

MIR and NIR comparisons of trace gas retrievals based on FTIR operation in Karlsruhe

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Matthäus Kiel, Thomas Blumenstock, Frank Hase – Ground-Based FTIR Remote Sensing

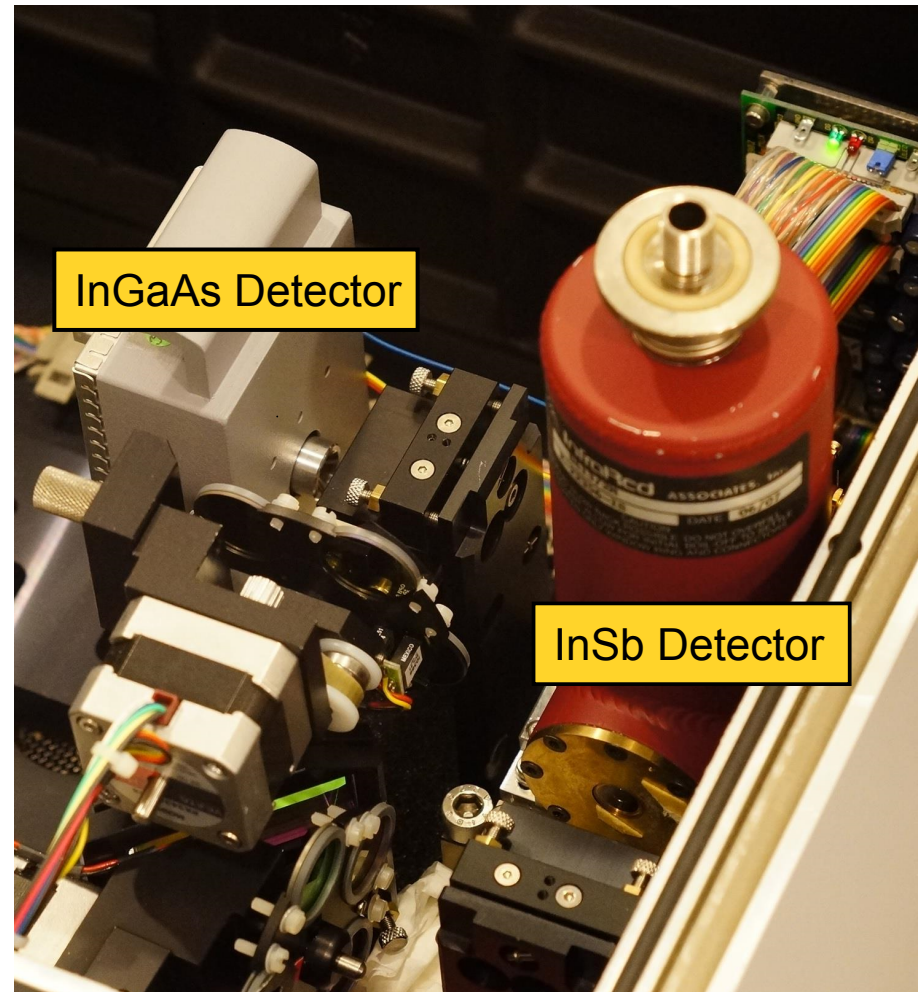
Institute for Meteorology and Climate Research – Atmospheric Trace Gases and Remote Sensing



@astro_reid: 10.Sept, twitter

Karlsruhe FTIR setup (49.1N , 8.4E, 111m a.s.l.)

- initiated in 2009
- CaF_2 beamsplitter
- specific dichroic setup:
Fa. MSO Jena Mikroschichtoptik GmbH
- simultaneous recording of
InGaAs and InSb spectra
- TCCON: MIR + NIR
at $\text{OPD}_{\text{max}} = 64\text{cm}$
MIR: $(3800 - 5250) \text{ cm}^{-1}$
NIR: $(5250 - 11000) \text{ cm}^{-1}$
- NDACC: MIR + NIR
at $\text{OPD}_{\text{max}} = 180\text{cm}$
NDACC filter: 2, 3, 4, 5



MIR and NIR retrieval strategy for CO

	MIR (NDACC)	NIR (TCCON)	NIR (PROFIT 9.6)
microwindows [cm⁻¹]	2057.5 - 2058.2 2069.4 - 2069.9 2140.4 - 2069.9 2153.2 - 2160.0	4208.7 - 4257.3 4262.0 - 4318.8	4208.7 - 4257.3 4262.0 - 4318.8
linelist	HITRAN ¹ 2008 HITRAN ¹ 2009 (H ₂ O)	atm.101, gct.101, fcia.101, scia.101	HITRAN ¹ 2008 HITRAN ¹ 2009 (H ₂ O)
software	PROFIT 9.6	GGG2014	PROFIT 9.6
constraint	Tikhonov regularisation DOF \approx 3.5	scaling of a priori profile	Tikhonov regularisation DOF \approx 2.0
a priori vmr	WACCM ² V.6	MkIV FTS balloon profiles	WACCM ² V.6
lamp correction	yes	continuum fit	yes
column-averaged dry-air mole fraction	use simultaneously measured O ₂ column ³	use simultaneously measured O ₂ column	use simultaneously measured O ₂ column

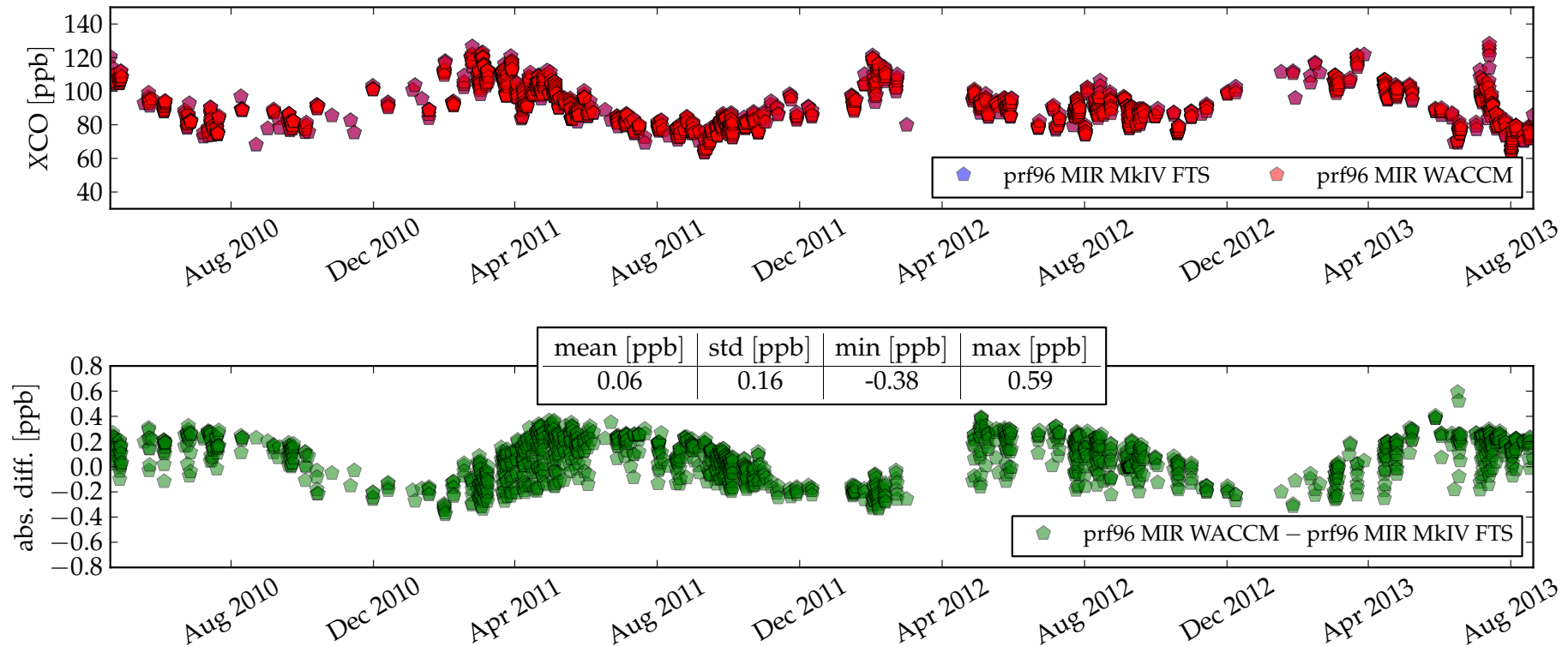
1: HITRAN - High-resolution transmission molecular absorption base

2: WACCM - Whole Atmosphere Chemistry Climate Model

3: no official NDACC IRWG product

Impact of varied a priori profiles on time series

■ WACCM V.6 profile (fixed) vs. TCCON a priori profile (day dependent)



■ mean offset: 0.08%, std: 0.18%

■ bias and seasonal variation induced by using different a priori profiles

Eliminating impact of varied a priori profiles

- a posteriori adjustment for a new a priori profile¹:

$$\begin{aligned}\vec{x} - \vec{x}_{true} &= (\mathbf{AK} - \mathbb{I}) (\vec{x}_{true} - \vec{x}_{apriori}) \\ \Rightarrow \vec{x} &= \mathbf{AK} (\vec{x}_{true} - \vec{x}_{apriori}) + \vec{x}_{apriori}\end{aligned}$$

- adjust a new a priori profile for the same retrieval strategy:

$$\tilde{\vec{x}} = \mathbf{AK} (\vec{x}_{true} - \tilde{\vec{x}}_{apriori}) + \tilde{\vec{x}}_{apriori}$$

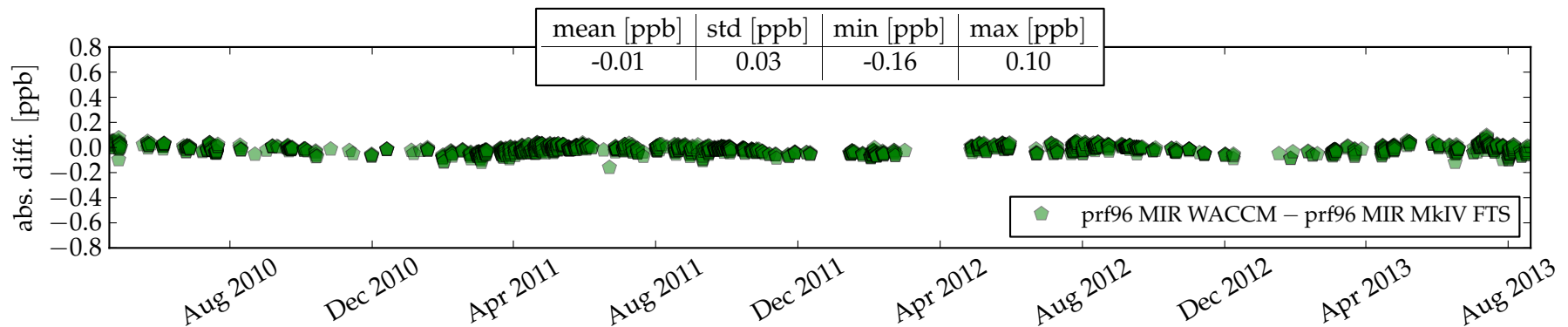
- a posteriori correction term:

$$\begin{aligned}\Delta &= \vec{x} - \tilde{\vec{x}} \\ &= (\mathbf{AK} - \mathbb{I}) (\tilde{\vec{x}}_{apriori} - \vec{x}_{apriori})\end{aligned}$$

1: Rodgers; Inverse Methods of Atmospheric Soundings - Theory and Praxis; World Scientific Pub Co (2000)

Eliminating impact of varied a priori profiles

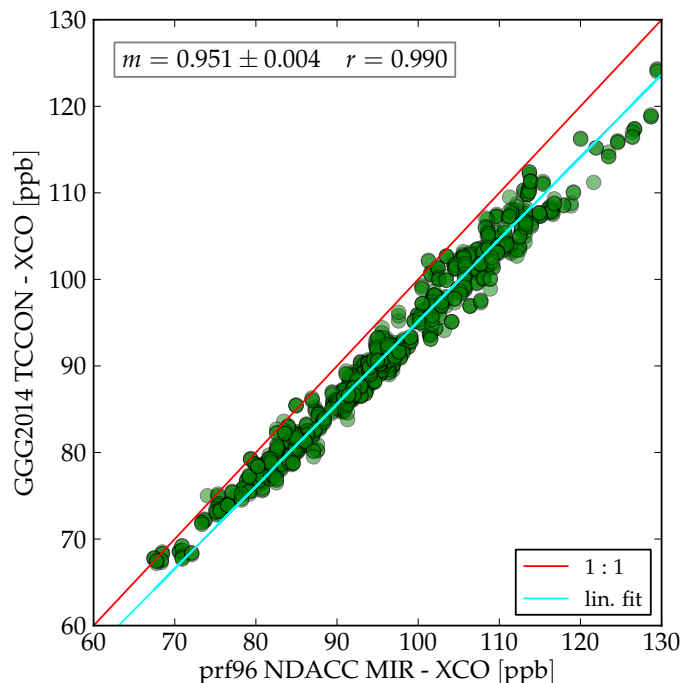
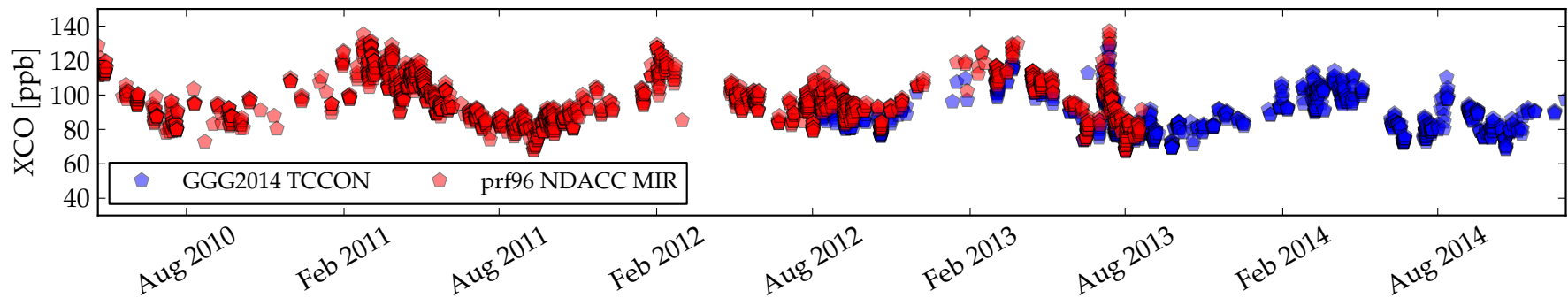
■ a posteriori adjustment of a priori profile: WACCM V.6 → TCCON a priori



	no adjustment	a posteriori adjustment
mean [ppb]	0.06	-0.01
std [ppb]	0.16	0.03
mean [%]	0.08	-0.02
std [%]	0.18	0.04

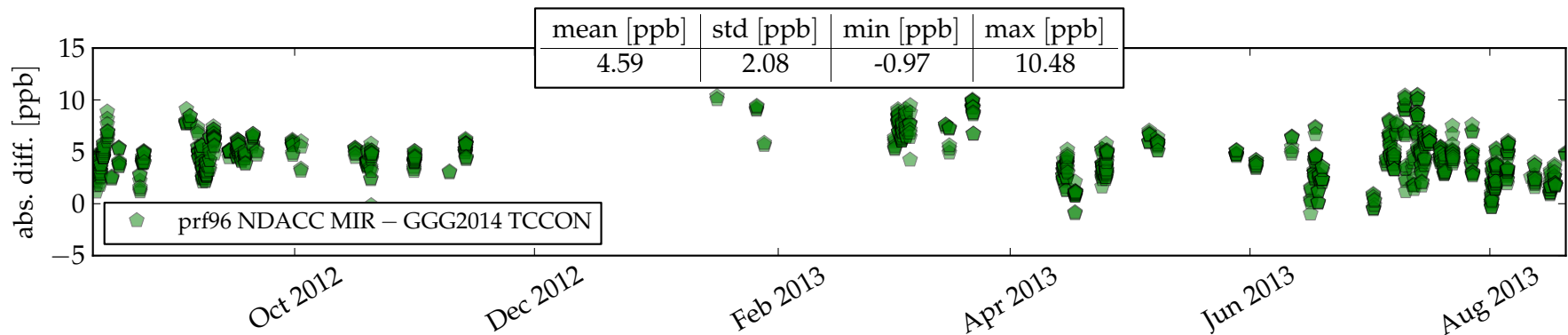
- a posteriori adjustment reduces bias and seasonal variation
- remaining seasonal variation driven by changes in the averaging kernels

Direct comparison of CO (NDACC vs. TCCON)



- one year of overlap data due to current GGG2014 reanalysis
- comparison of quasi-coincident measurements (15 minutes)
- slope: 0.951, correlation: 0.990 (obtained from linear fit forced through zero)
- mean offset: 4.97%, std: 2.00%

Direct comparison of CO (NDACC vs. TCCON)



- one year difference time series indicates seasonal cycle
- already corrected to common a priori profile
- different smoothing effects and dynamical variability main driver for seasonal cycle in difference time series
- no aircraft calibration factor applied to NDACC data (TCCON: 1.067)
- **NDACC - TCCON mean offset about 5%**

MIR and NIR retrieval strategy for CO

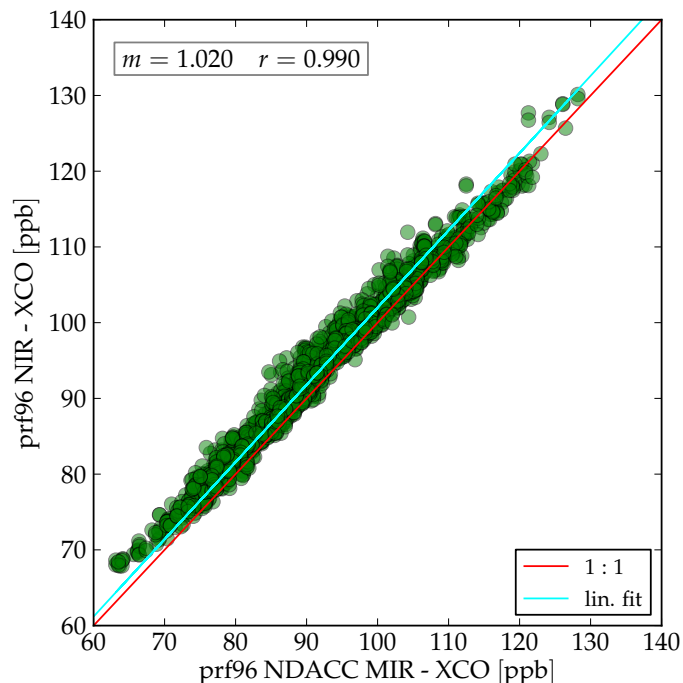
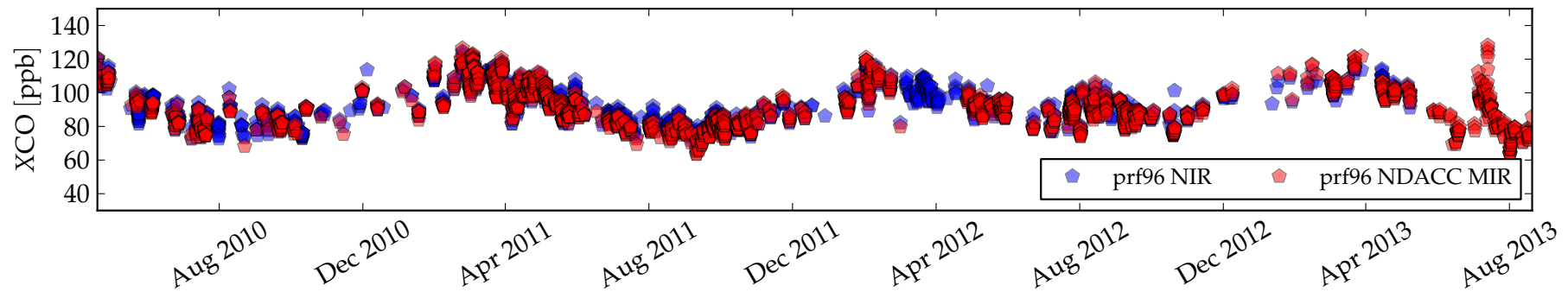
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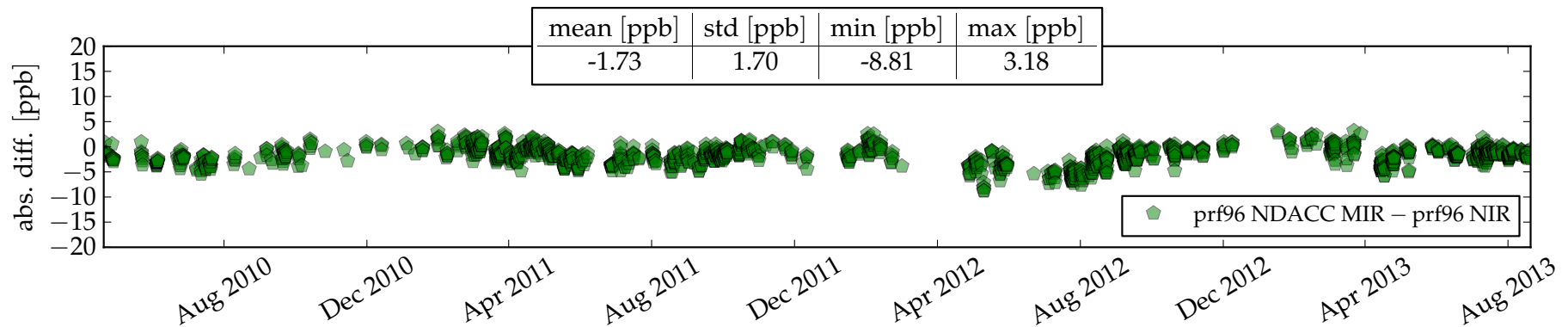
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Direct comparison of CO (NDACC vs. PRF96 NIR)

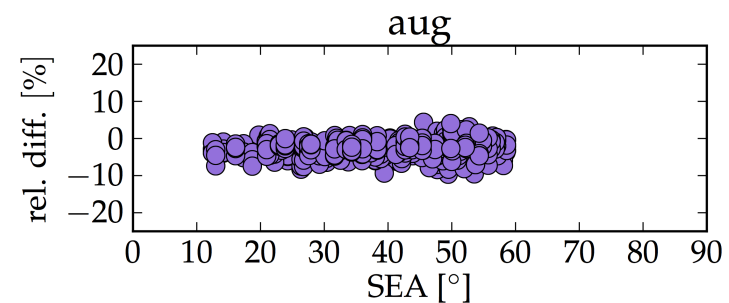
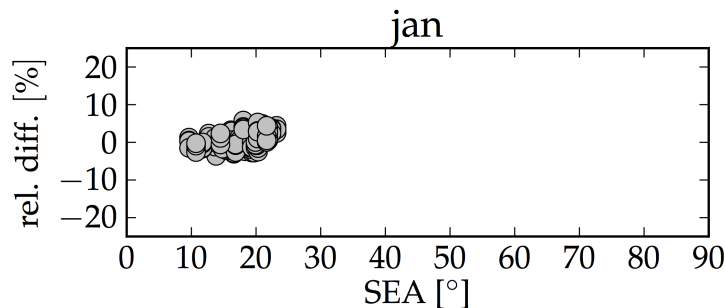


- comparison of quasi-coincident measurements (15 minutes)
- good agreement in seasonal variation
- slope: 1.020, correlation: 0.990 (obtained from linear fit forced through zero)
- mean offset: -1.11%, std: 2.70%

Direct comparison of CO (NDACC vs. PRF96 NIR)

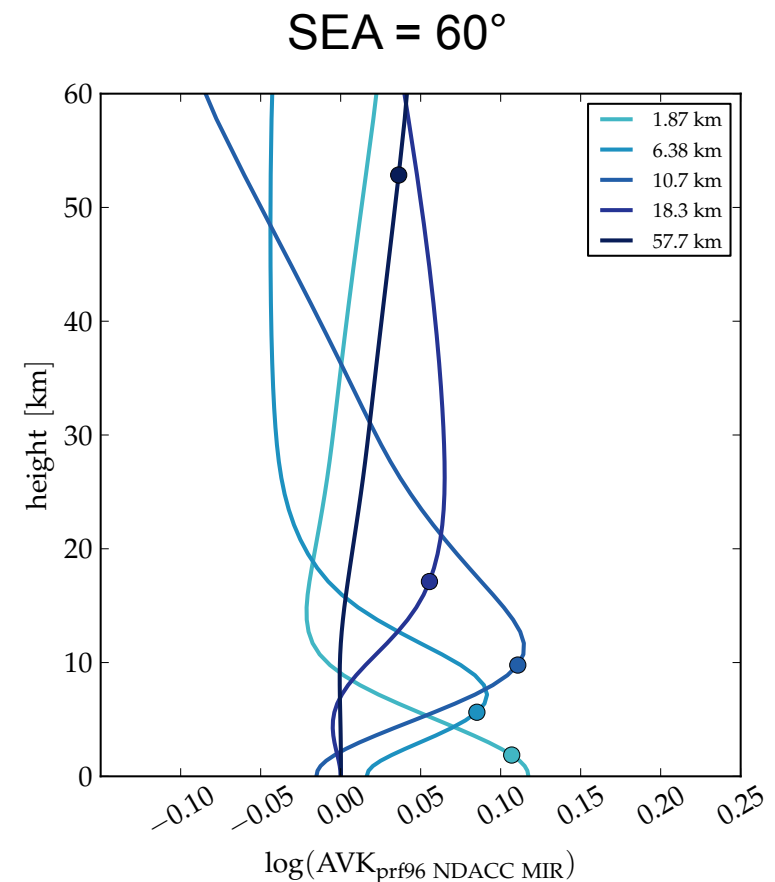
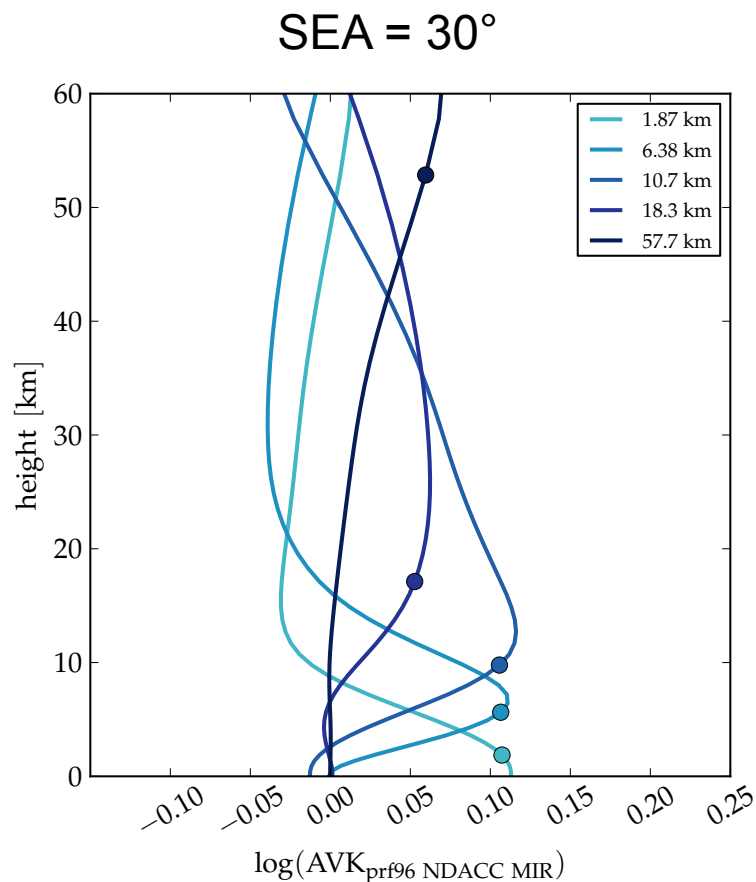


- seasonal variation in difference time series NDACC MIR - PRF96 NIR
- used same a priori profile (WACCM V.6) - seasonal variation not driven by different a priori profiles
- seasonal variation in difference time series not driven by airmass dependency



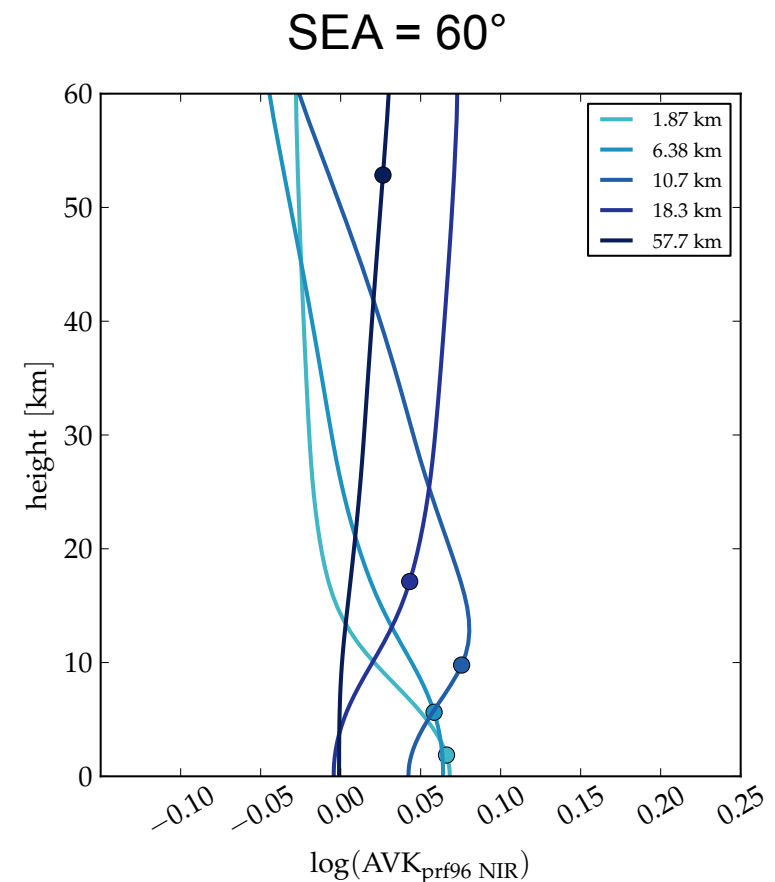
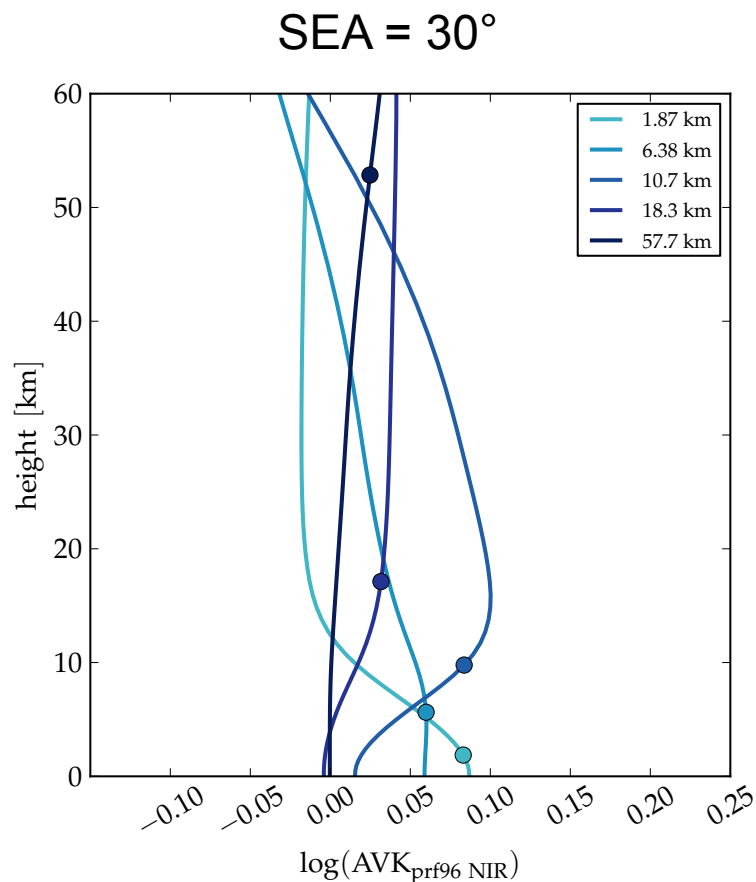
Averaging kernels as function of solar angle

■ change of averaging kernels (AVKs) for different solar angles for **NDACC MIR**



Averaging kernels as function of solar angle

■ change of averaging kernels (AVKs) for different solar angles for **PRF96 NIR**



Reduction of smoothing error

$$\vec{x}_{MIR} = \mathbf{AK}_{MIR} (\vec{x}_{true} - \vec{x}_{apriori,MIR}) + \vec{x}_{apriori,MIR}$$

$$\vec{x}_{NIR} = \mathbf{AK}_{NIR} (\vec{x}_{true} - \vec{x}_{apriori,NIR}) + \vec{x}_{apriori,NIR}$$

■ smoothing error correction term:

$$\Delta = \vec{x}_{MIR} - \vec{x}_{NIR}$$

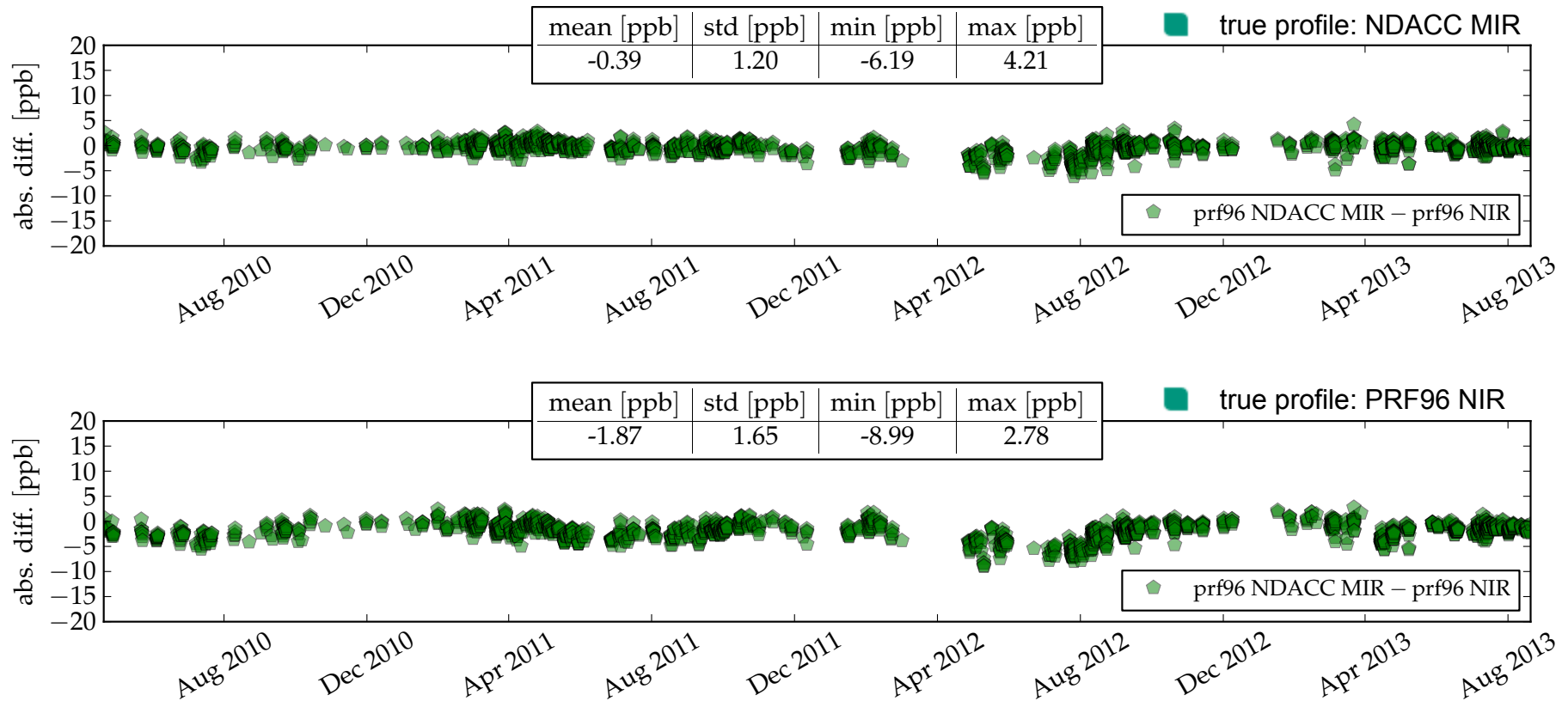
$$\vec{x}_{apriori,MIR} = \vec{x}_{apriori,NIR} = \vec{x}_{apriori}$$

$$\Delta = \mathbf{AK}_{MIR} (\vec{x}_{true} - \vec{x}_{apriori}) - \mathbf{AK}_{NIR} (\vec{x}_{true} - \vec{x}_{apriori})$$

■ use correction term as indicator for quality of retrieved profiles:
assume NDACC MIR and PRF96 NIR retrieved results as true profile
and apply the smoothing error correction:

→ **if retrieved profile close to true profile: reduction of seasonal variation in difference time series**

Reduction of smoothing effect



true profile	mean [ppb]	std [ppb]	correlation	slope
NDACC MIR	-0.39	1.20	0.995	1.004
PRF 96 NIR	-1.87	1.65	0.990	1.022

MIR and NIR retrieval strategy for CO

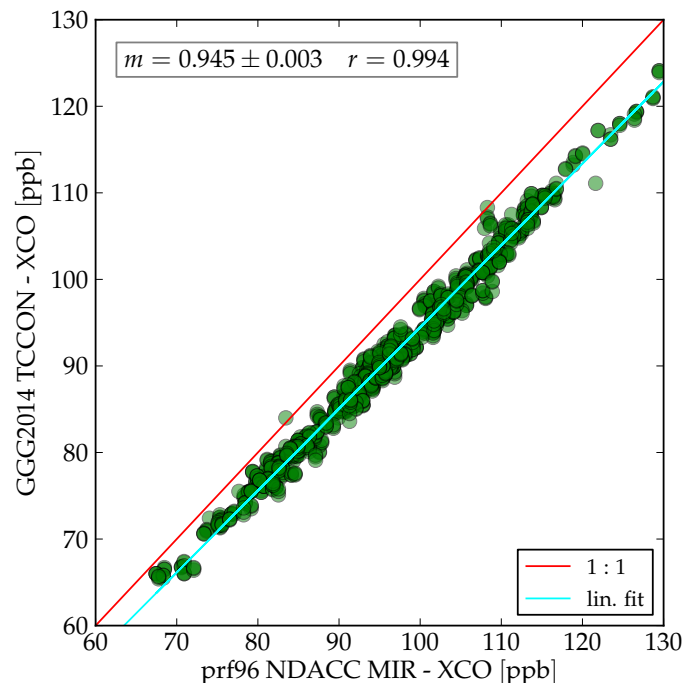
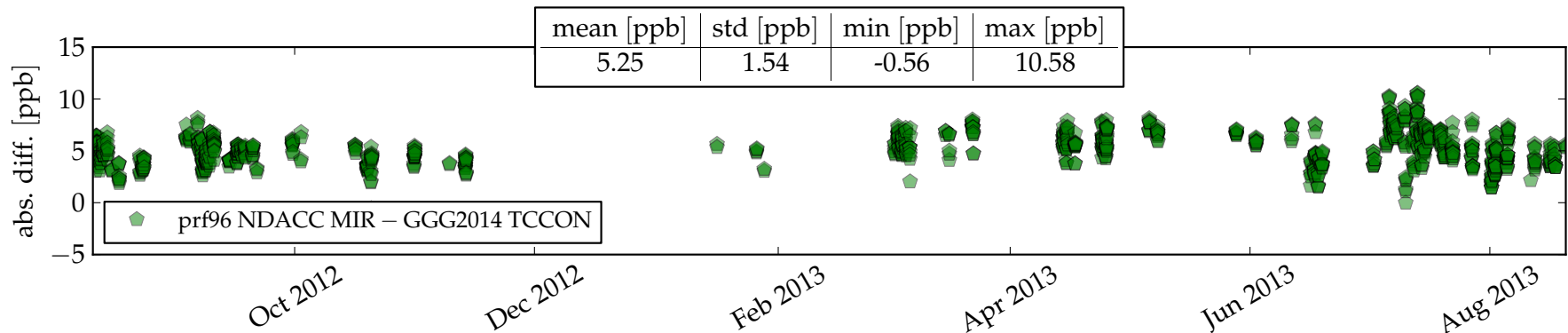
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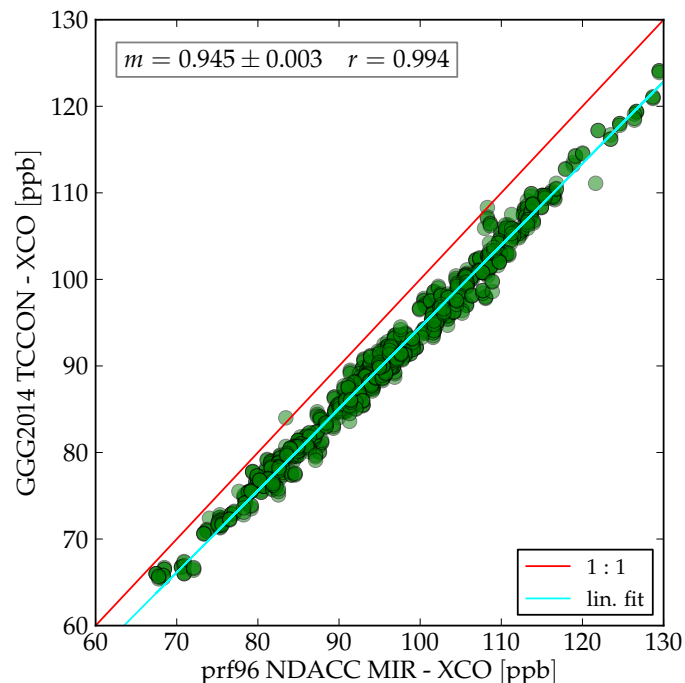
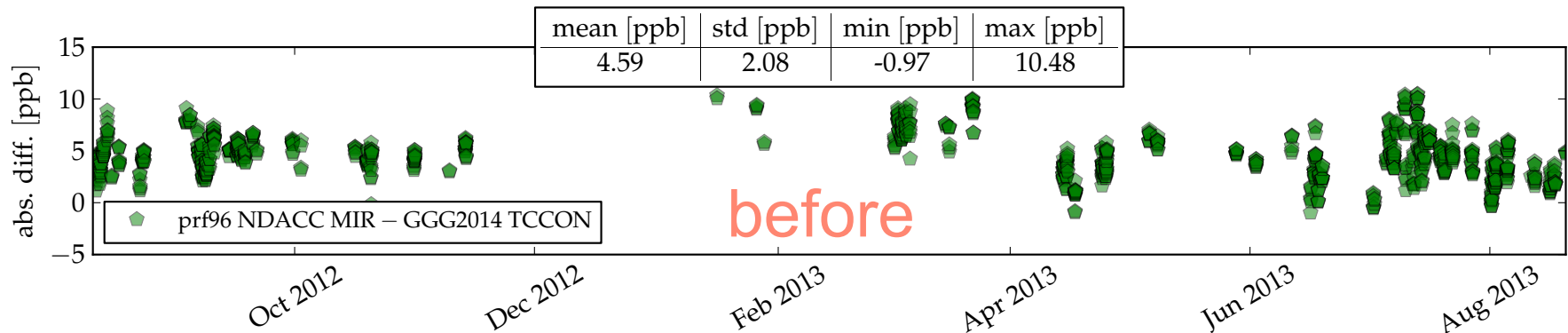
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Comparison of CO (NDACC vs. TCCON)



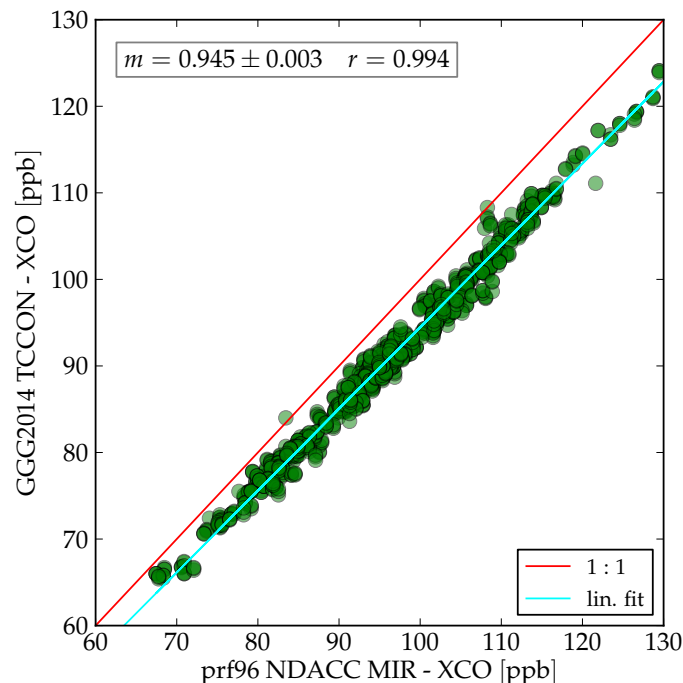
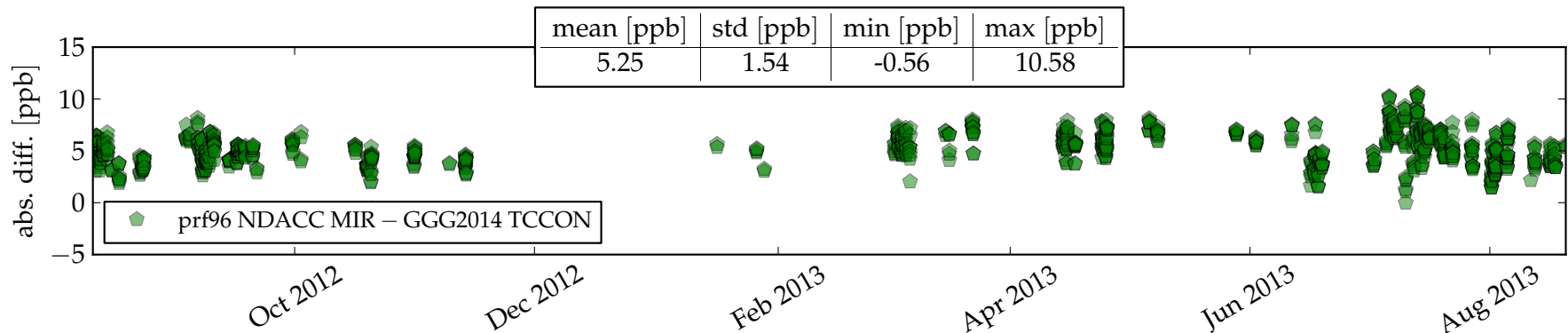
- use MIR regularization retrieval results as a priori for TCCON scaling retrieval
- reduction of seasonal variation
- slope: 0.945, correlation: 0.994 (obtained from linear fit forced through zero)
- mean offset: 5.78%, std: 1.49%
- reduction of standard deviation by 25%

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Summary

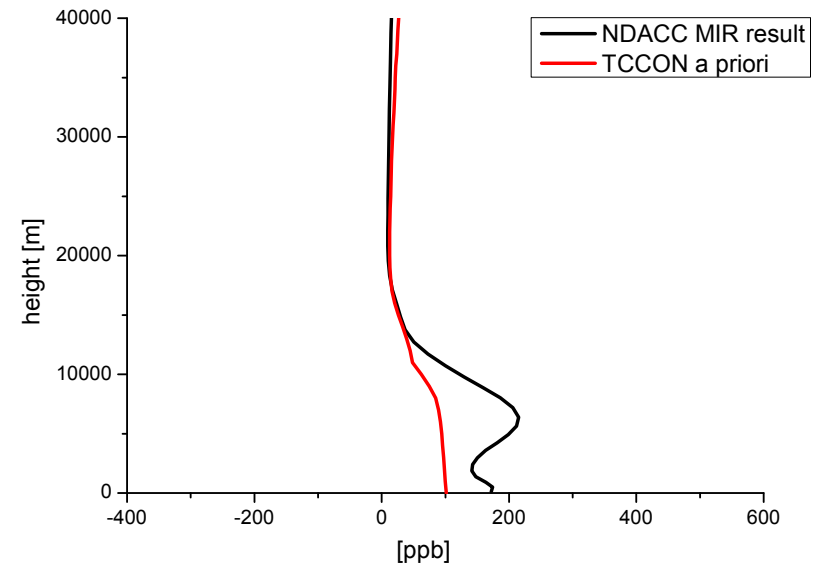
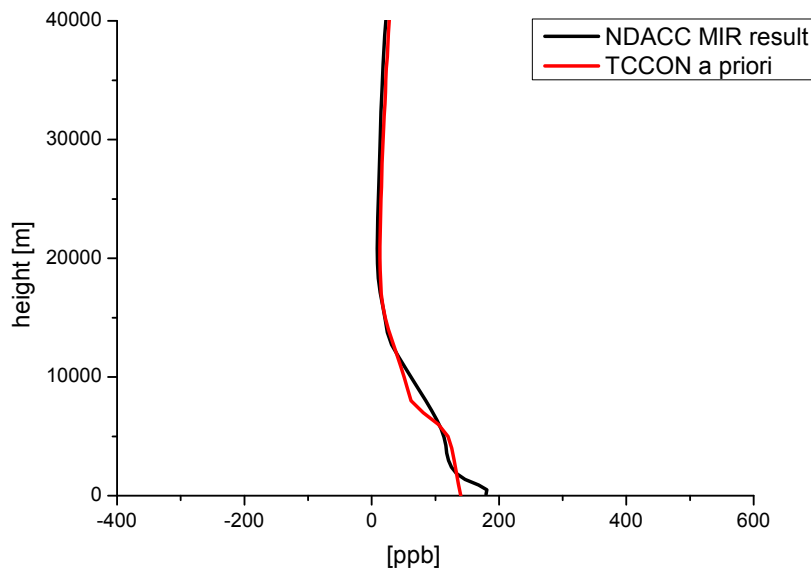
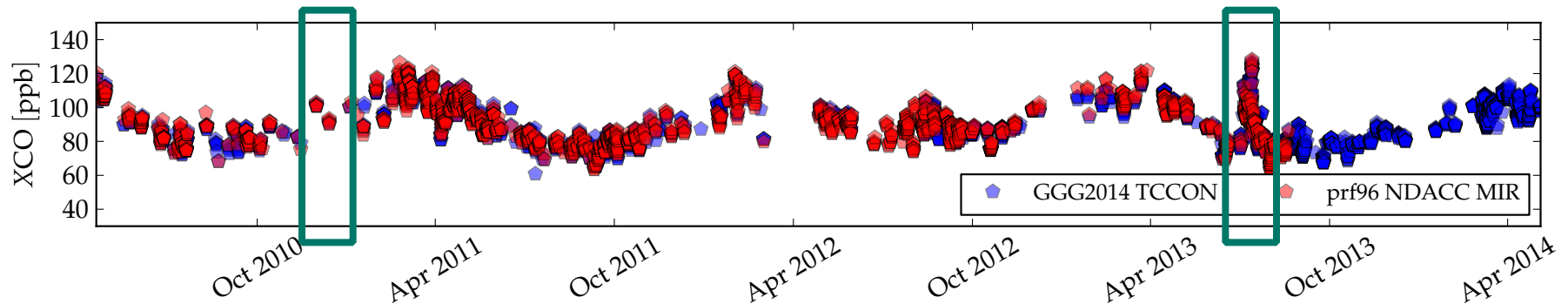
- **NDACC retrieval weakly affected by choice of a priori profile**
 - reduction of seasonal variation in difference time series after a posteriori correction
- **NDACC - TCCON comparison for CO**
 - seasonal variation due to smoothing effects and dynamical variability of atmos.
 - mean offset about 5%
 - **offset: 4.59 ppb, std: 2.08 ppb**
- **NDACC - PRF96 NIR comparison for CO**
 - NDACC MIR retrieved profiles close to true atmospheric profile
- **TCCON scaling retrieval with NDACC MIR retrieval results as a priori profiles**
 - reduction of seasonal variation
 - **offset: 5.25 ppb, std: 1.54 ppb**

Thank you for your attention!

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A priori comparison for unforeseen events



TCCON column sensitivity

