ICOS VS PI PROCESSING

On the need to understand and quantify the differences between custom PI and standardised ICOS processing

Focus on denoising procedure

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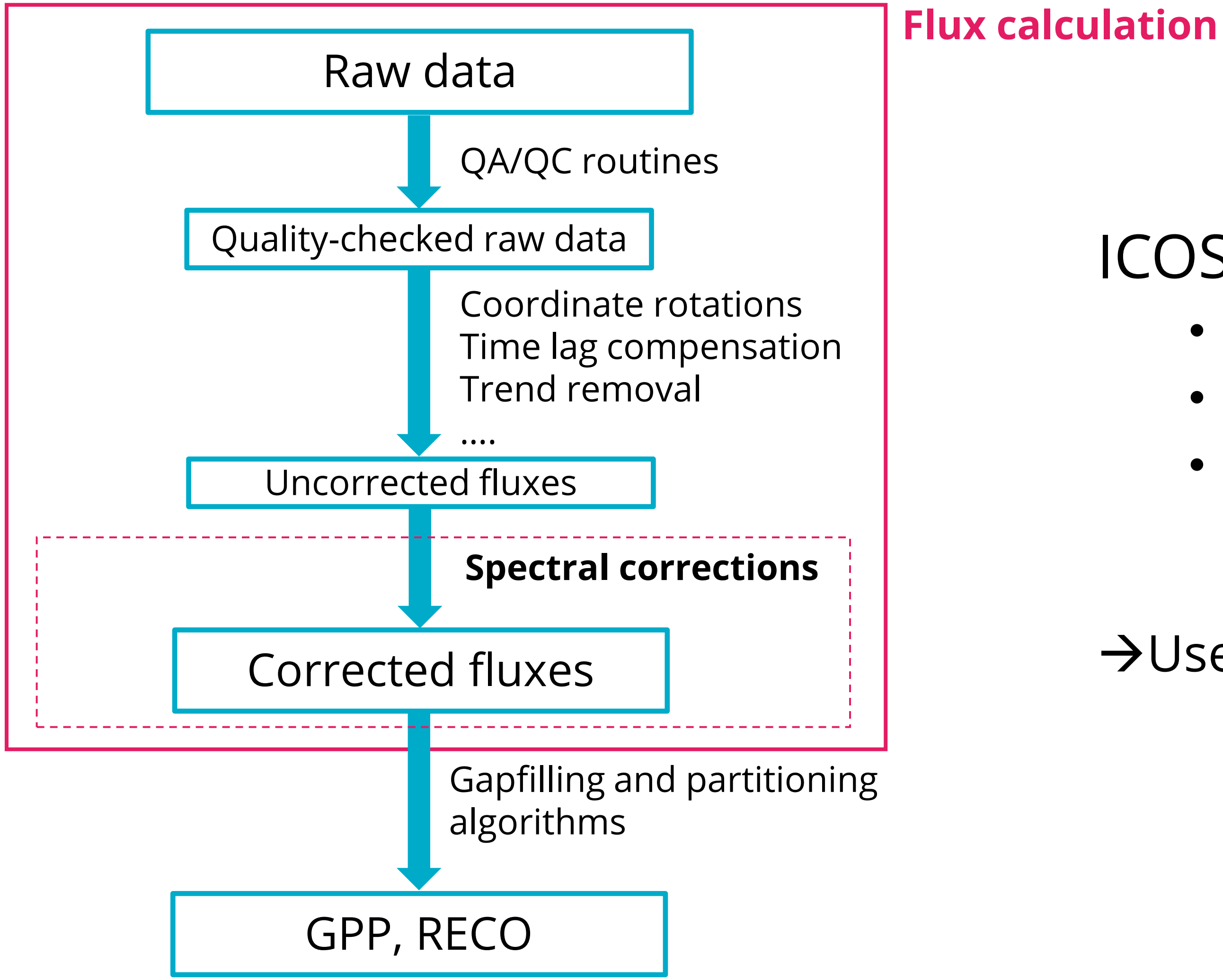
Introduction



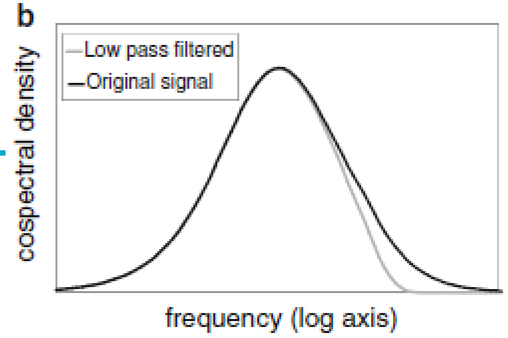
ICOS pipeline:

- Protocol by Sabbatini et al. 2018
- Vitale et al. 2020 for QC
- Package RFlux ETC on GitHub (https://github.com/icos-etc/RFlux/tree/master)

→Use of EddyPro

Theory reminder : spectral corrections

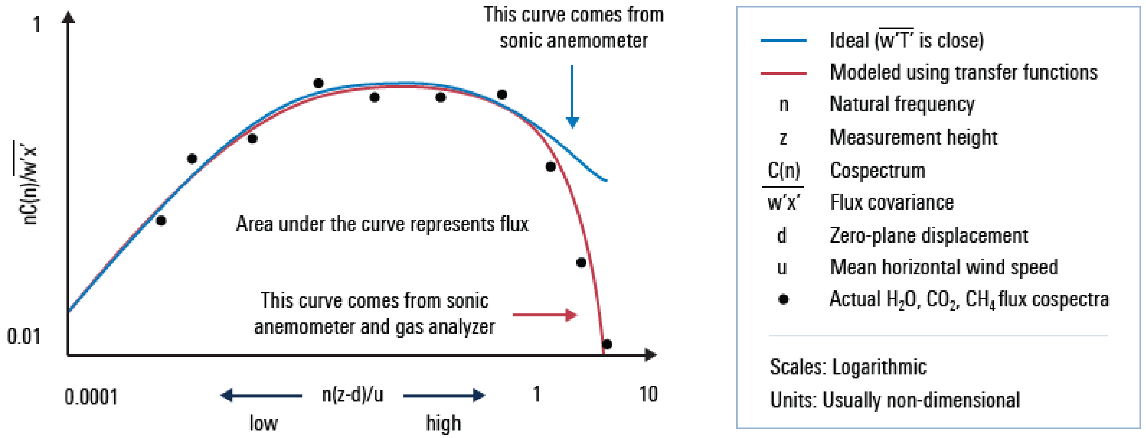
EC system acts as a **low-pass filter**



The measured fluxes are therefore **systematically underestimated** : need to correct them

Aubinet et al. 2012

Visualisation in the frequency domain : use of (co)spectra



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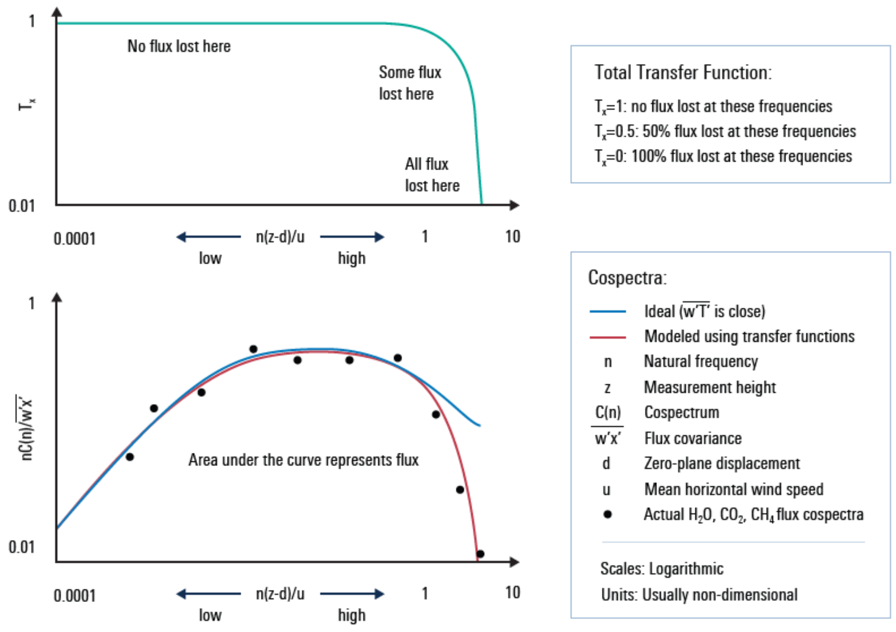
Theory reminder : spectral corrections

Correction procedure:

1. Evaluation of losses: transfer function approach
2. Correction factor computation



- Transfer functions describe how each sampling problem would affect the ideal cospectra at each frequency

Burba 2022

- Experimental approach → spectral/co-spectral
- Use of sonic temperature (co)spectra as reference
- Ratio of real over ideal normalised (co)spectra

Real (co)spectrum

$$H_{IIR}(f|f_c) = \frac{S_{hm}(f)}{S_h(f)} = \frac{1}{1+(f/f_c)^2},$$

Fratini et al. 2012

Transfer function

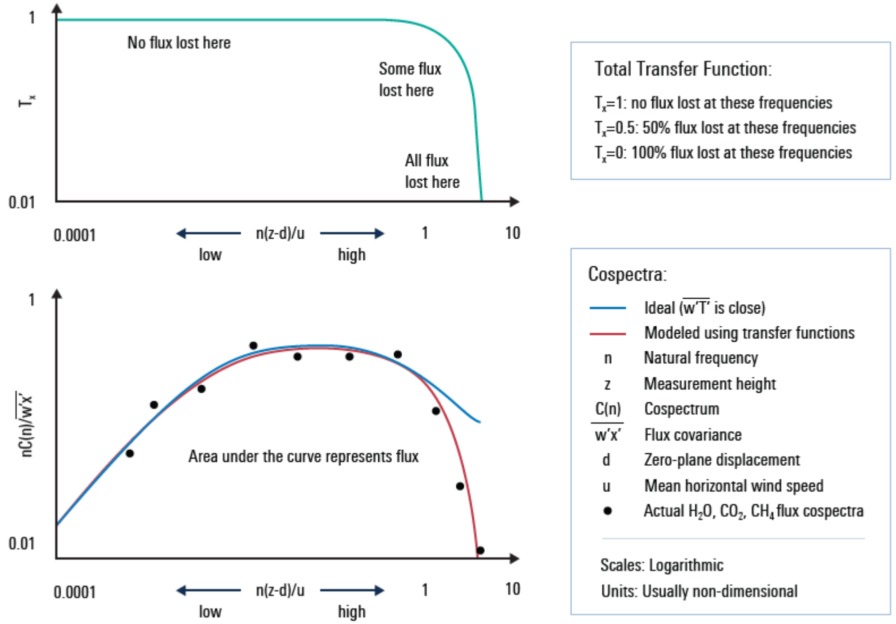
Ideal (co)spectrum

Fit function to find cut-off frequency

Theory reminder : spectral corrections

Correction procedure:

1. Evaluation of losses: transfer function approach
2. Correction factor computation



- Transfer functions describe how each sampling problem would affect the ideal cospectra at each frequency

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Ratio of degraded (through TF) to ideal covariances

$$F_l = \frac{\int_{f=f_{min}}^{f_{max}} CO_H(f)df}{\int_{f=f_{min}}^{f_{max}} CO_H(f)\sqrt{H_{IIR}(f|f_c)}df}$$

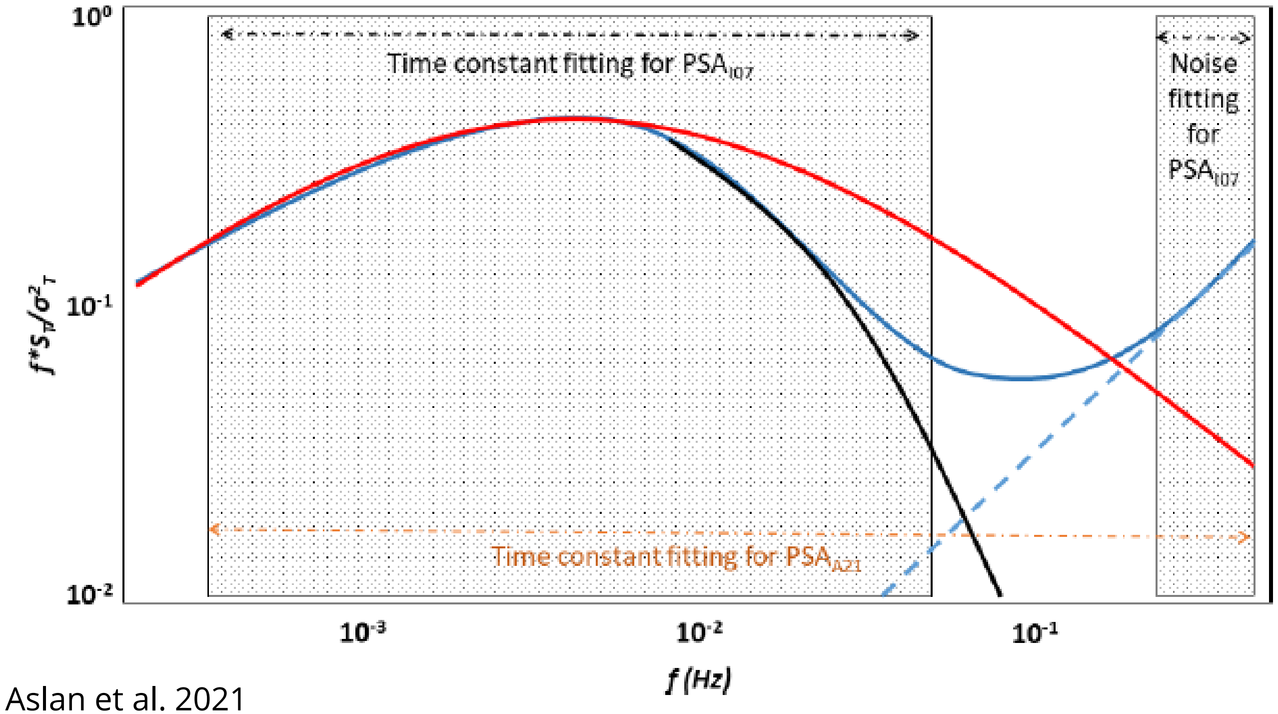
Ideal cospectrum

Correction factor

Ideal cospectrum*TF = degraded cospectrum

Fratini et al. 2012

Denoising



Aslan et al. 2021

Noise : potential bias in TF computation for spectral approach

Removal option:

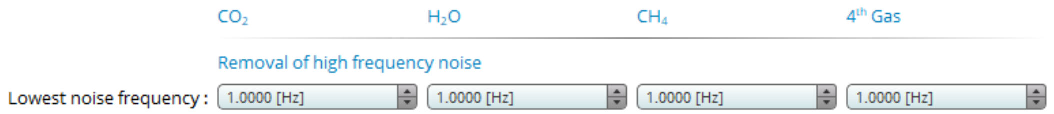
1. fit unconstrained linear equation in a defined frequency range where only noise is present
2. extrapolation to all the frequencies

Limitations:

- Assumption of **white noise**
- **Visual inspection** for frequency range selection
- Assumption of **absence of signal** in the selected range

Risk : removal of true signal thus artificially attenuating it. cof decreases, CF increases → Fluxes are overcorrected

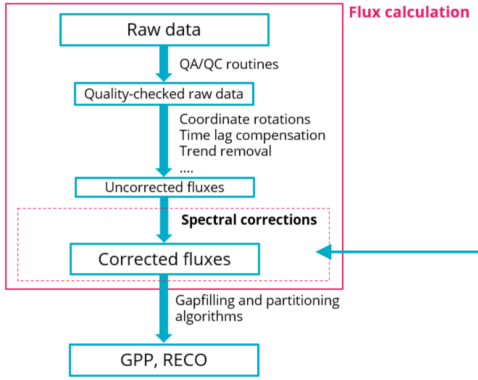
ICOS : default denoising at 1 Hz. **OK?**



Materials and methods

ETC dataset : ICOS (Class 1 and 2) sites, three denoising thresholds

- 0 Hz (no denoising)
- 1 Hz (EP default)
- 5 Hz (old EP default)



Input files (EP) :

- Full output
- Spectral assessment file
- Passive gases ensemble spectra

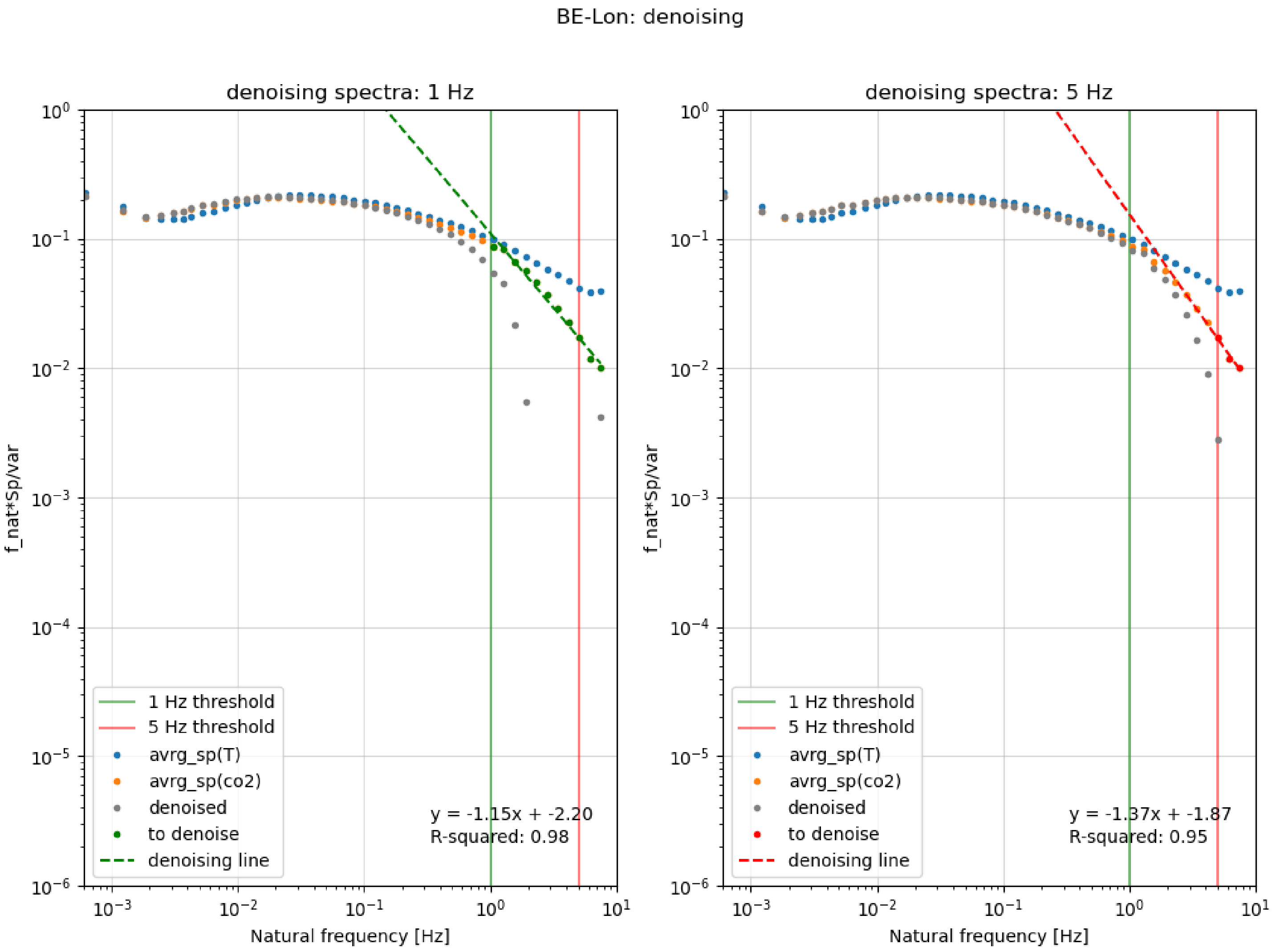
Data cleaning :

- FC > 15 or FC < -70 µmplm-2s-1
- qc == 2
- Unstable : Zeta <= 0
- Stable : Zeta > 0

	A	B	C	D
1	**Id**	**Name**	**Site type**	**Low site**
2	BE-Bra	Brasschaat	evergreen needleleaf forests	0
3	BE-Dor	Dorinne	grasslands	1
4	BE-Lon	Lonzee	croplands	1
5	BE-Maa	Maasmechelen	closed shrublands	1
6	BE-Vie	Vielsalm	mixed forests	0
7	CH-Dav	Davos	evergreen needleleaf forests	0
8	CZ-BK1	B	s	0
9	CZ-Lnz	L		0
10	DE-Geb	G		1
11	DE-HoH	H		0
12	DE-RuS	S		1
13	DE-Tha	Tharandt	evergreen needleleaf forests	0
14	DK-Sor	Soroe	deciduous broadleaf forests	0
15	DK-Vng	Voulundgaard	cropland	1
16	FI-Hyy	Hyytiala	evergreen needleleaf forests	0
17	FI-Sii	Siikaneva	permanent wetlands	1
18	FI-Sod	Sodankyla	evergreen needleleaf forests	0
19	FR-Bil	Bilos	evergreen needleleaf forests	0
20	FR-FBn	Font-Blanche	evergreen needleleaf forests	0
21	FR-Fon	Fontainebleau-Barbeau	deciduous broadleaf forests	0
22	FR-Gri	Grignon	cropland	1
23	FR-Hes	Hesse	deciduous broadleaf forests	0
24	FR-Lam	Lamasquere	croplands	1
25	FR-Lqu	Laqueuille	grasslands	1
26	FR-Lus	Lusignan	grasslands	1
27	FR-Pue	Puechabon	evergreen broadleaf forests	0

26 sites
11 low-measurement sites
15 forest sites

Results: white noise?



Results: white noise?

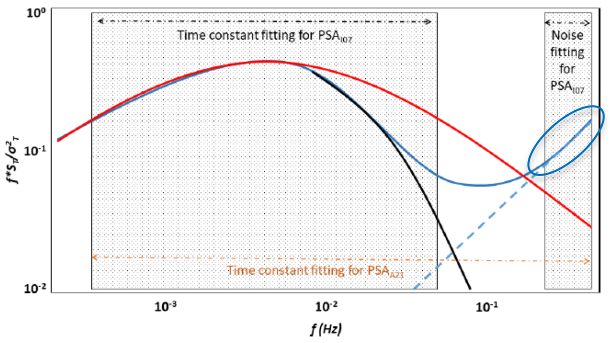
	1 Hz	5 Hz
BE-Bra	-0.73(0.37)	0.44(0.95)
BE-Dor	-0.99(0.99)	-0.54(0.58)
BE-Lon	-1.15(0.98)	-1.37(0.95)
BE-Maa	-0.33(0.74)	0.56(0.94)
BE-Vie	-0.12(0.07)	0.18(0.17)
CH-Dav	-0.17(0.50)	0.53(0.95)
CZ-BK1	-0.73(0.81)	0.40(0.86)
CZ-Lnz	-0.55(0.85)	0.47(0.94)
DE-Geb	-1.29(0.84)	-1.45(1.00)
DE-HoH	-0.34(0.75)	0.55(0.86)
DE-RuS	-0.44(0.51)	0.65(0.98)
DE-Tha	-0.22(0.36)	0.89(1.00)
DK-Sor	-0.02(0.03)	NA
DK-Vng	-1.15(0.98)	-0.28(0.50)
FI-Hyy	0.01(0.01)	NA
FI-Sii	-0.48(0.98)	NA
FI-Sod	-0.11(0.25)	NA
FR-Bil	-0.28(0.44)	0.56(0.94)
FR-FBn	0.04(0.02)	0.94(1.00)
FR-Fon	-0.18(0.31)	0.75(1.00)
FR-Gri	-0.78(0.97)	0.04(0.05)
FR-Hes	-0.38(0.50)	0.59(0.98)
FR-Lam	-0.68(0.99)	NA
FR-Lqu	-1.00(0.98)	-1.22(1.00)
FR-Lus	-0.80(0.92)	0.62(0.65)
FR-Pue	-0.25(0.42)	0.90(0.99)

Table: slope of linear regression (R^2 value)

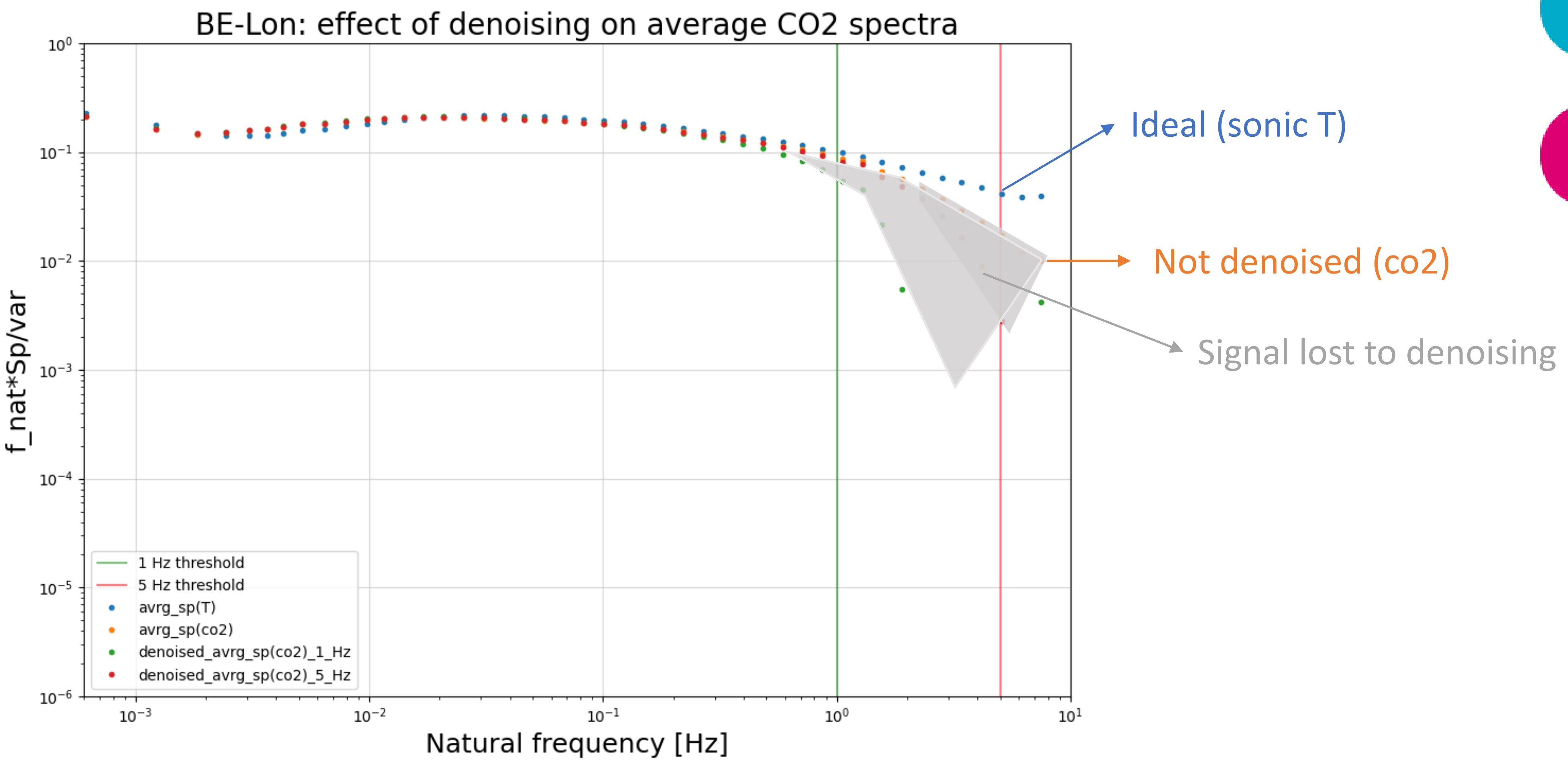
Assumption of white noise for denoising procedure

↓

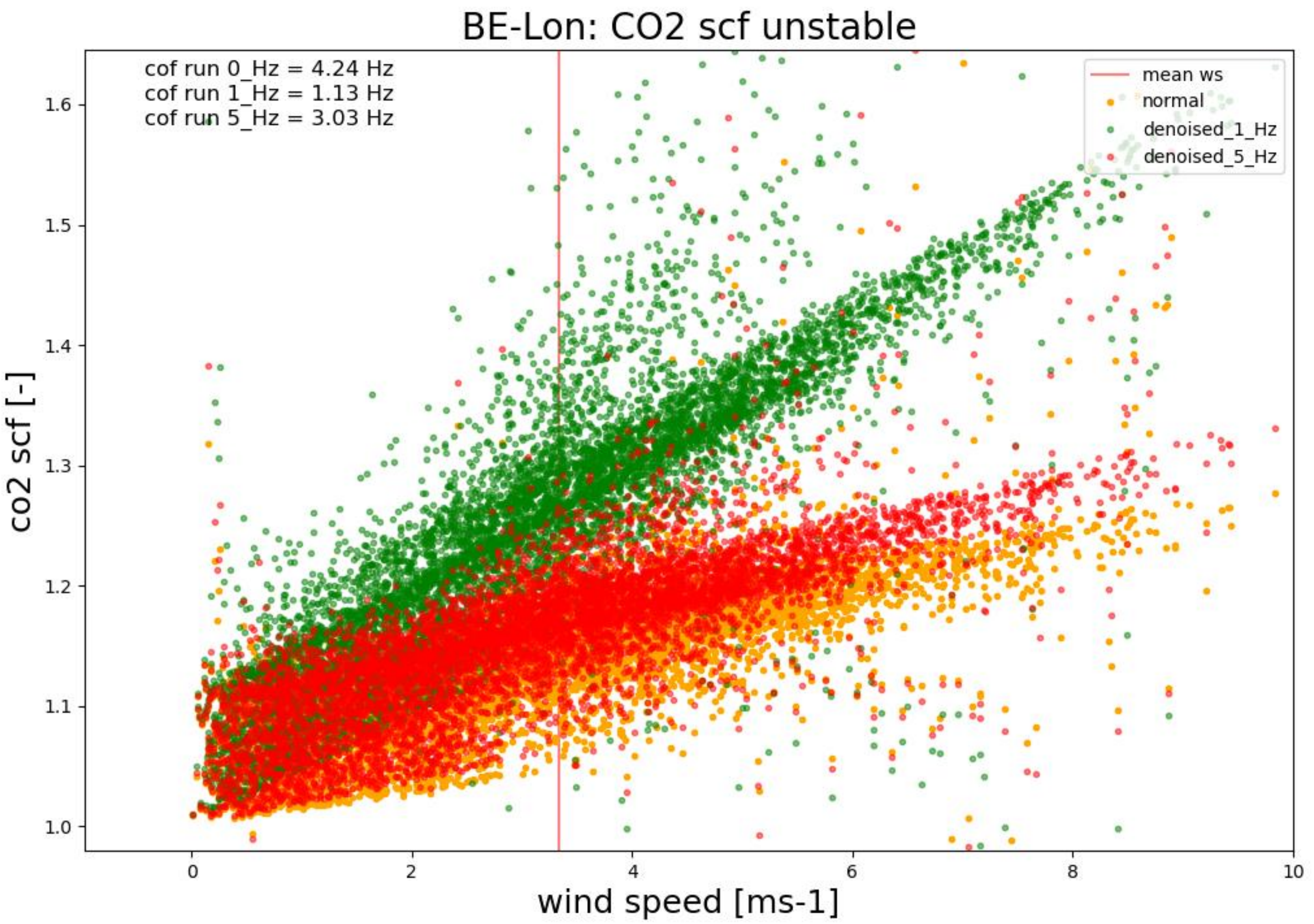
Slope of unconstrained linear equation should be = 1



Results : impact of denoising

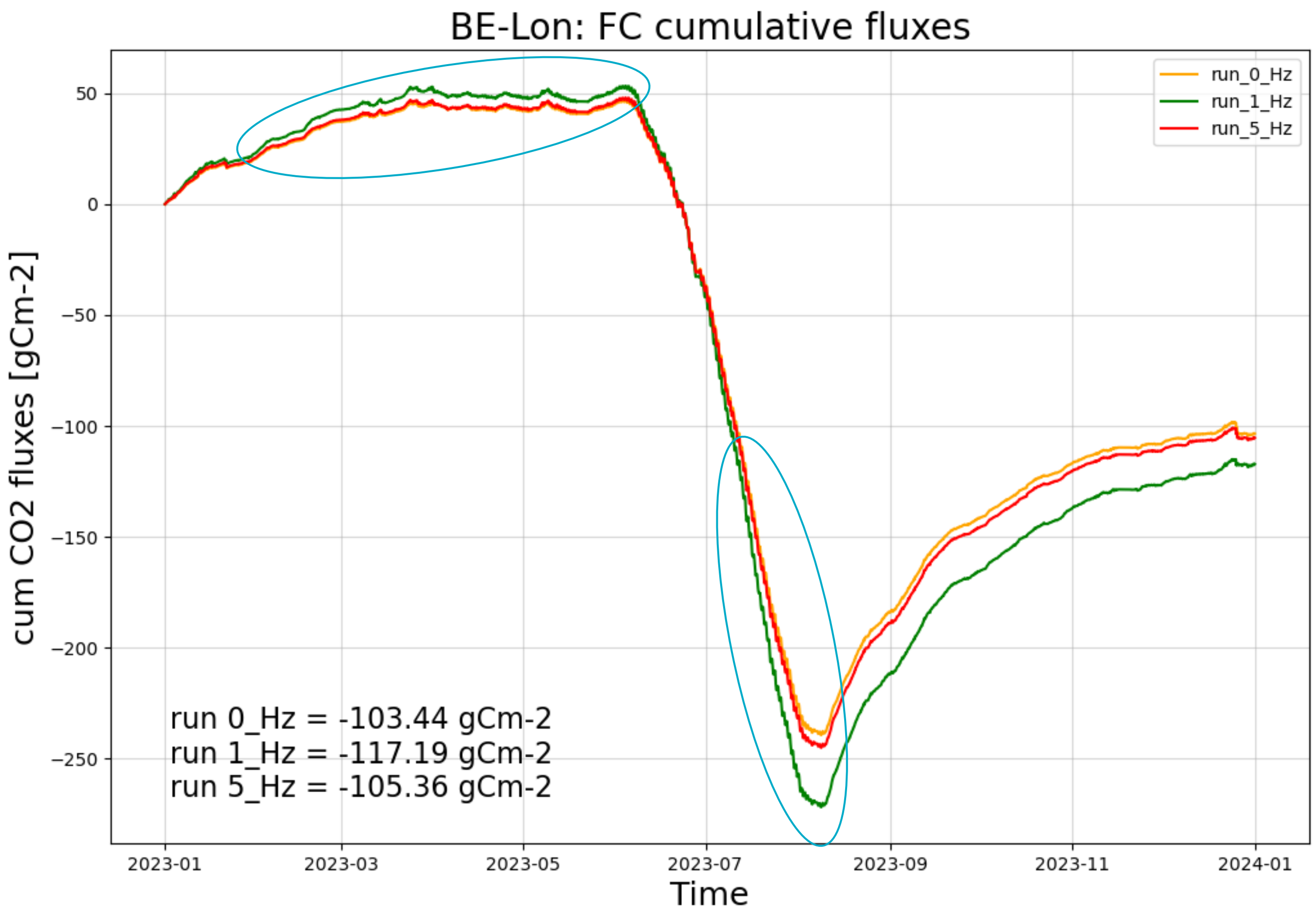


Results : impact of denoising



scf = spectral correction factor.
Final flux will be given by FC * scf

Results : impact of denoising

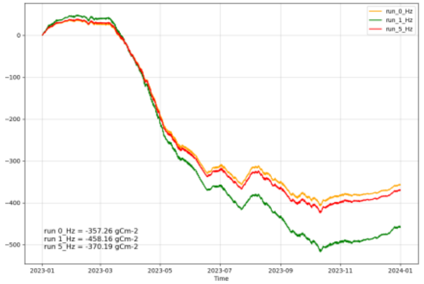


13% relative difference

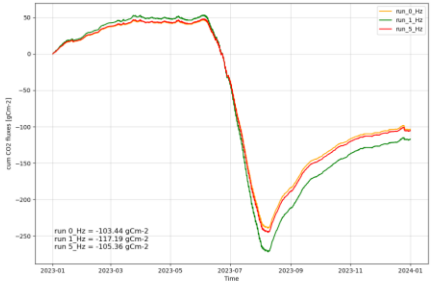
Results : low measuring sites

cum CO2 [gCm-2]

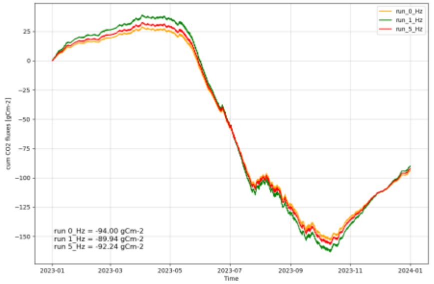
BE-Dor



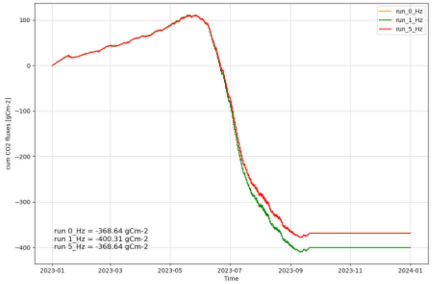
BE-Lon



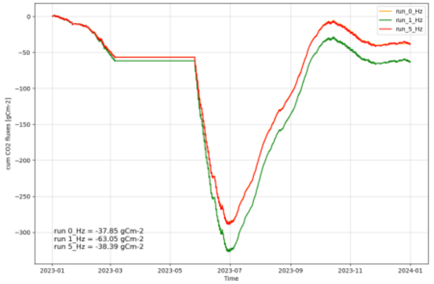
BE-Maa



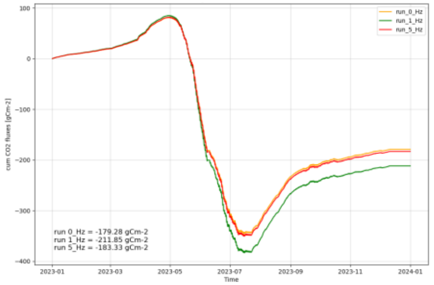
DE-Geb



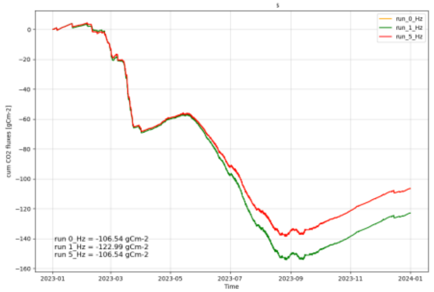
DE-Rus



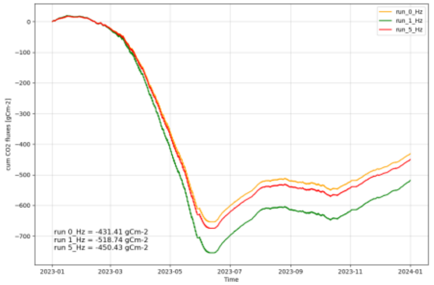
DK-Vng



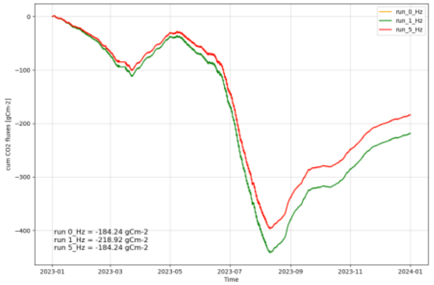
FI-Sii



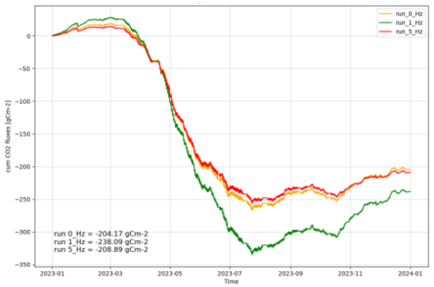
FR-Gri



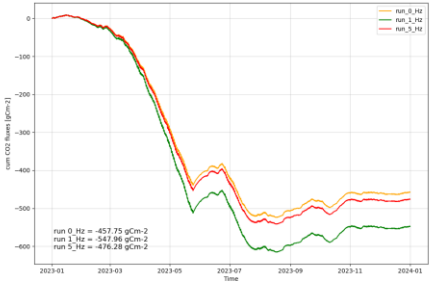
FR-Lam



FR-Lqu

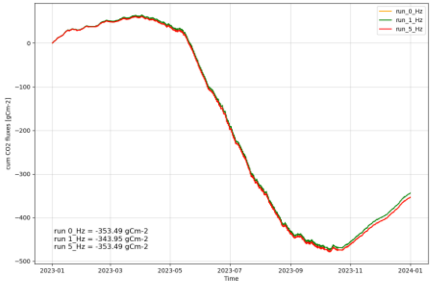


FR-Lus

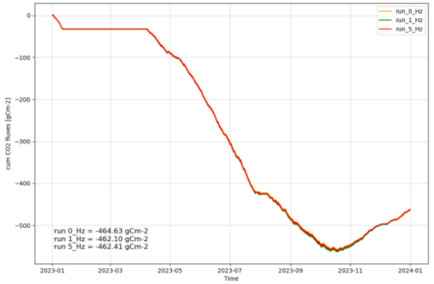


Results : forest sites

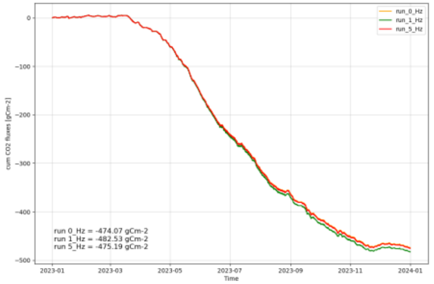
BE-Bra



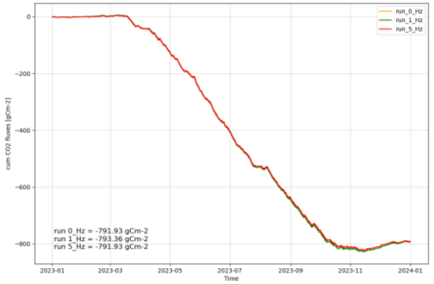
BE-Vie



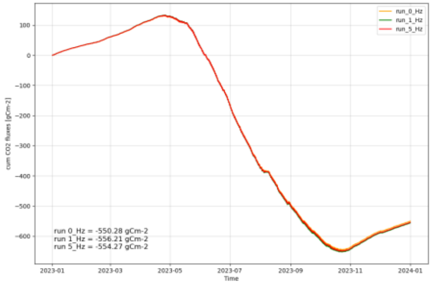
CH-Dav



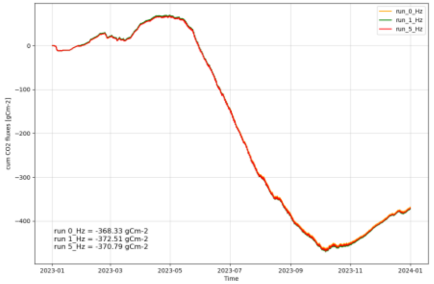
CZ-BK1



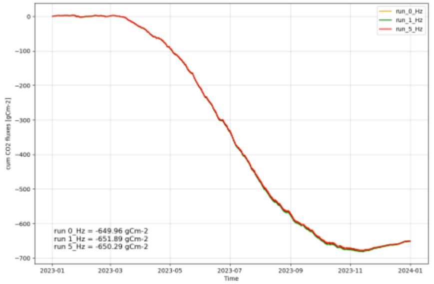
CZ-Lnz



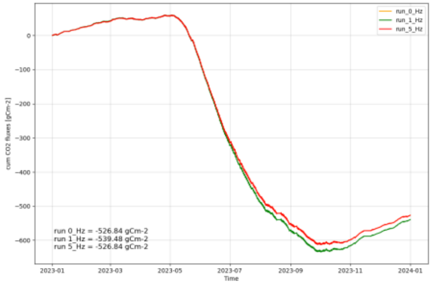
DE-HoH



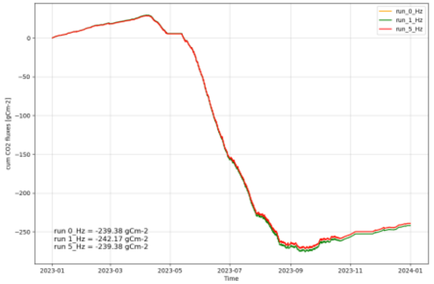
DE-Tha



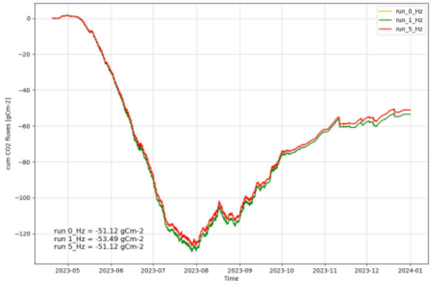
DK-Sor



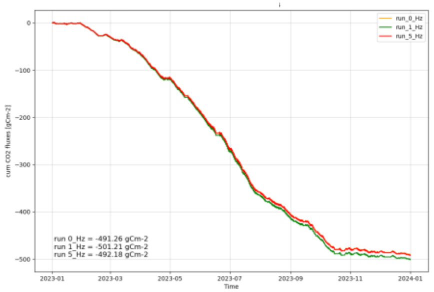
FI-Hyy



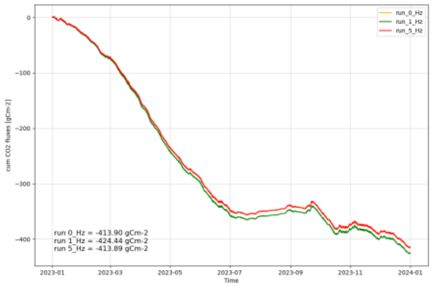
FI-Sod



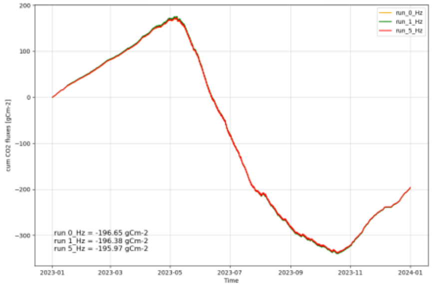
FR-Bil



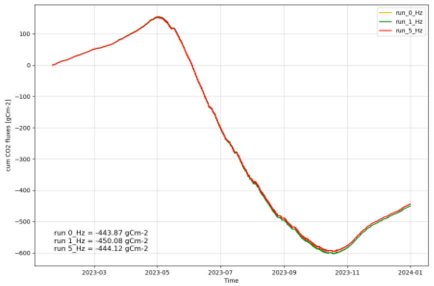
FR-FBn



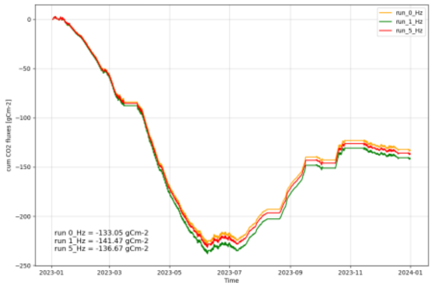
FR-Fon



FR-Hes



FR-Pue



Results : H2O

The same denoising procedure is applied to H2O (for each RH class). **OK?**

1. Check presence of white noise through slope of linear regression

Not found

2. Impact of denoising on fluxes?

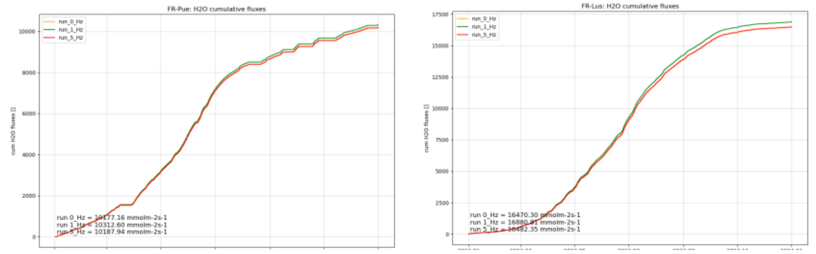
Stronger attenuation for H2O in the high frequencies (lower cof than CO2)
→ less/no true signal artificially removed
→ less impact on fluxes

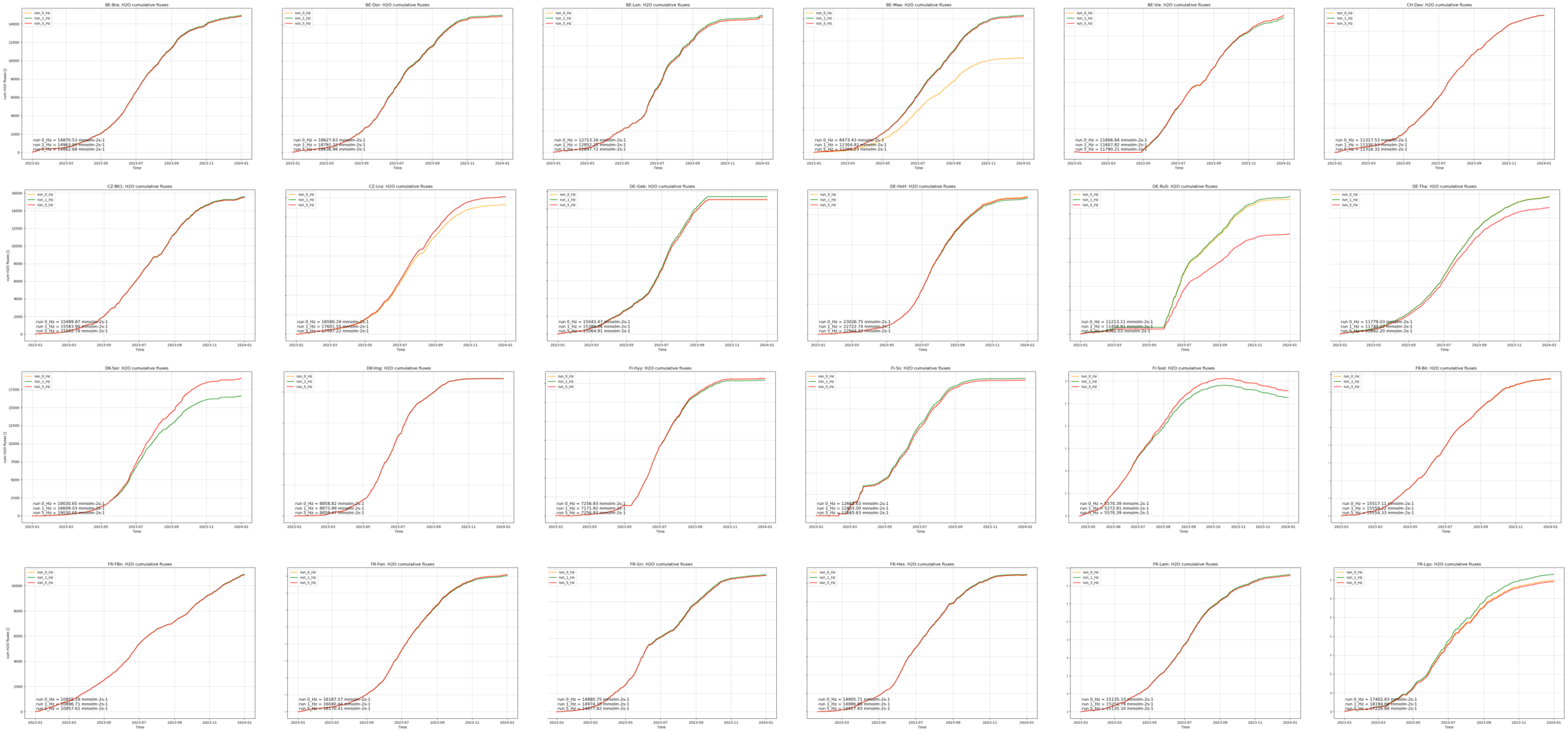
Spectral corrections calculated and applied by RH class

RH class : 35% - 45%	1 Hz	5 Hz
BE-Bra	-1.60(0.73)	-0.04(0.01)
BE-Dor	-1.14(0.79)	0.29(0.04)
BE-Lon	-2.25(0.99)	-1.15(0.92)
BE-Maa	-2.01(0.99)	-1.15(0.96)
BE-Vie	-1.51(0.99)	-0.72(0.86)
CH-Dav	-1.44(0.98)	-0.38(0.92)
CZ-BK1	-2.21(0.99)	-1.84(0.99)
CZ-Lnz	-1.97(0.99)	-1.43(0.95)
DE-Geb	-2.07(0.98)	-2.41(1.00)
DE-HoH	-1.54(0.99)	-0.56(0.79)
DE-RuS	-2.10(0.99)	-0.97(0.90)
DE-Tha	-1.55(0.96)	0.07(0.09)
DK-Sor	-0.37(0.21)	NA
DK-Vng	-1.87(0.86)	0.95(0.96)
FI-Hyy	-1.56(1.00)	NA
FI-Sii	-1.69(0.99)	NA
FI-Sod	-1.55(0.98)	NA
FR-Bil	-1.82(1.00)	-1.11(0.95)
FR-FBn	-1.13(0.88)	0.58(0.96)
FR-Fon	-0.78(0.70)	0.81(0.99)
FR-Gri	-2.15(0.99)	-2.16(0.99)
FR-Hes	-1.69(0.99)	-0.97(0.95)
FR-Lam	-1.91(1.00)	NA
FR-Lqu	-2.11(0.98)	-3.04(1.00)
FR-Lus	-2.45(0.99)	-1.45(0.78)
FR-Pue	-1.23(0.87)	1.02(0.99)

Table: slope of linear regression (R^2 value)

Results : H2O


FR-Pue: H2O cumulative fluxes
FR-Lus: H2O cumulative fluxes


BE-Bra: H2O cumulative fluxes
BE-Dor: H2O cumulative fluxes
BE-Lon: H2O cumulative fluxes
BE-Maa: H2O cumulative fluxes
BE-Vie: H2O cumulative fluxes
CH-Dav: H2O cumulative fluxes
CZ-BK1: H2O cumulative fluxes
CZ-Lnz: H2O cumulative fluxes
DE-Geb: H2O cumulative fluxes
DE-HoH: H2O cumulative fluxes
DE-RuS: H2O cumulative fluxes
DE-Tha: H2O cumulative fluxes
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FI-Sii: H2O cumulative fluxes
FI-Sod: H2O cumulative fluxes
FR-Bil: H2O cumulative fluxes
FR-FBn: H2O cumulative fluxes
FR-Fon: H2O cumulative fluxes
FR-Gri: H2O cumulative fluxes
FR-Hes: H2O cumulative fluxes
FR-Lam: H2O cumulative fluxes
FR-Lqu: H2O cumulative fluxes

Conclusions

- Tricky to apply the denoising procedure with a default threshold : potential major impact on fluxes
- Overall, no white noise detected in LI7200 for $CO2$ and $H2O$
- Suggestion:

Option I : deactivate denoising procedure

Option II : implement Aslan et al. 2021 approach (documented, tested). No need of visual inspection but need to know the type of noise!

…Other?

What's next

- Denoising is a non-issue when using co-spectra : noise does not correlate with wind speed
- Our historical procedure uses co-spectra: can it explain the differences we still see ?
- Can either the spectral or co-spectral method be considered more robust than the other?

Work in progress … for ICOS SC 2024 !

Thank you!