Rationale for Using Reference Radiosonde

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Key Climate Science Drivers for GRUAN

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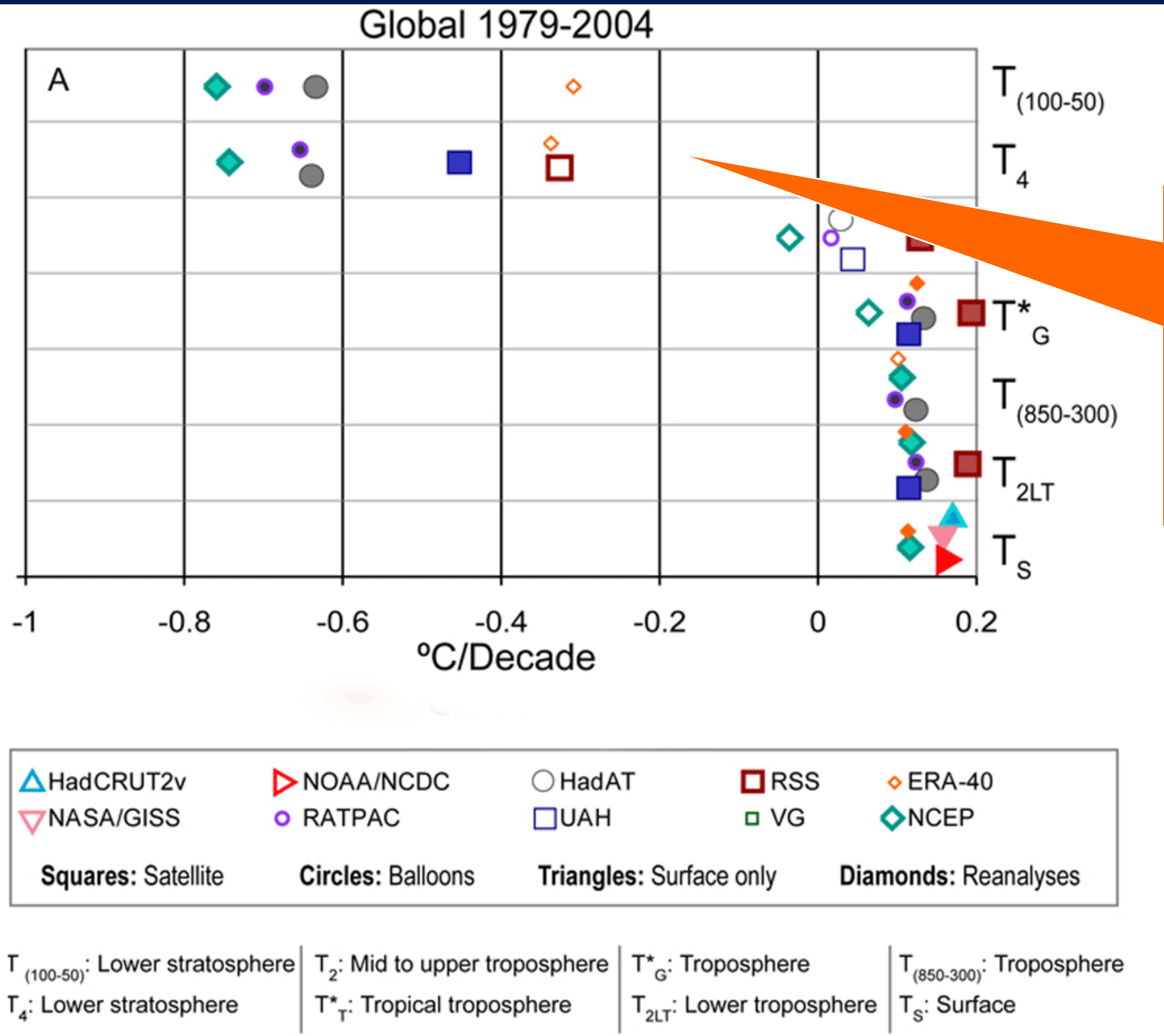
1. Monitoring and detecting climate variability and change
2. Understanding the vertical profile of temperature trends
3. Understanding the climatology and variability of water vapor, particularly in the upper-troposphere and lower stratosphere
4. Understanding and monitoring tropopause characteristic
5. Understanding and monitoring the vertical profile of ozone, aerosols and other constituents
6. Prediction of climate variations
7. Reliable reanalyses of climate change
8. Understanding climate mechanisms and improving climate models
9. Calibrating and validating satellite observations

Atmospheric temperature trends



CCSP (2006)

1. **The uncertainty is as big as the trend.**
2. **Better reference observations to reduce uncertainty using GRUAN.**

Q: Can current operational radiosondes meet the temperature requirements for GRUAN?

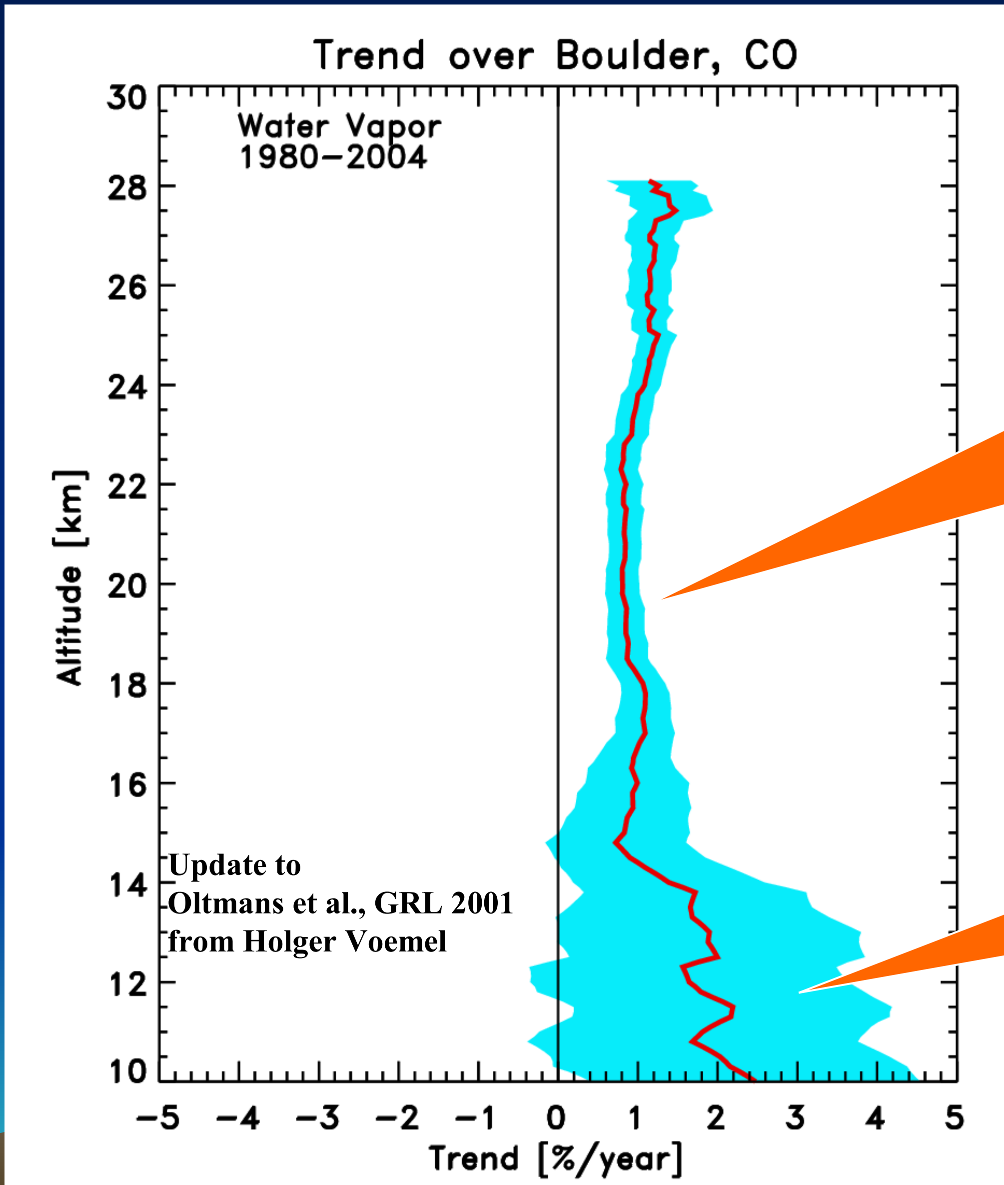
0.2 K precision, 0.1/0.2 K (TR/ST) accuracy and 0.05 K/decade long term stability

A: Yes for three-thermistor and RS92 IF:

- **Their radiation errors can be accurately evaluated,**
- **The radiation correction algorithm and the raw data are available to GRUAN,**
- **The processing algorithm is available to GRUAN,**
- **The sensor calibration is correct,**
- **The radiosonde signal channel electronics is reliable,**
- **Data transmission and reception are reliable.**

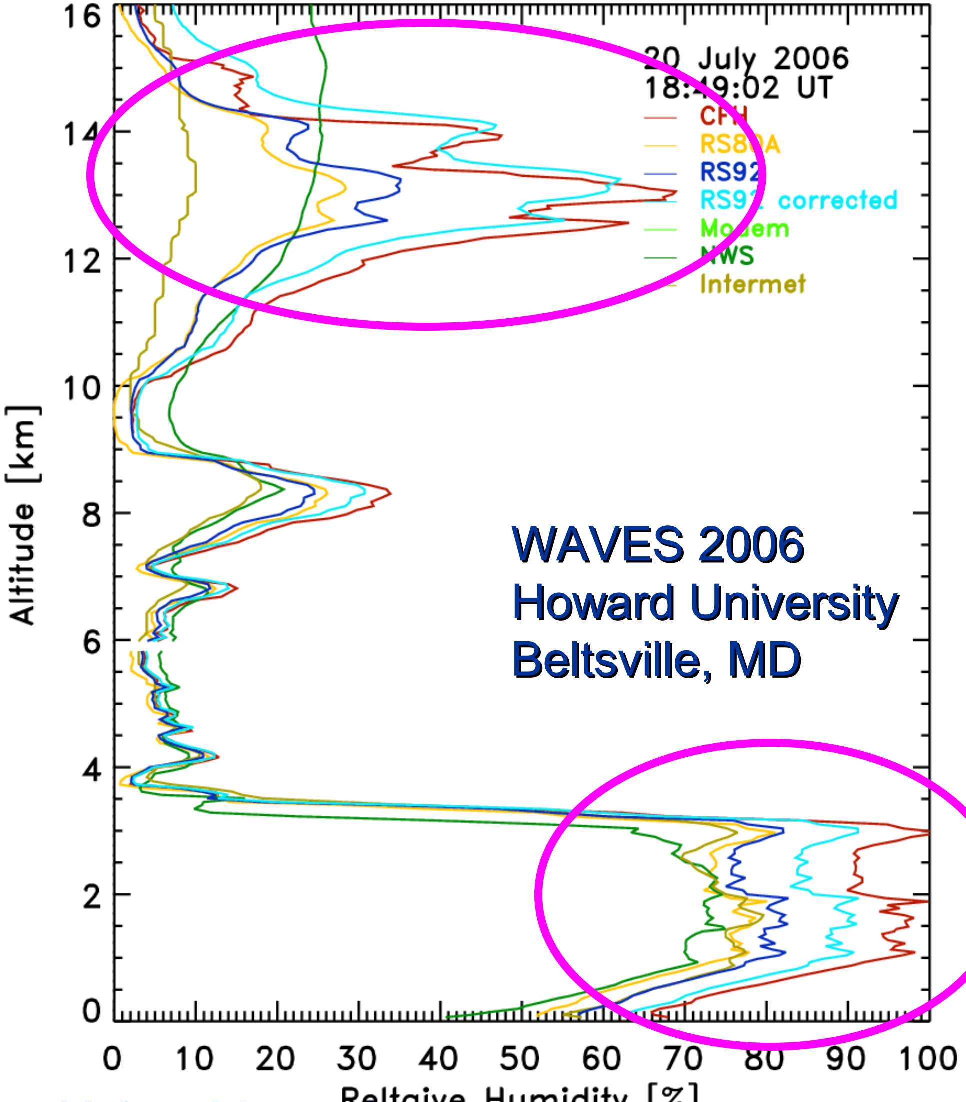
Based on Holger Voemel's talk and John Nash's talk in Seattle

Water vapor climatology and variability

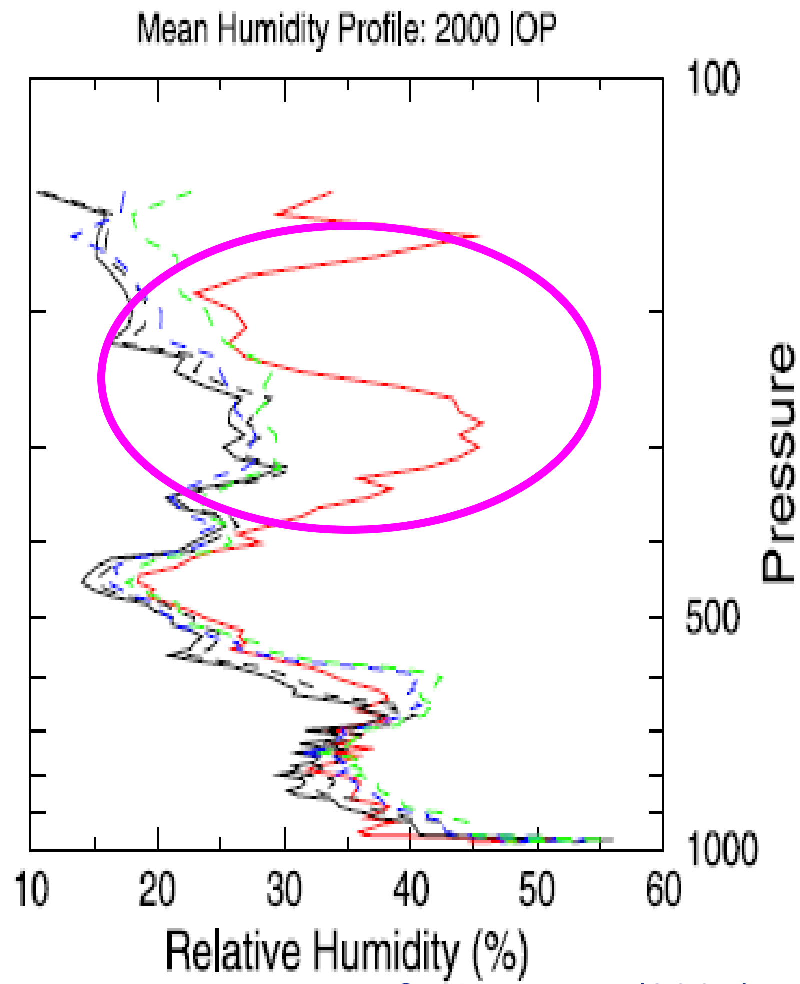


Stratosphere:
- No current operational radiosonde can provide humidity measurements in ST.
- Should we continue to ignore the ST?

Troposphere:
- Various problems still exist.
- Corrections are needed, but not effective in UT.

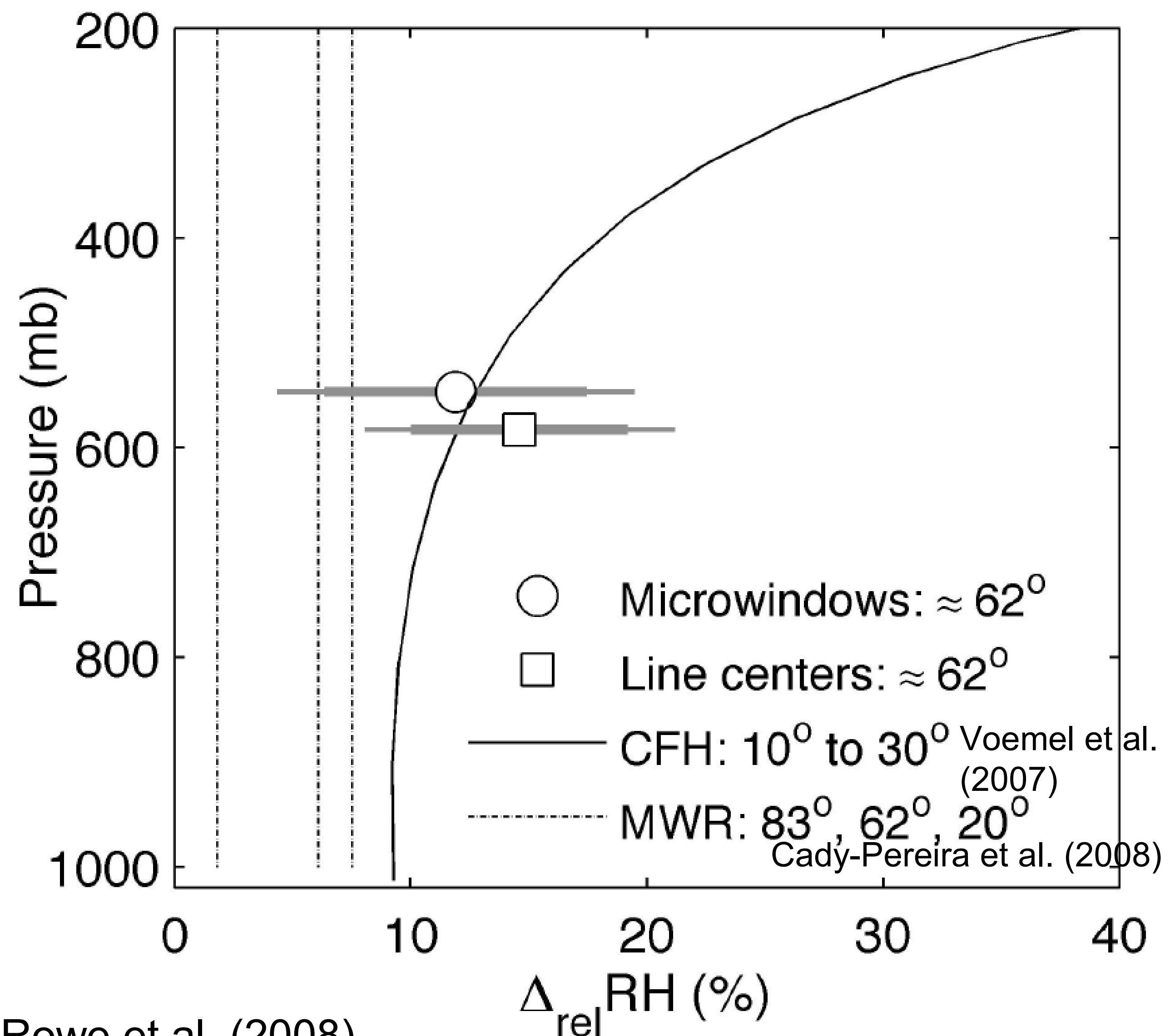


From Holger Voemel



Soden et al. (2004)

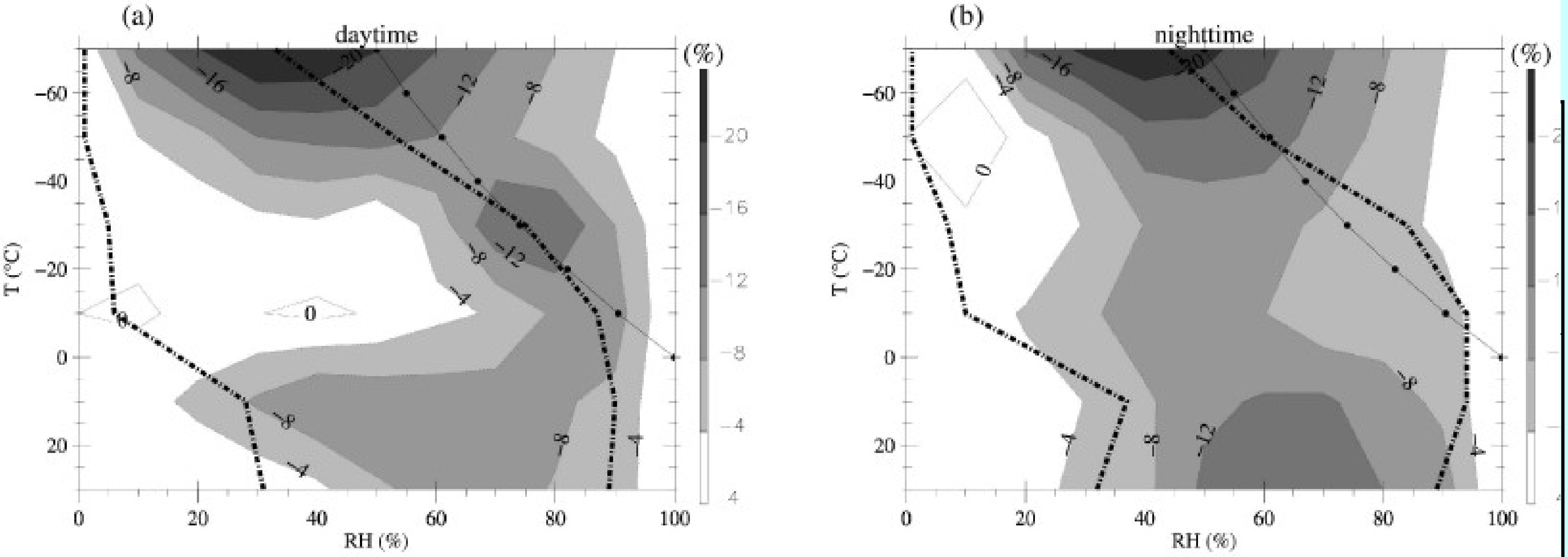
Solar radiation dry bias of RS90/RS92



Rowe et al. (2008)

Lessons learn from field campaigns

AMMA (African Monsoon Multi-disciplinary Analyses) (2006)



Nuret et al. (2008)

Fig. 2. Bias (in shading) for (a) day and (b) night of the Vaïsala RS80 sondes relative to RS92 sondes at Niamey for the learning sample. The axes are temperature and relative humidity as observed by RS80 sondes. Superposed dashed lines correspond to 1st and last percentiles (10% and 100% CDF isolines respectively). Thin line with dots

Are we there yet technologically for reference WV measurements?

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Measurement Range	Precision	Accuracy	Long-Term Stability
0.1 to 90000 ppmv	2%/5% in TR/ST	2%	1%/decade

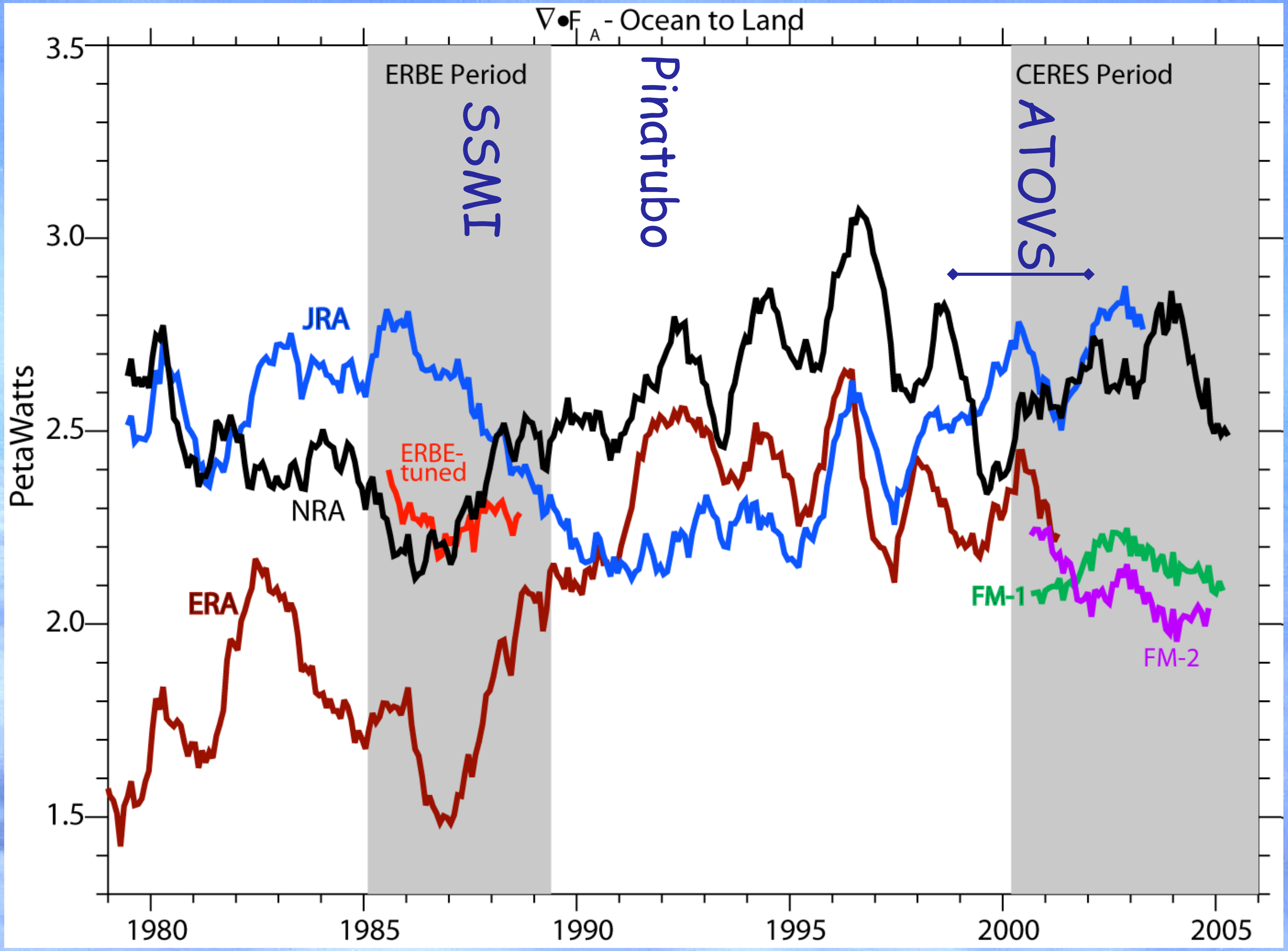
	Claimed accuracy	Calibration	Limitations	Dynamic range	History	Cost	Ease of use	Engineering
CFH	0.5°C DP/FP 4-9%	++	No "wet" clouds	++	+	- (o)	o	research / small series
Snow White	0.1°C DP/FP	+	Some clouds RH > 3-6% No ST	o	+	o	++	production small series
Lyman-alpha (FLASH)	9%	+	Night time only Descent only No LT	-	o	--	+	research / small series
Polymer (Vaisala RS92)	1% RH	-	No ST Large radiation error Chemical contamination Hard to trace sensor/ calibration changes	-	+	++	+ (++)	Large scale production
CFH/other sensor	++		???	++	+	-(o)	o	Research small series

AR4 **IPCC** assessment: Chapter 3 is an **indictment of many difficulties with continuity** of the climate record, and a **testament to the heroic struggles** of those who nonetheless make sense out of the data. **We can surely do better**.

Chief outstanding issue in reanalysis:

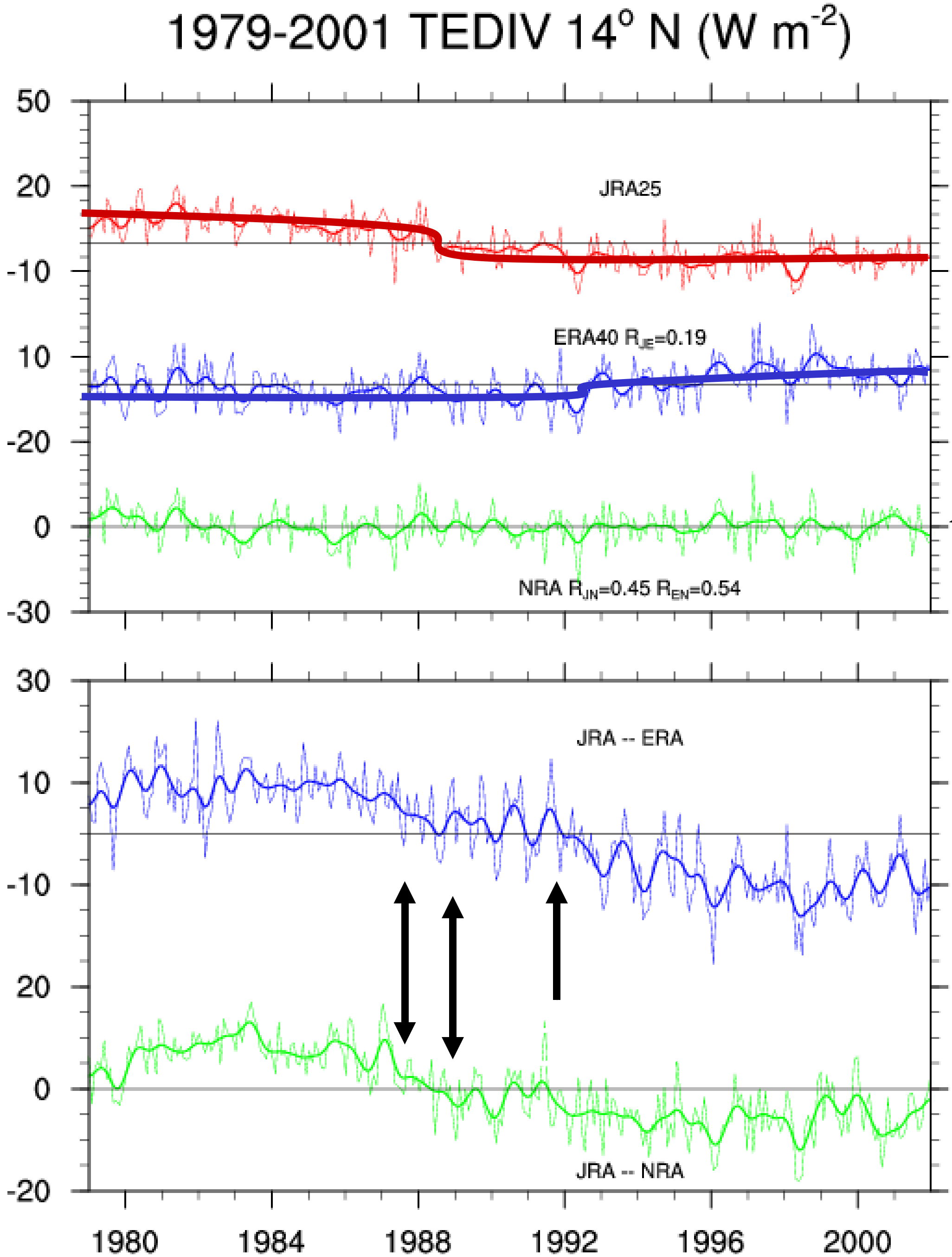
The underlying data base is not constant, and changes disrupt the climate record.

- No baseline **reference** network to anchor the data
- **Radiosondes** improve and change type over time
- **Satellites** mainly after 1979, last order 5 years, drift in orbit, change instruments, calibration
- **Bias corrections** are applied but remain imperfect
- **Continuity** is a key issue, especially for climate change
- Further **technological development**, change and improvement is expected.
- Major challenge is to deal with **changing observations**



Net ocean to land energy transport 12-month running means for ERBE and CERES R_T over land and $\delta A_E/\delta t$.

K. Trenberth



Spurious low frequency variability

Deficient low frequency variability on all time scales

Vertically-integrated total atmospheric energy divergence, zonally averaged at 14N from 3 reanalyses.

Challenges of making a sonde as a reference

- **Sensors: robust, accurate, affordable**
  (laboratory standards, target specifications, reliable calibration)
- **Instrument package: careful design to collect the best data**
  (ventilation, radiation, electronics, …)
- **Calibrations: traceable to NIST and other standards (in-house/in-field) and keeping a detailed metadata**
- **Inter-comparisons of multiple sensors and systems**
  (redundancy, pre-launch check, “Consensus ref. concept”…)
- **Real-time data quality monitoring and careful post data QC**
- **Effective communications among different stakeholders**
  (operational center, data center, manufactures, data users …)

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亡羊補牢，未晚也

Close the Barn Door after the Sheep are Stolen (Better Late than Never)

- **It is time to use reference radiosonde!**
- **GRUAN is the perfect opportunity!**

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Challenges to maintain long-term stability

- Deliver the best quality data
- Sustain consistence in operational procedures
- Maintain complete metadata
- Ongoing data QC and analysis to identify and fix problems
- Preserve raw data and other independent/redundant data for future reprocessing and reanalysis
- ???

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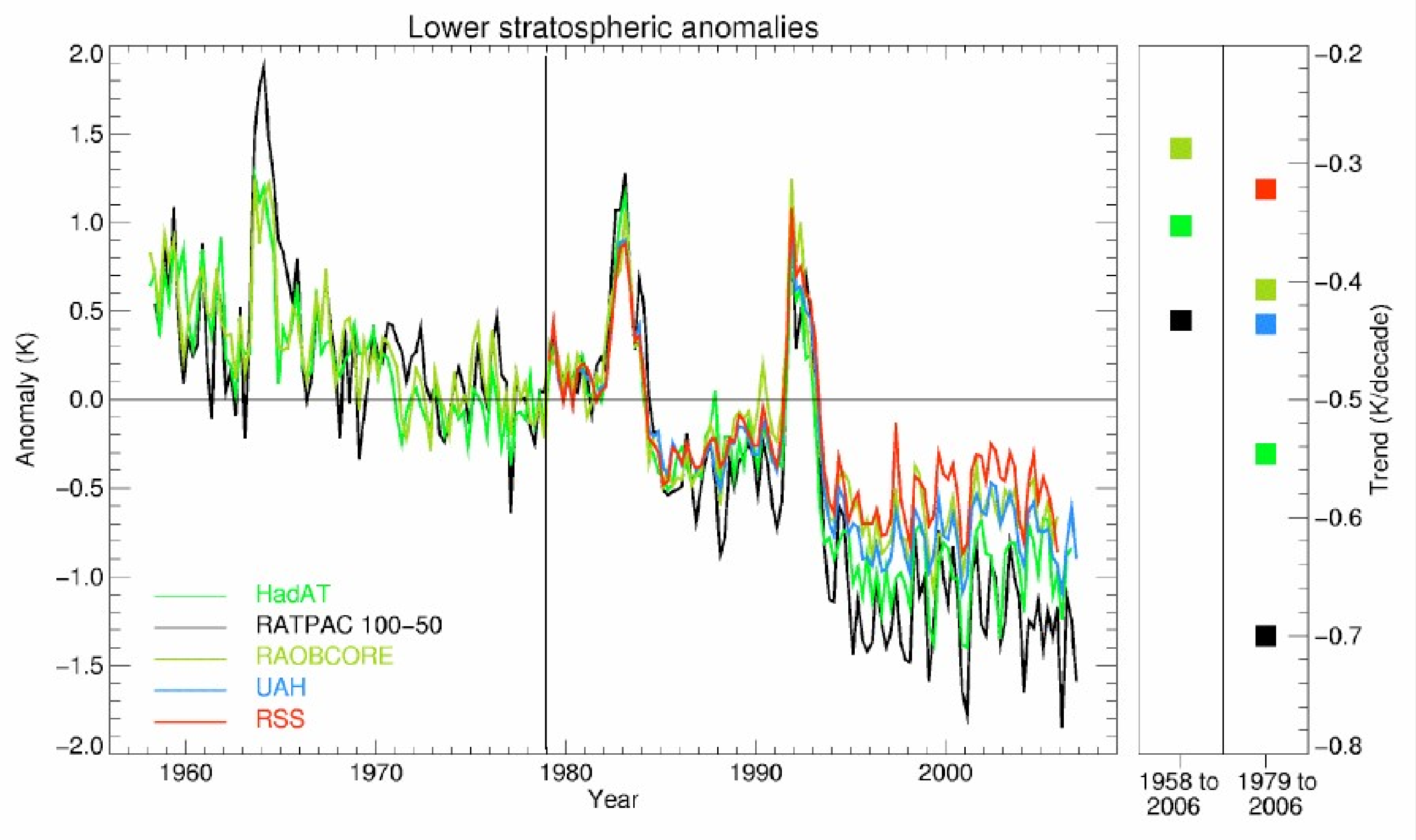
Rationale

1. Scientific needs
2. Why should GRUAN use reference radiosonde?
3. Are we there yet technologically?
4. Cost-effect

Requirements

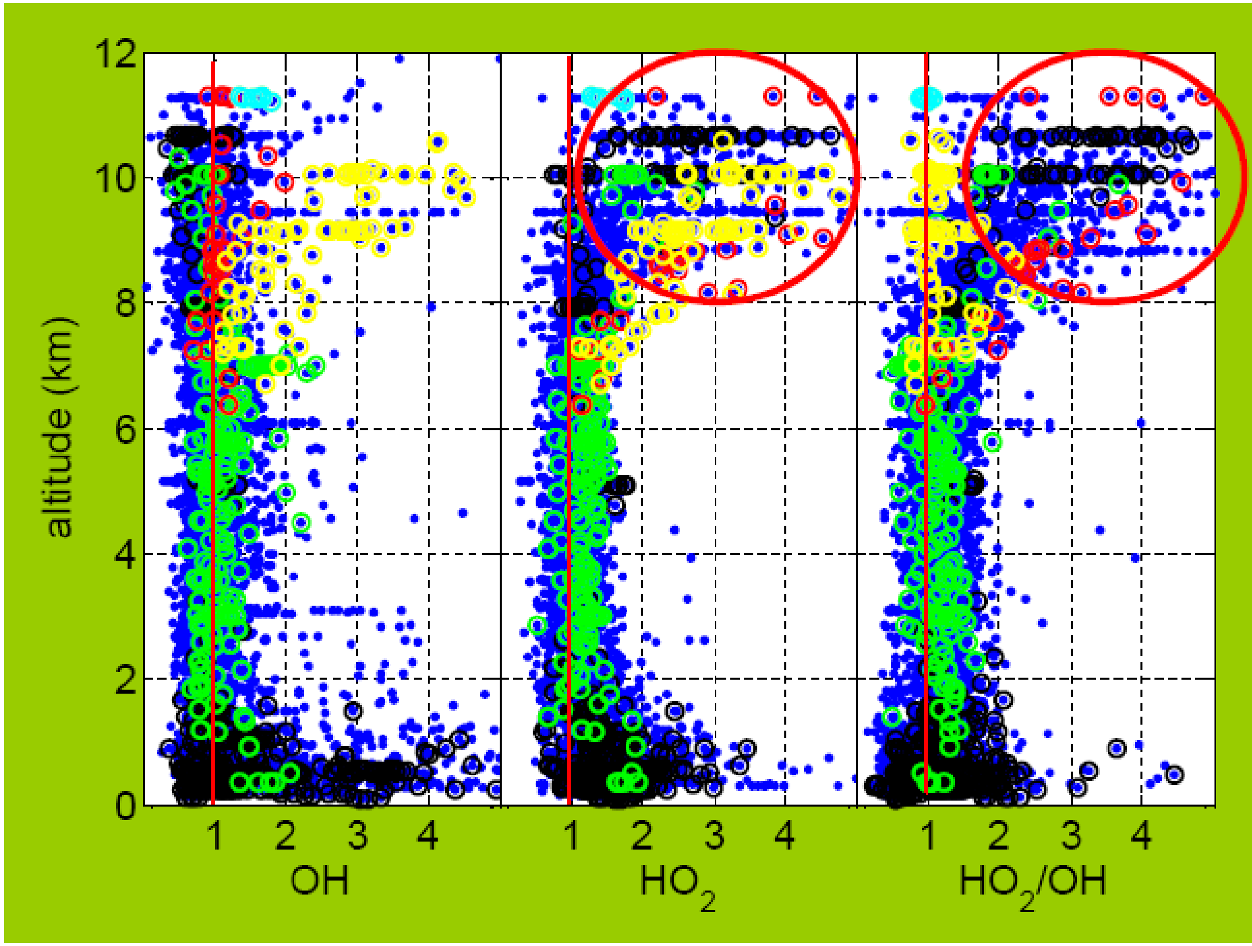
	Temperature	Water Vapor	Pressure	Vector Wind
Priority (1-4)	1	1	1	2
Measurement Range	100-350 K	0.1 to 90000 ppmv	1 to 1100 hPa	0 – 300 m/s
Vertical Range	0 km to stratopause	0 to ~30 km	0 km to stratopause	0 km to stratopause
Vertical Resolution	0.1 km (surface to ~30 km) 0.5 km (above ~30 km)	0.05 km (surface to 5 km) 0.1 km (5 to ~30 km)	0.1 hPa	0.05 km in troposphere 0.25 km in stratosphere
Precision	0.2 K	2% in troposphere 5% in stratosphere	0.1 hPa	0.5 m/s in troposphere 1.0 m/s in stratosphere
Accuracy	0.1 K in troposphere 0.2 K in stratosphere	2% in troposphere 5% in stratosphere	0.1 hPa	1.0 m/s[1]
Long-Term Stability	0.05 K[1]	[1]1%	0.1 hPa	0.5 m/s in troposphere 1.0 m/s in stratosphere

Arguez (2007), BAMS
Agreement in pre-satellite ERA?



Arguez et al. 2007, BAMS

deep convective clouds and chemistry (Brune, NSFUW)



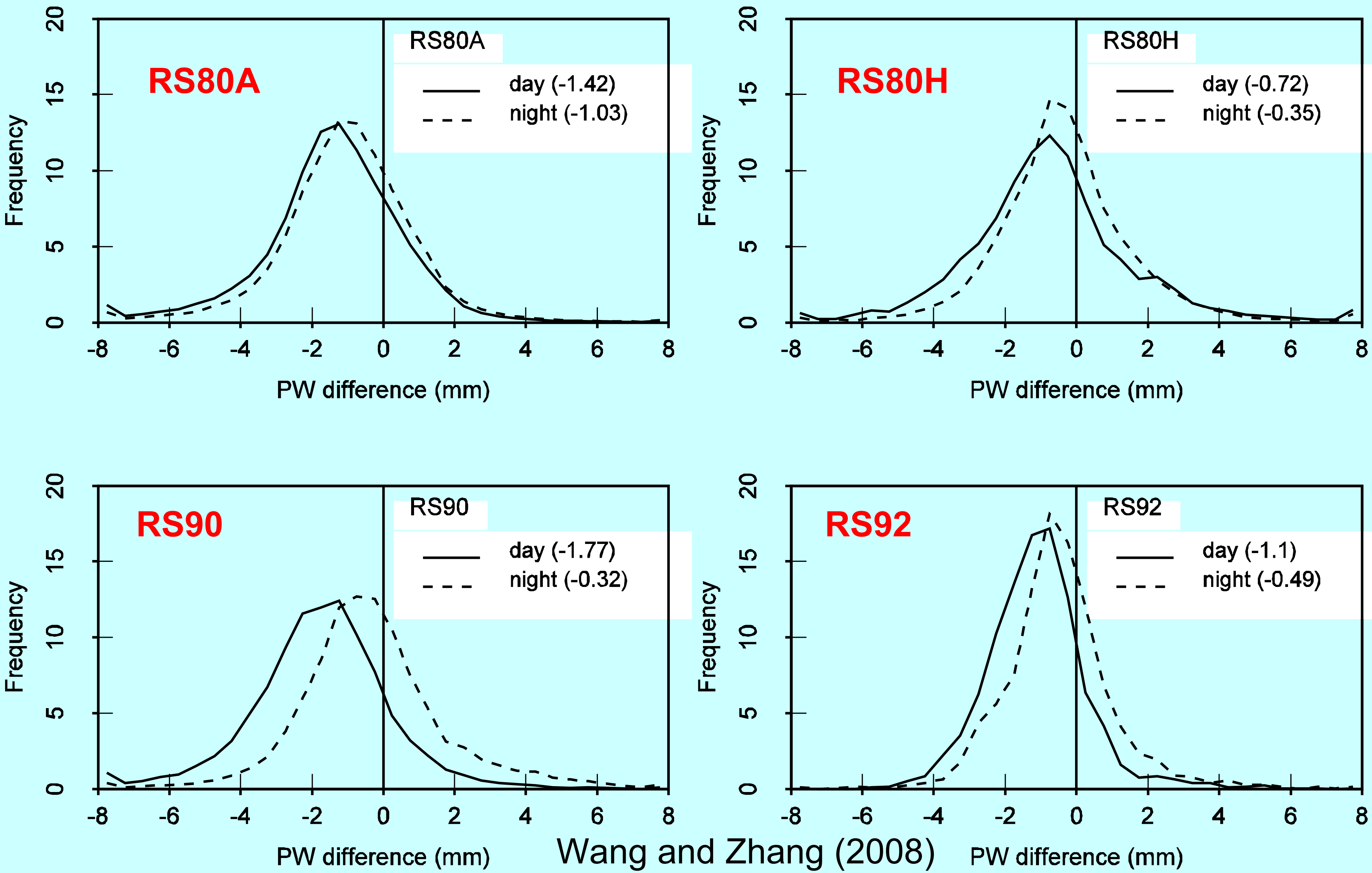
Observed-to-modeled ratios

- background
- o biomass
- o urban
- o stratosphere

(also, problems with prediction of CO, NOx, HCHO, HNO3 – Barth 2007)

- Observed HO_2 & HO_2/OH grow to 2- 4 times modeled values at high altitudes. HO_2 obs/mod ratio correlates with NO.
- Calculated O_3 production ~ 11 ppbv day^{-1} (typically only 1-2!).

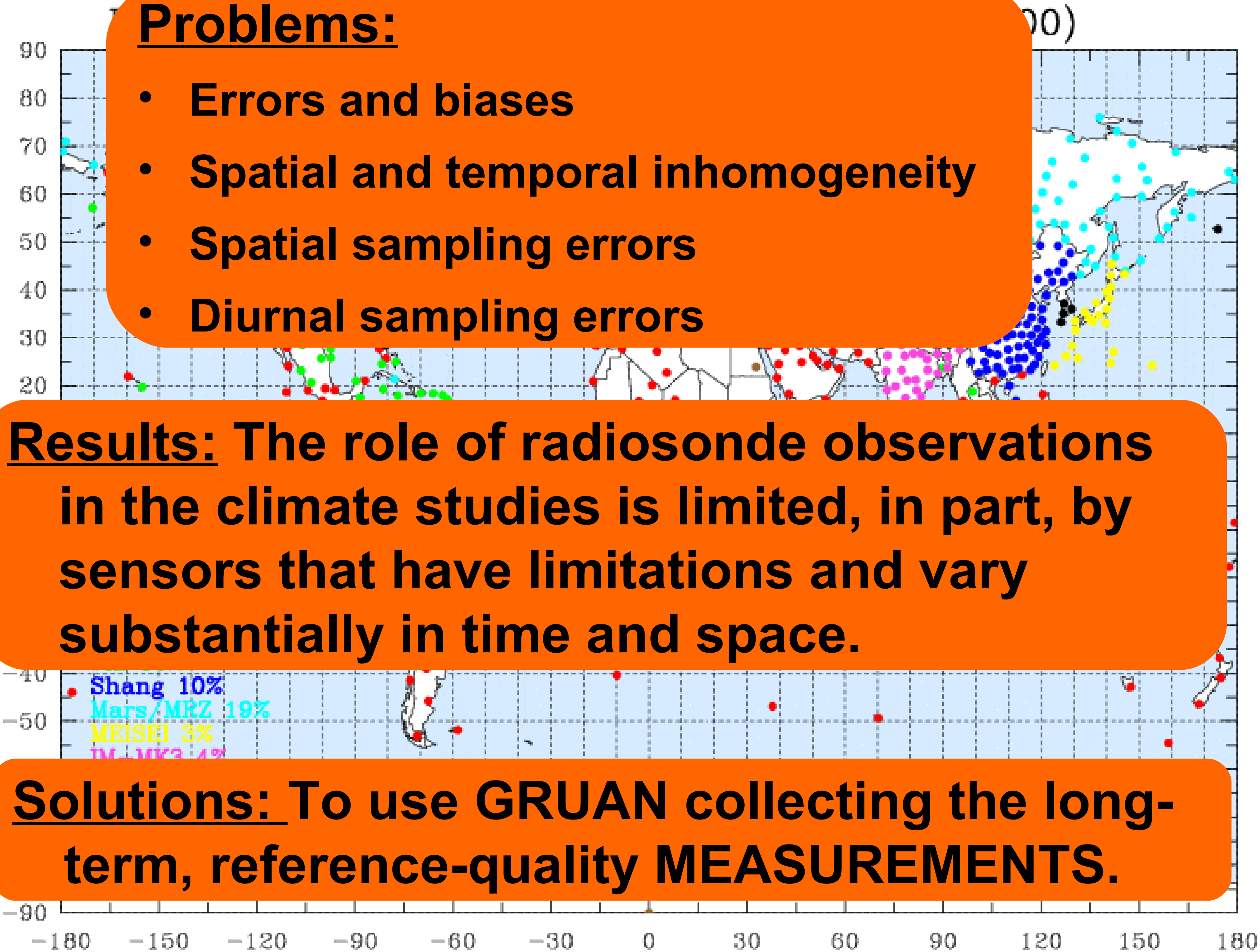
PW comparisons between radiosonde and GPS



Wang and Zhang (2008)

Problems:

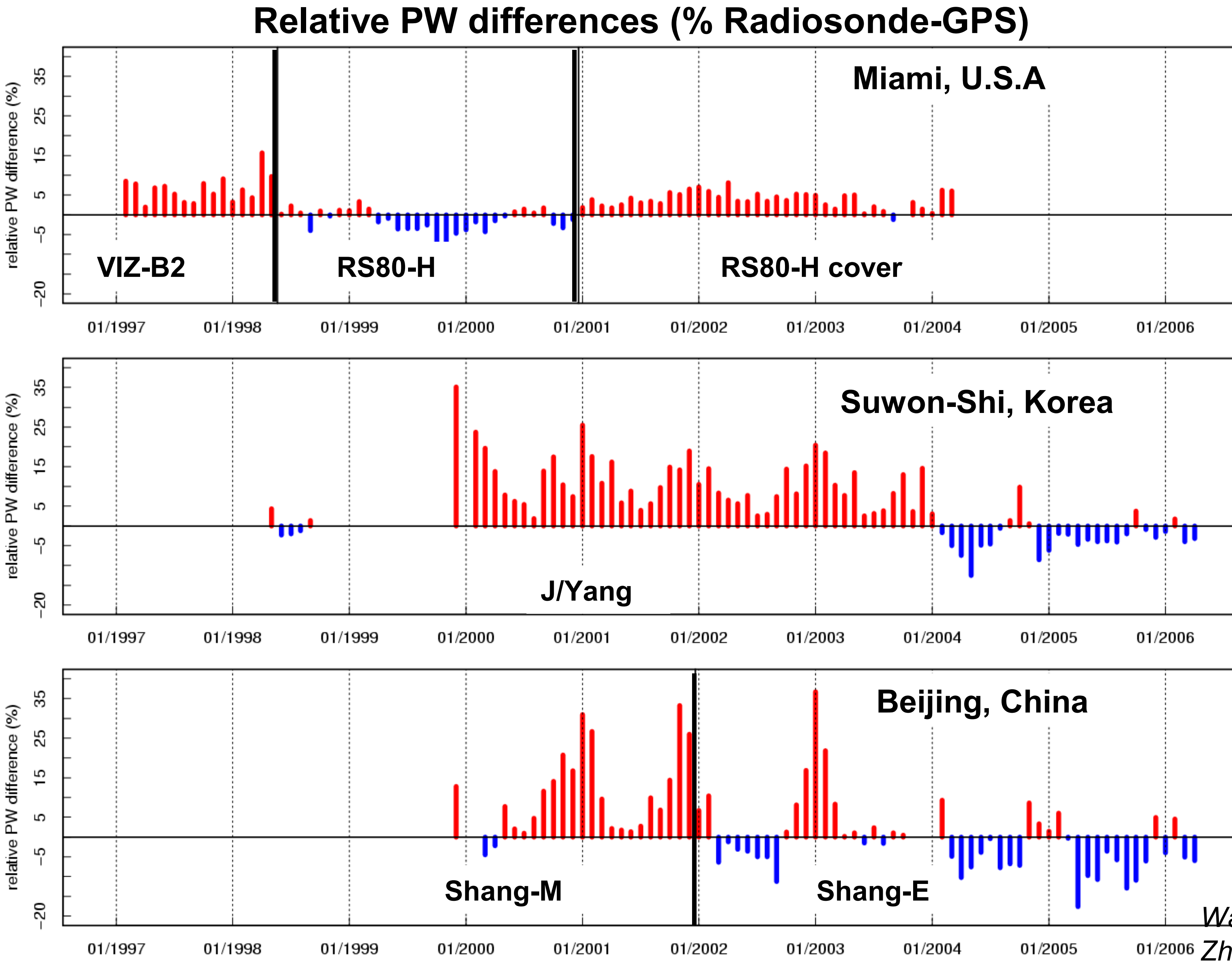
- Errors and biases
- Spatial and temporal inhomogeneity
- Spatial sampling errors
- Diurnal sampling errors



Results: The role of radiosonde observations in the climate studies is limited, in part, by sensors that have limitations and vary substantially in time and space.

Solutions: To use GRUAN collecting the long-term, reference-quality MEASUREMENTS.

Temporal inhomogeneity of radiosonde PW data



Wang and Zhang (2008)