ECMWF COPERNICUS REPORT

Copernicus Climate Change Service

Product Quality Assessment Report (PQAR) – ANNEX C for product CH4_GOS_SRPR (v2.3.9, 2009-2019)

C3S_312b_Lot2_DLR – Atmosphere

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History of modifications

Version	Date	Description of modification	Chapters / Sections
1.1	20-October-2017	New document for data set CDR1 (2009-2016)	All
2.0	4-October-2018	Update for CDR2 (2009-2017)	All
3.0	12-August-2019	Update for CDR3 (2009-2018)	All
3.1	03-November-2019	Update after review by Assimila: Primarily correction of typos.	All
4.0	18-August-2020	Update for CDR4 (2009-2019)	All

Related documents

Reference ID	Document
D1	Main PQAR: Buchwitz, M., et al., Product Quality Assessment Report (PQAR) – Main document for Greenhouse Gas (GHG: CO_2 & CH_4) data set CDR 4 (2003-2019), project C3S_312b_Lot2_DLR – Atmosphere, v4.0, 2020. ***Important Note:*** *This document is an ANNEX to the Main PQAR document and contains the quality assessment results of the data provider.* ***For the final overall quality assessment results of the data products described in this document see the Main PQAR document.***

Acronyms

Acronym	Definition
ATBD	Algorithm Theoretical Basis Document
CAR	Climate Assessment Report
C3S	Copernicus Climate Change Service
CCI	Climate Change Initiative
CDR	Climate Data Record
CDS	(Copernicus) Climate Data Store
CRG	Climate Research Group
D/B	Data base
EC	European Commission
ECMWF	European Centre for Medium Range Weather Forecasting
ECV	Essential Climate Variable
EO	Earth Observation
ESA	European Space Agency
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FP	Full Physics retrieval method
FTIR	Fourier Transform InfraRed
FTS	Fourier Transform Spectrometer
GCOS	Global Climate Observing System
GEOSS	Global Earth Observation System of Systems
GHG	GreenHouse Gas
GOSAT	Greenhouse Gases Observing Satellite
IPCC	International Panel in Climate Change
IUP	Institute of Environmental Physics (IUP) of the University of Bremen, Germany
JAXA	Japan Aerospace Exploration Agency
KIT	Karlsruhe Institute of Technology
L1	Level 1
L2	Level 2
L3	Level 3
L4	Level 4
LMD	Laboratoire de Météorologie Dynamique
MACC	Monitoring Atmospheric Composition and Climate, EU GMES project
NA	Not applicable
NetCDF	Network Common Data Format
NIES	National Institute for Environmental Studies
NIR	Near Infra Red

NOAA	National Oceanic and Atmospheric Administration
Obs4MIPs	Observations for Climate Model Intercomparisons
ppb	Parts per billion
ppm	Parts per million
PR	(light path) PRoxy retrieval method
PVIR	Product Validation and Intercomparison Report
QA	Quality Assurance
QC	Quality Control
REQ	Requirement
RMS	Root-Mean-Square
RTM	Radiative transfer model
SNR	Signal-to-Noise Ratio
SRON	SRON Netherlands Institute for Space Research
SWIR	Short Wave Infra Red
SZA	Solar Zenith Angle
TANSO	Thermal And Near infrared Sensor for carbon Observation
TANSO-FTS	Fourier Transform Spectrometer on GOSAT
TBC	To be confirmed
TBD	To be defined / to be determined
TCCON	Total Carbon Column Observing Network
TIR	Thermal Infra Red
TR	Target Requirements
TRD	Target Requirements Document
URD	User Requirements Document
WMO	World Meteorological Organization
Y2Y	Year-to-year (bias variability)

General definitions

Table 1 lists some general definitions relevant for this document.

Table 1: General definitions.

Item	Definition
XCO_2	Column-averaged dry-air mixing ratios (mole fractions) of CO_2
XCH_4	Column-averaged dry-air mixing ratios (mole fractions) of CH_4
L1	Level 1 satellite data product: geolocated radiance (spectra)
L2	Level 2 satellite-derived data product: Here: CO_2 and CH_4 information for each ground-pixel
L3	Level 3 satellite-derived data product: Here: Gridded CO_2 and CH_4 information, e.g., 5 deg times 5 deg, monthly
L4	Level 4 satellite-derived data product: Here: Surface fluxes (emission and/or uptake) of CO_2 and CH_4

Scope of document

This document is a Product Quality Assessment Report (PQAR) for the Copernicus Climate Change Service (C3S, https://climate.copernicus.eu/) greenhouse gas (GHG) component as covered by project C3S_312b_Lot2.

Within this project satellite-derived atmospheric carbon dioxide (CO_2) and methane (CH_4) Essential Climate Variable (ECV) data products will be generated and delivered to ECMWF for inclusion into the Copernicus Climate Data Store (CDS) from which users can access these data products and the corresponding documentation.

The GHG satellite-derived data products are:

- Column-averaged dry-air mixing ratios (mole fractions) of CO_2 and CH_4, denoted XCO_2 (in parts per million, ppm) and XCH_4 (in parts per billion, ppb), respectively.
- Mid/upper tropospheric mixing ratios of CO_2 (in ppm) and CH_4 (in ppb).

This document describes the validation / quality assessment of C3S product CH4_GOS_SRPR.

These products are XCO_2 and XCH_4 Level 2 products as retrieved from GOSAT using algorithms developed at SRON, The Netherlands.

Executive summary

This report summarizes the performance of the RemoTeC CH4_GOS_SRPR retrievals. In general, we find very good agreement with TCCON data for all three modes (gain H, gain M and sunglint). All have a very high degree of correlation with TCCON (R~0.9).

The station to station bias is 2.75 ppb and a standard deviation of around 14.47 ppb is observed for most TCCON stations. We also checked the stability of the bias over time as the GOSAT time series now spans a period of 10.5 years and found that there has been no significant change in the bias over time, indicating a very good detector stability. We achieved both Target Requirement (TR) requirements for accuracy and stability with 100 % in both cases.

1. Product validation methodology

Validation of the CH4_GOS_SRPR is performed by comparison a selection of ground-based FTS TCCON stations. These provide total column XCH4 measurements that are used to filter our retrievals and perform a bias correction of our data product. The final filtered and bias corrected product is then compared to TCCON to evaluate the global bias, retrieval accuracy and systematic biases (spatial and temporal) in the retrievals. In this validation the TCCON GGG2014 official release has been used.

1.1 Co-location method

We co-locate the GOSAT soundings with the TCCON measurements using the following criteria:

- GOSAT sounding within ±5 latitude and ±8 longitude of TCCON station
- GOSAT sounding within ±2 hours of TCCON measurements

In previous studies we have also employed a dynamic co-location method, based on a TM5-4DVAR forward model run. This essentially compares the modeled CO2 concentration at a GOSAT sounding and the TCCON site and co-locates the soundings if the CO2 concentrations are within 0.25 (or 0.5) ppm of each other. This is then used as a tracer for atmospheric transport. However, at the time of validating this dataset the dynamic co-locations for the newest year were not yet available. We therefore decided to use a box filter instead as we did want to include the newest year's data in our validation and wanted the whole dataset to have a consistent method for co-locating the GOSAT soundings.

We then average all the TCCON measurements within ±2 hours of a GOSAT measurement to create a set of GOSAT-TCCON pairs. These co-located pairs are then used to perform the validation procedure. Figure 1-3 shows the co-located example soundings for the gain H, gain M and sunglint stations respectively.

Figure 1: GOSAT co-located example soundings for each TCCON station for gain H soundings. The map shows the elevation with dark green being low elevations and light green showing elevated areas. The blue stars show the location of the TCCON site, while the red dots are co-located GOSAT soundings. Top to down (left column) stations: Bialystok, Darwin, Karlsruhe, Orleans, Saga, Wollongong. Top to down (right column) stations: Bremen, Garmisch, Lamont, Park Falls, Sodankyla.

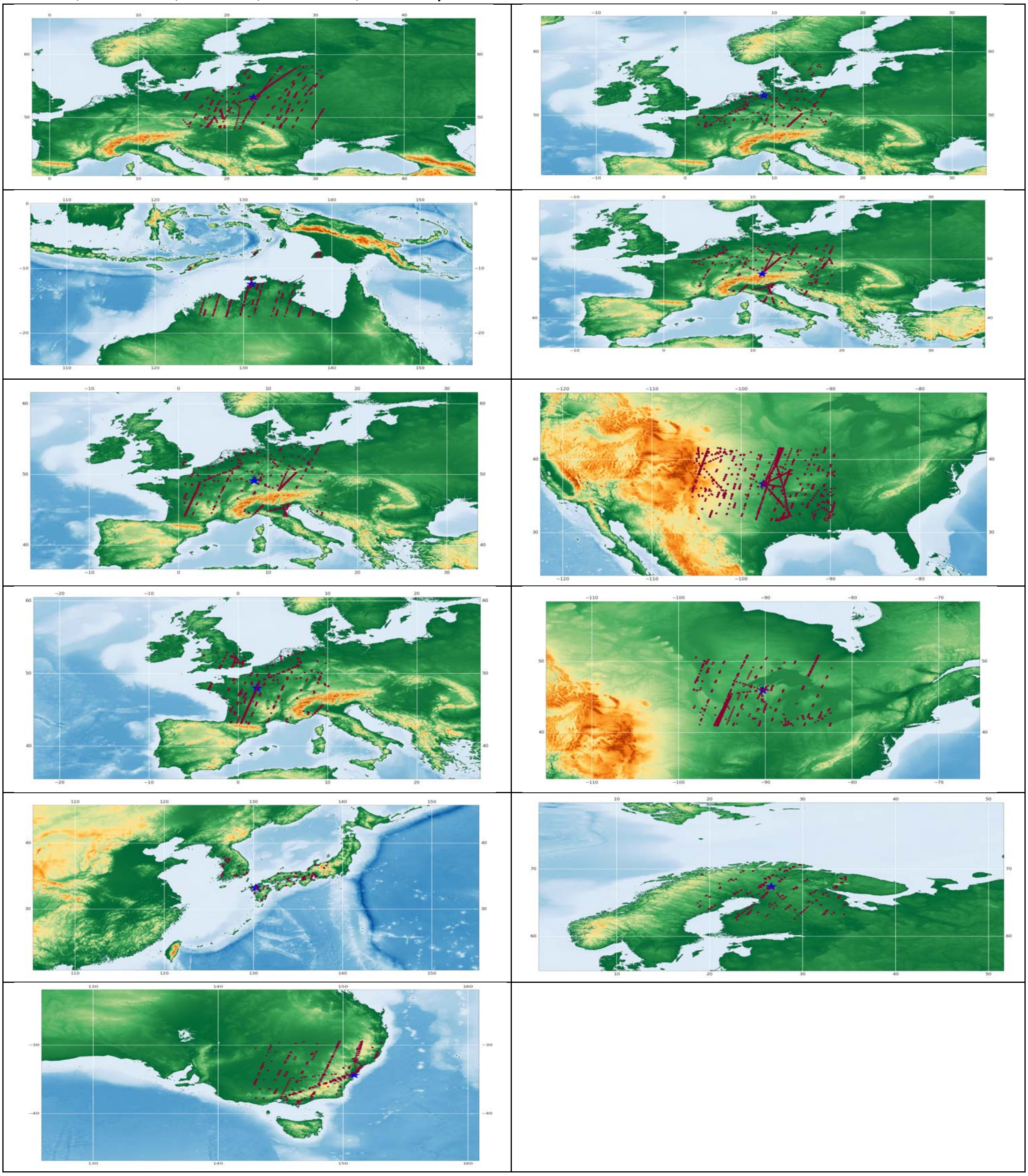


Figure 2: As Fig 1 but for gain M soundings. Stations are Dryden (left) and Wollongong (right).

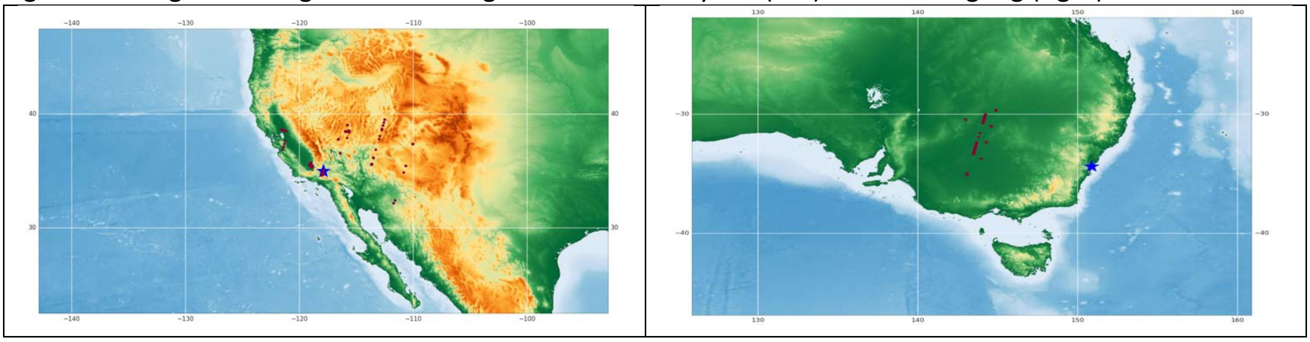
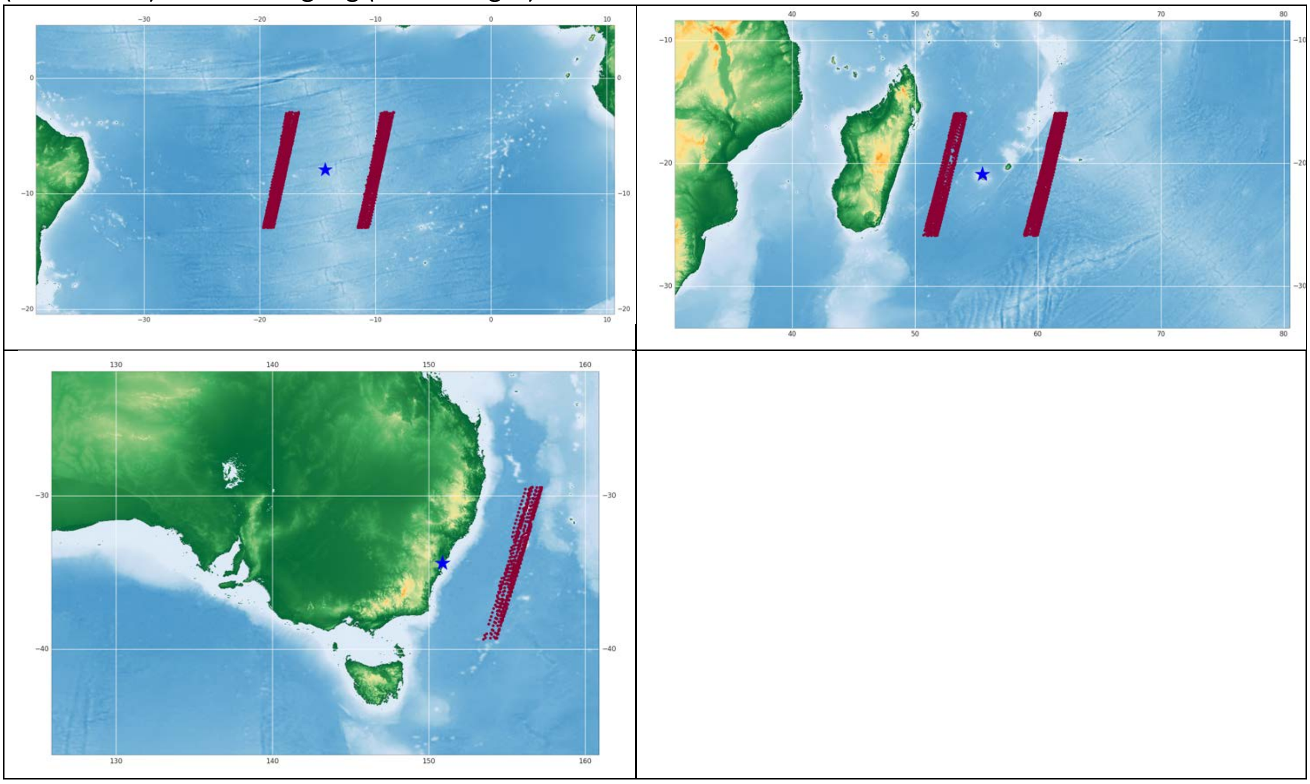


Figure 3: As Fig 1 but for sunglint soundings. Stations are Ascension (top left), Izana (top right), Reunion (bottom left) and Wollongong (bottom right).

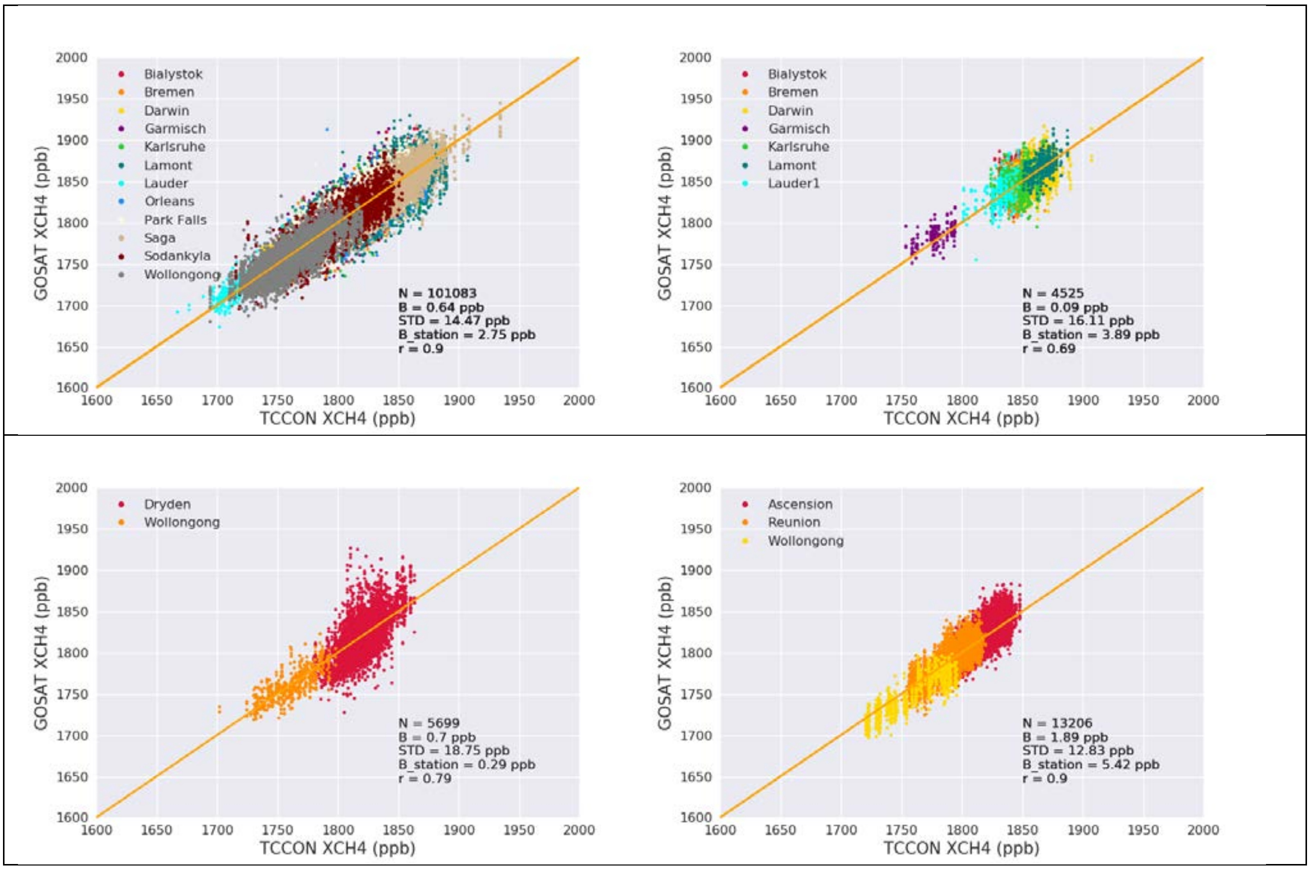


2. Validation Results

2.1 Product CH4_GOS_SRPR

2.1.1 Validation

Figure 4: Validation of XCH_4 retrieved by GOSAT-RemoTeC with ground based TCCON measurements for gain H (Top left), gain H year 2019 only (top right), gain M (bottom left) and sunglint (bottom right) soundings. N(coloc) indicates the number of GOSAT-TCCON colocations, B indicates the bias between GOSAT and TCCON, and STD the standard deviation of the GOSAT TCCON difference (for individual measurements) and B_station the station to station bias.



The above figures all show a strong correlation of the retrieved (bias-corrected) XCH4 with the TCCON XCH4 (r ~ 0.9). This gives us confidence that our bias correction based on the retrieved albedo works correctly and takes out most of the bias. The 2019 only data shows a remaining bias of 0.09 ppb.

The figure below (Fig 5) shows in detail for each station the remaining bias and standard deviation for the co-located GOSAT soundings. Unlike for the CO2_GOS_SRFP dataset, we do not include Izana here in the gain M validation, as its high altitude causes a large offset between measurements at the TCCON station and the Sahara desert.

In the case of gain H, the station to station standard deviation is 2.75 ppb. Saga also remains an outlier with a strong remaining negative bias, possibly due to inclusion of soundings in more polluted areas. Garmisch and Park Falls both show a positive offset, possibly due to the elevation of the TCCON stations (740 and 440 m respectively). Lamont clearly shows the most co-locations and dominates the total statistical comparison.

For gain M and sunglint we removed Darwin from the comparison as using the static spatial co-location criterion it only had limited co-located measurements.

Figure 5: The bias, standard deviation and # of measurements per station for gain H (top), gain M (middle) and sunglint (bottom) soundings for the period between the year 2009 and 2019.

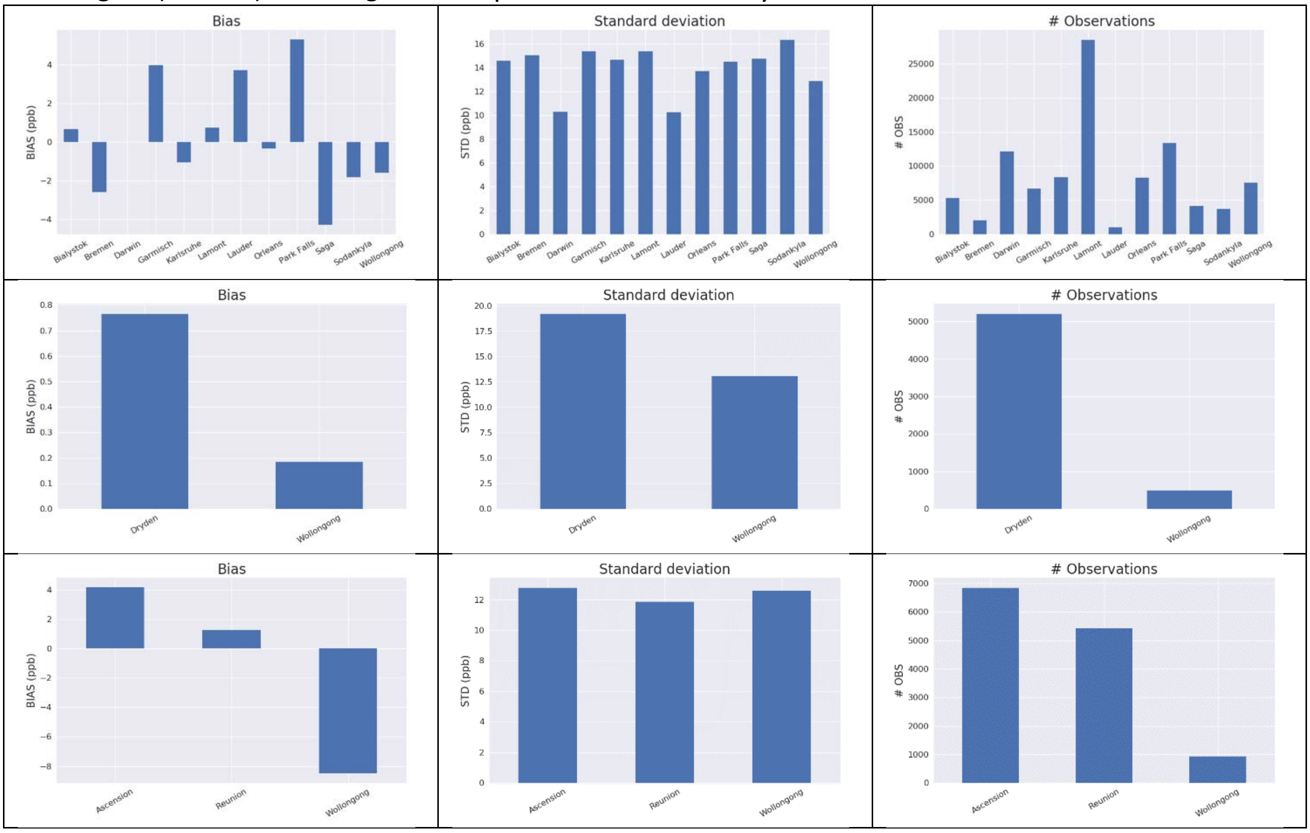
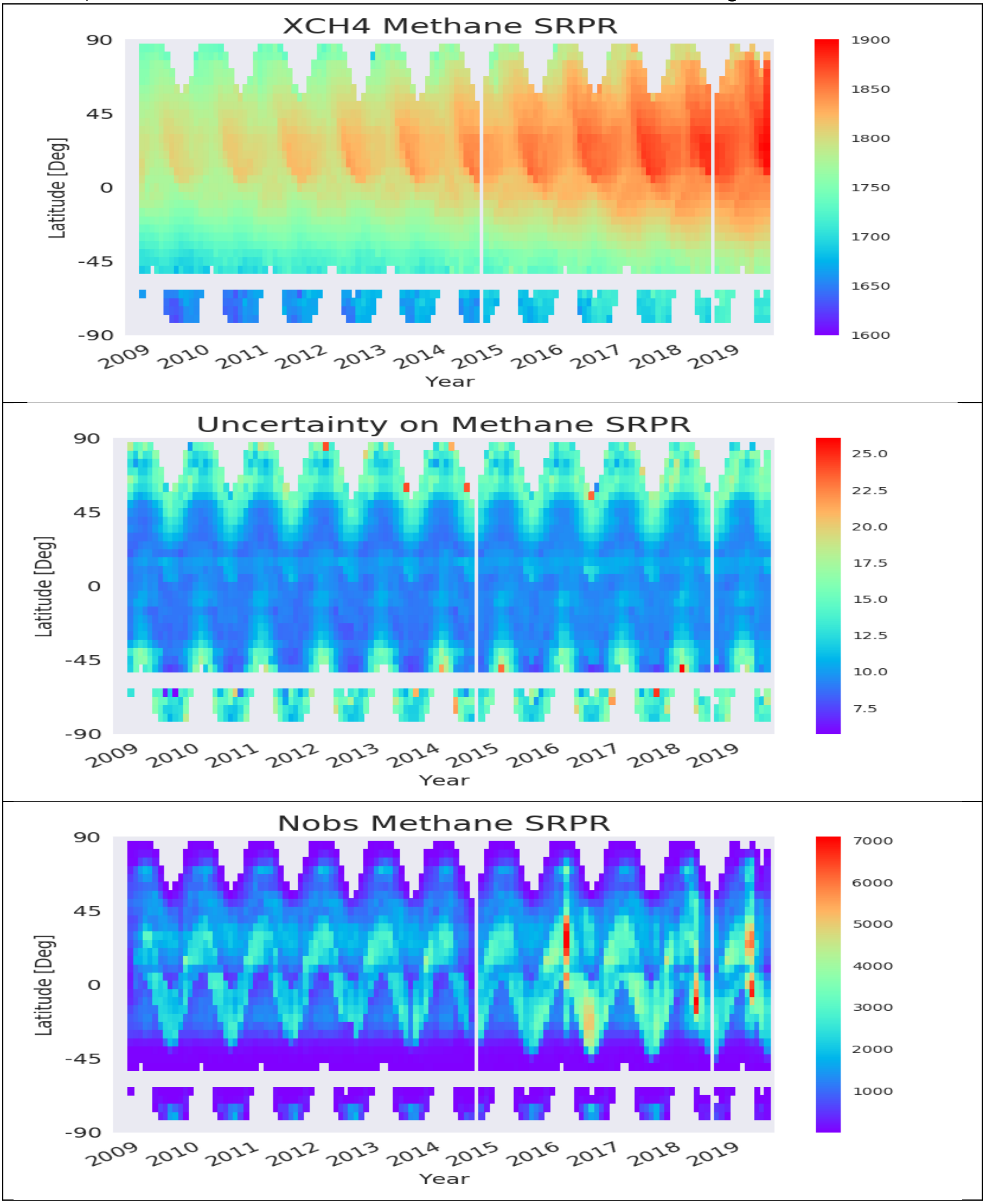


Figure 6: The CH4_GOS_SRPR global dataset in slices of 10 degrees latitude as a function of time. The increase in XCH4 concentrations during the last couple of years can clearly be seen. The gap in data coverage during Dec 2014, Jan 2015 and December 2018 is due to GOSAT maintenance and testing.



2.1.2 Stability

Stability (both linear and year-to-year variability) is an essential part of the validation and can reveal potential degradation or other time-dependent effects in the GOSAT data products.
Fig. 7-11 show the time series for the individual stations. As can be seen the time coverage for different stations can differ significantly and occasionally gaps occur due to maintenance of the TCCON station.
To determine the linear stability, we add all co-located TCCON measurements together and fit a linear relation to the remaining bias as a function of time. The year-to-year bias variability is the difference between the minimum of the bias in one year versus the maximum of the bias in one year. The results are shown in Table 2.

Figure 7: Timeseries for the individual stations for gain H.

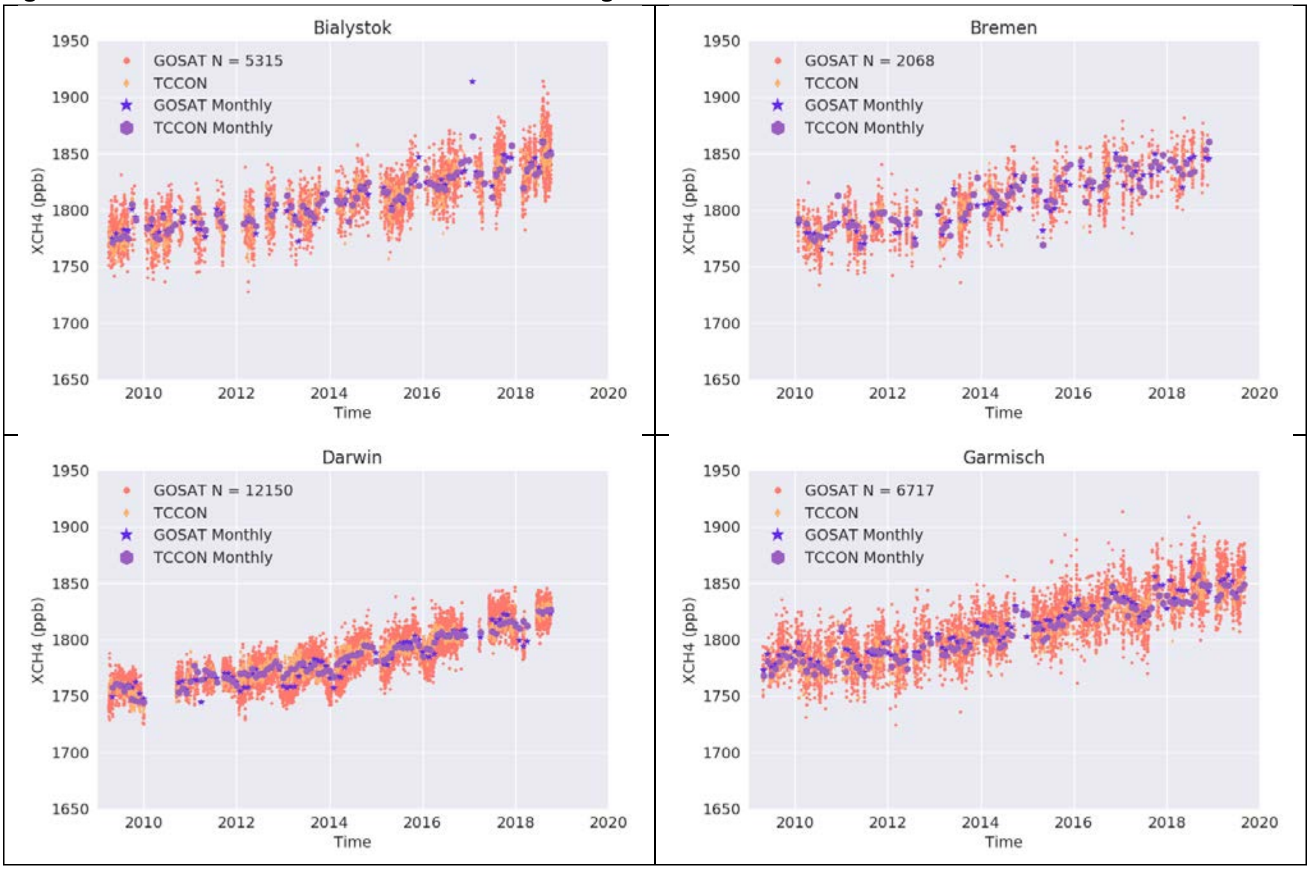


Figure 8: Timeseries for the individual stations for gain H (continued from Fig 6).

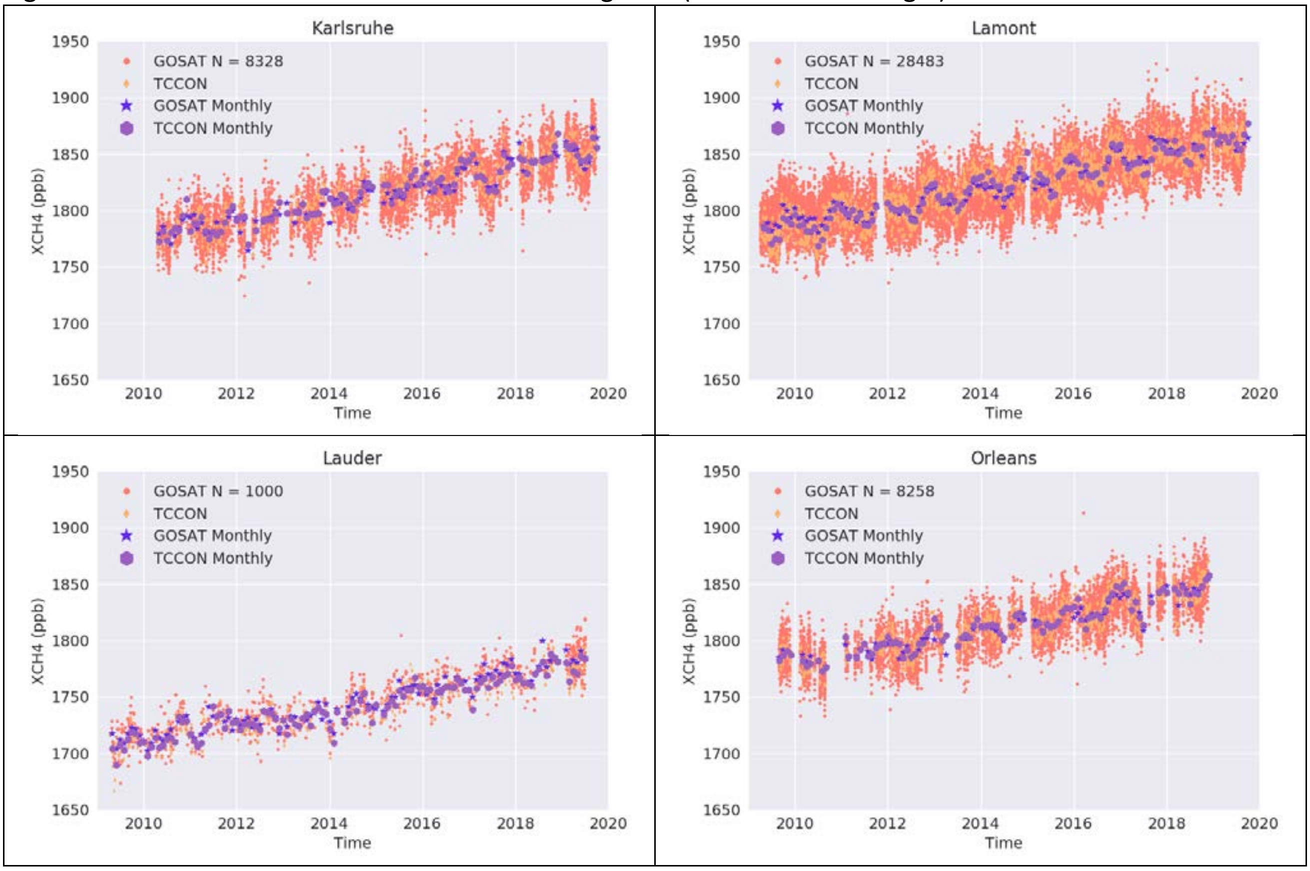


Figure 9: Timeseries for the individual stations for gain H (continued from Fig 6).

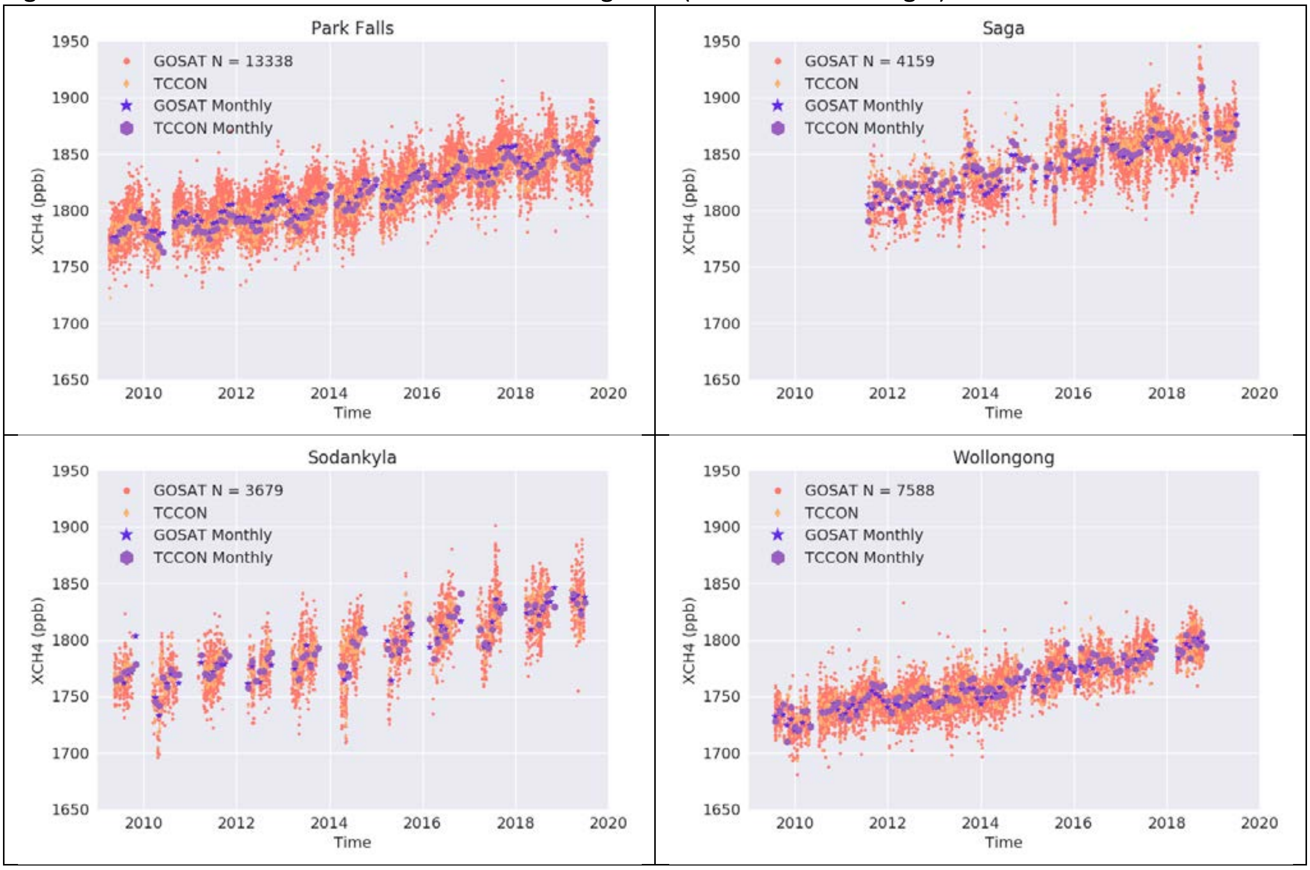


Figure 10: Timeseries for the individual stations for gain M.

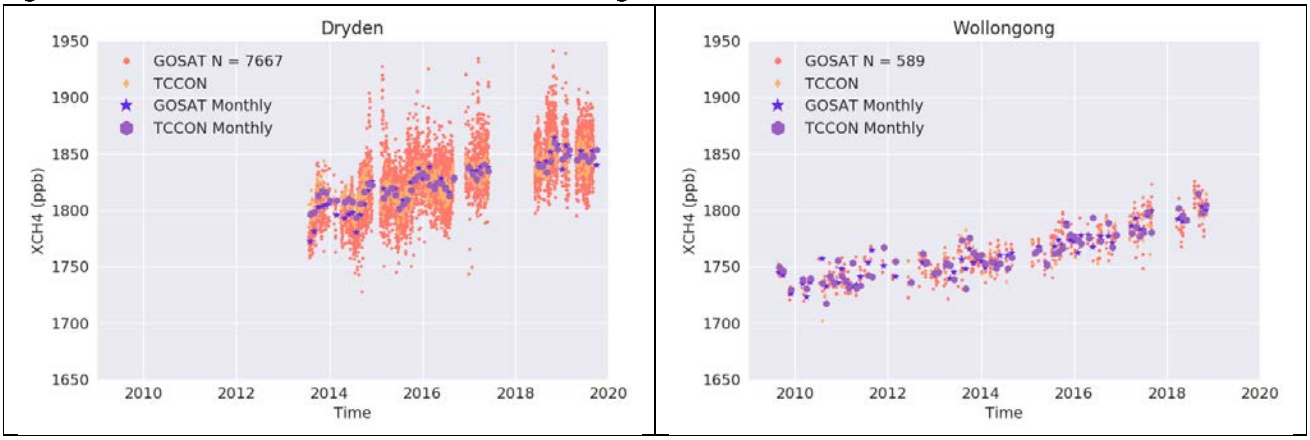
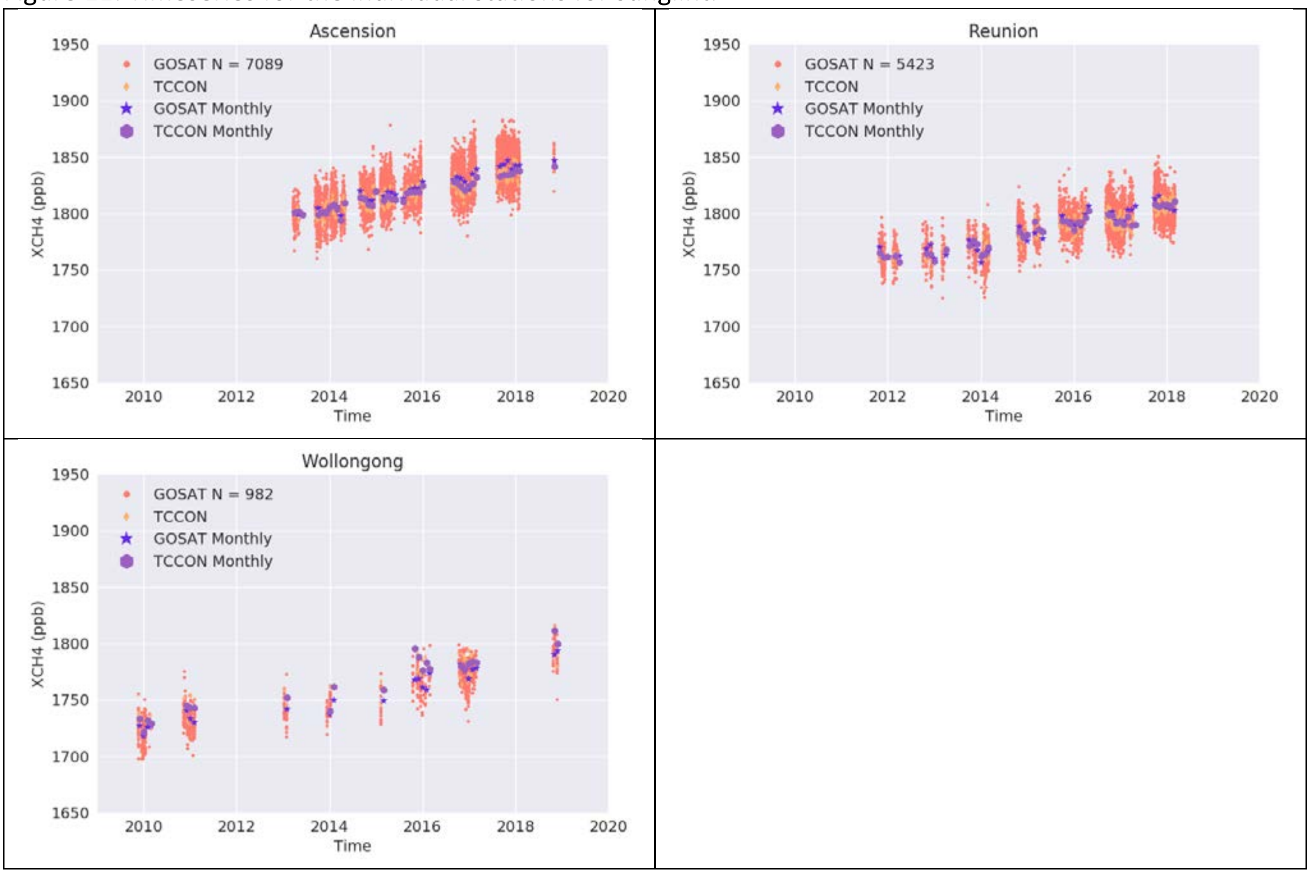


Figure 11: Timeseries for the individual stations for sunglint.



2.1.3 Validation summary

The validation results are summarized in the table below.

Table 2 - Product Quality Summary Table for product CH4_GOS_SRPR.

Product Quality Summary Table for Product: CH4_GOS_SRPR Level: 2, Version: 2.3.9, Time period covered: 6.2009 – 12.2019				
Parameter [unit]	Achieved performance	Requirement	TR	Comments
Single measurement precision (1-sigma) in [ppb]	14.42	< 34 (T) < 17 (B) < 9 (G)	-	-
Uncertainty ratio) in [-]: Ratio reported uncertainty to standard deviation of satellite-TCCON difference	1.26	-	-	No requirement but value close to unity expected for a high quality data product.
Mean bias [ppb]	0.64	-	-	No requirement but value close to zero expected for a high quality data product.
Accuracy: Relative systematic error [ppb]	Spatial – spatiotemporal: 2.75 – 5.42	< 10	Probability that accuracy TR is met: 92%	-
Stability: Linear bias trend [ppb/year]	-0.29 +/- 0.25 (1-sigma)	< 3	Probability that stability TR is met: 99%	-
Stability: Year-to-year bias variability [ppb/year]	7.83 +/- 2.51 (1-sigma)	< 3	-	-

3. Application(s) specific assessments

No application specific assessments have been carried out.

4. Compliance with user requirements

For the CH4_GOS_SRPR product we achieved 100% for TR's Accuracy and 100 % for TR's Stability

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