Management of Changes in GRUAN:

Number of dual sonde flights required for radiosonde changes

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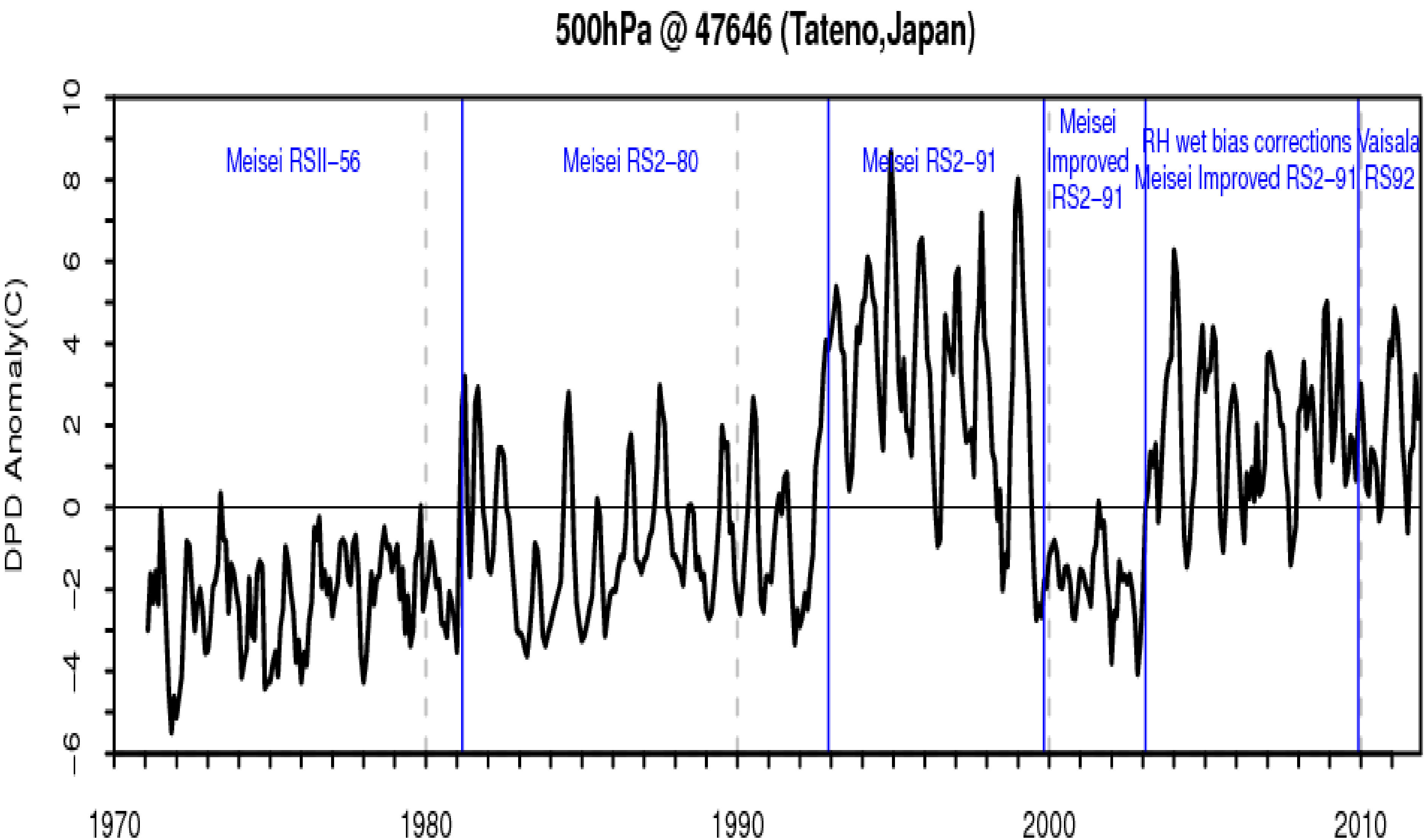
What is the problem?



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Question: How many dual sonde flights are needed to accurately assess the bias between old and new sondes?

Approach: *(Peterson and Durre 2002)*

- To calculate the standard error of differences between dual-sonde data collected from Lindenberg and Tateno for different numbers of samplings;
- To estimate numbers required for the standard error to be less than the GRUAN accuracy requirement (long term stability: 0.05°C & 0.3%).

Data:

- Lindenberg: RS80 v.s. RS90FN & RS92 v.s. RS90FN
- Tateno: RS92 vs. Meisei RS2-91

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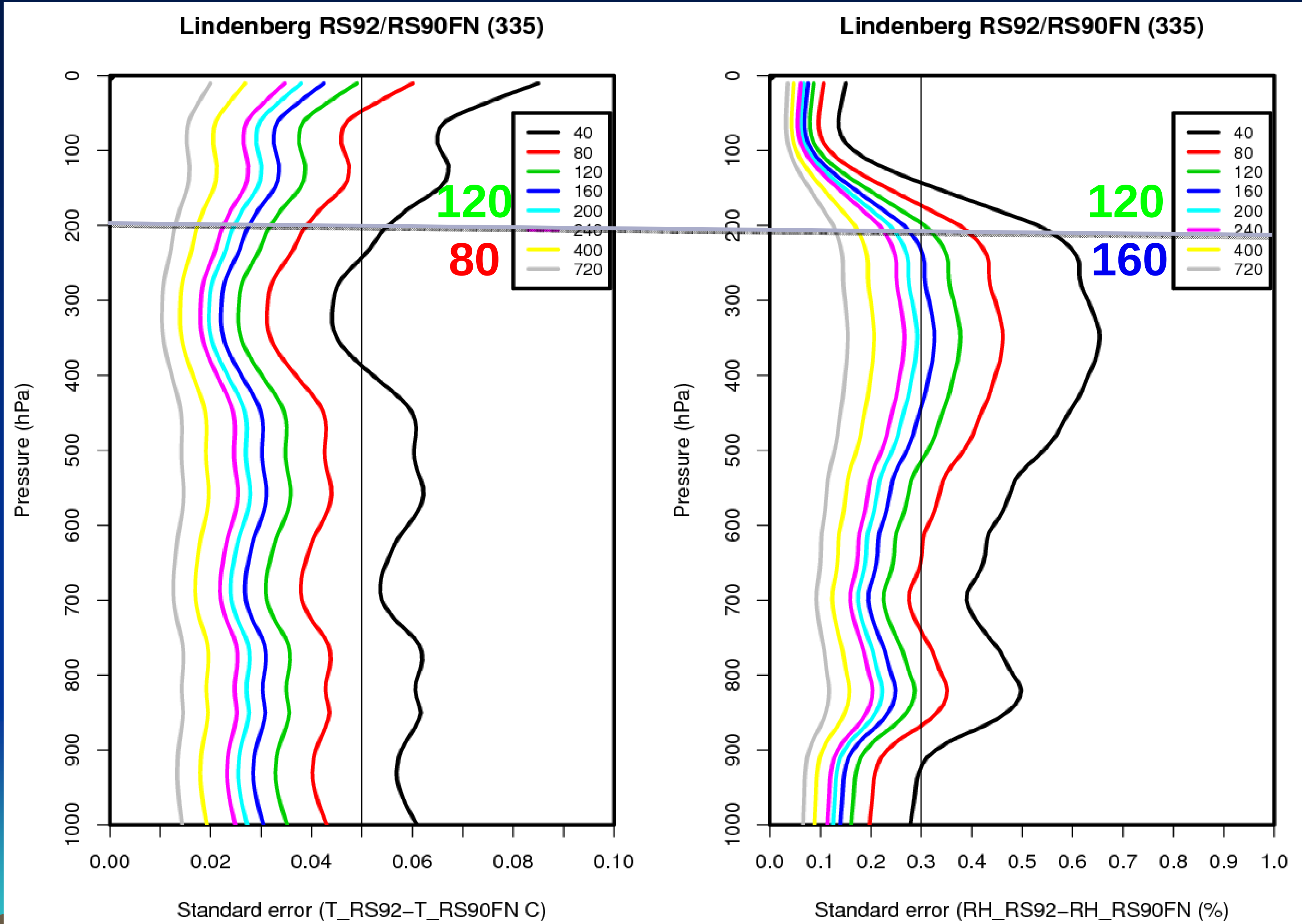
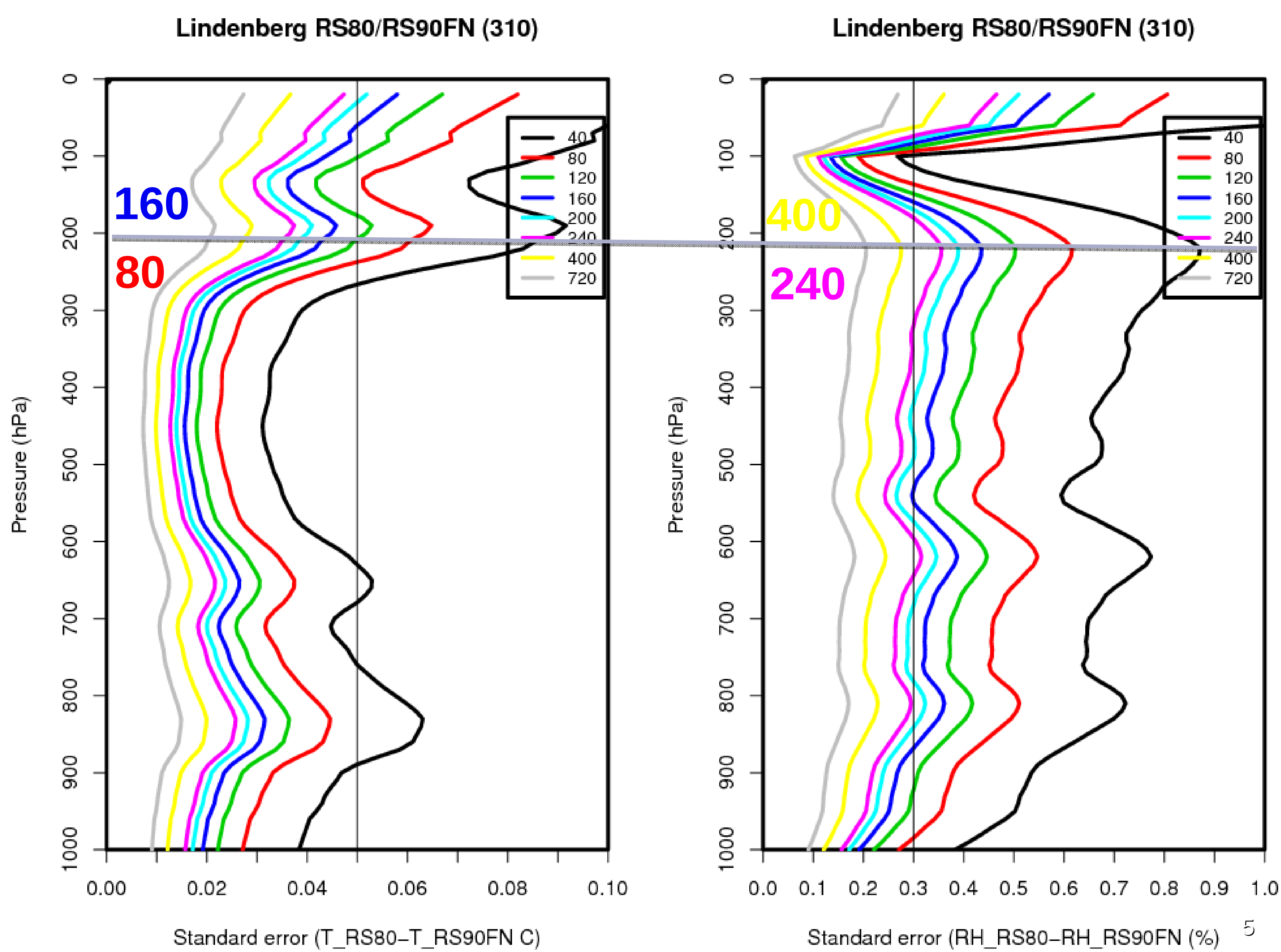
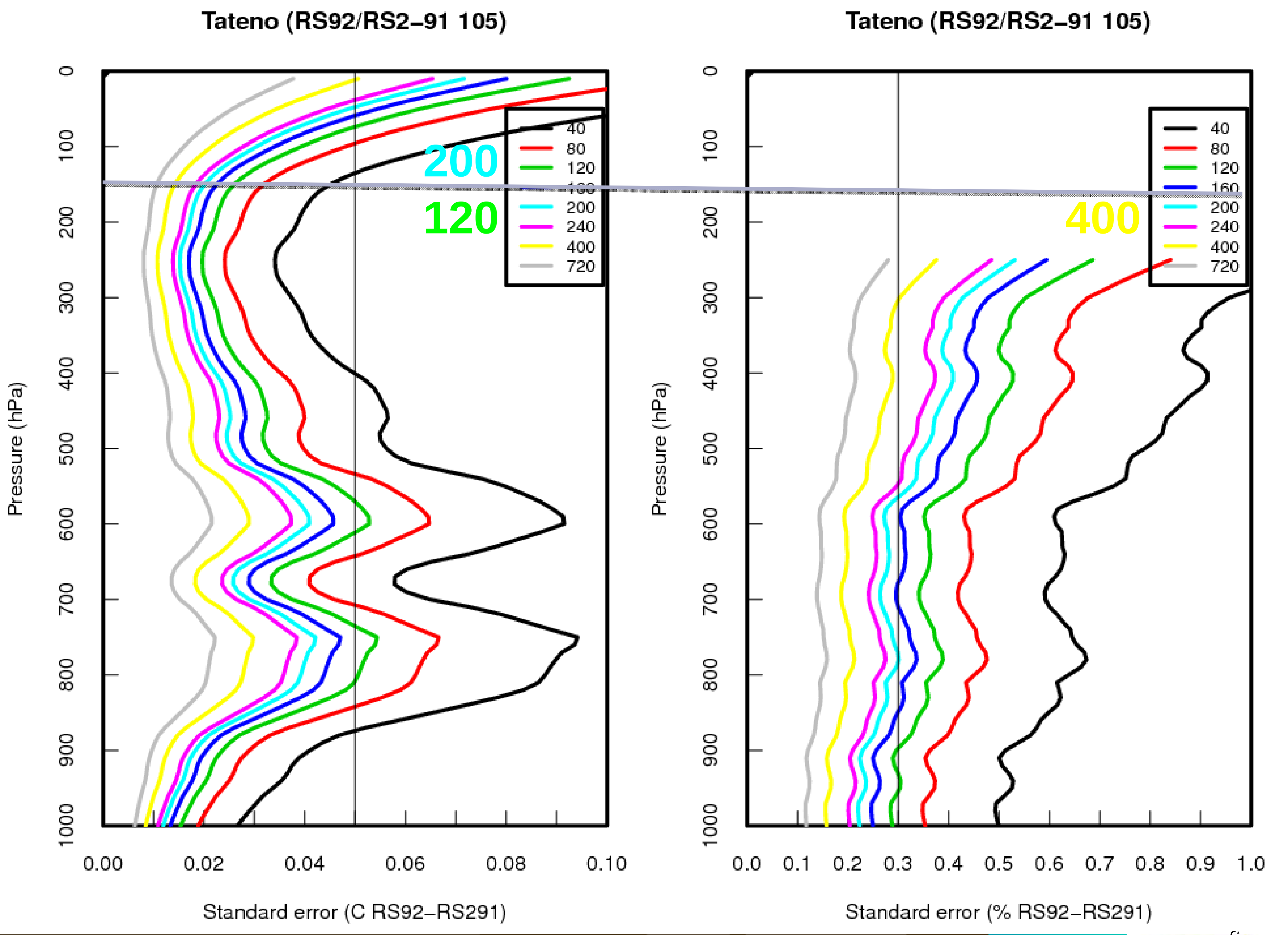


Lindenberg RS92/RS90FN (335)
Pressure (hPa)
Standard error (T_RS92–T_RS90FN C)
40
80
120
160
200
240
400
720
120
80
Lindenberg RS92/RS90FN (335)
Pressure (hPa)
Standard error (RH_RS92–RH_RS90FN (%)
120
160



Lindenberg RS80/RS90FN (310)
Pressure (hPa)
Standard error (T_RS80−T_RS90FN C)
40
80
120
160
200
240
400
720
160
80
Lindenberg RS80/RS90FN (310)
Pressure (hPa)
Standard error (RH_RS80−RH_RS90FN (%)
400
240


Tateno (RS92/RS2–91 105)
Pressure (hPa)
Standard error (C RS92–RS291)
200
120
40
80
120
160
200
240
400
720
Tateno (RS92/RS2–91 105)
Pressure (hPa)
Standard error (% RS92–RS291)
400
40
80
120
160
200
240
400
720

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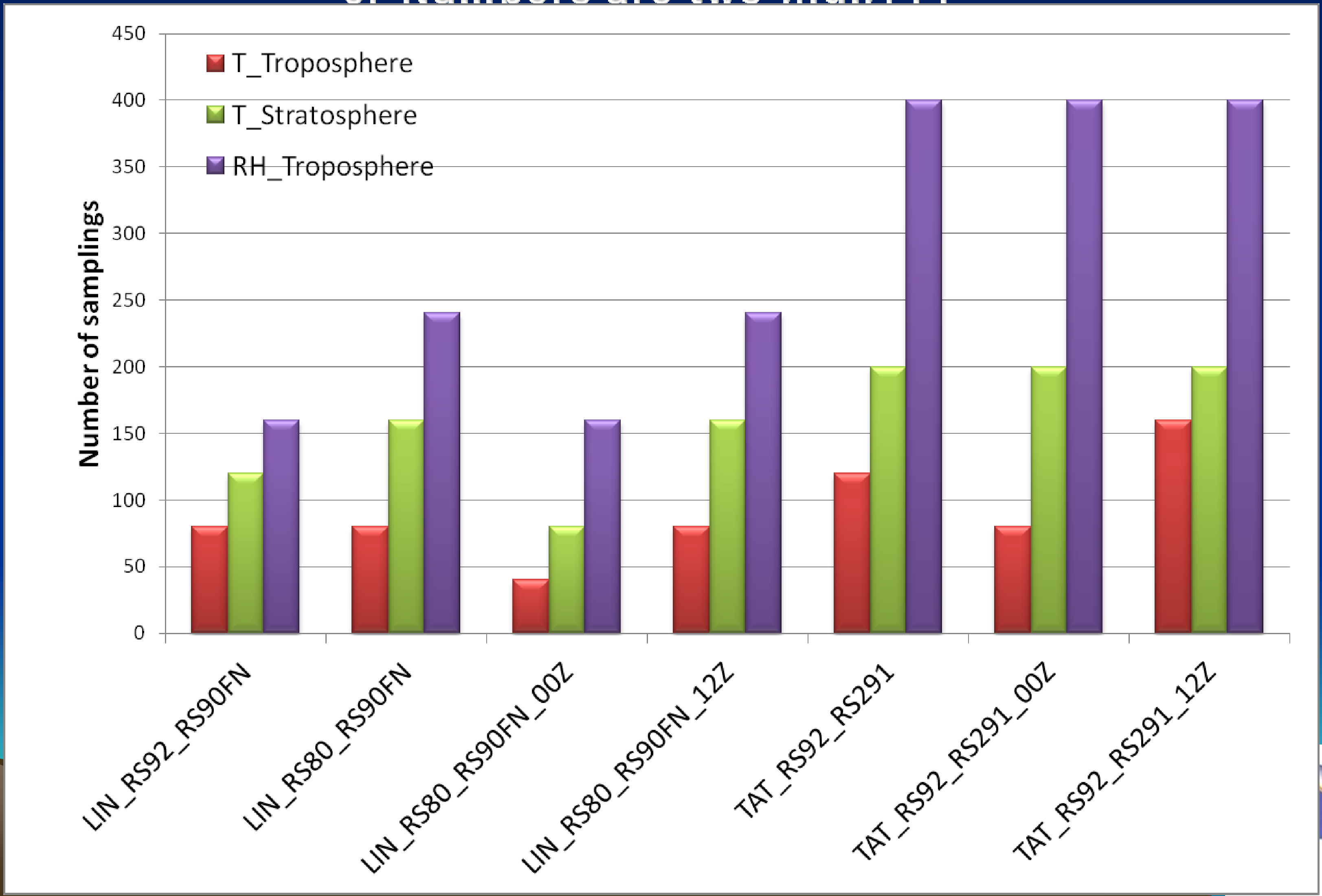
Summary

1. T_Troposphere: 160
2. T_Stratosphere: 200
3. RH _Troposphere: 240/400
4. Numbers vary with old/new radiosonde types, T/RH structures and variability, time of the day
5. Numbers are two high???



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General guidelines on overlap dual-sonde flights

- *New sonde has been tested and evaluated both in lab and in the field and deemed reliable enough*
- *On the same balloon or in a sequence as closely in space and time as possible*
- *Cover day/night and the entire annual cycle*
- *?? flights spread out over all four seasons*
- *Quantitative analysis of the dual-sonde data in near real-time*
- *Collaborations with instrument makers to solve discovered problems and improve the system*
- *Make use of other redundant obs.*

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Homogenization of Daily Global Radiosonde Humidity Data:

Vaisala RS92 Bias Correction and Impact

Constrain and calibrate data from more spatially-comprehensive global observing systems:

1. Importance of Management of Changes

2. Contributions of GRUAN RS92 GDP & corrections

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Supported by NOAA Climate Program Office &
NCAR Water System Program

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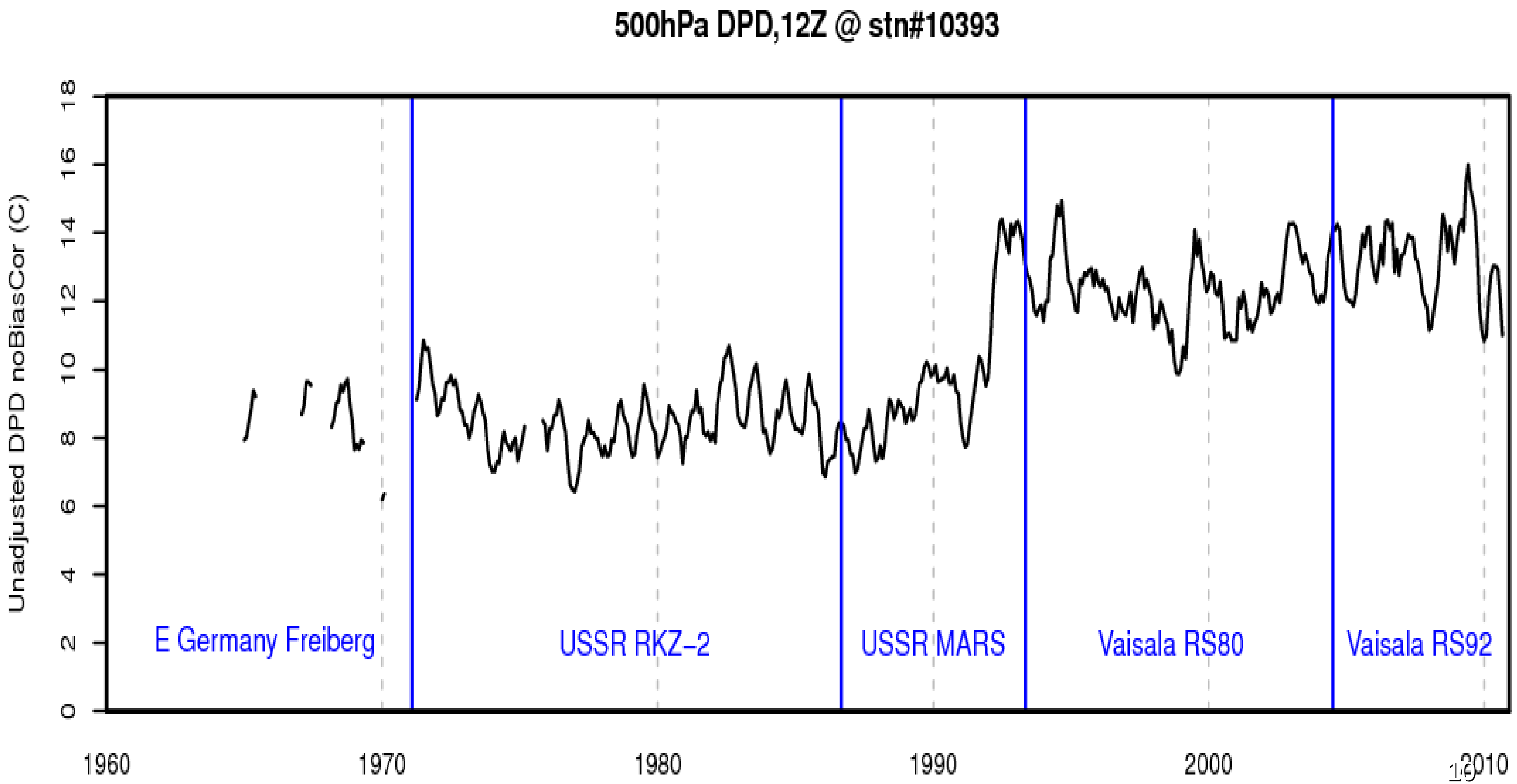
What is the problem?

- Identify change points
- Select reference segment
- Make adjustment



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Statistical homogenization method

Daily Dew Point Depression (DPD)

↓

Break point detection (KS/PMT)

↓

Cold/dry bias correction

↓

Quantile-matching based DPD adjustment

↓

Homogenized daily DPD ← RICH v1.4 T adjustment

↓

Daily q, RH, PW

↓

Homogenized monthly DPD, q, RH, PW

- No reference time series needed
- Applying to individual soundings

Dai et al. (2011, J Climate)

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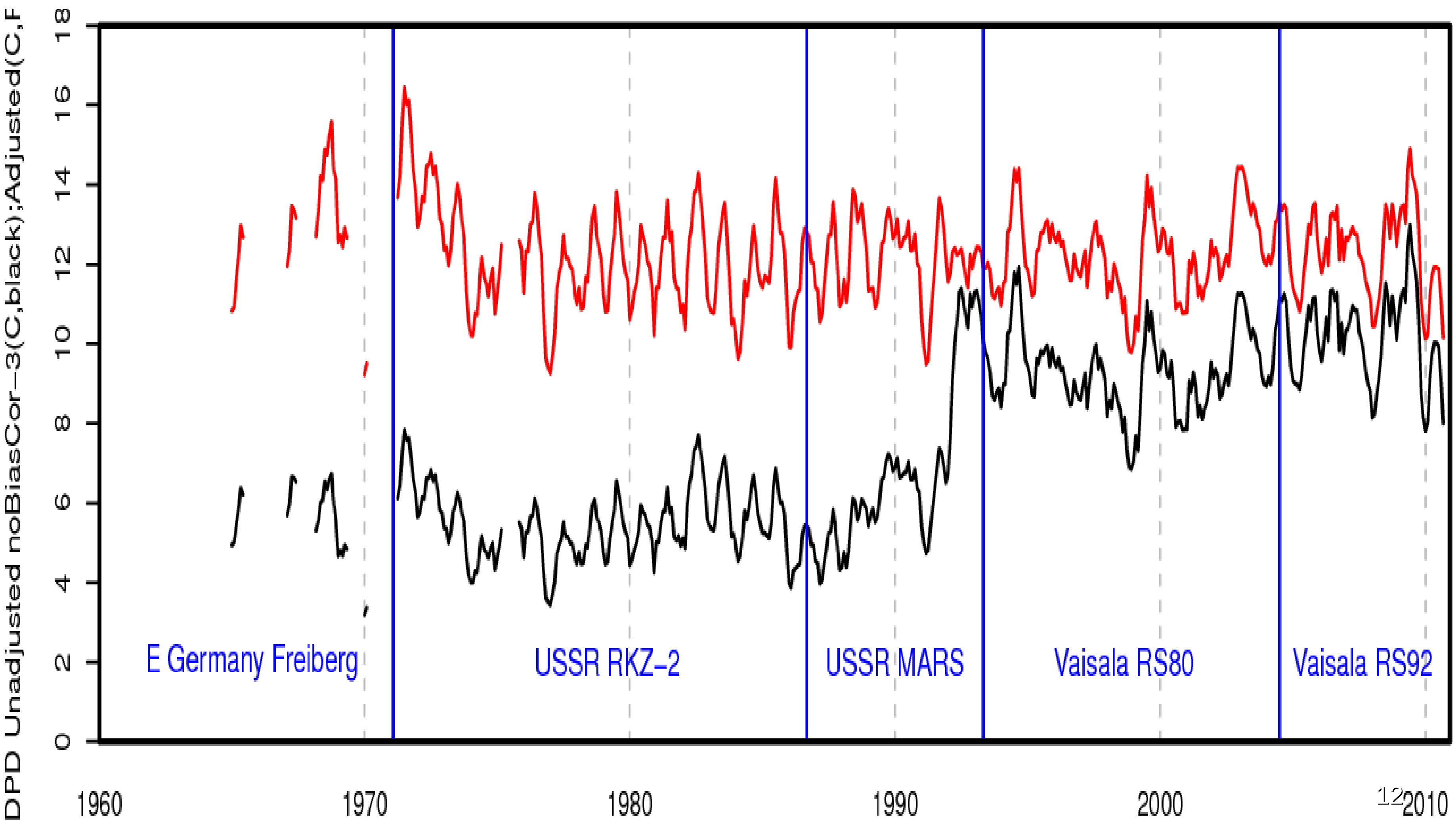
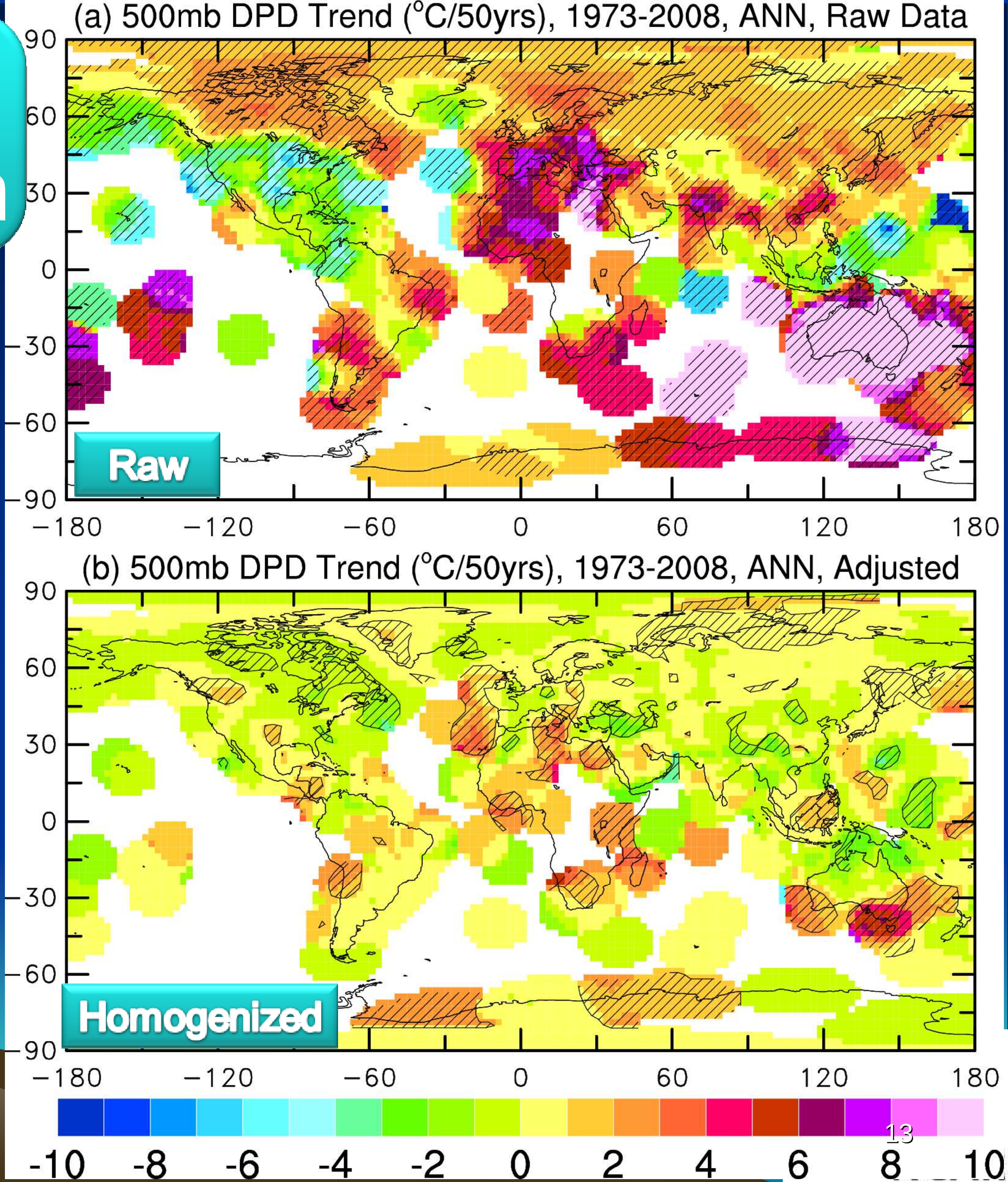
Impact of Homogenization

Dew-Point-Depression (DPD) at 500hPa in Lindenberg

(Raw & Homogenized)



Impact of Homogenization

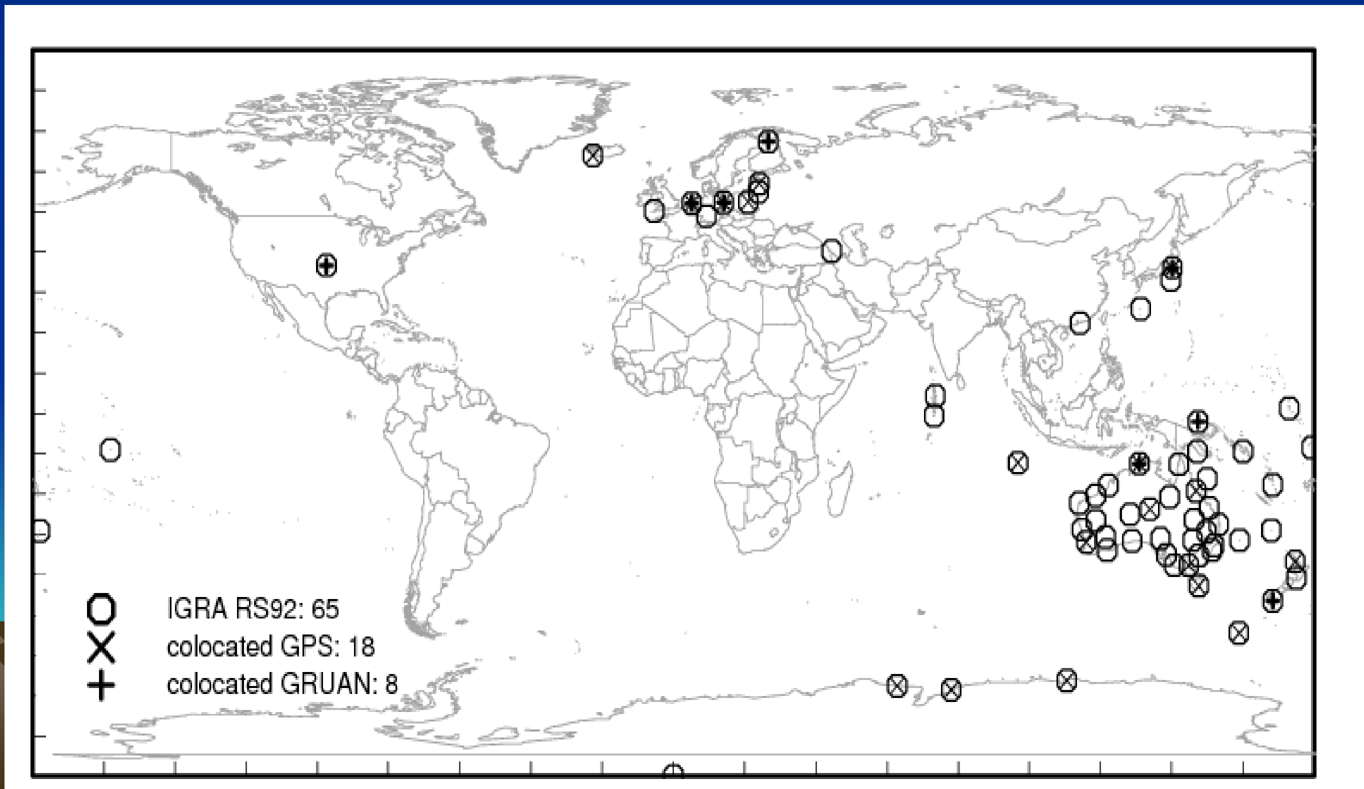


Solar Radiation Dry Bias Correction

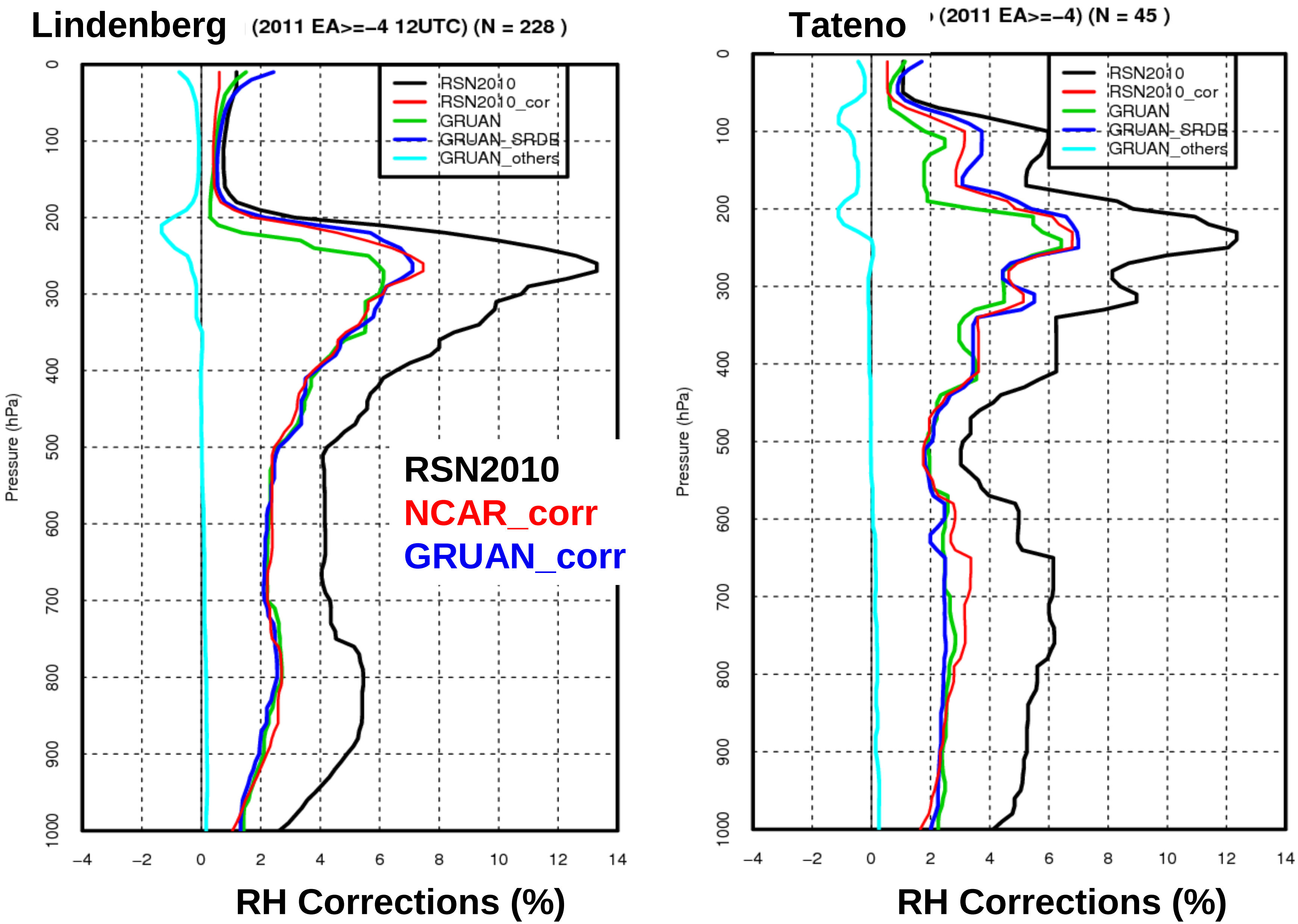
$$RH_{corr} = RH_m \frac{e(T + 13 * \Delta T_{corr})}{e(T)}$$

Radiative heating of temperature sensor ΔTcorr:

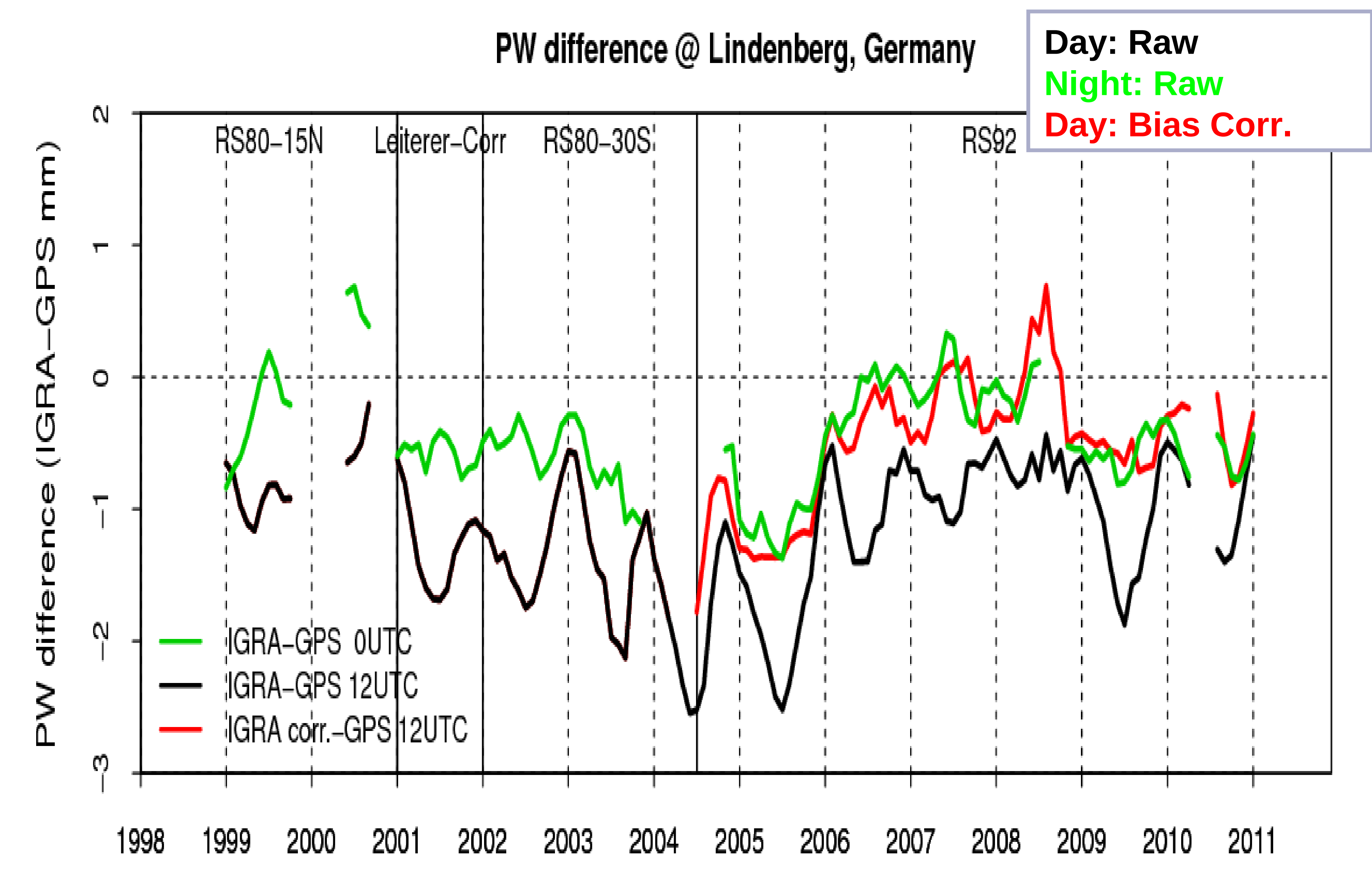
Solar radiation flux, pressure, ventilation rate



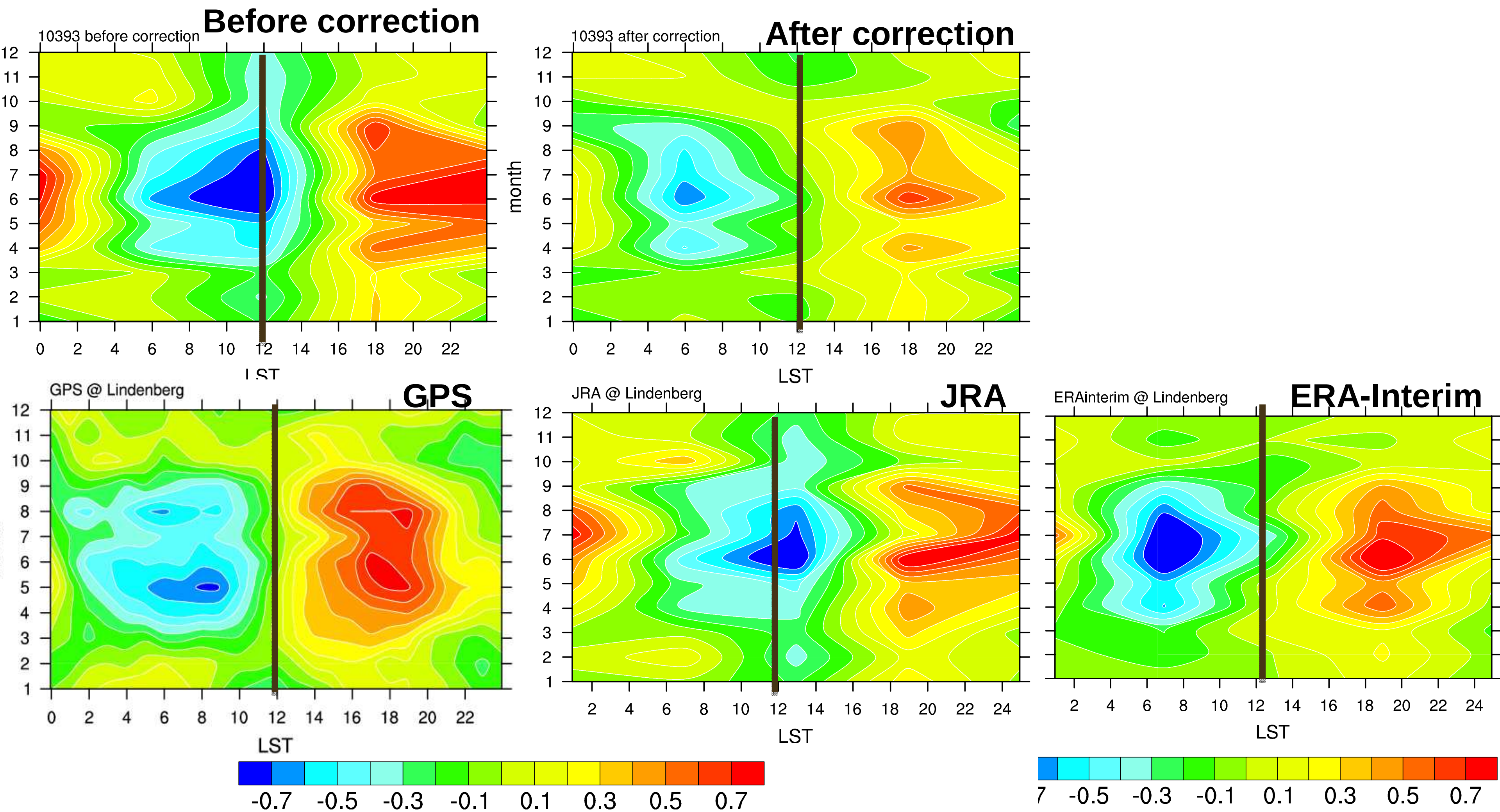
Comparison with GRUAN Corrections (LIN/TAT)



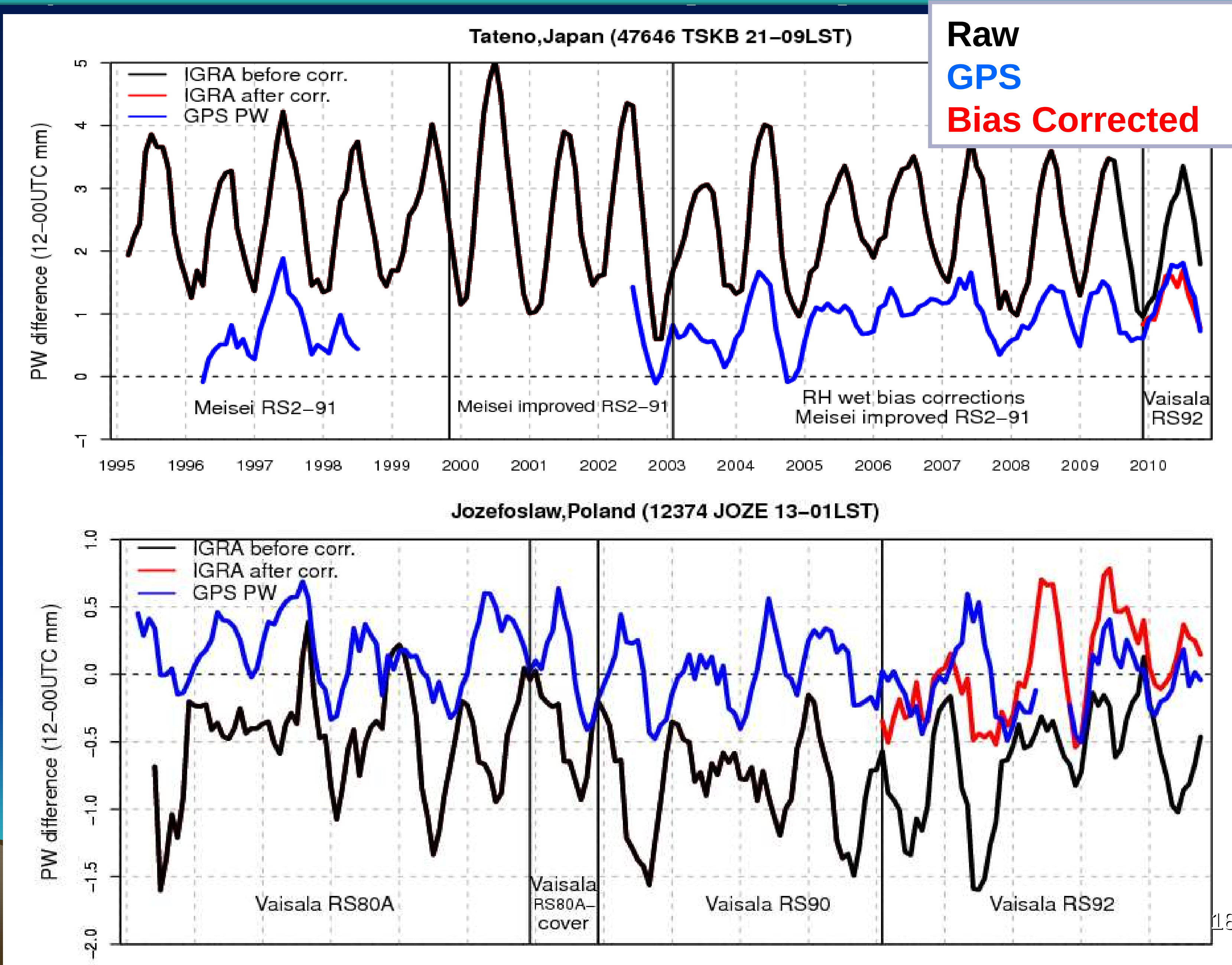
PW comparison (Radiosonde – GPS)



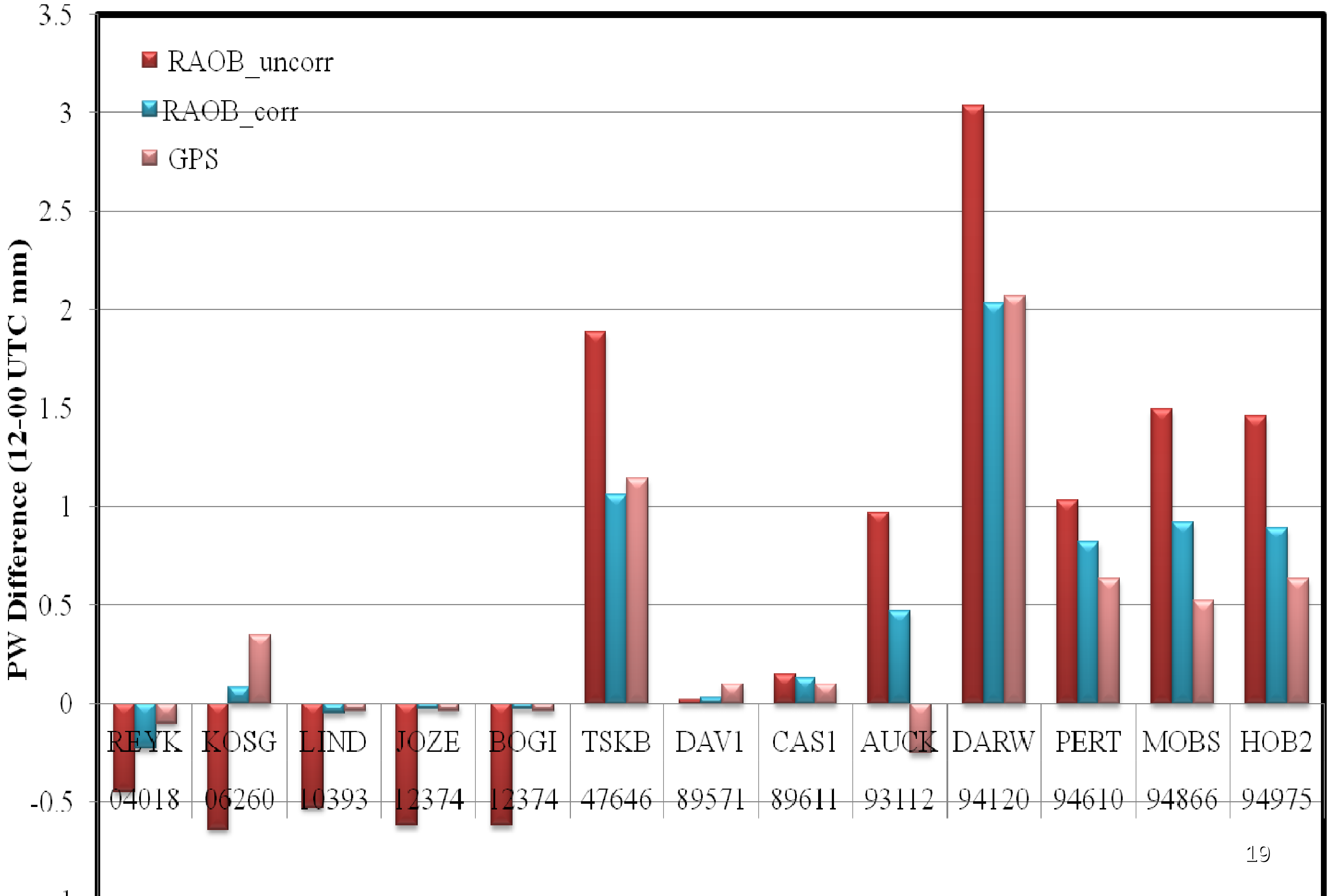
PW comparison with GPS (Diurnal Cycle)



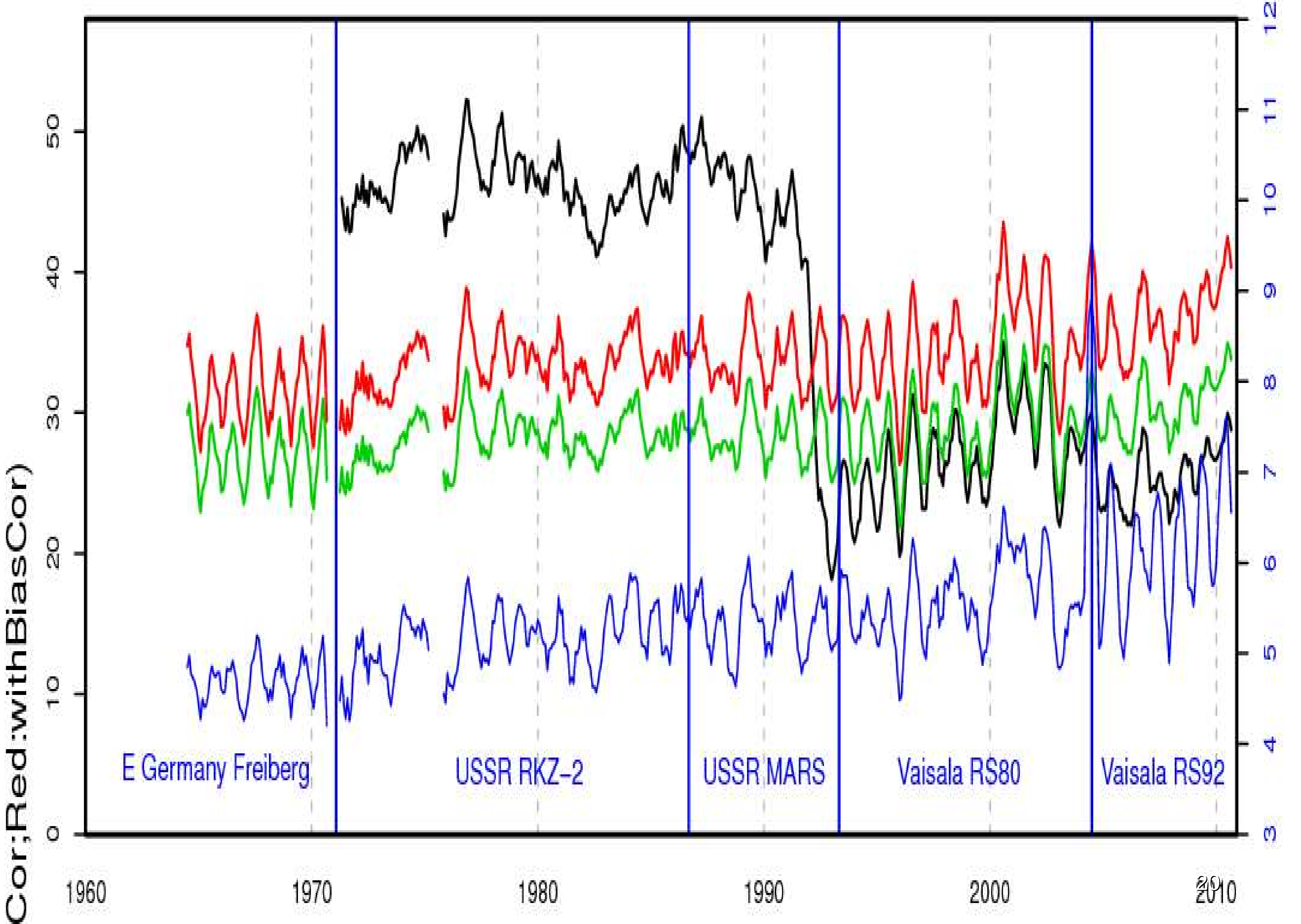
Impact on PW diurnal cycle (12 – 00 UTC)

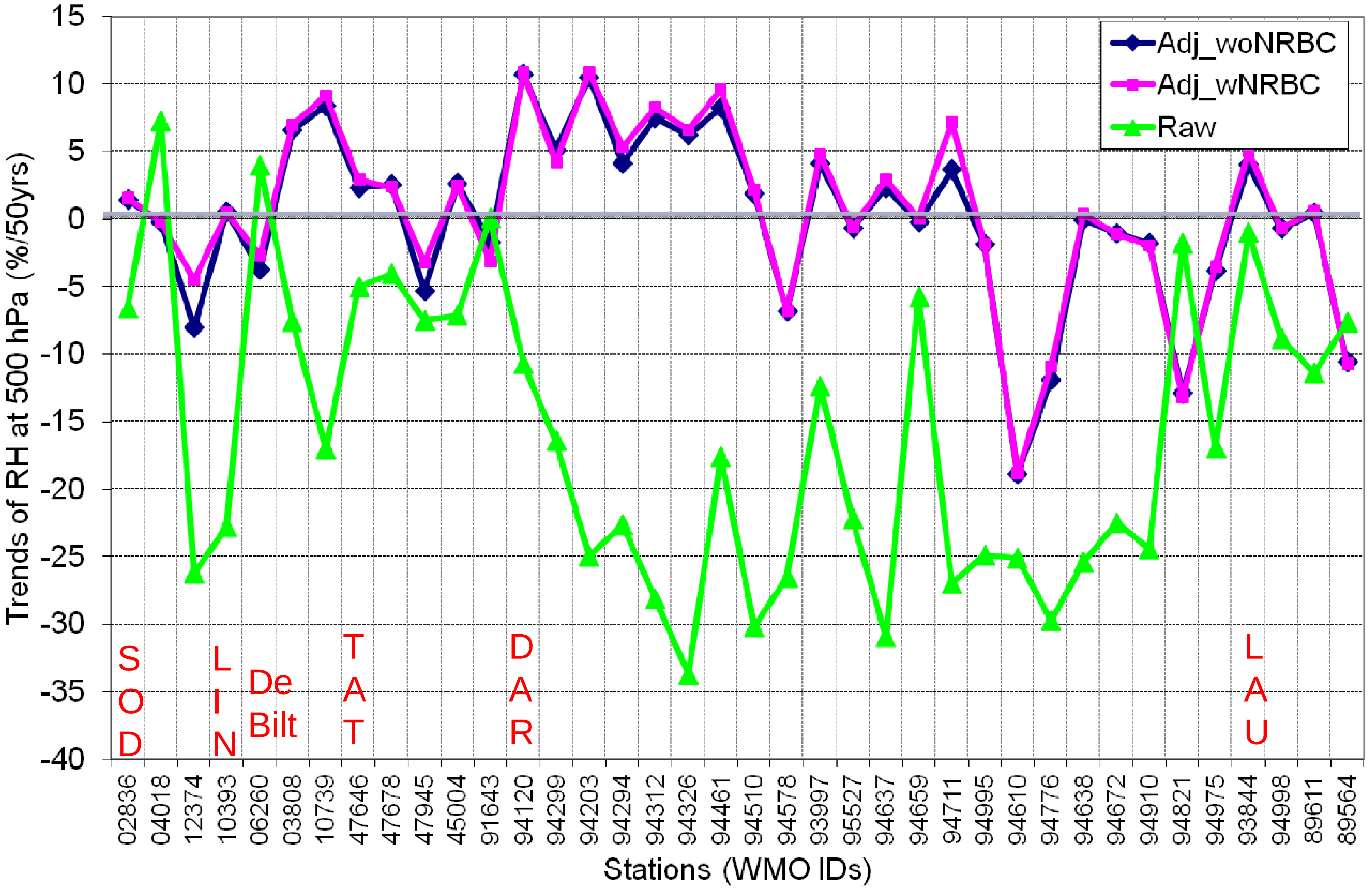


Impact on PW diurnal cycle (12 – 00 UTC)



Raw Adj_woBiasCorr Adj_wBiasCorr **300 hPa (5.27±1.06%)**




Adj_woNRBC
Adj_wNRBC
Raw
Trends of RH at 500 hPa (%/50yrs)
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
SOD
LIN
De Bilt
TAT
DAR
LAU
02836
04018
12374
10393
06260
03808
10739
47646
47678
47945
45004
91643
94120
94299
94203
94294
94312
94326
94461
94510
94578
93997
95527
94637
94659
94711
94995
94610
94776
94638
94672
94910
94821
94975
93844
94998
89611
89564
Stations (WMO IDs)

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Conclusions

Significance to GRUAN:

✓ Meet one of GRUAN goals: "Constrain and calibrate data from more spatially-comprehensive global observing systems";

✓ First time to use GRUAN data???;

✓ First time to apply physical-based bias corrections to historical daily radiosonde humidity data;

✓ Highlight the importance of "Management of Change".

Homogenization leads to:

✓ temporally more homogenous humidity data;

✓ smaller, spatially-more-coherent long term trends.

RS92 bias corrections lead to:

✓ reduced bias comparing with GPS PW data;

✓ better agreements with GPS on PW diurnal cycle in phase, magnitude and its seasonal variations;

✓ consistently larger RH values throughout the time record comparing with the adjusted data without corrections;

✓ insignificant impact on long-term trends.

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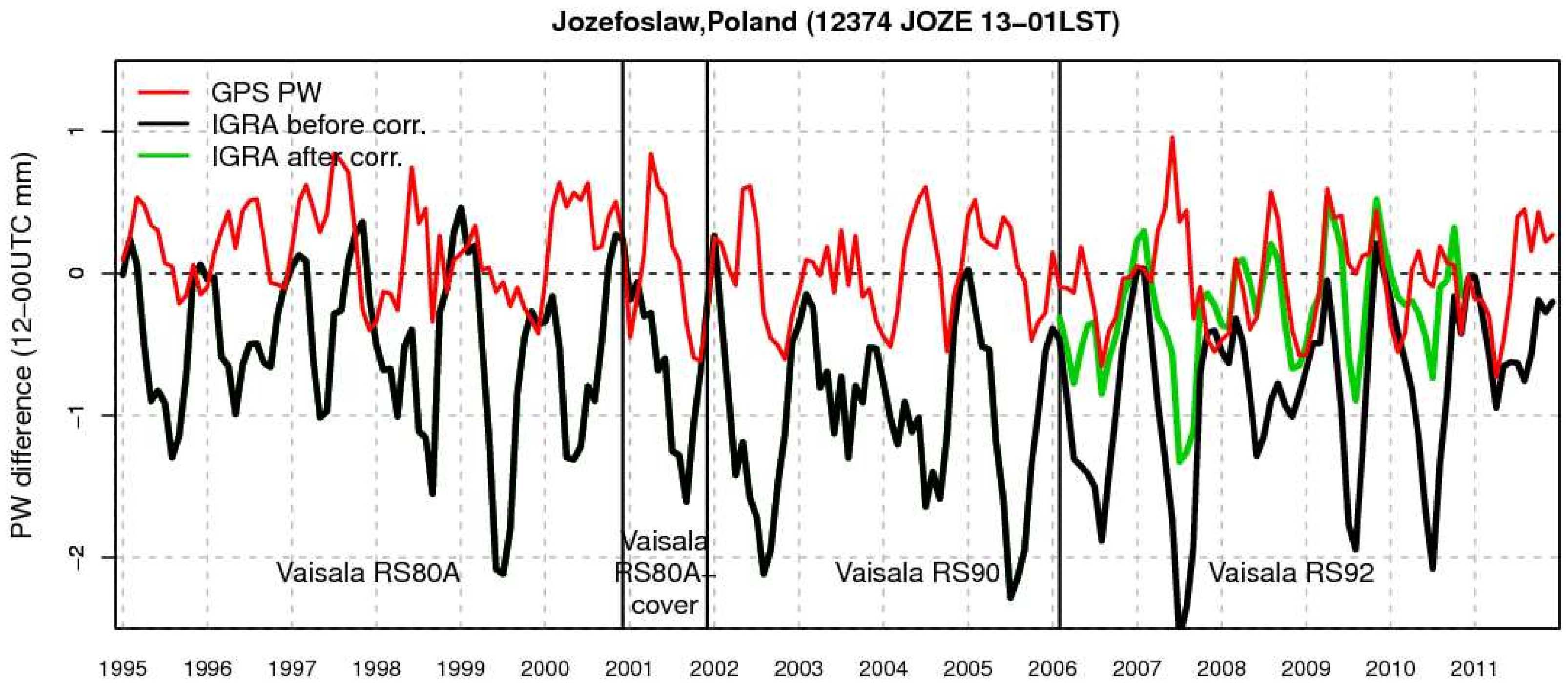
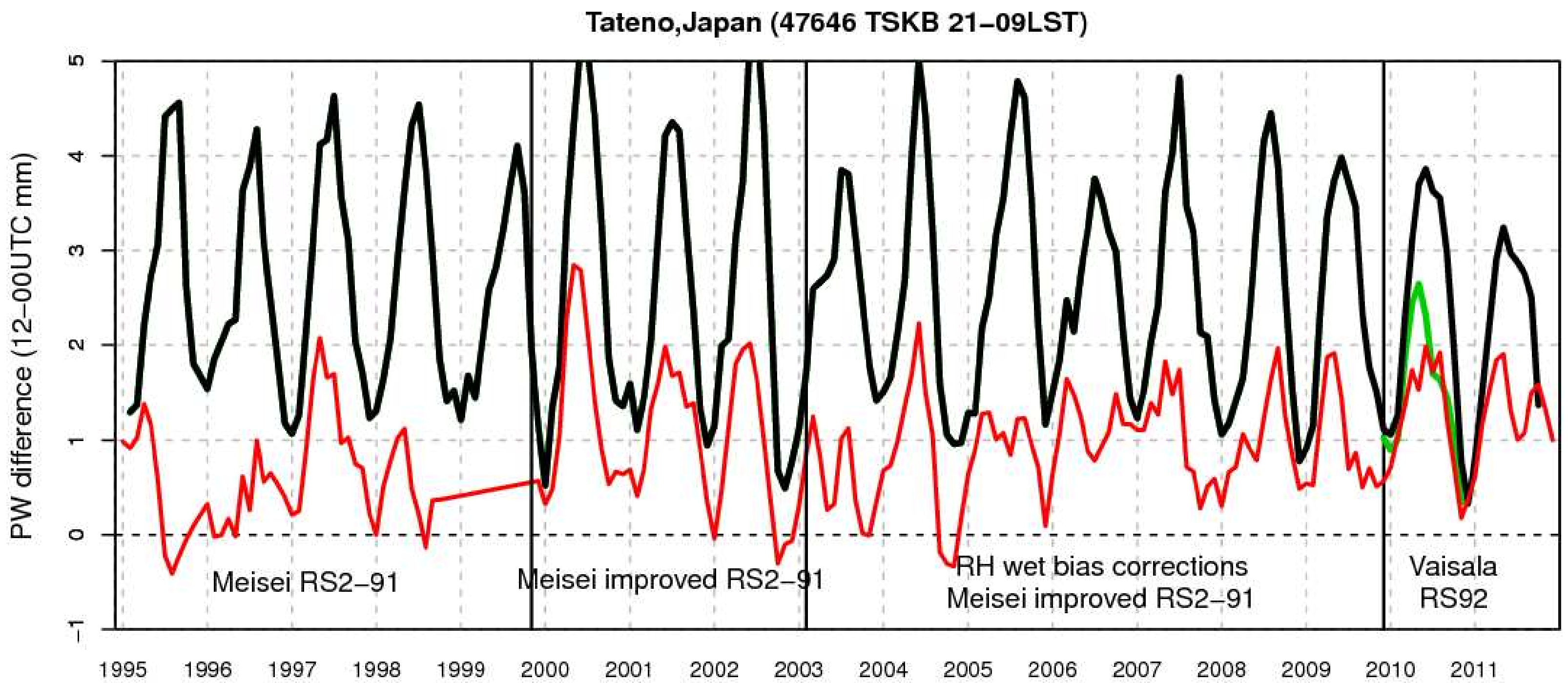
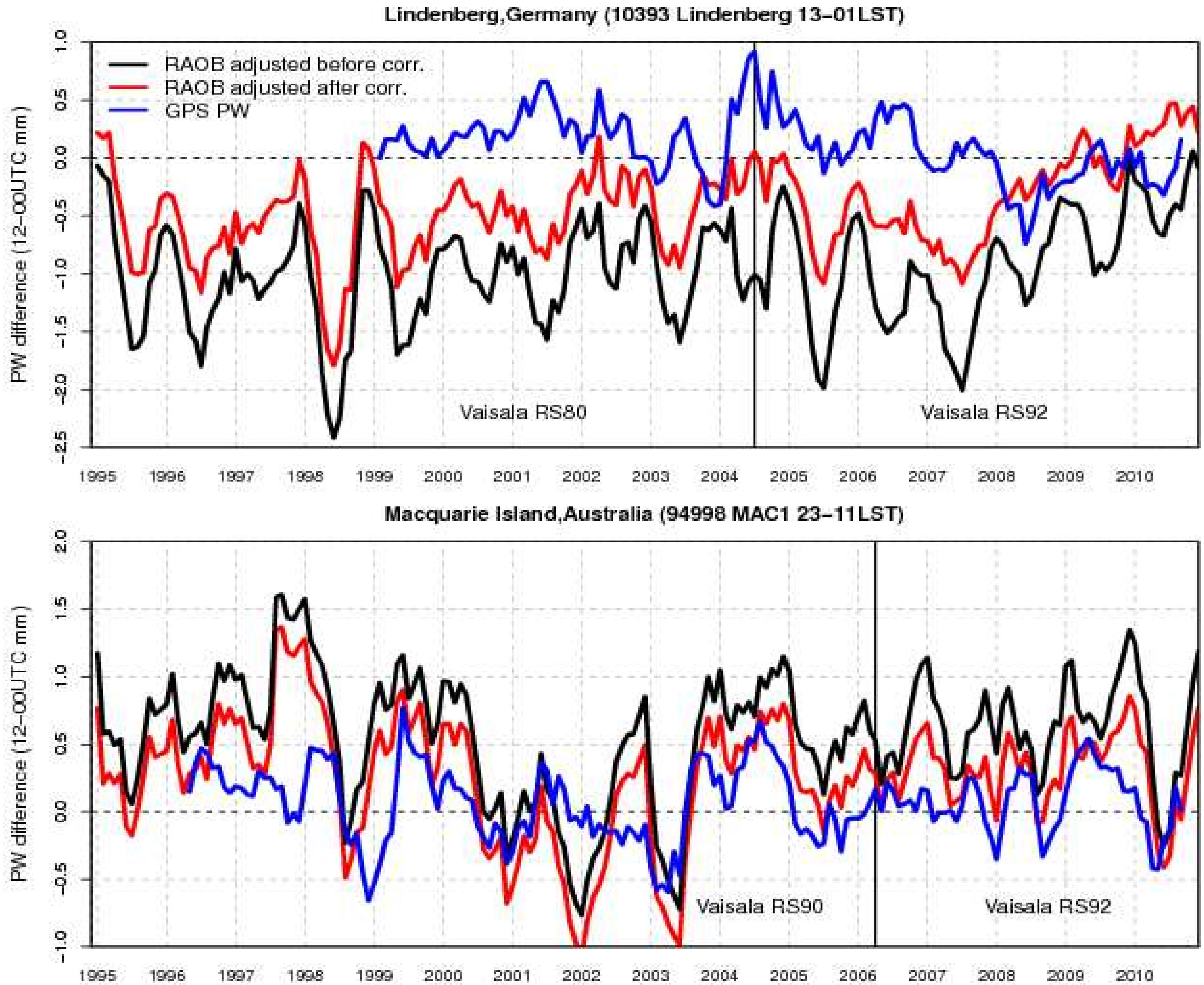
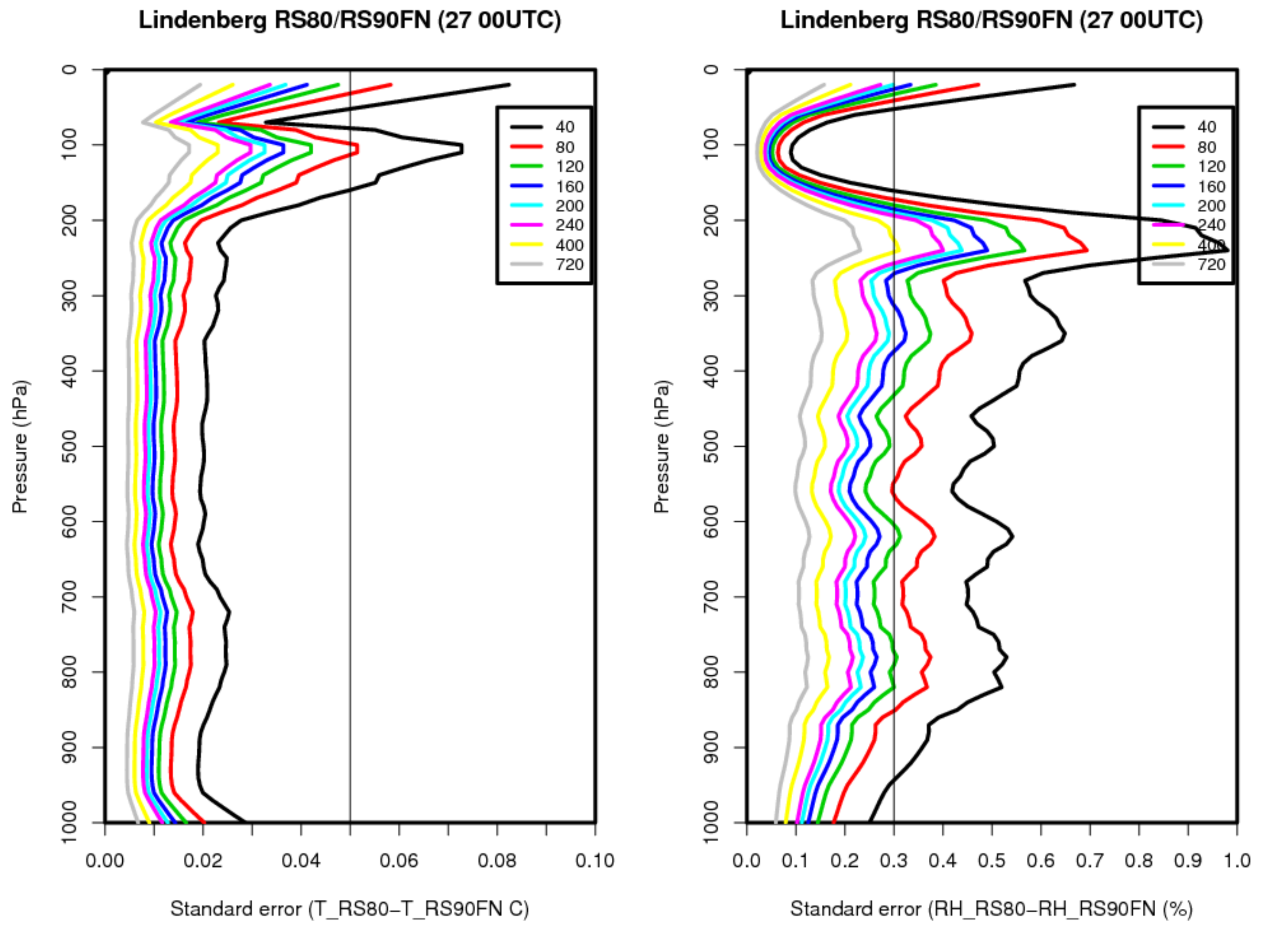
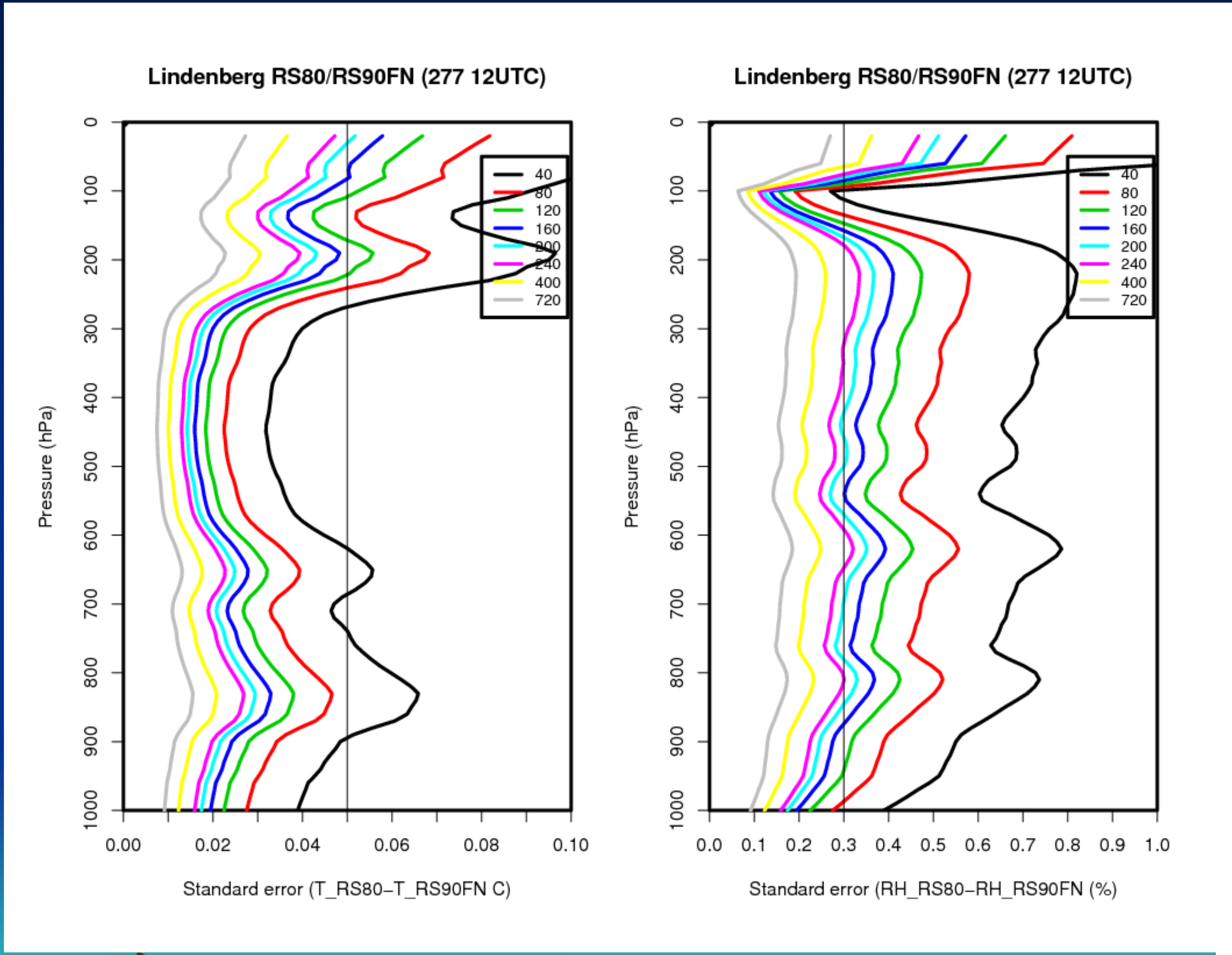

Jozefoslaw,Poland (12374 JOZE 13–01LST)
GPS PW
IGRA before corr.
IGRA after corr.
PW difference (12–00UTC mm)
Vaisala RS80A
Vaisala RS80A+ cover
Vaisala RS90
Vaisala RS92
1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011


Tateno,Japan (47646 TSKB 21–09LST)
PW difference (12–00UTC mm)
Meisei RS2–91
Meisei improved RS2–91
RH wet bias corrections
Meisei improved RS2–91
Vaisala RS92
1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011


Lindenberg,Germany (10393 Lindenberg 13-01LST)
RAOB adjusted before corr.
RAOB adjusted after corr.
GPS PW
PW difference (12-00UTC mm)
Vaisala RS80
Vaisala RS92
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Macquarie Island,Australia (94998 MAC1 23-11LST)
PW difference (12-00UTC mm)
Vaisala RS90
Vaisala RS92


Lindenberg RS80/RS90FN (27 00UTC)
Pressure (hPa)
Standard error (T_RS80−T_RS90FN C)
Lindenberg RS80/RS90FN (27 00UTC)
Pressure (hPa)
Standard error (RH_RS80−RH_RS90FN (%)
40
80
120
160
200
240
400
720


Lindenberg RS80/RS90FN (277 12UTC)
Pressure (hPa)
0
100
200
300
400
500
600
700
800
900
1000
0.00
0.02
0.04
0.06
0.08
0.10
Standard error (T_RS80−T_RS90FN C)
40
80
120
160
200
240
400
720
Lindenberg RS80/RS90FN (277 12UTC)
Pressure (hPa)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Standard error (RH_RS80−RH_RS90FN (%)

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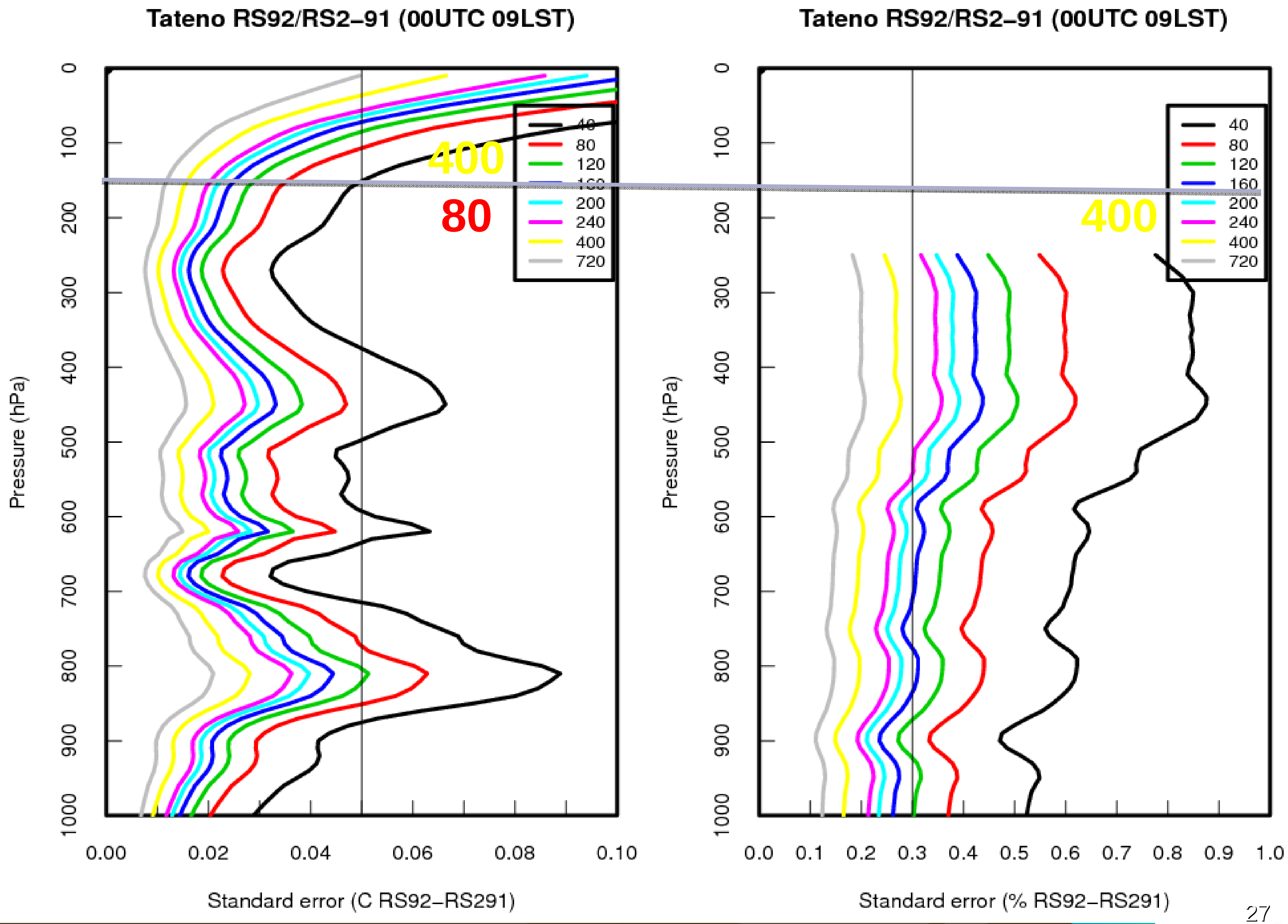
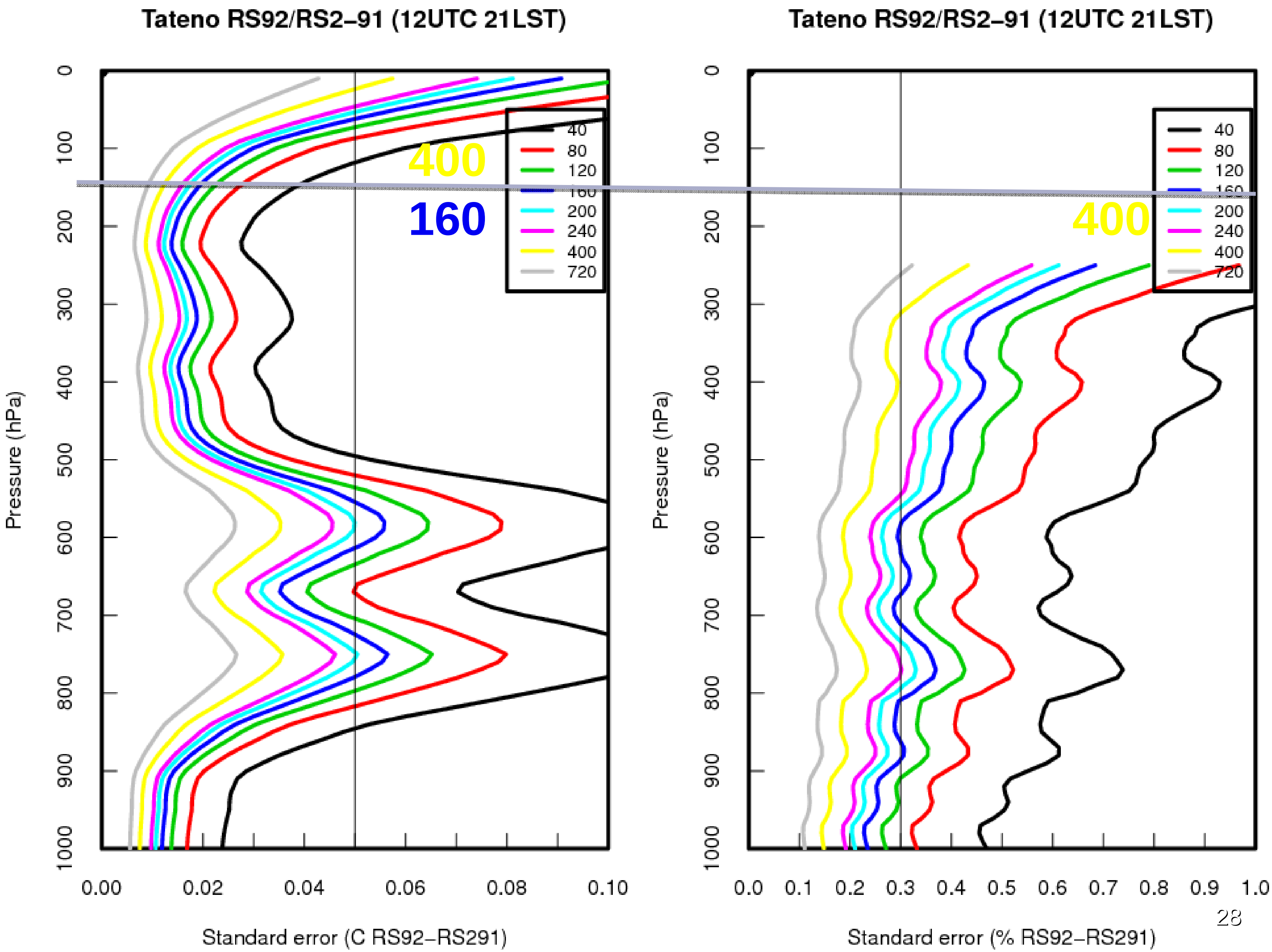
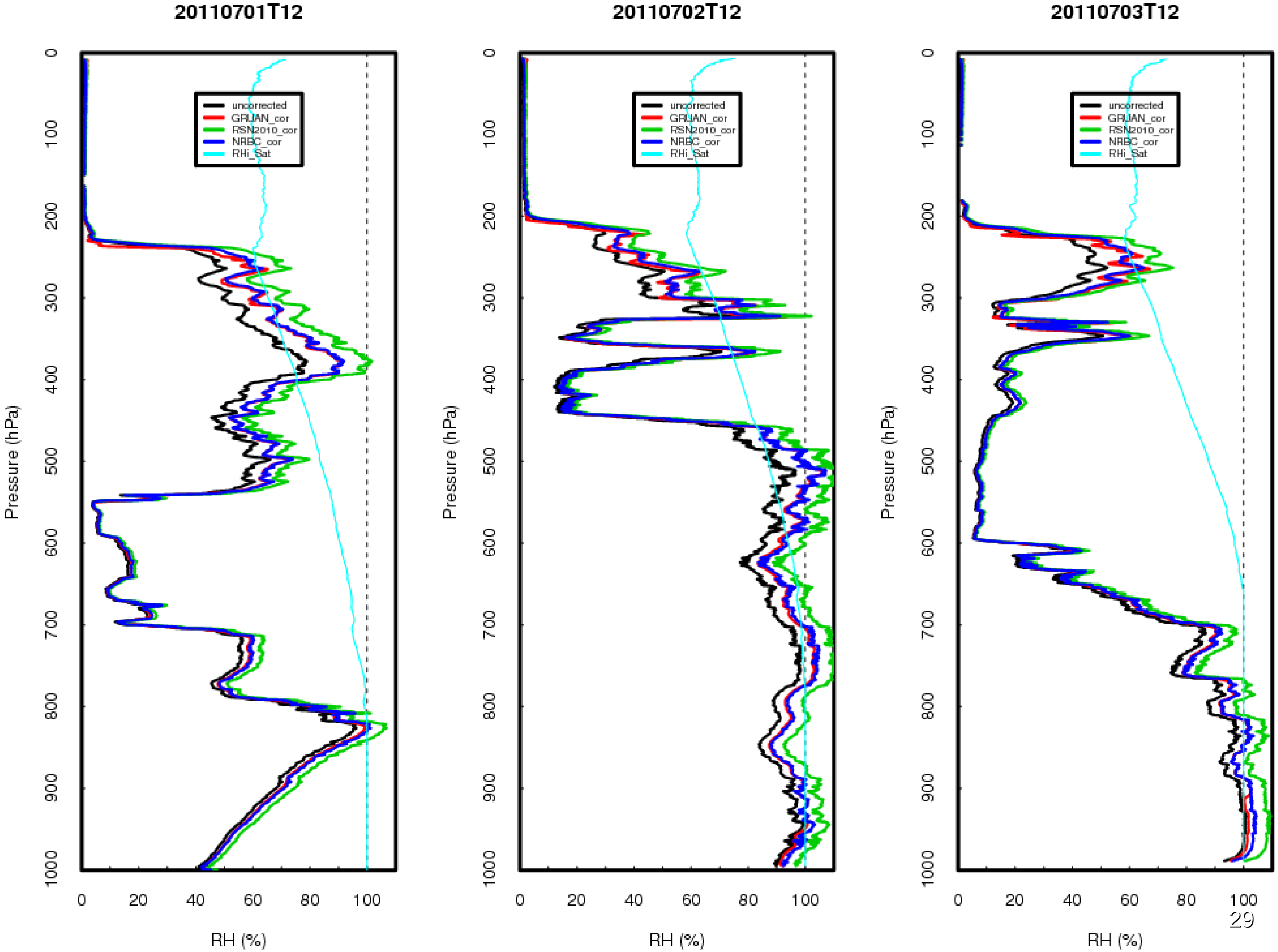
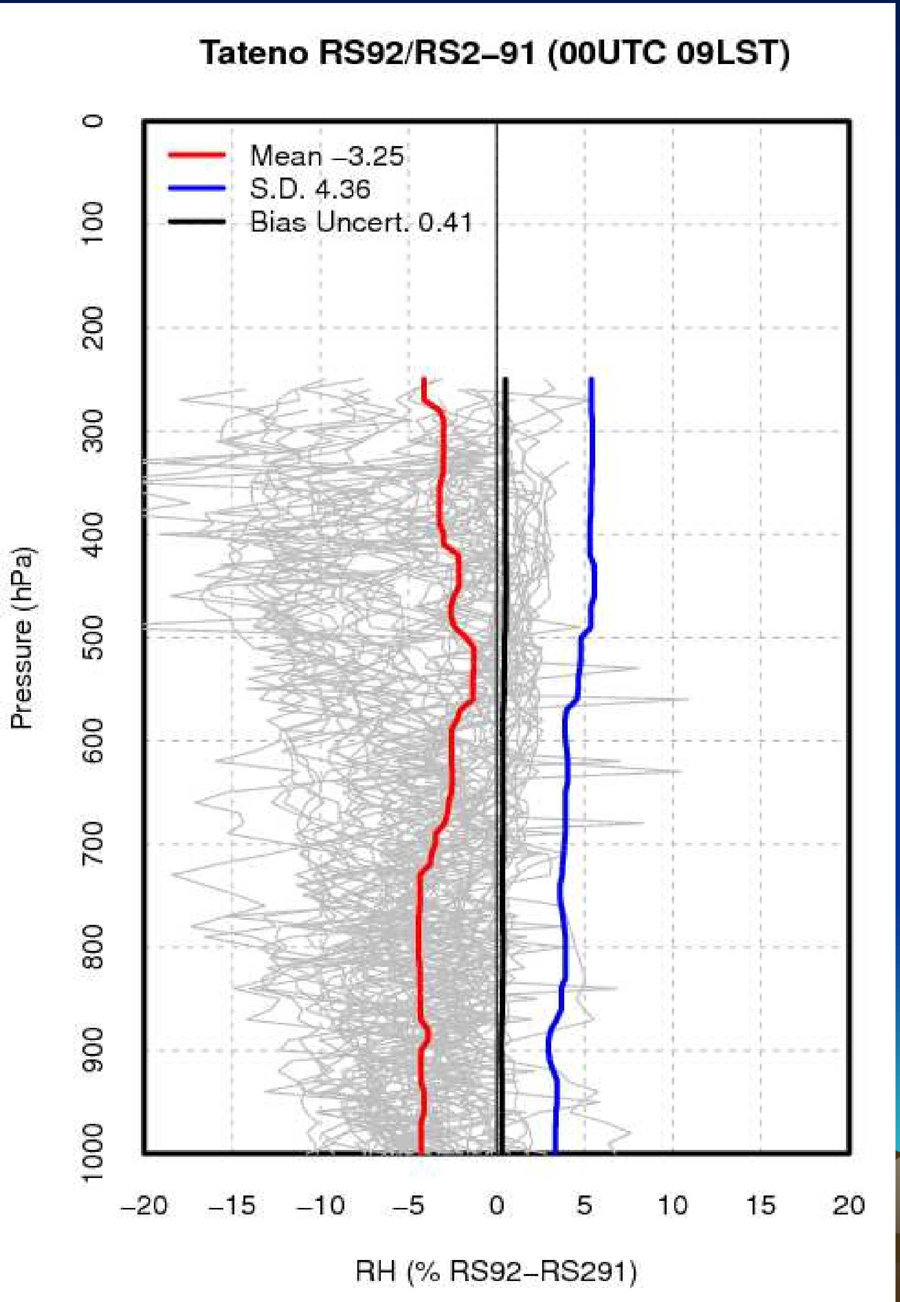


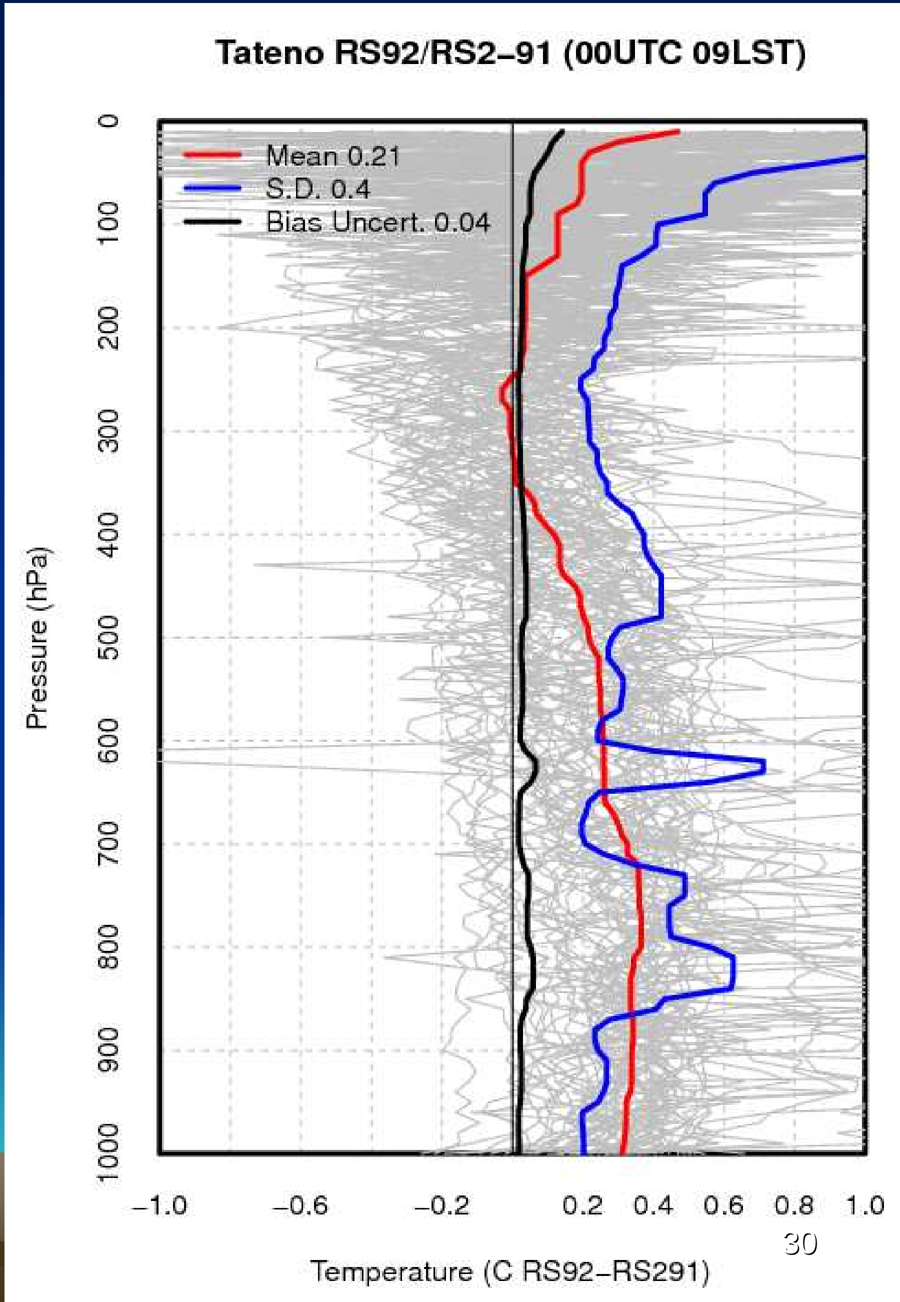
Tateno RS92/RS2–91 (00UTC 09LST)
Pressure (hPa)
Standard error (C RS92–RS291)
400
80
40
80
120
160
200
240
400
720
0
100
200
300
400
500
600
700
800
900
1000
0.00
0.02
0.04
0.06
0.08
0.10
Tateno RS92/RS2–91 (00UTC 09LST)
Pressure (hPa)
Standard error (% RS92–RS291)
400
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0


Tateno RS92/RS2–91 (12UTC 21LST)
Pressure (hPa)
Standard error (C RS92–RS291)
400
160
40
80
120
160
200
240
400
720
Tateno RS92/RS2–91 (12UTC 21LST)
Pressure (hPa)
Standard error (% RS92–RS291)
400

Uncorrected **NCAR_corr** **GRUAN_corr**

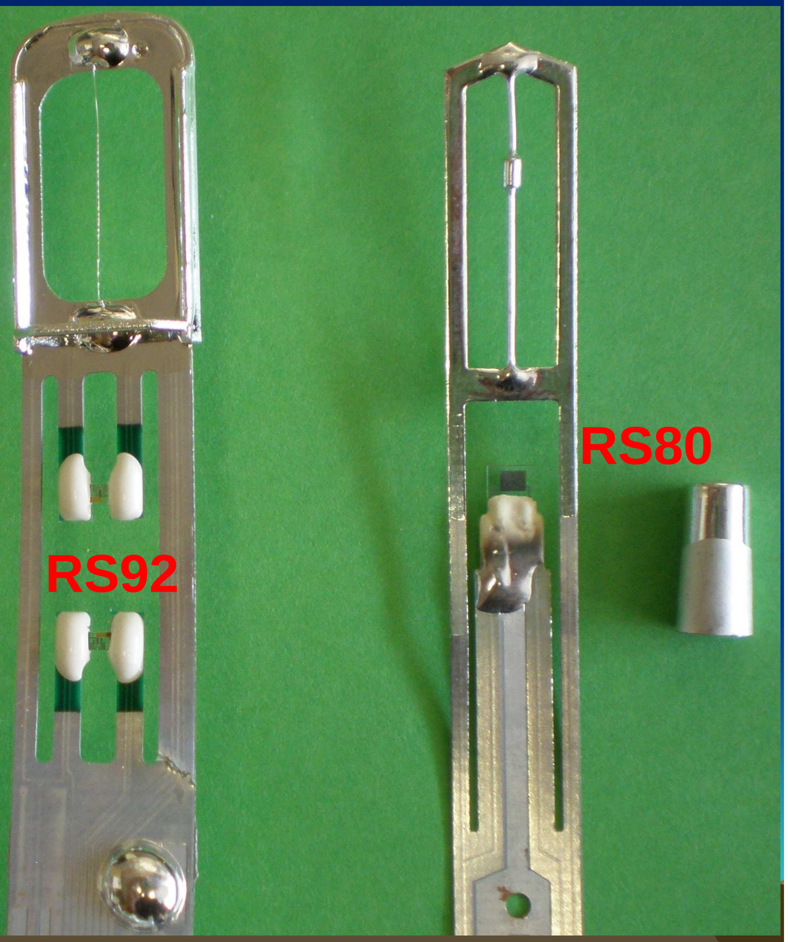


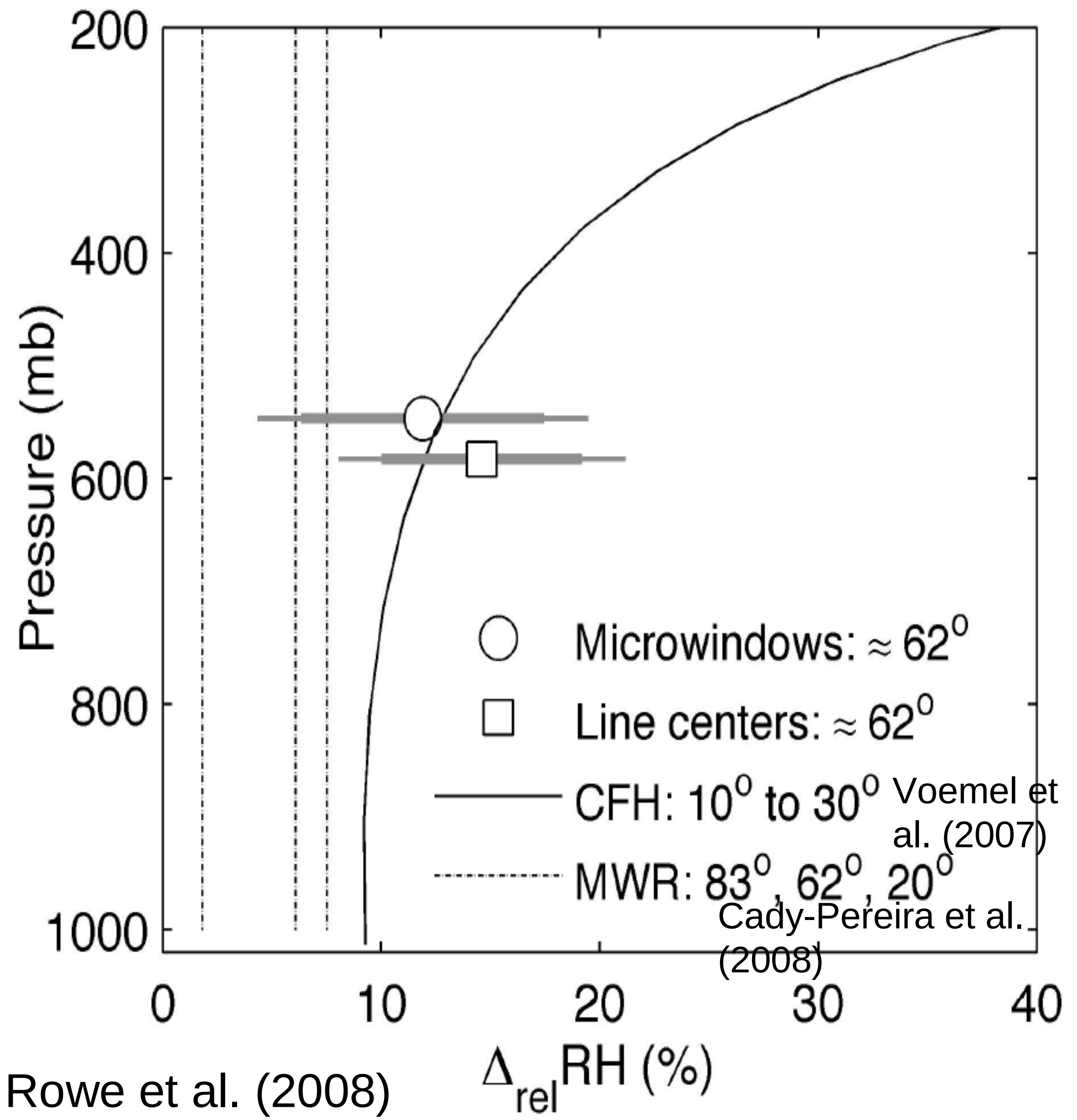

Tateno RS92/RS2–91 (00UTC 09LST)
Mean –3.25
S.D. 4.36
Bias Uncert. 0.41
Pressure (hPa)
0
100
200
300
400
500
600
700
800
900
1000
–20
–15
–10
–5
0
5
10
15
20
RH (% RS92–RS291)


Tateno RS92/RS2–91 (00UTC 09LST)
Mean 0.21
S.D. 0.4
Bias Uncert. 0.04
Pressure (hPa)
0
100
200
300
400
500
600
700
800
900
1000
–1.0
–0.6
–0.2
0.2
0.4
0.6
0.8
1.0
Temperature (C RS92–RS291)

Solar Radiation Dry Bias of Vaisala RS92

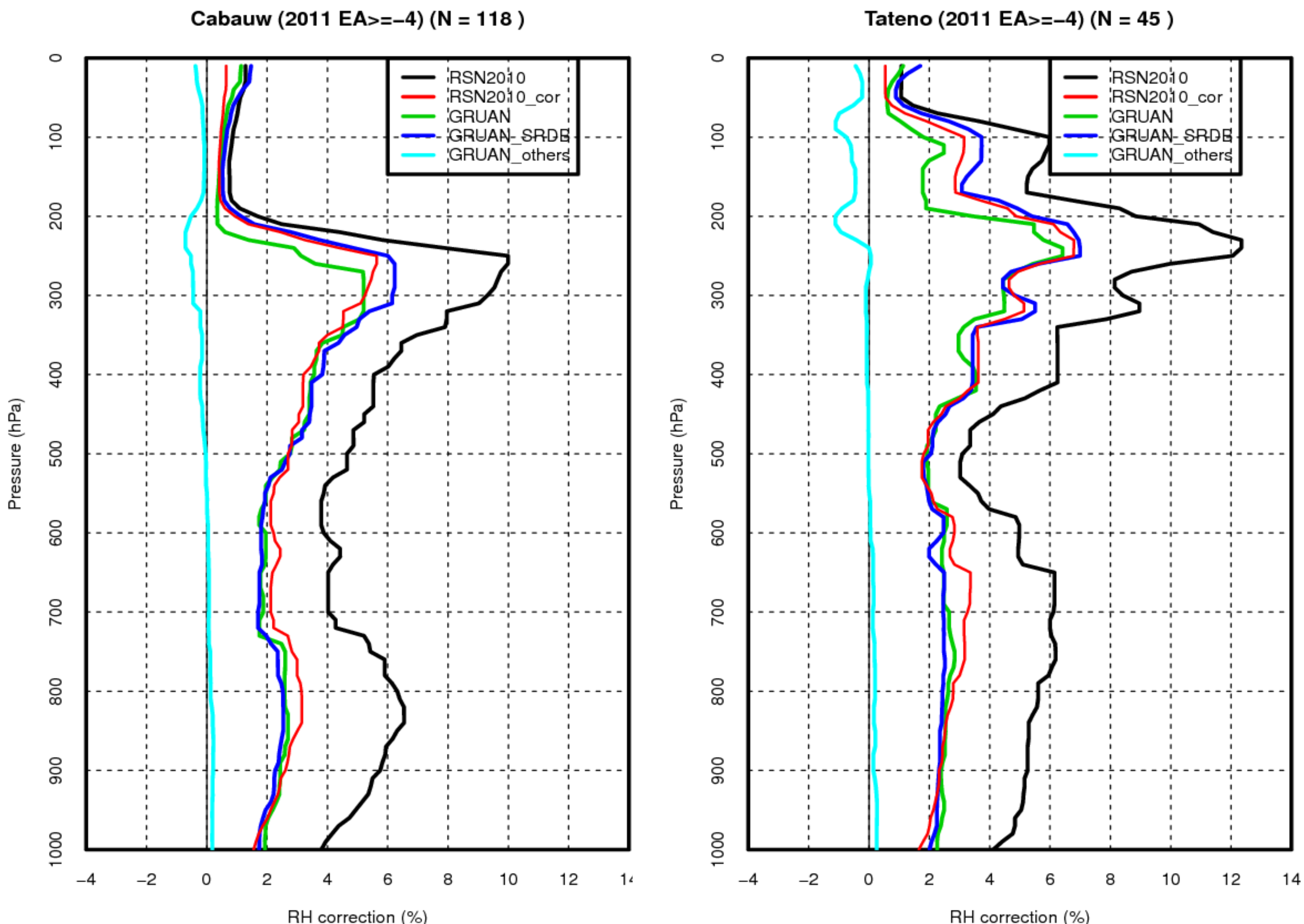
RS92: ~30% of global stations



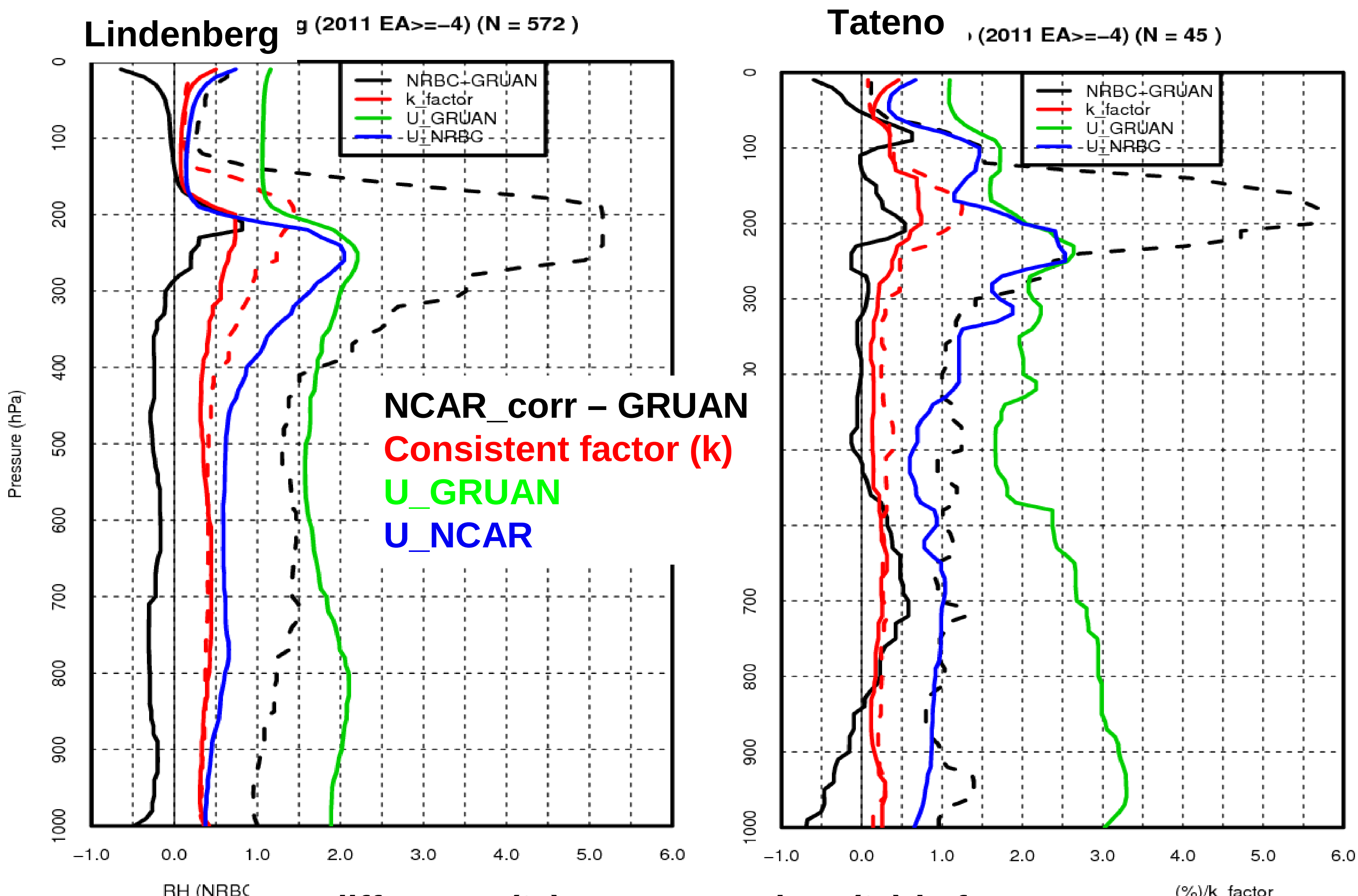


Rowe et al. (2008)

Variable	Temperature	Water Vapour	Pressure
Priority (1-4)	1	1	1
Measurement Range	170 – 350 K	0.1 – 90000 ppmv	1 –1100 hPa
Vertical Range	0 – 50 km	0 to ~30 km	0 – 50 km
Vertical Resolution	0.1 km (0 to ~30 km) 0.5 km (above ~30 km)	0.05 km (0 – 5 km) 0.1 km (5 to ~30 km)	0.1 hPa
Precision	0.2 K	2% (troposphere) * 5% (stratosphere)	0.01 hPa
Accuracy	0.1 K (troposphere) 0.2 K (stratosphere)	2% (troposphere) * 2% (stratosphere)	0.1 hPa
Long-Term Stability	0.05 K *	1% (0.3%/decade) *	0.1 hPa
Comments	*The signal of change over the satellite era is in the order of 0.1–0.2K/decade (cf. section 3.1), therefore long-term stability needs to be an order of magnitude smaller to avoid ambiguity	*Precision, accuracy and stability are relative with respect to mixing ratio	


Cabauw (2011 EA>=-4) (N = 118)
Tateno (2011 EA>=-4) (N = 45)
RSN2010
RSN2010_cor
GRUAN
GRUAN_SRDB
GRUAN_others
Pressure (hPa)
RH correction (%)
0
100
200
300
400
500
600
700
800
900
1000
-4
-2
0
2
4
6
8
10
12
14

Comparison with GRUAN Corrections (LIN/TAT)



RH difference (%), RH uncertainty (%) k_factor

Raw Adj_woBiasCorr Adj_wBiasCorr