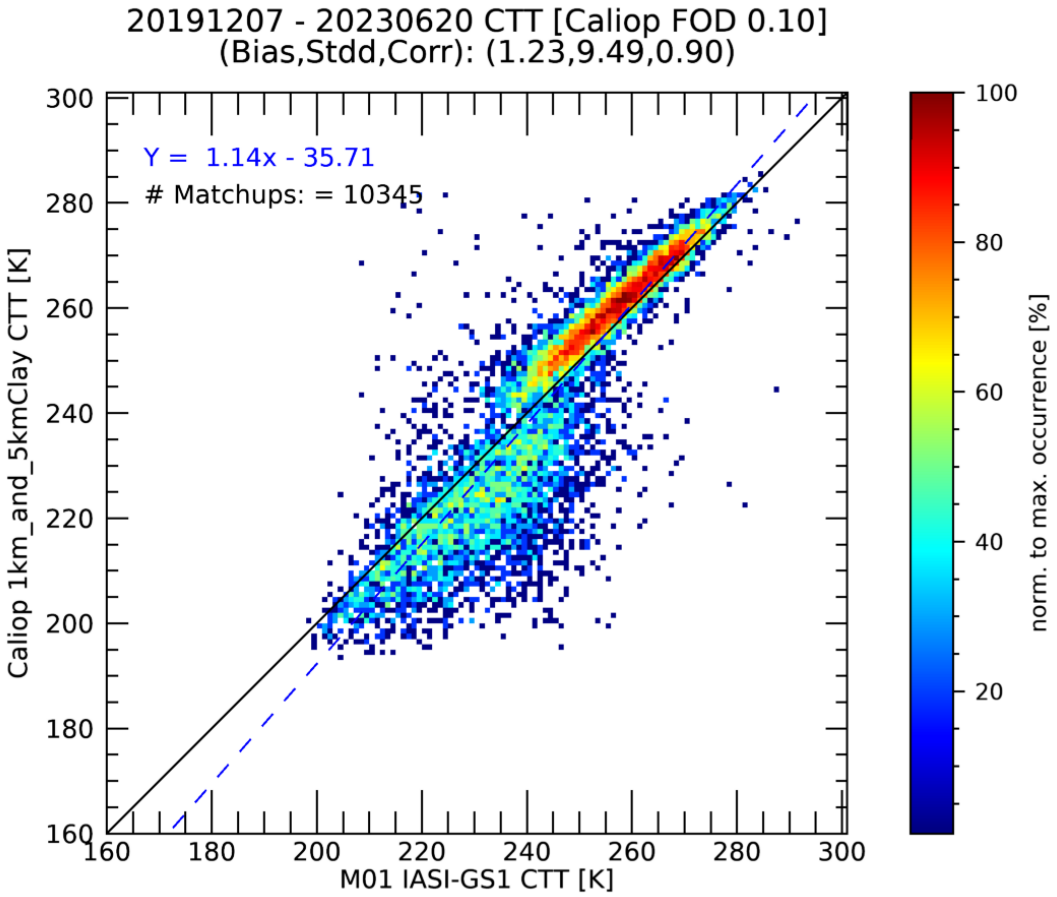

Figure 3.16: 2D Histograms for Cloud Top Temperature between IASI L2 and Caliop, Northern Hemisphere statistics with M01 IASI L2 from GS1

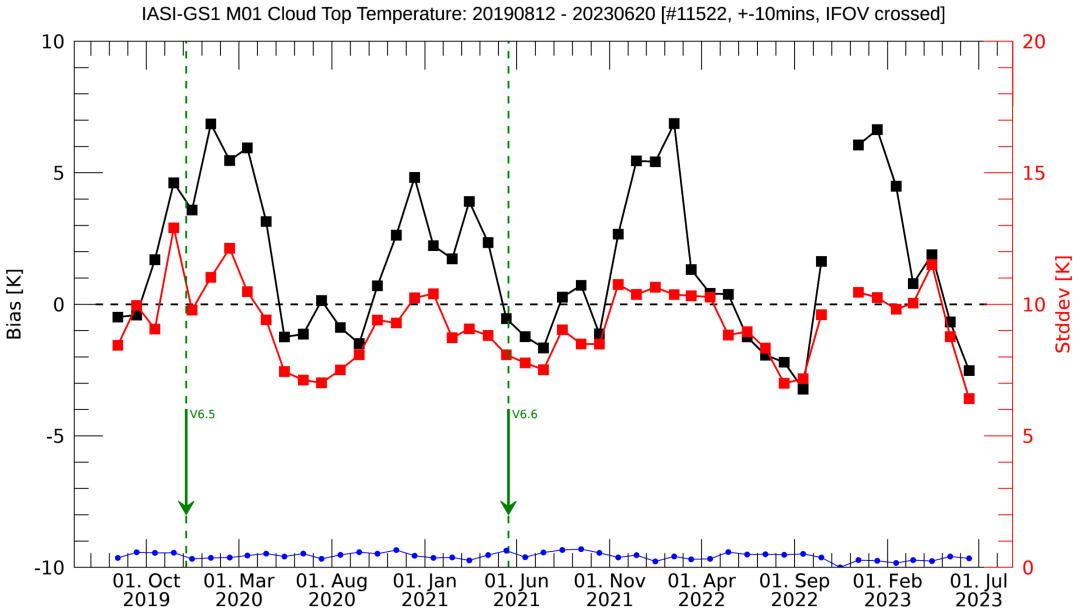

Figure 3.17: Long-Term Cloud Top Temperature Time Serie Bias and Standard Deviation of the differences, including fractional number of matchups per month (bottom blue) and #total-number-of-matchups (title). Northern Hemisphere statistics with M01 IASI L2 from GS1.

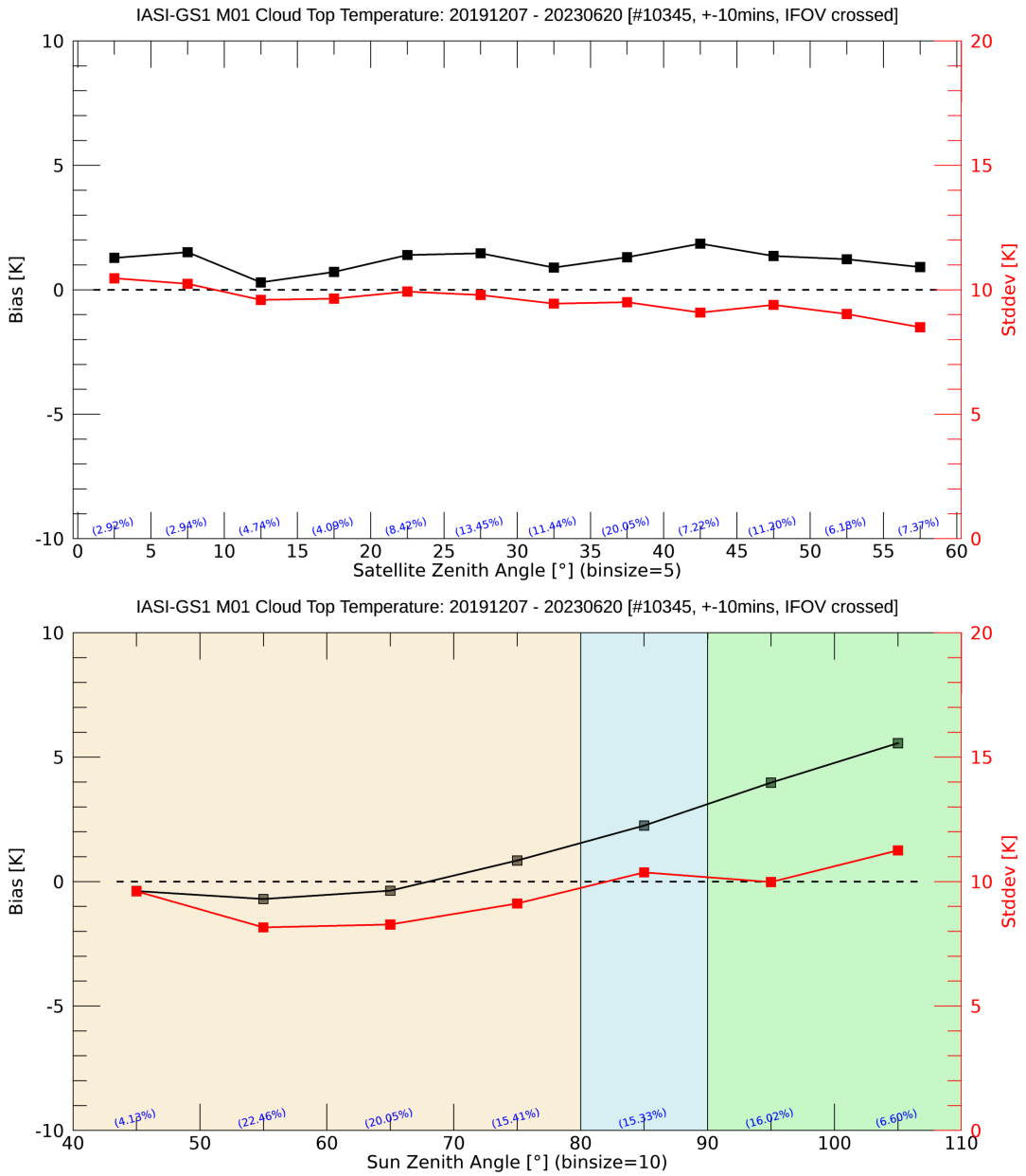

Figure 3.18: Satellite Zenith Angle (top) and Sun Zenith Angle (bottom) dependendencies on Cloud Top Temperature differences between IASI L2 and Caliop, Northern Hemisphere statistics with M01 IASI L2 from GS1

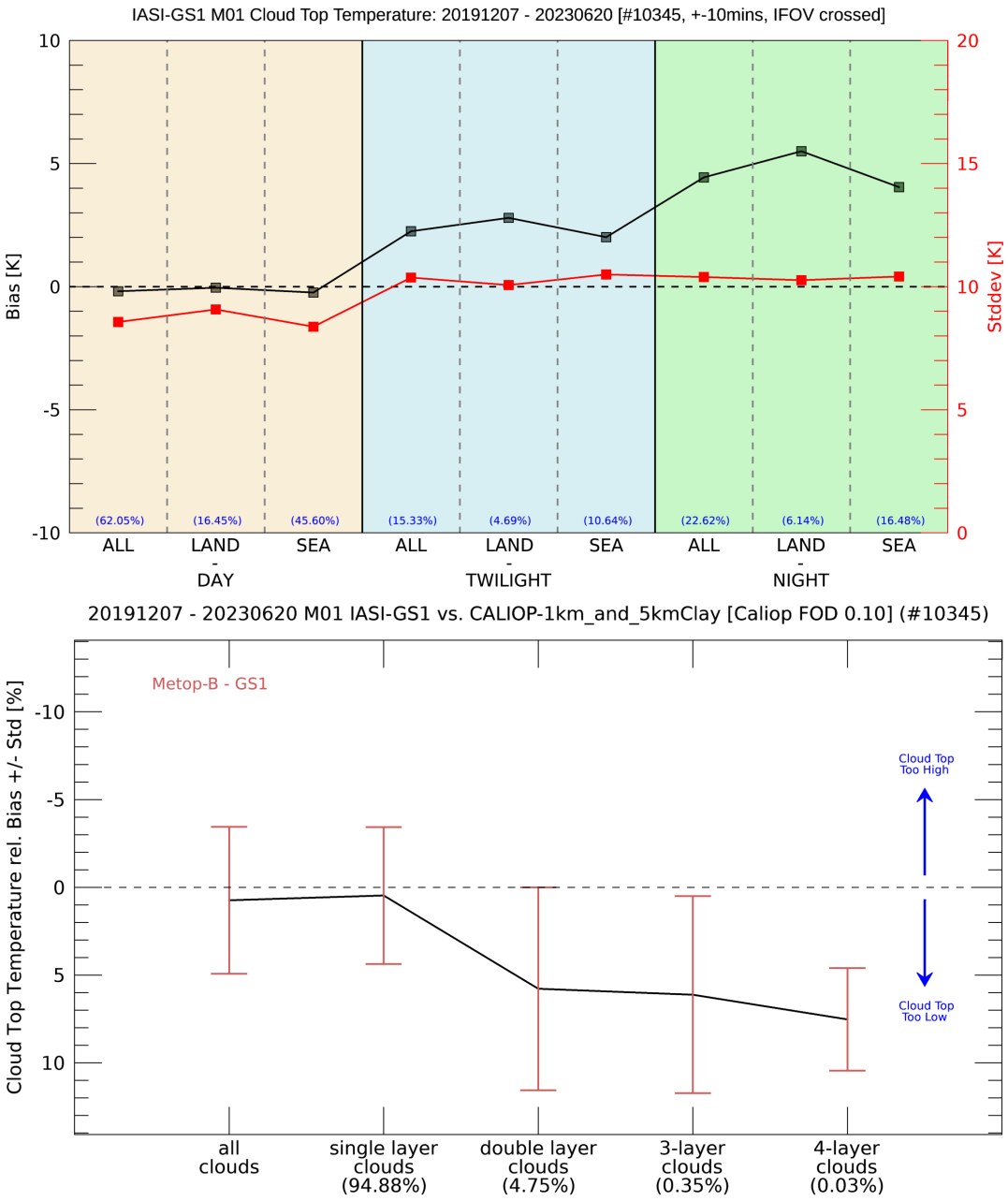

Figure 3.19: Cloud Top Temperature dependencies on Daytime/Land/Sea (top) and number of Caliop Cloud layer (bottom) between IASI L2 and Caliop, Northern Hemisphere statistics with M01 IASI L2 from GS1

3.6 Cloud Type based statistics

The Caliop cloud products define 7 different cloud types (3 low, 2 mid and 2 high cloud types). In this section the performance of the IASI-L2 cloud top products are validated based on different cloud types!

3.6.1 Caliop Cloud Type Fraction Time Series

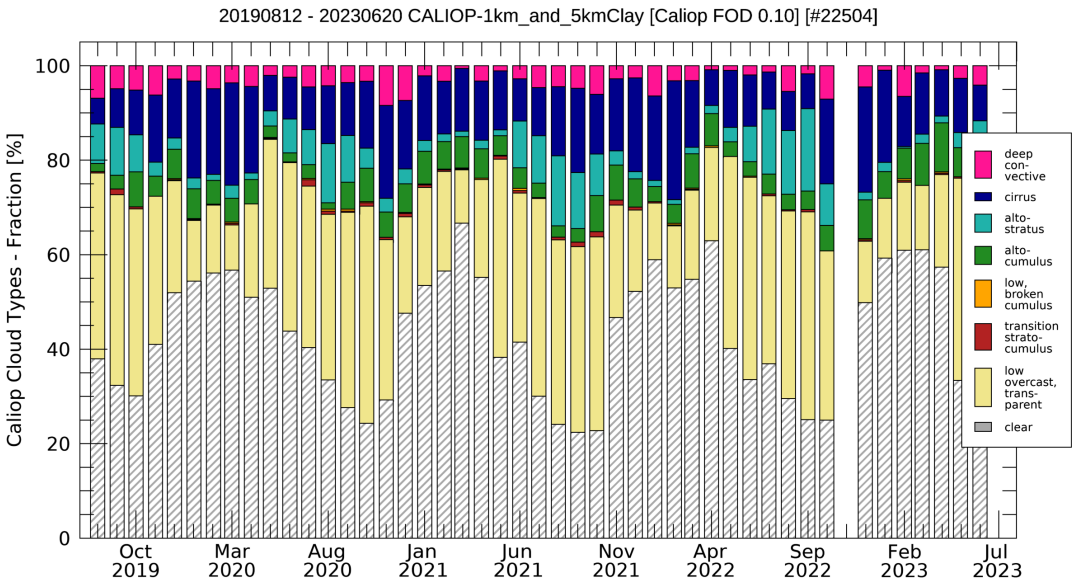

Figure 3.20: Long-Term Caliop Cloud Type Time Serie as fraction of cloud type appearance, including fractional number of matchups per month (bottom blue) and #total-number-of-matchups (title). Northern Hemisphere collocations with M01 IASI L2 from GS1.

3.6.2 Cloud Mask

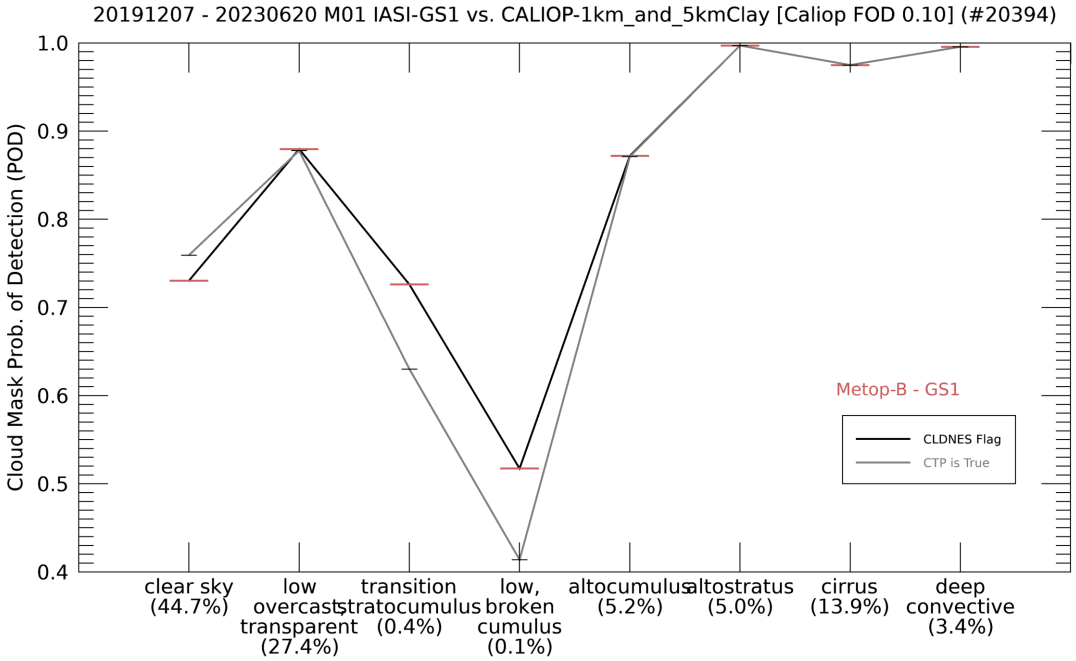

Figure 3.21: Cloud Type based statistics for Cloud Mask differences between IASI L2 and Caliop, Northern Hemisphere statistics with M01 IASI L2 from GS1

3.6.3 Cloud Top Pressure

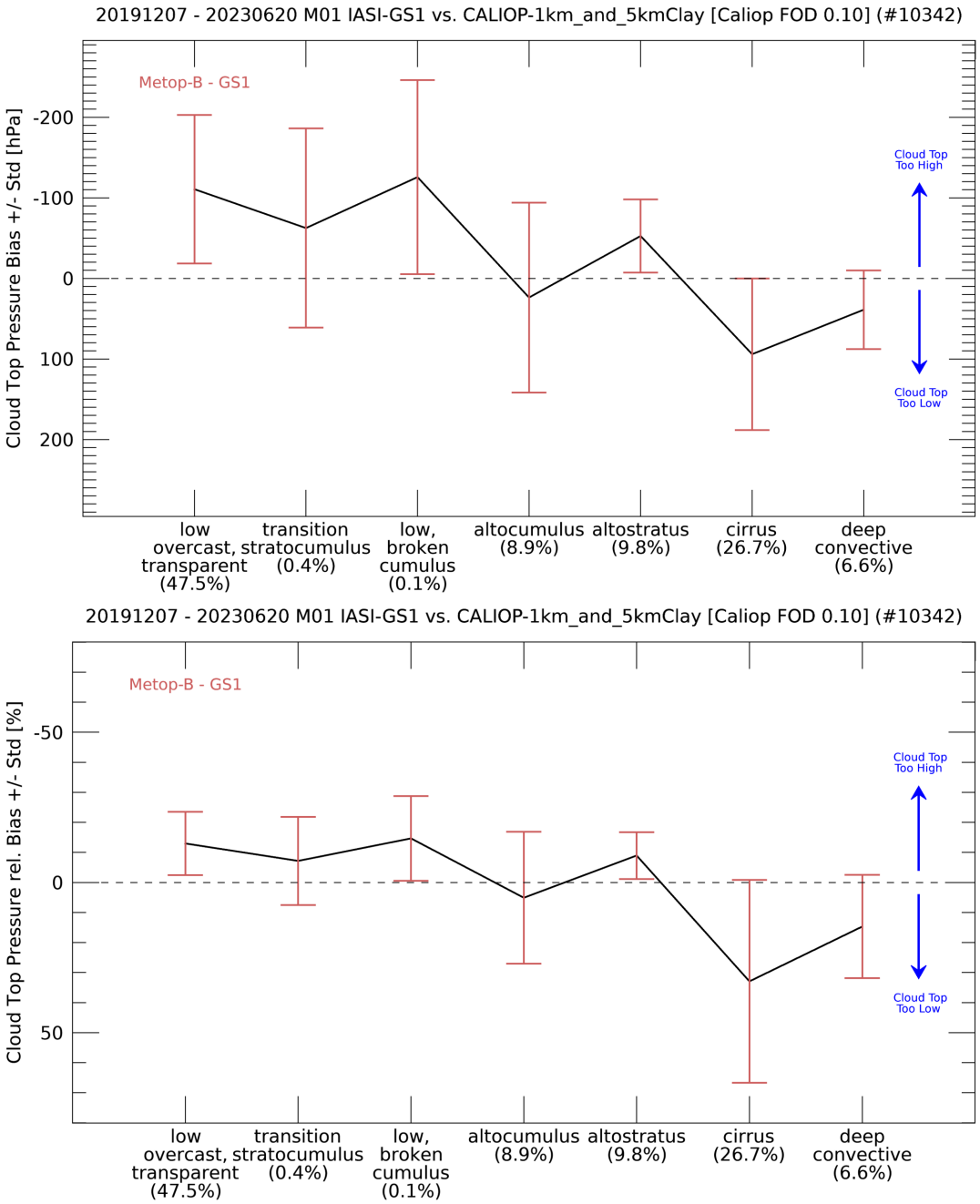

Figure 3.22: Cloud Type based statistics for Cloud Top Pressure absolute (top) and relative (bottom) differences between IASI L2 and Caliop, Northern Hemisphere statistics with M01 IASI L2 from GS1

3.6.4 Cloud Top Temperature

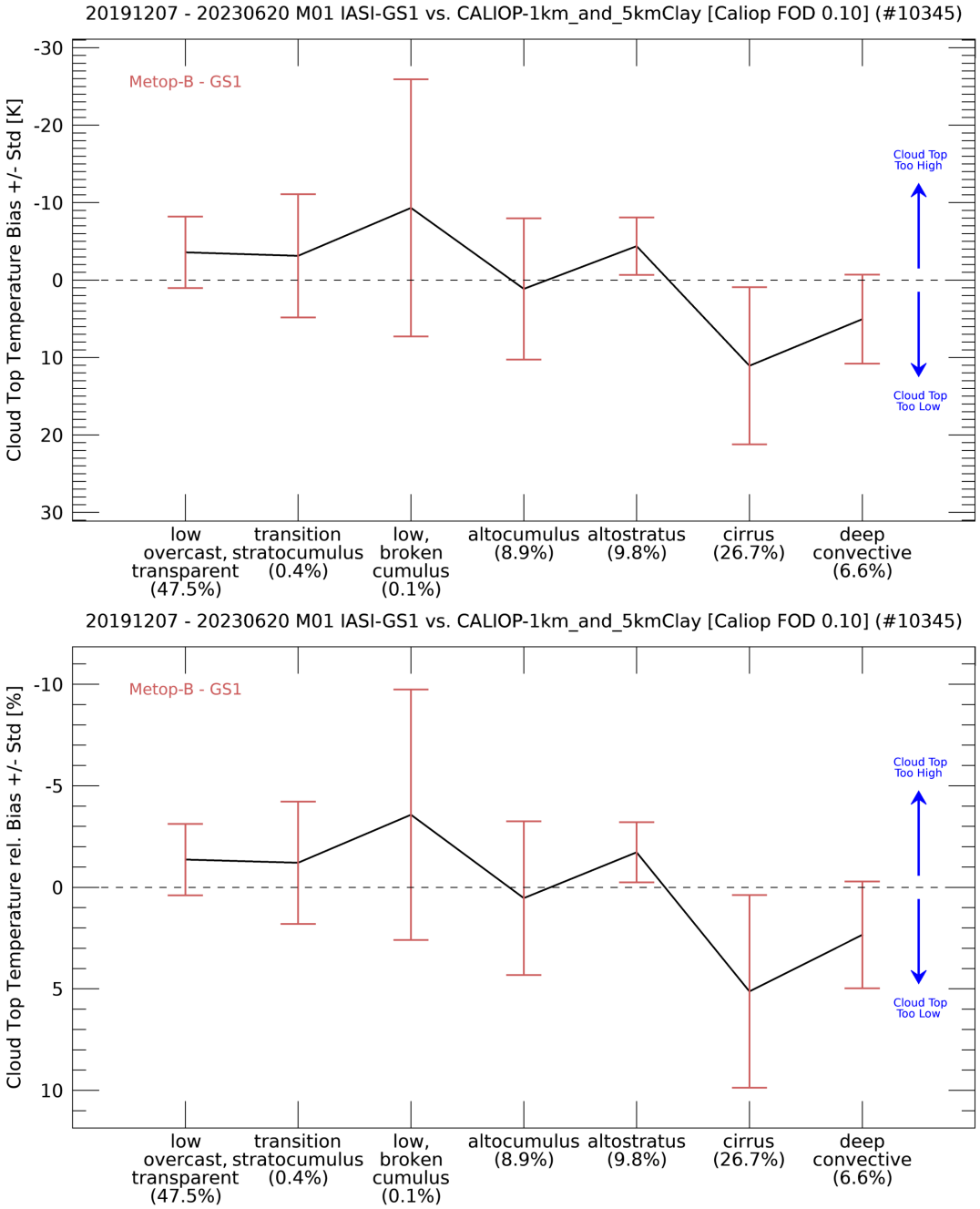

Figure 3.23: Cloud Type based statistics for Cloud Top Temperature absolute (top) and relative (bottom) differences between IASI L2 and Caliop, Northern Hemisphere statistics with M01 IASI L2 from GS1

3.7 Cloud Phase vs Cloud Top Temperature

This section shows the liquid cloud fraction (LCF:= Fraction of clouds classified as liquid) for different cloud top temperatures (CTT, Binsize=10K). For CTT'S below -40 degree Celsius (*ice*) no liquid clouds should be present and the LCF should be 0%. In the transition zone between -40 degree celsius and 0 degree celsius (*supercooled*) the LCF should increase with increasing CTT and the LCF should eventually be 100% if the CTT's are greater 0 degree Celsius (*liquid*). Please note that mixed-typed cases have been removed from the IASI cloud phase product when compared to Caliop.

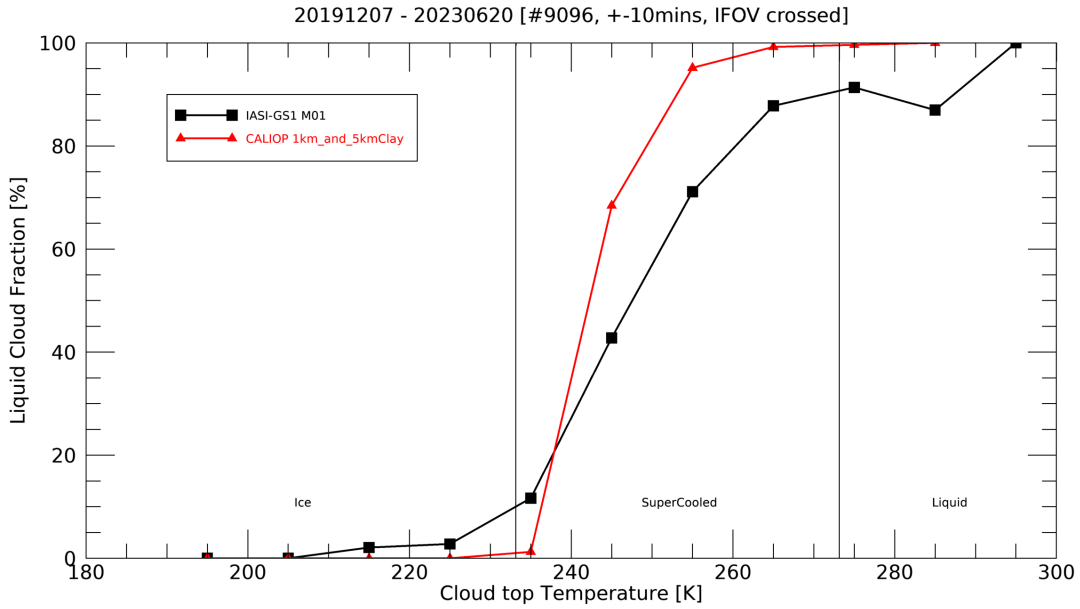

Figure 3.24: IASI (red) *vs* Caliop (black) Cloud Phase vs Cloud Top Temperature. Northern Hemisphere statistics with M01 IASI L2 from GS1

4 SOUTHERN HEMISPHERE

4.1 Matchups

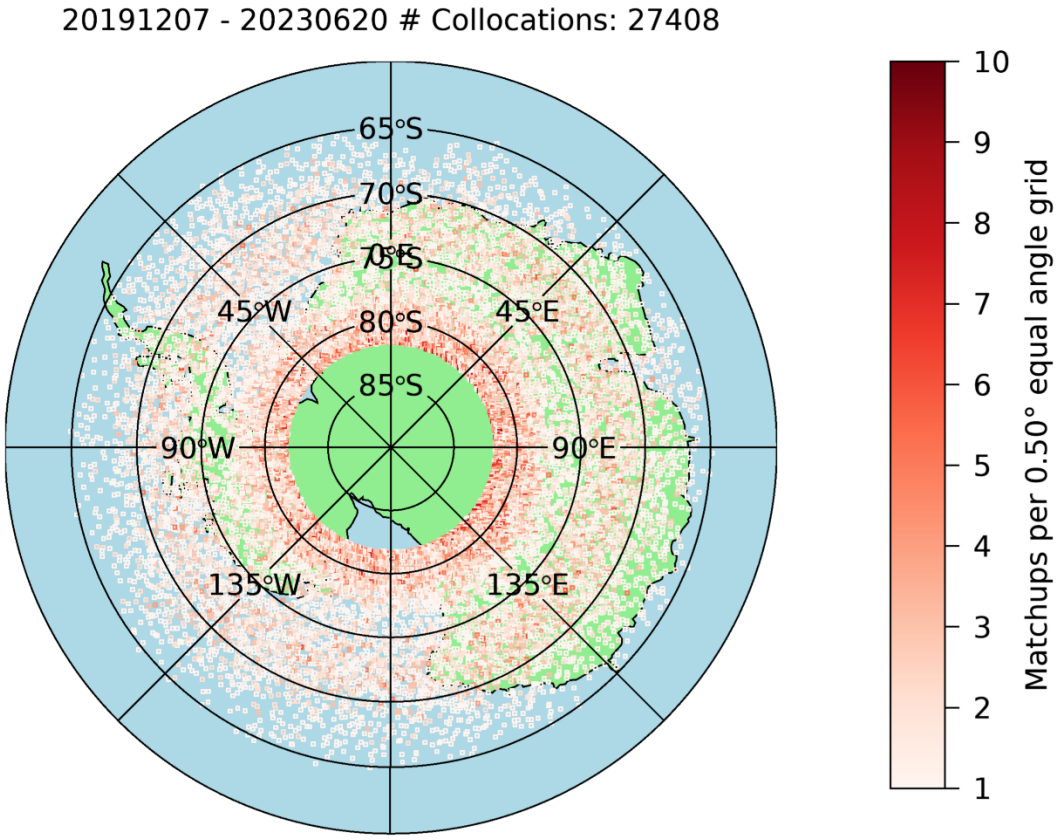

Figure 4.1: Southern Hemisphere Matchups between Calipso and M01 IASI L2 from GS1

4.2 Cloud Mask

The Calipso Cloud products provide a binary cloud mask, clear or cloudy. In order to compare both masks, the IASI-L2 cloud mask was set to binary by setting CLDNES Flag values 1 and 2 to clear and values 3 and 4 to cloudy! The collocation homogeneity criteria (Section 1.3) makes sure that all caliop pixel crossing the IASI IFOV are either clear or cloudy and not mixed!

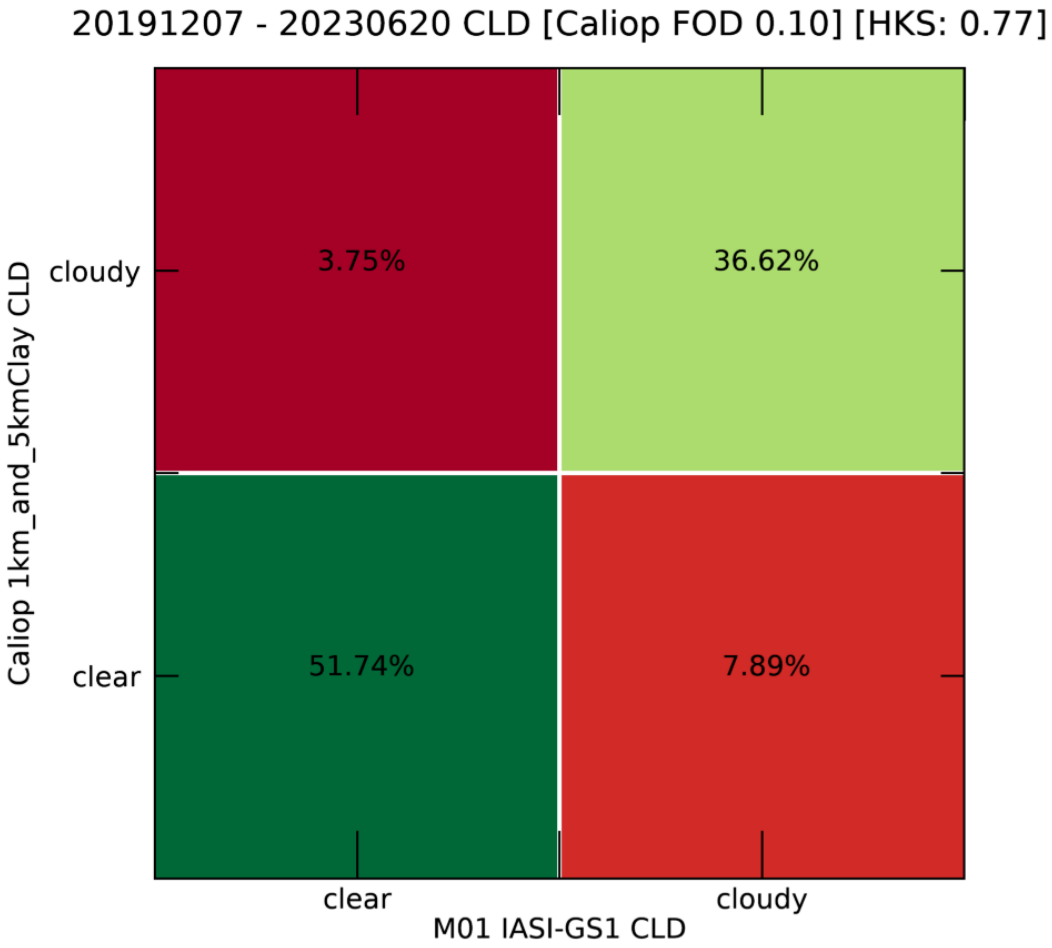

Figure 4.2: Long-Term Cloud Mask contingency table incl. Hanssen Kuiper's skill score. Southern Hemisphere statistics with M01 IASI L2 from GS1

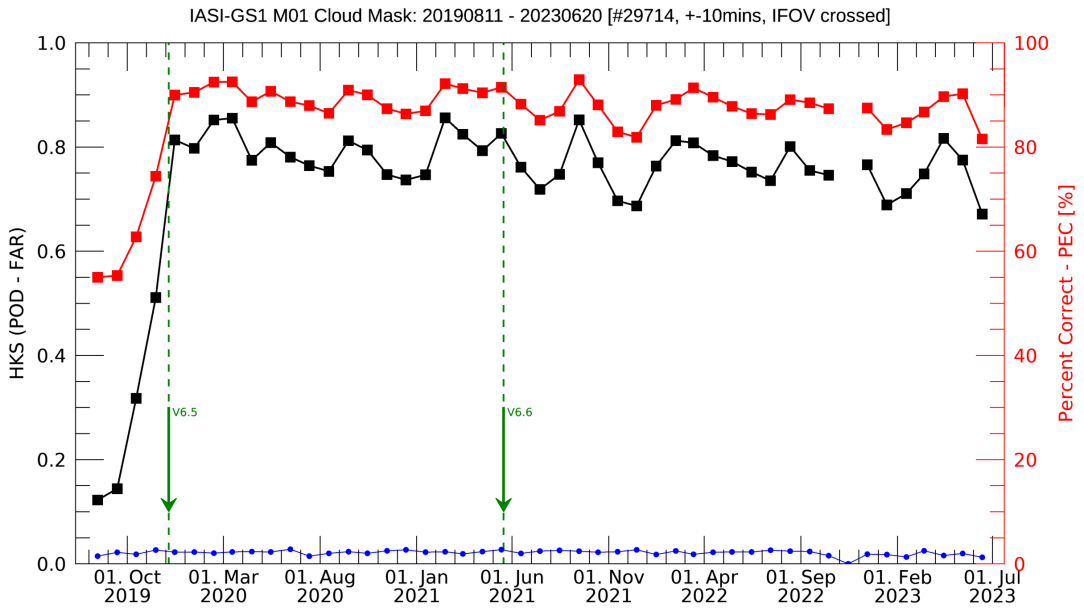

Figure 4.3: Long-Term Cloud Mask Time Serie for Hanssen Kuiper's skill score and Percent Correct, including fractional number of matchups per month (bottom blue) and #total-number-of-matchups (title). Southern Hemisphere statistics with M01 IASI L2 from GS1.

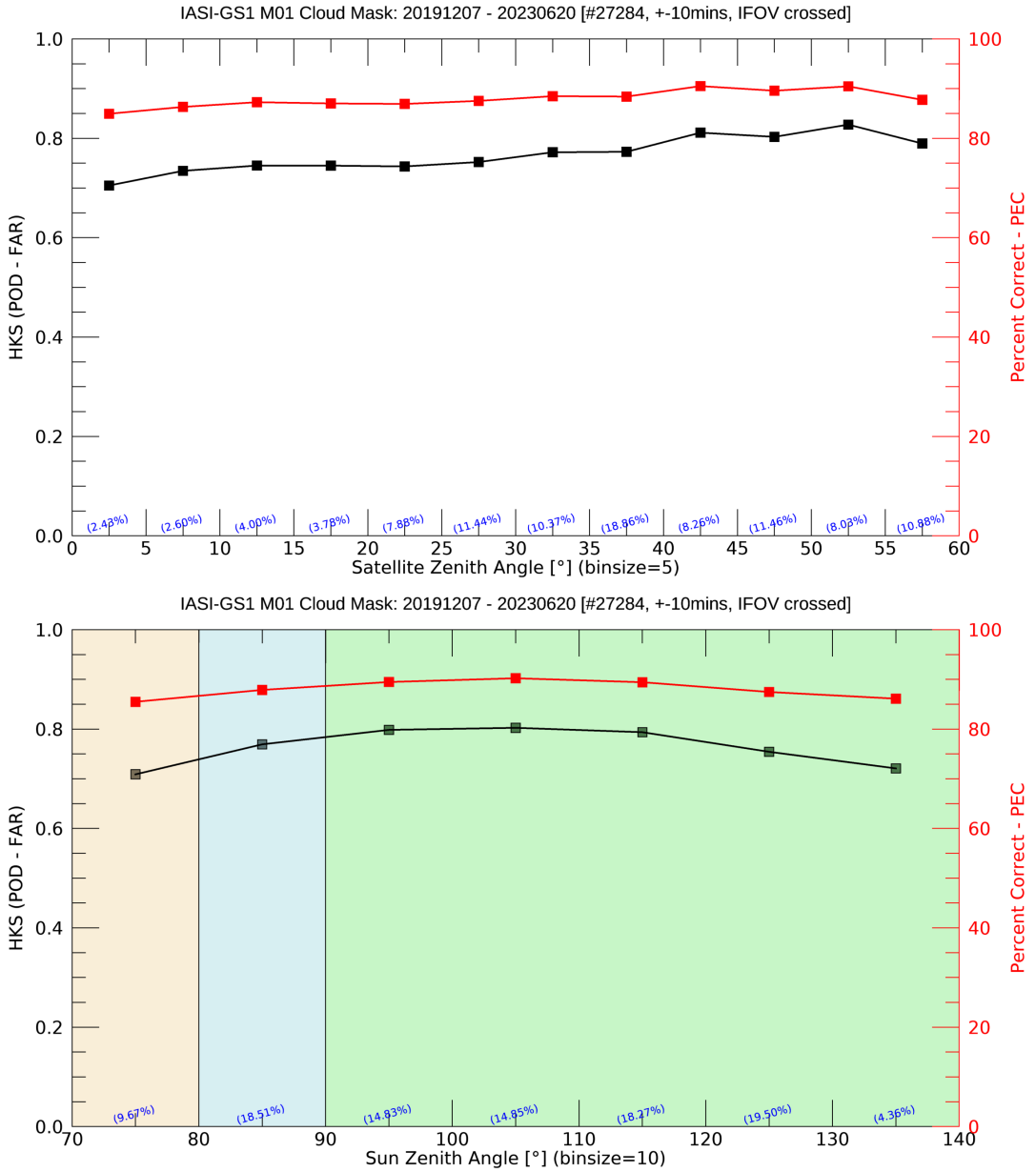

Figure 4.4: Satellite Zenith Angle (top) and Sun Zenith Angle (bottom) dependendencies on Cloud Mask differences between IASI L2 and Caliop, Southern Hemisphere statistics with M01 IASI L2 from GS1

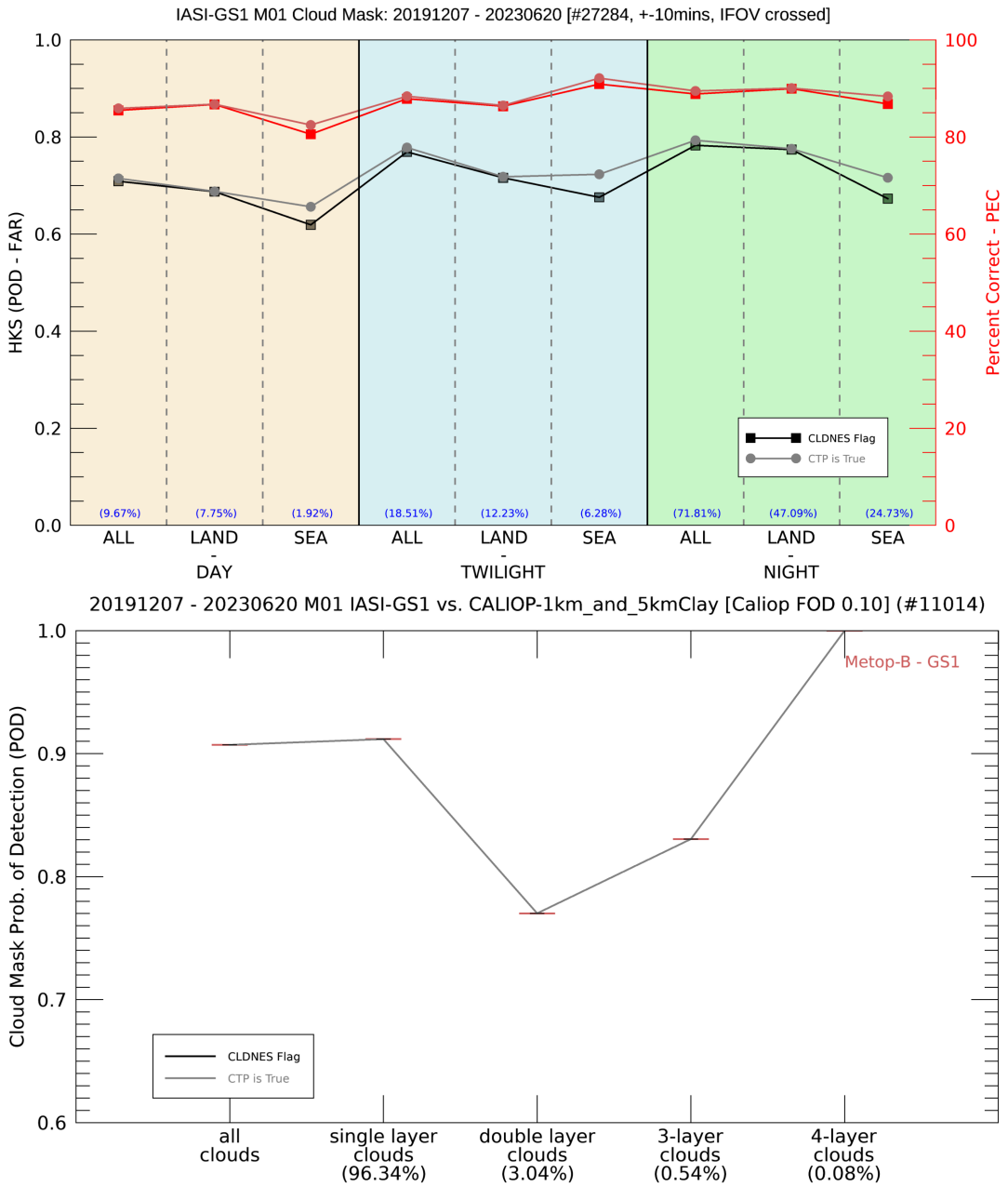

Figure 4.5: Cloud Mask dependencies on Daytime/Land/Sea (top) and number of Caliop Cloud layer (bottom) between IASI L2 and Caliop, Southern Hemisphere statistics with M01 IASI L2 from GS1

4.3 Cloud Phase

The Calipso Cloud products provides 3 different states to describe the thermodynamic phase of clouds, 1: randomly oriented ice, 2: horizontally oriented ice and 3: water. The IASI-L2 provides the classification liquid, ice and mixed. In order to compare Caliop to the IASI-L2 cloud phase product both masks were set to a binary phase mask by combining the 2 ice phases of Caliop into a single *ice* class and removing the mixed statement from the IASI-L2 products. The homogeneity criteria (Section 1.3) makes sure that all caliop pixel crossing the IASI IFOV are either liquid or ice and not mixed!

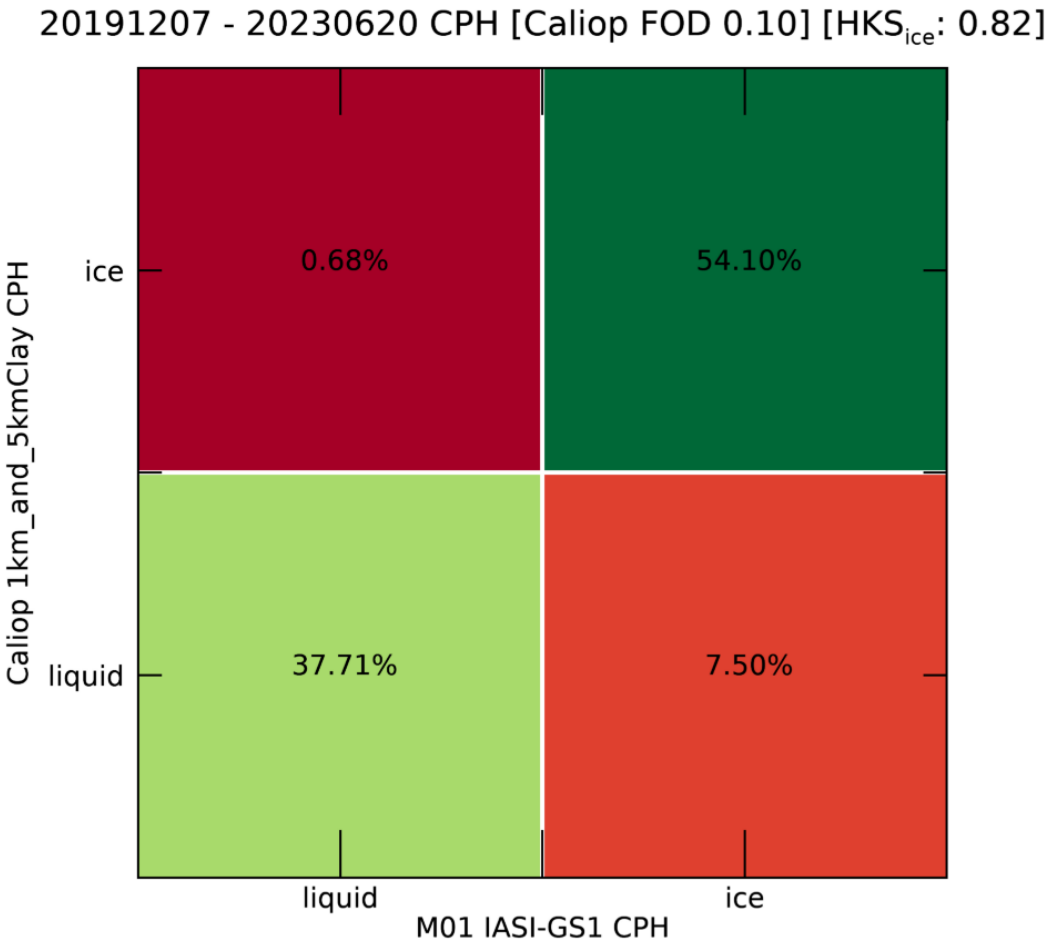

Figure 4.6: Long-Term Cloud Mask contingency table incl. Hanssen Kuiper's skill score. Southern Hemisphere statistics with M01 IASI L2 from GS1

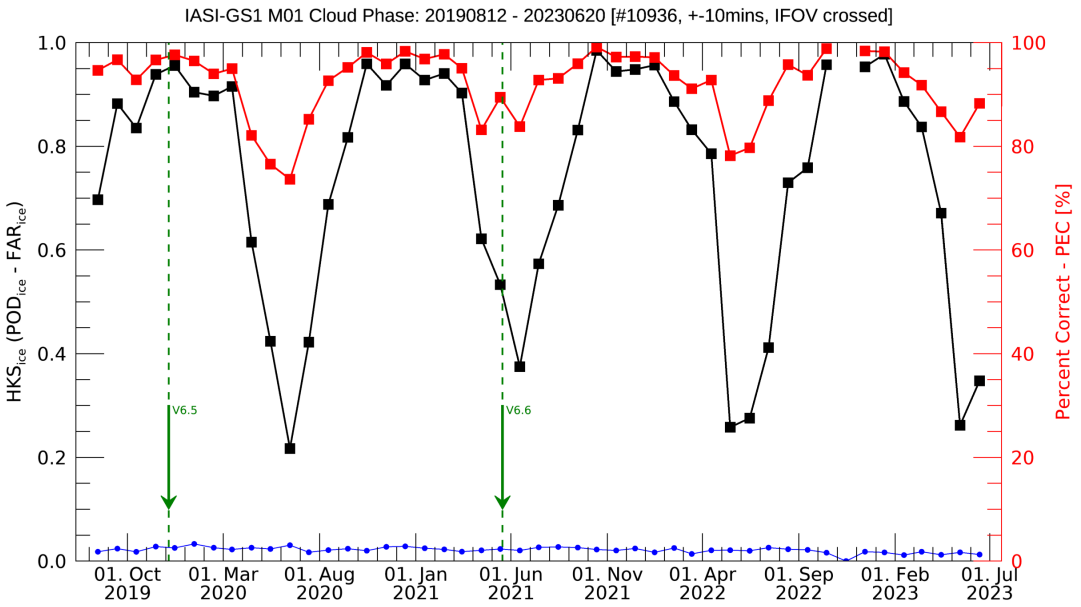

Figure 4.7: Long-Term Cloud Phase Time Serie for Hanssen Kuiper's skill score and Percent Correct, including fractional number of matchups per month (bottom blue) and #total-number-of-matchups (title). Southern Hemisphere statistics with M01 IASI L2 from GS1.

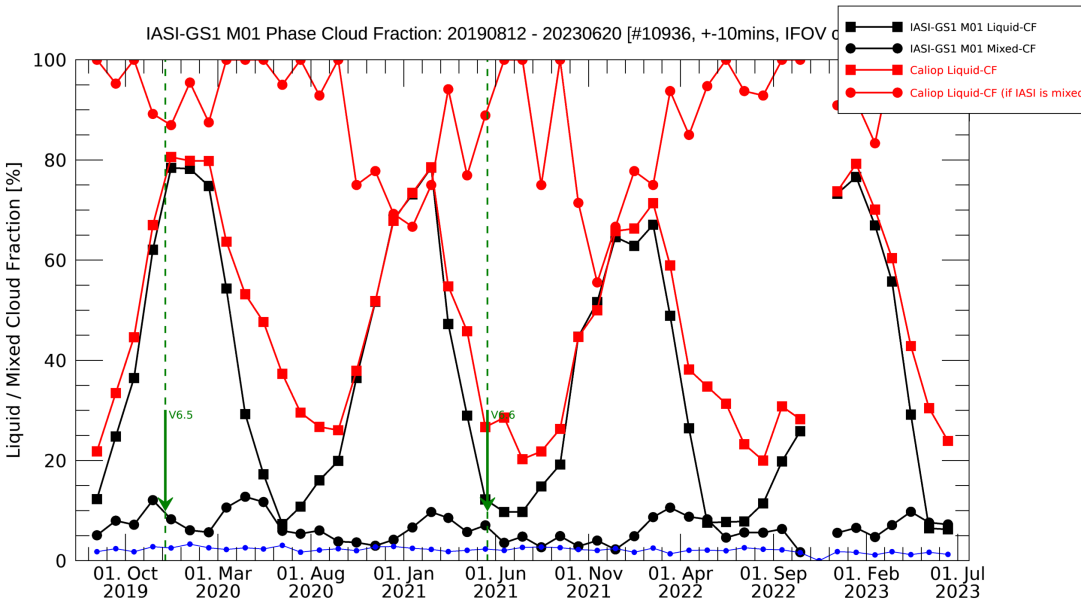

Figure 4.8: Long-Term Cloud Phase Time Serie for Liquid and Mixed cloud fraction in percent, including fractional number of matchups per month (bottom blue) and #total-number-of-matchups (title). Southern Hemisphere statistics with M01 IASI L2 from GS1.

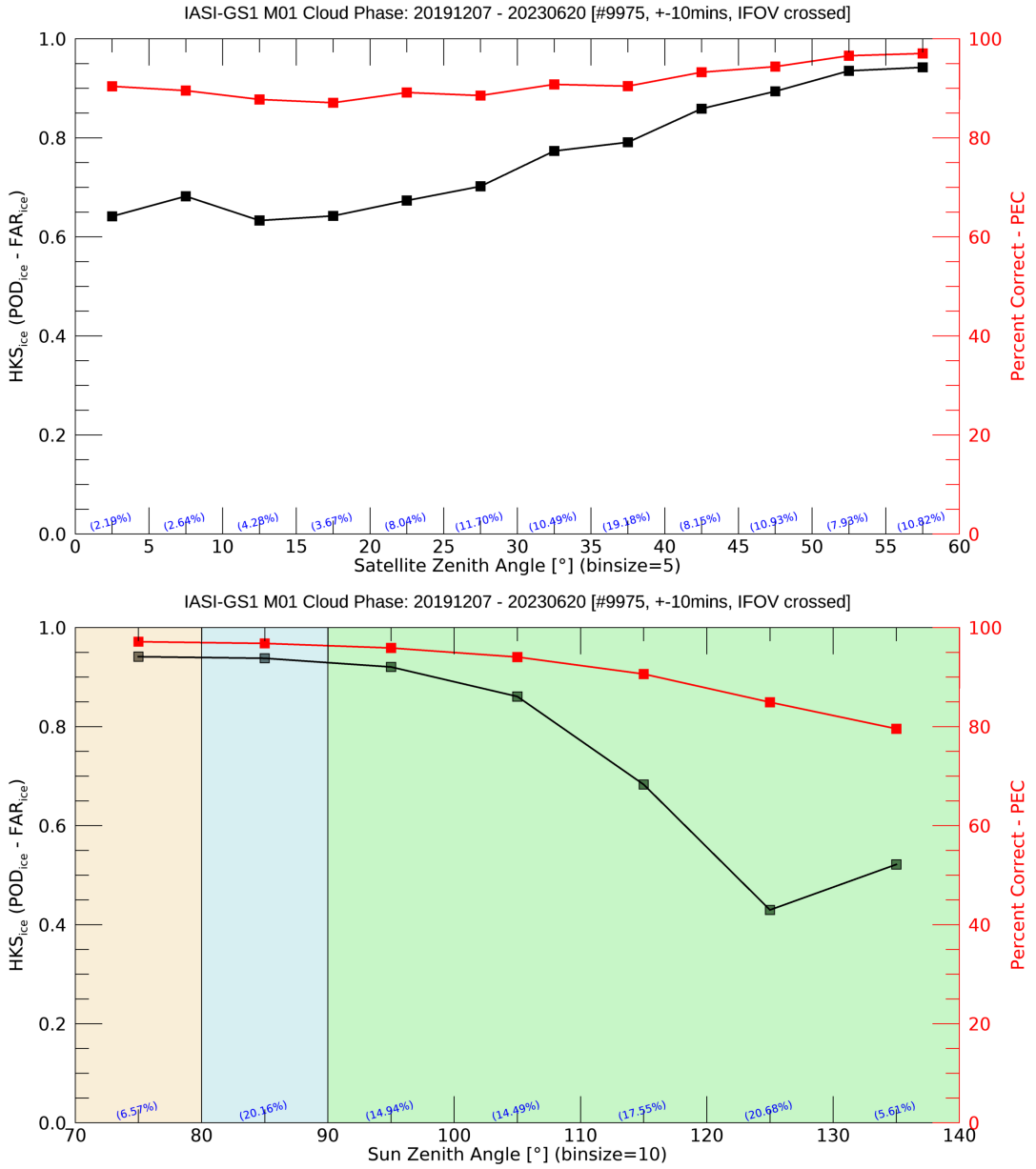

Figure 4.9: Satellite Zenith Angle (top) and Sun Zenith Angle (bottom) dependencies on Cloud Phase differences between IASI L2 and Caliop, Southern Hemisphere statistics with M01 IASI L2 from GS1

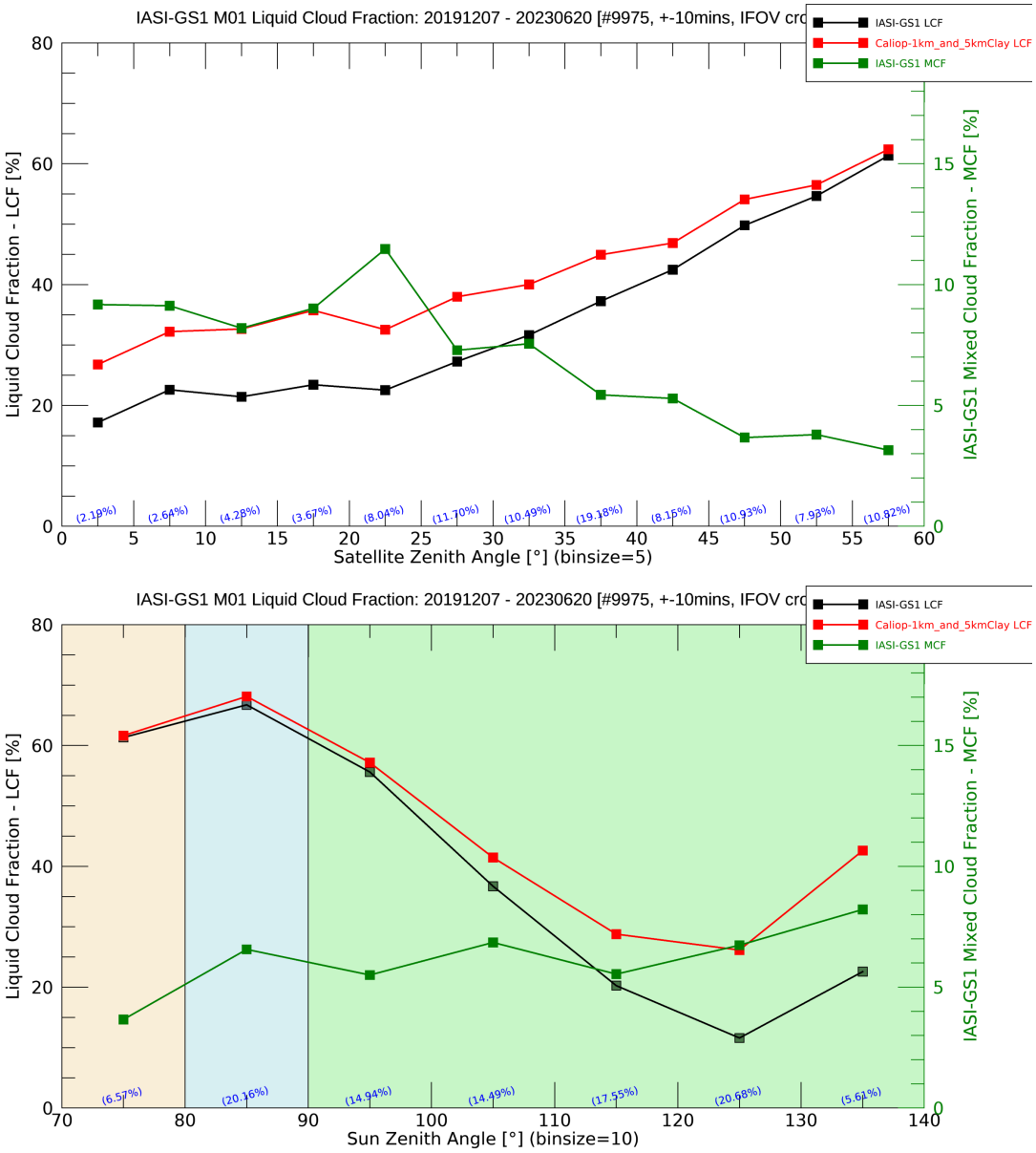

Figure 4.10: Satellite Zenith Angle (top) and Sun Zenith Angle (bottom) dependendencies on Liquid and Mixed Cloud Fraction for IASI L2 and Caliop, Southern Hemisphere statistics with M01 IASI L2 from GS1

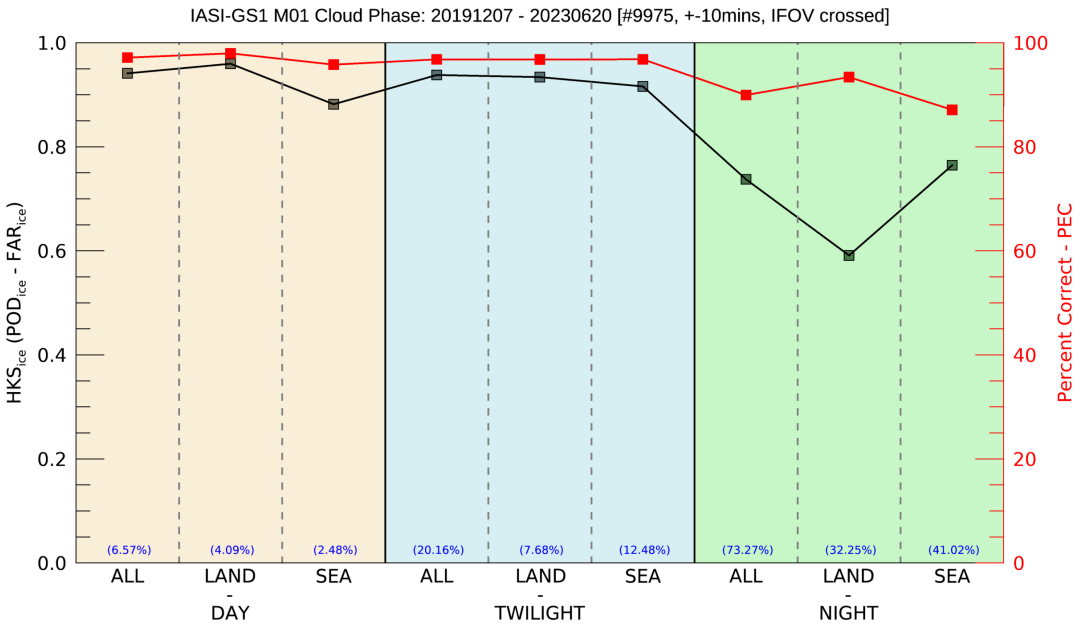

Figure 4.11: Cloud Phase dependencies on Daytime/Land/Sea between IASI L2 and Caliop, Southern Hemisphere statistics with M01 IASI L2 from GS1

4.4 Cloud Top Pressure

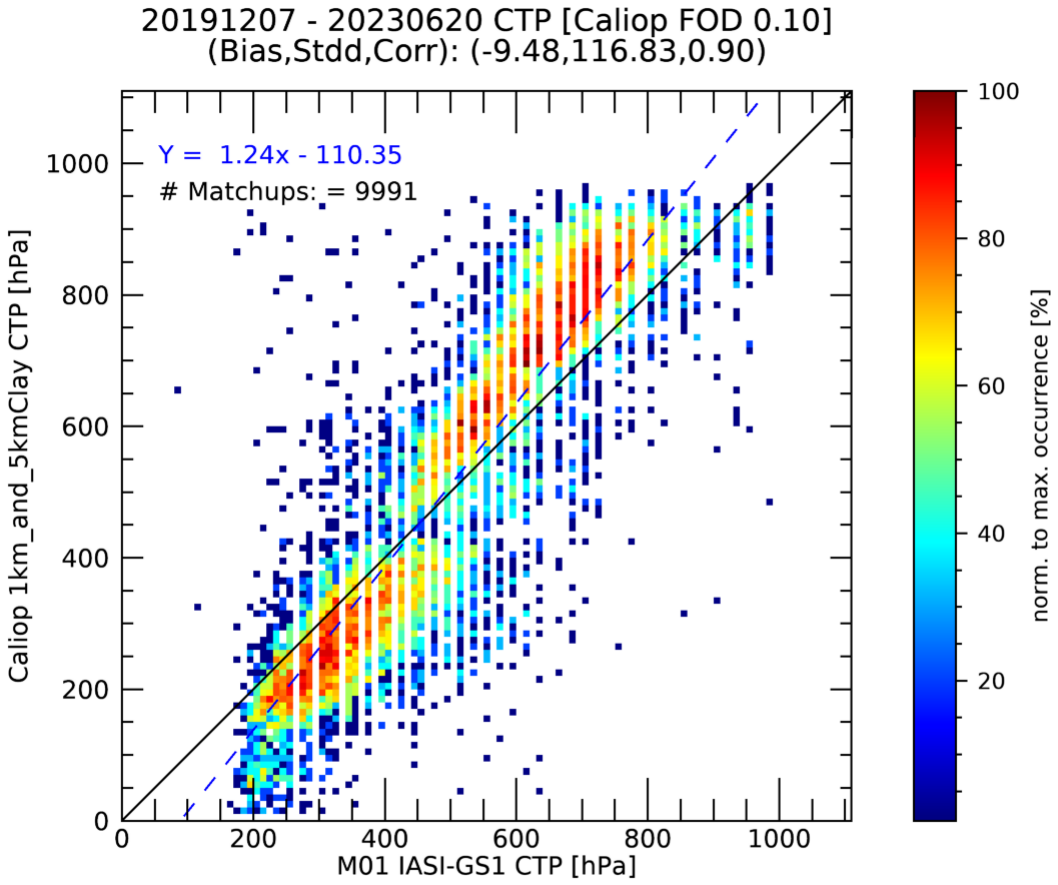

Figure 4.12: 2D Histograms for Cloud Top Pressure between IASI L2 and Caliop, Southern Hemisphere statistics with M01 IASI L2 from GS1

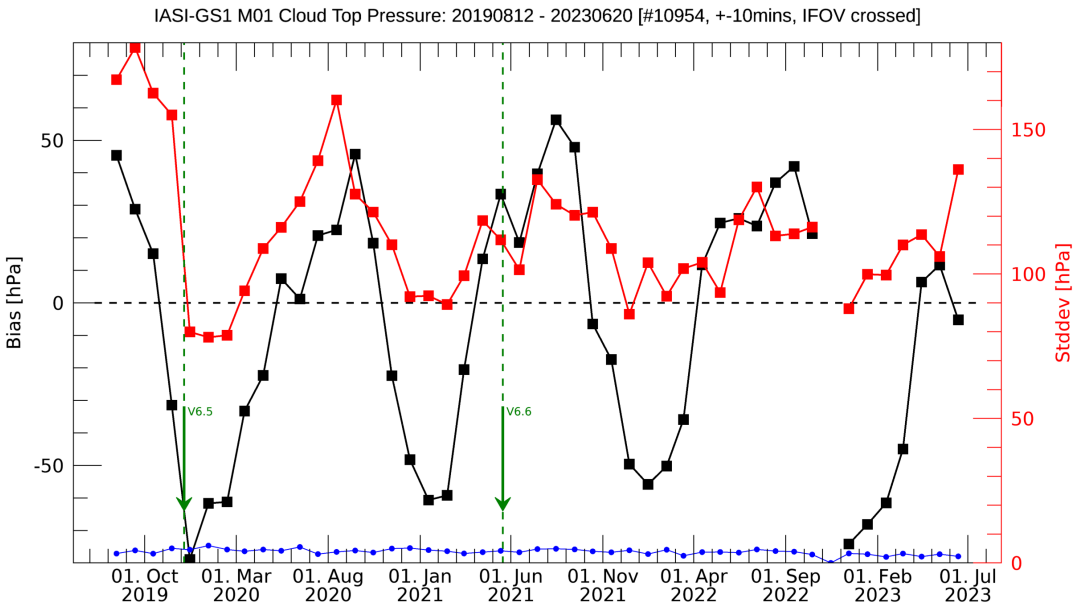

Figure 4.13: Long-Term Cloud Top Pressure Time Serie Bias and Standard Deviation of the differences, including fractional number of matchups per month (bottom blue) and #total-number-of-matchups (title). Southern Hemisphere statistics with M01 IASI L2 from GS1.

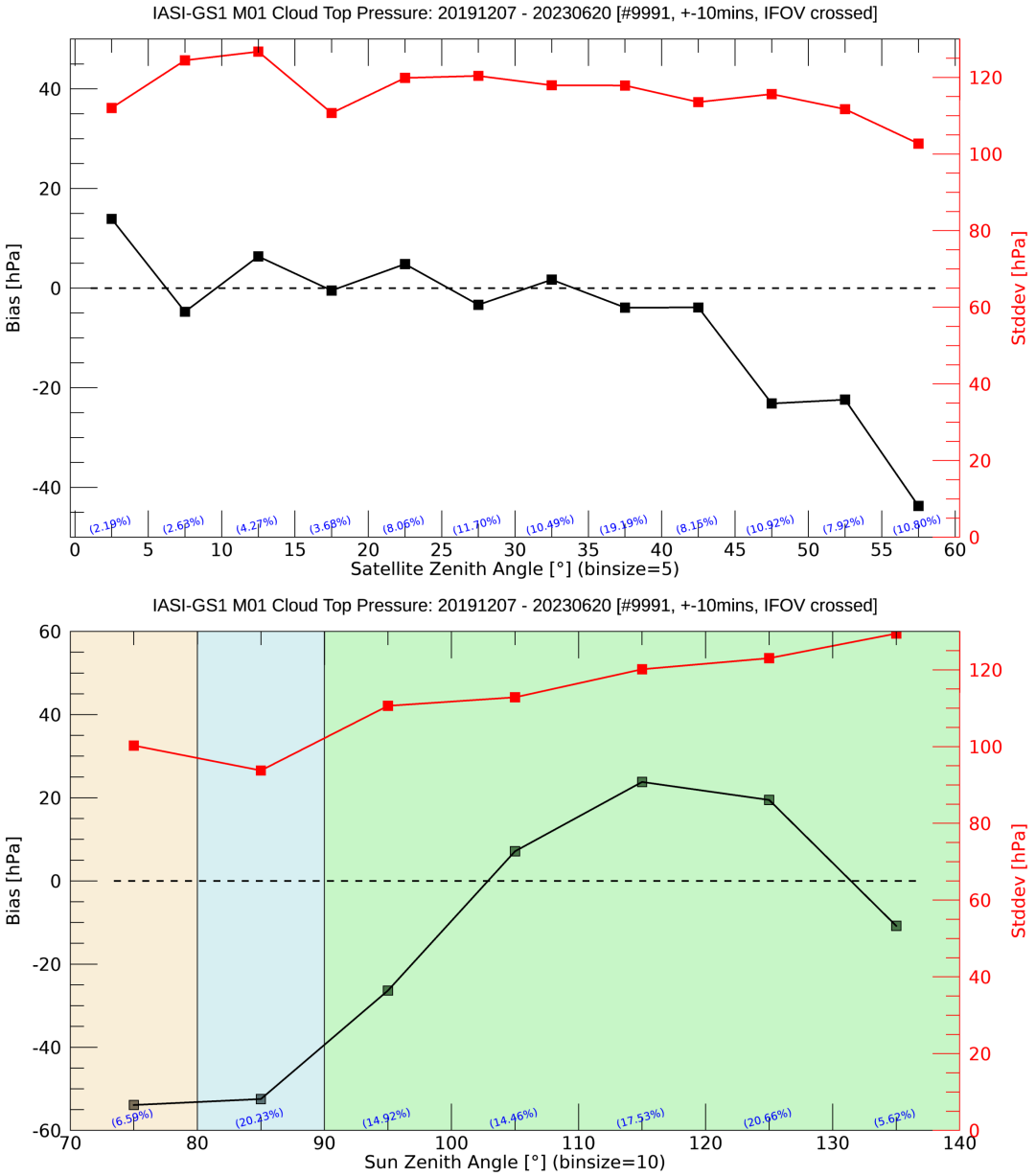

Figure 4.14: Satellite Zenith Angle (top) and Sun Zenith Angle (bottom) dependendencies on Cloud Top Pressure differences between IASI L2 and Caliop, Southern Hemisphere statistics with M01 IASI L2 from GS1

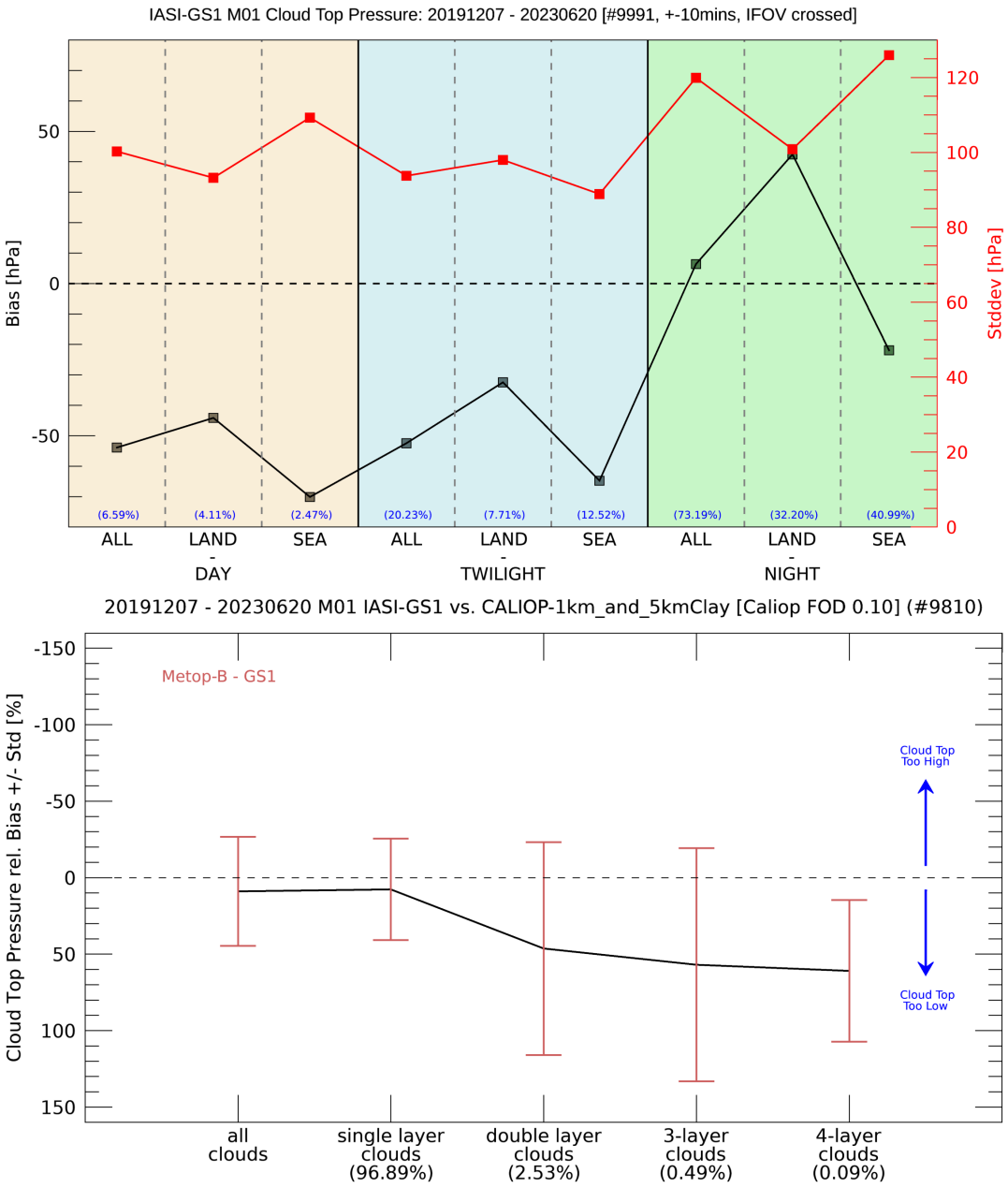

Figure 4.15: Cloud Top Pressure dependencies on Daytime/Land/Sea (top) and number of Caliop Cloud layer (bottom) between IASI L2 and Caliop, Southern Hemisphere statistics with M01 IASI L2 from GS1

4.5 Cloud Top Temperature

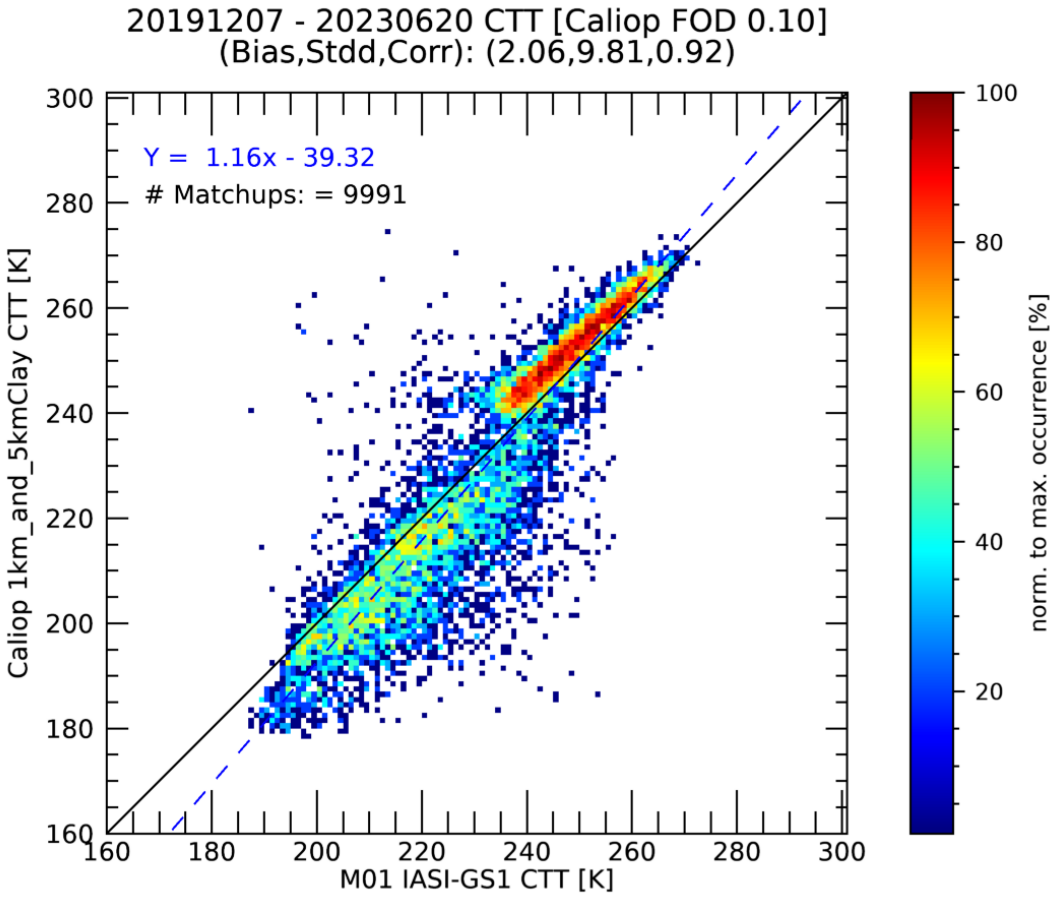

Figure 4.16: 2D Histograms for Cloud Top Temperature between IASI L2 and Caliop, Southern Hemisphere statistics with M01 IASI L2 from GS1

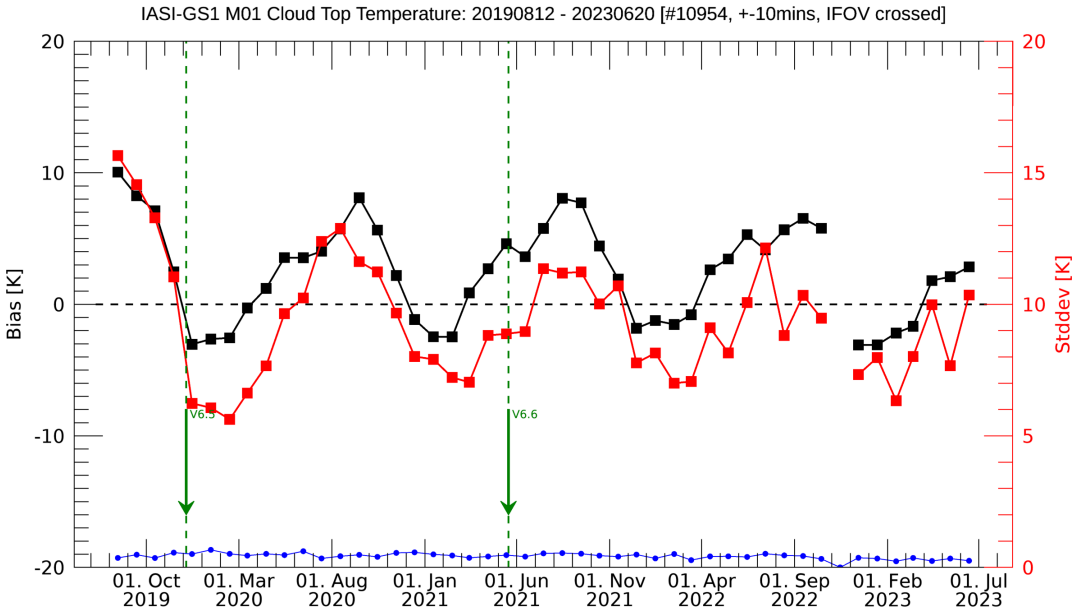

Figure 4.17: Long-Term Cloud Top Temperature Time Serie Bias and Standard Deviation of the differences, including fractional number of matchups per month (bottom blue) and #total-number-of-matchups (title). Southern Hemisphere statistics with M01 IASI L2 from GS1.

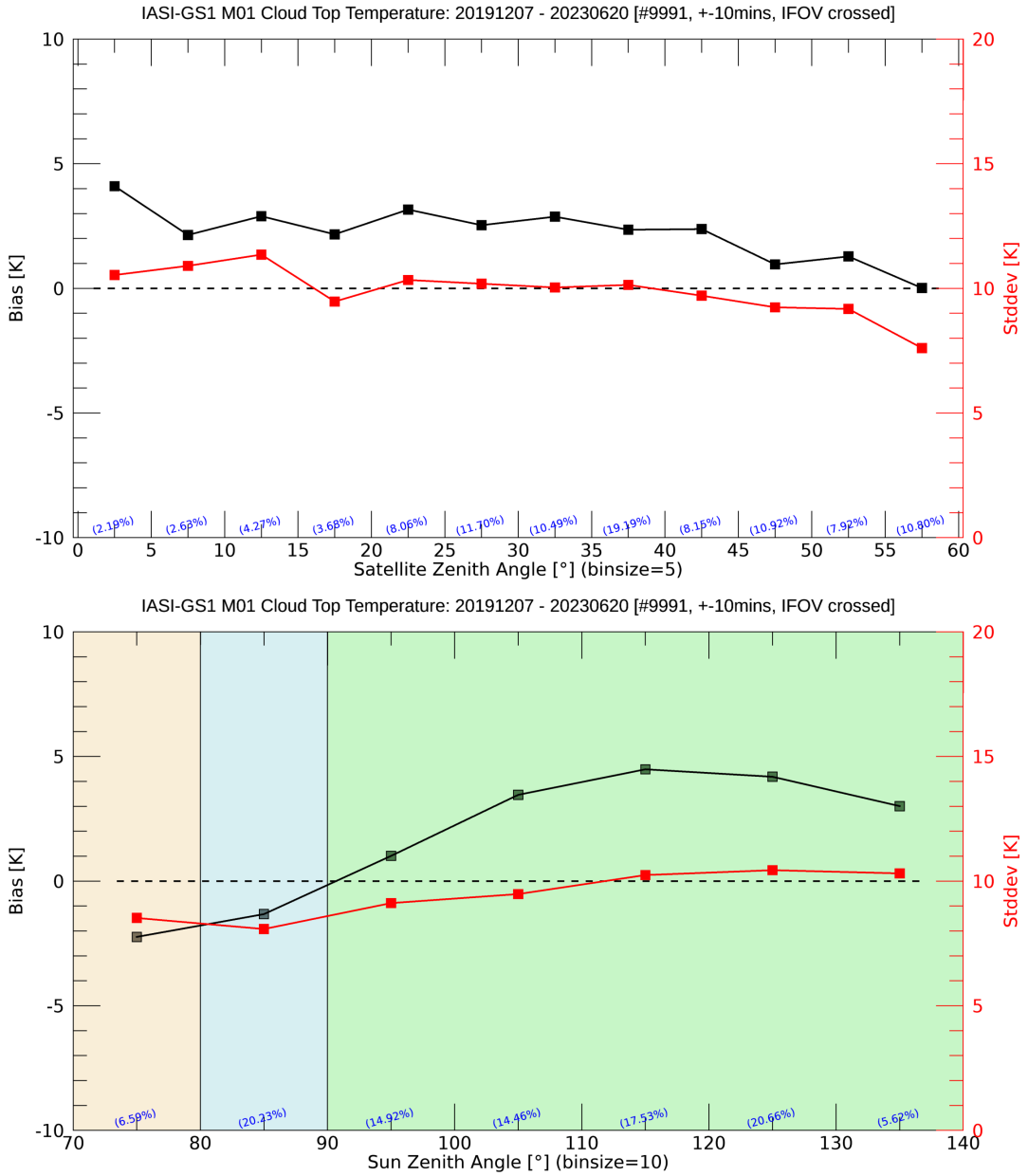

Figure 4.18: Satellite Zenith Angle (top) and Sun Zenith Angle (bottom) dependendencies on Cloud Top Temperature differences between IASI L2 and Caliop, Southern Hemisphere statistics with M01 IASI L2 from GS1

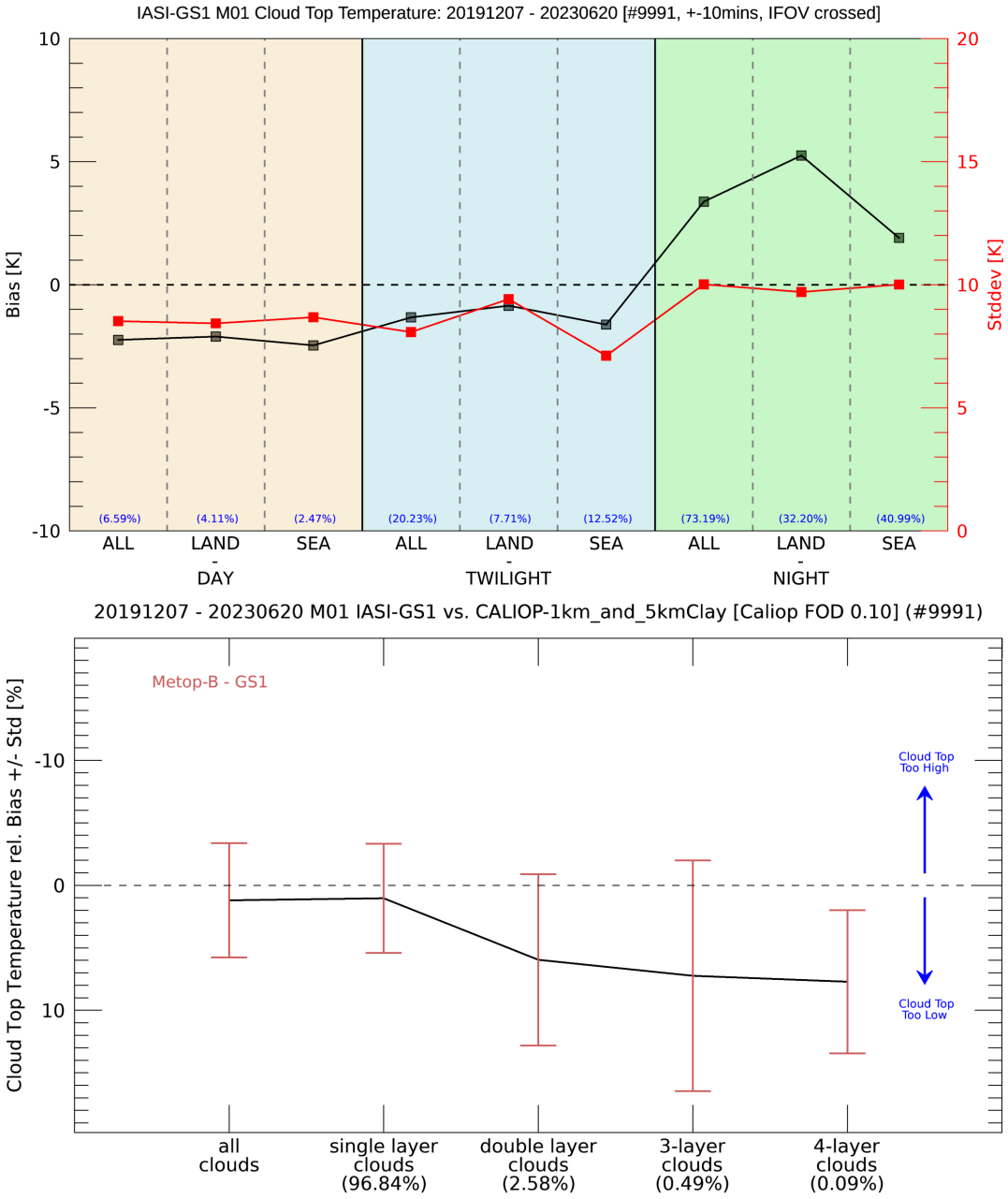

Figure 4.19: Cloud Top Temperature dependencies on Daytime/Land/Sea (top) and number of Caliop Cloud layer (bottom) between IASI L2 and Caliop, Southern Hemisphere statistics with M01 IASI L2 from GS1

4.6 Cloud Type based statistics

The Caliop cloud products define 7 different cloud types (3 low, 2 mid and 2 high cloud types). In this section the performance of the IASI-L2 cloud top products are validated based on different cloud types!

4.6.1 Caliop Cloud Type Fraction Time Series

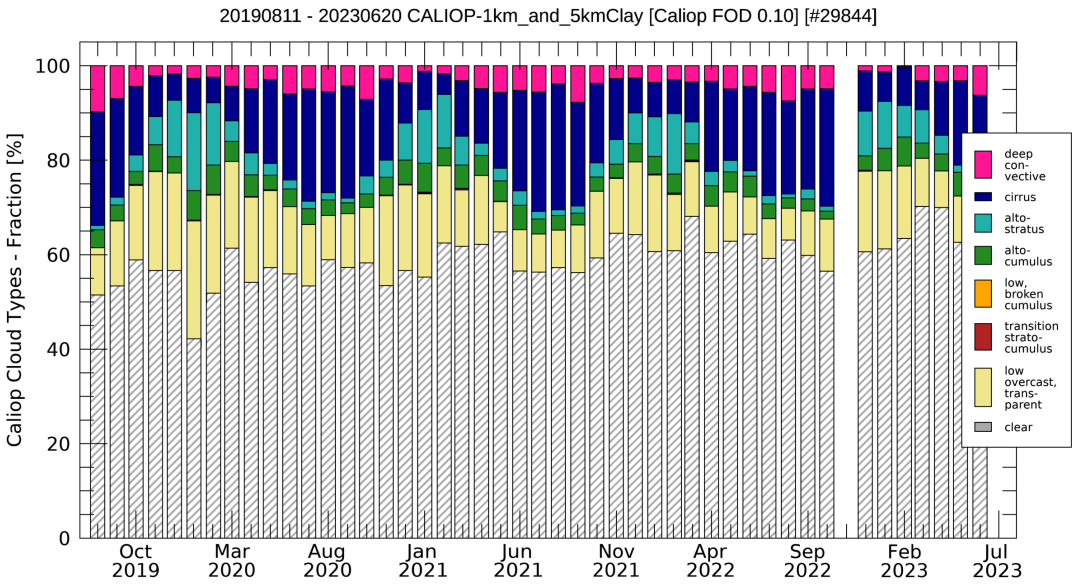

Figure 4.20: Long-Term Caliop Cloud Type Time Serie as fraction of cloud type appearance, including fractional number of matchups per month (bottom blue) and #total-number-of-matchups (title). Southern Hemisphere collocations with M01 IASI L2 from GS1.

4.6.2 Cloud Mask

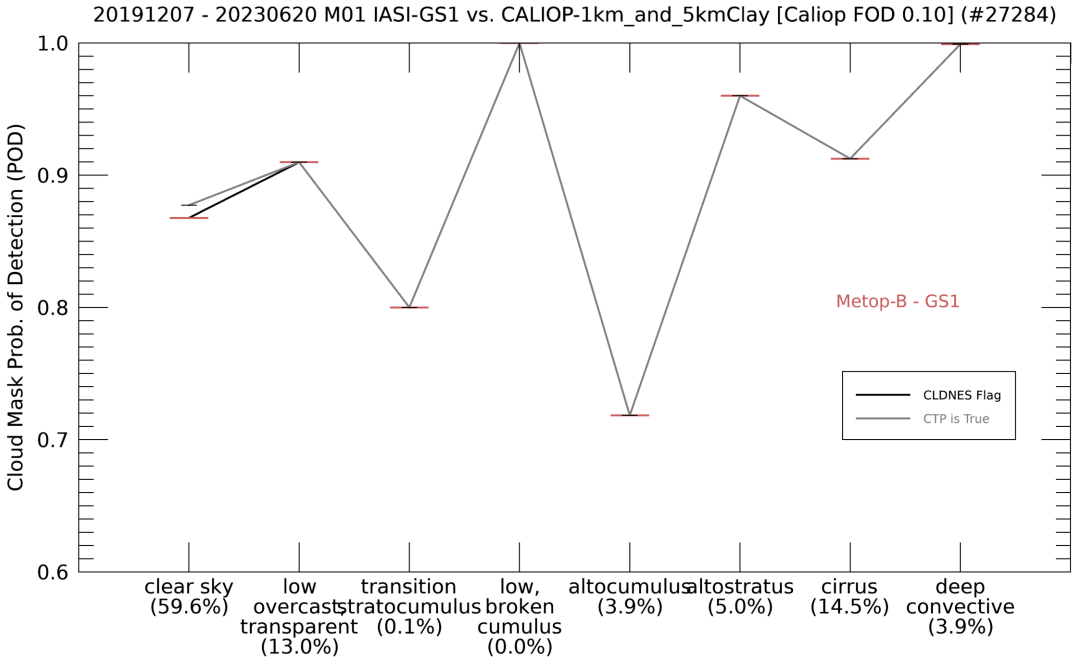

Figure 4.21: Cloud Type based statistics for Cloud Mask differences between IASI L2 and Caliop, Southern Hemisphere statistics with M01 IASI L2 from GS1

4.6.3 Cloud Top Pressure

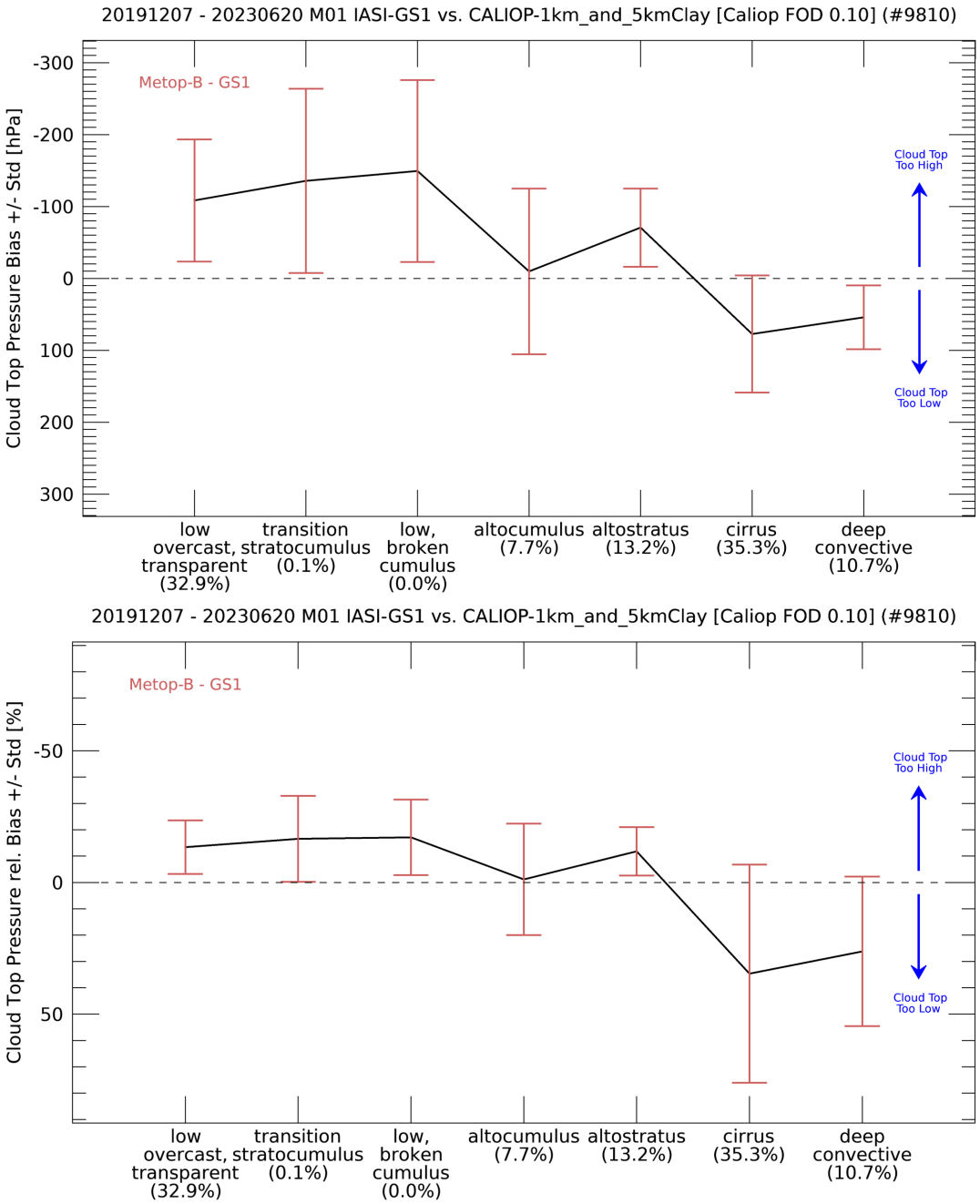

Figure 4.22: Cloud Type based statistics for Cloud Top Pressure absolute (top) and relative (bottom) differences between IASI L2 and Caliop, Southern Hemisphere statistics with M01 IASI L2 from GS1

4.6.4 Cloud Top Temperature

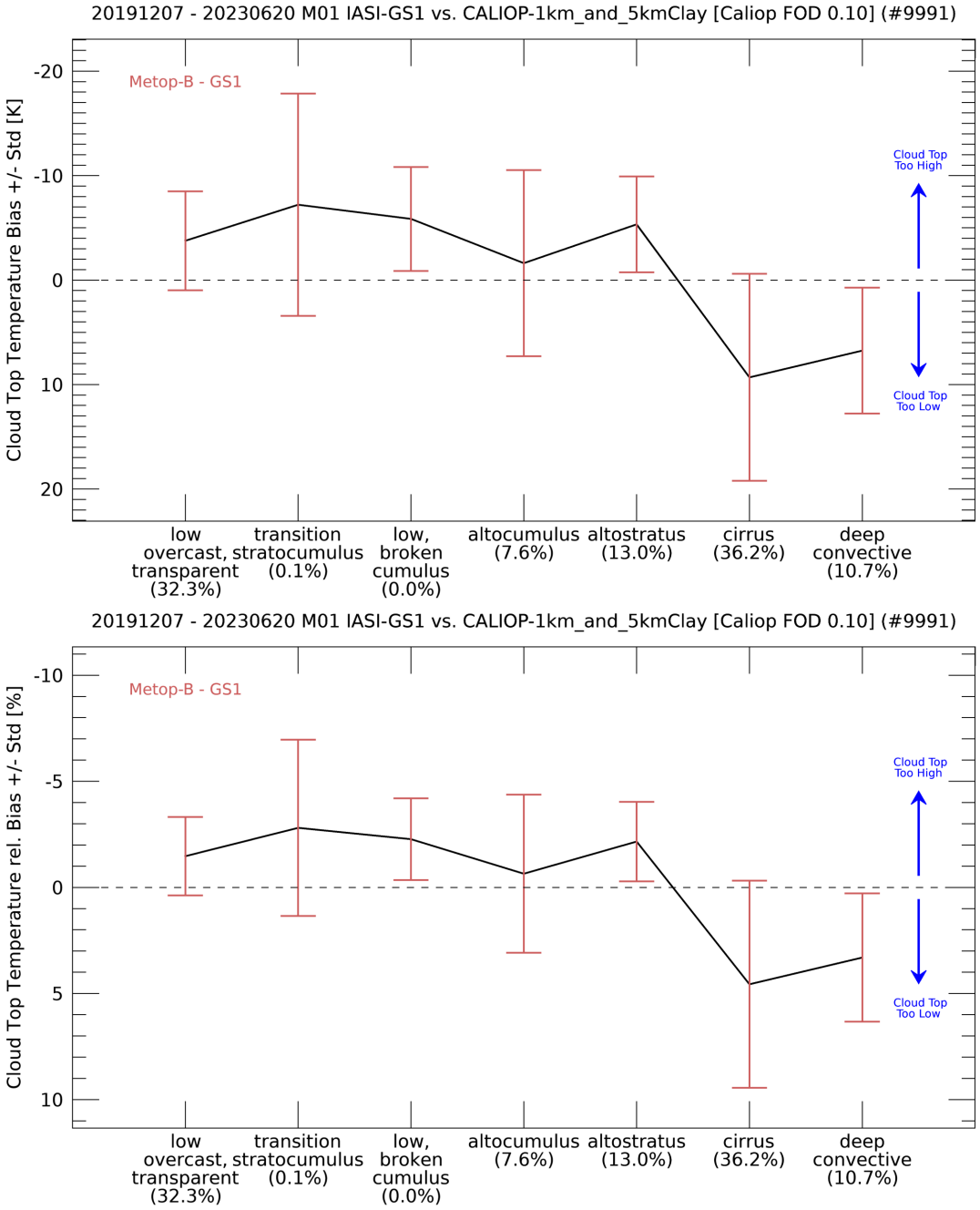

Figure 4.23: Cloud Type based statistics for Cloud Top Temperature absolute (top) and relative (bottom) differences between IASI L2 and Caliop, Southern Hemisphere statistics with M01 IASI L2 from GS1

4.7 Cloud Phase vs Cloud Top Temperature

This section shows the liquid cloud fraction (LCF:= Fraction of clouds classified as liquid) for different cloud top temperatures (CTT, Binsize=10K). For CTT'S below -40 degree Celsius (*ice*) no liquid clouds should be present and the LCF should be 0%. In the transition zone between -40 degree celsius and 0 degree celsius (*supercooled*) the LCF should increase with increasing CTT and the LCF should eventually be 100% if the CTT's are greater 0 degree Celsius (*liquid*). Please note that mixed-typed cases have been removed from the IASI cloud phase product when compared to Caliop.

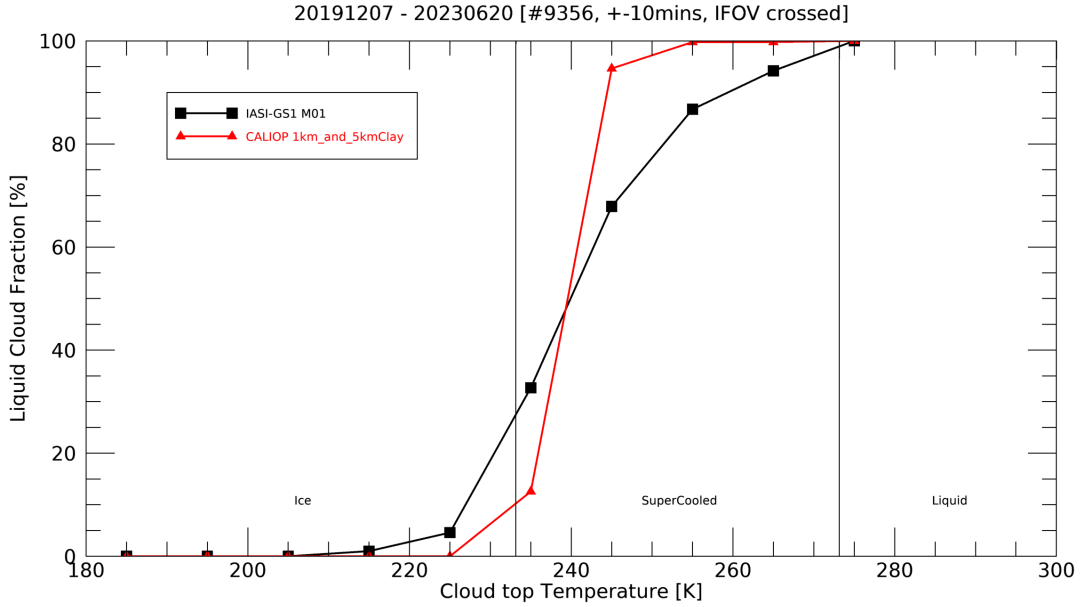

Figure 4.24: IASI (red) *vs* Caliop (black) Cloud Phase vs Cloud Top Temperature. Southern Hemisphere statistics with M01 IASI L2 from GS1

5 QUICKVIEWS NORTH VS. SOUTH

5.1 Cloud Mask

The Calipso Cloud products provide a binary cloud mask, clear or cloudy. In order to compare both masks, the IASI-L2 cloud mask was set to binary by setting CLDNES Flag values 1 and 2 to clear and values 3 and 4 to cloudy! The collocation homogeneity criteria (Section 1.3) makes sure that all caliop pixel crossing the IASI IFOV are either clear or cloudy and not mixed!

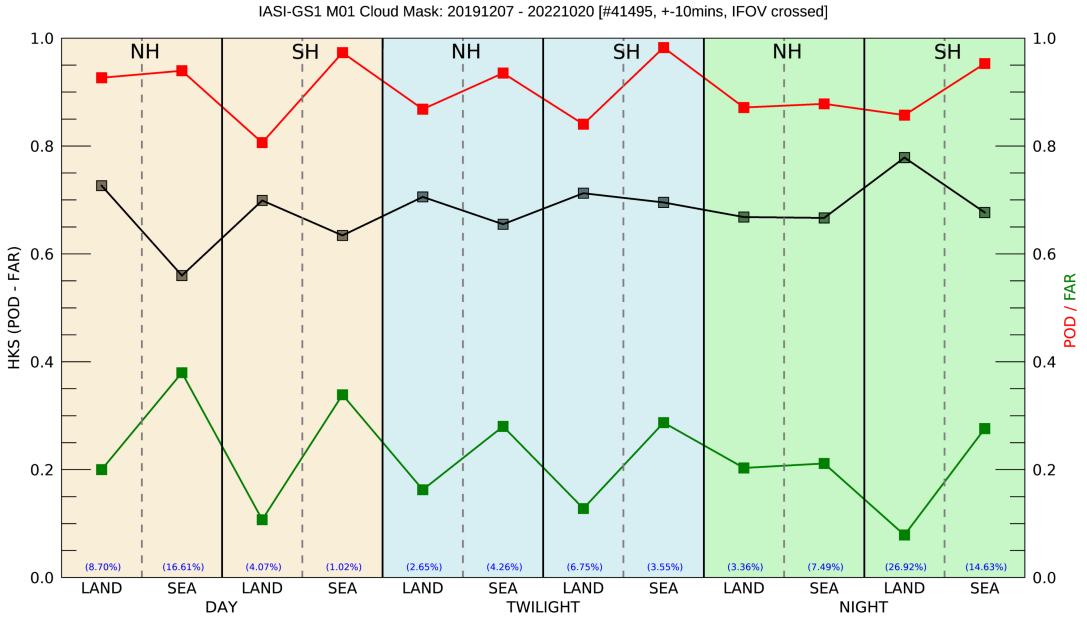

Figure 5.1: Cloud Mask dependencies on Daytime for Northern (NH) and Southern Hemisphere (SH) separated for Land and Sea between IASI L2 and Caliop, statistics with M01 IASI L2 from GS1

5.2 Cloud Phase

The Calipso Cloud products provides 3 different states to describe the thermodynamic phase of clouds, 1: randomly oriented ice, 2: horizontally oriented ice and 3: water. The IASI-L2 provides the classification liquid, ice and mixed. In order to compare Caliop to the IASI-L2 cloud phase product both masks were set to a binary phase mask by combining the 2 ice phases of Caliop into a single *ice* class and removing the mixed statement from the IASI-L2 products. The homogeneity criteria (Section 1.3) makes sure that all caliop pixel crossing the IASI IFOV are either liquid or ice and not mixed!

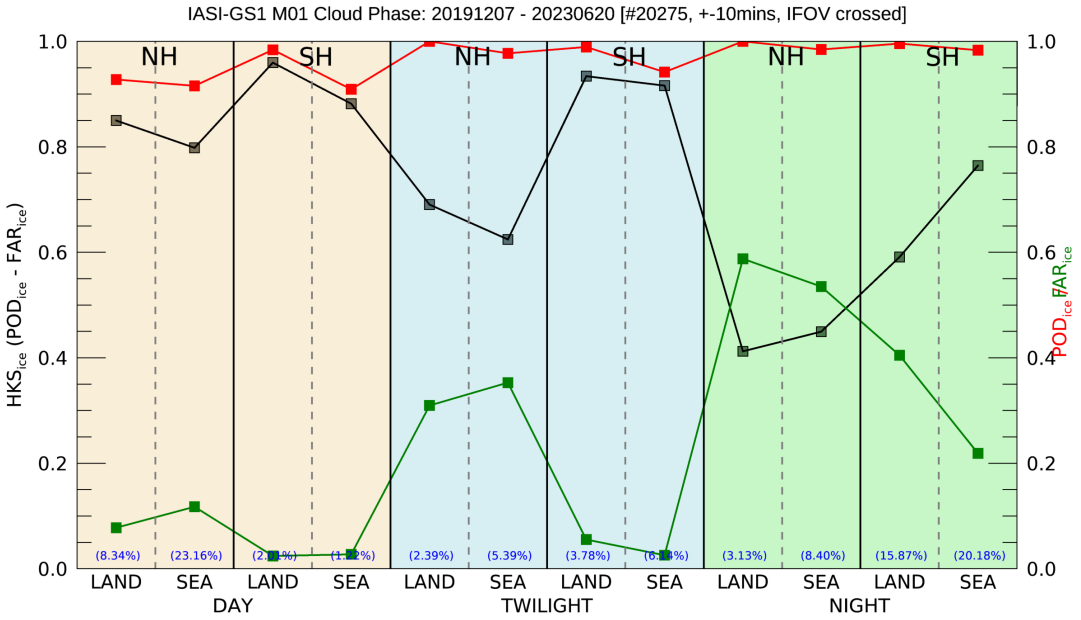

Figure 5.2: Cloud Phase dependencies on Daytime for Northern (NH) and Southern Hemisphere (SH) separated for Land and Sea between IASI L2 and Caliop, statistics with M01 IASI L2 from GS1

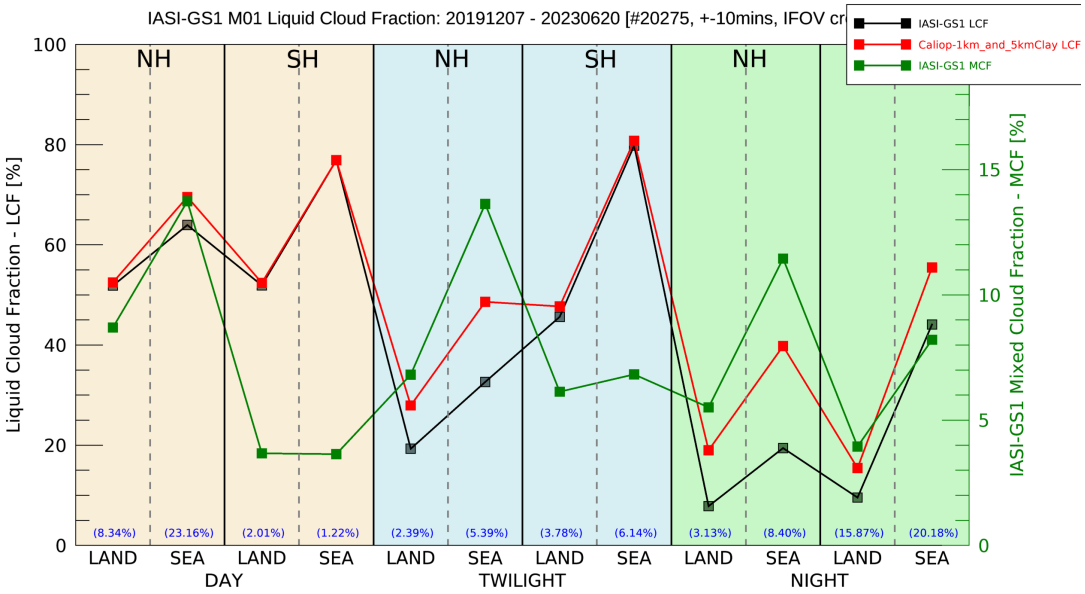

Figure 5.3: Cloud Phases Fractions dependencies on Daytime for Northern (NH) and Southern Hemisphere (SH) separated for Land and Sea between IASI L2 and Caliop, statistics with M01 IASI L2 from GS1

5.3 Cloud Top Pressure

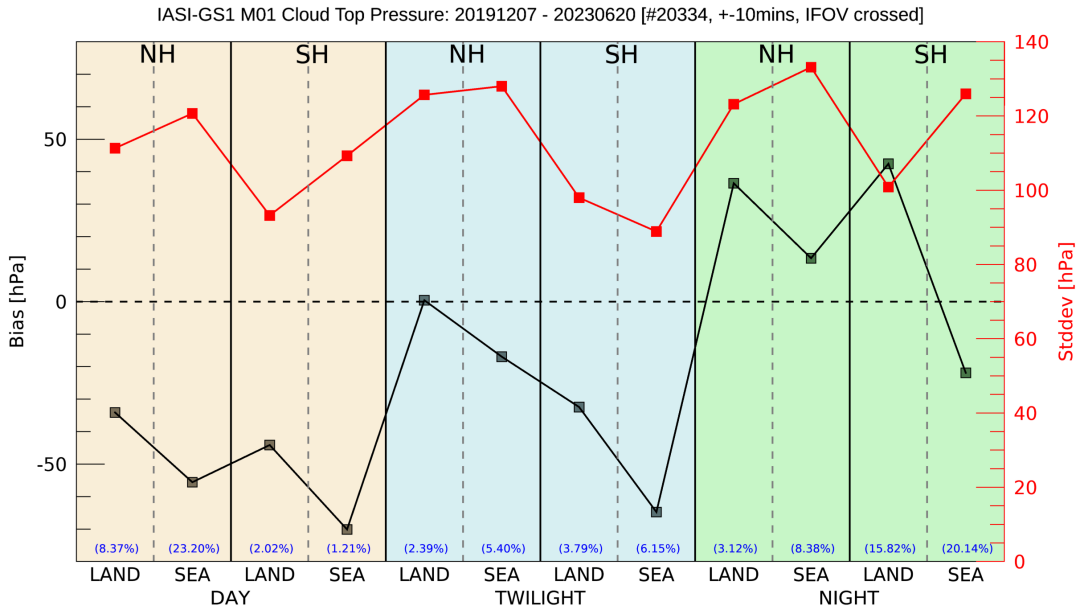

Figure 5.4: Cloud Top Pressure dependencies on Daytime for Northern (NH) and Southern Hemisphere (SH) separated for Land and Sea between IASI L2 and Caliop, statistics with M01 IASI L2 from GS1

5.4 Cloud Top Temperature

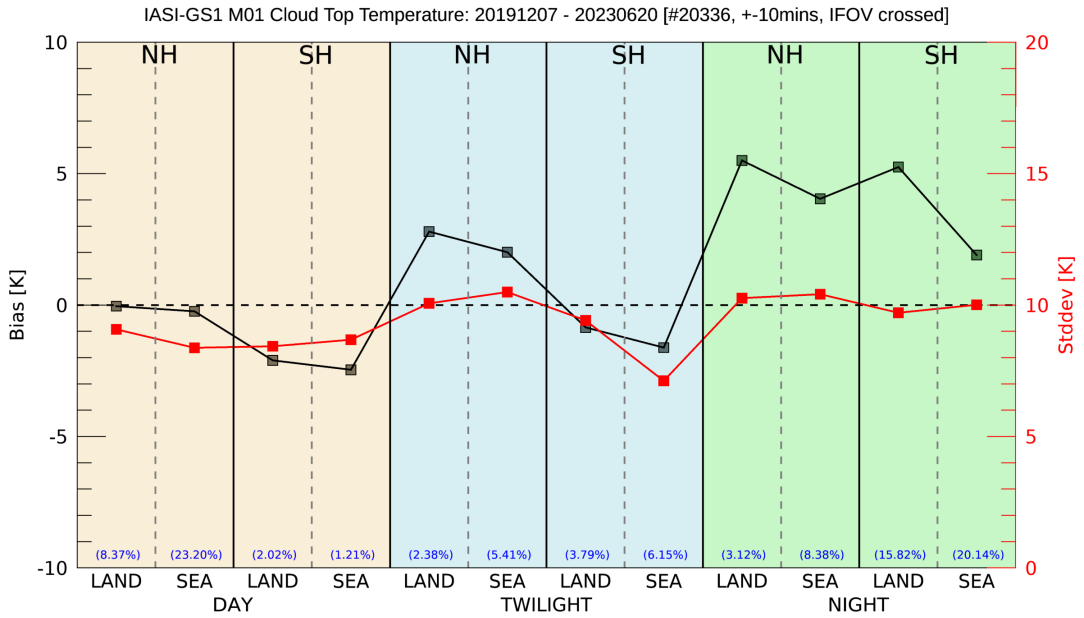

Figure 5.5: Cloud Top Temperature dependencies on Daytime for Northern (NH) and Southern Hemisphere (SH) separated for Land and Sea between IASI L2 and Caliop, statistics with M01 IASI L2 from GS1