climate change initiative

LONG-LIVED GREENHOUSE GAS PRODUCTS PERFORMANCES

Dataset harmonization and validation/inter-comparison: Nadir products

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lolipop cci

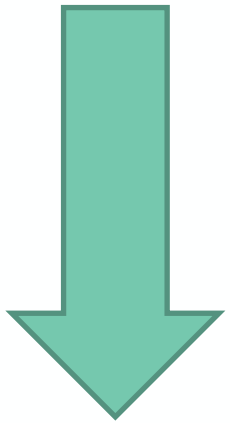
Harmonization

- N2O:
  - TES
  - AIRS-CLIMCAPS
  - CrIS-CLIMCAPS
  - TANSO-FTS-FOCAL
  - IASI-NOPIR (BIRA-IASB)
  - IASI-SOFRID (B. Barret)
  - IASI-TN2OR (U.Toulouse)
  - IASI-MUSICA (KIT)

- CFCs
  - IASI-ULB

Harmonisation Goals

Individual formats in the LOLIPOP cluster



Unified Data format

- Directory structure
- File format
- Vocabulary and (Global) attributes

https://climate.esa.int/en/data/policy/

https://climate.esa.int/media/documents/CCI_DataStandards_v2-3.pdf

HARP readable

name	species	Profile/Total Column	AVK	LV or LA	fixed grid?	P0=surf?	units	Other species	Notes
TES	N_2O	P	Y	LV	Y	Y w -999 dummy	vmr & molec cm^{-2}	O3	deep directory tree w lots of additional content
AIRS-CLIMCAPS	N_2O	P	N	LA	Y no dummy	N	molec m^{-2}	CH4,CO2, CO,H2O, HNO3,O3 ,SO2	3D, lots of additional content, N2O only lacking AVK?
CrIS-CLIMCAPS	N_2O	P	N	LA	Y no dummy	N	molec m^{-2}	CH4,CO, H2O,HNO 3,O3,SO2	3D, no CO2,lots of additional content, N2O only lacking AVK?
TANSO-FTS-FOCAL	XN_2O	TC	N	TC only	TC only	TC only	ppb	no	profile scaling approach, simple file (26 variables)
IASI-EUMETSAT	N_2O	TC	N	TC only	TC only	TC only	kg m^{-2}	H2O,O3, CO,CH4, CO2	IASI_native format,
IASI-NOPIR	N_2O	PC (80-800 hPa)	Y	LV	Y	N	molec cm^{-2}	H2O	no variable info embedded in file
IASI-SOFRID	N_2O	P+TC+TropC	Y (indirect)	LV	Y	N w -999 dummy	ppm, molec cm^{-2}	CO, H2O	comes in gridded and L2 form, Error covariance matrixes
IASI-TN2OR	N_2O	P	Y	LV	Y*	N w-999 dummy	ppb	CH4	*13 fixed level pressures + variable Psurf level which only gens data if >1000
IASI-MUSICA	N_2O	P	Y	LV	N* (p+alt),	N w 9.96921E 36 dummy	ppm	CH4, T, WV, HNO3	* but behaves as one,N2O embedded in ghg together with CH4
IASI-ULB	CFC increase	TC	N	TC only	TC only	TC only	ppt	all data single file	monthly mean vmr

+ many more differences (time, quality indicator, structure, etc….

Harmonization methodology

Extract priority parameters (time, lat, lon, vert grid dimensions, pressure weights, conc, uncertainty, a priori, AVK, quality flag), and/or variables that allow me to construct the above parameters and assign uniform variable names and units

Unify units and order of parameters

Allow for fixed grid w dummy ([0] = top of atmosphere, empty values = -999, lowest pressure_boundary value = surface pressure)

Separate variable names for N2O and XN2O

Both pressure midpoints and boundaries included

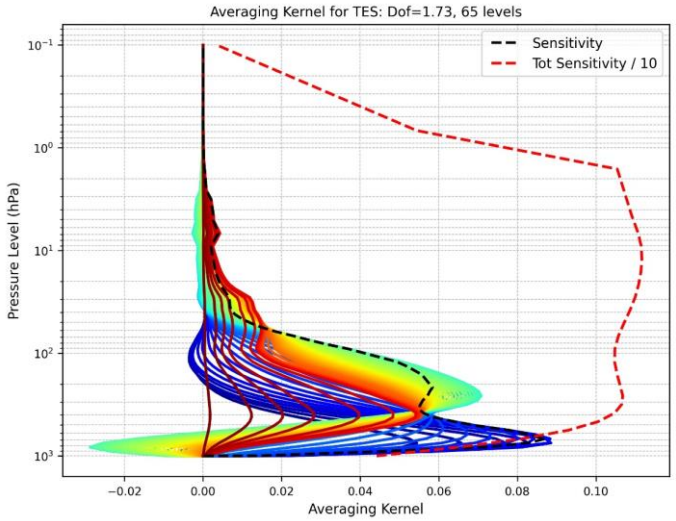
Harmonization

Even though we have 8 nadir viewing N2O satellite products, they all differ significantly:

CrIS and AURA yield ‘profiles’ but no averaging kernel information

GOSAT-2 FOCAL is a profile scaling algorithm: only total column information

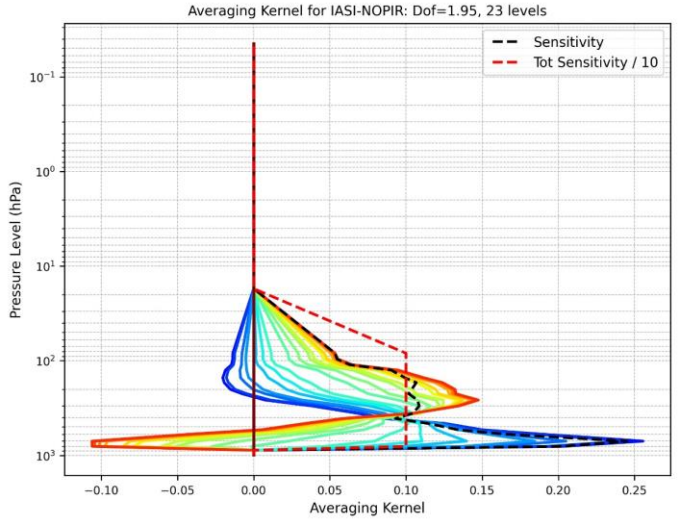
IASI products all have very different vertical sensitivities

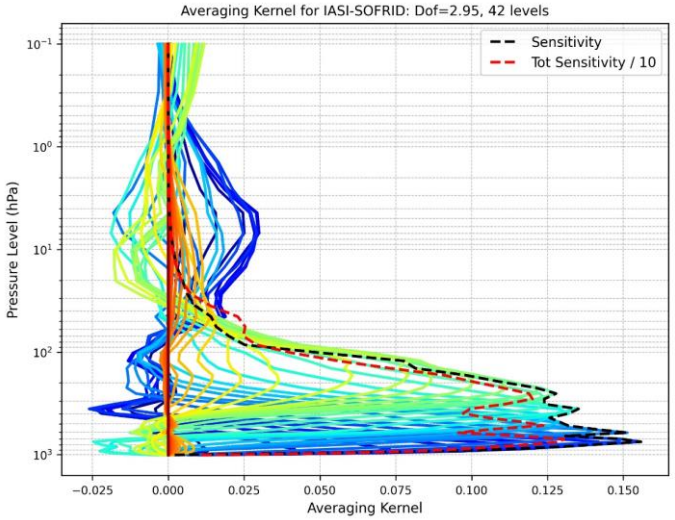


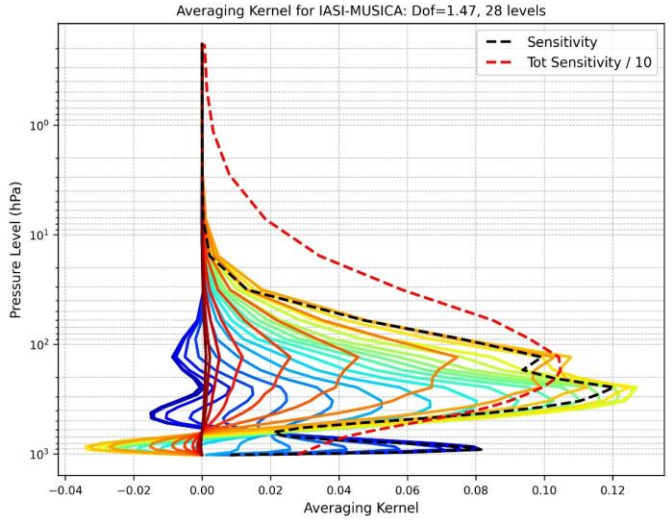
Intercomparison (N2O only)

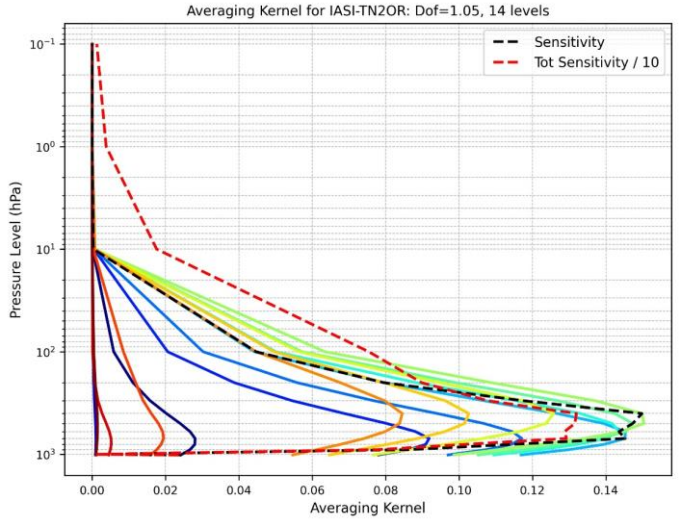
These differences also informed their respective validation strategies:

- TN2OR: sensitivity peak around 300 hPa
- SOFRID: highest dof, sometimes erratic avk values at high altitudes
- NOPIR: Relatively uniform sensitivity between 800-80hPa
- MUSICA: widest sensitivity band





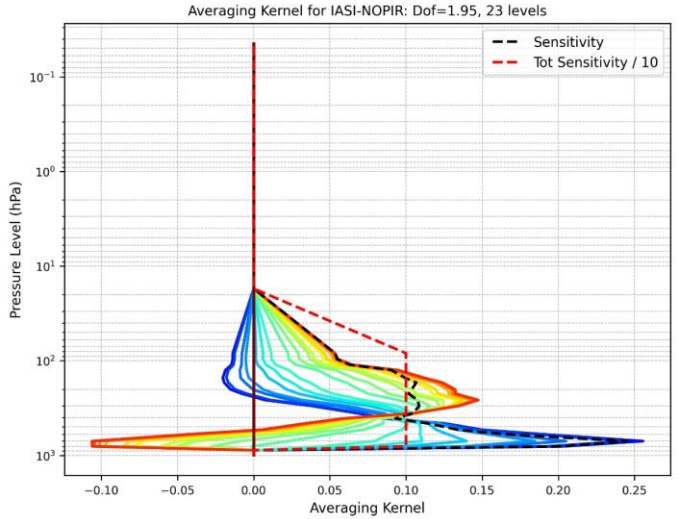


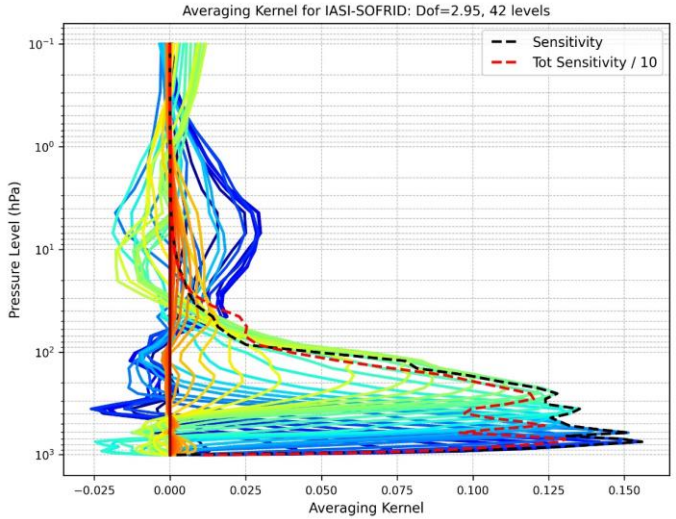


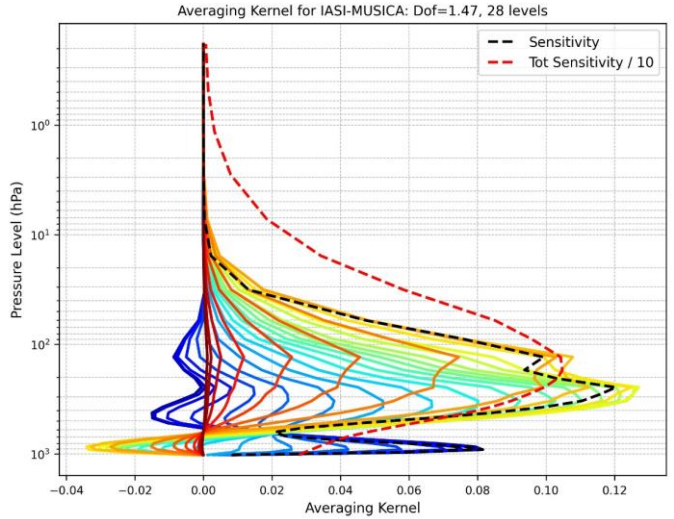
Intercomparison (N2O only)

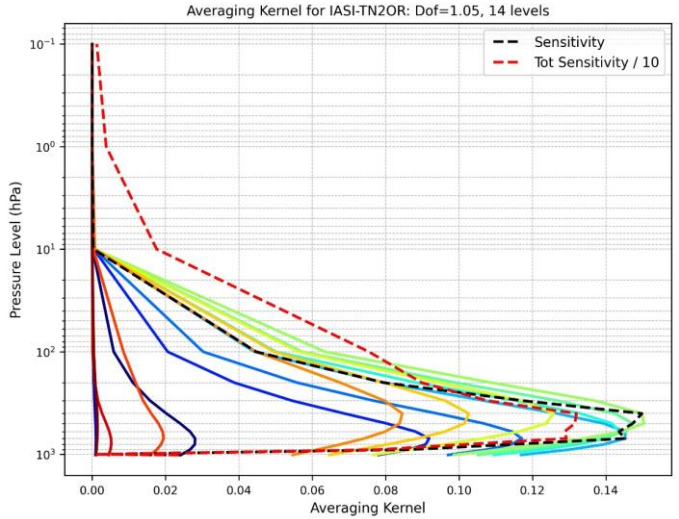
These differences also informed their respective validation strategies:

- TN2OR: smooth -> look at 300hPa layer
- SOFRID: surf-700hPa, 700-350hPa, 350-110hPa
- NOPIR: compare partial column 800-80hPa
- MUSICA: 4.2 km (~600hPa) + UTLS
- **Uniform strategy: Differences seen between products may just reflect their inherent property differences, not differences in quality!**

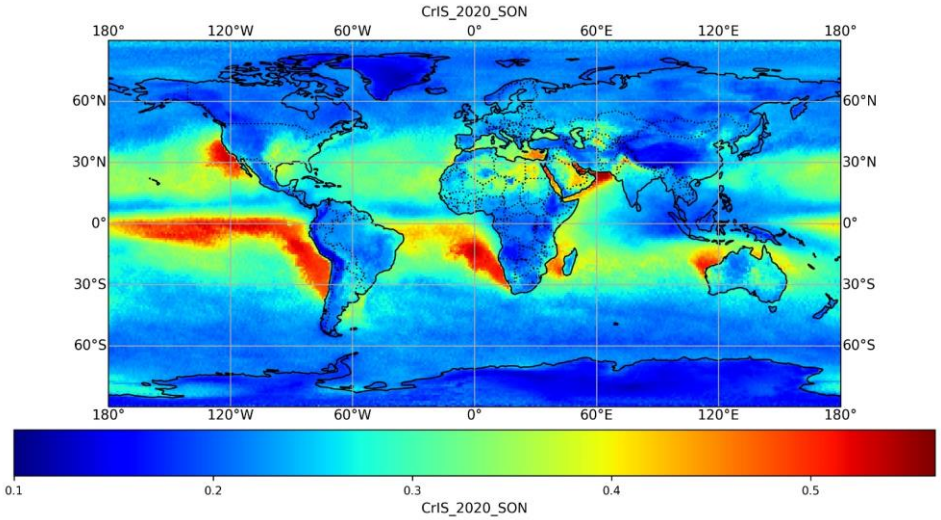


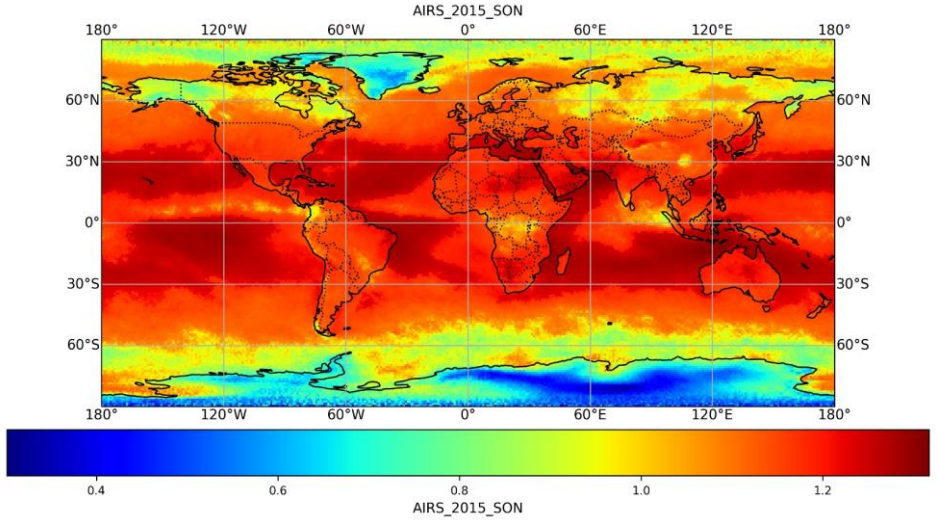


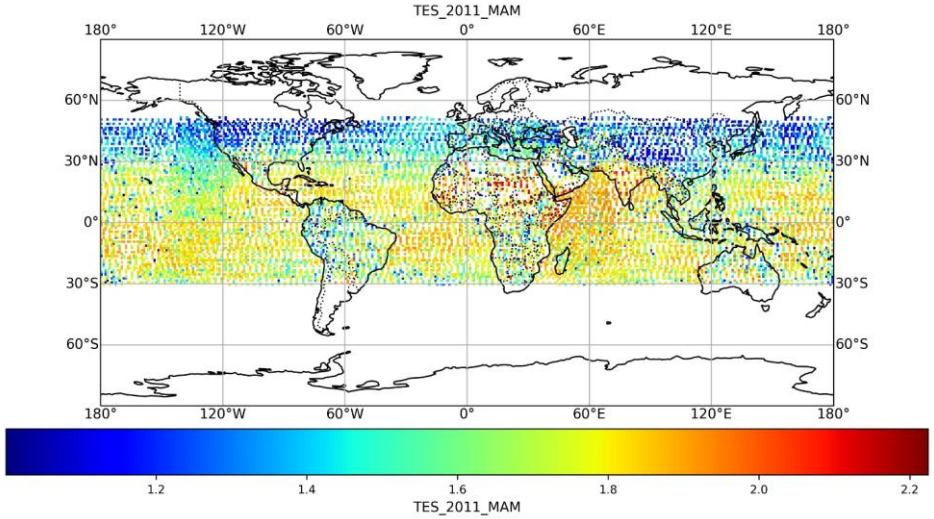




Degrees of freedom

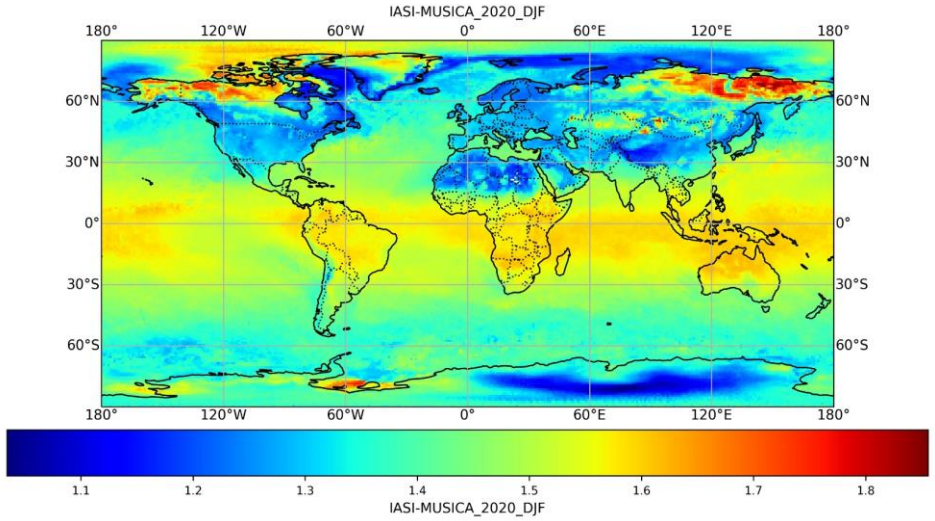


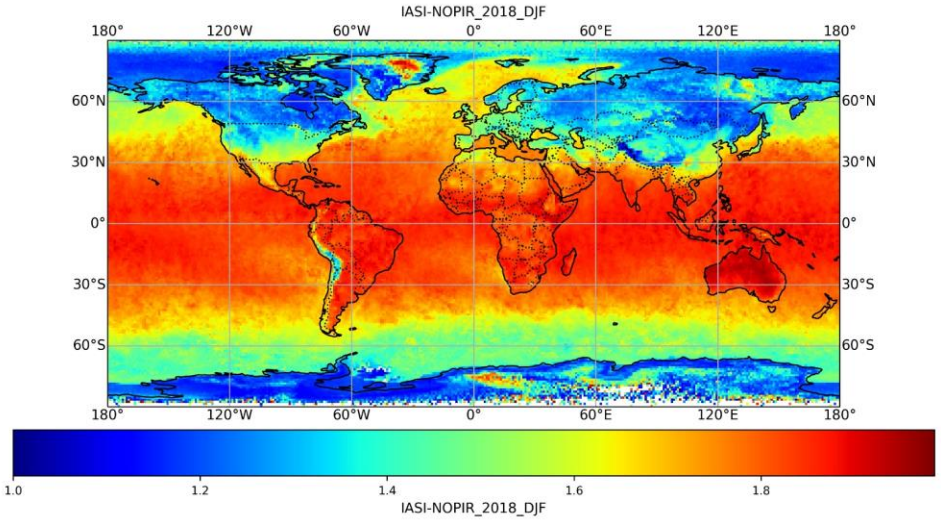


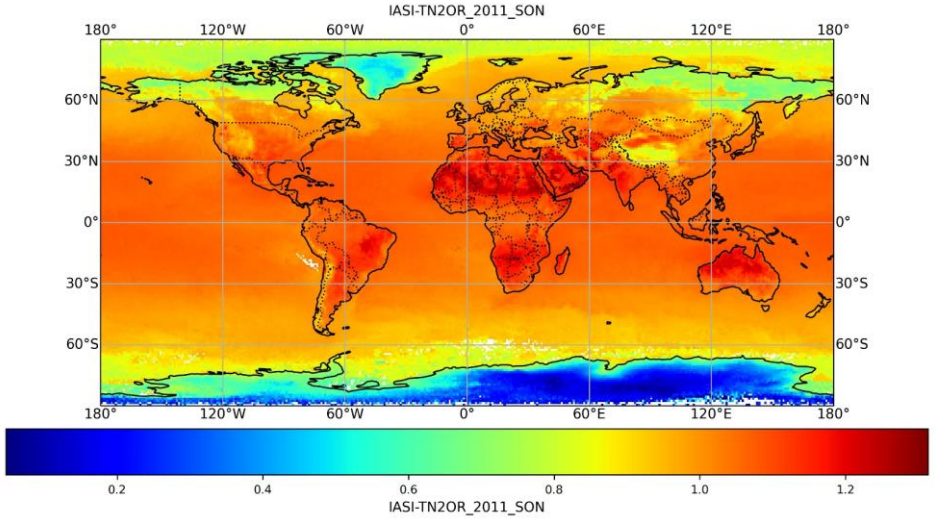


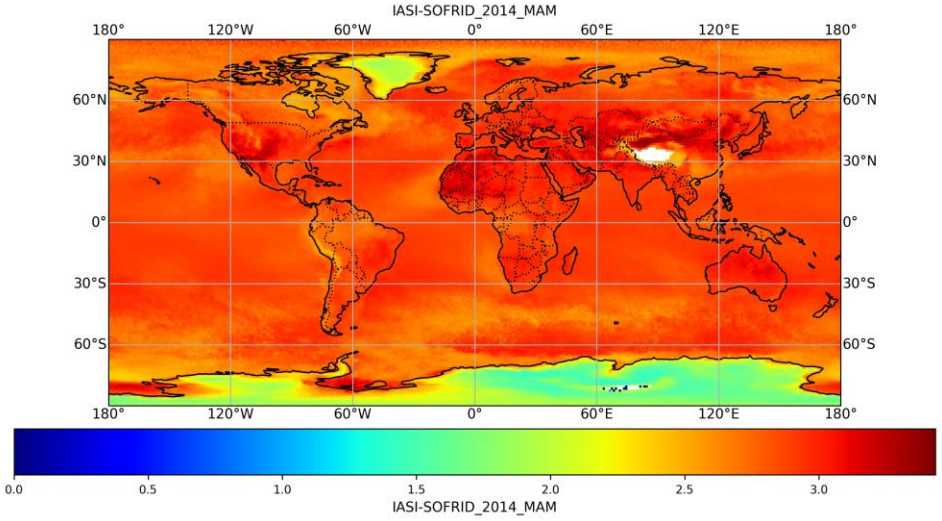
Scales are not uniform!
Highest number
CrIS ~0.6
AIRS ~1.3
TES ~2.2

Degrees of freedom (IASI)





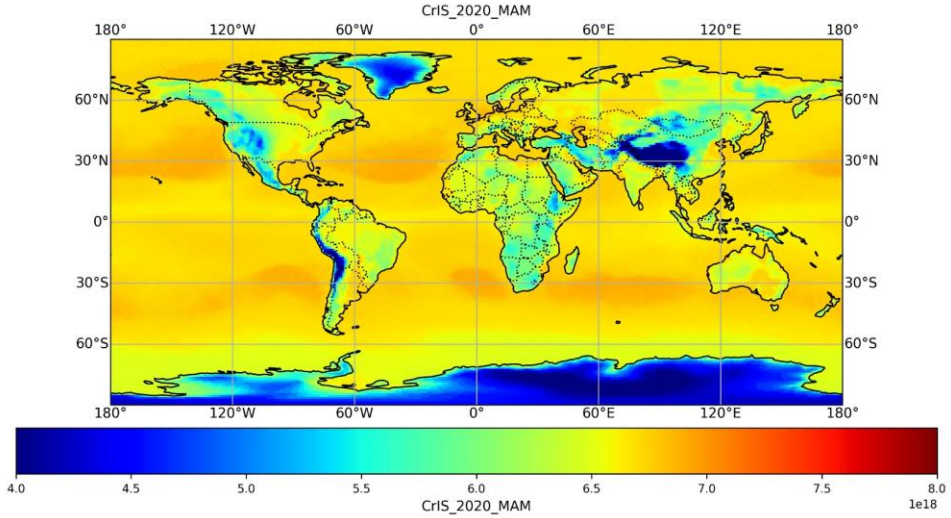


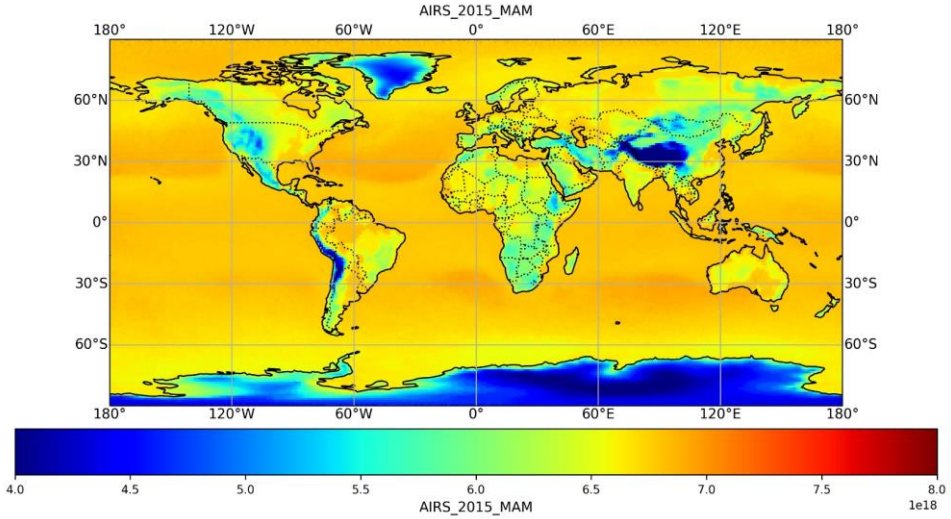


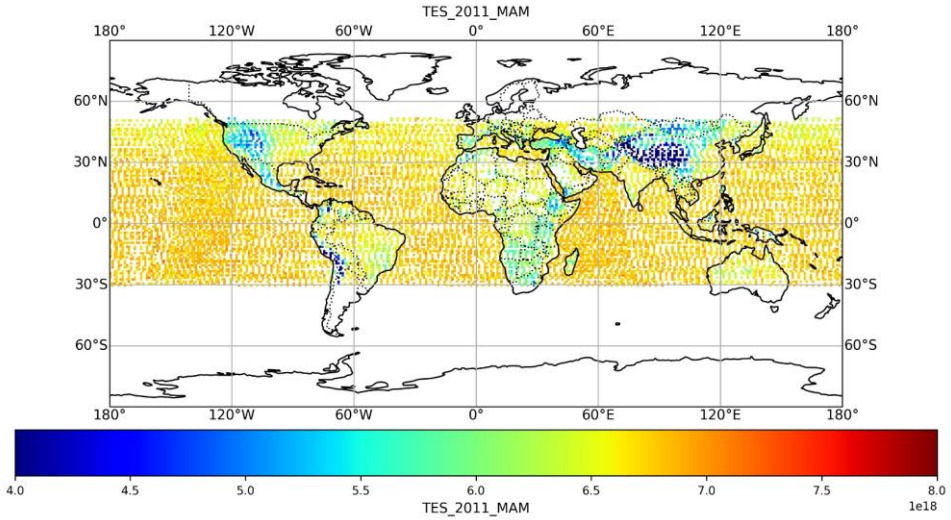
Much higher DOFs for SOFRID

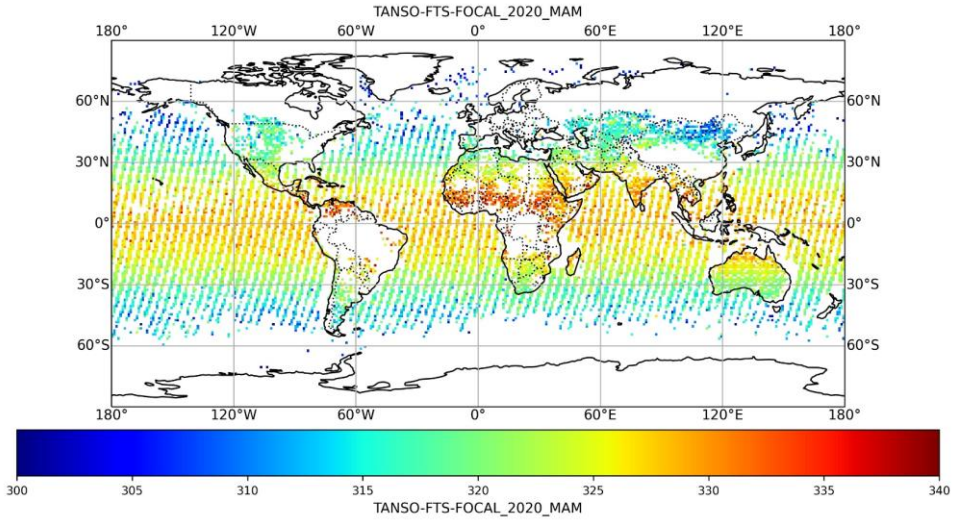
MUSICA+NOPIR : some very high dofs at high latitudes + stronger latitudinal gradient

N2O concentration



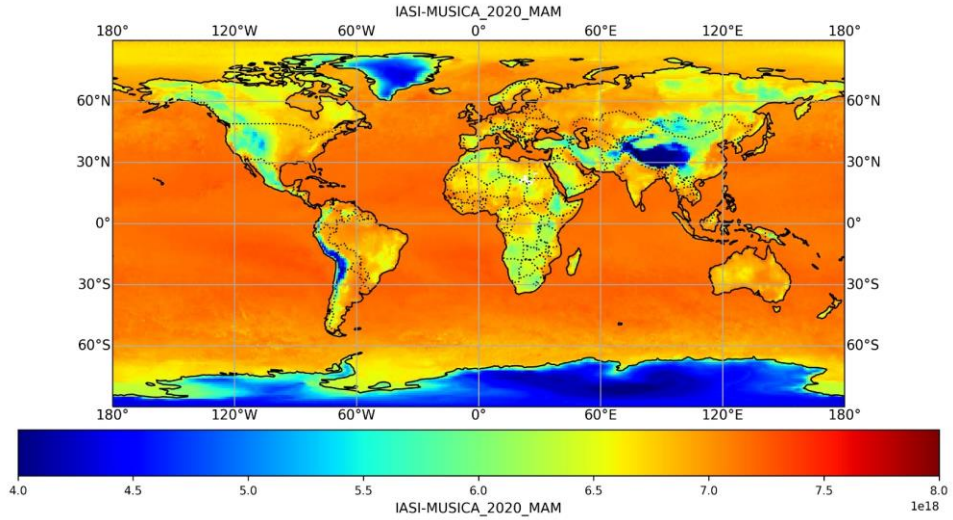


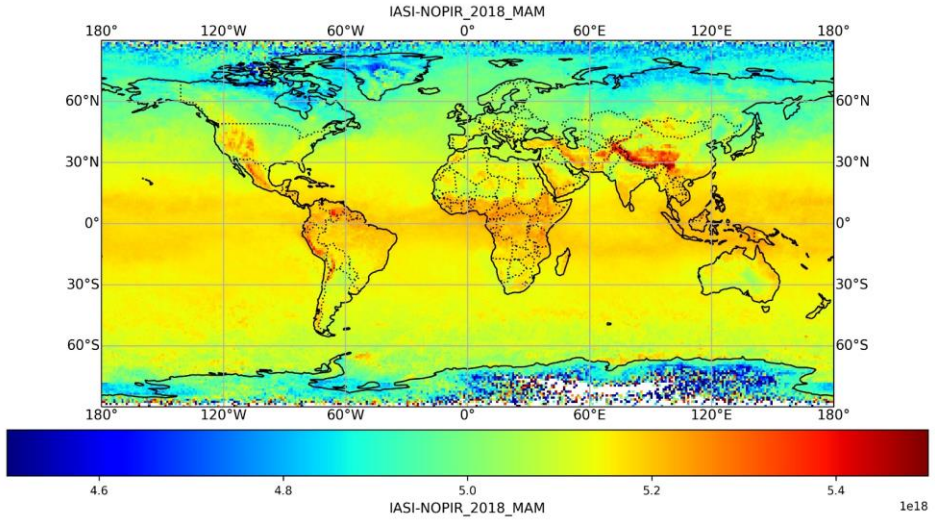




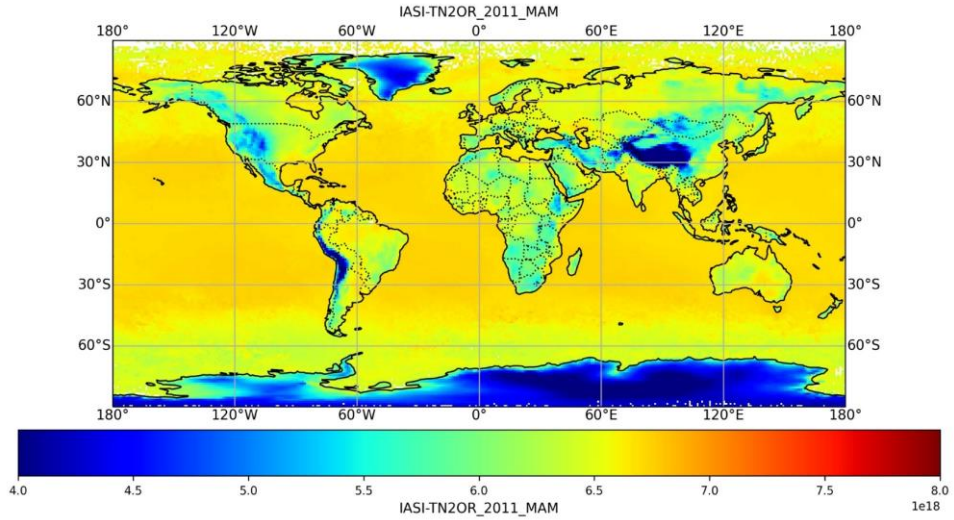
CrIS (and AIRS): higher concentrations in sub-tropics vs tropics

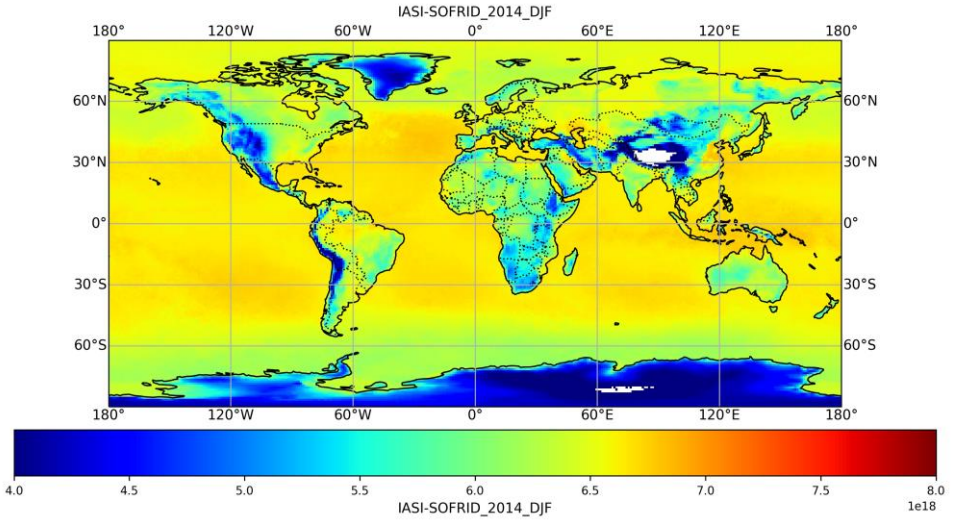
N2O concentration





NOPIR: high values over mountains?





1x1° map difference wrt CrIS (DJF)

CrIS (2020) 6.4e+18

AIRS (2015) 6.5e+18

TES (2011) 6.6e+18

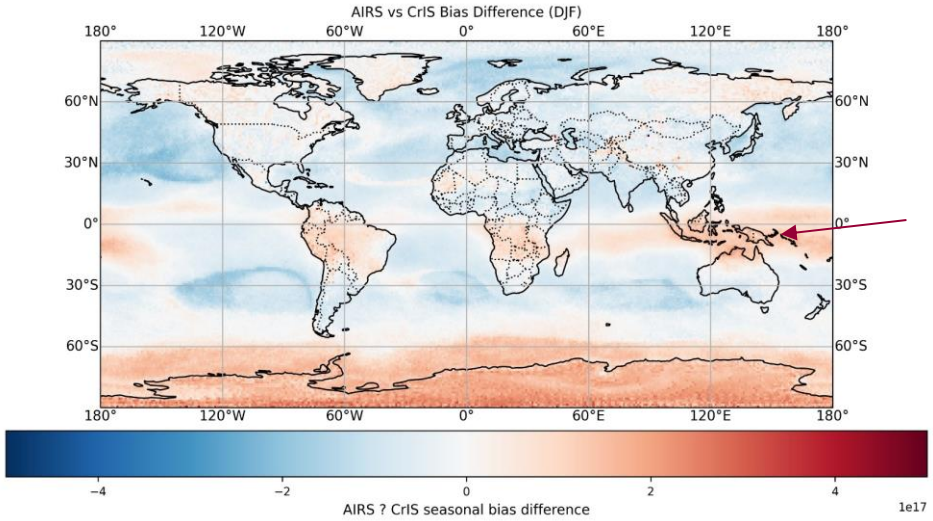
IASI-MUSICA (2020) 6.7e+18

TANSO-FTS-FOCAL (2020) 6.8e+18

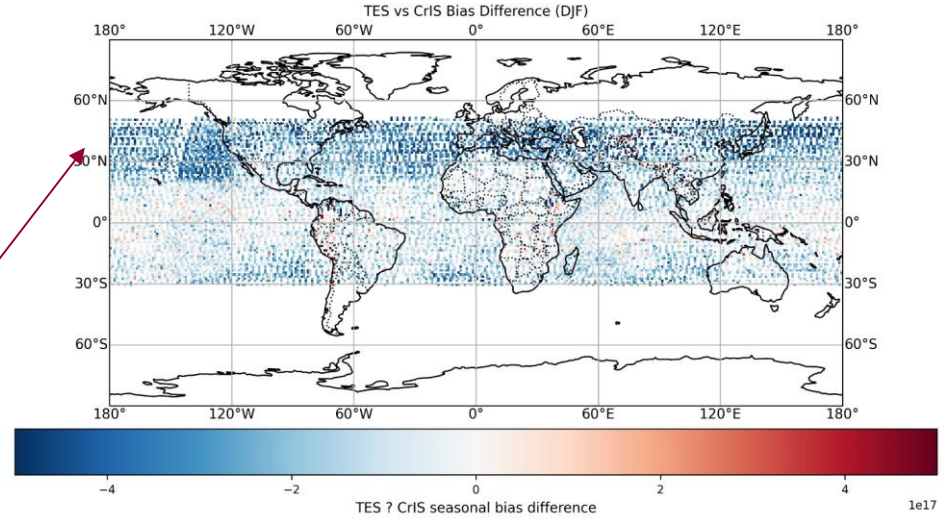
IASI-SOFRID (2014) 6.2e+18

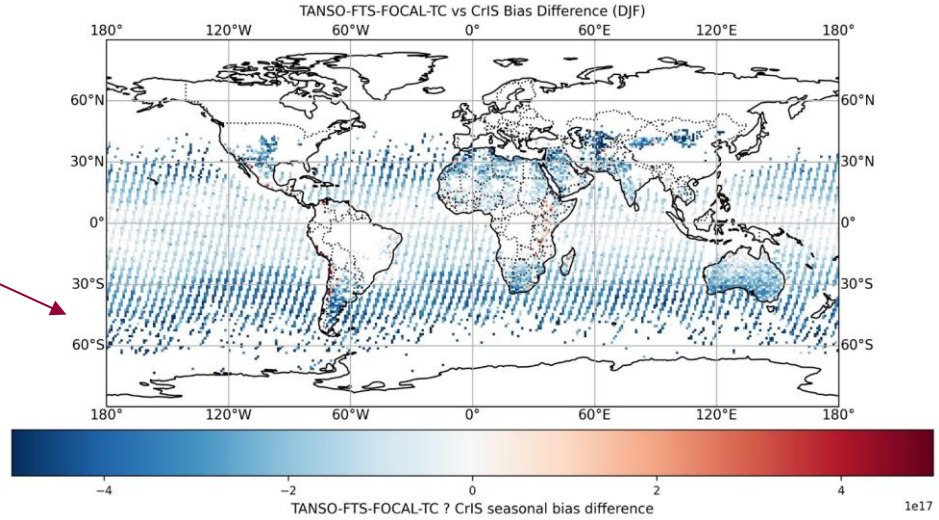
IASI-TN2OR (2011) 6.35e+18

CrIS PC (2020) 5.0e+18

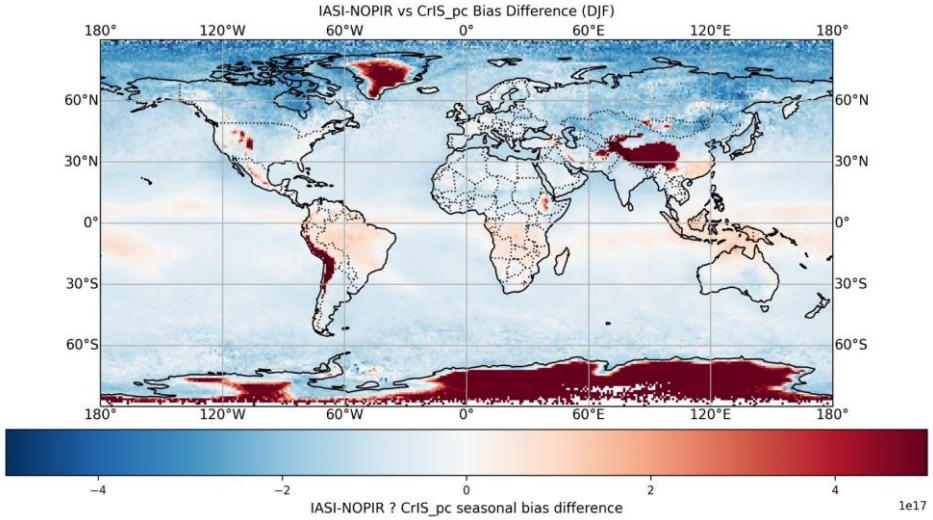


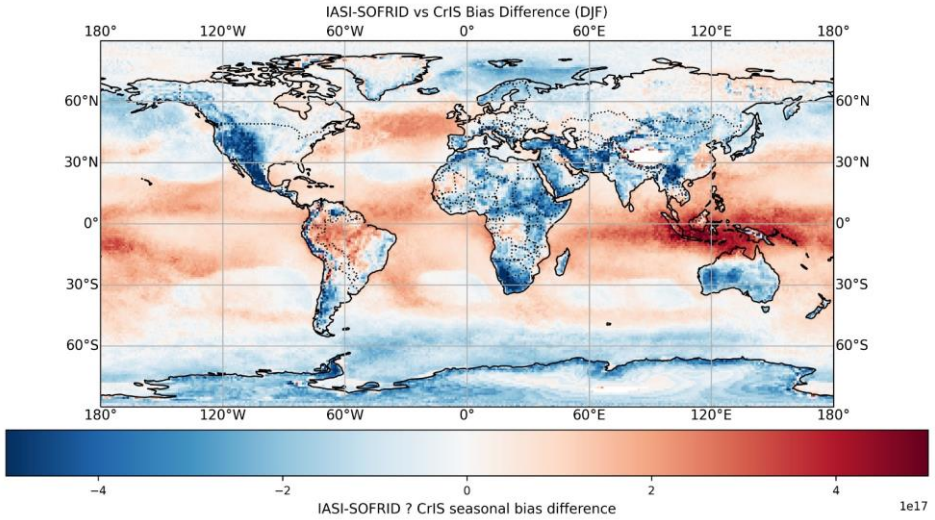
Little bit less tropical dip compared to CrIS





1x1° map difference wrt CrIS





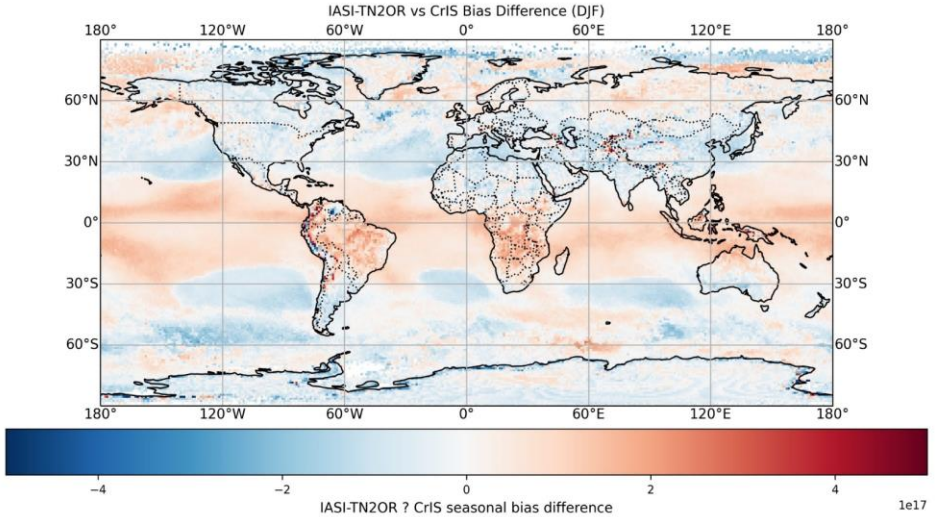
Differences more outspoken

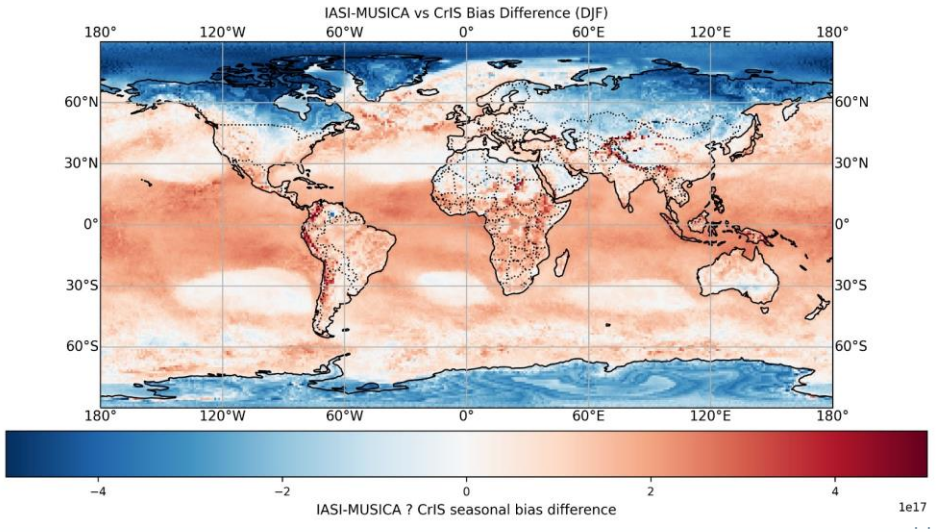
Higher conc in tropics.

NOPIR: strong pos biases in isolated regions

Musica stronger lat gradiant

SOFRID high contrast in Africa+Indonesia increase over tropical forests





Reference data TCCON

Total Carbon Column Observing network

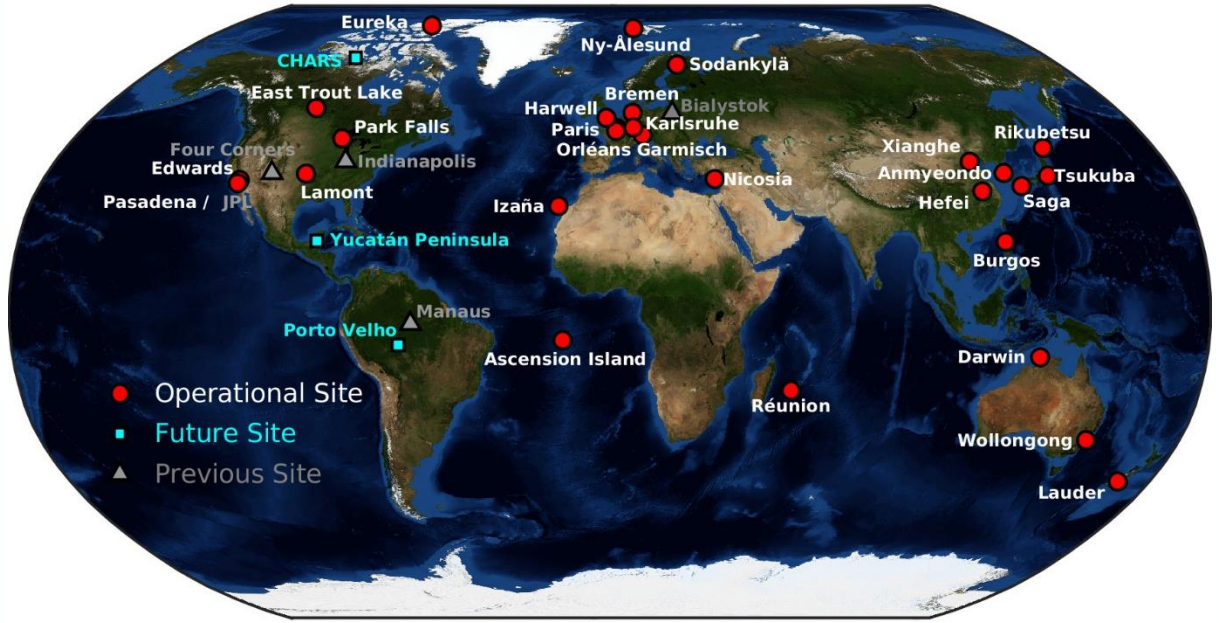
+ Highly centralized (harmonization, quality control)

+ Calibrated (and corrected) using in situ aircraft measurements

- CO2, CH4, **N2O**, HF, CO, H2O and HDO only

- Profile scaling retrieval

- Shorter Timeseries (later start + GGG2020)



Reference data NDACC

Network for the detection of Atmospheric Composition Change

+ long timeseries

+ Optimal estimation retrieval => 'Profile' information

N2O: 3-5 DOF

CFCs: ~1

- Less harmonization

	Required by IRWG		Measured		Episodic/Some Sites
	Species	DOFS	Species	DOFS	Species
1	C_2H_6	< 2	CCl_3F (CFC-11)	1*	SO_2
2	HCN	< 2.5	CH_3D	~1	CH_3OH
3	CH_4	2.5 - 3.5	$CHClF_2$ (HCFC-22)	1*	ClO
4	$ClONO_2$	1*	CO_2	2 - 3.5	C_2H_2
5	CO	2.5 - 4	COF_2	< 2	CCl_4
6	HCl	2.5 - 4	H_2CO	1	CF_4
7	HF	2.5 - 3.5	H_2O	< 3	CH_3OH
8	HNO_3	2.5 - 4	CCl_2F_2 (CFC-12)	1*	
9	N_2O	3 - 5	HDO	< 3	
10	O_3	3 - 5	N_2	~1	
11			NO	~1	
12			NO_2	< 2	
13			O_2	~1	
14			OCS	~2.5	
15			SF_6	1*	
16			HCOOH	~1	
17			C_2H_4	~1	
18			NH_3	~1	

Reference data AGAGE

- *The Advanced Global Gases Experiment*
- *Surface In situ*
- *ALE/GAGE/AGAGE since 1978*
- *CFC-11, CFC-12, CFC-113, $CHCl_3$, CCl_4, CH_3CCl_3, CH_4 and N_2O at all sites + many more at selected sites*

- https://agage.mit.edu/instruments
- Primarily used to assess long term trend analysis

Principles and Methodology

Use an as uniform as possible approach.

Collocation criteria: 500km within 2 hours

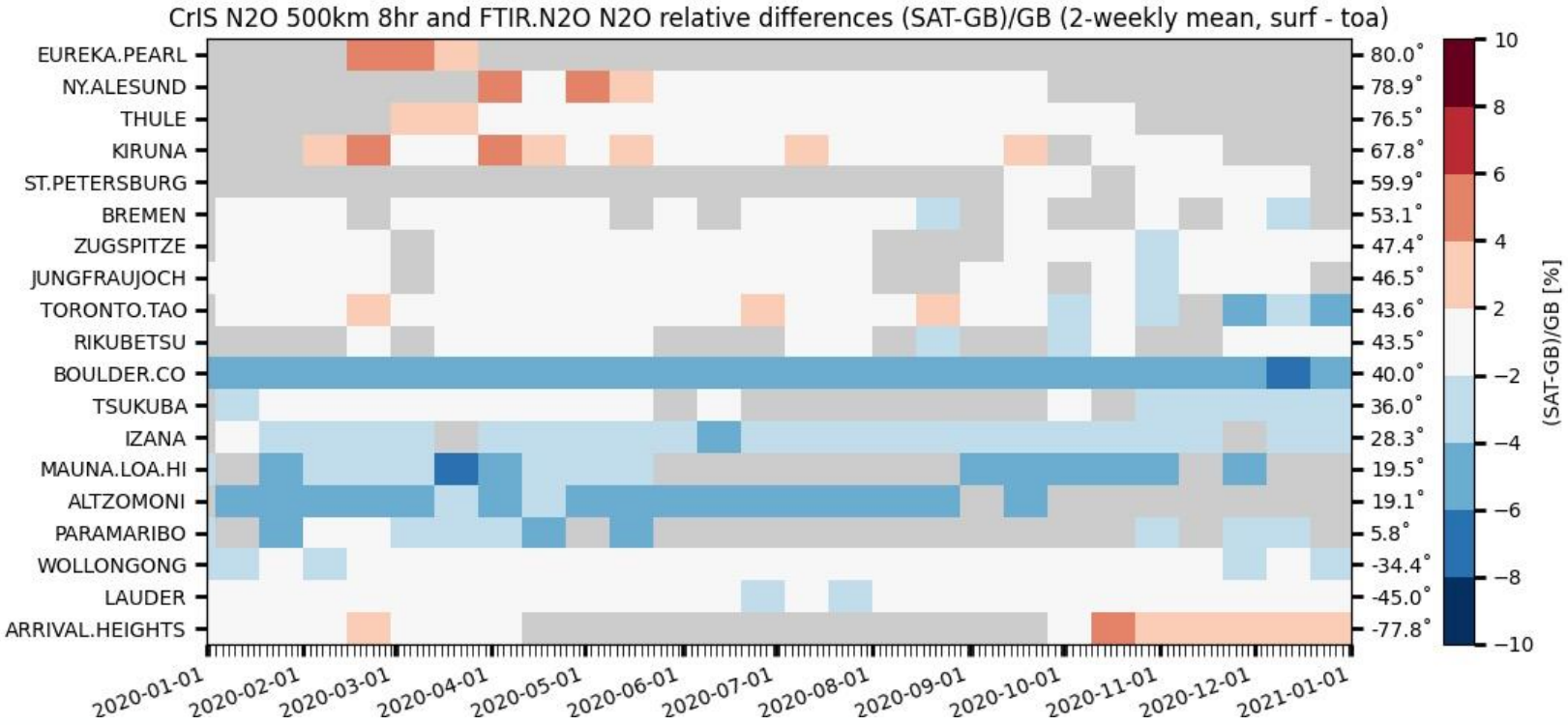
Compare satellite measurement with ‘what the algorithm would have retrieved if the reference measurement were to represent the true state’

If present: Use a uniform *a priori* profile (given that we have competing Algorithms we will use the reference data *a priori*)

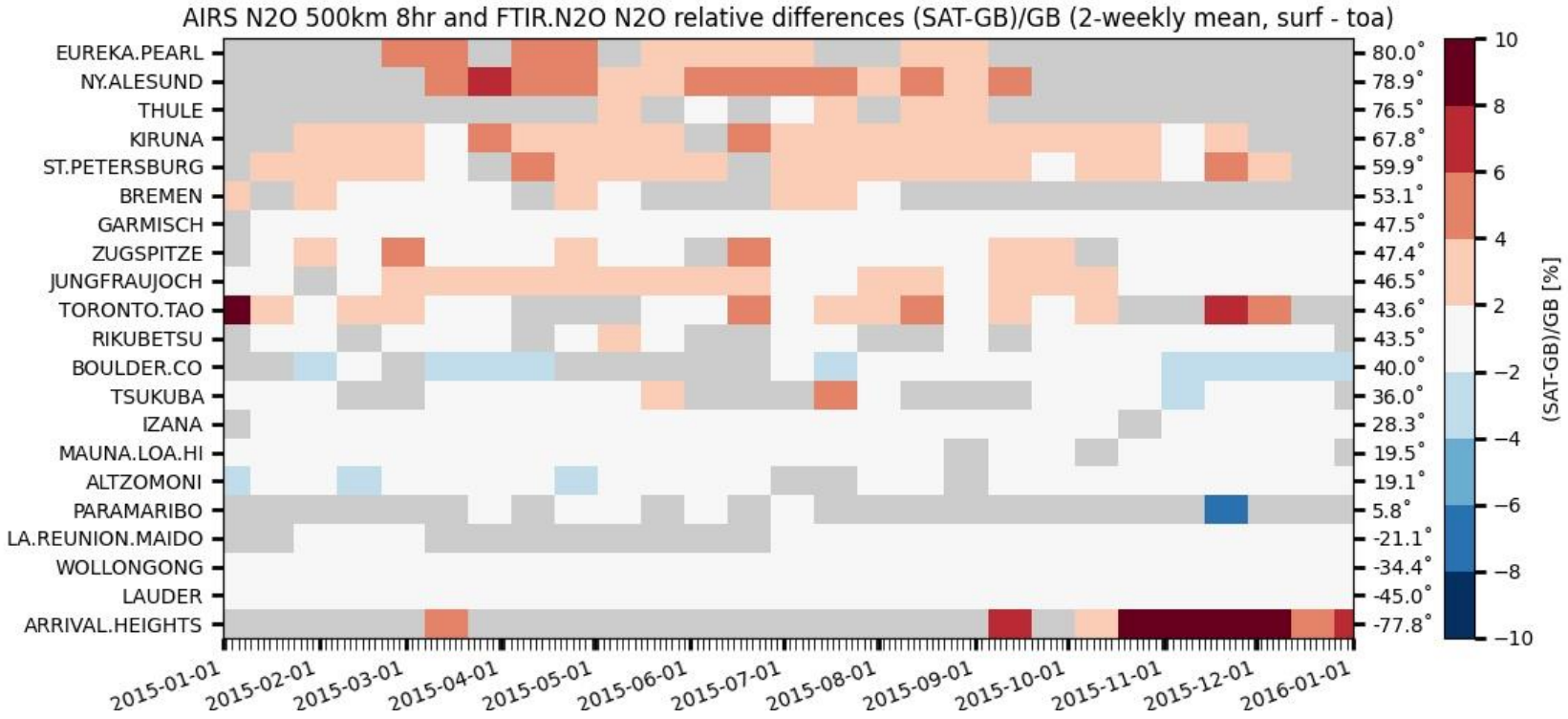
Apply the satellites vertical sensitivity information onto the reference measurement profile

For TCCON, no profile information is available, therefore we apply this to its scaled a priori profile

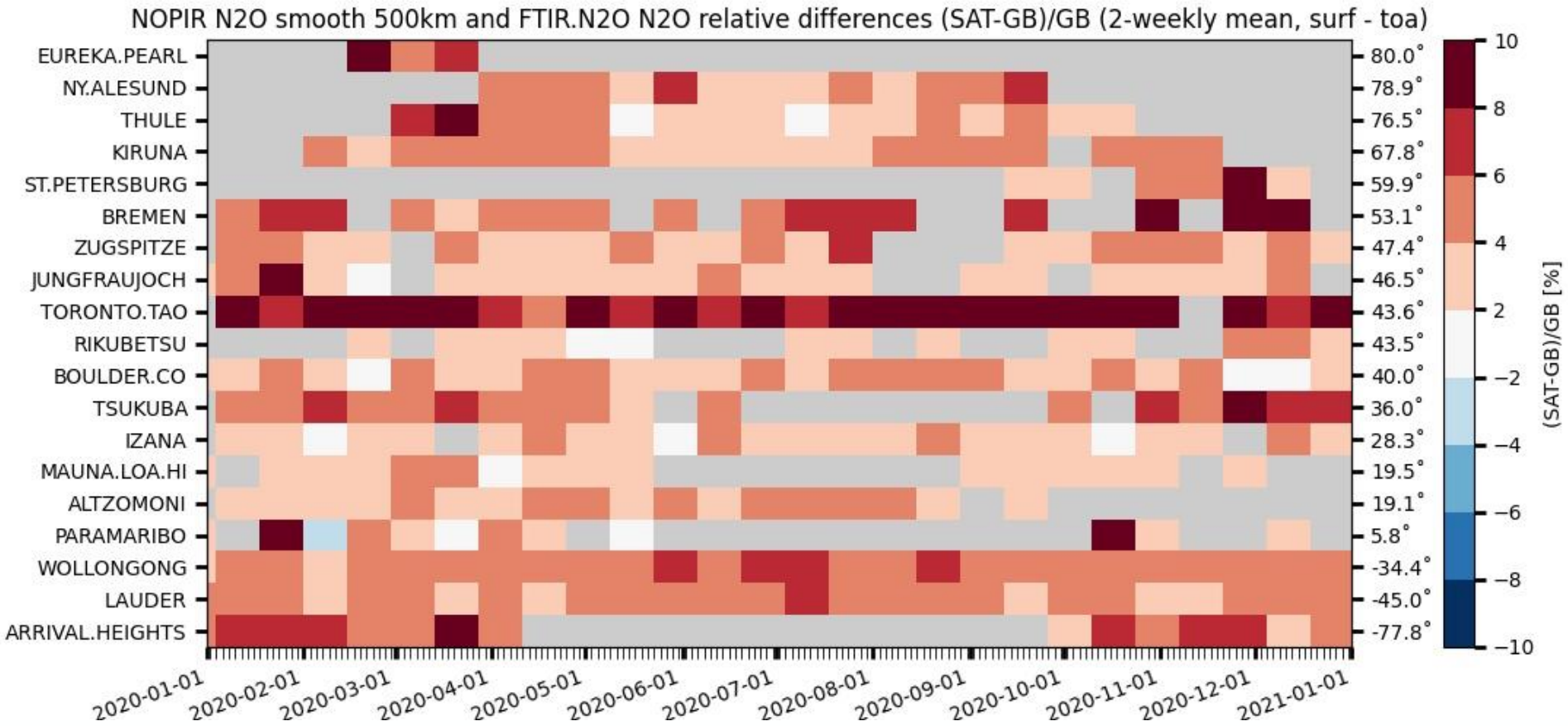
Validation: CrIS-NDACC



Validation: AIRS-NDACC

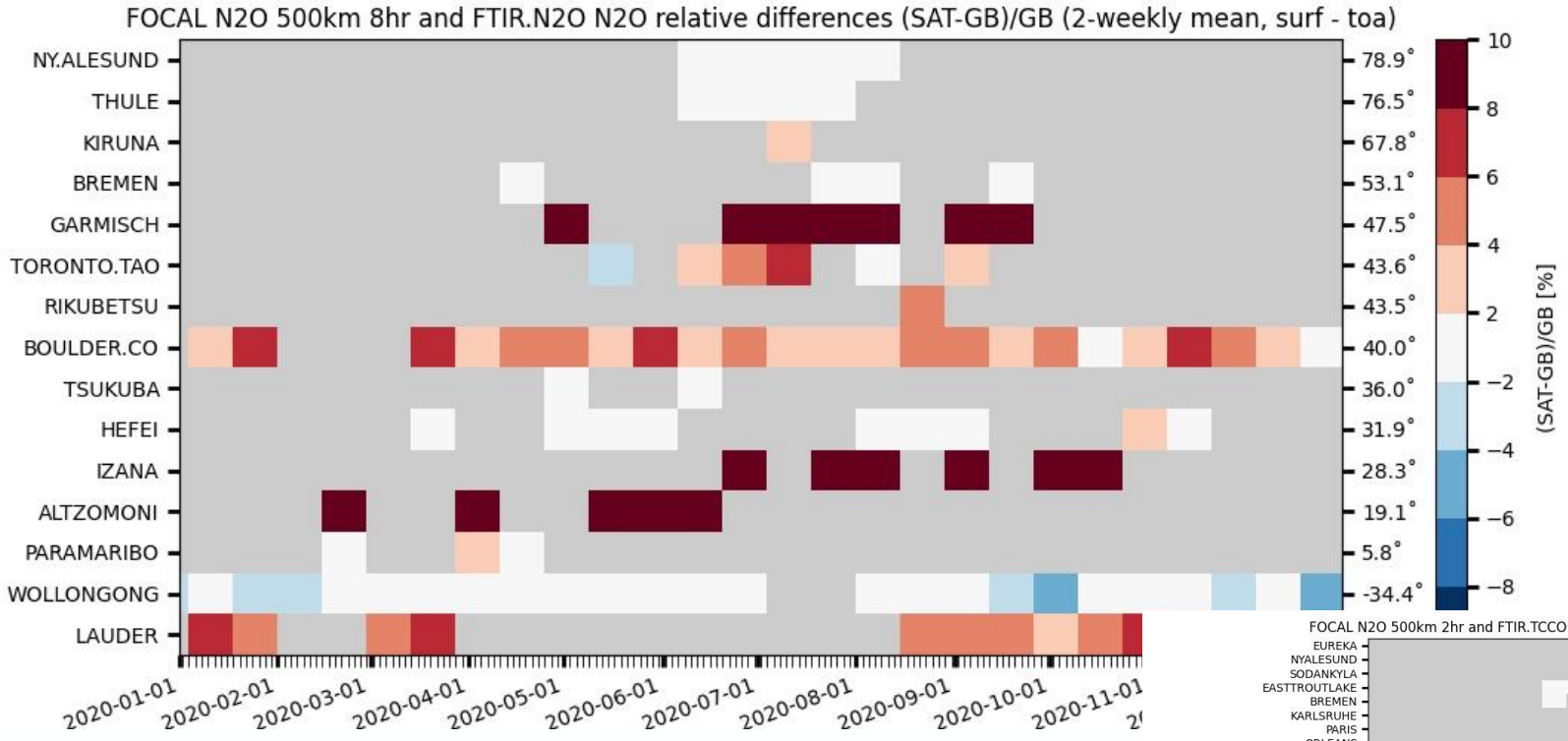


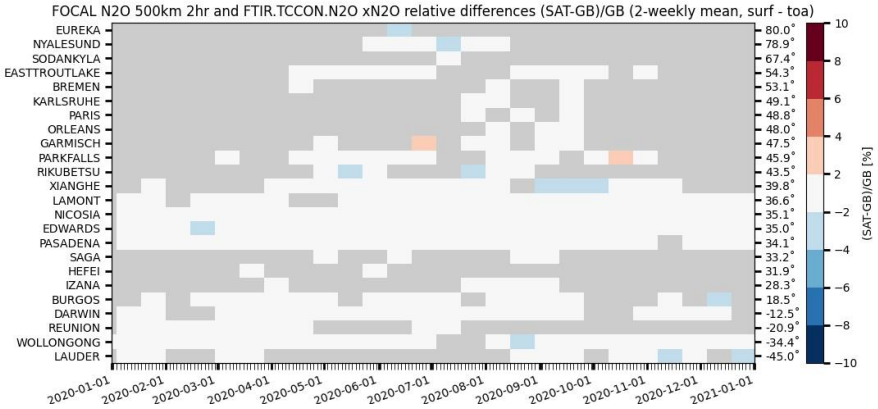
Validation NOPIR-NDACC



Overall positive bias. Toronto=?(issue with NDACC)
Stronger biases for Southern stations

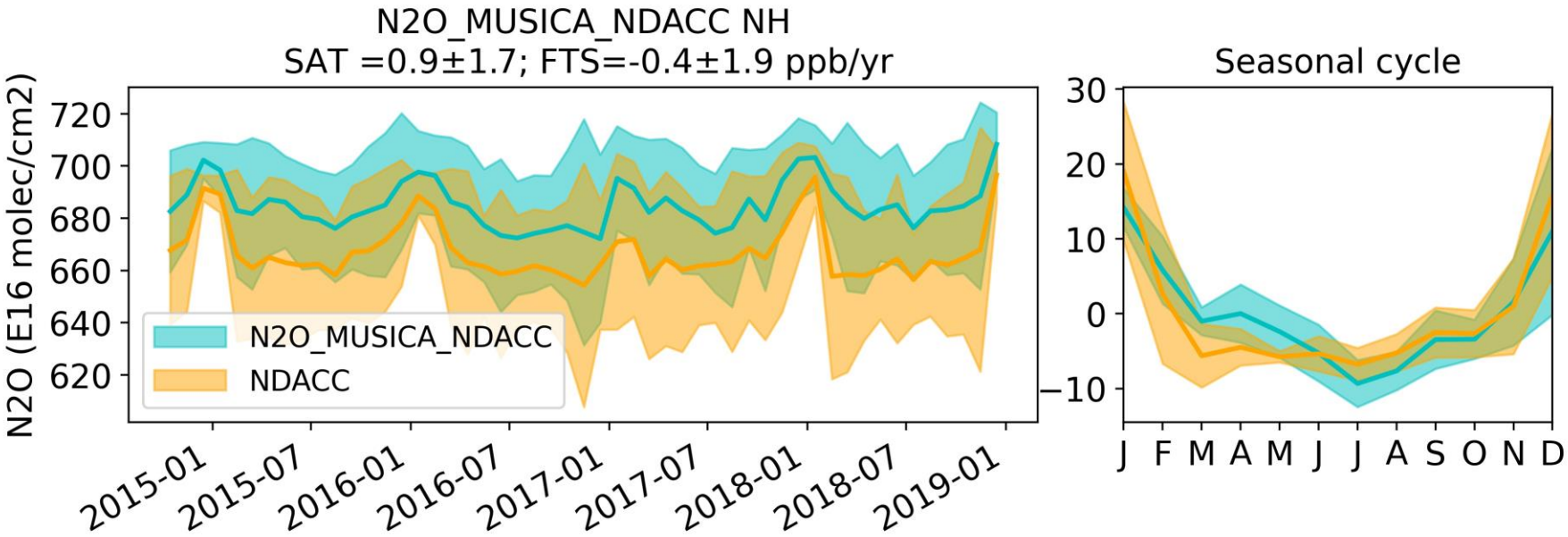
Validation: FOCAL-NDACC

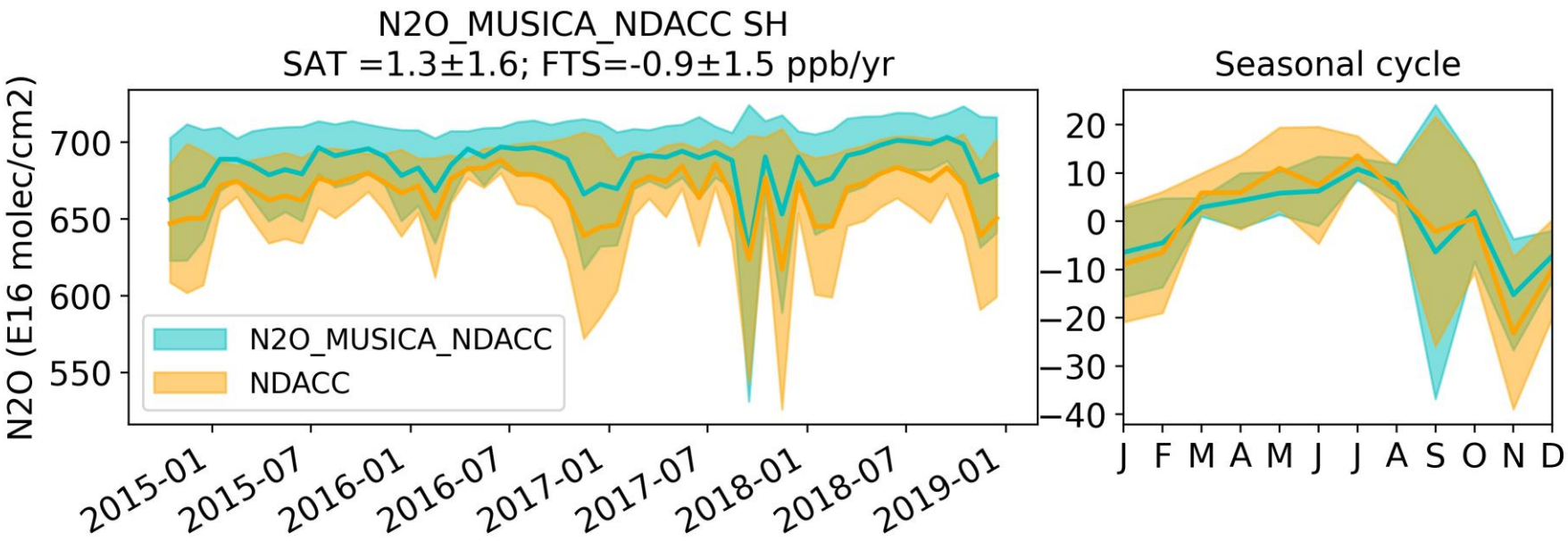




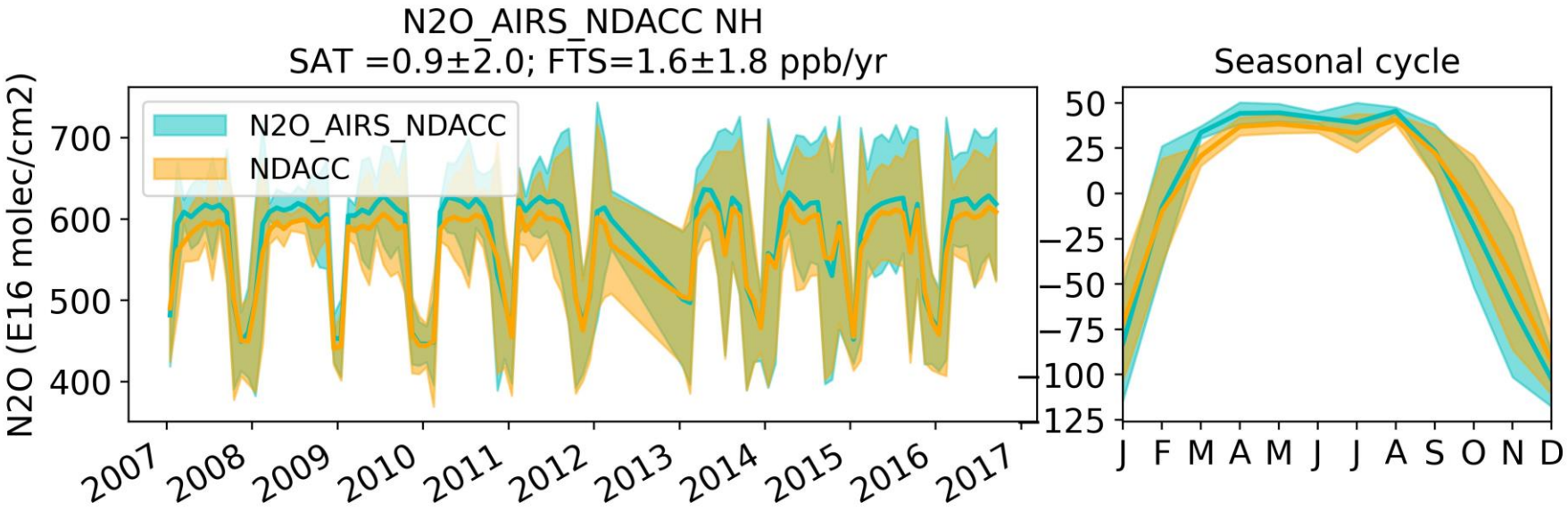
Limited consistent data: with outspoken biases for high altitude sites

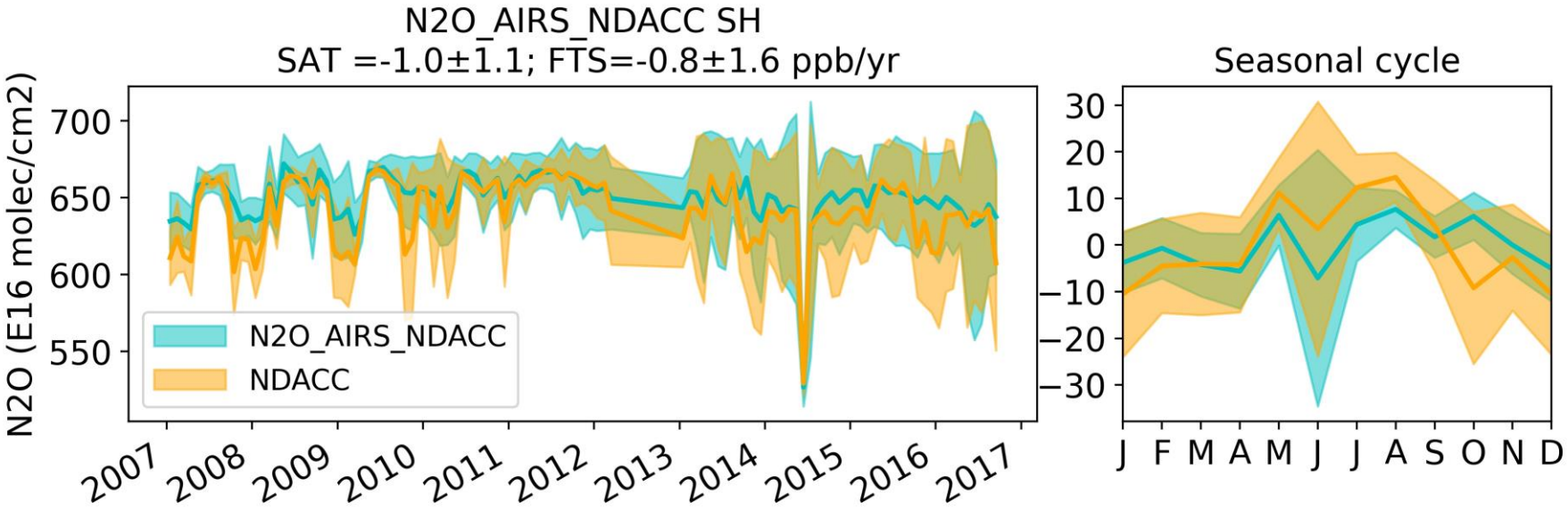
MUSICA trend analysis



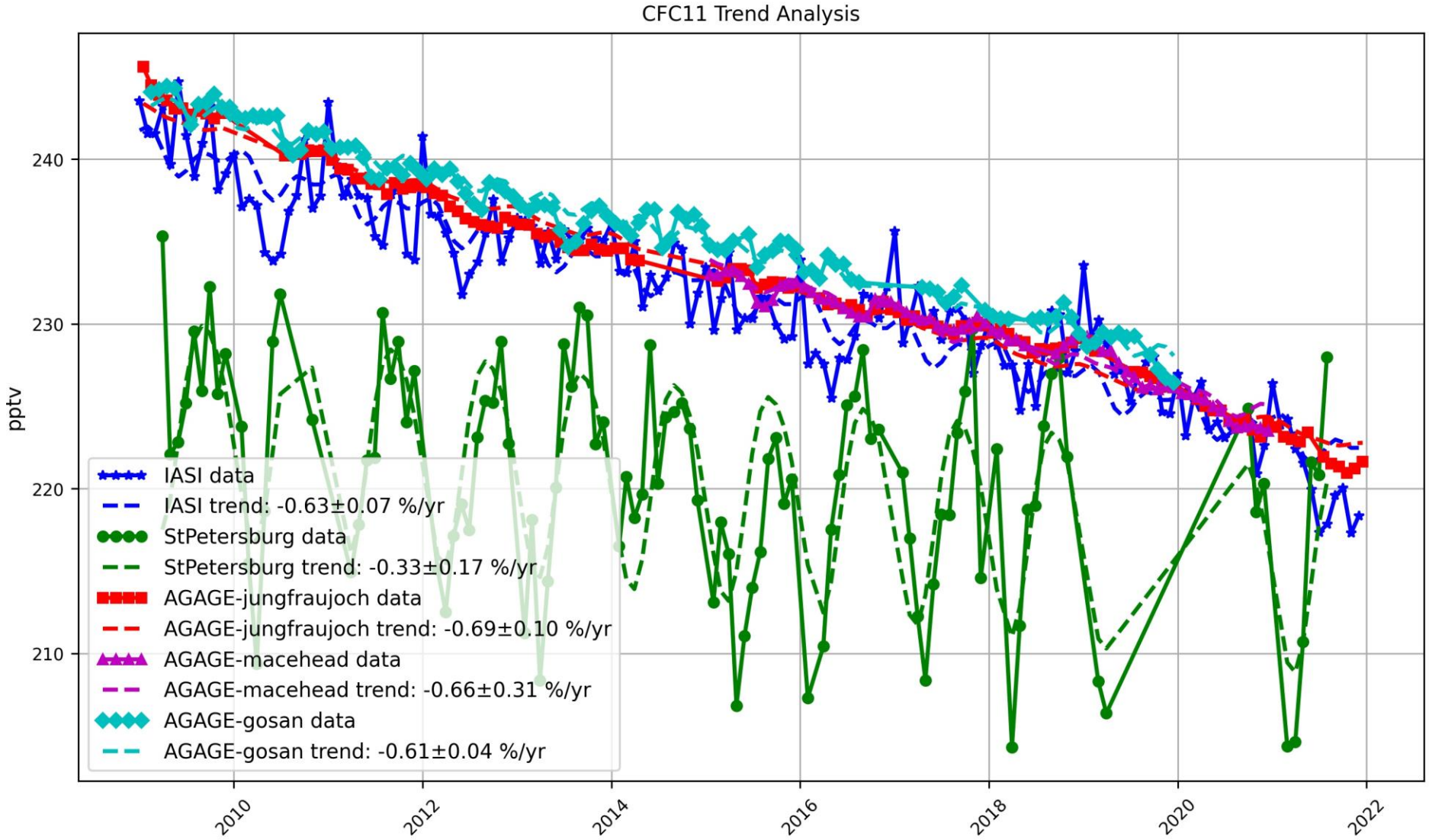


AIRS Trend analysis

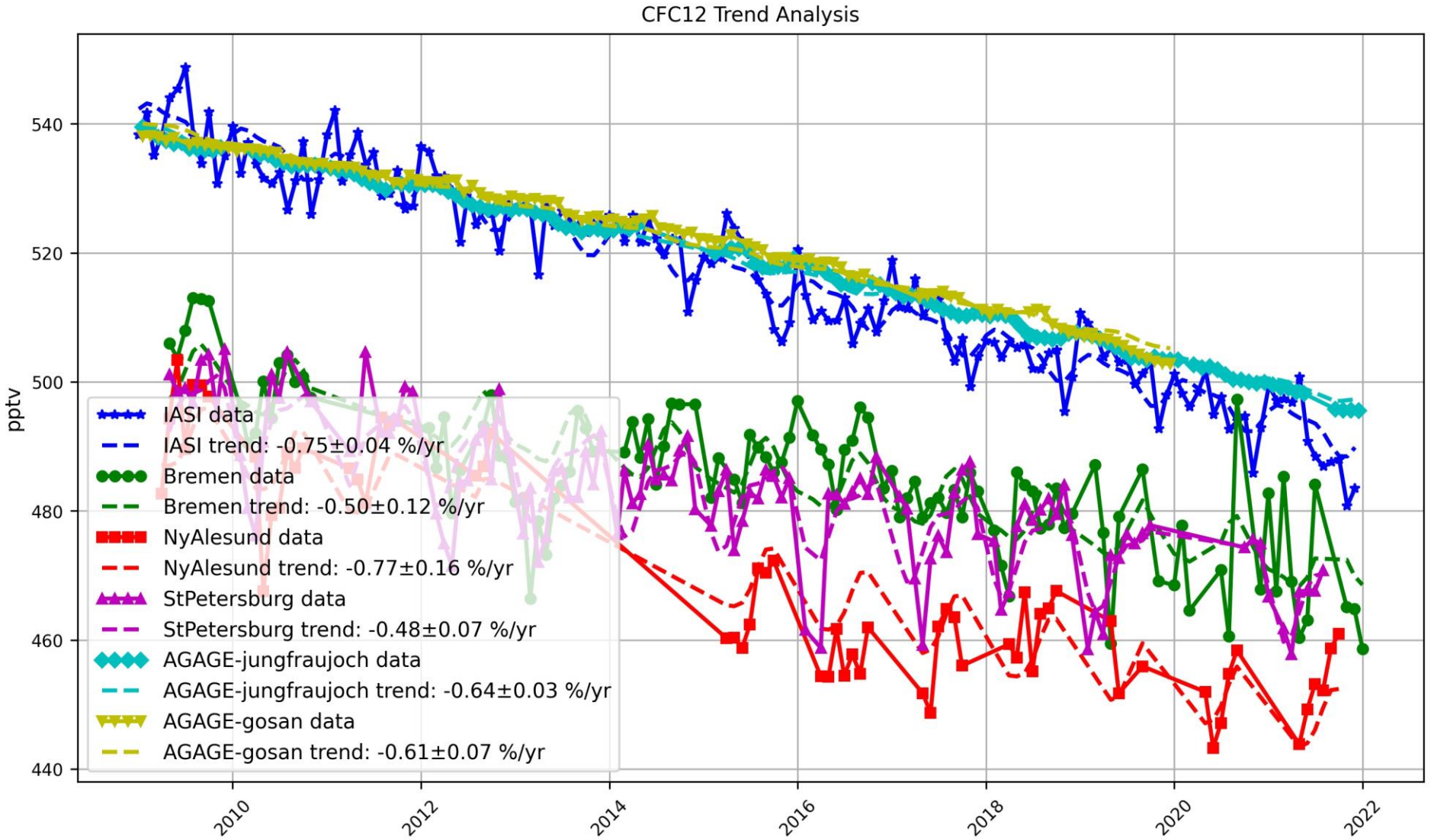




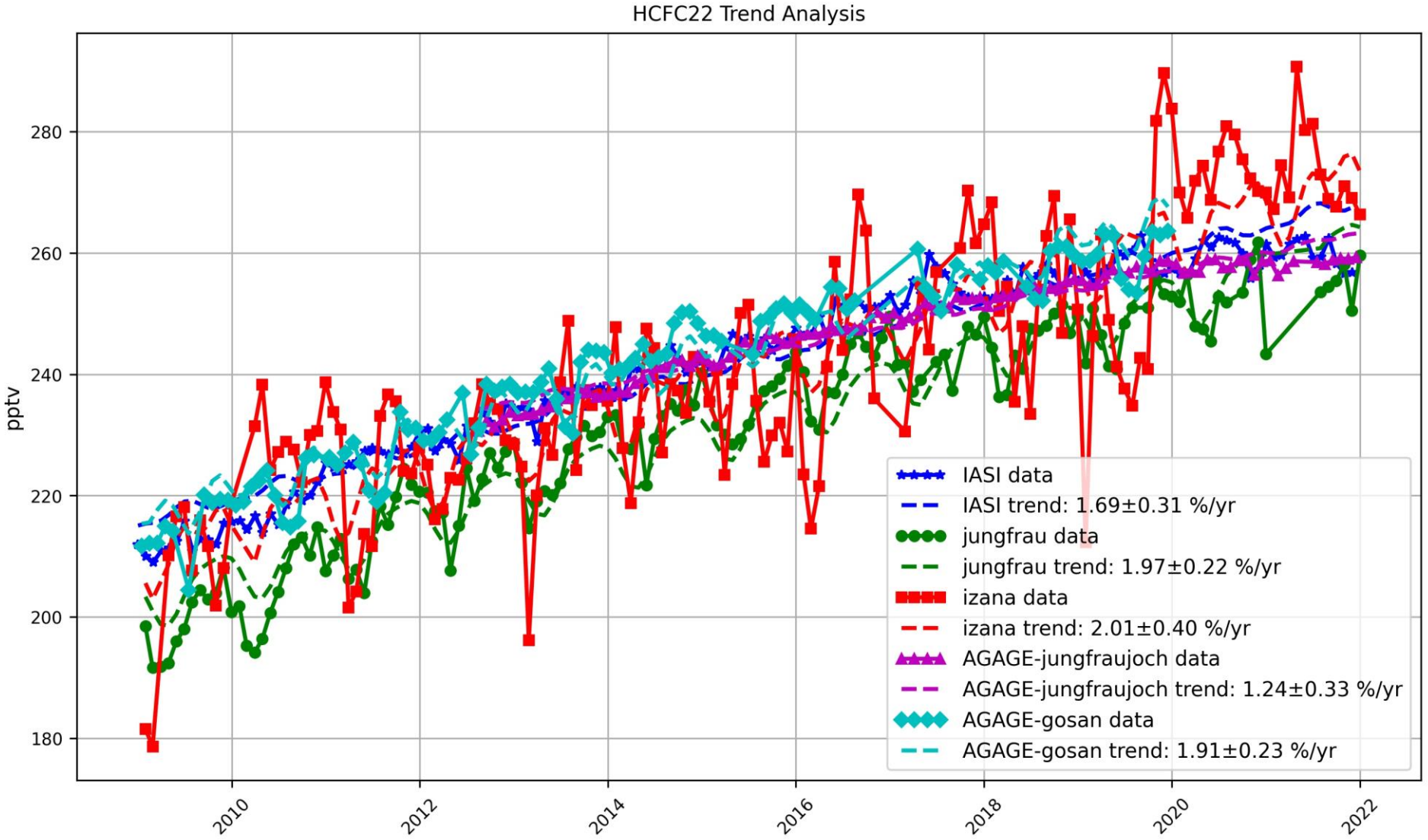
CFC11 Trend analysis



CFC12 Trend Analysis



HCFC22 trend analysis



Statistical parameters

To avoid impact from strong outliers (or outlier stations due to high altitude/urban centres etc.) we us

- Median
- Scaled Median Absolute Deviation (SMAD)
  - 1.4826 median(| x – median(x) |)
- In brackets we show the 95% confidence bands using a bootstrapping method

SMP: SMAD (SAT-FTS)/FTS (in %)

Bias: Median (SAT-FTS)/FTS (in %)

RA: SMAD (Bias per station)

SRA: SMAD (seasonal bias per station)

Med R: Median (R per station)

R all: R using all SAT-FTS pairs regardless of station

N: number of SAT-FTS data pairs

Validation (NDACC)

%	CrIS(2020)	AIRS(2015)	TES(2009)	MUSICA2018	TN2OR(2011)	NOPIR(2020)	FOCAL(2020
SMP	3.45 [2.70, 4.45]	3.57 [2.03, 4.74]	1.66 [1.58, 1.77]	1.39 [1.29, 1.45]	1.42 [0.81, 1.79]	2.53 [2.11, 2.82]	*1.26 [1.19, 1.44]* 2.28 [1.54, 3.12]
Bias	2.13 [-4.92, 4.40]	3.42 [-2.62, 4.92]	1.37 [0.50, 1.69]	2.92 [2.06, 3.63]	0.83 [0.42, 0.94]	3.90 [2.83, 4.62]	*-0.44 [-0.78,-0.22]* 2.49 [-2.32, 4.33]
RA	5.53 [-7.88, 9.23]	4.80 [-6.59, 7.53]	0.70 [0.01, 1.22]	1.37 [0.90, 2.14]	0.62 [0.25, 1.11]	1.20 [0.50, 1.91]	*0.51 [0.10, 0.74]* 3.73 [-2.87, 6.74]
SRA	6.56 [3.10, 9.41]	4.99 [1.91, 7.08]	0.93 [0.54, 1.30]	1.46 [1.16, 1.94]	0.68 [0.37, 0.89]	1.23 [0.65, 1.57]	*0.55 [0.32, 0.71]* 3.86 [2.00, 5.80]
Med R	0.11 [0.03, 0.16]	0.16 [0.08, 0.23]	0.55 [0.23, 0.91]	0.89 [0.85, 1.05]	0.02 [-0.29, 0.04]	0.04 [-0.05, 0.06]	*0.40 [0.28, 0.48]* 0.13 [-0.10, 0.22]
R all	0.38	0.32	-0.73	0.13	0.30	0.28	*0.59* 0.86
N	117819	123623	1096	1259704	329918	867476	*4638* 1283

Limited lat band!

Limited lat band!

Conclusion

Apart from CrIS (lack of DOFs and AVK information), AIRS (lack of AVK info) and TES (extremely limited sampling in public dataset), which hamper a decent in depth analysis, it is too soon to favor one of the other scientific N2O products

As for the CFCs, ULB’s retrieval method looks well suited to capture long term CFC trends in the atmosphere

lolipop
cci