Karlsruhe Institute of Technology

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

NORS/NDACC/GAW workshop 5 - 7 November 2014, Brussels, Belgium

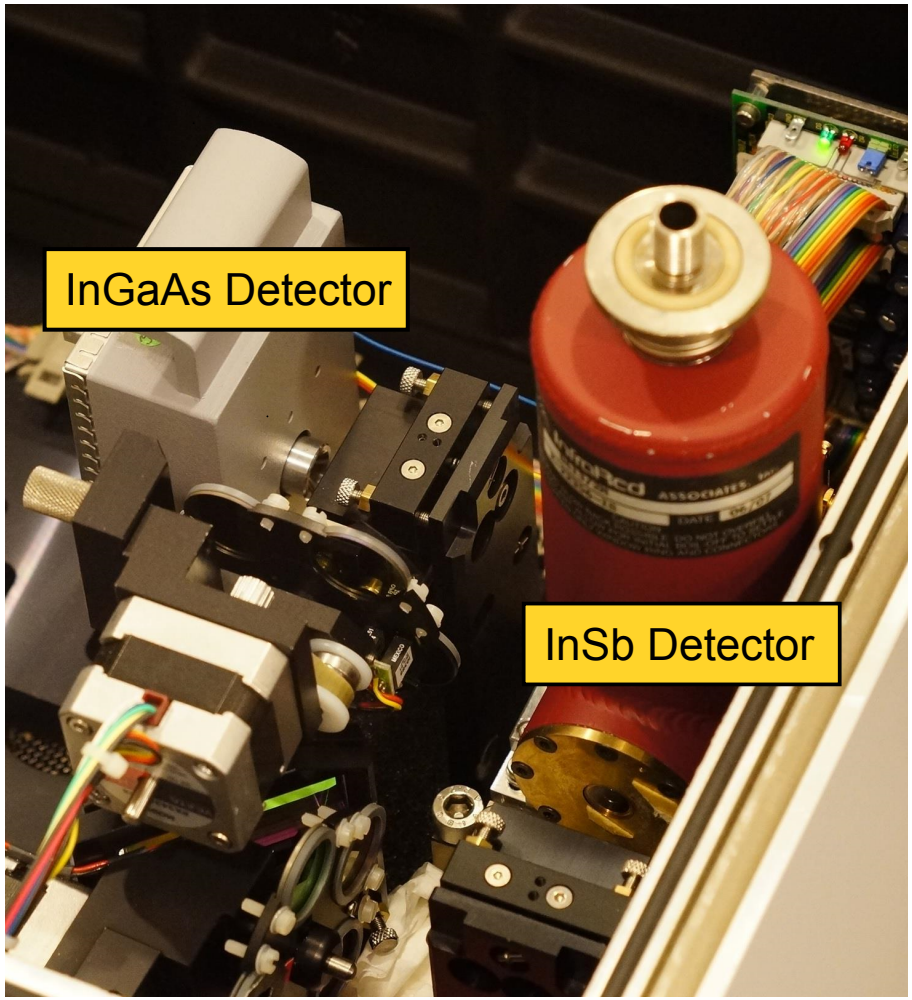
Matthäus Kiel[1], Thomas Blumenstock, Frank Hase – Ground-Based FTIR Remote Sensing

1: matthaeus.kiel@kit.edu

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

TCCON Site Karlsruhe (KIT CAMPUS)

- 49.1N , 8.4E, 111m a.s.l.
- CaF_2 beamsplitter
- specific dichroic setup:
  simultaneous recording of
  InGaAs and InSb spectra
- TCCON: SN + SM
  at OPD_{max} = 64cm
  SM: (3900 - 5250) cm^{-1}
  SN: (5000 - 10000) cm^{-1}
- NDACC: SN + SX
  at OPD_{max} = 180cm
  X: Filter M, NDACC: 2, 3, 4, 5
- 23047 paired spectra recorded
  since 2009



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MIR and NIR retrieval strategy for CO

	NDACC (MIR)	TCCON (NIR)	NIR (PROFFIT 9.6)
microwindows [cm^{-1}]	2057.5 - 2058.2 2069.4 - 2069.9 2140.4 - 2141.4	4208.7 - 4257.3 4262.0 - 4318.8	4208.7 - 4257.3 4262.0 - 4318.8
software	PROFFIT 9.6	GGG2014	PROFFIT 9.6
linelist	HITRAN[1] 2008 HITRAN[1] 2009 (H_2O)	atm.101, ct.101, fcia.101, scia.101	HITRAN[1] 2008 HITRAN[1] 2009 (H_2O)
constraint	Tikhonov regularisation DOF ≈ 3.5	scaling of a priori profile	Tikhonov regularisation DOF ≈ 2.0
a priori vmr	WACCM[2] V.6	MkIV FTS balloon profiles	WACCM[2] V.6
black body correction	yes	no	yes
pT intraday variability	yes	no	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

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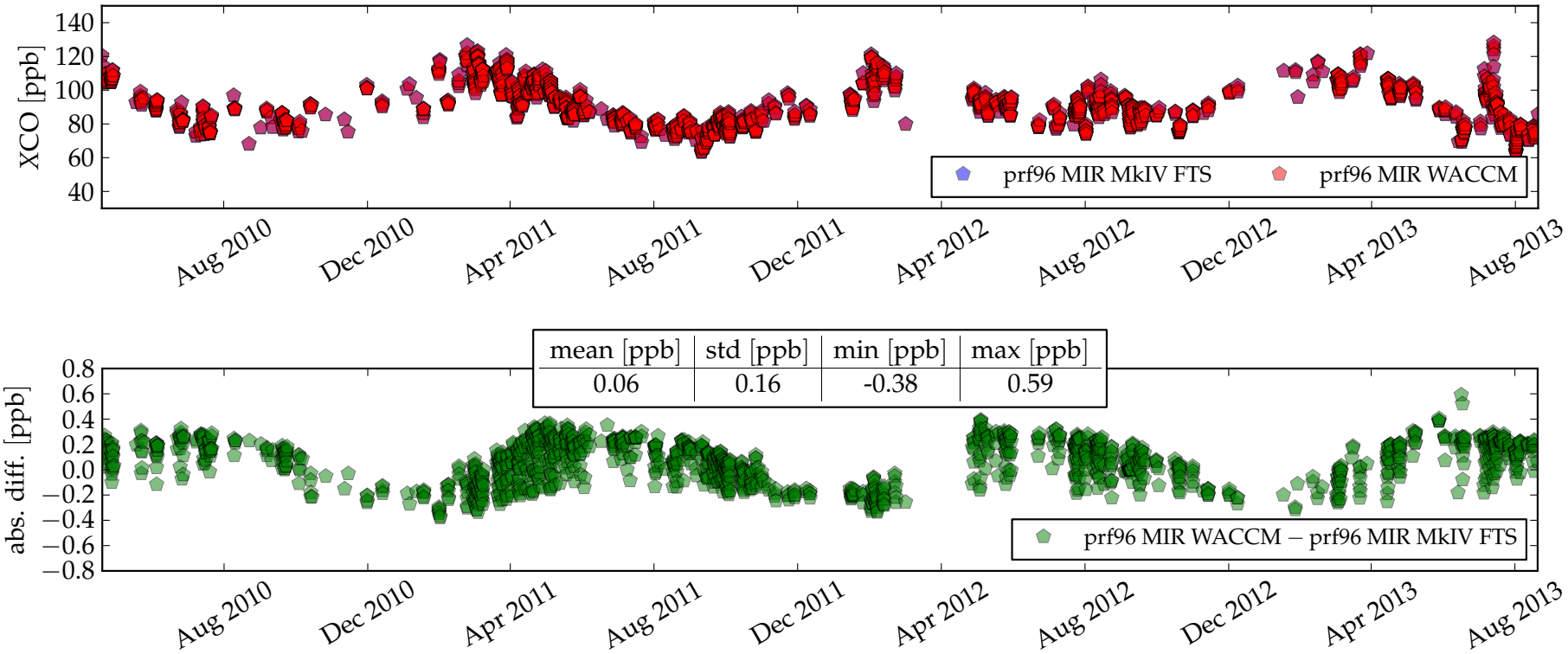
Impact of varied a priori profiles on time series

- WACCM V.6 profile (fixed) vs. MkIV FTS profile (day dependent)



- mean offset: 0.08% ; std: 0.18%
- bias and seasonal variation induced by using different a priori profiles

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Eliminating impact of varied a priori profiles

- a posteriori adjustment for a new a priori profile[1]:

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

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

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

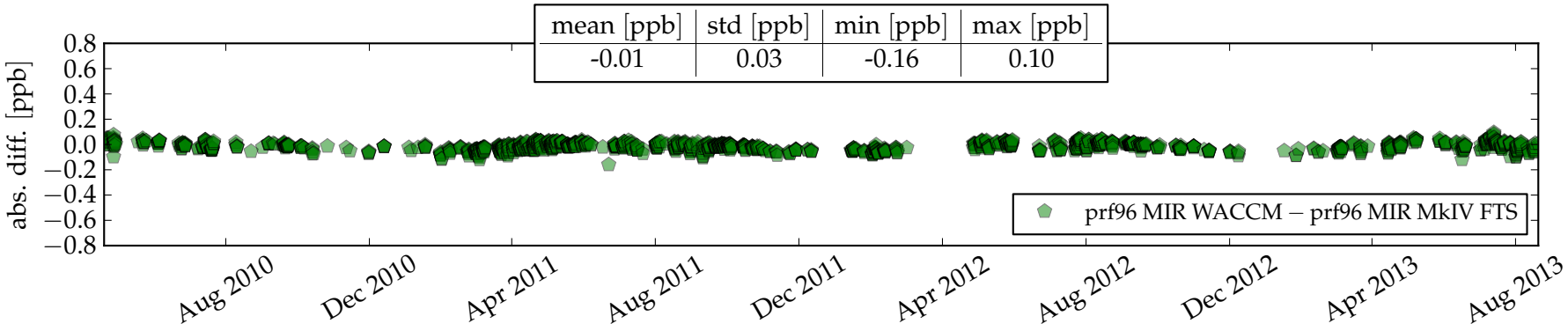
- a posteriori correction term:

$$\Delta = \vec{x} - \tilde{\vec{x}}$$
$$= (\mathbf{AK} - \mathbb{I})\left(\tilde{\vec{x}}_{apriori} - \vec{x}_{apriori}\right)$$

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 → MkIV FTS



	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

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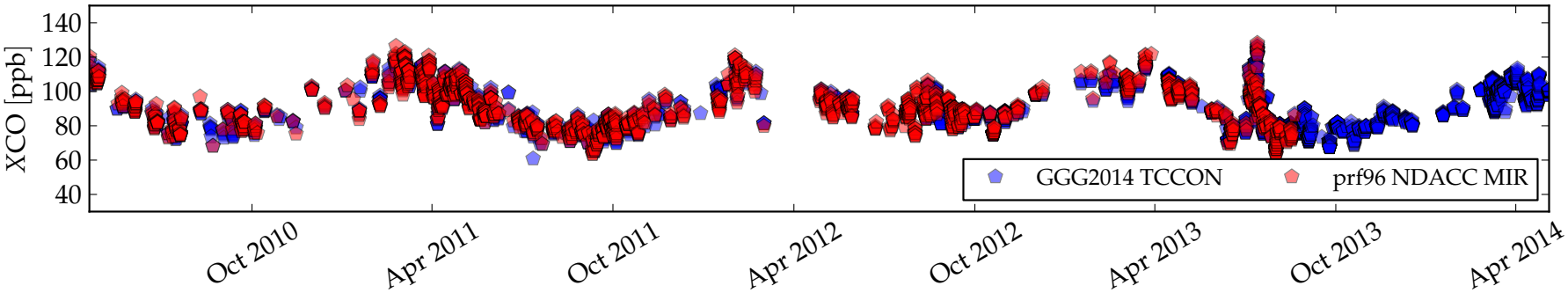
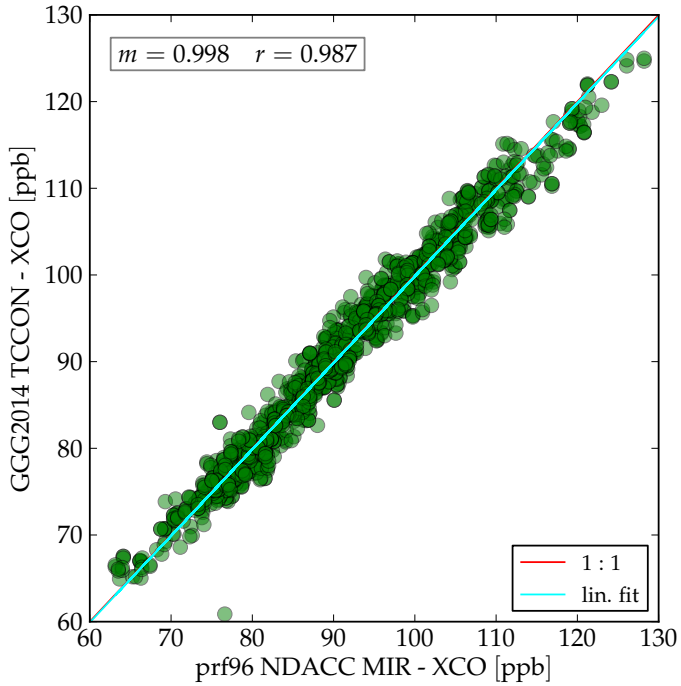
Direct comparison of CO (NDACC vs. TCCON)





- comparison of quasi-coincident measurements (time range 15 minutes)
- good agreement in seasonal variations
- slope: 0.998 ; correlation: 0.987 (obtained from linear fit forced through zero)
- mean offset: 0.11% ; std: 2.28%

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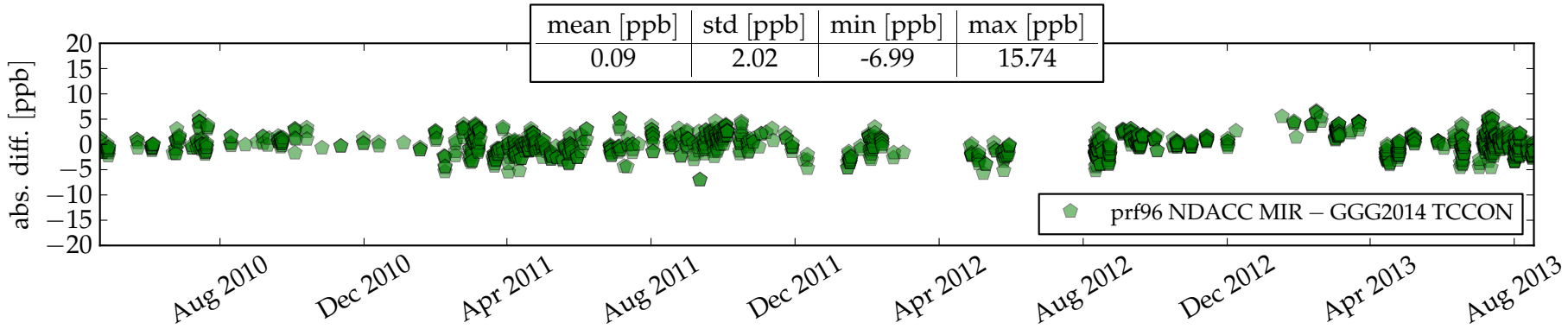
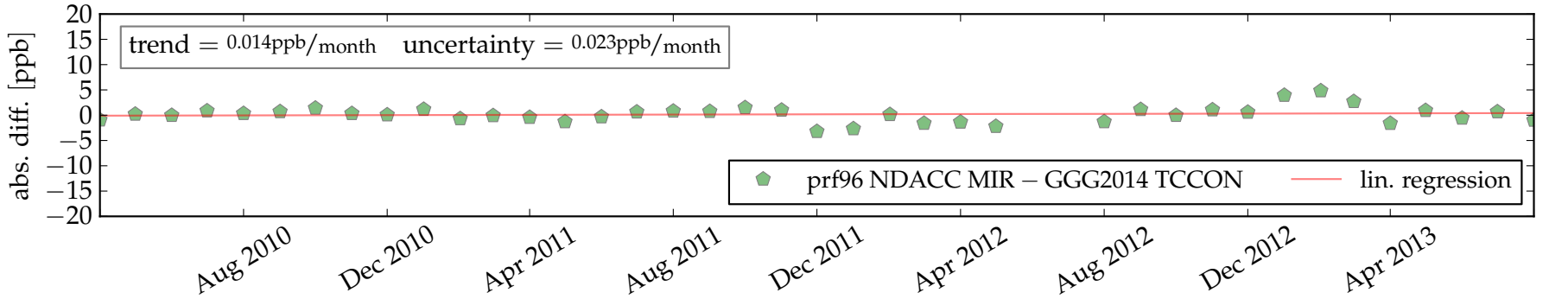
Direct comparison of CO (NDACC vs. TCCON)



- no seasonal variation in difference time series NDACC - TCCON



- no significant trend (obtained by linear fit to monthly mean difference)
- **no NDACC - TCCON intercalibration factor needed for CO for Karlsruhe**

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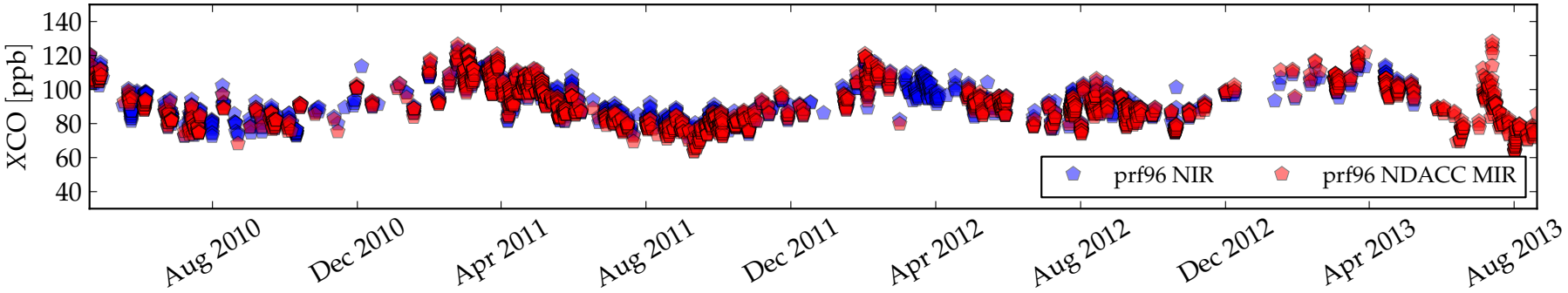
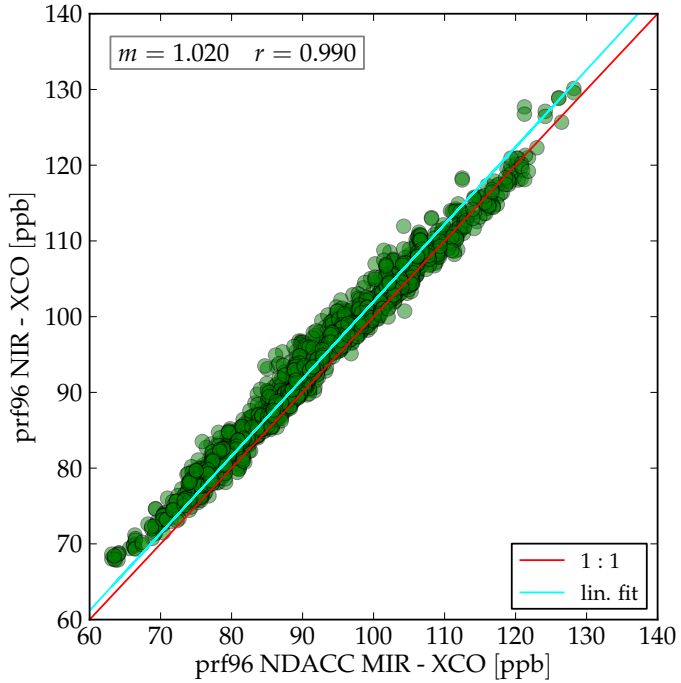
Direct comparison of CO (NDACC vs. PRF96 NIR)





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

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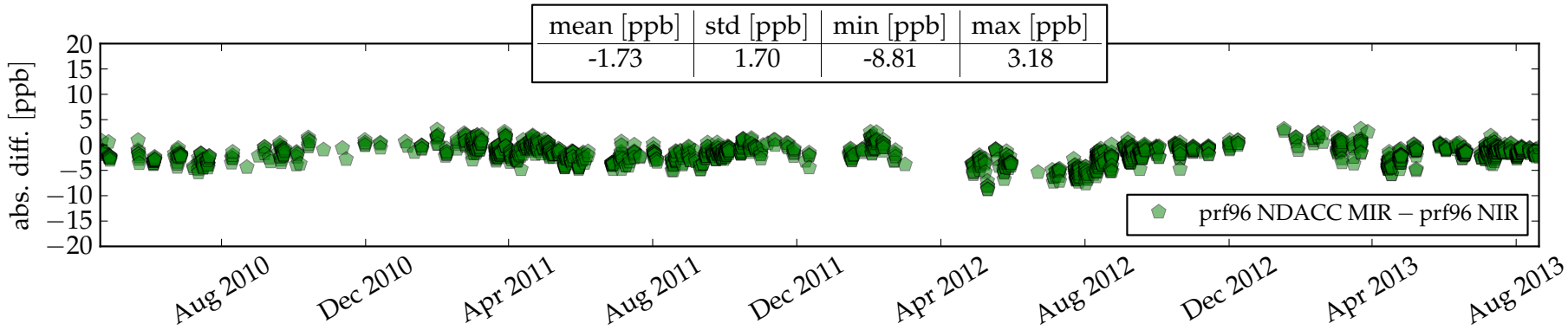
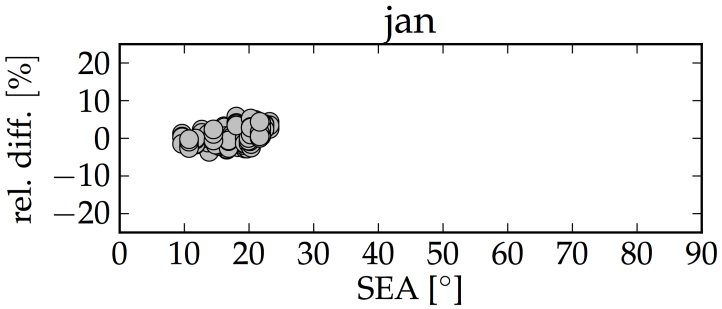
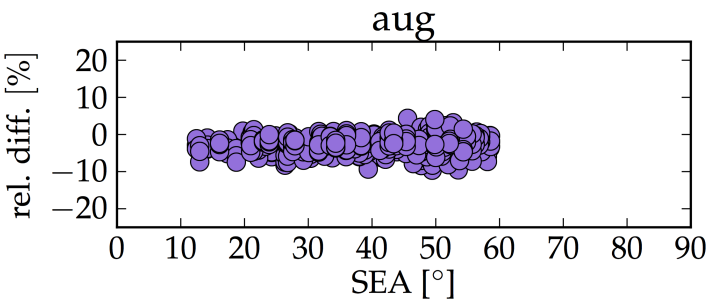
Direct comparison of CO (NDACC vs. PRF96 NIR)



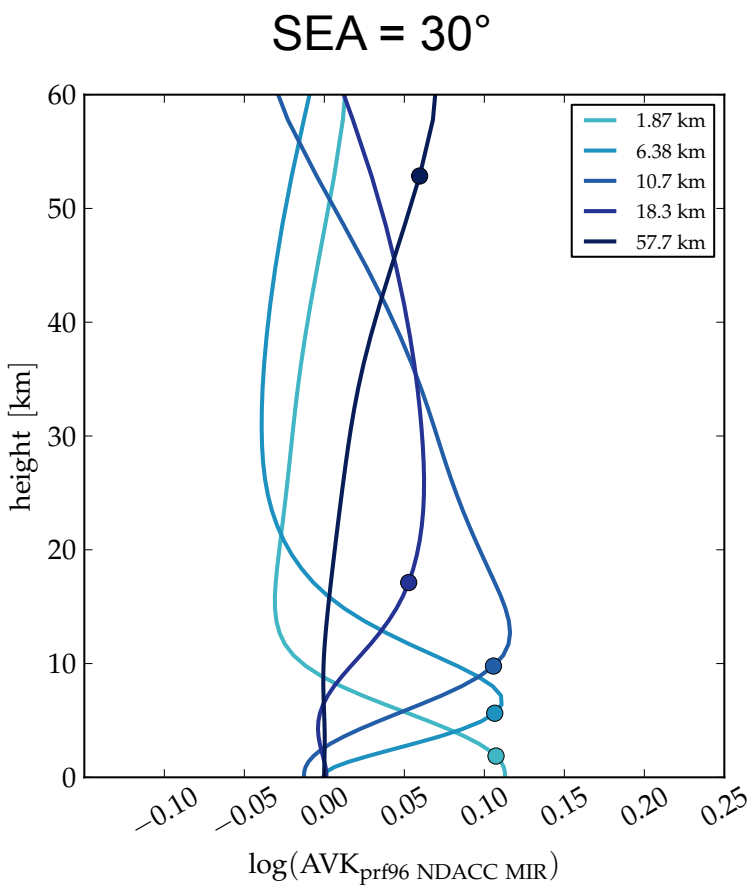
- seasonal variation in difference time series NDACC MIR - PRF96 NIR
- used same a priori profile (WACCM V.6) - seasonal variation not driven by different a priori profiles
- seasonal variation in difference time series not driven by airmass dependency

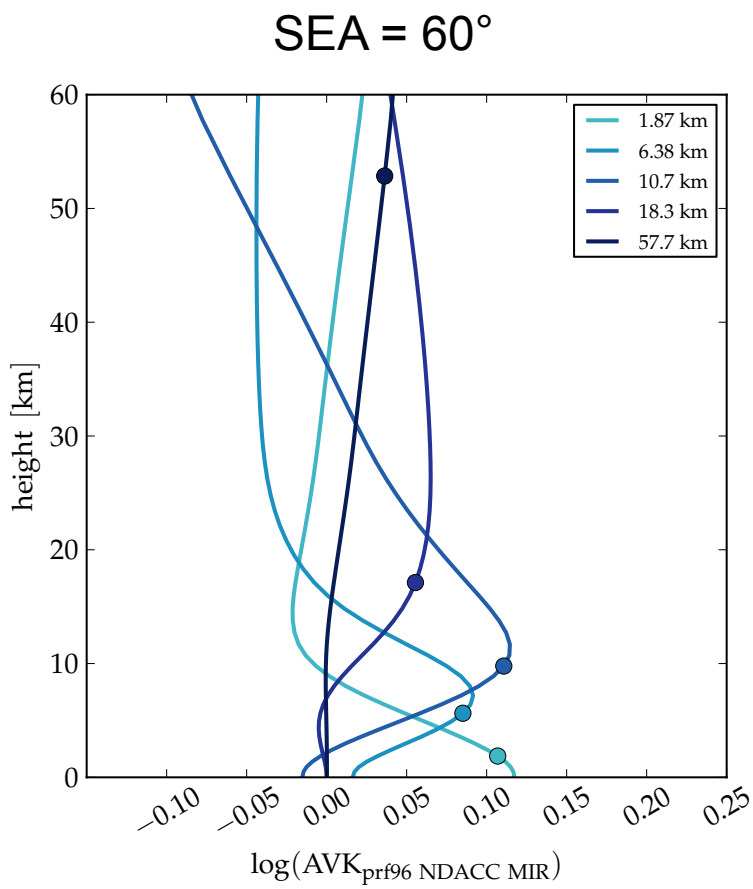




Averaging kernels as function of solar angle

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





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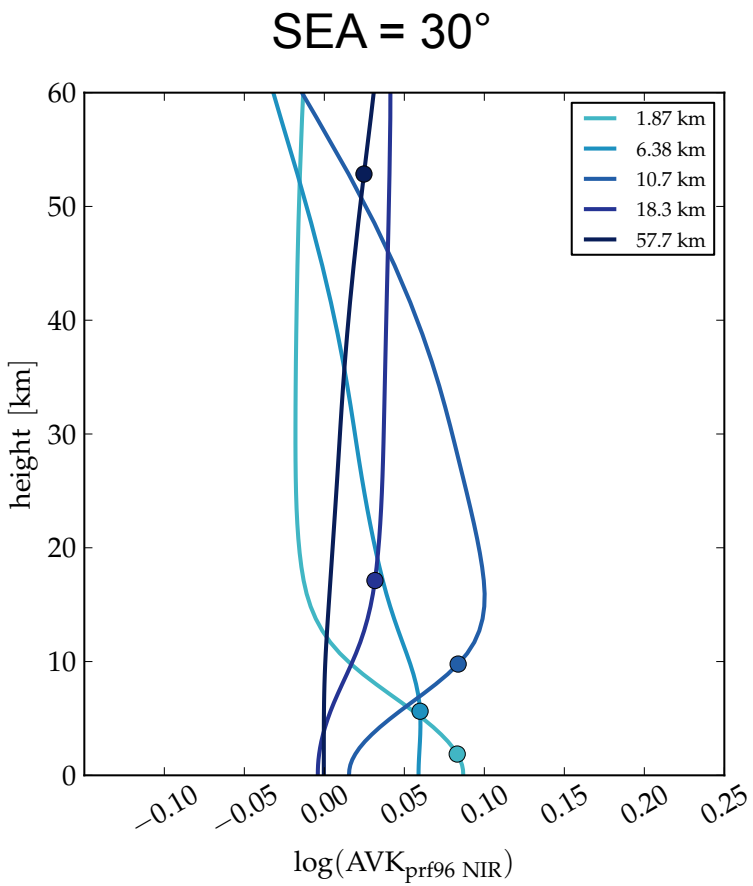
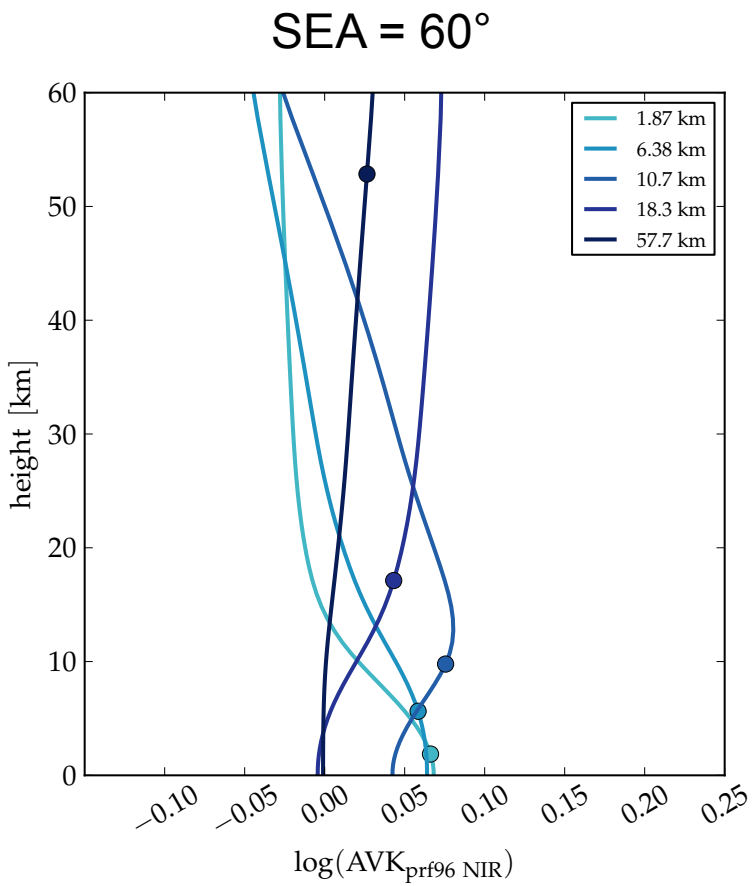
Averaging kernels as function of solar angle

- change of averaging kernels (AVKs) for different solar angles for **prf96 NIR**





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Reduction of smoothing error

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

- smoothing error correction term:

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

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

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

- 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**

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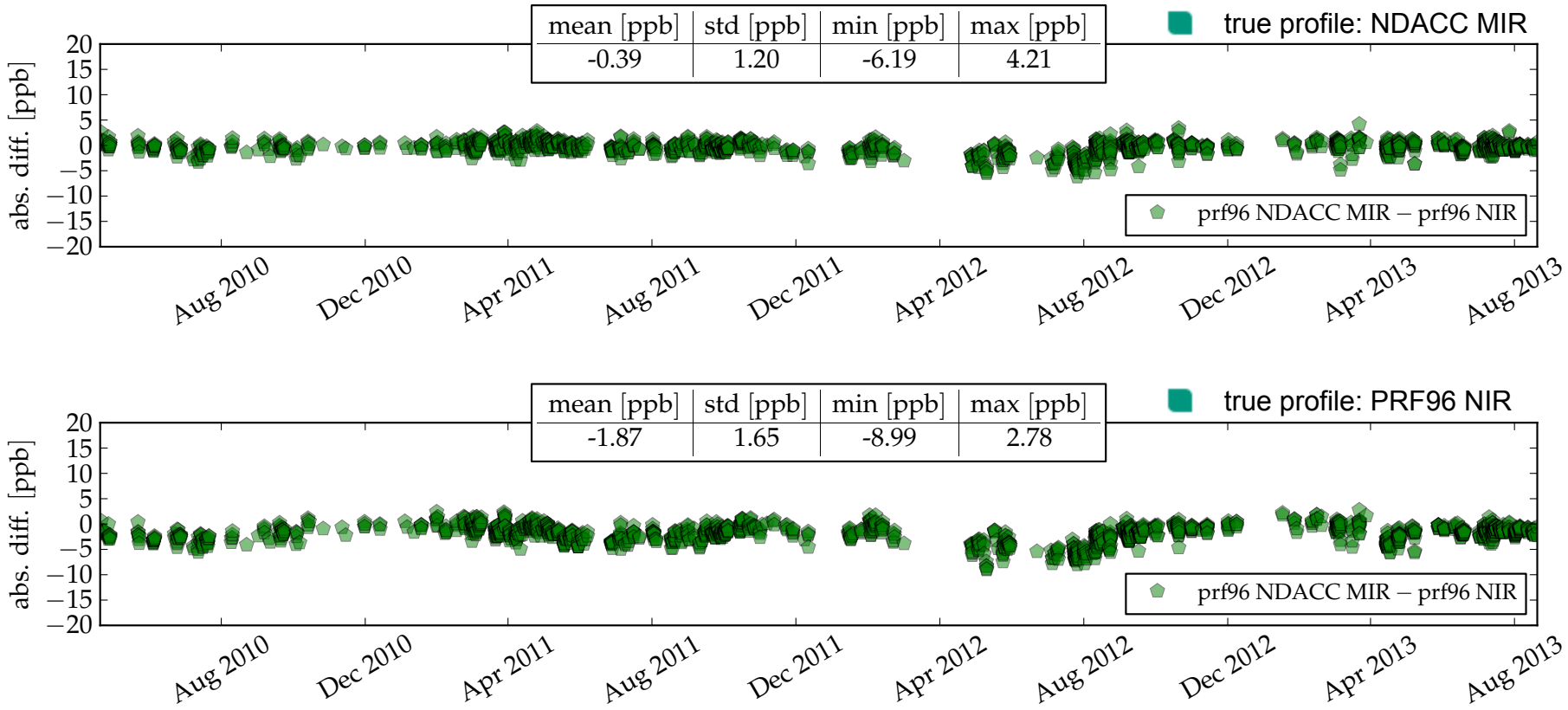
Reduction of smoothing error



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

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constraint	Tikhonov regularisation DOF ≈ 3.5	scaling of a priori profile	scaling of a priori profile
a priori vmr	WACCM[2] V.6	MkIV FTS balloon profiles	NDACC (MIR) results
black body correction	yes	no	yes
pT intraday variability	yes	no	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
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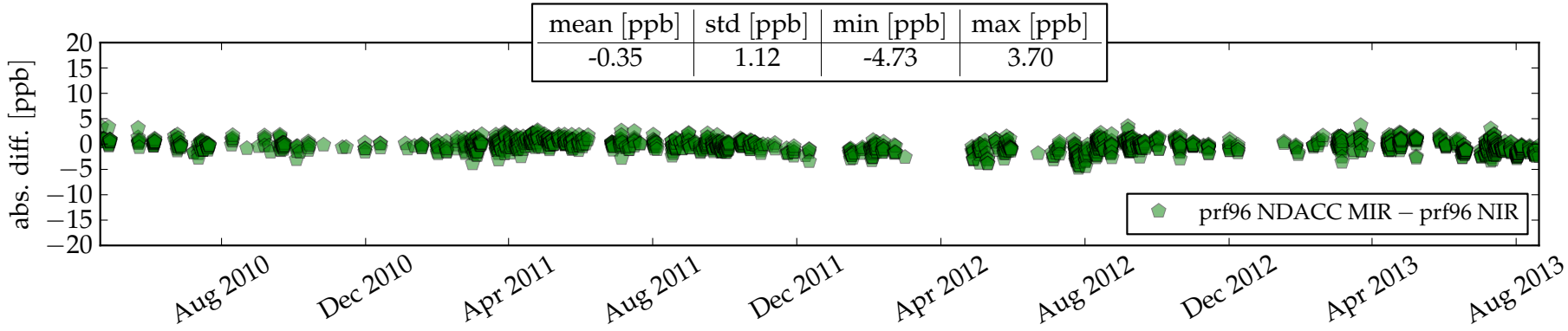
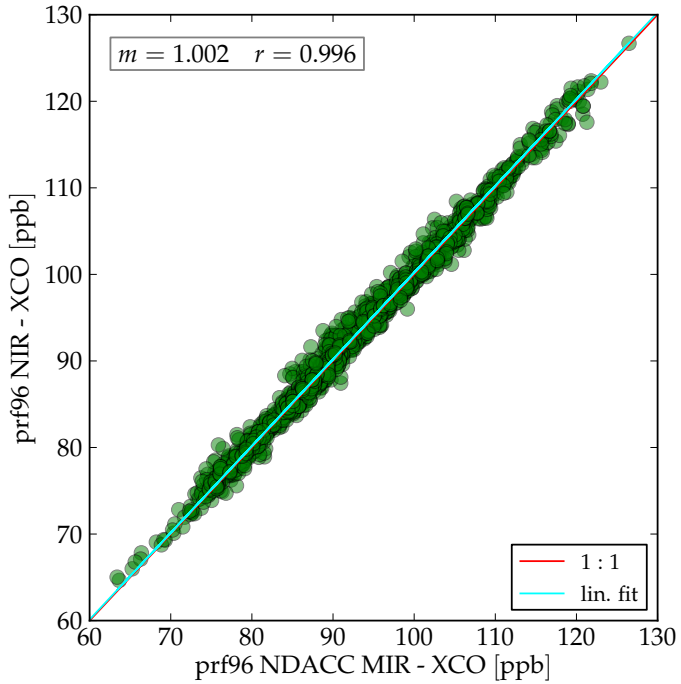
Comparison of CO (NDACC MIR vs. PRF96 NIR)





- use MIR regularisation retrieval results as a priori for NIR scaling retrieval
- reduction of seasonal variation
- slope: 1.002 ; correlation: 0.996 (obtained from linear fit forced through zero)
- mean offset: -0.36% ; std: 1.19%
- no significant trend in difference time series

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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**
  → no seasonal variation, no trend
  → no intercalibration factor needed
  → **offset: 0.09 ppb ; std: 2.02 ppb**
- **NDACC - PRF96 NIR comparison for CO**
  → NDACC MIR retrieved profiles close to true profile
  → PRF96 scaling retrieval with NDACC MIR retrieval results as a priori profiles
  → reduction of seasonal variation, no trend
  → **offset: -0.35 ppb ; std: 1.12 ppb**

Outlook

- compare TCCON/NDACC data for CH_4, N_2O, H_2O, CO_2, …
- determine NDACC - TCCON intercalibration factors

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Thank you for your attention!

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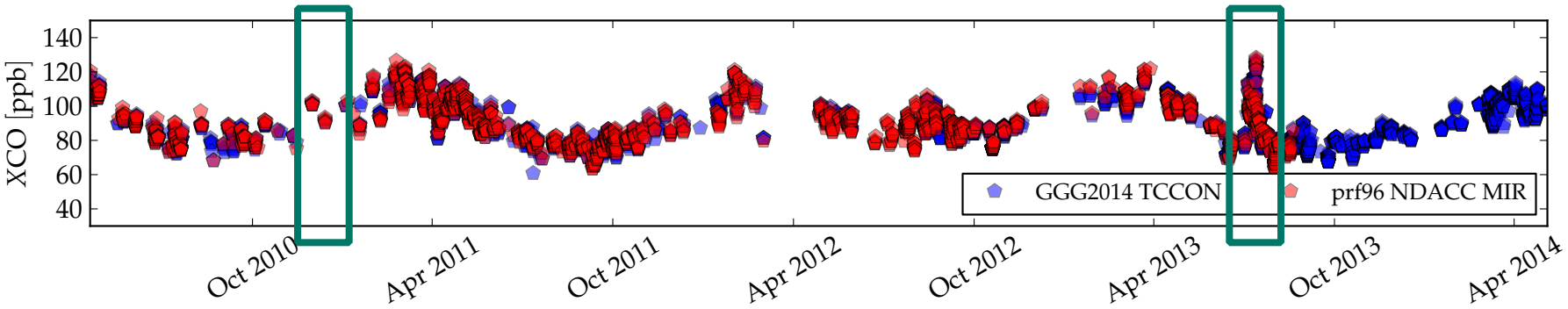
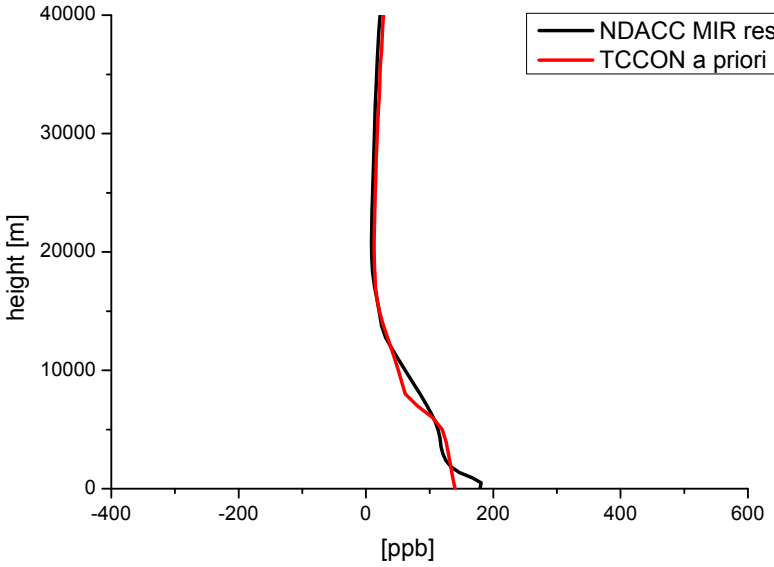
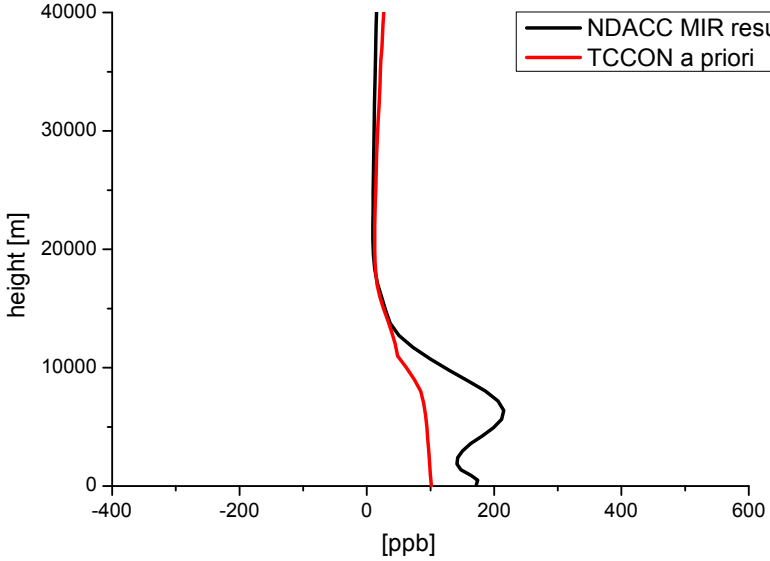
A priori comparison for unforeseen events







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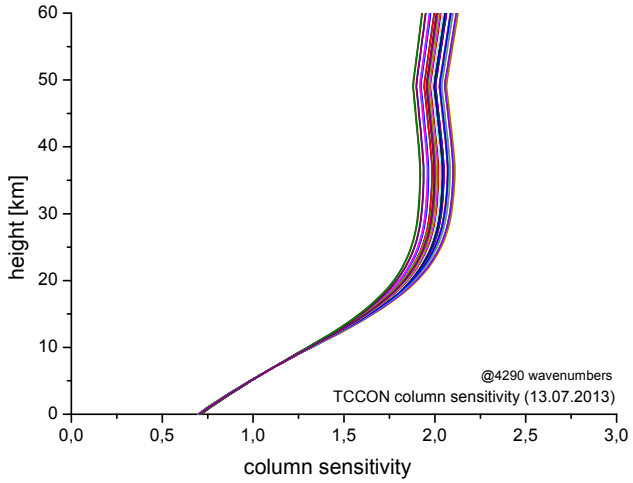
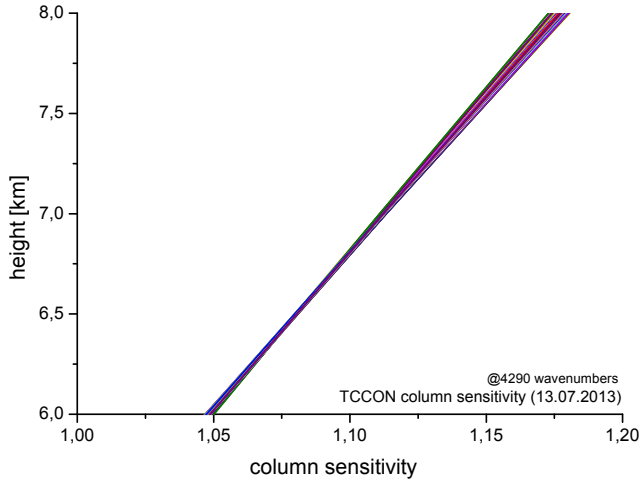
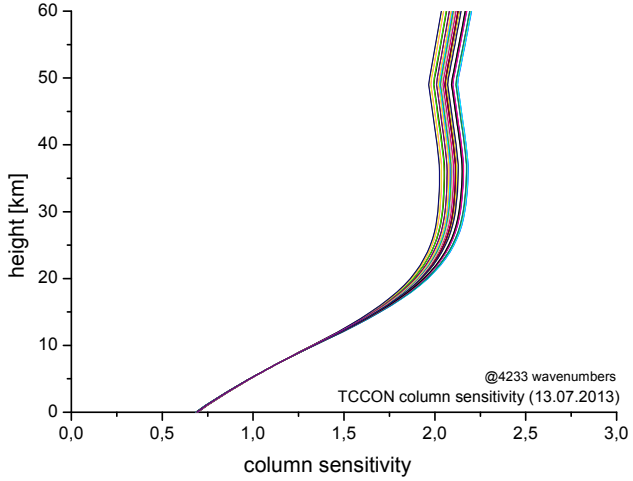
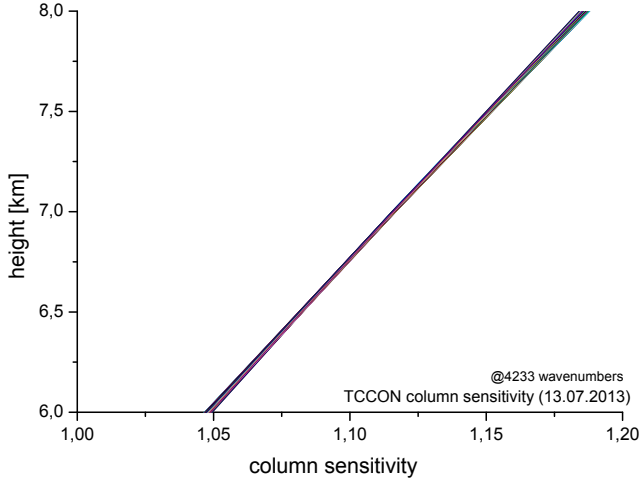
TCCON column sensitivity









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