EUMETSAT Satellite Application Facility on Climate Monitoring

Validation Report

ICDR AVHRR – based on CLARA-A2 methods

Cloud Products

Fractional Cloud Cover	**CM-6010**
Cloud Top level	**CM-6030**
Cloud Phase	**CM-6040**
Liquid Water Path	**CM-6050**
Ice Water Path	**CM-6060**

Reference Number:	SAF/CM/DWD/ICDR/CLARA/CLD/VAL
Issue/Revision Index:	2.1
Date:	01.02.2021

Document Signature Table

	Name	Function	Signature	Date
Authors	Karl-Göran Karlsson Martin Stengel Irina Solodovnik Jan Fokke Meirink	CM SAF scientist (SMHI) CM SAF scientist (DWD) CM SAF scientist (DWD) CM SAF scientist (KNMI)		16.11.2020 01.02.2021
Editor	Rainer Hollmann Johannes Kaiser	Science Coordinator Operations Manager		23.11.2020 01.02.2021
Approval	CM SAF Steering Group			
Release	Rainer Hollmann	Project Manager		

Distribution List

Internal Distribution	
Name	**No. Copies**
DWD Archive	1
CM SAF Team	1

External Distribution		
Company	**Name**	**No. Copies**
PUBLIC		1

Document Change Record

Issue/ Revision	Date	DCN No.	Changed Pages/Paragraphs
2.0	16/11/2020	SAF/CM/DWD/ICDR/CLARA/CLD/ VAL	Initial version
2.1	01/02/2021	SAF/CM/DWD/ICDR/CLARA/CLD/ VAL	Update after review with implemented corrections Layout revision and barrier free conversion

Applicable documents

Reference	Title	Code
AD 1	EUMETSAT CM SAF CDOP 3 Product Requirements Document (PRD)	SAF/CM/DWD/PRD/ 3.7, 19.10.2020

Reference Documents

Reference	Title	Code
RD 1	Product User Manual ICDR AVHRR Cloud Products	SAF/CM/DWD/ICDR/CLARA/CLD/PUM, 2.1
RD 2	Algorithm Theoretical Baseline Document (level-1 – level-2/2b – level-3) ICDR AVHRR Cloud Products	SAF/CM/DWD/ICDR/CLARA/CLD/ATBD, 2.1
RD 3	Algorithm Theoretical Basis Document ICDR AVHRR – based on CLARA-A2 methods, Cloud Fraction	SAF/CM/SMHI/ICDR/CLARA/CLD/ATBD_CMA/2.0
RD 4	Algorithm Theoretical Basis Document ICDR AVHRR – based on CLARA-A2 methods, Cloud Top level	SAF/CM/SMHI/ICDR/CLARA/CLD/ATBD_CTX/2.0

Reference	Title	Code
RD 5	Algorithm Theoretical Basis Document ICDR AVHRR – based on CLARA-A2 methods, Cloud Physical Products	SAF/CM/SMHI/ICDR/CLARA/CLD/ATBD_CPP/2.0
RD 6	Algorithm Theoretical Basis Document, CM SAF Cloud, Albedo, Radiation data record, AVHRR-based, Edition 2 (CLARA-A2), Probabilistic cloud masks – CMA-prob, A complementary product to level-2/level-2b	SAF/CM/SMHI/ATBD/GAC/PBCM/1.2

Table of Contents

List of Tables

List of Figures

The EUMETSAT SAF on Climate Monitoring

In 2000 the EUMETSAT Member States amended the EUMETSAT convention to affirm that the EUMETSAT mandate is also to “contribute to the operational monitoring of the climate and the detection of global climatic changes". Already in 1999, recognizing the importance of climate monitoring with satellites, EUMETSAT established within its Satellite Application Facility (SAF) network a dedicated centre, the SAF on Climate Monitoring (CM SAF, http://www.cmsaf.eu).

The consortium of CM SAF currently comprises the Deutscher Wetterdienst (DWD) as host institute, and the partners from the Royal Meteorological Institute of Belgium (RMIB), the Finnish Meteorological Institute (FMI), the Royal Meteorological Institute of the Netherlands (KNMI), the Swedish Meteorological and Hydrological Institute (SMHI), the Meteorological Service of Switzerland (MeteoSwiss), the Meteorological Service of the United Kingdom (UK MetOffice), and the Centre National de la Recherché Scientifique (CNRS). Since the beginning in 1999, the EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) has developed and will continue to develop capabilities for a sustained generation and provision of Climate Data Records (CDR’s) derived from operational meteorological satellites.

In particular, the generation of long-term data records is pursued. The ultimate aim is to make the resulting data records suitable for the analysis of climate variability and potentially the detection of climate trends. CM SAF works in close collaboration with the EUMETSAT Central Facility and liaises with other satellite operators to advance the availability, quality and usability of Fundamental Climate Data Records (FCDRs) as defined by the Global Climate Observing System (GCOS). As a major task the CM SAF utilizes FCDRs to produce Thematic Climate Data Records (TCDRs) for Essential Climate Variables (ECVs) as defined by GCOS. Thematically, the focus of CM SAF is on ECVs associated with the global energy and water cycle.

Another essential task of CM SAF is to produce data records that can serve applications related to the new Global Framework of Climate Services initiated by the WMO World Climate Conference-3 in 2009. CM SAF is supporting climate services at national meteorological and hydrological services (NMHSs) with long-term data records, i.e. FCDRs and TCDRs, but also with data records produced close to real time that can be used to prepare monthly/annual updates of the state of the climate, i.e. Interim Climate Data Records (ICDRs). Both types of products together allow for a consistent description of mean values, anomalies, variability and potential trends for the chosen ECVs. CM SAF ECV data records also serve the improvement of climate models both at global and regional scale.

As an essential partner in the related international frameworks the CM SAF - together with the EUMETSAT Secretariat assumes the role as main implementer of EUMETSAT’s commitments in support to global climate monitoring. This is achieved through:

- Application of highest standards and guidelines as lined out by GCOS for the satellite data processing,
- Processing of satellite data within a true international collaboration benefiting from developments at international level and pollinating the partnership with own ideas and standards,
- Intensive validation and improvement of the CM SAF climate data records,
- Taking a major role in data record assessments performed by research organisations such as WCRP (World Climate Research Program). This role provides the CM SAF with deep contacts to research organizations that form a substantial user group for the CM SAF CDRs,
- Maintaining and providing an operational and sustained infrastructure that can serve the community within the transition of mature CDR products from the research community into operational environments.

A catalogue of all available CM SAF products is accessible via the CM SAF webpage, https:/www.cmsaf.eu/. Here, detailed information about product ordering, add-on tools, sample programs and documentation is provided.

1 Introduction

The Interim Climate Data Record (ICDR) AVHRR, based on CLARA-A2 methods, provides a routinely generated continuation of the product suite of the CLARA-A2.1 (CM SAF cLoud, Albedo and RAdiation) products, AVHRR-based, edition 2.1; http://dx.doi.org/10.5676/EUM_SAF_CM/CLARA_AVHRR/V002_01) record (see Figure 1-1), which in turn is an update and extension of the CLARA-A2 data record (Karlsson et al., 2017).

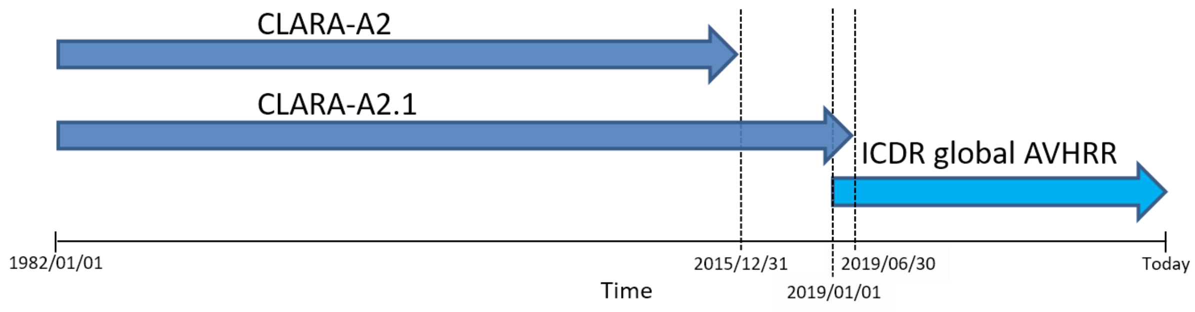


Figure 1-1: Schematic view of ICDR AVHRR continuing the CLARA-A2 records series.

As the heritage record CLARA-A2.1, the ICDR AVHRR features a range of cloud products: cloud mask, cloud top temperature/pressure/height (CTT/CTP/CTH), cloud thermodynamic phase (CPH), cloud optical thickness (COT), cloud particle effective radius (REF) and cloud water path (CWP). Cloud products are available as monthly and daily averages and also as daily resampled global products (Level 2b) for individual satellites. Cloud parameter results are also presented as single-parameter distributions (frequency histograms of CTP, CTT, COT, REF and CWP) and multi-parameter distributions (joint frequency histograms of COT, CTP and CPH for daytime conditions). Surface albedo is presented as monthly and pentad (5 day) averages and is derived using all available data during the studied period. Surface radiation products are provided as monthly averages for the downwelling shortwave (including also daily averages) and the down- and upwelling longwave components. All monthly and daily averages are available on a 0.25°x0.25° global grid. Surface albedo and cloud products are also provided in two equal area grids with a resolution of 25 km x 25 km covering the Polar Regions. Daily resampled cloud products (level 2b) are provided in a global grid with a resolution of 0.05°x0.05°. For the latter, also a probabilistic cloud mask (denoted CMA-prob) is added as an experimental product.

For information about surface radiation and albedo products of the ICDR AVHRR record, the reader is referred to the following landing page:

https://wui.cmsaf.eu/safira/action/viewICDRDetails?acronym=CLARA_AVHRR_V002_ICDR

This Validation Report (VAL) presents the results inferred from evaluating the ICDR AVHRR **cloud properties**. Descriptions of the applied retrieval algorithms are available in the Algorithm Theoretical Baseline Document (ATBD, [RD 2] – [RD 6]), while general guidance on the cloud properties can be found in the Product User Manual (PUM, [RD 1]).

2 Evaluation of ICDR AVHRR Clouds

In this section the evaluation results for the ICDR AVHRR cloud properties are presented. The evaluation was solely done by comparisons to the corresponding TCDR (CLARA-A2.1) for a 6-month overlap period (01/2019-06/2019). The evaluation in this section is separated by product level (level-2b: Section 2.1; level-3: Section 2.2).

It will be shown that the ICDR and TCDR cloud properties are very similar, but there are some differences. The primary cause for these differences are the sources of numerical weather prediction (NWP) data used as input to the retrievals. The ICDR cannot take data from the ERA-Interim reanalysis as input, as is done for the TCDR, but instead uses data from the current ECMWF operational forecast model (IFS). These NWP datasets differ in various ways including horizontal and vertical resolution, model version and data assimilation system. The NWP information can impact the results of the cloud retrievals in various ways, which are analysed in detail in Section 3.

2.1 Evaluation of ICDR AVHRR clouds level-2b products

Figure 2-1 shows global L2b maps for the ICDR, the TCDR and their difference for one selected day for NOAA-18 – for cloud mask (CMA), CPH, CTP and CWP. The global and regional pattern of the cloud properties are very similar in both sets. Differences are generally very small, of very small scale and of noisy pattern. Clusters of systematic differences can – if at all – be identified in the Antarctic, Southern Hemispheric Mid-latitudes, Northern Hemispheric continents and in the Arctic, depending on whether CMA, CTP or CWP are considered, while CPH does not show any significant difference. Again, the found differences are very small compared to the absolute value of the cloud properties. Figure 2-2 shows the same data for Metop-A with very similar results.

2.2 Evaluation of ICDR AVHRR level-3 products

Figure 2-3 presents global maps of monthly mean comparisons between the ICDR and the TCDR for CFC, CPH, CTP, LWP and IWP for March 2019 for Metop-A. For CFC and CPH patterns of small systematic differences (positive and negative) are found for Northern Hemispheric land regions, where the Sahara desert and Himalaya seem most prominent and some regions at higher latitude are less prominent but still visible. For LWP and IWP differences are mainly found for Himalaya and higher latitudes of the Northern Hemispheric land regions with quite some horizontal extent suggesting an impact of the underlying snow information. This is supported by Figure 2-4, showing the results for a norther hemispheric summer month (June 2019), where these differences are not visible anymore. The ICDR shows generally lower values than the TCDR for these properties. For cloud top pressure difference pattern are also of larger scale and are found in both continental and maritime regions. Compared to the TCDR, the ICDR CTP is higher (lower cloud top heights) mainly in the maritime stratocumulus regions and over the oceans in the northern and southern Mid-latitudes. Lower ICDR CTP (higher cloud top heights) are for example found in the trade cumulus regions and in the Arctic.

All these findings are also reflected in the zonal mean plots (including Jan. to Jun. 2019) and monthly time series plots of Figure 2-5. The zonal mean plots highlight again the consistency between the ICDR and the TCDR with small systematic deviations found in the mid and high latitudes only. The consistency is also visible in the time series plots. For CFC the smaller global mean values are seen consistently throughout all months, however only amounting to 0.1% cloud fraction. CPH differences are not visible, while global mean values of the ICDR CTP are permanently lower, however, only by around 1 hPa or less. Higher LWP and IWP values are most pronounced in Feb., Mar. and Apr., probably due to snow cover being highest in these months in the Northern Hemisphere.

In general, it was found that the difference patterns for all satellites are highly comparable. Consequently, the results for the AVPOS products (AVPOS refers to the average of all available satellites), displayed in Figures Figure **2-6** and Figure **2-7**, are very similar to the results for the Metop-A products as mentioned above, thus allowing similar conclusions.

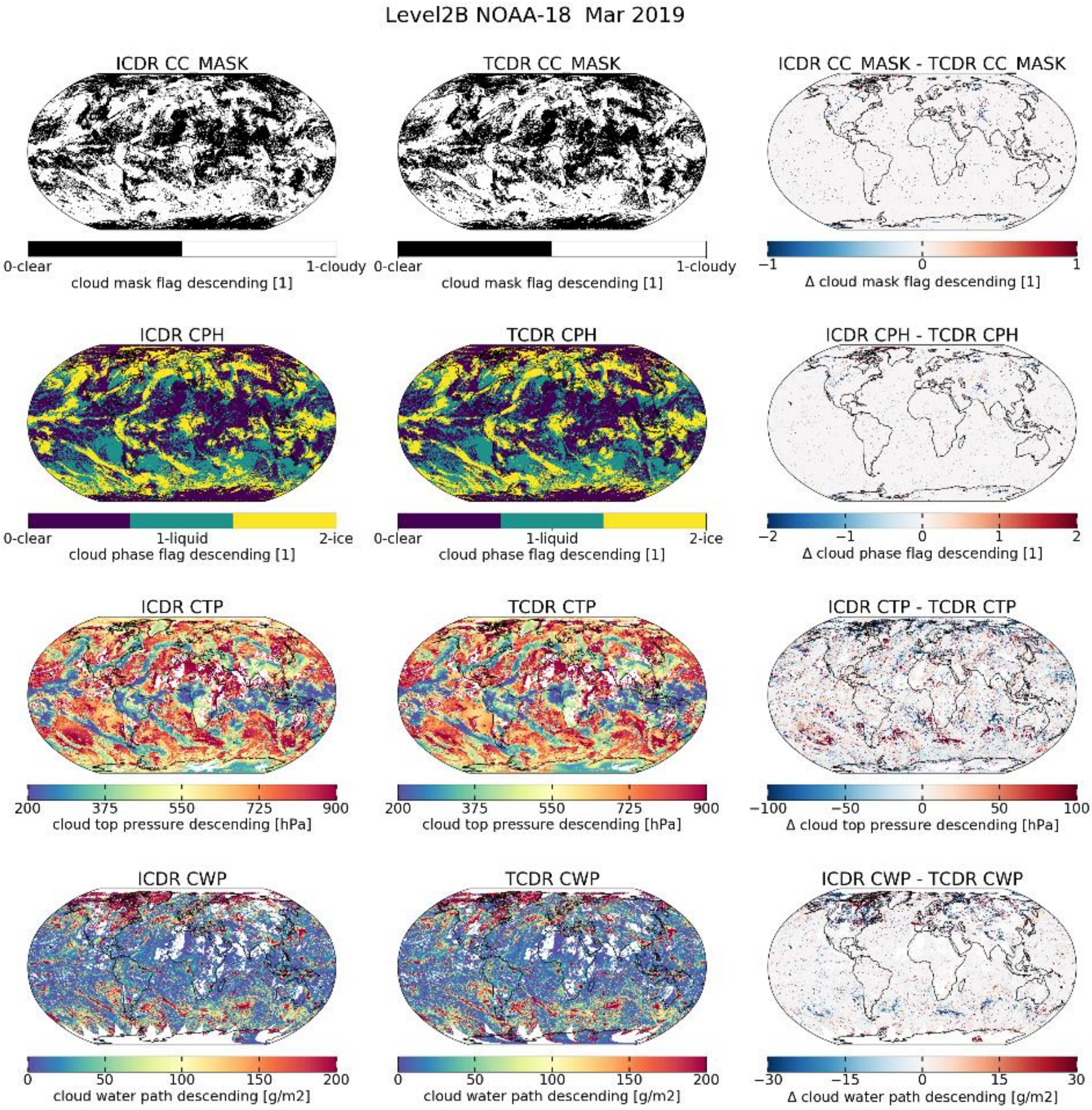


Figure 2-1: Level-2b comparisons between ICDR global AVHRR and corresponding TCDR (CLARA-A2.1) for cloud mask, cloud phase, cloud top pressure and cloud water path (from top to bottom) for 15/03/2019 and NOAA-18.

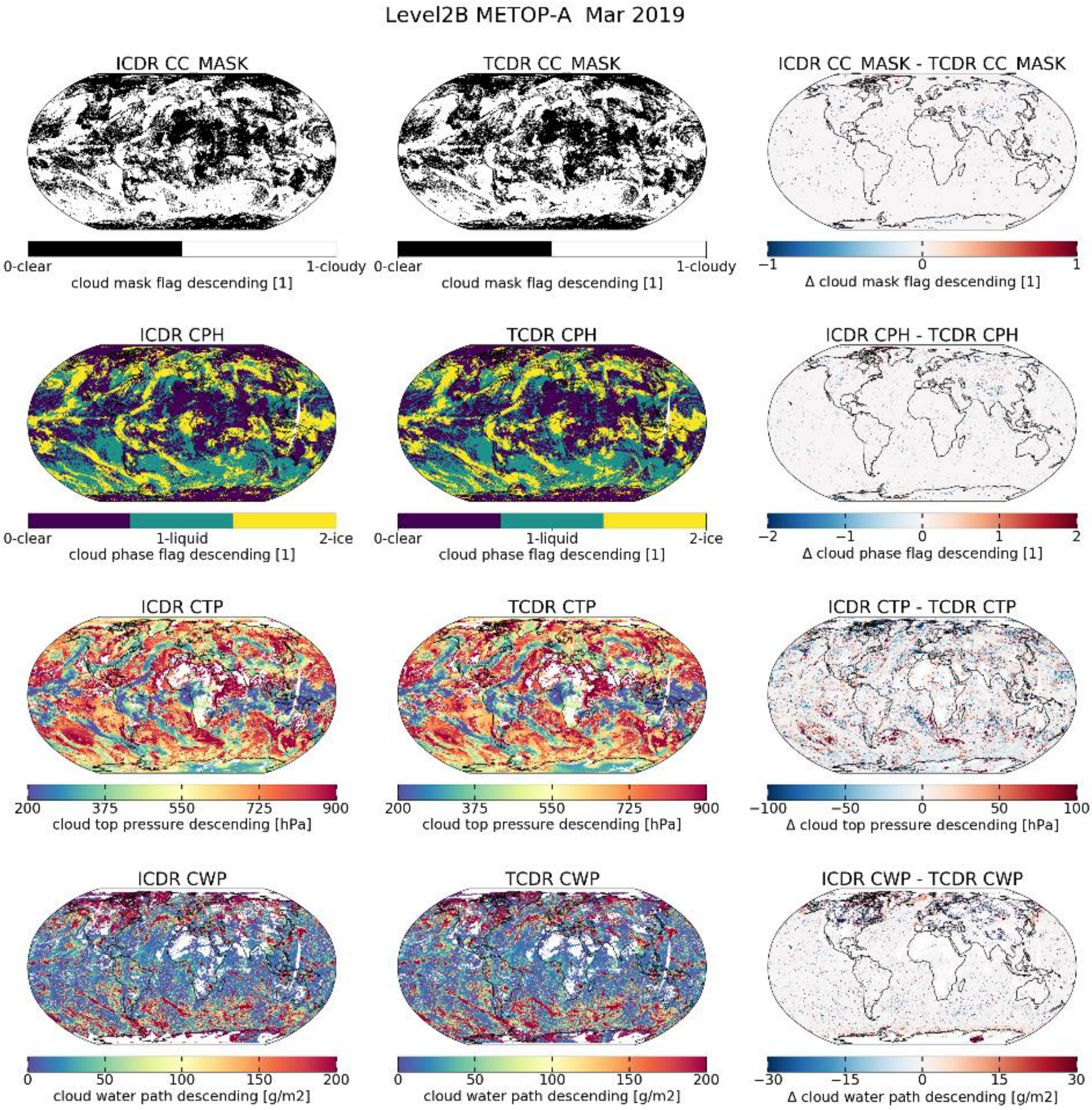


Figure 2-2: As Figure 2-1 but for Metop-A.

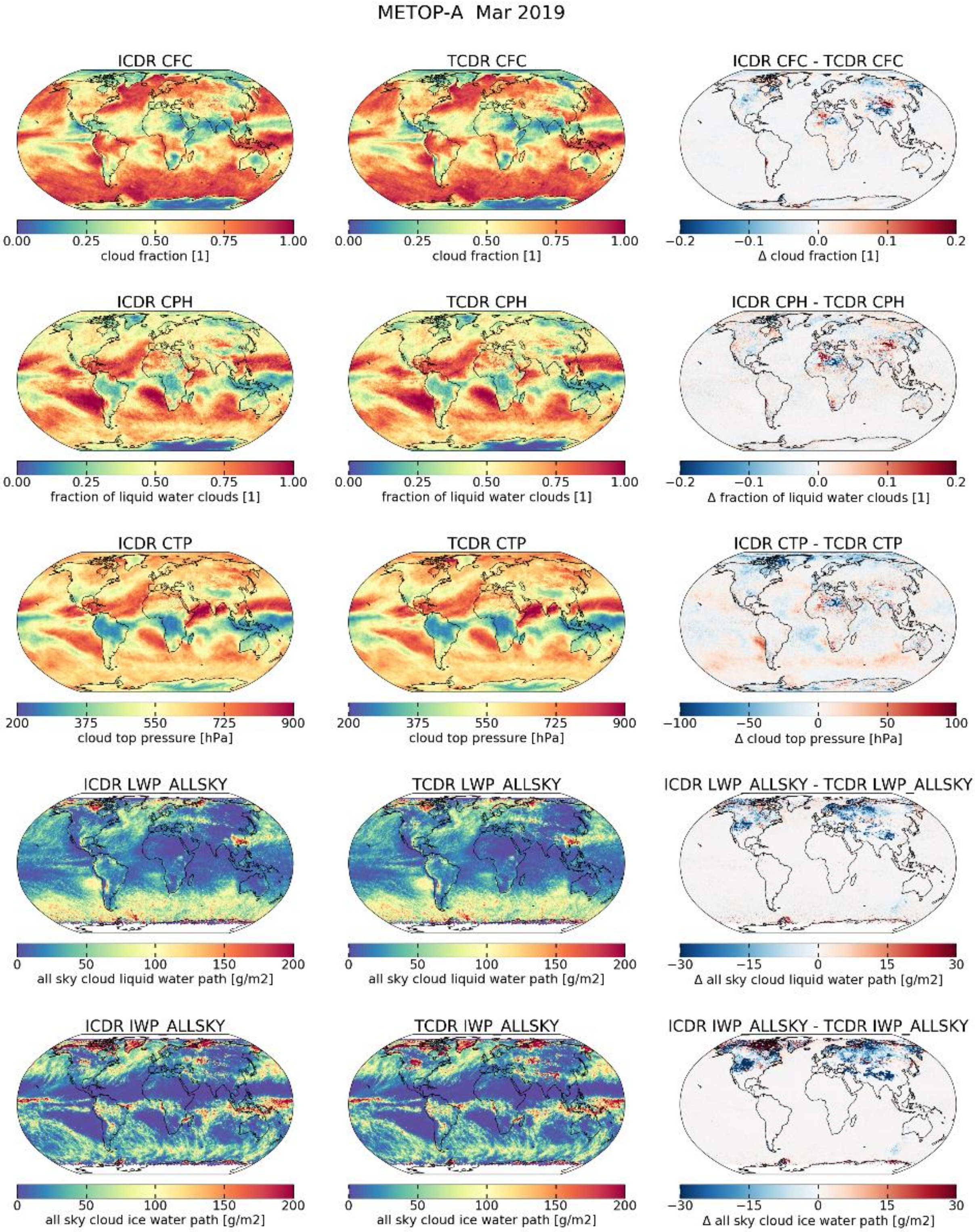


Figure 2-3: Level-3 monthly mean comparisons between ICDR global AVHRR and corresponding TCDR (CLARA-A2.1) for cloud fraction, cloud phase (liquid cloud fraction), cloud top pressure, liquid water path and ice water path (from top to bottom) for 03/2019 and Metop-A.

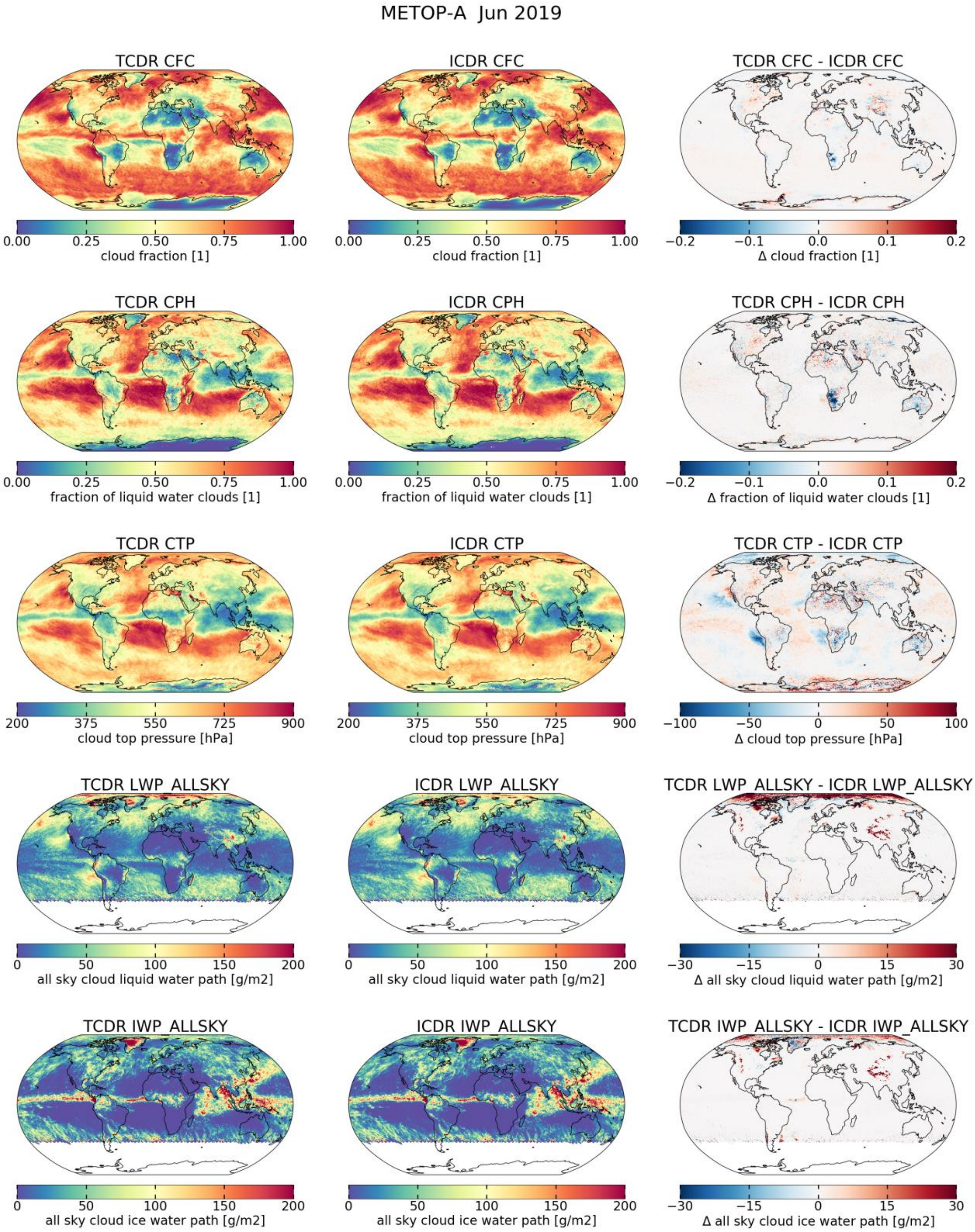


Figure 2-4: As Figure 2-3 but for 06/2019.

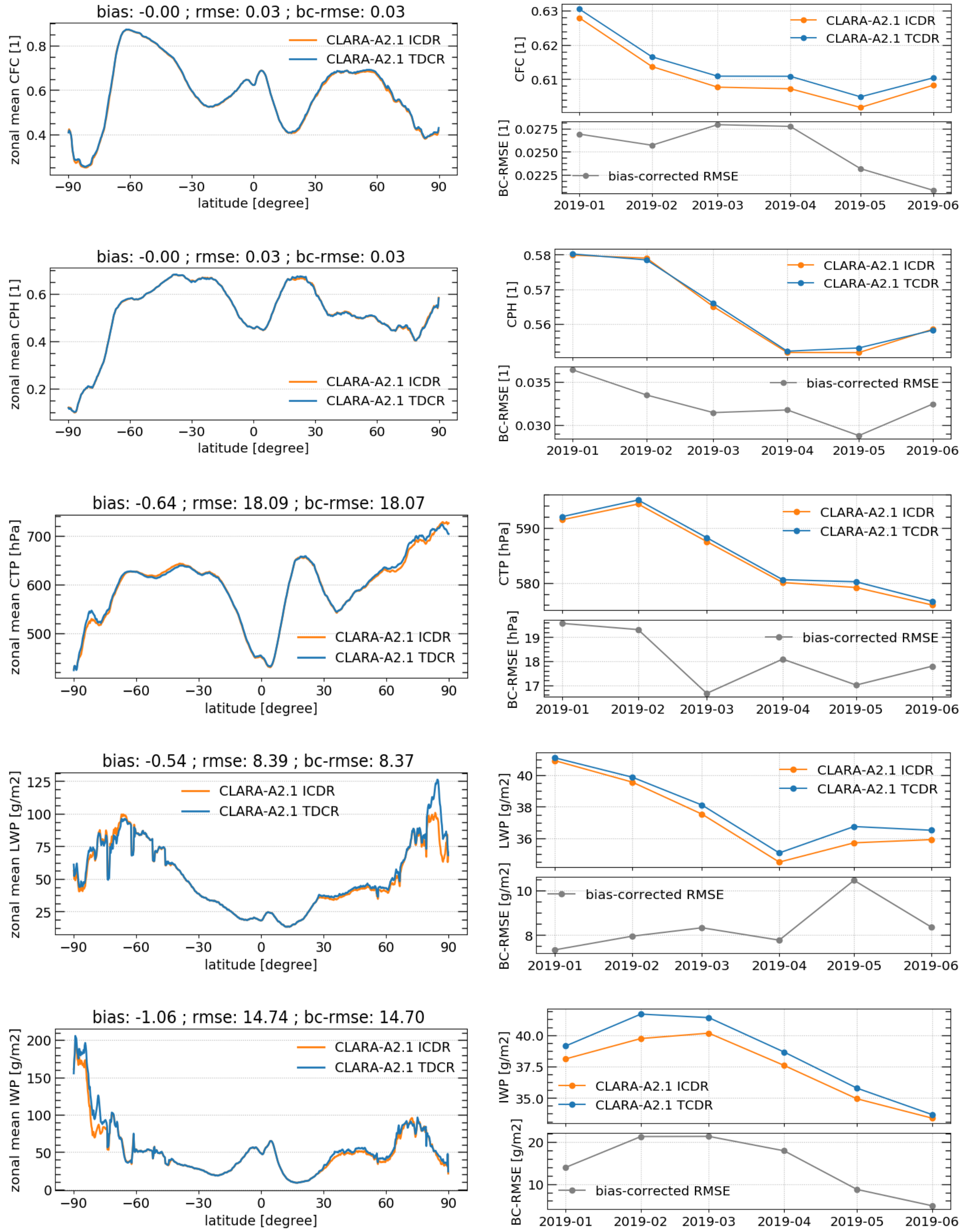


Figure 2-5: Zonal mean plot (left, including 01-06/2019) and time series of monthly global mean values and bc-RMSE (right) for the ICDR global AVHRR and the TCDR (CLARA-A2.1) for cloud fraction, cloud phase (liquid cloud fraction), cloud top pressure, liquid water path and ice water path (from top to bottom) for Metop-A.

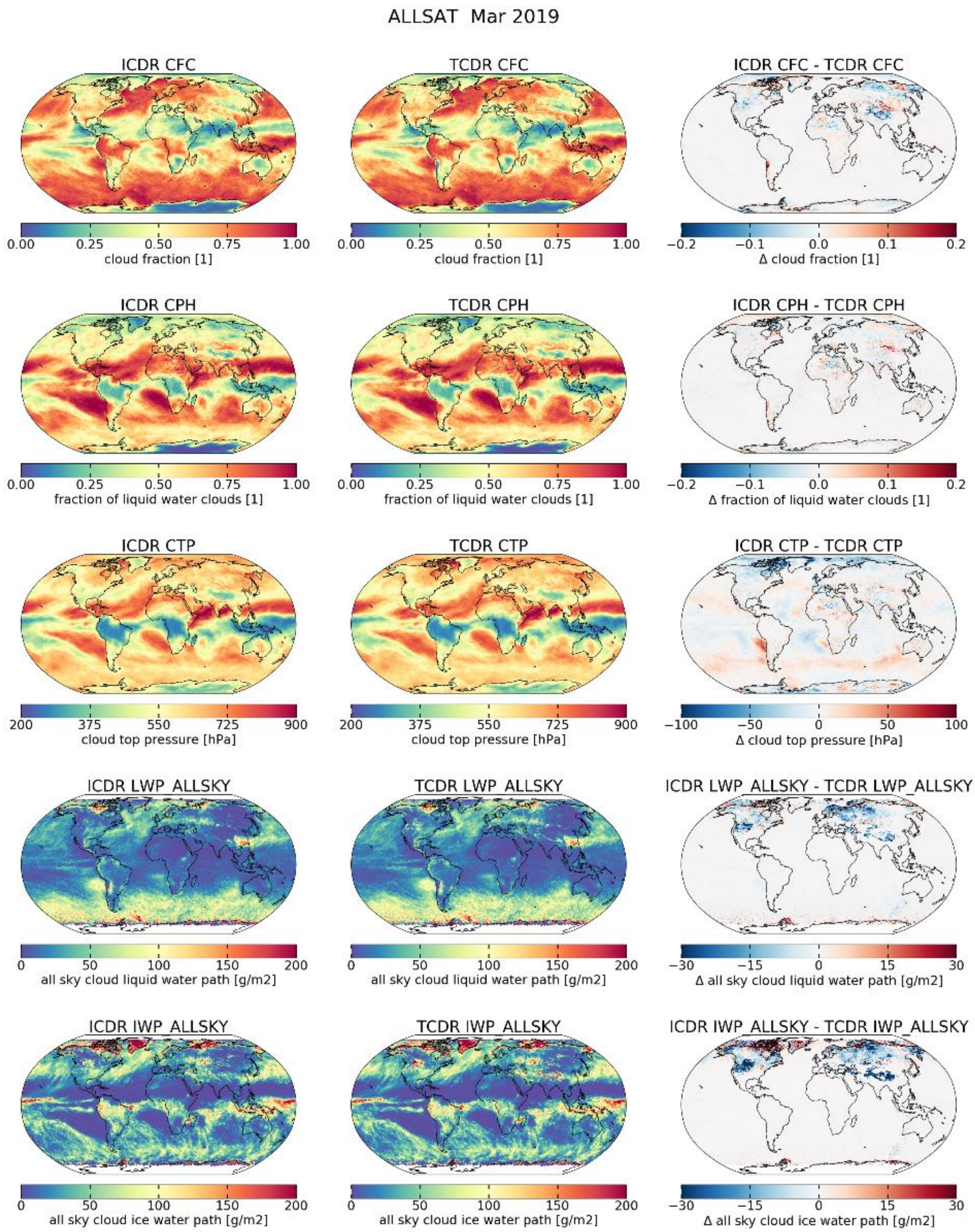


Figure 2-6: As Figure 2-3 but for AVPOS.

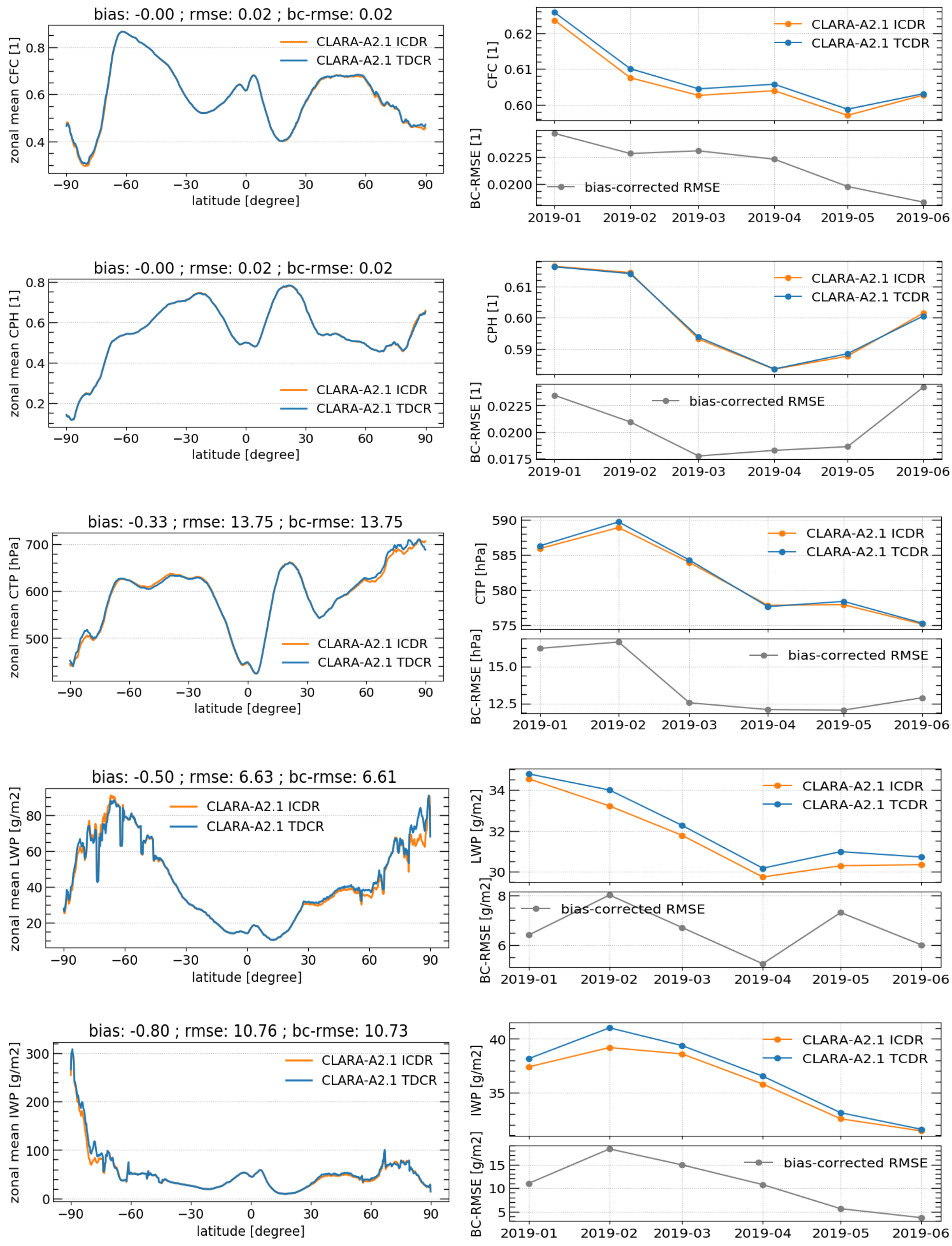


Figure 2-7: As Figure 2-5 but for AVPOS.

3 Analysis of the impact of varying NWP and ancillary data on ICDR compared to the TCDR

The PPS cloud processing software has been using ancillary data from ERA-Interim as input data when producing the cloud products for the compilation of CLARA-A2.1. Especially, temperature information for the surface and a few other vertical layers as well as information on the total column integrated moisture content were used in the initial cloud detection procedure. These variables are needed when reading Lookup Tables (prepared from previously performed RTTOV RTM simulations) to determine appropriate thresholds for the cloud detection process. For the cloud top height retrieval, full profiles of temperature and moisture are also needed as the basic profile reference. In addition, for the experimental probabilistic cloud mask (CMA-prob) information on snow cover has been taken from ERA-Interim. For the retrieval of cloud optical and microphysical properties surface temperature, total column water vapour and snow depth and albedo are used.

Unfortunately, ERA-Interim data are only available until June 2019 and the CLARA-A2.1 ICDR AVHRR production must therefore use other data sources replacing ERA-Interim. This is a challenge since alternative data will not be able to exactly simulate the content of the previous ERA-Interim dataset. Consequently, it is very likely that this will introduce some differences to the CLARA-A2.1 ICDR AVHRR results compared to the original CLARA-A2.1 TCDR.

CM SAF has chosen to use analyses and short-term forecasts from the current ECWMF operational forecast model (IFS) to replace ERA-Interim. However, ERA-Interim re-analyses and the operational IFS analyses are fundamentally different for at least four different reasons.

1. Different horizontal and vertical resolutions

   ERA-Interim has 80 km horizontal resolution and 60 vertical layers compared to 9 km horizontal resolution and 137 vertical layers for IFS.

2. Different underlying forecast model system

   ERA-Interim is based on IFS model version CY31R2 while the current (2020) IFS version is CY47R1. IFS version CY31R2 was initially introduced in 2006 and version CY47R1 in 2020. Consequently, almost 15 years of development have lead to considerable changes which affect both dynamics and physical parameterisations in the model.

3. Differences in data assimilation methods

   The two mentioned model versions are also associated with two different data assimilation systems. In the same way, the data assimilation methods have also undergone considerable development since IFS CY31R2.

4. Different observational input to data assimilation

   New observation data sources have been introduced in CY47R1 and also the treatment of some previously available observations has changed.

The effect of different horizontal resolutions has been accounted for to some extent by sampling both ERA-Interim and operational IFS at the same spatial resolution of 0.5 degrees, which in practice means that ERA-Interim is oversampled from 0.75 to 0.5 degrees and operational IFS is undersampled from 0.08 to 0.5 degrees. Vertical profile information was ingested at the native model resolution, i.e. 60 and 137 levels for ERA-Interim and the IFS operational model, respectively. The other effects are naturally not possible to correct for.

In the following subsections some differences between the NWP input data for the ICDR and TCDR will be highlighted and effects on the retrieval products will be illustrated.

3.1 Horizontal resolution differences in NWP input

When comparing the ICDR and TCDR NWP input, the difference in resolution is very clear, in particular in the near-surface parameters. As an example, **Figure 3-1** shows the surface temperature in a region in southeastern Africa. The IFS operational model field shows much more detail than the ERA-Interim counterpart. Apart from an overall somewhat higher surface temperature in IFS, the difference field mainly reflects this difference in resolution. Over ocean (right part of the images), the surface temperature varies much less and therefore the differences between IFS and ERA-Interim are also much smaller. Thus, although IFS and ERA-Interim output were sampled at the same horizontal resolution of 0.5 degrees in latitude and longitude, the higher native resolution of IFS is well noticeable. This has an effect on level-2 products but tends to be averaged out to some extent in level-3 products. However, structural differences between both models are also present and a few examples of these are given in the next subsections.

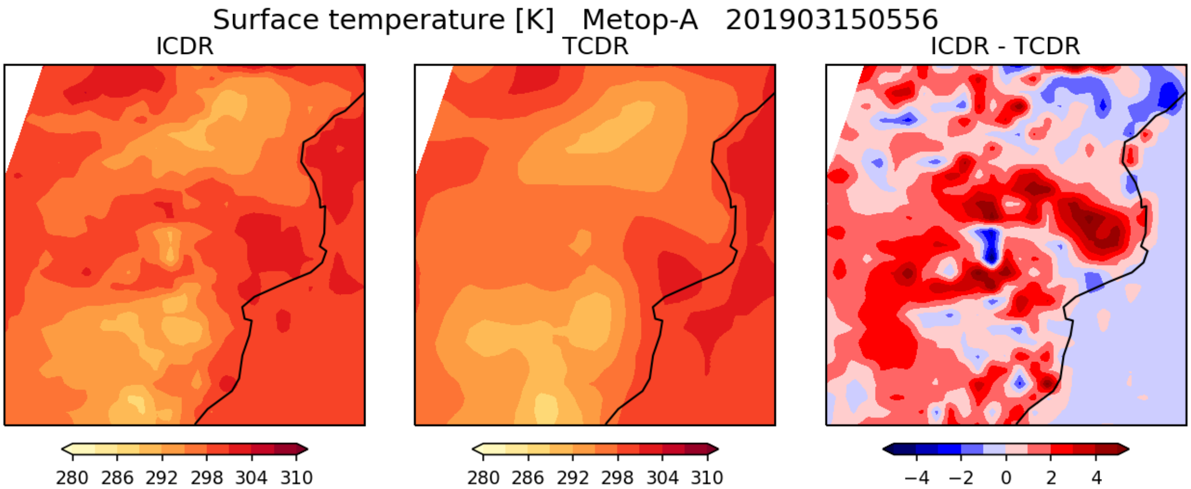
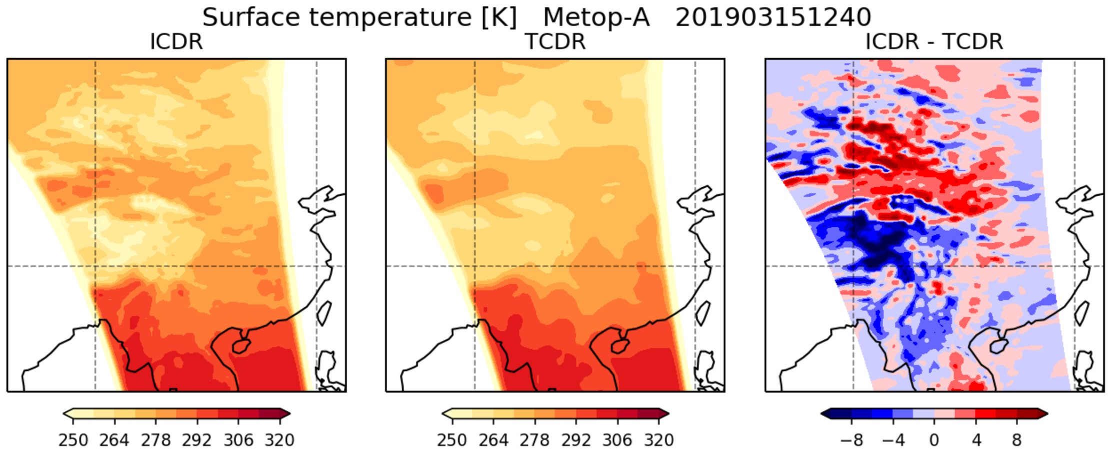


Figure 3-1: Surface temperature from IFS used as input for the ICDR (left), from ERA-Interim used as input for the ICDR (middle) and their difference (right) for the daytime part of a Metop-A orbit along the southeast African coast on 15 March 2019.

3.2 Effects of surface temperature on the cloud mask

Comparisons between ICDR and TCDR March 2019 monthly mean cloud fractions, presented in Figure 2-3, indicated systematic differences in particular over central Asia. The temperature of the surface (T_s) is an important piece of information going into the cloud mask algorithm because the decision whether a pixel is labelled cloudy depends on the contrast of the observed brightness temperature (BT) of the scene with the clear-sky BT simulated based on the surface temperature.



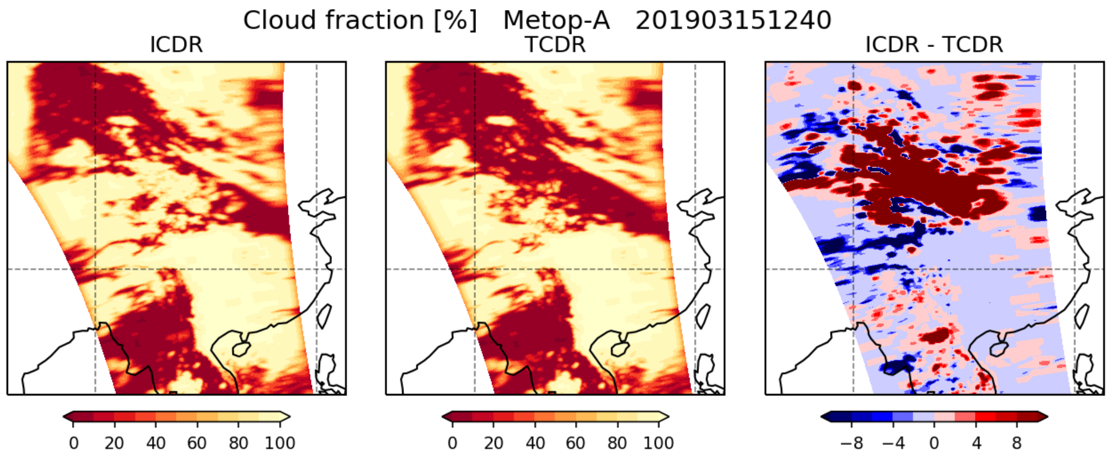
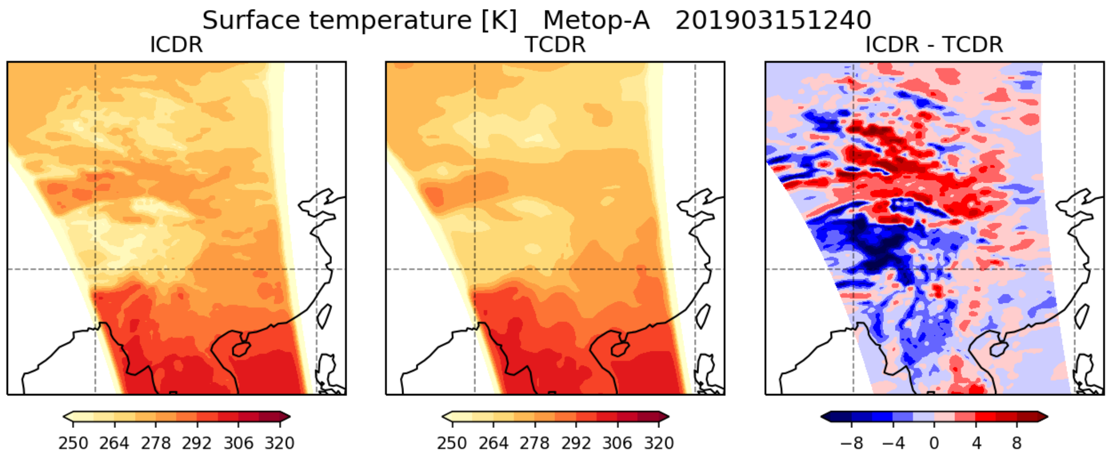


Figure 3-2 shows that over Central Asia differences of up to 10 K between T_s from the ICDR and TCDR occur. The main features are lower temperatures in the ICDR over the Himalayas and higher temperatures to the northeast of this. These patterns cause systematic differences in the ICDR and TCDR cloud masks, as shown in the bottom row of



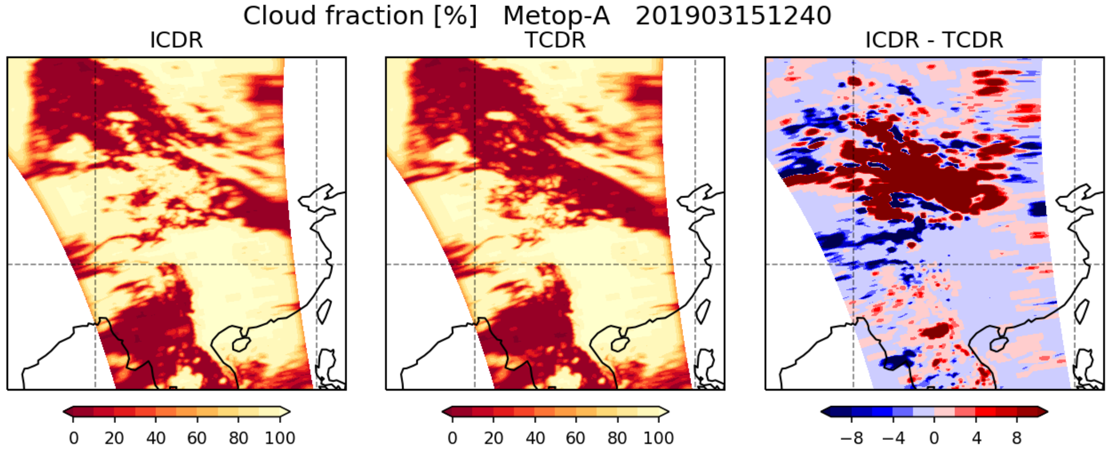


Figure 3-2. An (assumed) colder surface has less contrast with clouds, resulting in a lower retrieved cloud fraction and vice versa. Over most of the globe, however, the surface temperatures of the two NWP datasets are more similar, yielding also much better agreement in cloud fractions. In particular, differences in sea surface temperatures are generally very small and correspondingly the ICDR and TCDR cloud masks agree well. During daytime additional information from the shortwave channels is available for cloud detection. Therefore, the surface temperature has less impact on the retrievals and ICDR-TCDR differences are indeed somewhat smaller (not shown).

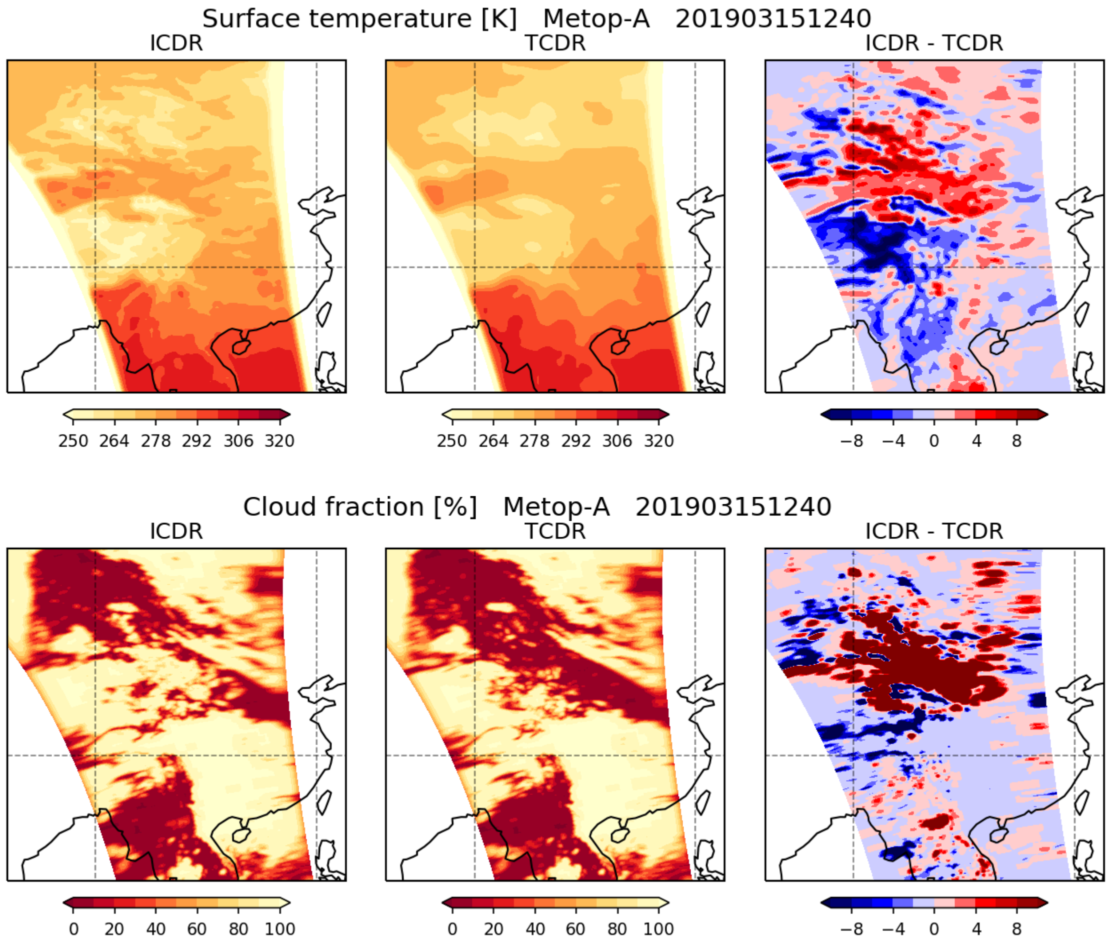
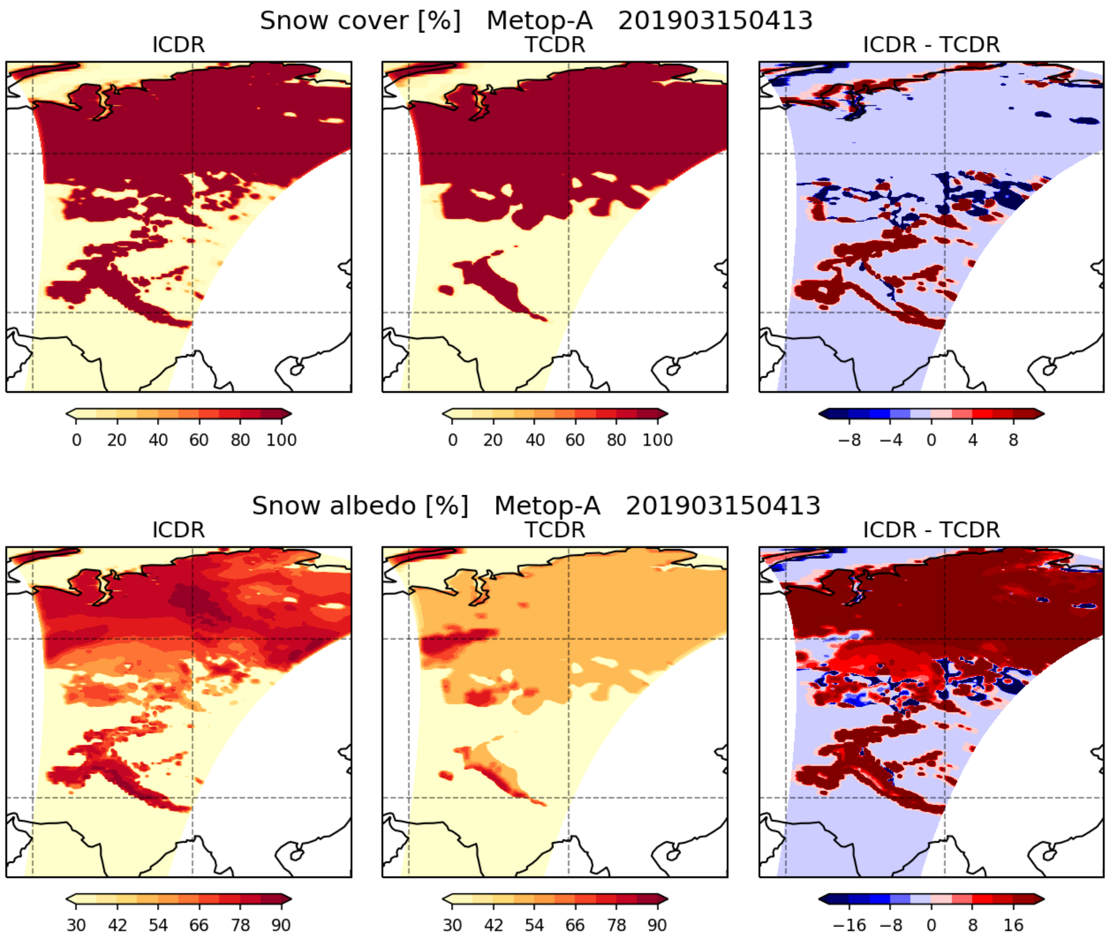


Figure 3-2: Surface temperature (top row) used as input data, and retrieved cloud mask/fraction (bottom row) for the ICDR (IFS operational model; left), TCDR (ERA-Interim; middle), and ICDR-TCDR difference (right) for the nighttime part of a Metop-A orbit over Asia on 15 March.

3.3 Effects of snow depth and albedo on cloud optical thickness

Snow cover is a complicating factor for cloud retrievals in general and for the retrieval of cloud optical thickness (COT) in particular. COT is retrieved from the reflectance in the visible channel around 0.6 micron and in that spectral range a snow covered surface has a similar albedo as a cloud. Since the climatological surface albedo database used for CLARA-A2 does not take snow cover into account, NWP model information is employed. NWP snow depth is used to delineate snow covered areas (using a threshold depth of 5 cm), while the corresponding albedo is estimated on the basis of NWP snow albedo. Both fields are shown in



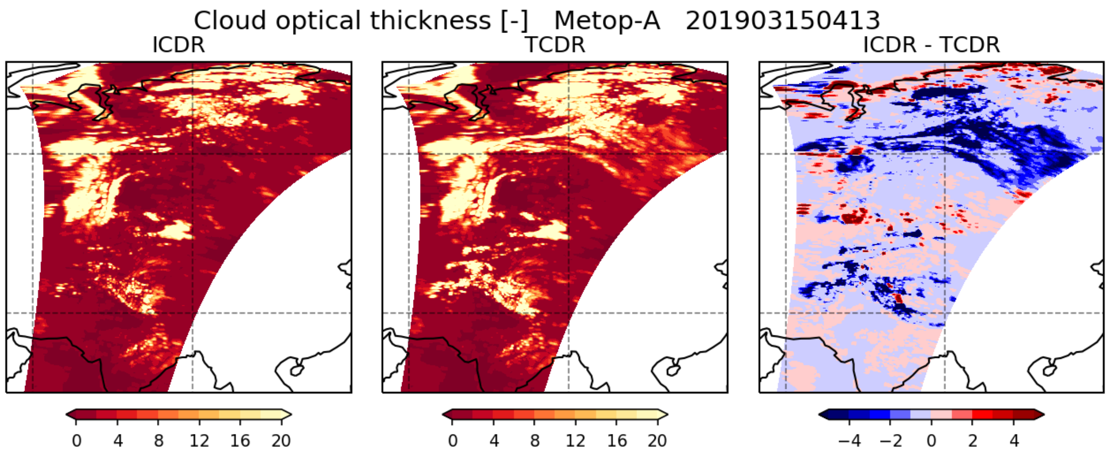
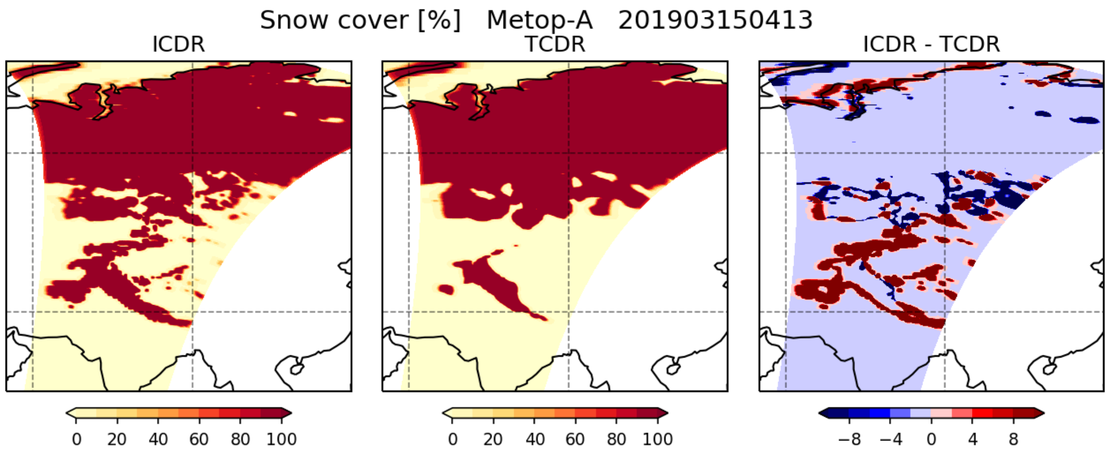


Figure 3-3. Large differences between the ICDR snow parameters, from IFS, and the TCDR snow parameters, from ERA-Interim, are apparent. The snow cover around the Himalayan area is larger in the operational IFS model, while more to the North the snow cover is 100% in both models according to the definition used. The snow albedo in ERA-Interim is much more constant and overall lower than in IFS. This has considerable effects on the retrieved cloud optical thickness. In most of the Himalayan area the snow is absent in the TCDR, giving a darker surface and thus larger retrieved COT, i.e. the ICDR-TCDR COT difference is negative. At higher latitudes, the snow albedo, which is higher in the IFS, causes the retrieved COT also to be lower in the ICDR. There are only a few smaller patches where the TCDR has a lower albedo and COT.

It is recognized that this discussion is somewhat speculative. There are opposing effects which may vary over time, and a full analysis is outside the scope of this report, but it is clear that the differences in snow parameters between the NWP datasets are considerable and thus also a significant impact on the retrieved cloud properties can be expected in the high-latitude continental areas. Indeed, Figure 2-3 showed overall lower LWP and IWP for the ICDR compared to the TCDR in Northern Hemispheric continental areas, which is consistent with the lower COT observed in



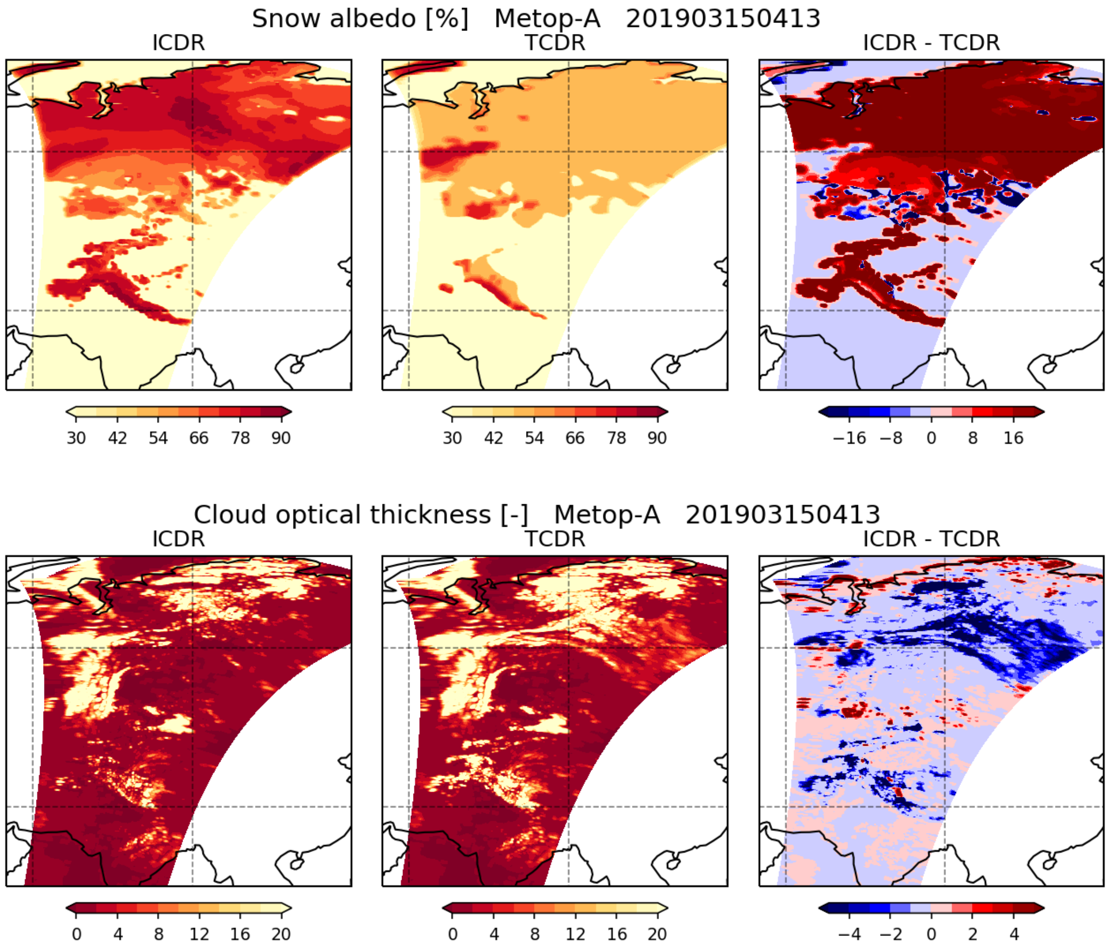


Figure 3-3. However, the uncertainty of the retrievals in snow conditions is large, and therefore the differences in retrievals are overall judged to be acceptable.

Snow cover information from NWP is not only used in the COT-REF (and thus LWP/IWP) retrieval but also in the CMA-prob algorithm. Generally, if snow cover increases, the cloud probability will decrease during night time. This is linked with the fact that snow-covered surfaces are generally colder than snow-free surfaces at night, thus leading to more problematic cloud detection conditions (i.e., less contrast between clouds and surfaces). However, daytime cloud detection should not be affected that much by snow cover because of the good ability to detect clouds thanks to cloud reflection in the 1.6 or 3.7 micron channel.

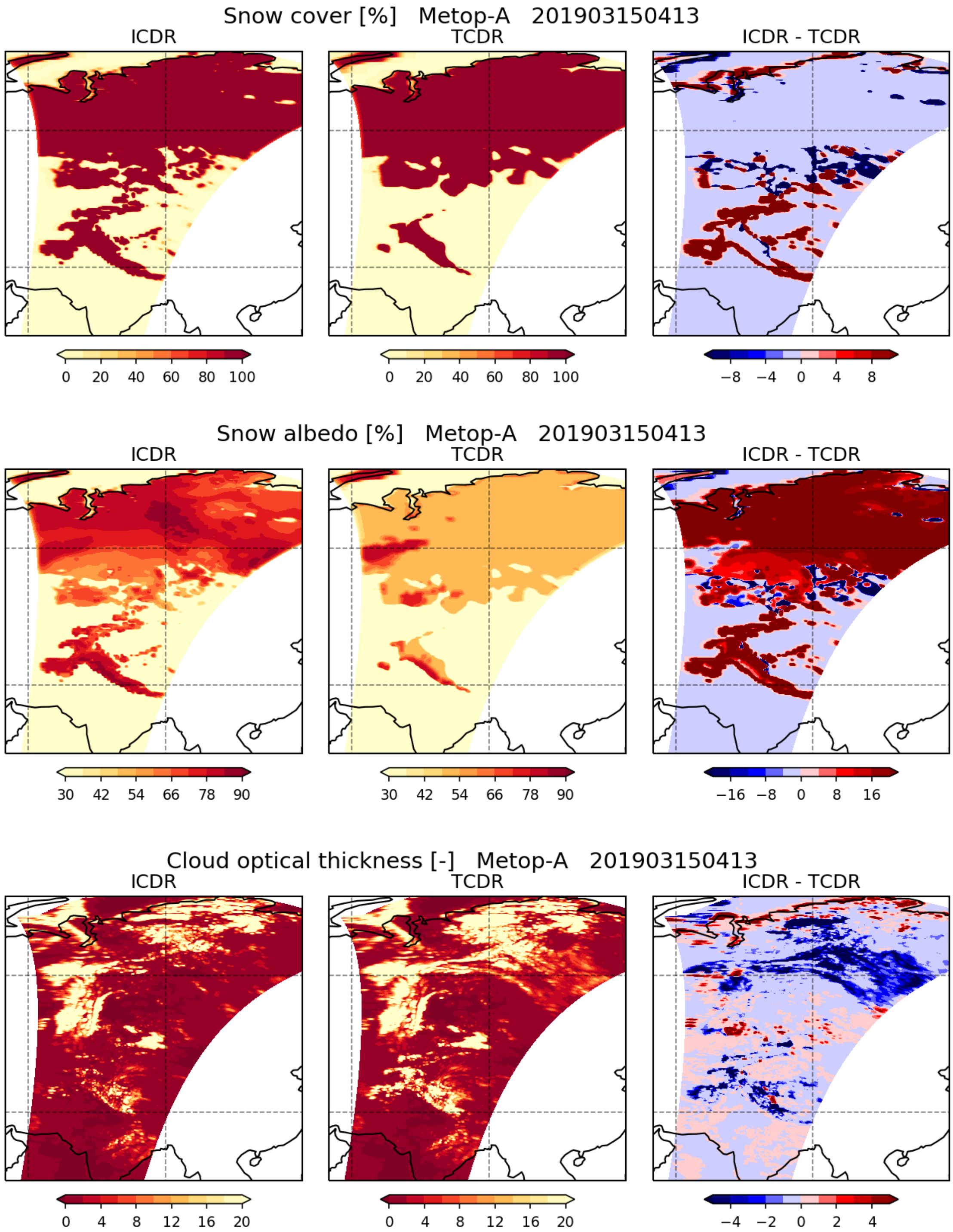


Figure 3-3: Snow cover (top row) and snow albedo (middle row) used as input data, and retrieved cloud optical thickness (bottom row) for the ICDR (left), TCDR (middle), and ICDR-TCDR difference for the daytime part of a Metop-A orbit over Asia on 15 March 2019. Snow cover is set to 0 or 100% depending on the snow depth being smaller or larger than the threshold of 5 cm, respectively, following the way it is done in the retrieval algorithm. Snow albedo is only shown in locations where snow cover is 100%, while in the figure a low value of 15% is set elsewhere, reflecting a typical albedo if no snow is present.

3.4 Effects of atmospheric temperature profiles on cloud top height

In Figure 2-3, persistent differences in retrieved cloud top pressure over several oceanic regions are reported. A particular example are the differences between ICDR and TCDR CTP of low clouds (mainly stratocumulus) over the Pacific west of Chile, the ICDR yielding up to 50 hPa higher monthly mean CTP, which is equivalent to several hundreds of meters lower CTH. This feature is further analysed in this subsection. **Figure 3-4** shows the ICDR and TCDR CTH for an exemplary Metop-A orbit. Both retrievals are overall similar except for a considerable number of isolated areas, for which the ICDR CTH is more than 2 km lower than the TCDR CTH. These features are not visible in the comparison of cloud top temperature: CTT differences are smaller than 2 K everywhere. The NWP temperature profiles, shown at 850 hPa – corresponding to about 1.5 km altitude – in **Figure 3-4**, differ in some places more than 5 K but not in the regions where the CTH features are observed. The actual explanation of the CTH features is related to the vertical resolution of the NWP model and to the representation of the vertical position and depth of the temperature inversion. The sharp inversion typical of stratocumulus clouds is known to give rise to ambiguities in CTH retrievals from infrared radiances (Hamann et al., 2004). As visible in Figure 3-5, the vertical position and depth of the temperature inversion is represented differently in ERA-Interim and IFS. In particular the missing depth of the temperature inversion in ERA-Interim (compared to IFS) is striking. Consequently, the ICDR retrieval can more often match the observed brightness temperature to the NWP profile just below the inversion, resulting in a much lower CTH. In instantaneous retrievals this occurs in isolated areas, but when aggregating to monthly means, a rather smooth pattern of negative ICDR-TCDR CTH differences emerges.

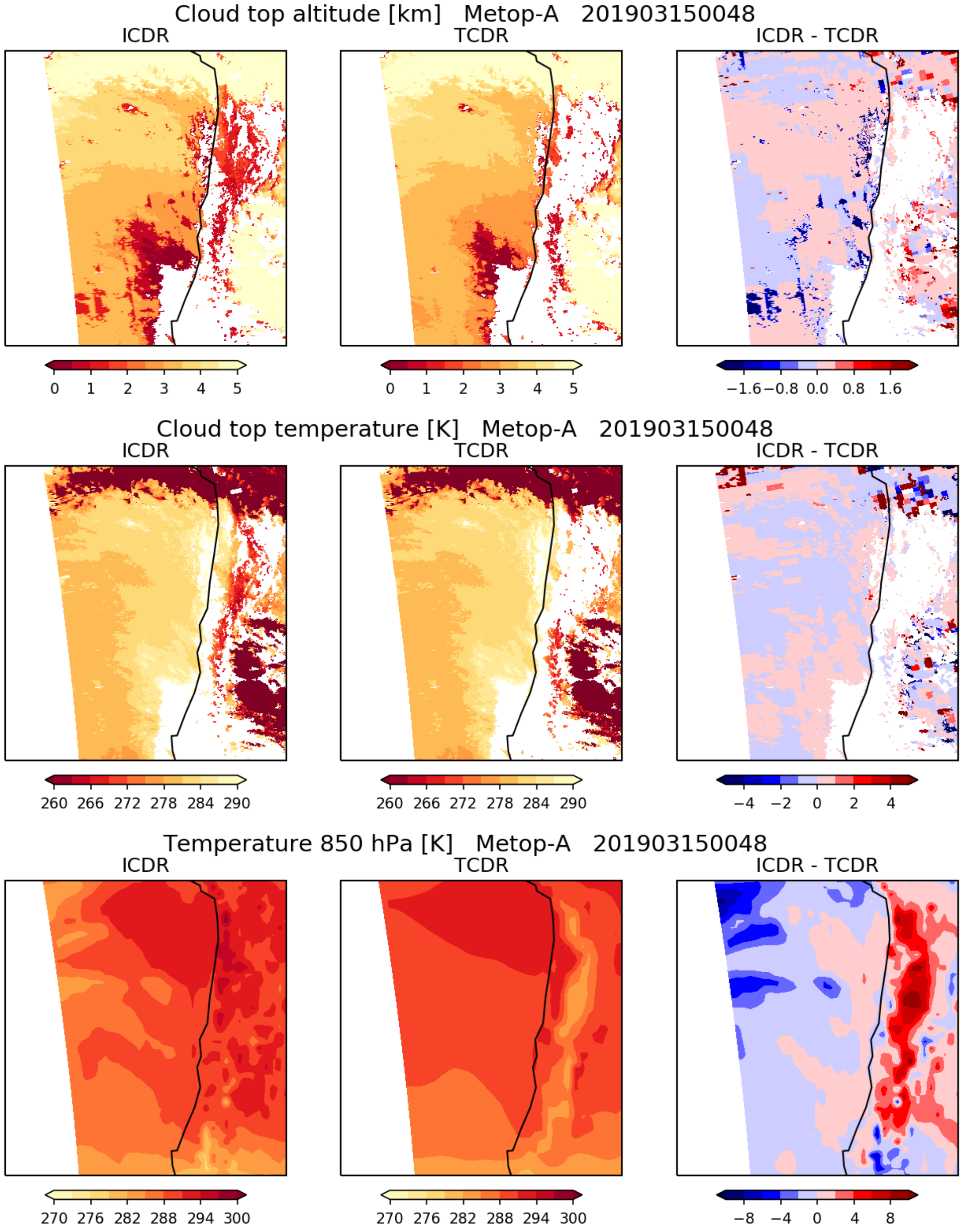
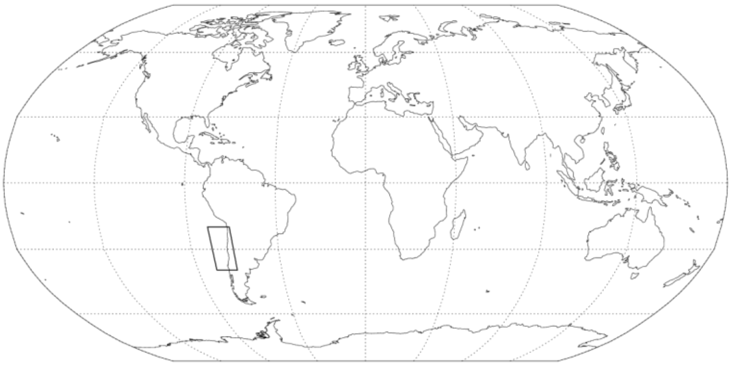


Figure 3-4: Cloud top height (top row), cloud top temperature (middle row) and 850-hPa NWP temperature (bottom row) for the ICDR (left), TCDR (middle), and ICDR-TCDR difference for the nighttime part of a Metop-A orbit along the west coast of south America on 15 March 2019.



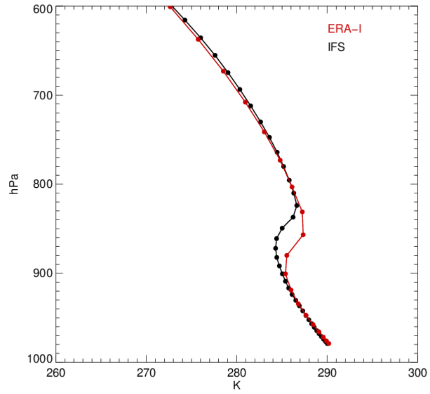


Figure 3-5: Left: Selected region for investigating NWP temperature profiles. Right: mean temperature profiles for ERA-Interim and operational IFS NWP output for the oceanic region indicated in the map (land pixels were omitted). Data is for 2019/03/15 at 00UTC.

4 Conclusions

The goal of this report was to evaluate the consistency between the ICDR AVHRR and CLARA-A2.1 TCDR. In Section 2, comparisons between various cloud properties from the respective level-2b and level-3 products for the first half of 2019 were presented. Overall very small deviations were found. Specific spatial patterns with regionally larger deviations were identified. To a large extent these can be explained by changes in the NWP input, which was extracted from ERA-Interim for the TCDR but from the operational IFS model for the ICDR. In Section 3, a number of examples were presented, illustrating how changes in NWP parameters such as surface temperature and snow depth affect the retrieved cloud properties.

A summary of the ICDR-TCDR differences in comparison with the accuracy requirements is given in Table 4-1. In general these differences are an order of magnitude smaller than the requirements. Given that CLARA-A2.1 has been shown to fulfil the requirements, it can be concluded that the ICDR AVHRR also fulfils the requirements. Whether this continues to be the case for ICDR AVHRR products to be produced after June 2019, will be addressed in future annual assessments.

Table 4-1: Comparison of CLARA-A2.1/ICDR AVHRR accuracy and precision requirements with the differences between the global mean ICDR and TCDR cloud properties presented in

Figure **2-7**.

Product	Accuracy requirement (bias)	ICDR-TCDR bias 01-06/2019 (absolute value)	Precision requirement (bc-RMSE)	ICDR-TCDR bc-RMSE 01-06/2019
Cloud fraction (CFC)	5 % (absolute)	< 0.5 %	20 % (absolute)	2 %
Liquid cloud fraction (CPH)	10 % (absolute)	< 0.5 %	20 % (absolute)	2 %
Cloud top pressure (CTP)	50 hPa	0.3 hPa	100 hPa	14 hPa
Liquid water path (LWP)	10 g m^{-2}	0.5 g m^{-2}	20 g m^{-2}	6.6 g m^{-2}
Ice water path (IWP)	20 g m^{-2}	0.8 g m^{-2}	40 g m^{-2}	10.7 g m^{-2}

5 References

Hamann, U., et al., 2014: Remote sensing of cloud top pressure/height from SEVIRI: analysis of ten current retrieval algorithms, Atm. Meas. Tech., 7, 2839-2867, doi:10.5194/amt-7-2839-2014.

Karlsson, K.-G., Anttila, K., Trentmann, J., Stengel, M., Meirink, J. F., Devasthale, A., Hanschmann, T., Kothe, S., Jääskelainen, E., Sedlar, J., Benas, N., van Zadelhoff, G.-J., Schlundt, C., Stein, D., Finkensieper, S., H°akansson, N., and Hollmann, R., 2017: CLARA-A2: the second edition of the CM SAF cloud and radiation data record from 34 years of global AVHRR data, Atmospheric Chemistry and Physics, 17, 5809–5828, doi:10.5194/acp-17-5809-2017.

6 Glossary

ATBD	Algorithm Theoretical Baseline Document
AVHRR	Advanced Very High Resolution Radiometer
bc-RMSE	Bias-Corrected RMSE
BT	Brightness Temperature
CDOP	Continuous Development and Operations Phase
CFC	Fractional Cloud Cover
CLARA-A	CM SAF cLoud, Albedo and Radiation products, AVHRR-based
CMA	Cloud Mask
CMA-prob	Probabilistic Cloud Mask
CM SAF	Satellite Application Facility on Climate Monitoring
COT	Cloud Optical Thickness
CPH	Cloud Phase
CTH	Cloud Top Height
CTO	Cloud Top product
CTP	Cloud Top Pressure
CTT	Cloud Top Temperature
CPP	Cloud Physical Properties
CWP	Cloud Water Path
DWD	Deutscher Wetterdienst (German MetService)
ECMWF	European Centre for Medium Range Forecast
ERA-Interim	Second ECMWF Re-Analysis dataset
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FCDR	Fundamental Climate Data Record
GAC	Global Area Coverage (AVHRR)
GCOS	Global Climate Observing System
ICDR	Interim Climate Data Record
IFS	Integrated Forecasting System (of ECMWF)

IWP	Ice Water Path
JCH	Joint Cloud properties Histogram
KNMI	Koninklijk Nederlands Meteorologisch Instituut
LWP	Liquid Water Path
NOAA	National Oceanic & Atmospheric Administration
NWC SAF	SAF on Nowcasting and Very Short Range Forecasting
NWP	Numerical Weather Prediction
PPS	Polar Platform System (NWC SAF polar cloud software package)
PRD	Product Requirement Document
PUM	Product User Manual
REF	Cloud particle effective radius
RMSE	Root Mean Square Error
RTTOV	Radiative Transfer model for TOVS
SAF	Satellite Application Facility
SMHI	Swedish Meteorological and Hydrological Institute
TCDR	Thematic Climate Data Record