Towards near-real-time XCO_2 retrieval from OCO-2 observations using Neural Network techniques

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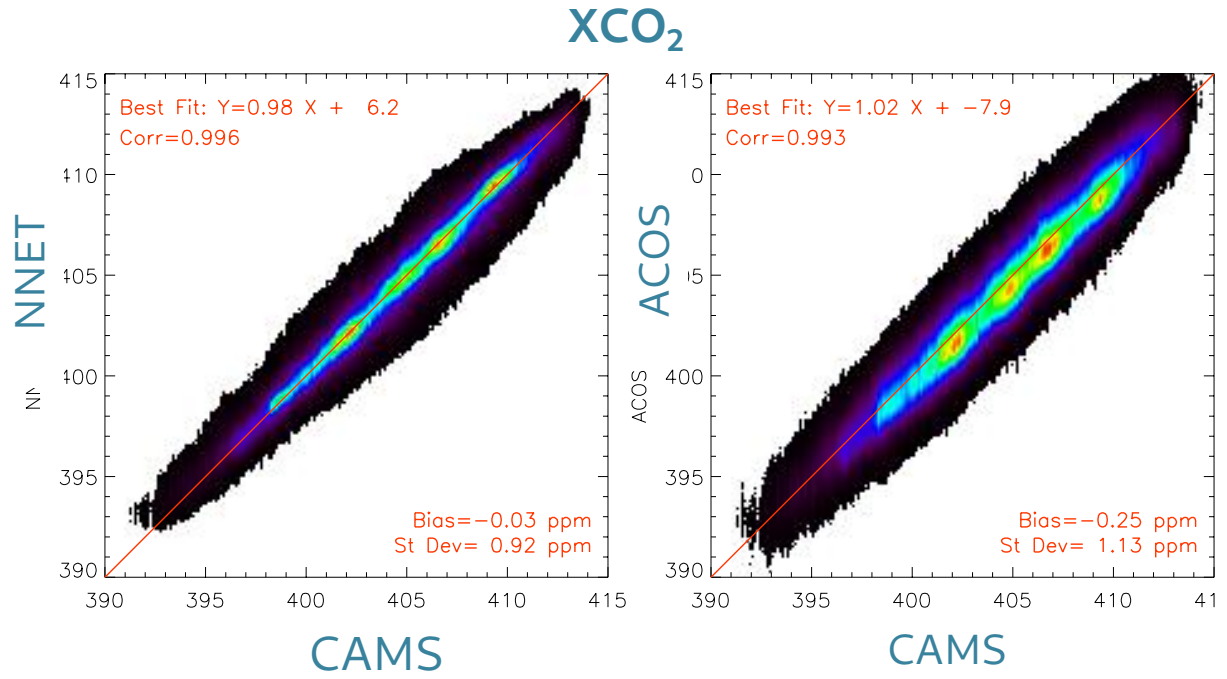
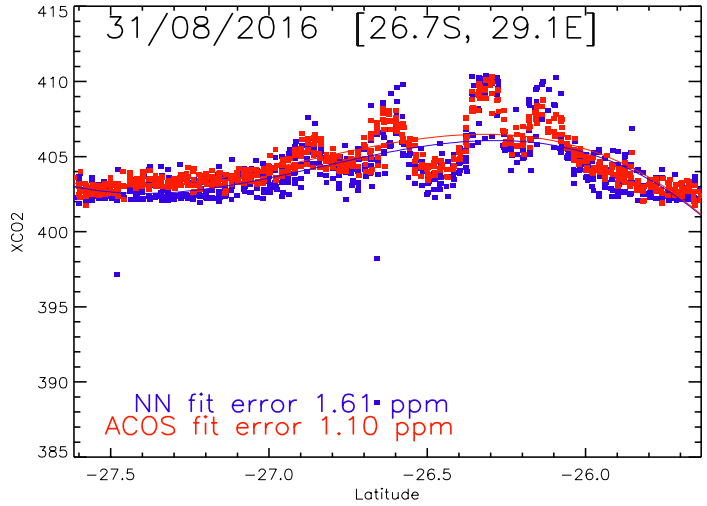
Background

- Neural Networks (NNETs) can estimate XCO_2 from OCO-2 spectra with high accuracy (*@David et al. (2021)*)
  - Training on {real spectra, CAMS CO_2 inversions}
  - Application to very clear soundings (ACOS L2 flag)

- Very fast, no bias-correction required, compared to ACOS full-physics retrievals

- NNETs are able to generate features (e.g. plumes) that are not contained in CAMS training dataset (*@Bréon et al. (in revision)*)





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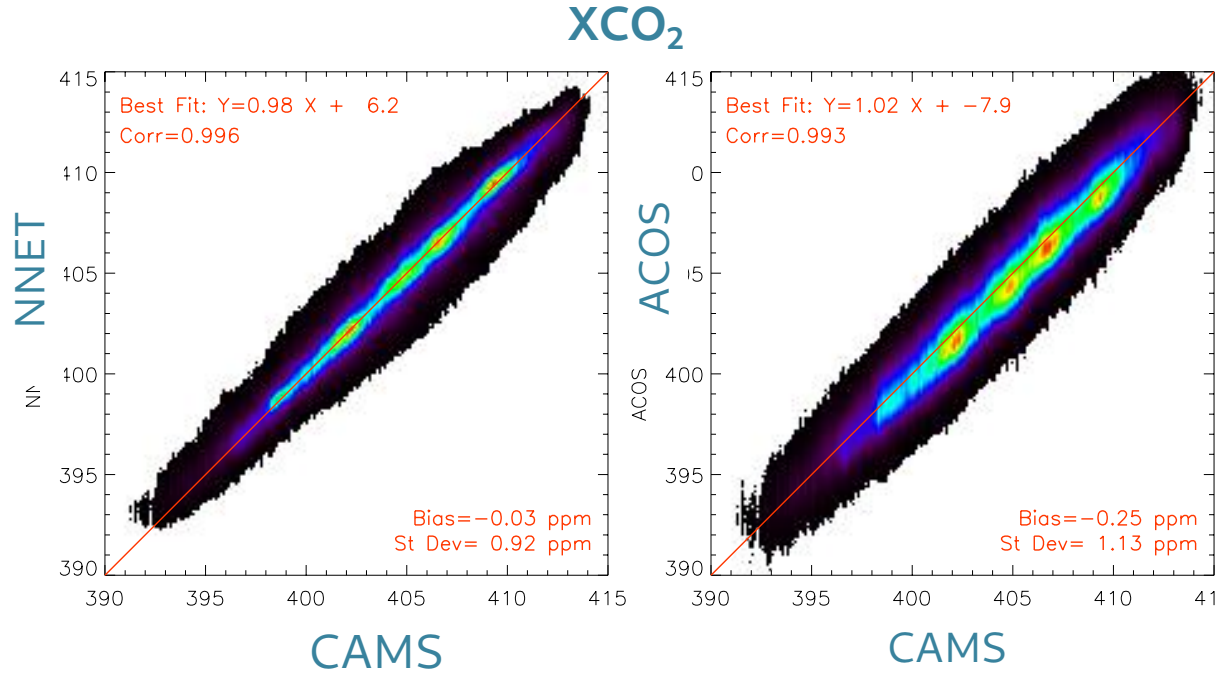
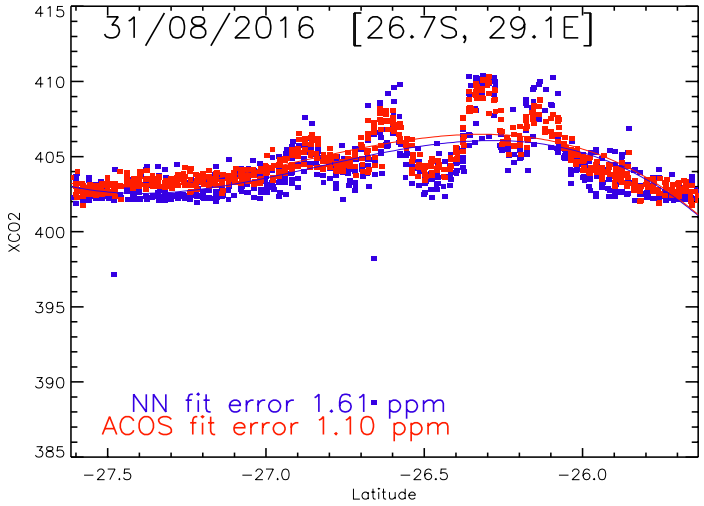




Limitations wrt near-real time processing

- NRT production requires NRT cloud detection

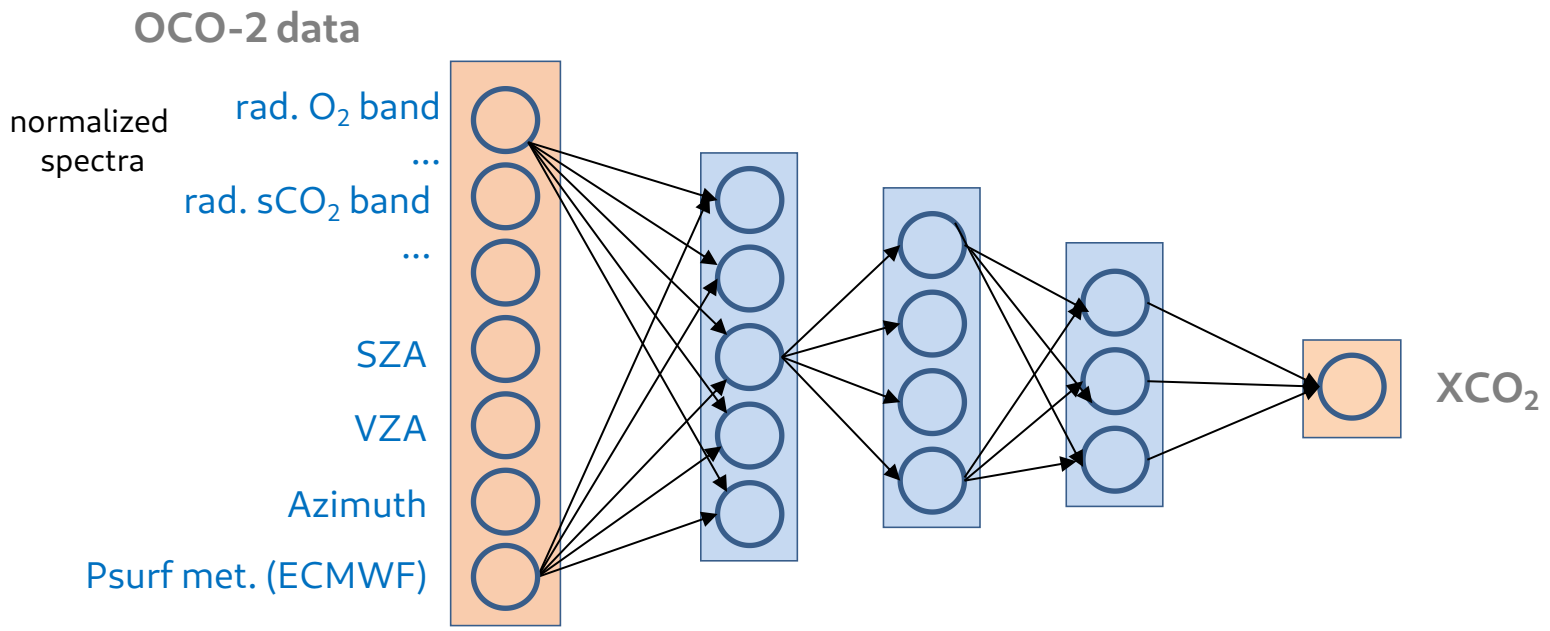
- NNET needs training against a **representative dataset**
  - This may be an issue as "recent" observations may be with larger XCO_2 than those of the training dataset based on older observations

XCO_2 retrieval

OCO-2 data

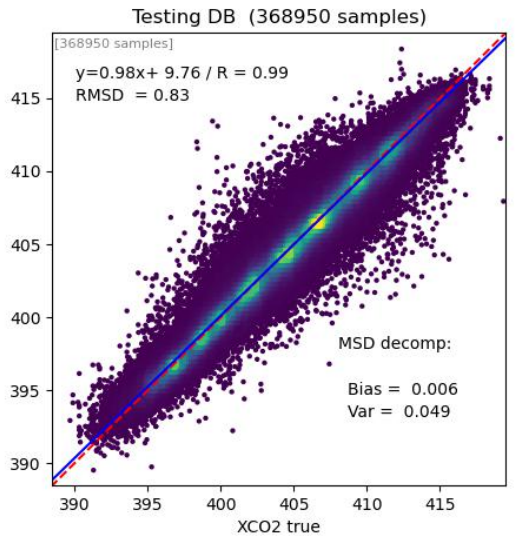
- Period: 2014-2020
- Nadir viewing over land
- Channel selections
  - O_2 band: 845 channels
  - sCO_2 band: 469 channels
  - bad_color = 0
- AOD ≤ 0.3

- Training of two NNETs
  - over very clear sounding only
  - over both probably and very clear soundings
  - based on *cloud_flag_idp* of the ACOS product

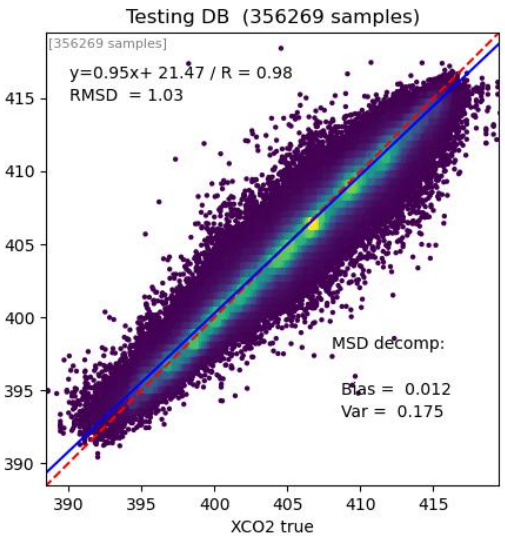


Retrieval performance

very clear



probably + very clear

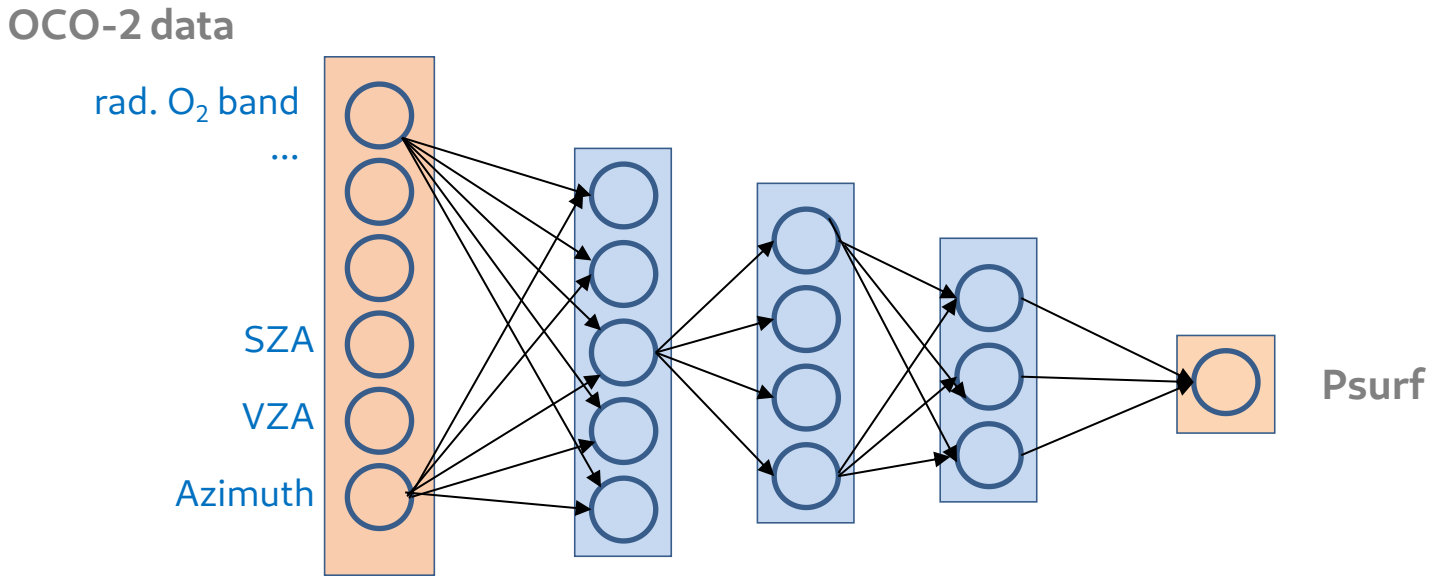


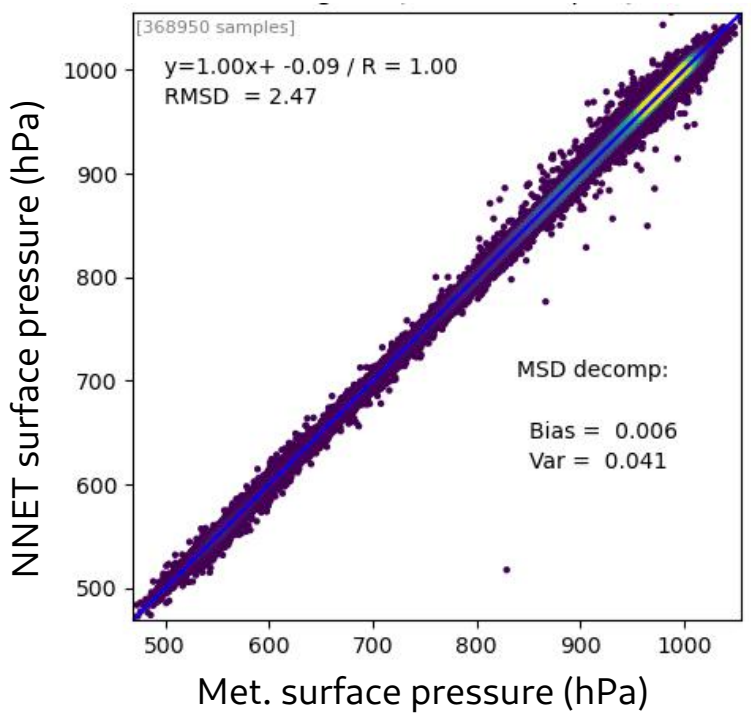
- Good performance of the NNETs over their respective domain of application

NRT clear-sky detection

Option 1: based on Surface Pressure retrieval

- **Hypothesis**
  - Cloudy observations lead to surface pressure estimates with large errors
- **Approach**
  - Use NNET to estimate surface pressure from the O_2 band and compare to ECMWF estimate
  - Reject if $|P_{NNET}-P_{ECMWF}|> 2.5$ hPa





- In clear conditions, NNET can retrieve Psurf with high accuracy (σ(ECMWF-NNET) < 2.5 hPa)

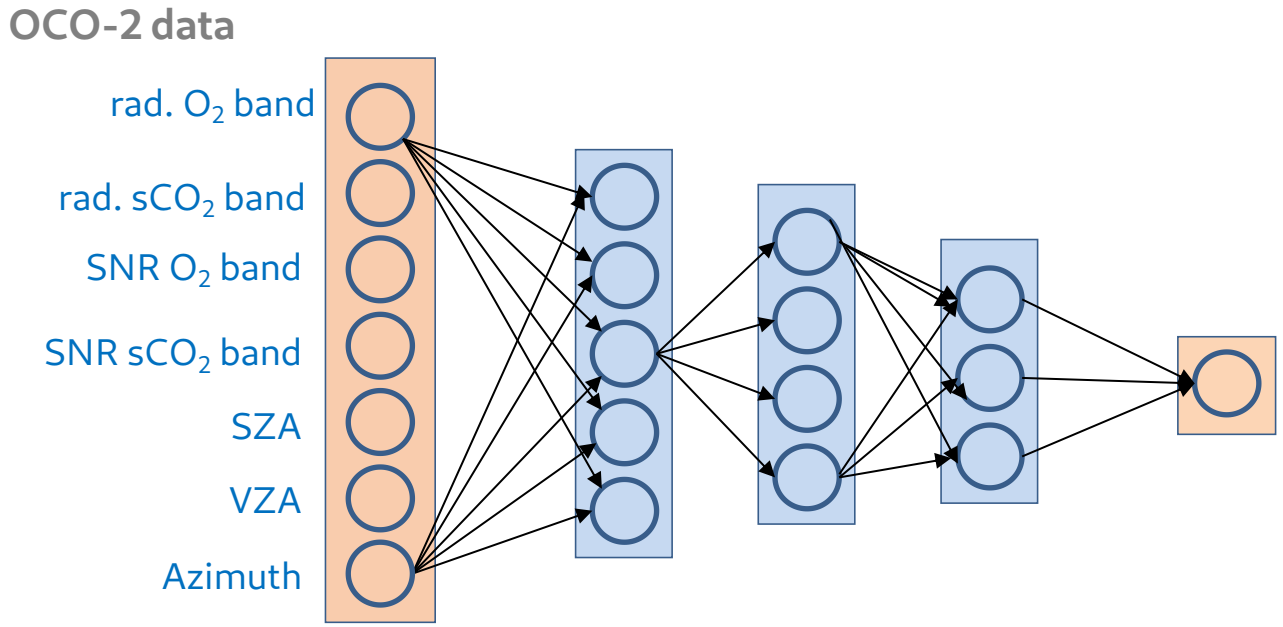
NRT clear-sky detection

Option 2: based on the retrieval of ACOS Cloud Flag

- Clear-sky soundings:
  - ACOS CF=2: probably clear
  - ACOS CF=3: very clear
- Cloudy soundings:
  - soundings in L1b files which are not is L2 files
  - soundings in L2 files with *cloud_flag_idp* ≠ 2-3

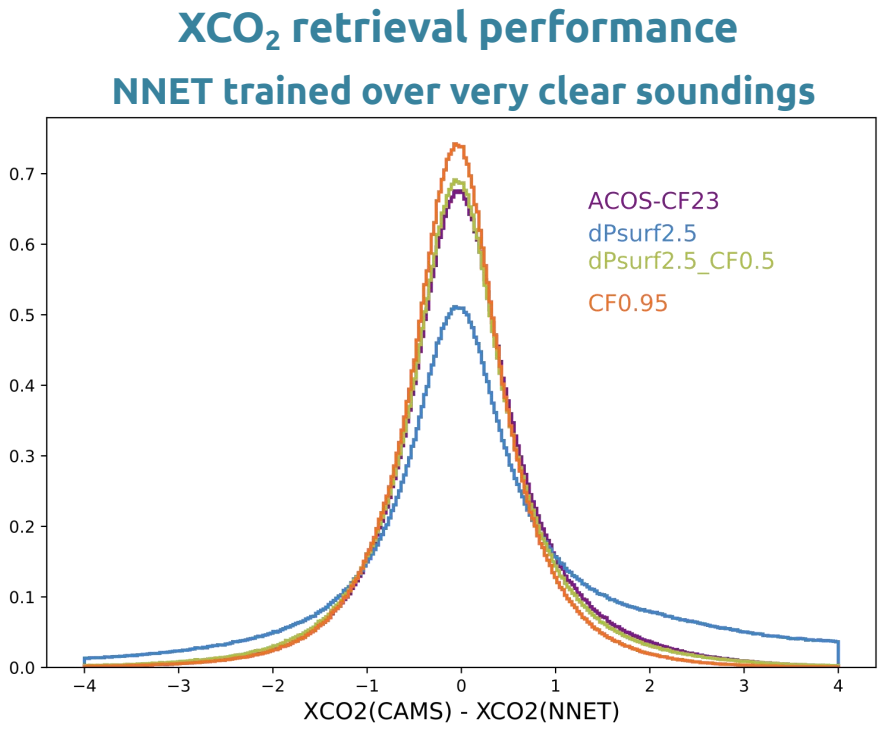
Identification performances (cloudy & clear conditions)

Probability threshold	Classified pixels	Classification Accuracy
0.5	100.0%	93.7%
0.6	96.6%	95.1%
0.7	92.3%	96.3%
0.8	88.3%	97.4%
0.9	81.6%	98.6%



Evaluation of the clear-sky detection approaches

- Year 2016
- Evaluation against XCO_2(CAMS)



Approach	Training over very clear soundings		Training over probably + very clear soundings	
	σ (ppm)	# soundings	σ (ppm)	# soundings
ACOS Clear (CF=2,3)	0.89	3 863 646	0.89	3 863 646
ΔPsurf ≤ 2.5 hPa	2.26	7 048 544	1.99	7 046 521
ΔPsurf ≤ 2.5 hPa & ProbaCF ≥ 0.5	0.93	4 095 422	0.85	4 095 418
ProbaCF ≥ 0.95	0.79	3 682 470	0.77	3 682 471

- The approach based on the learned Cloud Flag alone provides the best estimation accuracy
  - number of selected soundings in closer agreement to ACOS

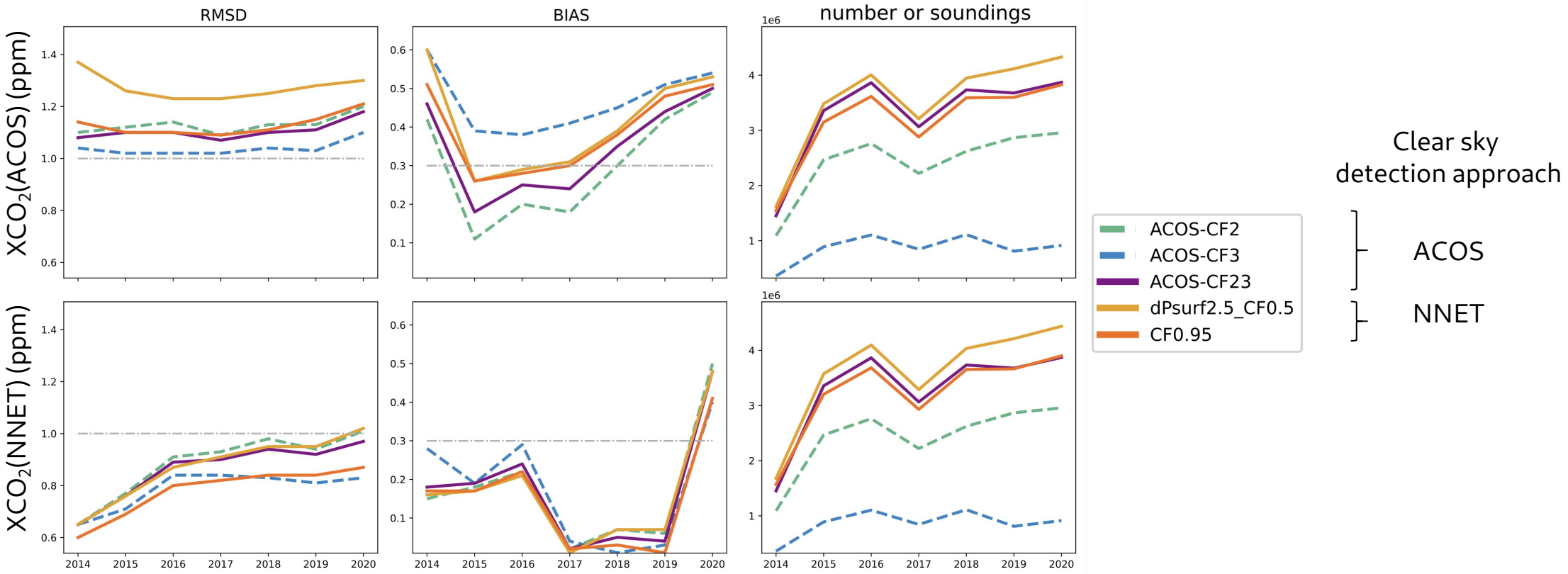
- For a NRT processing of "all" clear-sky conditions, the NNET trained over probably & very clear soundings provides marginal improvements

Overall performances

- Evaluation against CAMS CO_2 inversions over 2014-2020
- Comparison against ACOS XCO_2 retrievals

ACOS vs CAMS

NNET vs CAMS



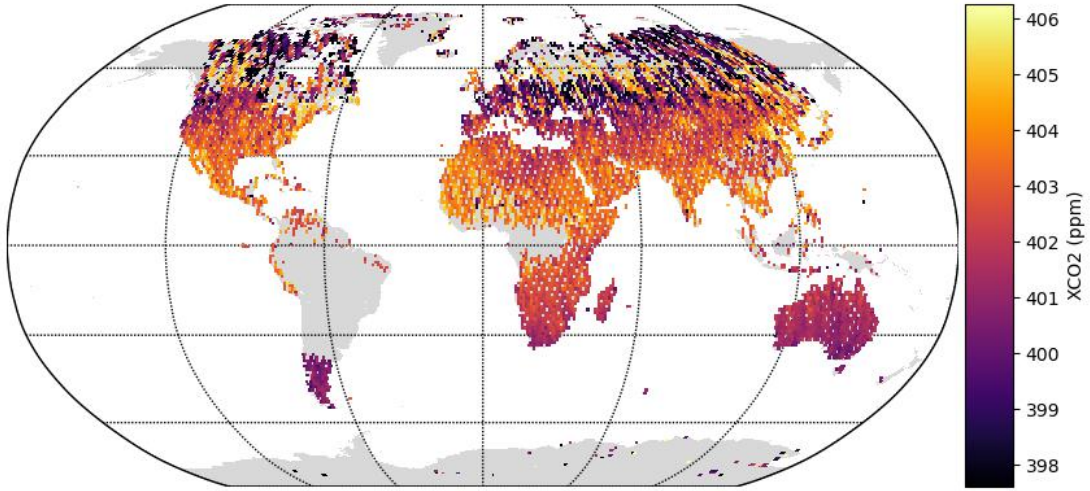
- XCO_2(NNET) (bottom) is in higher agreement with CAMS than XCO_2(ACOS) (top)
- The clear sky detection based on the Cloud Flag learned from ACOS provides the highest retrieval performances
- Temporal variation of the retrieval bias, with significant increase in 2020 > not understood yet

Discussion & Perspectives

The neural network approach can be used for both the identification of clear-sky sounding and the estimation of XCO_2

Limitation: spatial distribution of XCO2(NNET)

- The NNET approach requires that all selected channels be present
- This has a large impact on the coverage over South America where most observations contain bad pixels
  → need for spectral interpolation



year 2016

Perspectives

- Evaluation against CAMS for 2021
- Training over recent CAMS data (climatological fluxes)
  - Update frequency for the NNET-XCO_2 to be defined
- Definition of the NNETs for Glint mode