Management of Changes in GRUAN:
Lessons learn from Lindenberg & Tateno radiosonde data

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Outline

‘Inevitable & desirable”

Changes: instrumentation, operating procedures, data processing algorithms, operators.

1. What is the problem?
2. Document and identify changes
3. Quantify and adjust changes
4. Recommendations on GRUAN practices

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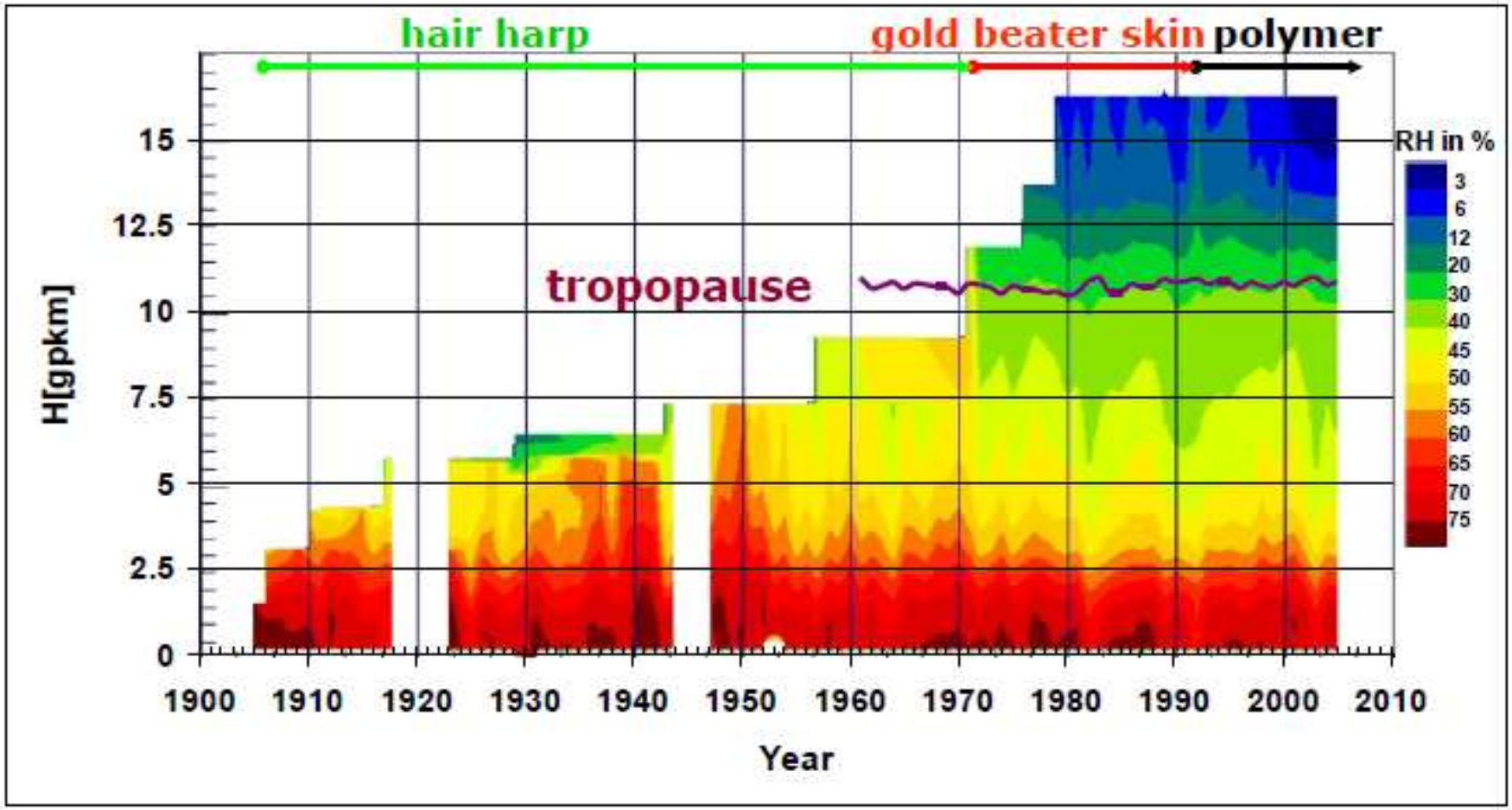
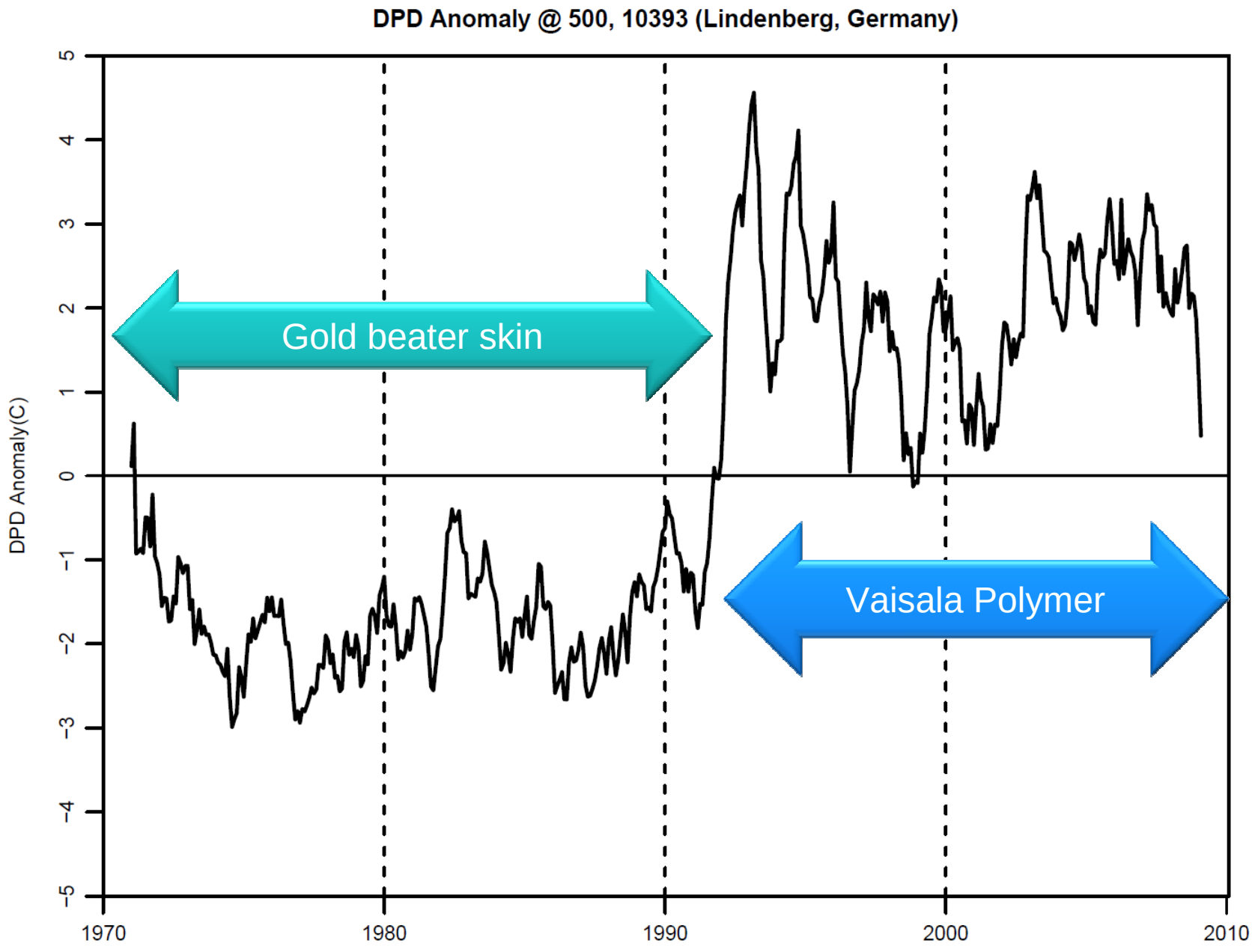
What is the problem?

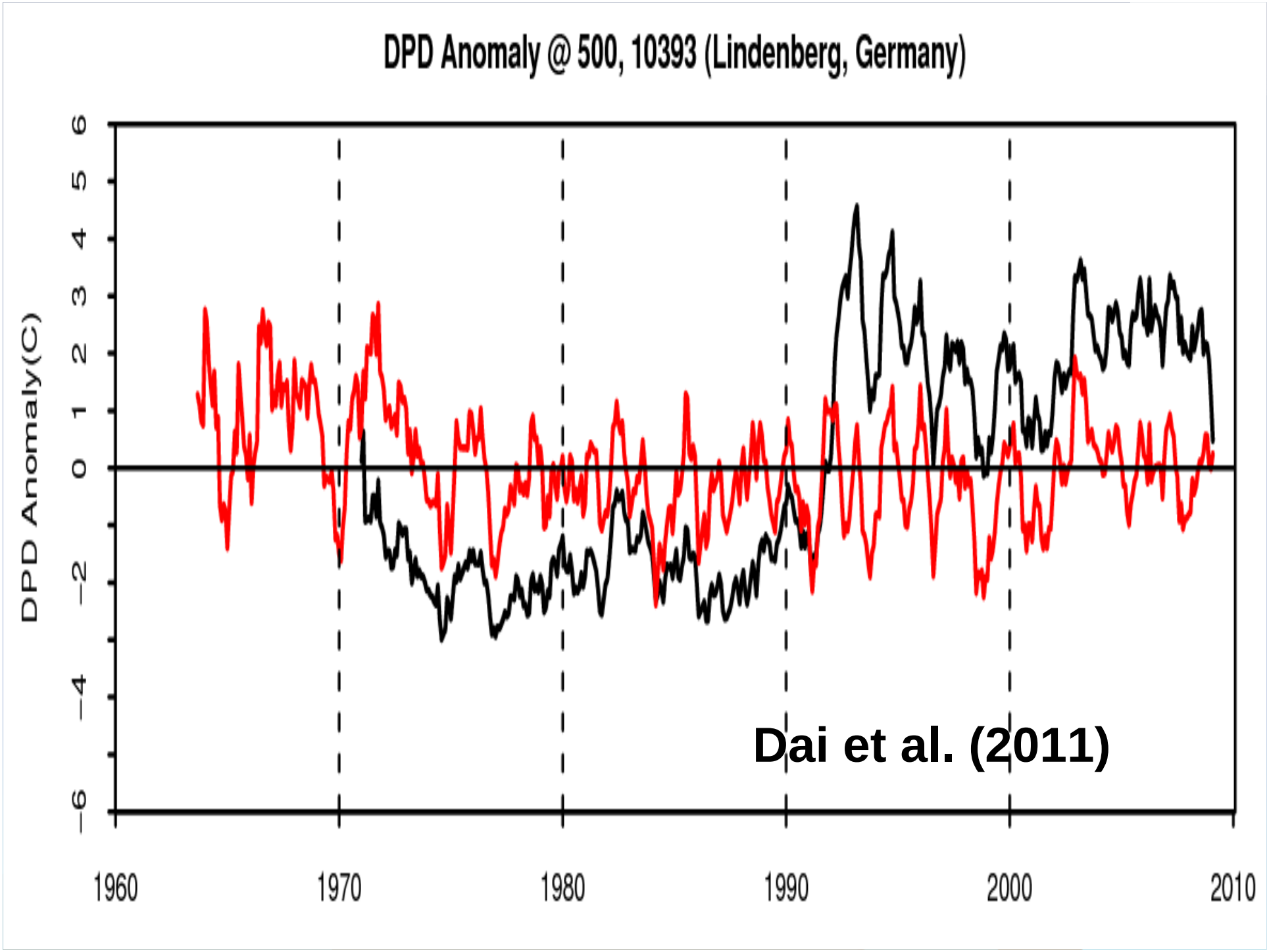
Humidity Profile Lindenberg / corrected:



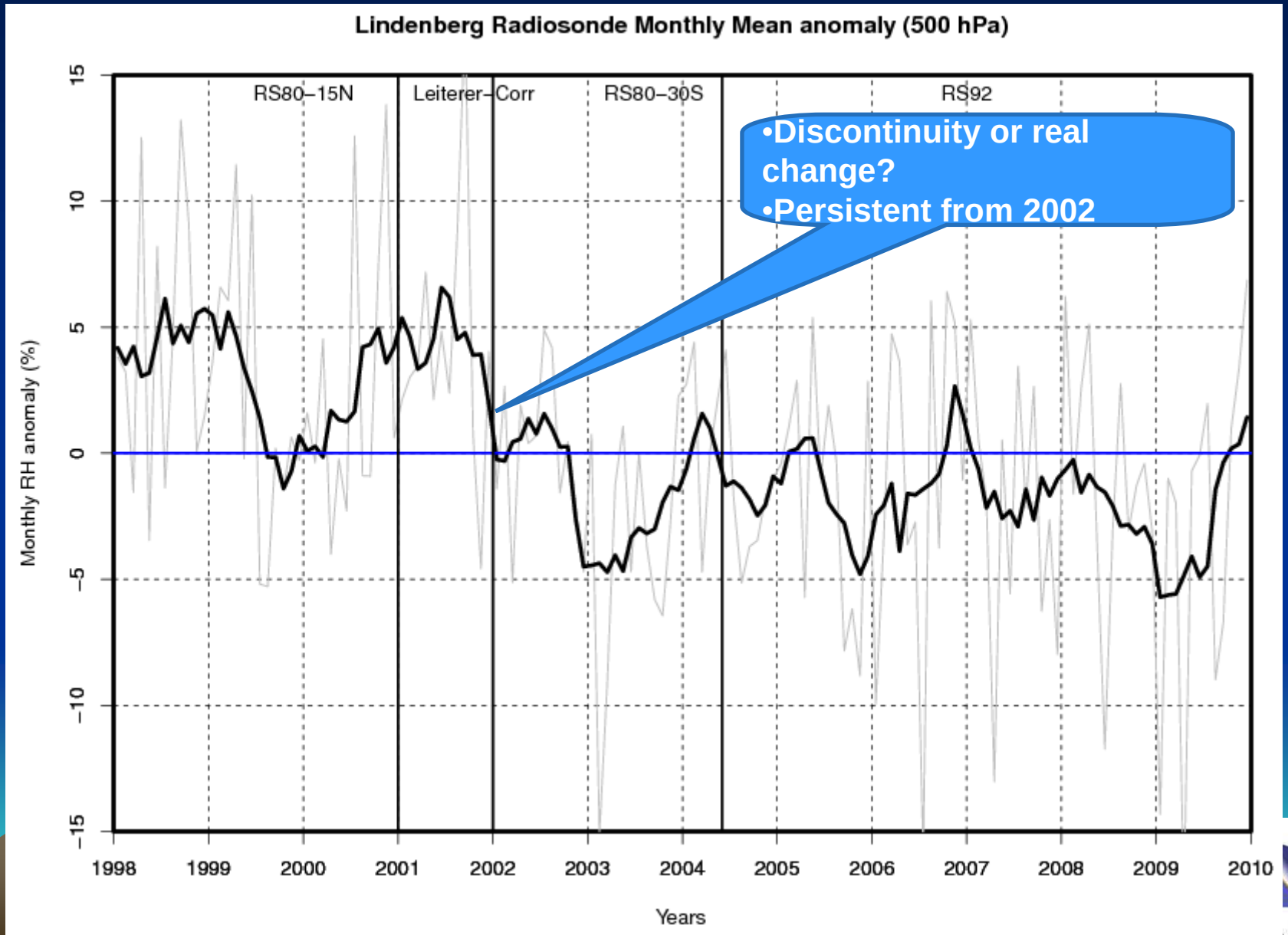
from Wolfgang Kusch

What is the problem?




DPD Anomaly @ 500, 10393 (Lindenberg, Germany)
DPD Anomaly(C)
6
5
4
3
2
1
0
−2
−4
−6
1960
1970
1980
1990
2000
2010
Dai et al. (2011)

Metadata for change point identification



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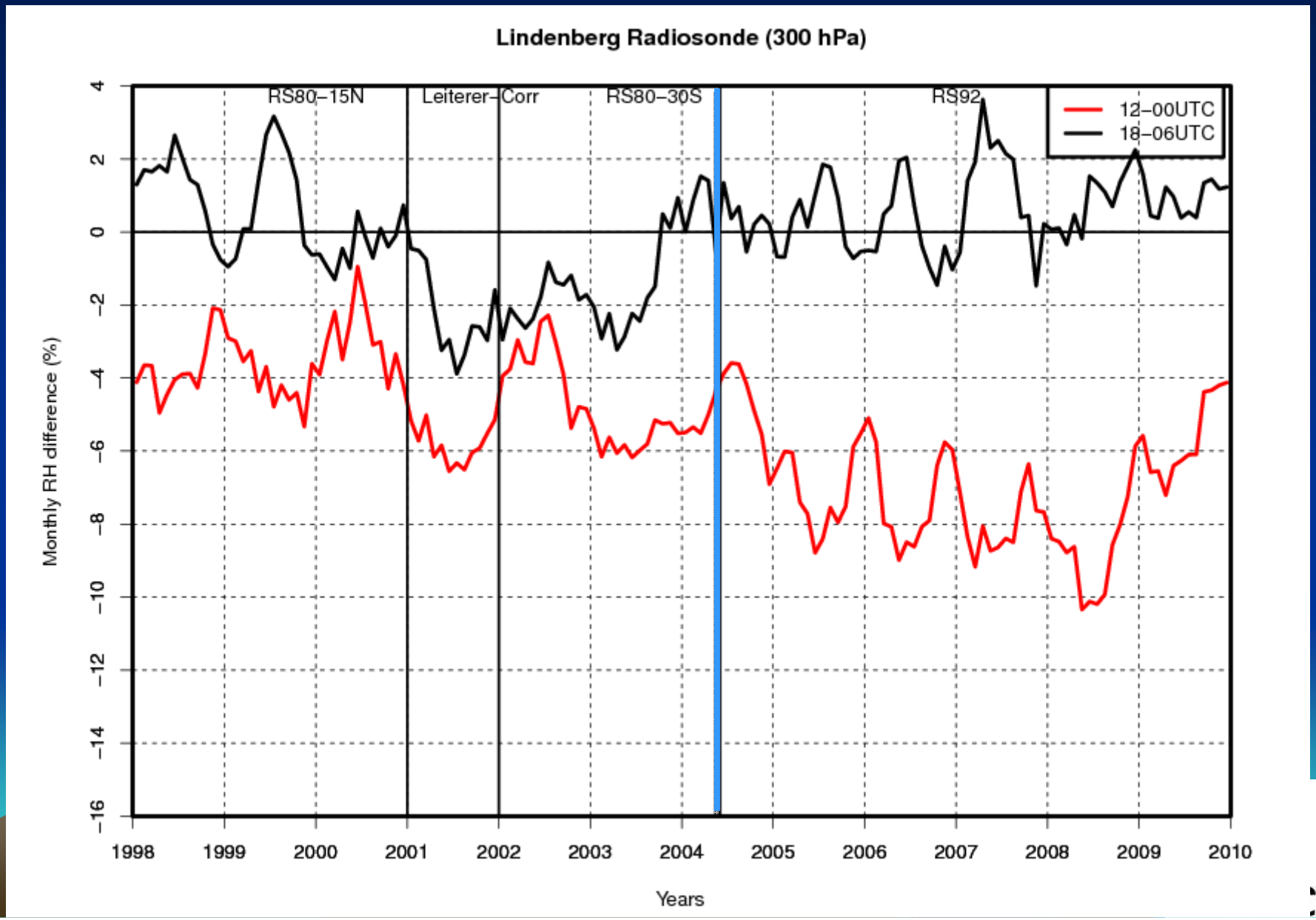
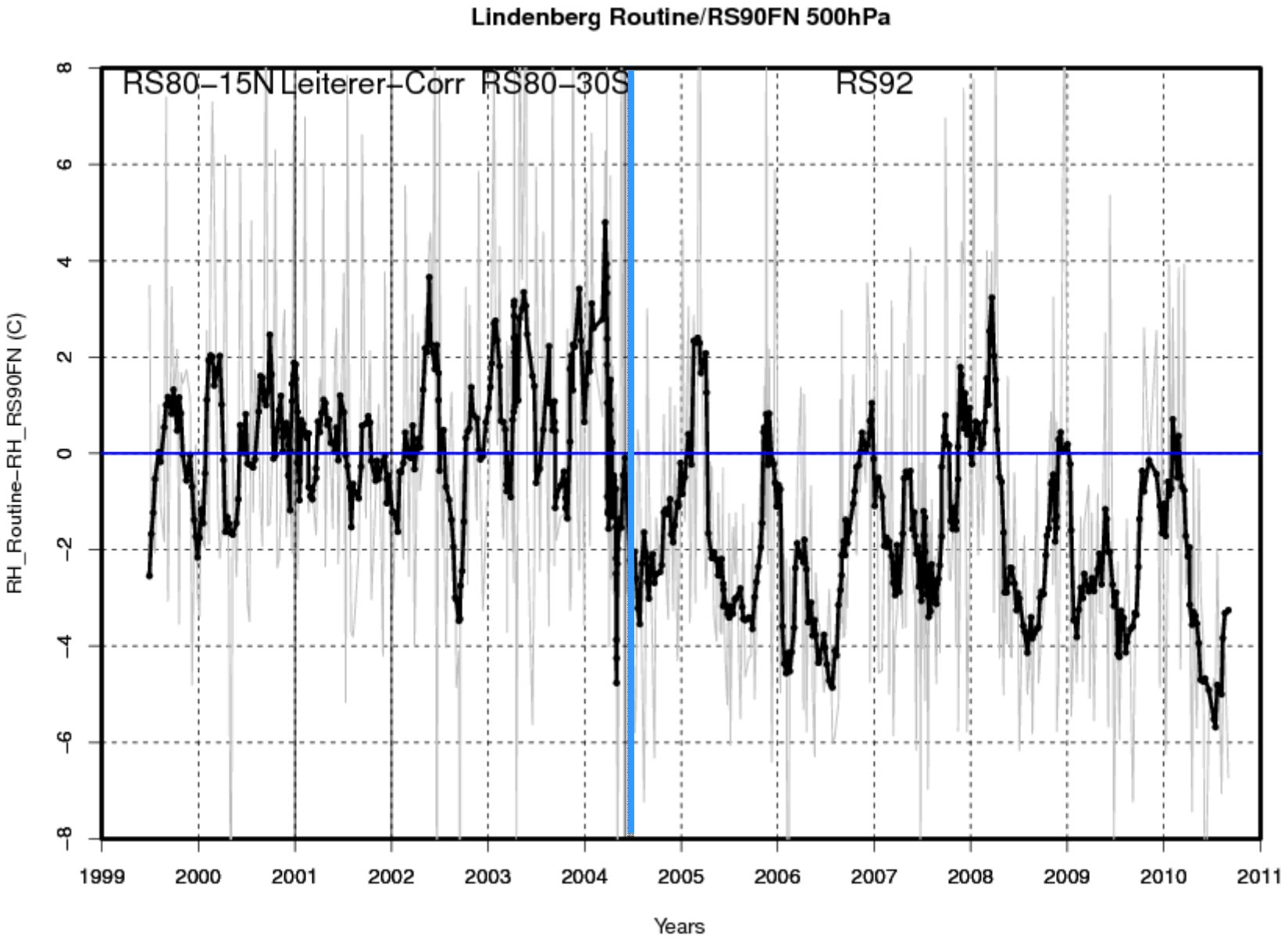
Solar Zenith Angle for CPI



Independent data for CPI



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Consistency test (Immler et al. 2010)

$\lvert m_1 - m_2 \rvert < k\sqrt{u_1^2 + u_2^2}$	TRUE	FALSE	significance level
k=1	consistent	suspicious	32%
k=2	in agreement	significantly different	4.5%
k=3	-	inconsistent	0.27%

- m_1 & u_1 are corrected RS92 data (GRUAN corrections)
- m_2 & u_2 are RS90FN data (corrected for T, but uncorrected for RH, u_2 = 2% for RH)

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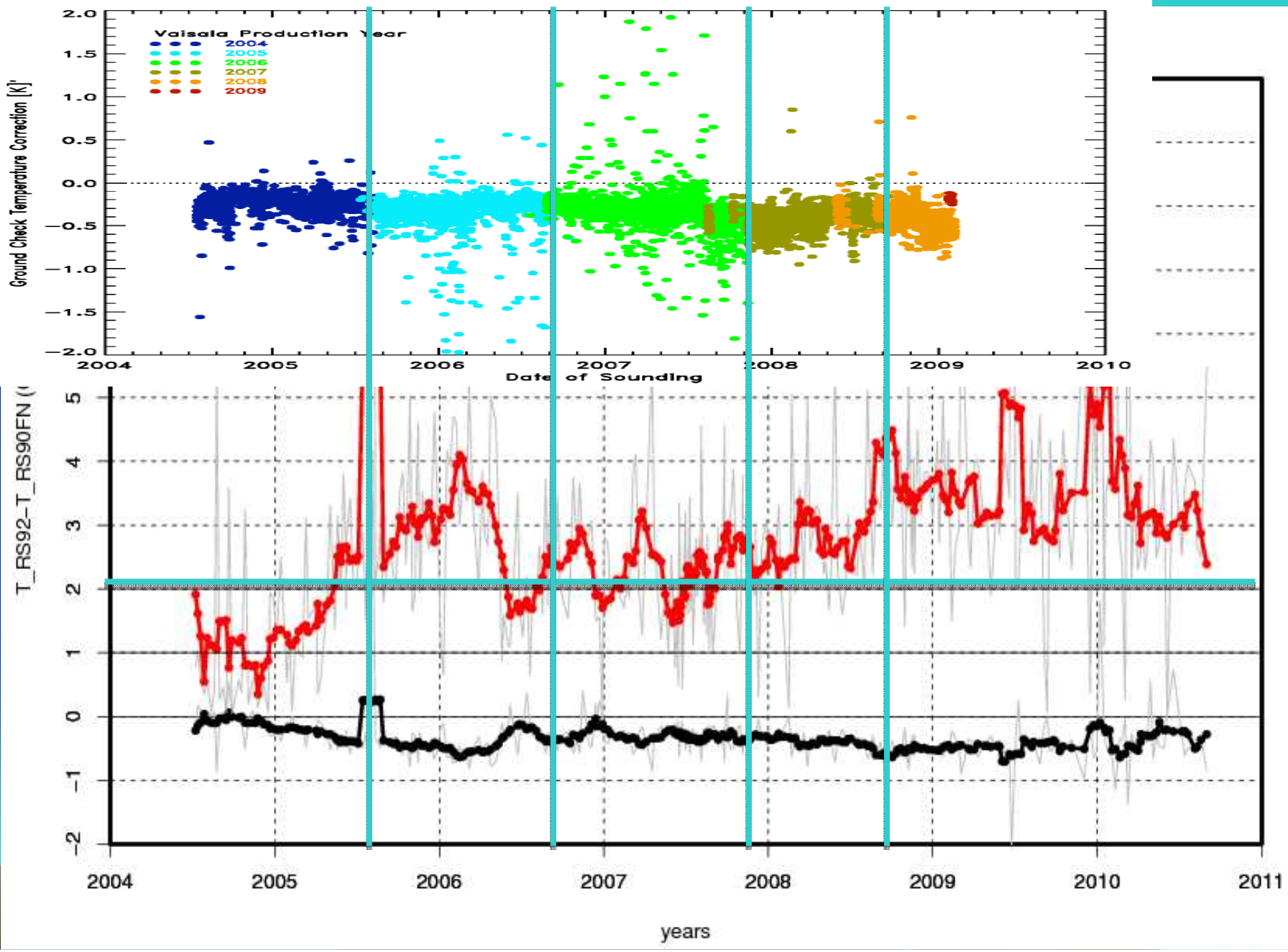
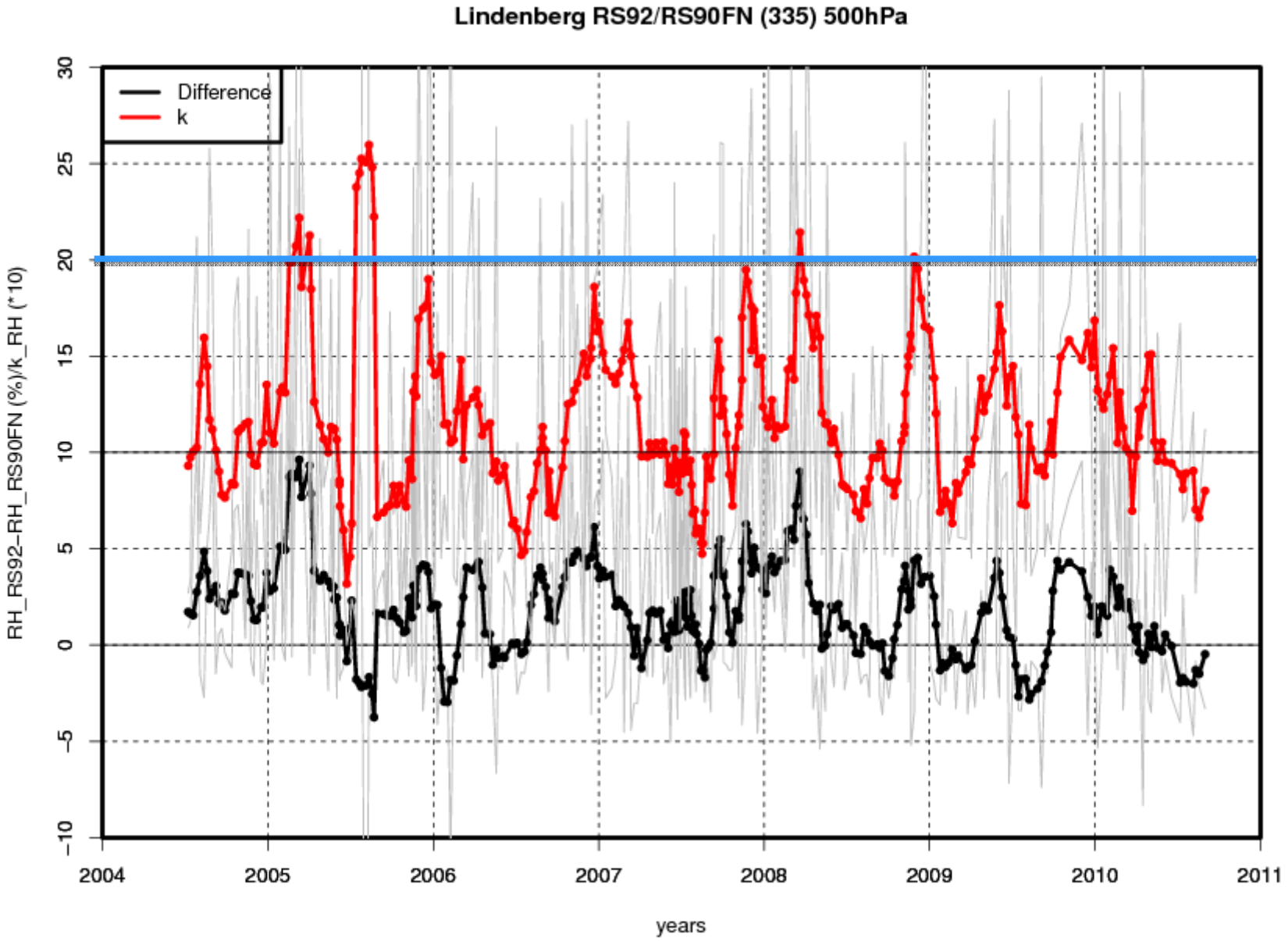
Temperature difference (Routine-FN) at 500 hPa



RH difference (RS92_corr-FN) at 500 hPa



Quantify and adjust changes

1. Independent, redundant measurements: ***routine vs RS90FN in Lindenberg***
2. Corrections of known errors/biases: ***GRUAN RS92 corrections***
3. Overlap dual-sonde (old vs new) data: ***Tateno case***
4. Statistical methods: ***Dai et al. (2011)***

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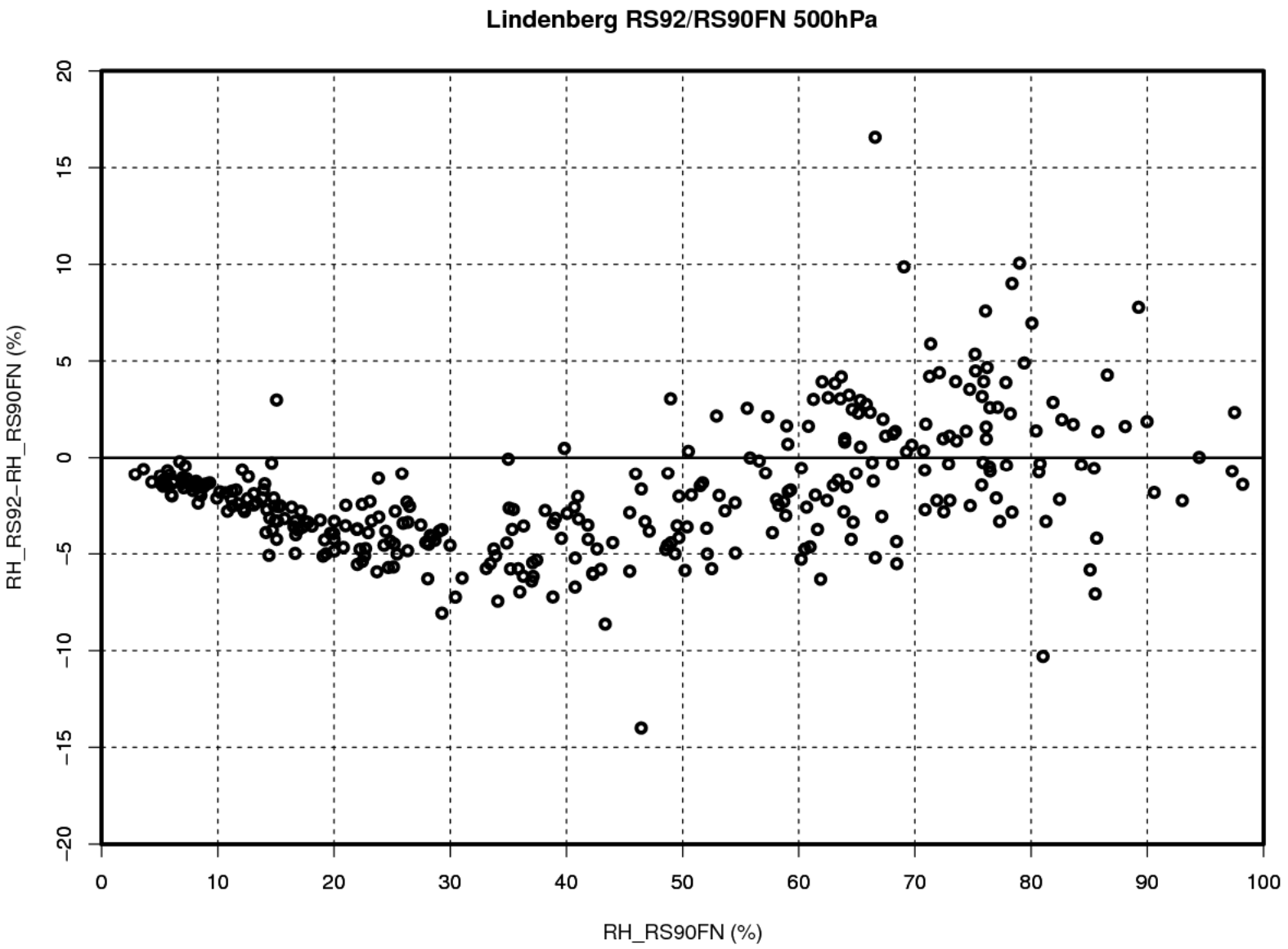
Independent reference: RS90FN



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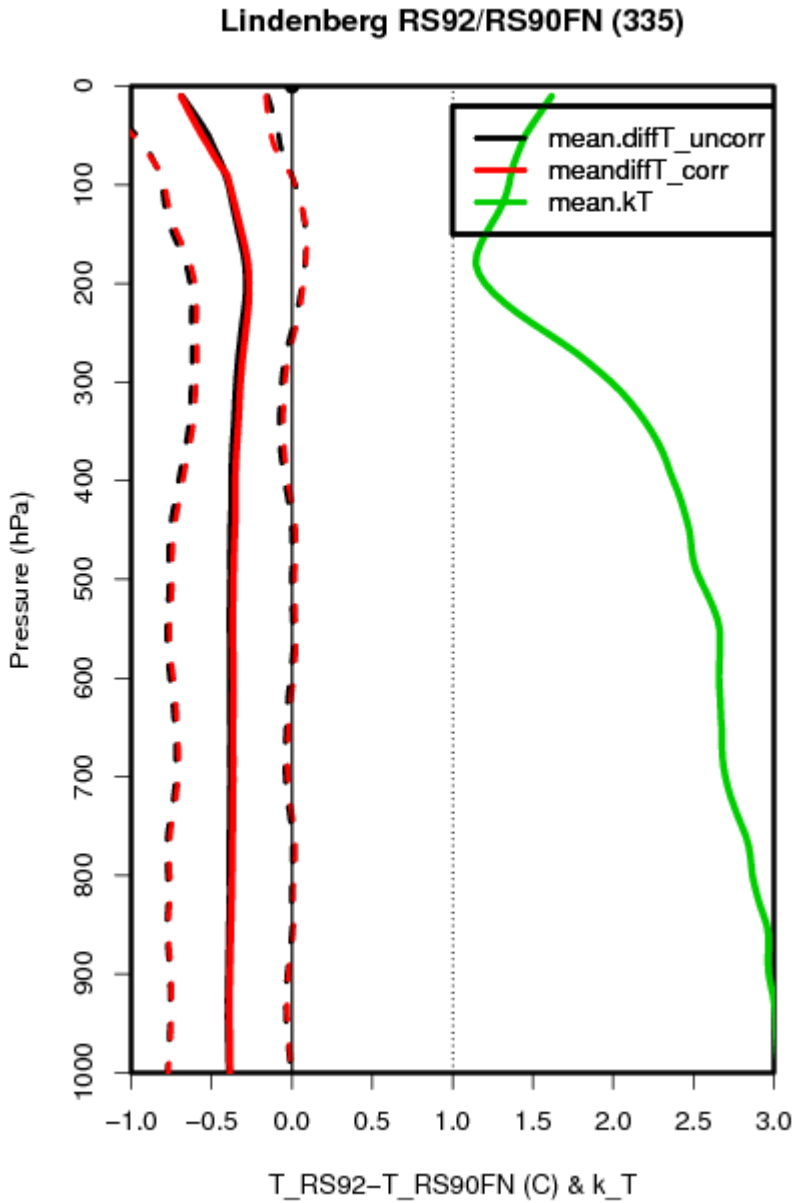
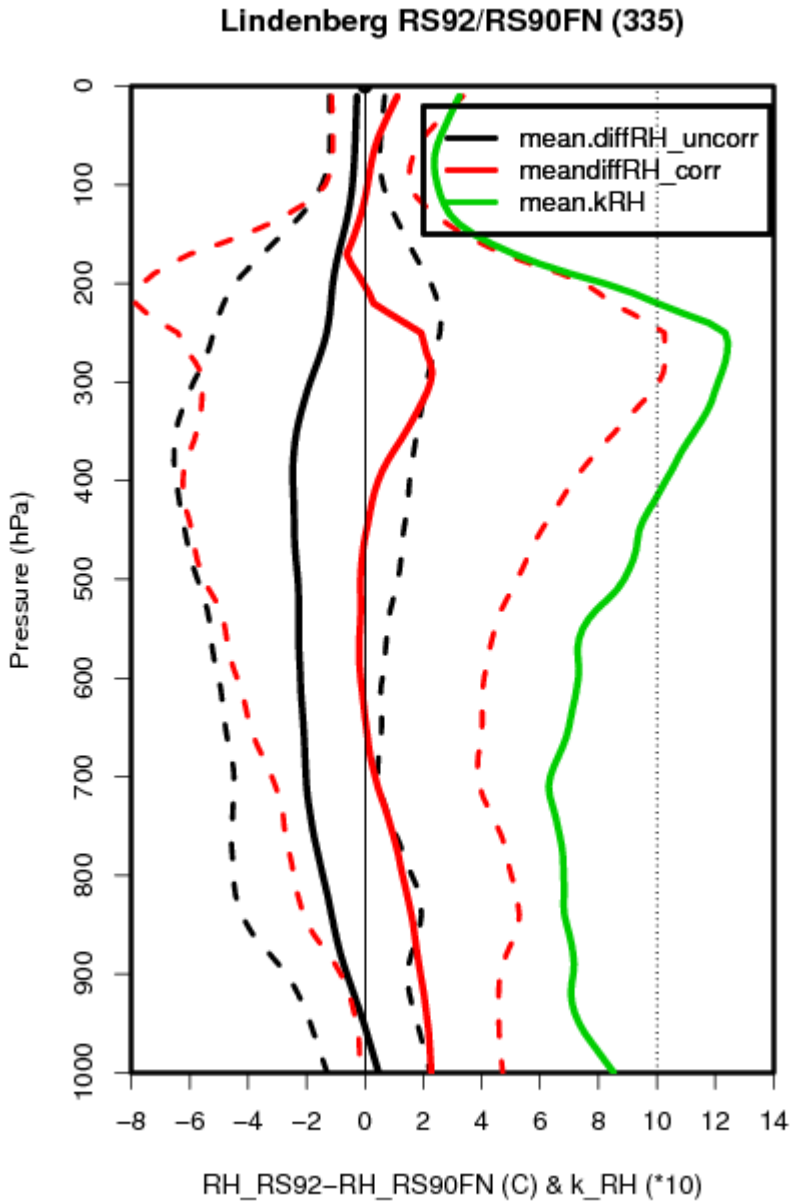
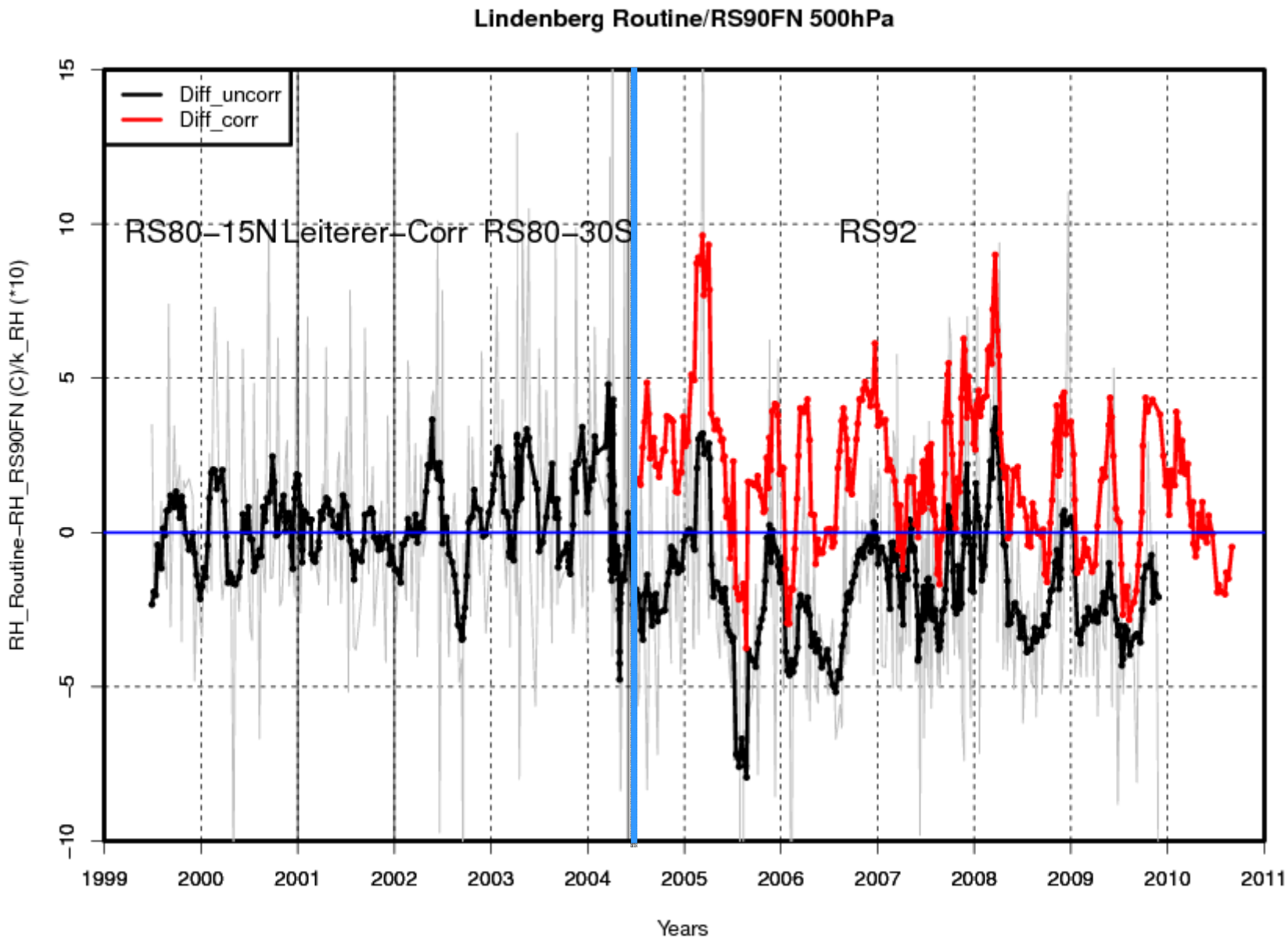
GRUAN RS92 corrections






Lindenberg Routine/RS90FN 500hPa
Diff_uncorr
Diff_corr
RS80–15N Leiterer–Corr
RS80–30S
RS92
RH_Routine–RH_RS90FN (C)/k_RH (*10)
15
10
5
0
–5
–10
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Years

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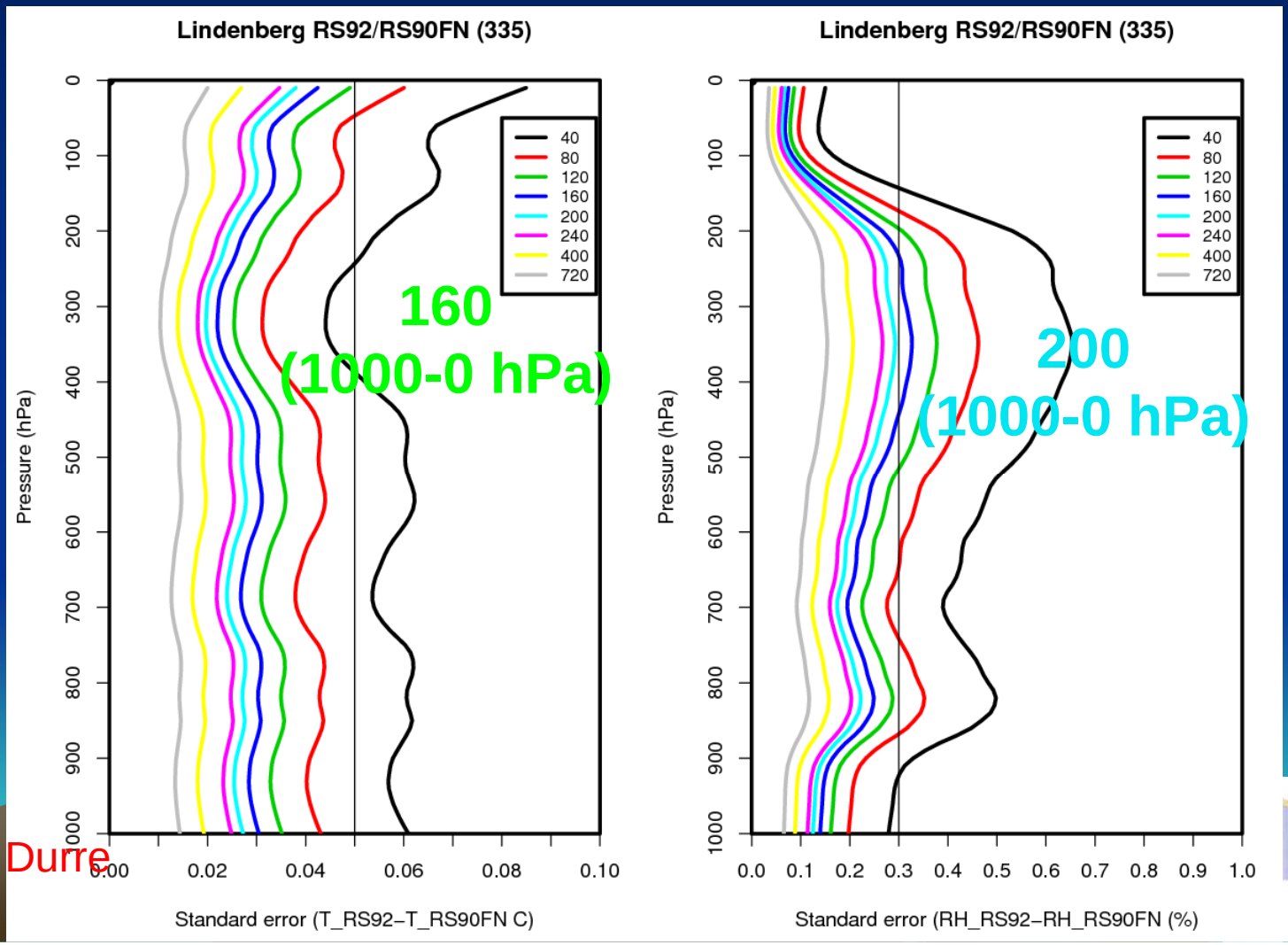
Q: How many dual sonde flights are needed to accurately assess the bias between old and new sondes?

Q: What is the variability in the dual sonde data that would be used in determining the bias between any two sondes?



Peterson & Durre (2002)

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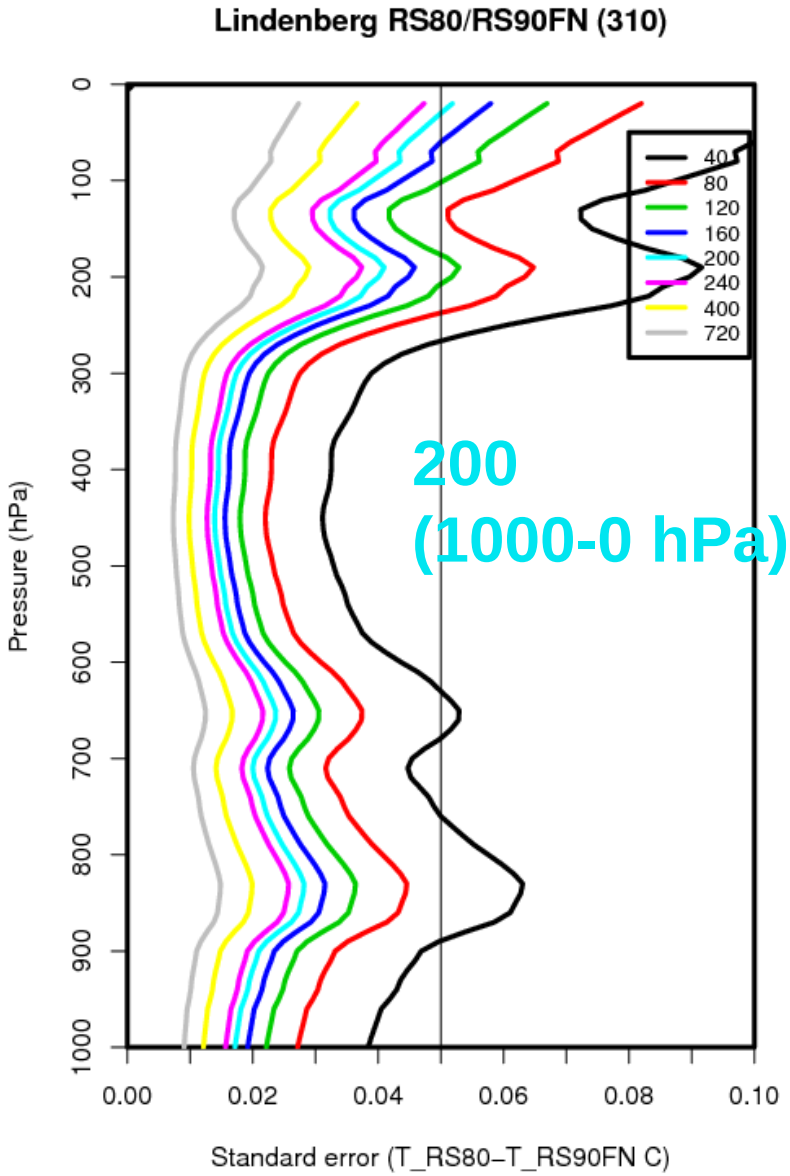
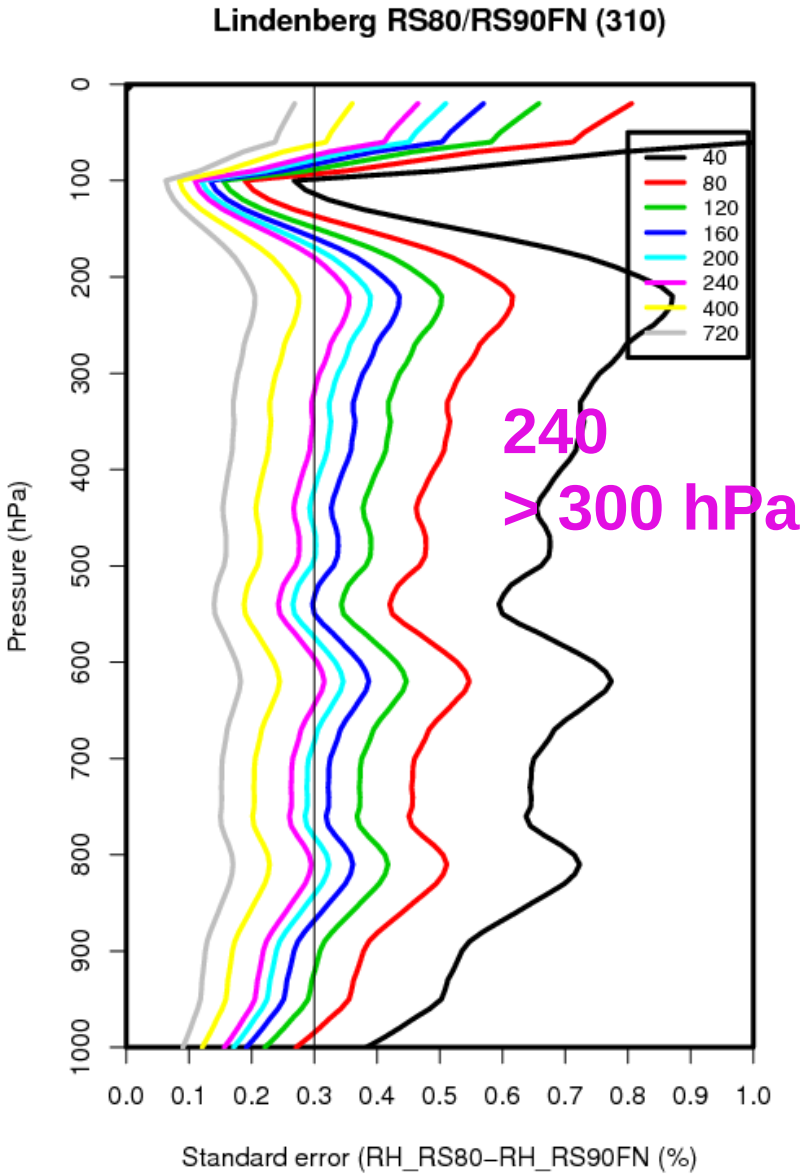
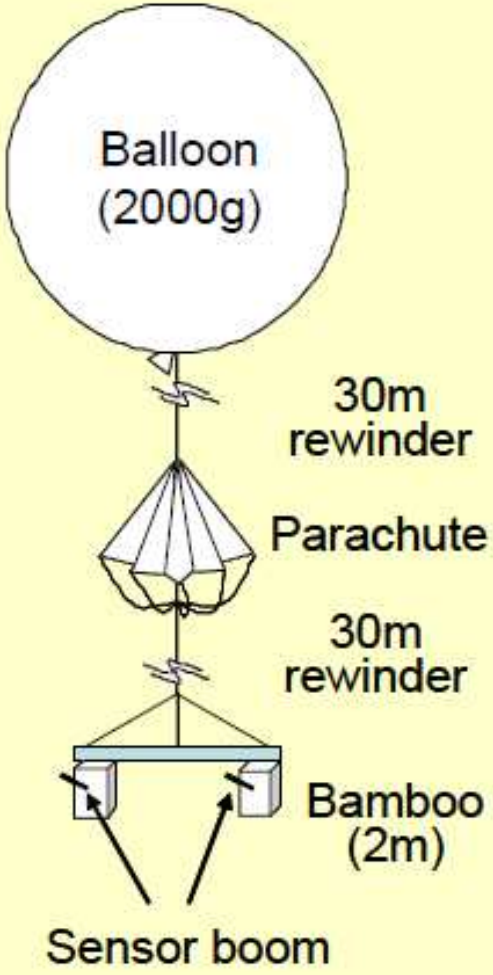

Lindenberg RS80/RS90FN (310)
Pressure (hPa)
0
100
200
300
400
500
600
700
800
900
1000
40
80
120
160
200
240
400
720
200
(1000-0 hPa)
0.00
0.02
0.04
0.06
0.08
0.10
Standard error (T_RS80–T_RS90FN C)


Lindenberg RS80/RS90FN (310)
Pressure (hPa)
0
100
200
300
400
500
600
700
800
900
1000
40
80
120
160
200
240
400
720
240
> 300 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 (%)

Overlap dual sonde data

Flight configuration of dual sounding



From Hakaru Mizuno

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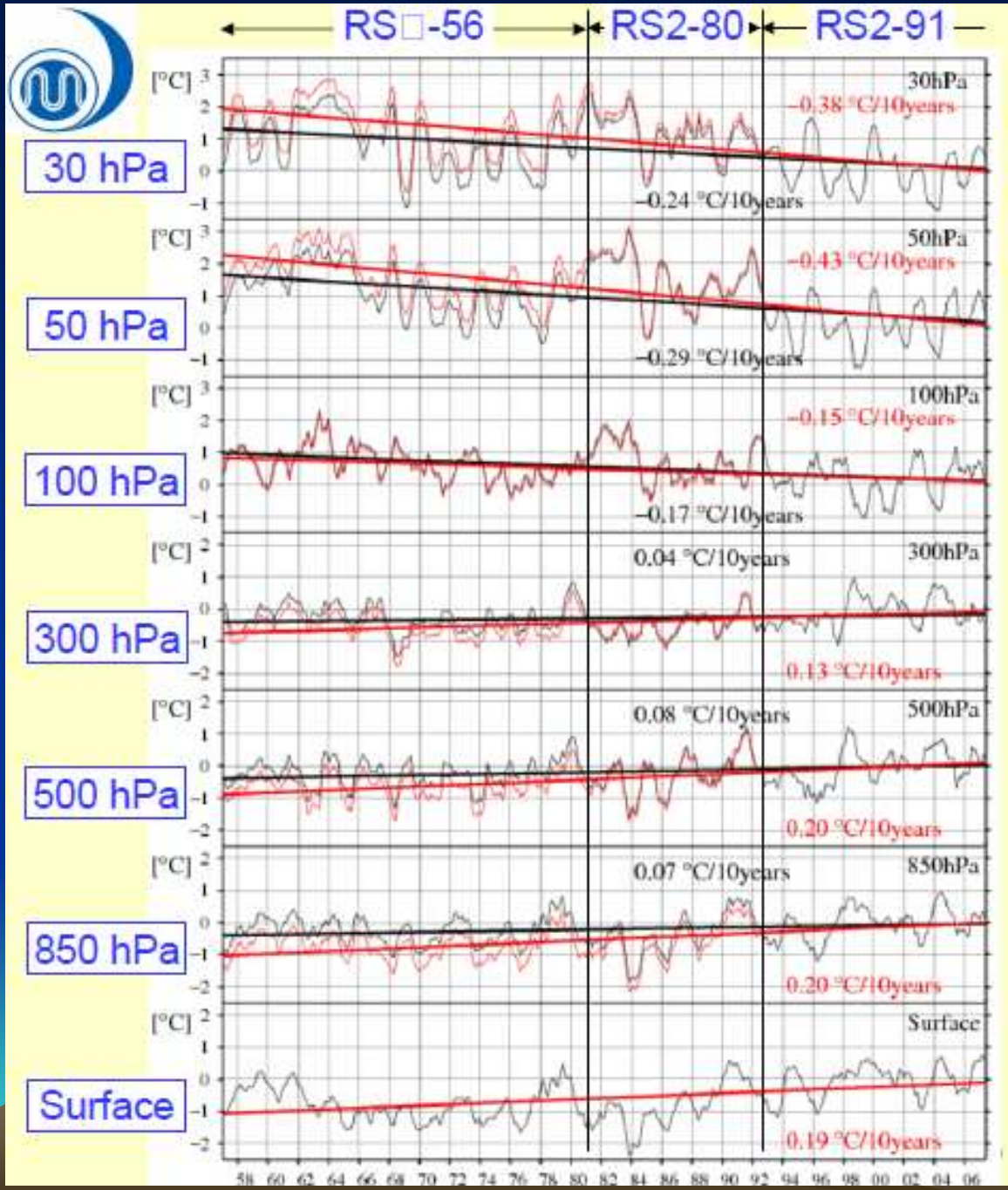
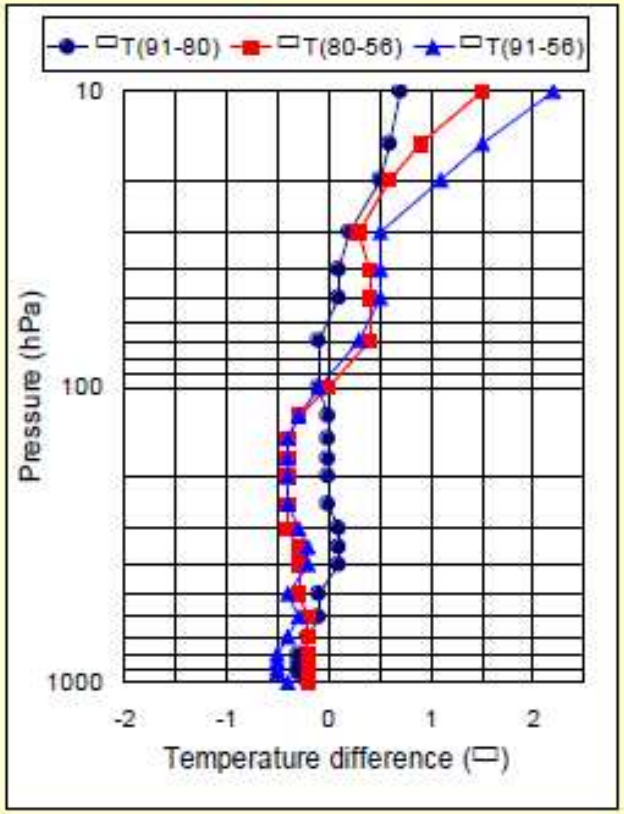


Temperature trend for 12 UTC (21 LST) considering historical changes of radiosonde



Uesato et al., 2008: J. Aerological Observatory, **68**, 15-22

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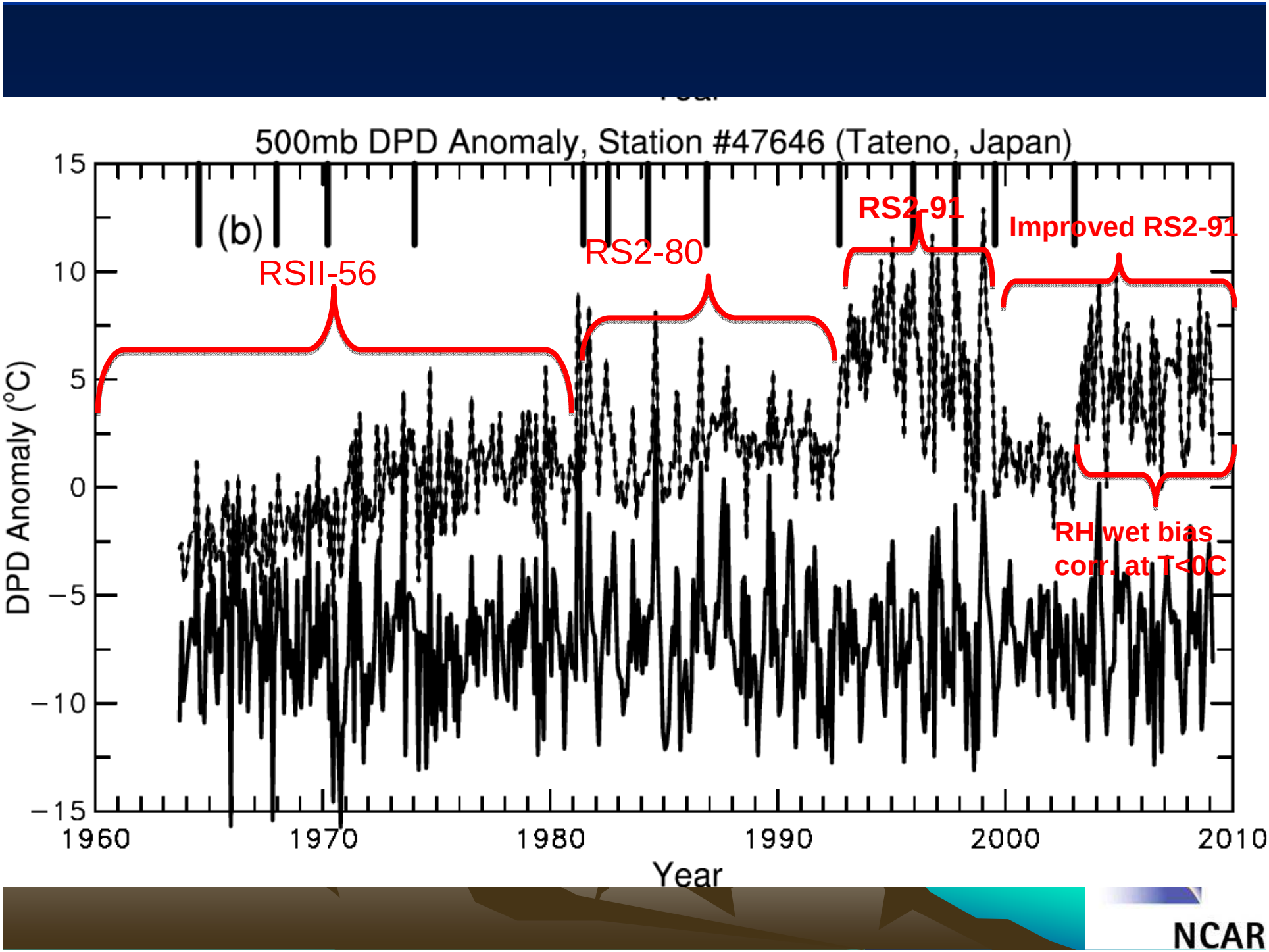
500mb DPD Anomaly, Station #47646 (Tateno, Japan)
(b)
RSII-56
RS2-80
RS2-91
Improved RS2-91
RH wet bias corr. at T<0C
DPD Anomaly (°C)
15
10
5
0
−5
−10
−15
1960
1970
1980
1990
2000
2010
Year
NCAR

Recommendations on managing changes: Radiosonde

1. Independent , redundant measurements:

- *Apply same procedures (GC for RS90FN)*
- *Implement changes in different times*
- *Minimize differences caused by factors other than measurement errors, such as not sampling the same air.*

2. Corrections of known errors/biases:

- *Consider one type of changes, so need detailed meta-data*
- *Need extensive validation/evaluation*
- *Retain raw data for future improvements*

4. Statistical methods:

- *Maintain detailed meta-data on changes*
- *Make last or one segment as “reference”*

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Recommendations on managing changes: Radiosonde (cont.)

3. Overlap dual-sonde (old vs new) data:

- ***New sonde has been tested and evaluated both in lab and in the field (WMO intercomparison) and deemed reliable enough***
- ***On the same balloon or in a sequence as closely in space and time as possible***
- ***Include additional measurements (3rd sonde or R.S.) coincident with the ascents***
- ***Cover day/night and the entire annual cycle***
- ***240 flights (~twice weekly) 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***

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Where to go from here?

1. Implement GRUAN RS92 data corrections to Lindenberg and Tateno,
2. Homogenize the long-term data and study the impacts on long-term trends,
3. Other refinements,
4. Prepare a journal paper.

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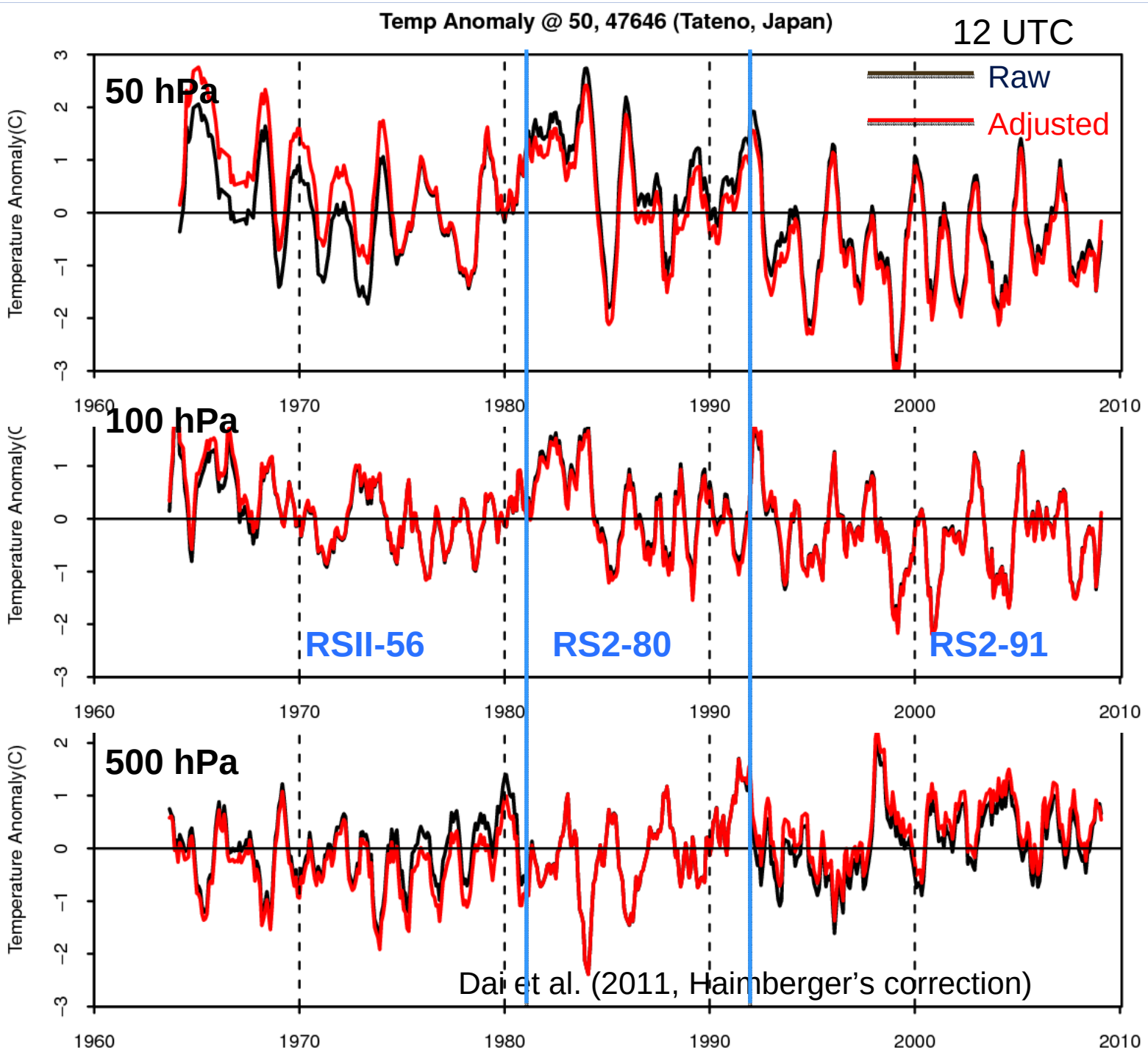
Temp Anomaly @ 50, 47646 (Tateno, Japan)
12 UTC
Raw
Adjusted
50 hPa
100 hPa
500 hPa
Temperature Anomaly(C)
RSII-56
RS2-80
RS2-91
1960
1970
1980
1990
2000
2010
Dai et al. (2011, Haimberger's correction)

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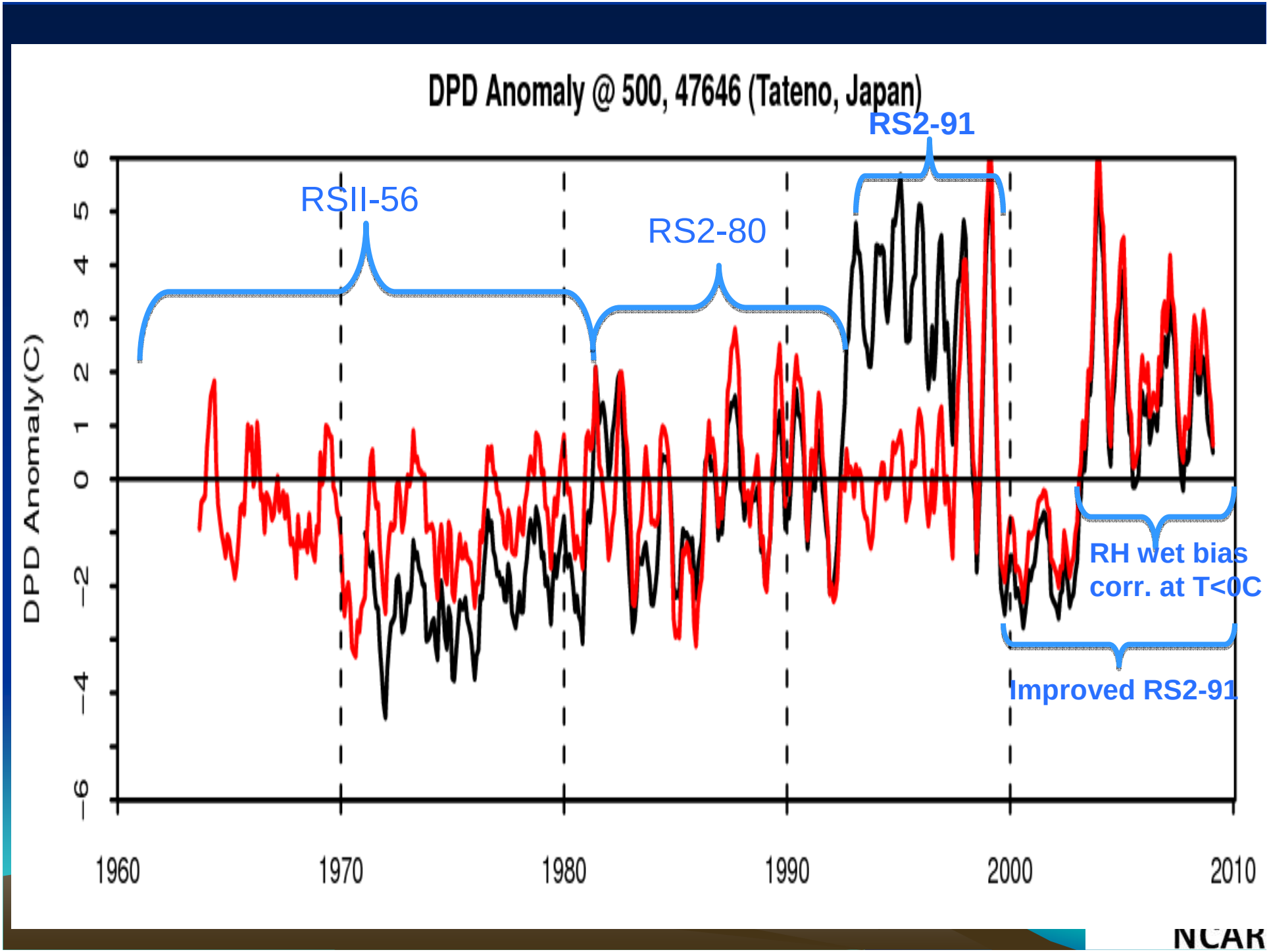
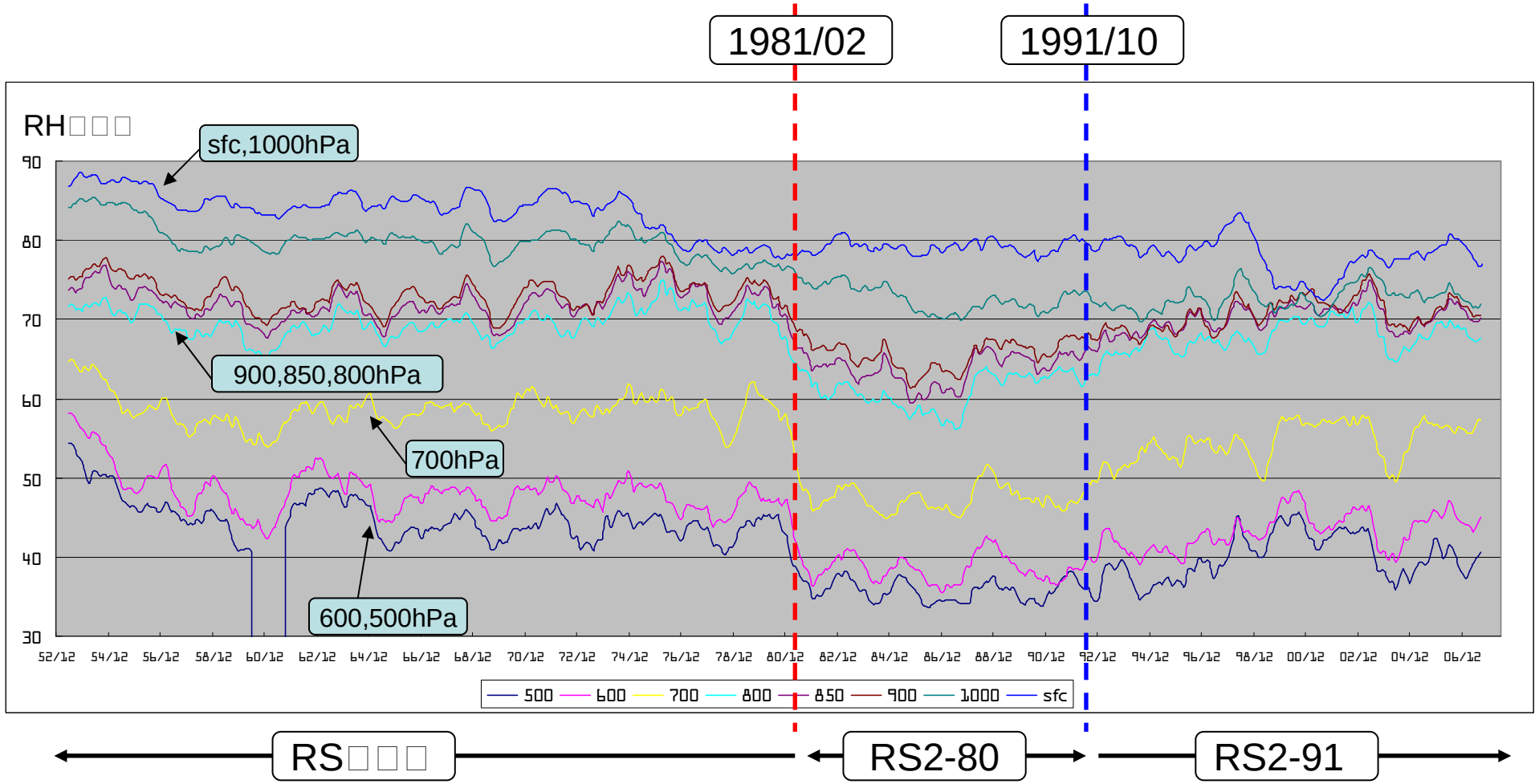

DPD Anomaly @ 500, 47646 (Tateno, Japan)
RS2-91
RSII-56
RS2-80
RH wet bias
corr. at T<0C
Improved RS2-91
DPD Anomaly(C)
6
5
4
3
2
1
0
−2
−4
−6
1960
1970
1980
1990
2000
2010

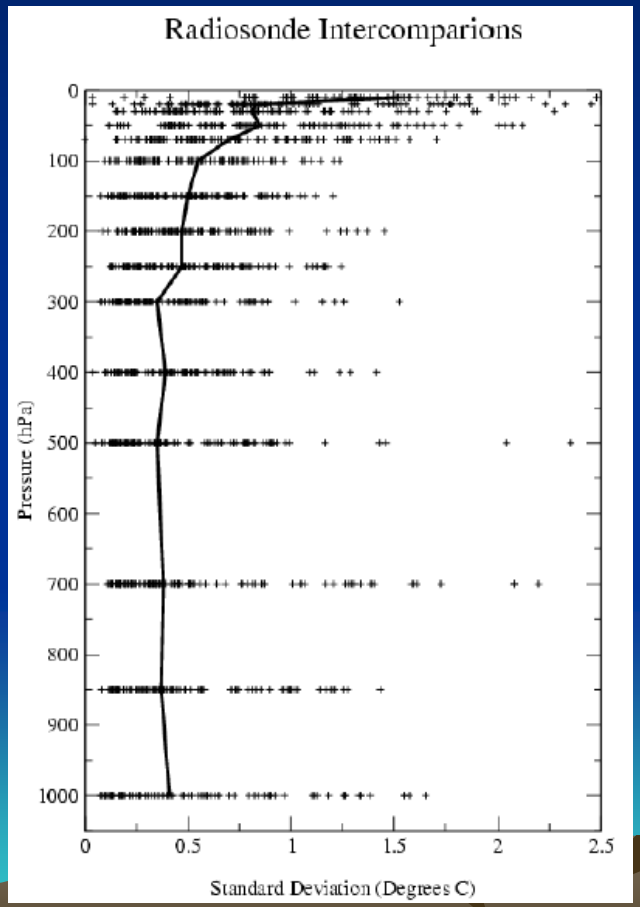
RH_tateno,□December 1952□December 2007□

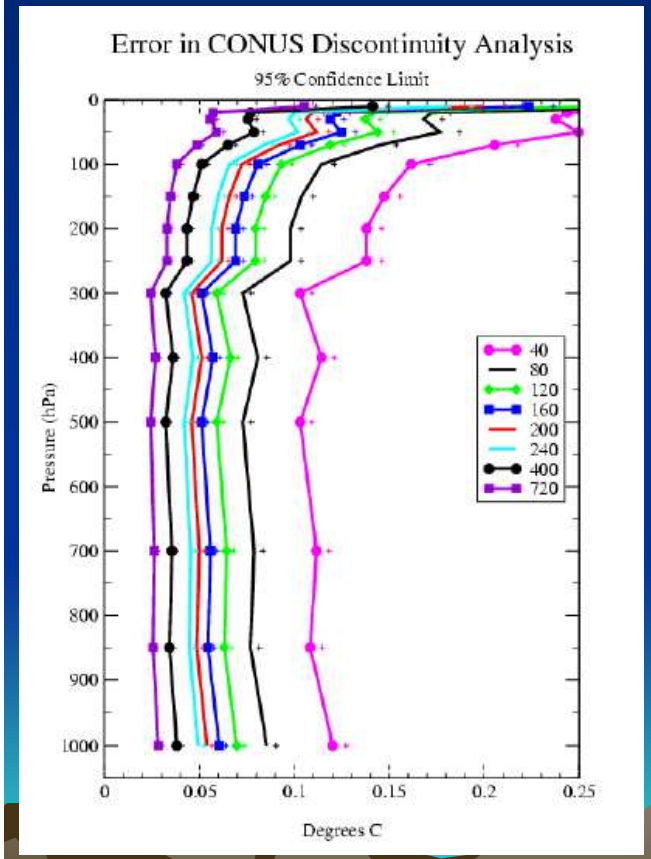


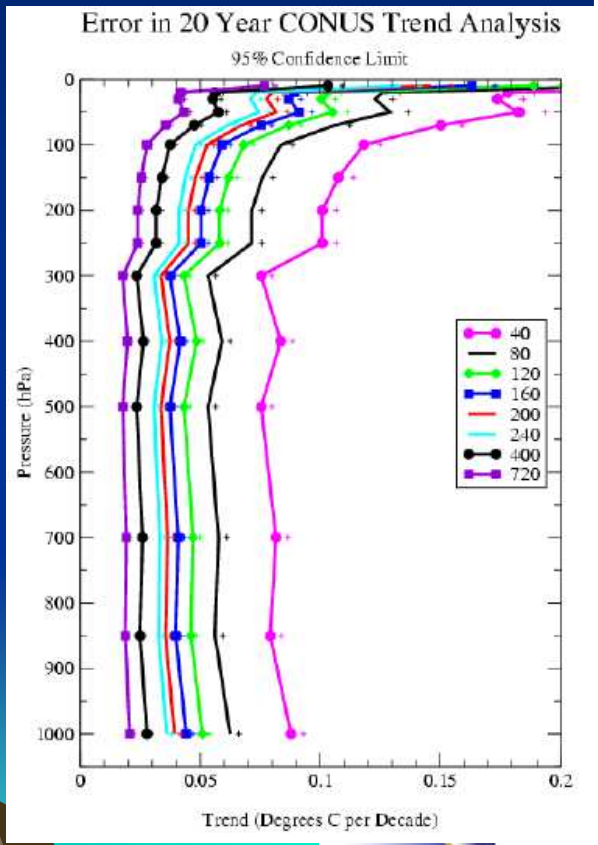
A CLIMATE CONTINUITY STRATEGY FOR THE RADIOSONDE REPLACEMENT SYSTEM TRANSITION

Thomas C. Peterson * and Imke Durre

- Only for temperature and only over contiguous U.S.
- 200 flights spread out over all four seasons required to achieve <0.05C discontinuity







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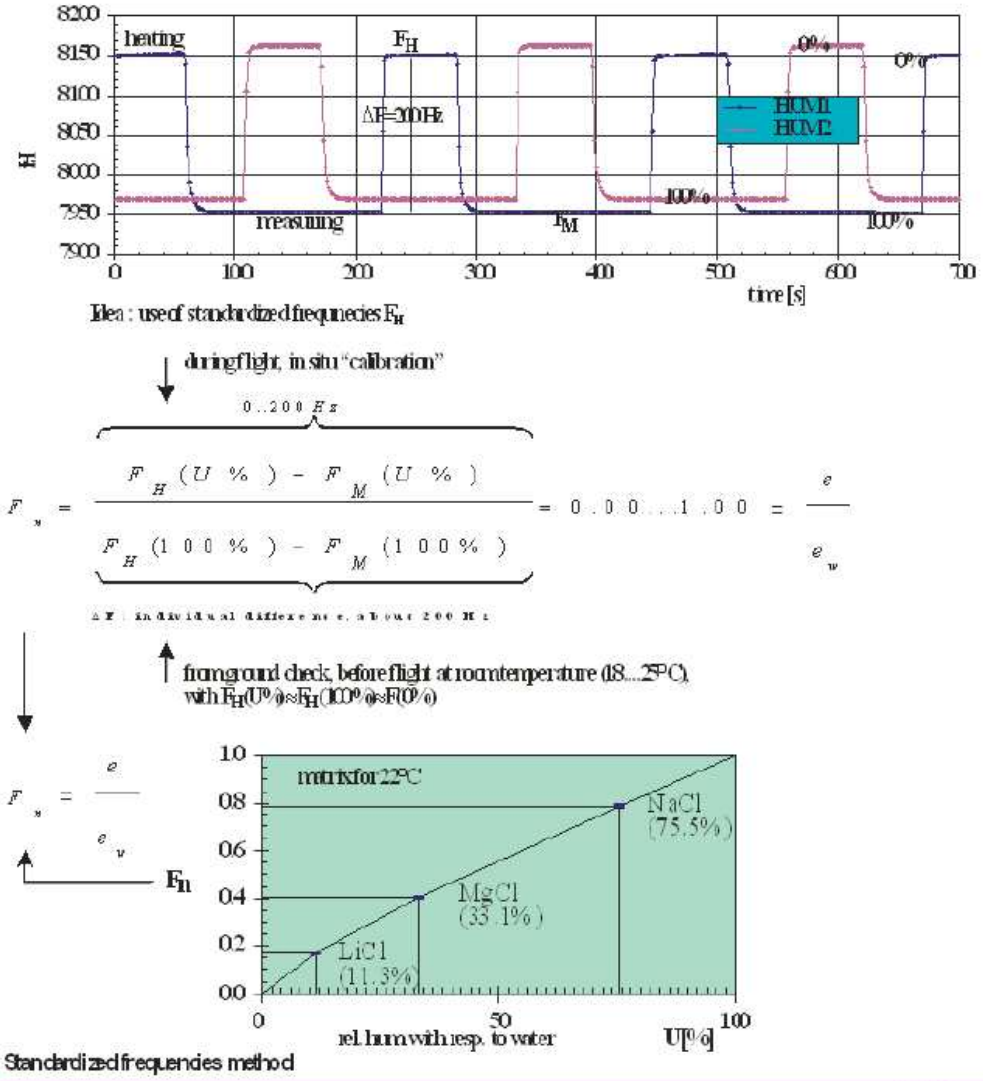
FN-Method

Leiterer, U. at al.; 2004: *A Correction Method for RS80-A Humicap Profiles and their Validation by Lidar Backscattering Profiles in Tropical Cirrus Clouds*. JAOT, Vol. 22, No. 1, 18-29.



Fact: Changes are inevitable for any observation network.

Goal: To provide scientific bases to develop operational practices in better managing changes at GRUAN sites from one instrument type to another and to accurately merge the two data segments to create a homogeneous time series.

Approaches: To make use of dual-sonde data collected at GRUAN sites (Lindenberg and Tateno) in the past either continuously or at times when changes were made.

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Lindenberg dual-sonde data
(high resolution (5s) with detailed metadata)

	Routine	Sonde Types	RS90fn	Sonde Types	RS92fn	Sonde Types
1998	1449	RS80-30, RS80-15S, RS80-15NS, RS80-15N				
1999	1410	RS80-15N	24	FN90NC		
2000	1430	RS80-15N	56	FN90NC, FN9052		
2001	1457	RS80-15N	57	FN90NC, FN9052		
2002	1449	RS80-30S	54	FN90NC, FN9052, FN9040		
2003	1452	RS80-30S	63	FN90NC, FN9052, FN9040		
2004	1447	RS80-30S, RS92-AGP	83	FN90NC, FN9052, FN9040		
2005	1460	RS92-AGP	59	FN90NC, FN9052, FN9040		
2006	1468	RS92-AGP, RS92-SGP	58	FN90NC, FN9052		
2007	1748	RS92-SGP	107	FN90NC, FN9052, FN9040		
2008	1540	RS92-SGP, RS92-SGP(V)	60	FN90NC, FN9052	35	RS92-SGP
2009	781	RS92-SGP(V)	15	FN90NC, FN9052	13	RS92-SGP
TOTAL	17091					

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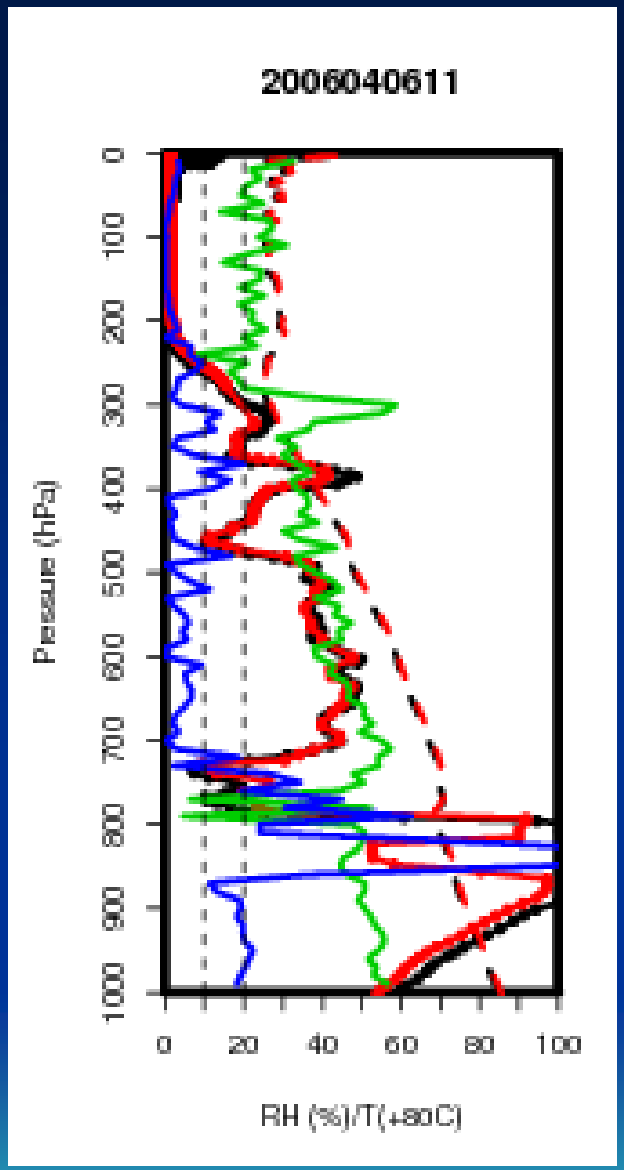
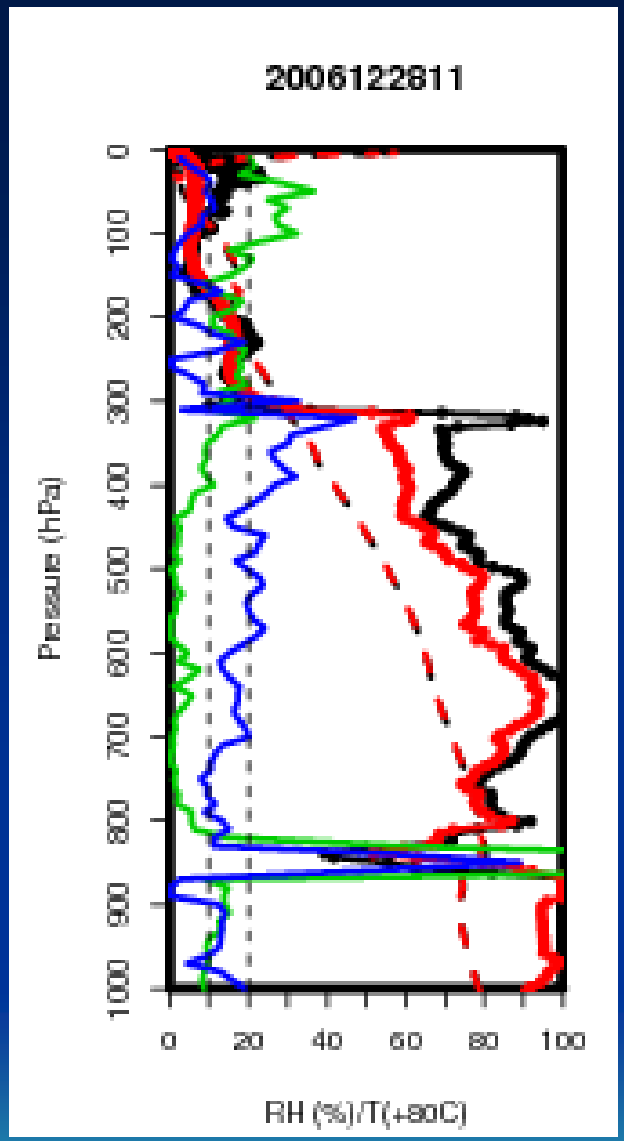

2006040611
Pressure (hPa)
0
100
200
300
400
500
600
700
800
900
1000
0
20
40
60
80
100
RH (%)/T(+80C)


2006122811
Pressure (hPa)
0
100
200
300
400
500
600
700
800
900
1000
0
20
40
60
80
100
RH (%)/T(+80C)

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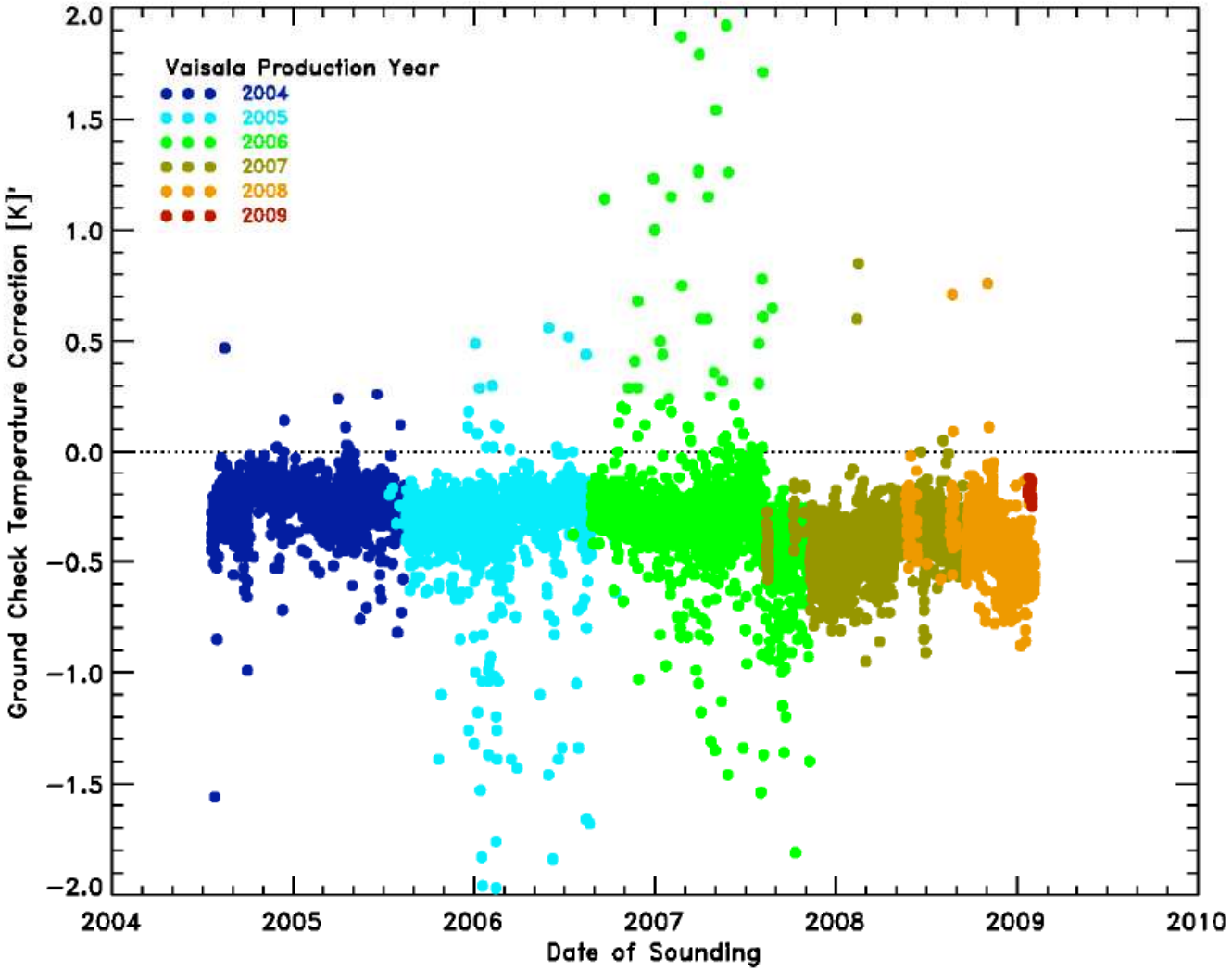
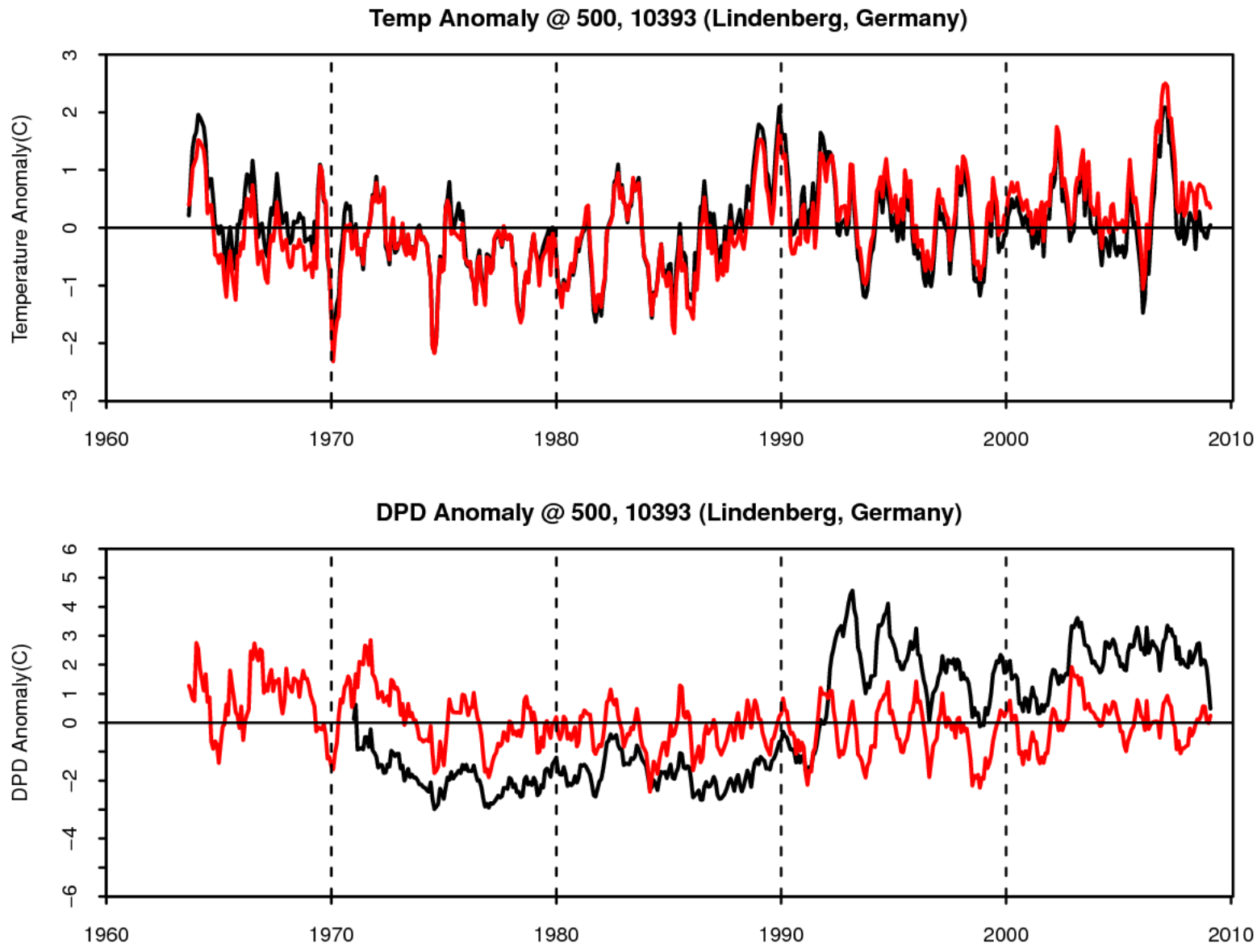
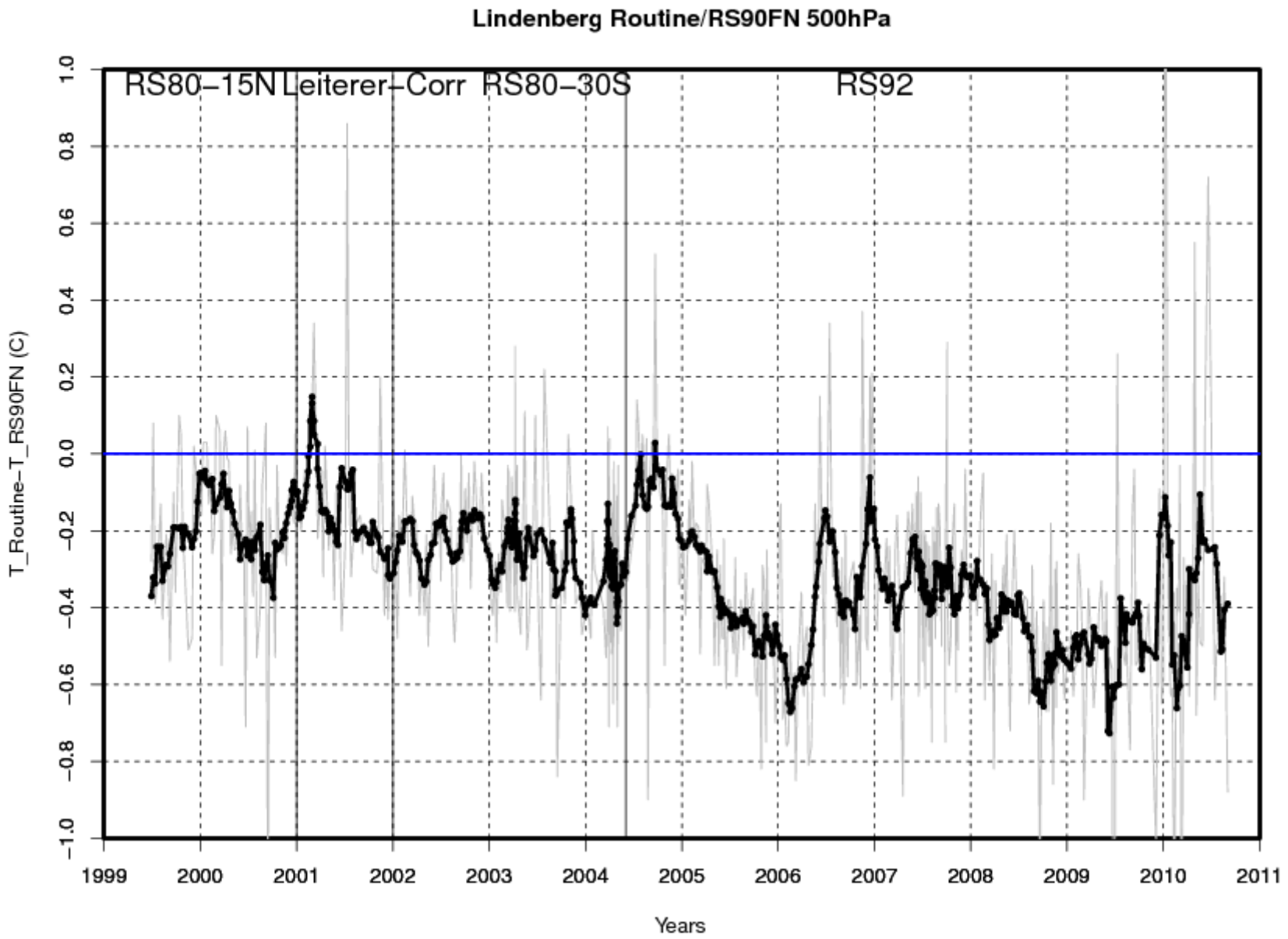
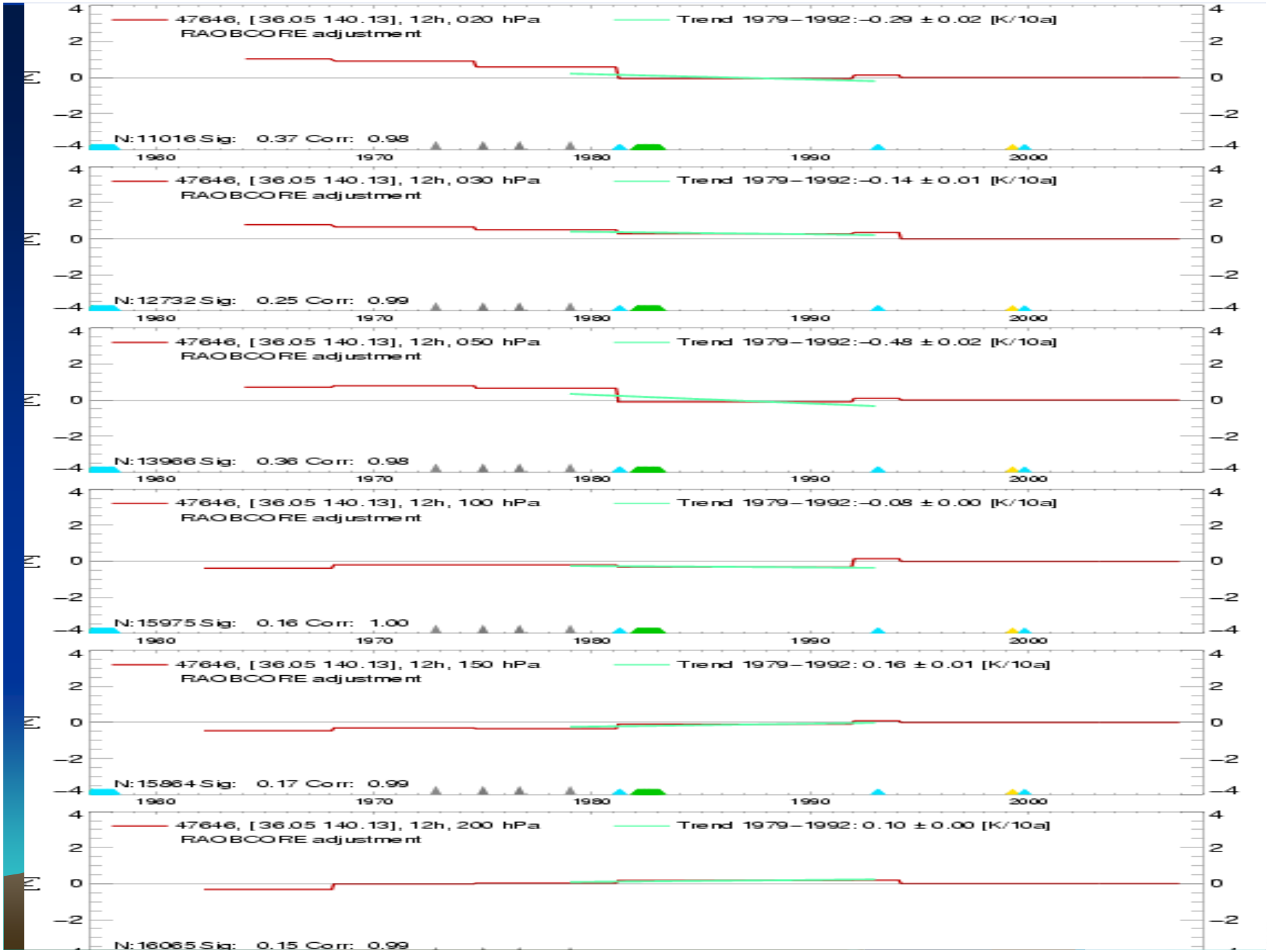
Temperature: Ground check




Temp Anomaly @ 500, 10393 (Lindenberg, Germany)
Temperature Anomaly(C)
3
2
1
0
−1
−2
−3
1960
1970
1980
1990
2000
2010
DPD Anomaly @ 500, 10393 (Lindenberg, Germany)
DPD Anomaly(C)
6
5
4
3
2
1
0
−2
−4
−6
1960
1970
1980
1990
2000
2010

Temperature difference (Routine-FN) at 500 hPa




47646, [36.05 140.13], 12h, 020 hPa
RAOBCORE adjustment
Trend 1979–1992: –0.29 ± 0.02 [K/10a]
N: 11016 Sig: 0.37 Corr: 0.98
47646, [36.05 140.13], 12h, 030 hPa
RAOBCORE adjustment
Trend 1979–1992: –0.14 ± 0.01 [K/10a]
N: 12732 Sig: 0.25 Corr: 0.99
47646, [36.05 140.13], 12h, 050 hPa
RAOBCORE adjustment
Trend 1979–1992: –0.48 ± 0.02 [K/10a]
N: 13966 Sig: 0.36 Corr: 0.98
47646, [36.05 140.13], 12h, 100 hPa
RAOBCORE adjustment
Trend 1979–1992: –0.08 ± 0.00 [K/10a]
N: 15975 Sig: 0.16 Corr: 1.00
47646, [36.05 140.13], 12h, 150 hPa
RAOBCORE adjustment
Trend 1979–1992: 0.16 ± 0.01 [K/10a]
N: 15864 Sig: 0.17 Corr: 0.99
47646, [36.05 140.13], 12h, 200 hPa
RAOBCORE adjustment
Trend 1979–1992: 0.10 ± 0.00 [K/10a]
N: 16065 Sig: 0.15 Corr: 0.99
1980
1970
1980
1990
2000