The 9th GRUAN Implementation-Coordination Meeting
June 12-16, 2017
Helsinki, Finland

On the accuracy of the upper-air temperature observations: Vaisala RS41 versus RS92

Bomin Sun[1,2] and Tony Reale[2]

1 IMSG, Rockville, Maryland
2 NOAA/NESDIS/Center for Applications and Research (STAR), College Park, Maryland

Acknowledgements:
Chi Ao (JPL), Joe Nielsen (ROM SAF), Jack Woollen and Dennis Keyser (NOAA NCEP), Steve Schroeder (Texas A&M), Xavier Calbet (AEMET), Mike Pettey and Ryan Smith (NOAA NESDIS)

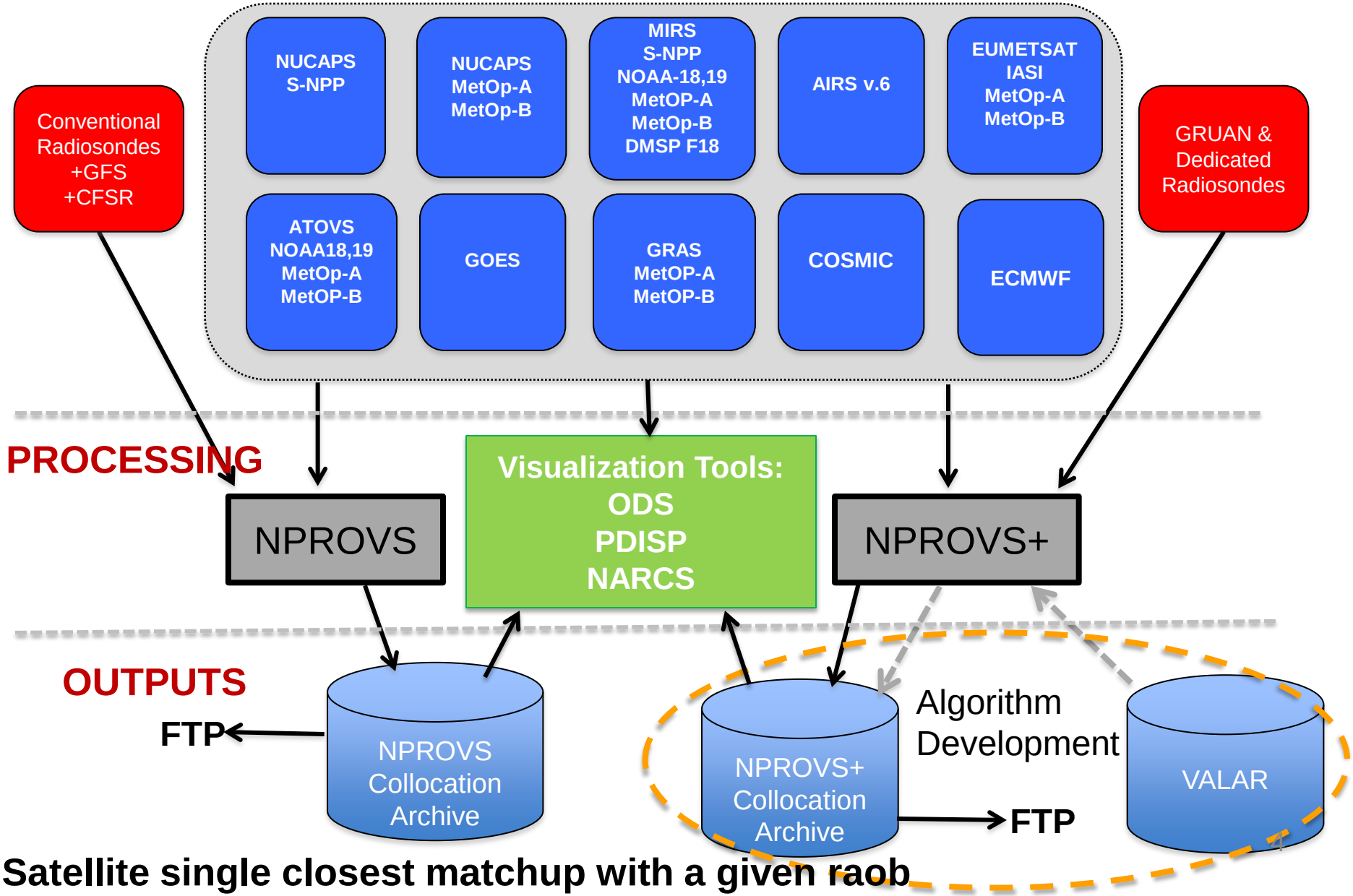
Methodologies

- Use NWP radiation correction (RADCOR) scheme:
  - **Compute RAOB-minus-forecast background (O-B) at different solar angles and heights for all individual sonde types.**
  - Adjust O-B to the nighttime values of the selected reference sonde (e.g., RS92).
- Use GPSRO Tdry as the truth
  - Sun et al. (2013, JGR)

Data (2015-2016)

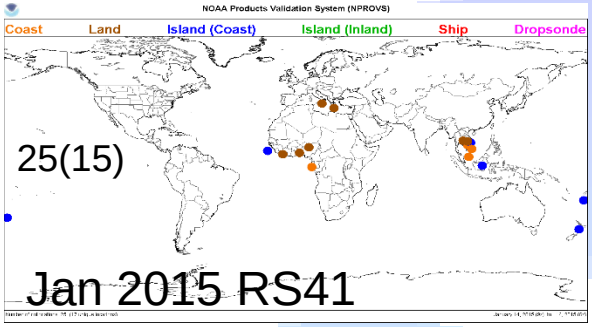
- Conventional radiosonde data
  - Vaisala RS41 (~44,000) and RS92 (~274,000)
- NWP data (used for O-B)
  - NOAA Climate Forecast System Re-analysis (CFSR) forecast background
- GPSRO Tdry (used as the truth)
  - UCAR COSMIC
  - ROM SAF GRAS
- NOAA Products Validation System (NPROVS)

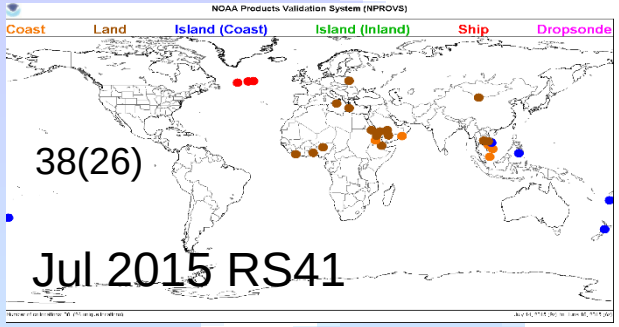
NOAA Products Validation System: NPROVS and NPROVS+

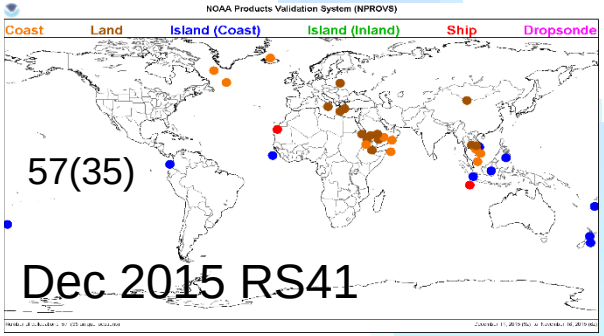


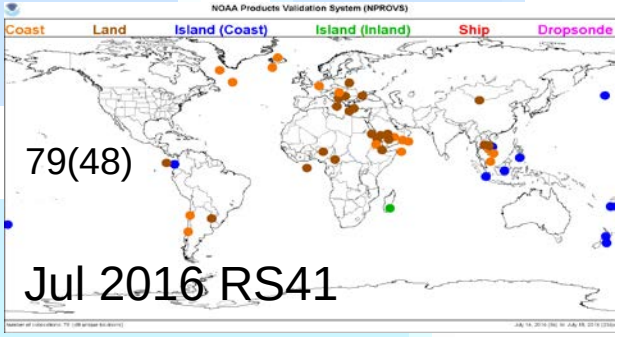
Satellite single closest matchup with a given raob

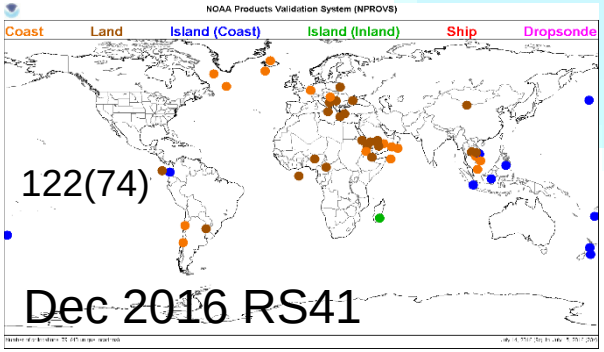
Conventional RS41 launches

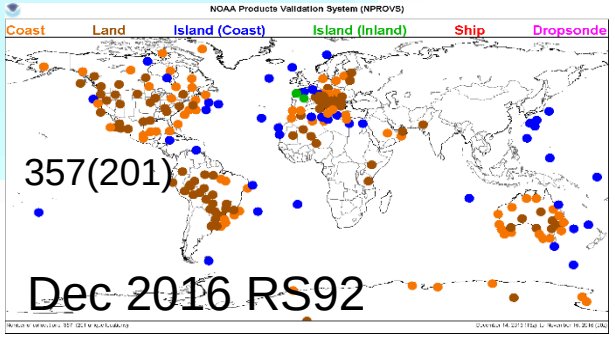






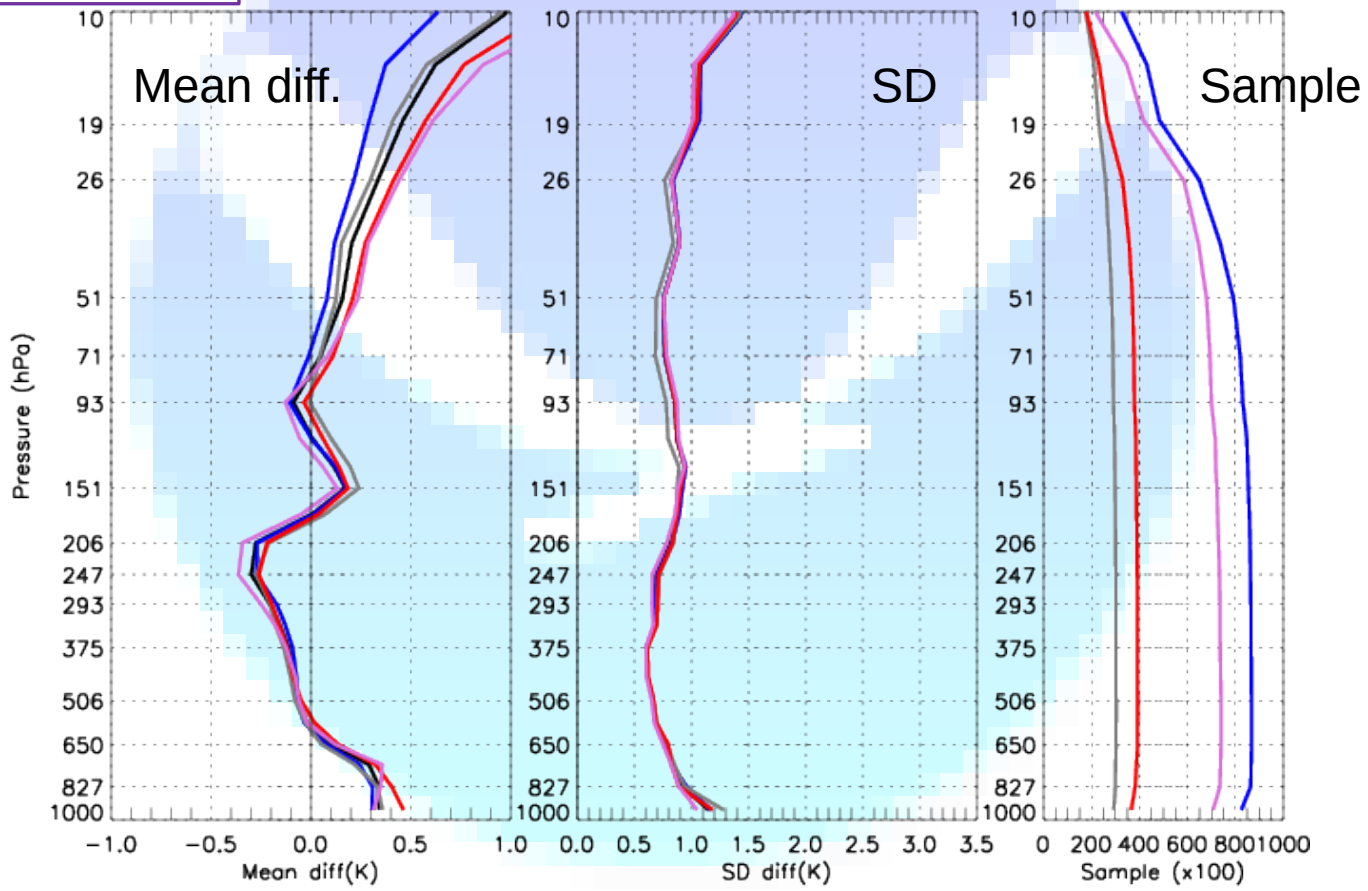






RS92-minus-CFSR BG
Global

Solar Elevation Categories
- NIGHT (<−7.5 deg)
- DAWN/DUSK (−7.5 – 7.5 deg)
- LOW (7.5 – 22.5 deg)
- HIGH (>22.5 deg)



e.g., 12Z BG: 3-hr forecast made at 09Z

RS41-minus-CFSR BG
Global

Solar Elevation Categories
- NIGHT (<−7.5 deg)
- DAWN/DUSK (−7.5 – 7.5 deg)
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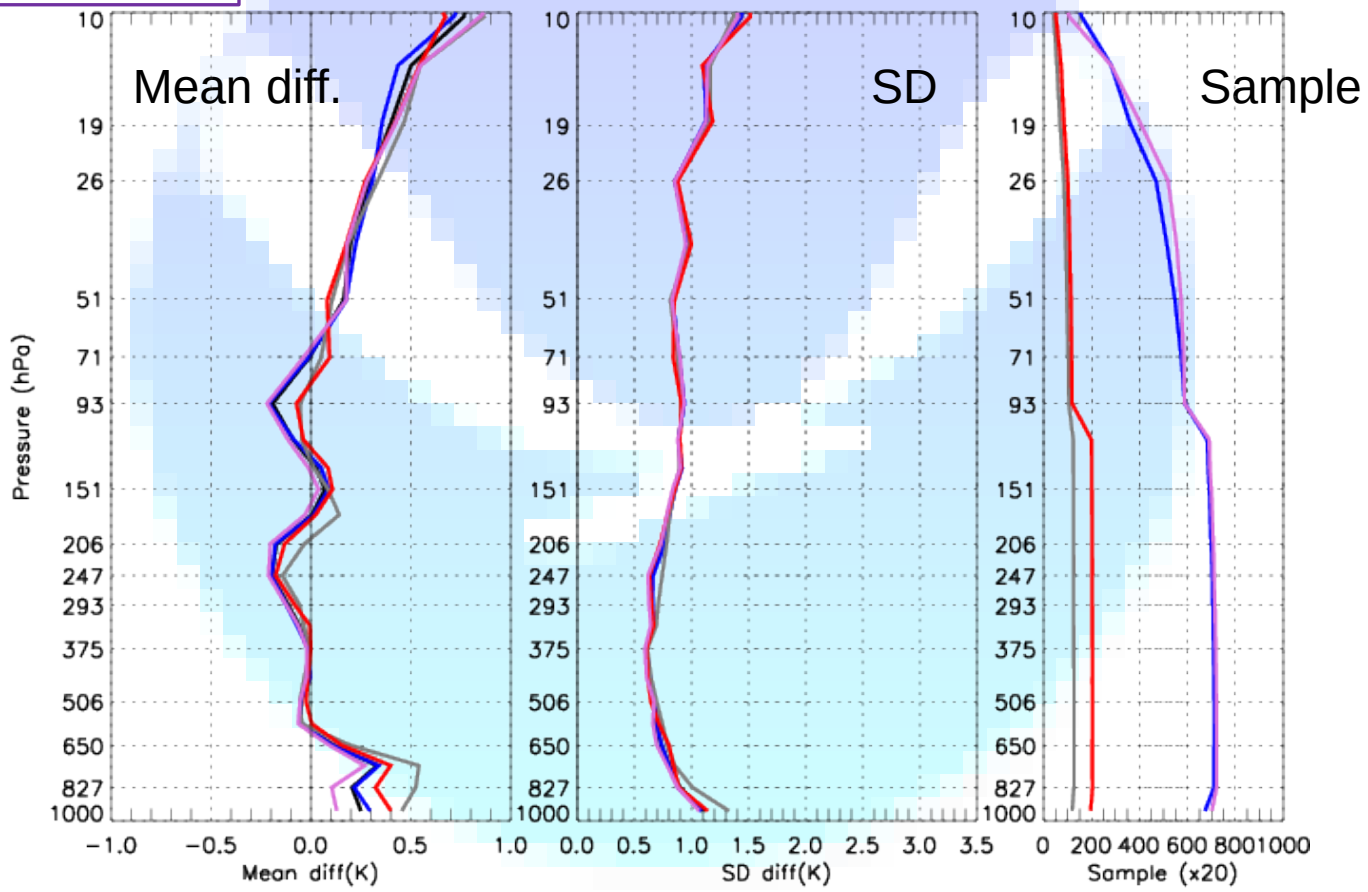

e.g., 12Z BG: 3-hr forecast made at 09Z

(RS92-BG) – (RS41-BG)

Solar Elevation Categories
- NIGHT (<−7.5 deg)
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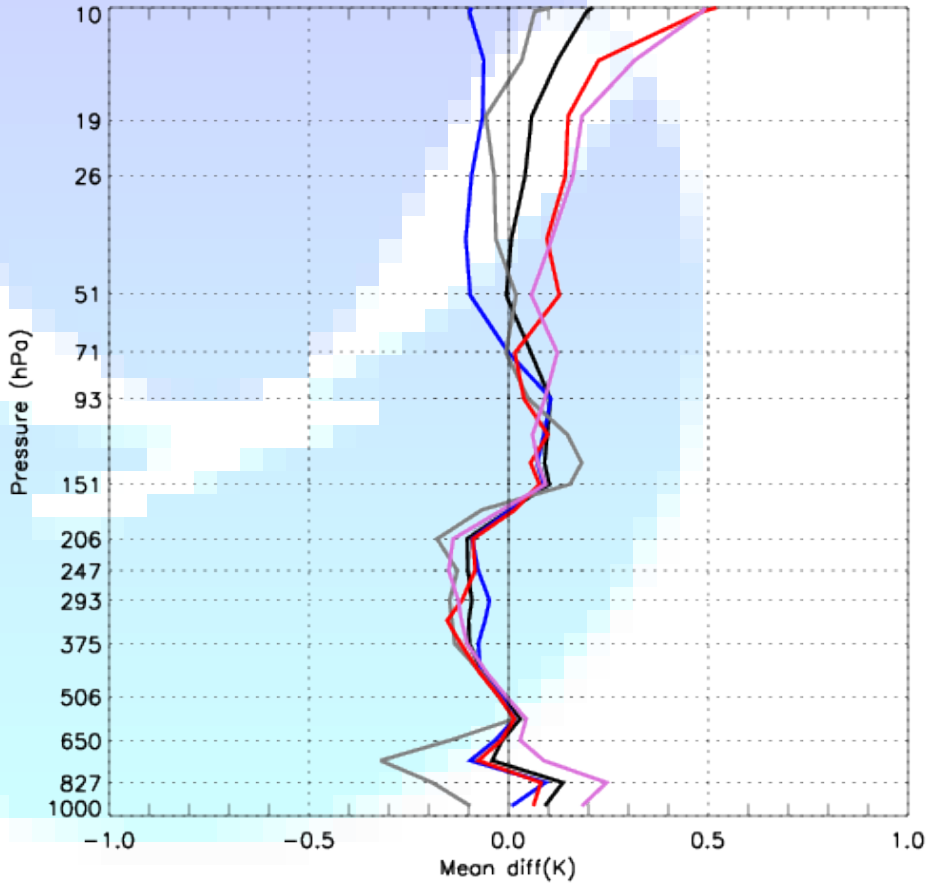


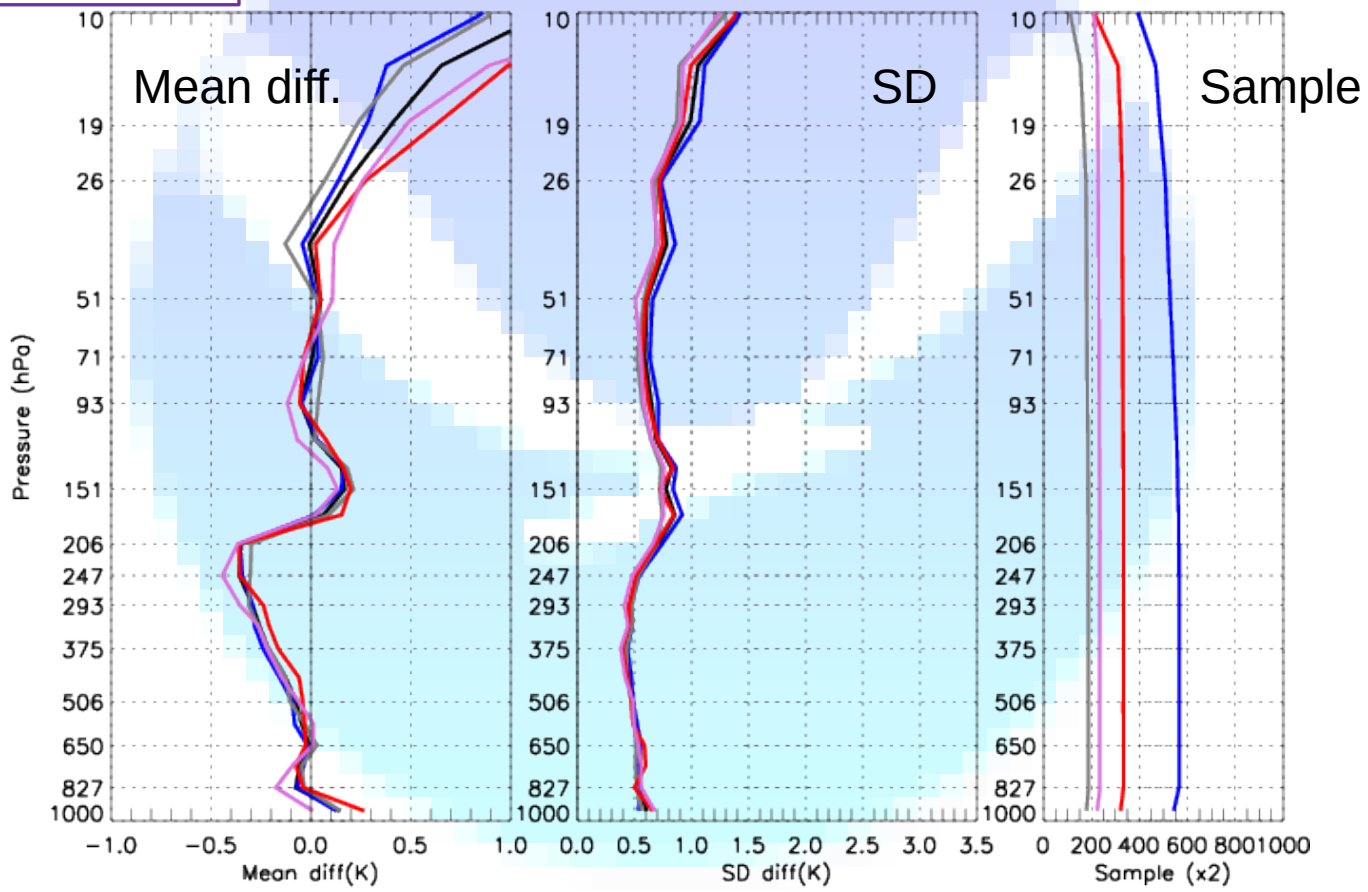
RS92 -minus- RS41

For 21-32 hPa
Night -0.09 K
High Solar Elevation 0.16 K

For 32-43 hPa
Night -0.11 K
High Solar Elevation 0.11 K

RS92-minus-CFSR BG
Lindenburg, Germany

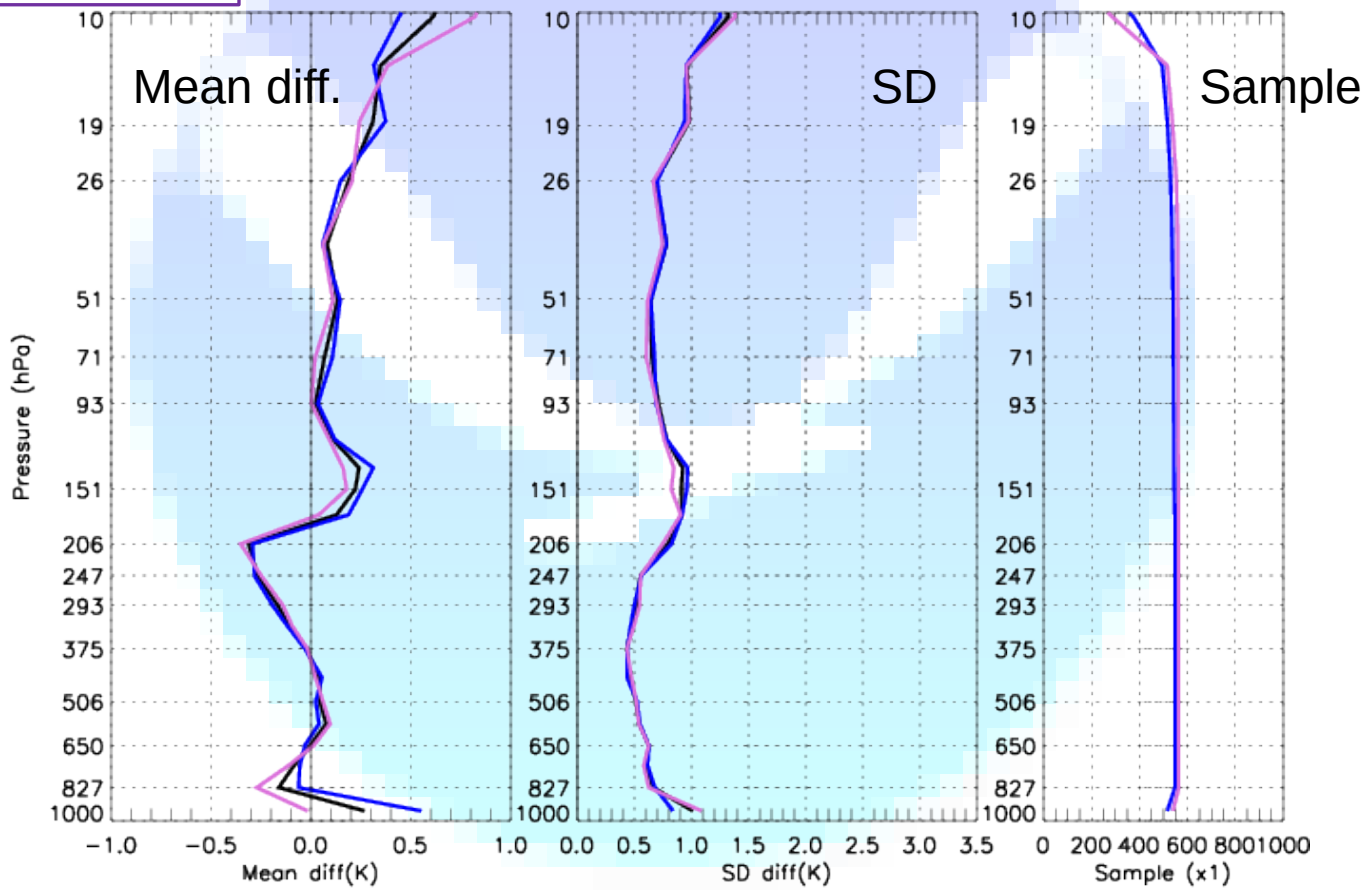
Solar Elevation Categories
- NIGHT (<−7.5 deg)
- DAWN/DUSK (−7.5 – 7.5 deg)
- LOW (7.5 – 22.5 deg)
- HIGH (>22.5 deg)



10393 (52.21N, 14.12E) 4 times/day, Vaisala RS92

RS41-minus-CFSR BG
Zagreb/Maksimir, Croatia

Solar Elevation Categories
- NIGHT (<−7.5 deg)
- DAWN/DUSK (−7.5 – 7.5 deg)
- LOW (7.5 – 22.5 deg)
- HIGH (>22.5 deg)



14240 (45.82N, 16.03E) 2 times/day, Vaisala RS41

GPS RO Tdry accuracy

- For the UTLS (~10 – 25 km)
  - The accuracy/bias is within 0.1 – 0.2 K averaged from many (e.g., hundreds of) profiles
  - The precision of the individual profile is within 0.5 - 1 K

- For the middle stratosphere and higher (30 – 50 km)
  - The accuracy is 0.5 – 5 K (degrading with altitude)

Chi Ao (JPL, personal communication)

Steiner et al. (2011, Radio Sci)

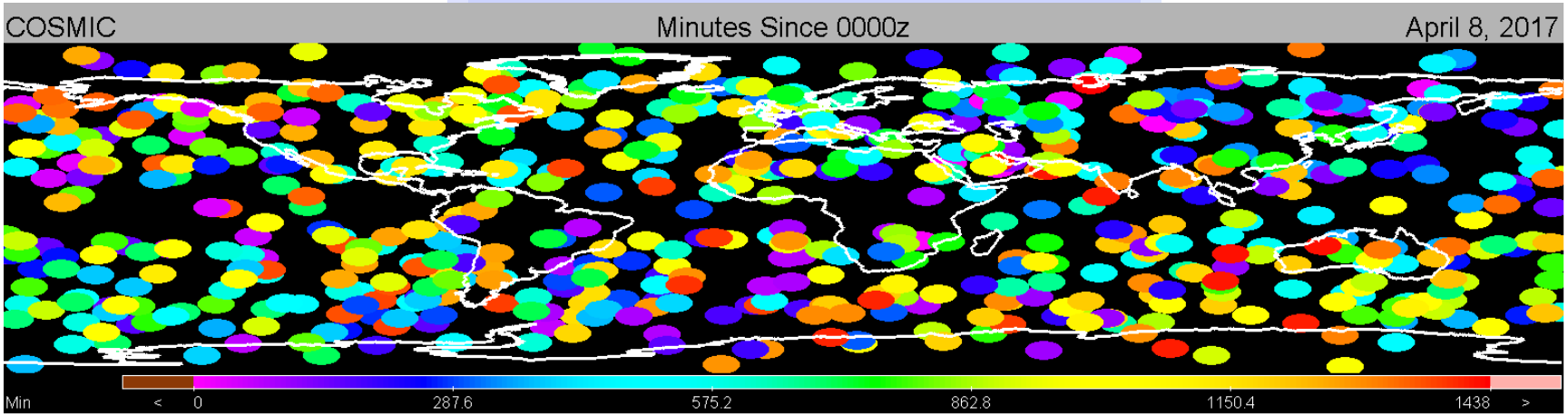
Hajj et al. (2004, JGR)

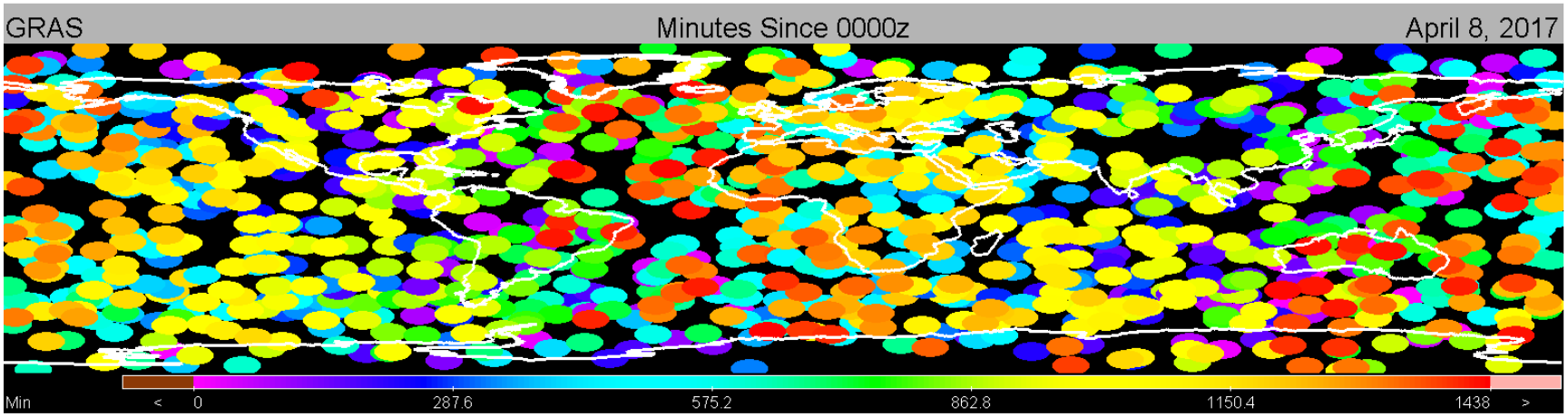
Kursinski et al. (1997, JGR)

For Vaisala sondes , Reproducibility: 0.3 – 0.5 K for pressure <100 hPa

COSMIC and GRAS RO

(April 8, 2017)

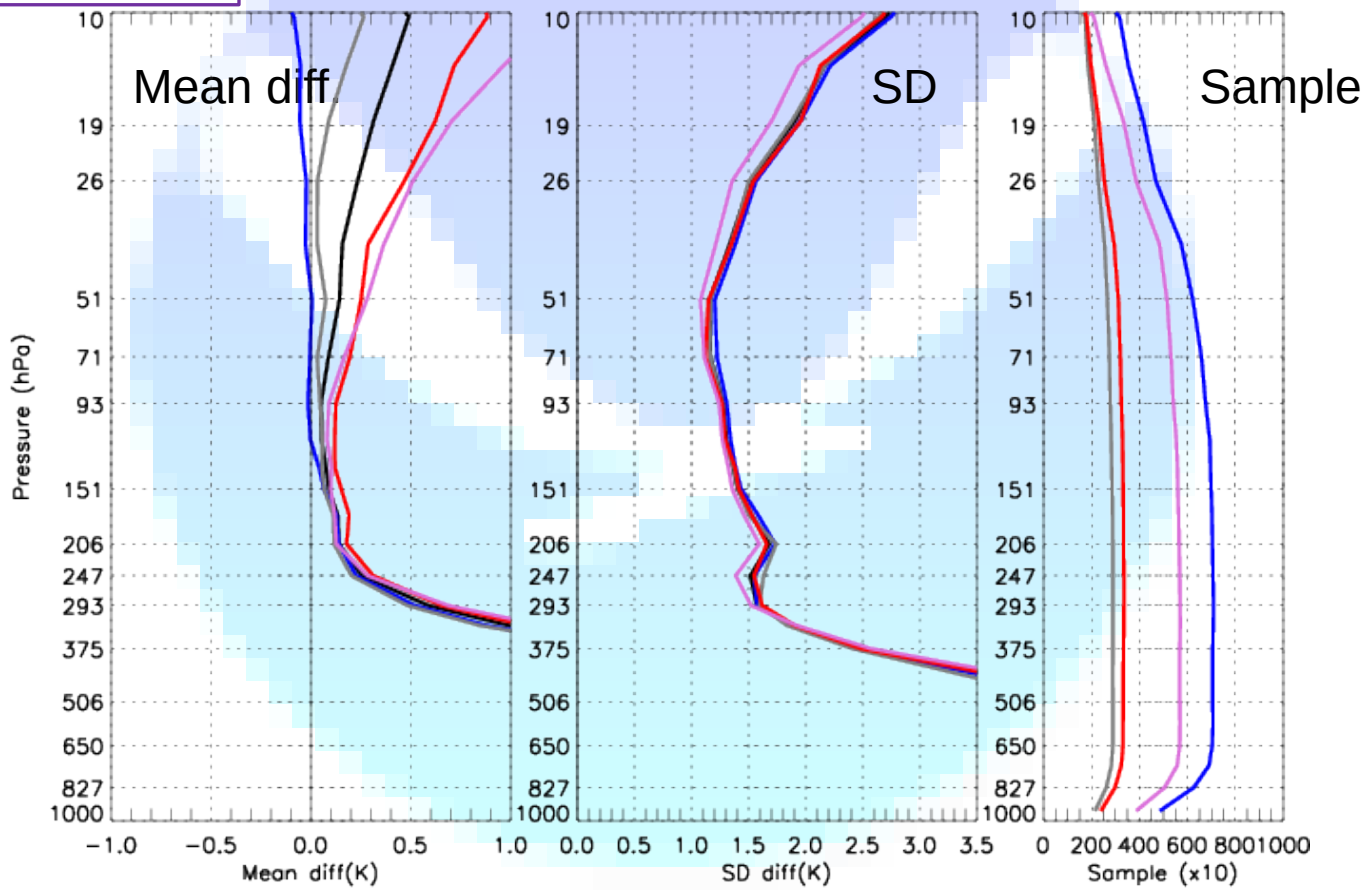




COSMIC RO profiles: 618
GRAS RO profiles: 1200

RS92-minus-Tdry COSMIC Global (3hr/250km)

Solar Elevation Categories
- NIGHT (<−7.5 deg)
- DAWN/DUSK (−7.5 – 7.5 deg)
- LOW (7.5 – 22.5 deg)
- HIGH (>22.5 deg)



Similar to Sun et al. (2013, JGR) based on 2008-2011 data

RS41-minus-Tdry COSMIC Global (3hr/250km)

Solar Elevation Categories
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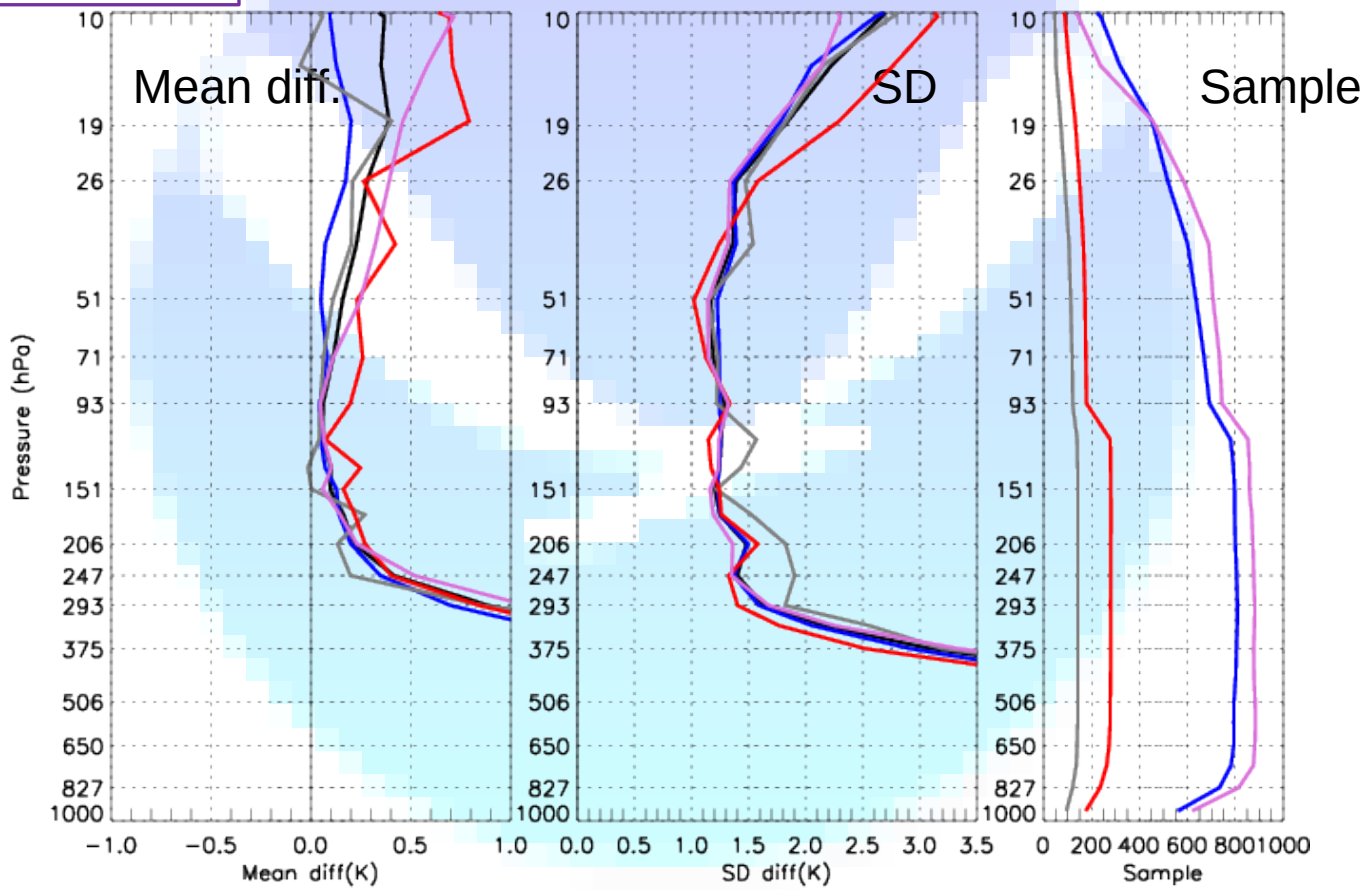
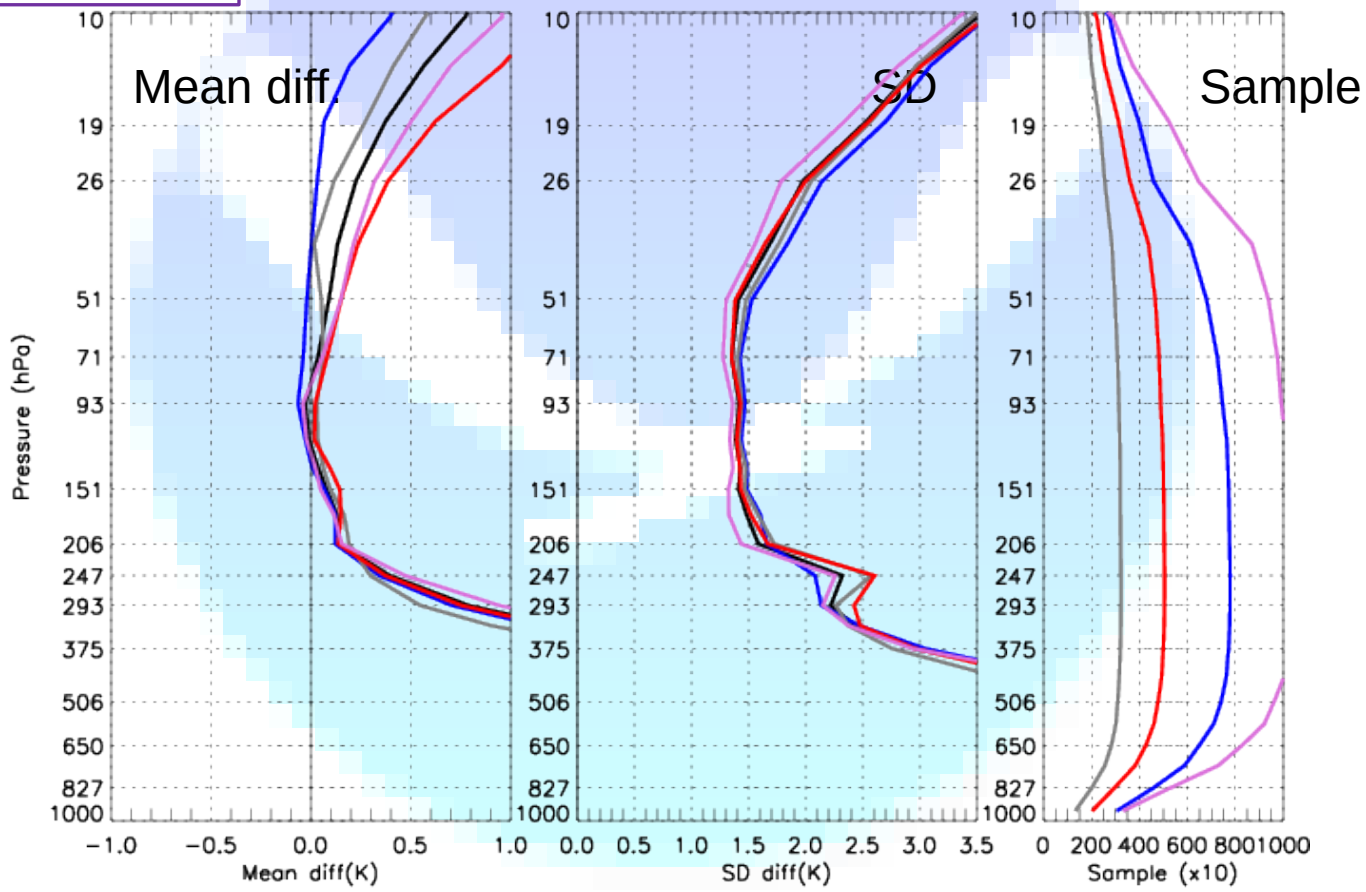


RS92-minus-Tdry GRAS Global (3hr/250km)

Solar Elevation Categories
- NIGHT (<−7.5 deg)
- DAWN/DUSK (−7.5 – 7.5 deg)
- LOW (7.5 – 22.5 deg)
- HIGH (>22.5 deg)



RS92-minus-Tdry COSMIC Global (3hr/250km)

Solar Elevation Categories
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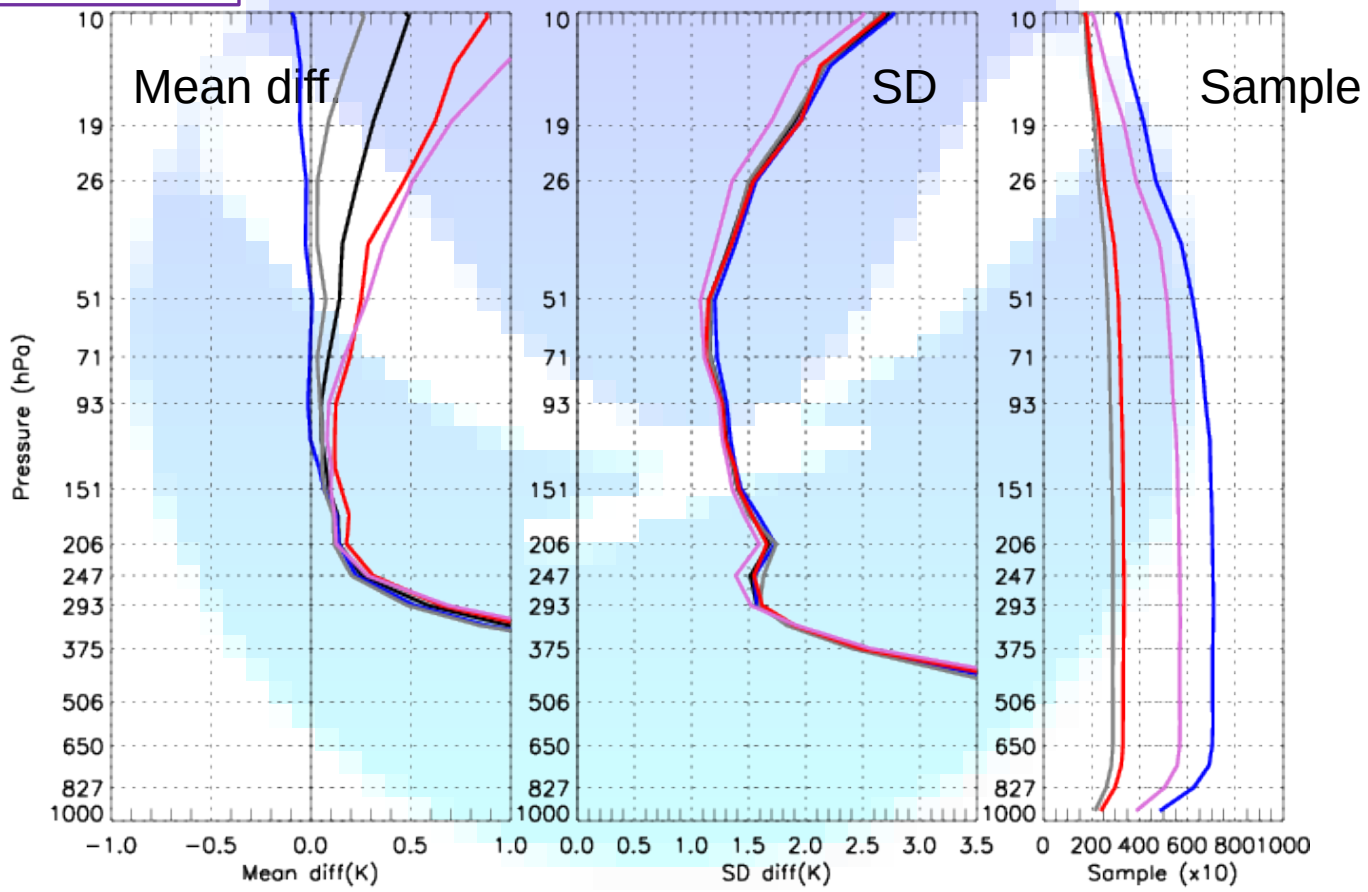

Similar to Sun et al. (2013, JGR) based on 2008-2011 data

RS92-minus-Tdry GRAS Global (3hr/250km)

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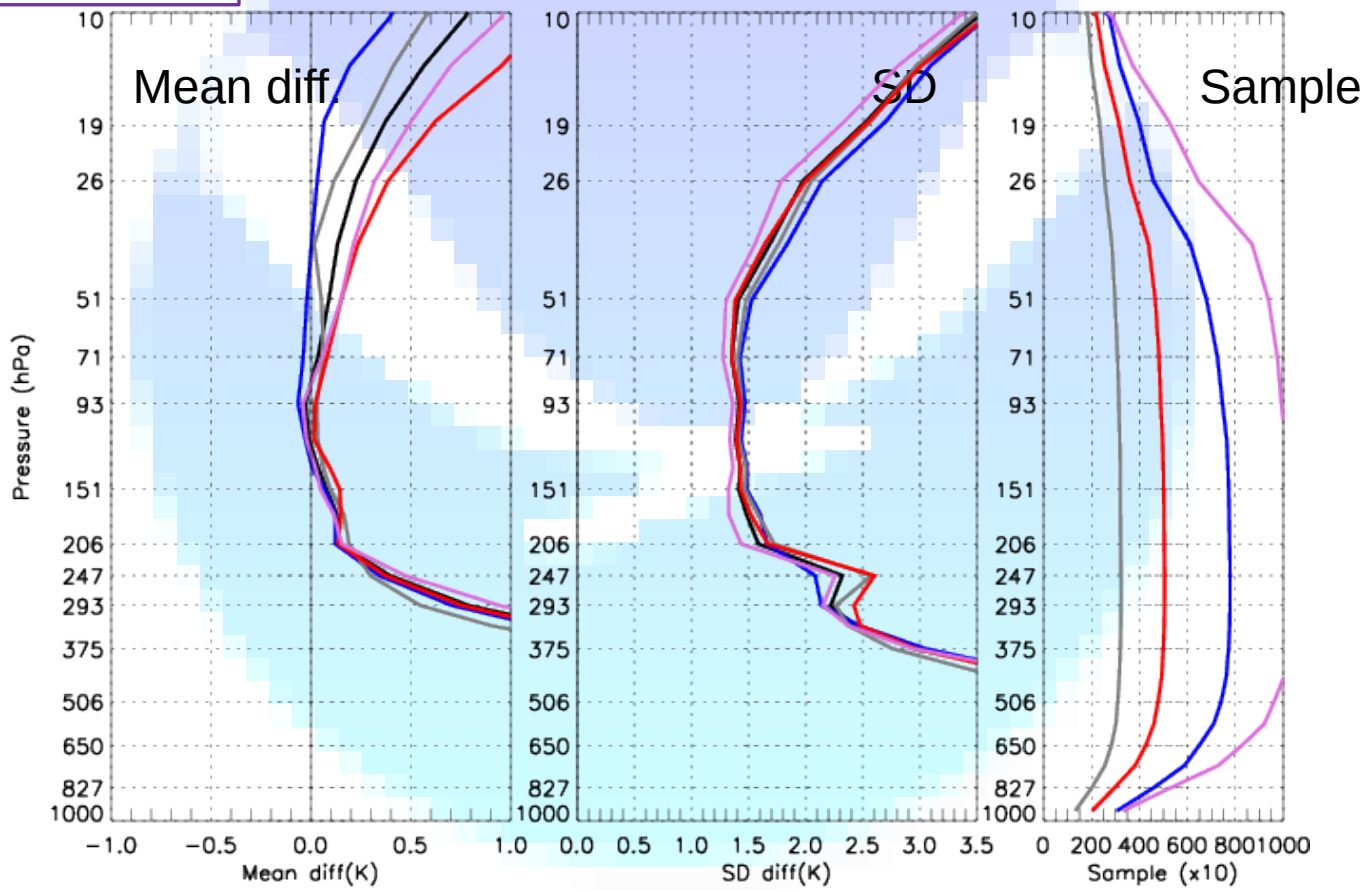

RS41-minus-Tdry GRAS Global (3hr/250km)

Solar Elevation Categories
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- DAWN/DUSK (−7.5 – 7.5 deg)
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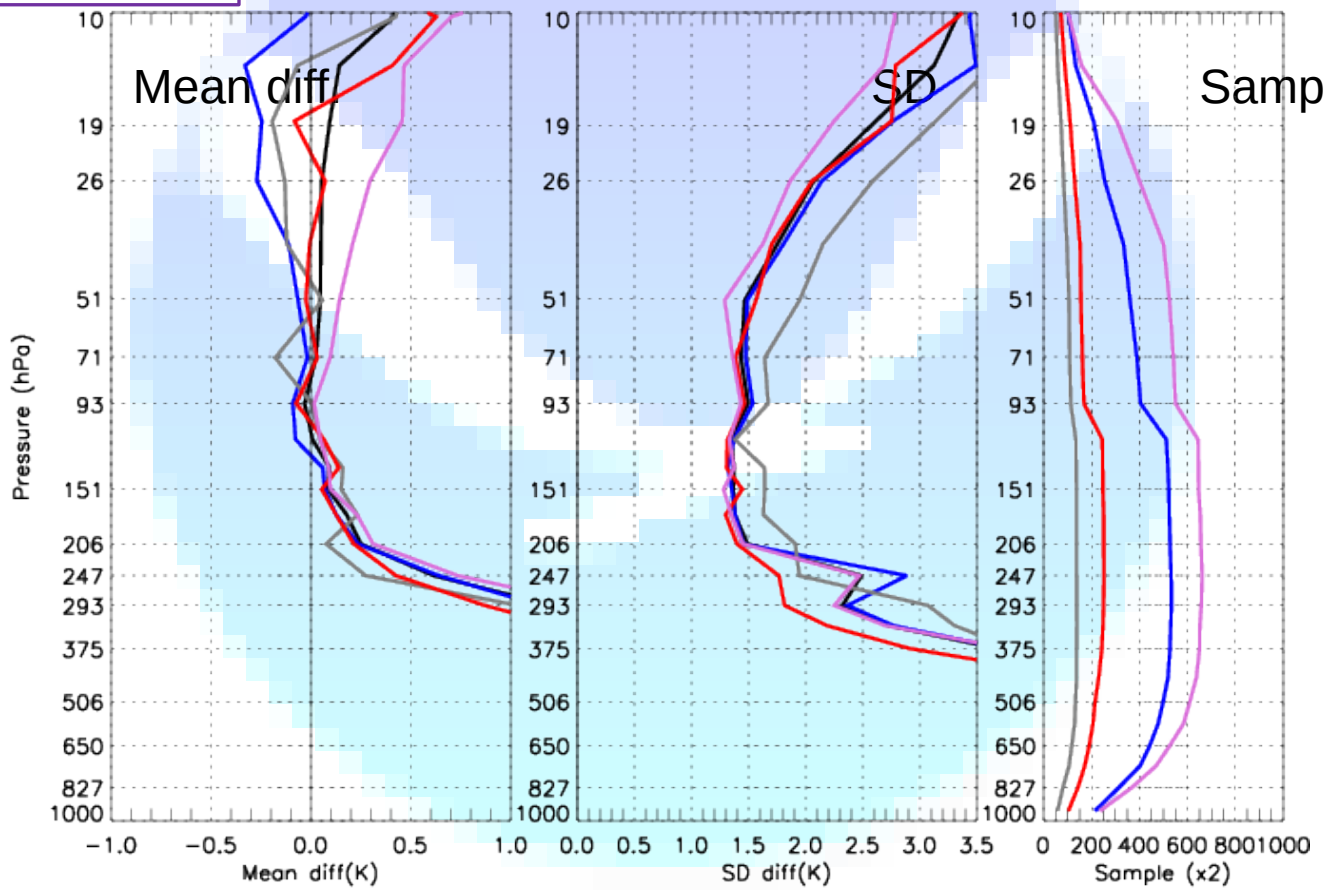
- HIGH (>22.5 deg)



Preliminary Results

- Two yrs of global conventional RS41 vs RS92 were analyzed using NWP (CFSR BG and analysis, and ECMWF analysis), and GPS RO Tdry of UCAR COSMIC and ROM SAF GRAS:
- RS41 appears to be less sensitive to solar elevation angle change than RS92.
- The RS92-RS41 difference in the lower stratosphere appears to be within 0.1 - 0.2 K, globally.
- The NWP model data, *i.e.*, CFSR BG and analysis, and ECMWF analysis, are systematically colder (by 0.1-0.5K) than RS92/RS41 in the upper atmosphere (10 -100 hPa).
- Sample size matters when Tdry is used as the reference for RAOB accuracy assessment.
- Use different Tdry products in the RAOB assessment.

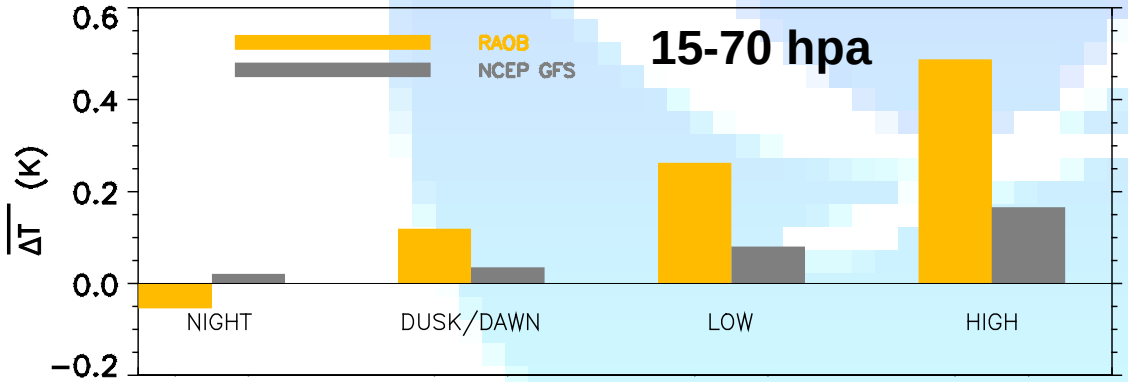
Extra

For 32.2 ~ 43.1 hPa

		RS92-minus-target	RS41-minus-target	(RS92)-minus-(RS41)
Night	(CFSR BG)	0.12 ±0.90 (73,600)	0.20 ±0.97 (10,300)	-0.09
High Solar	(CFSR BG)	0.29 ±0.90 (64,600)	0.20 ±0.95 (11,100)	0.11
All data	(CFSR BG)	0.20 ±0.89 (201,200)	0.20 ±0.97 (25,400)	*0.01*
Night	(EC ANA)	0.20 ±0.79 (65,000)	0.20 ±0.81 (8,350)	*-0.01*
High Solar	(EC ANA)	0.34 ±0.74 (58,000)	0.22 ±0.80 (9,000)	0.11
All data	(EC ANA)	0.28 ±0.77 (181,100)	0.23 ±0.82 (21,000)	0.05
Night	(Tdry COSMIC)	-0.03 ±1.38 (5,700)	0.07 ±1.39 (600)	
High Solar	(Tdry COSMIC)	0.37 ±1.21 (4,800)	0.32 ±1.32 (690)	
All data	(Tdry COSMIC)	0.16 ±1.33 (16,100)	0.23 ±1.36 (1,560)	
Night	(Tdry GRAS)	0.00 ±1.84 (6,100)	-0.11 ±1.81 (670)	
High Solar	(Tdry GRAS)	0.21 ±1.56 (8,700)	0.21 ±1.62 (1,000)	
All data	(Tdry GRAS)	0.13 ±1.68 (22,000)	0.05 ±1.75 (2,200)	

Biases in RAOB and GFS forecast relative to COSMIC Tdry

(global average over all stations)
2008.05 – 2011.08



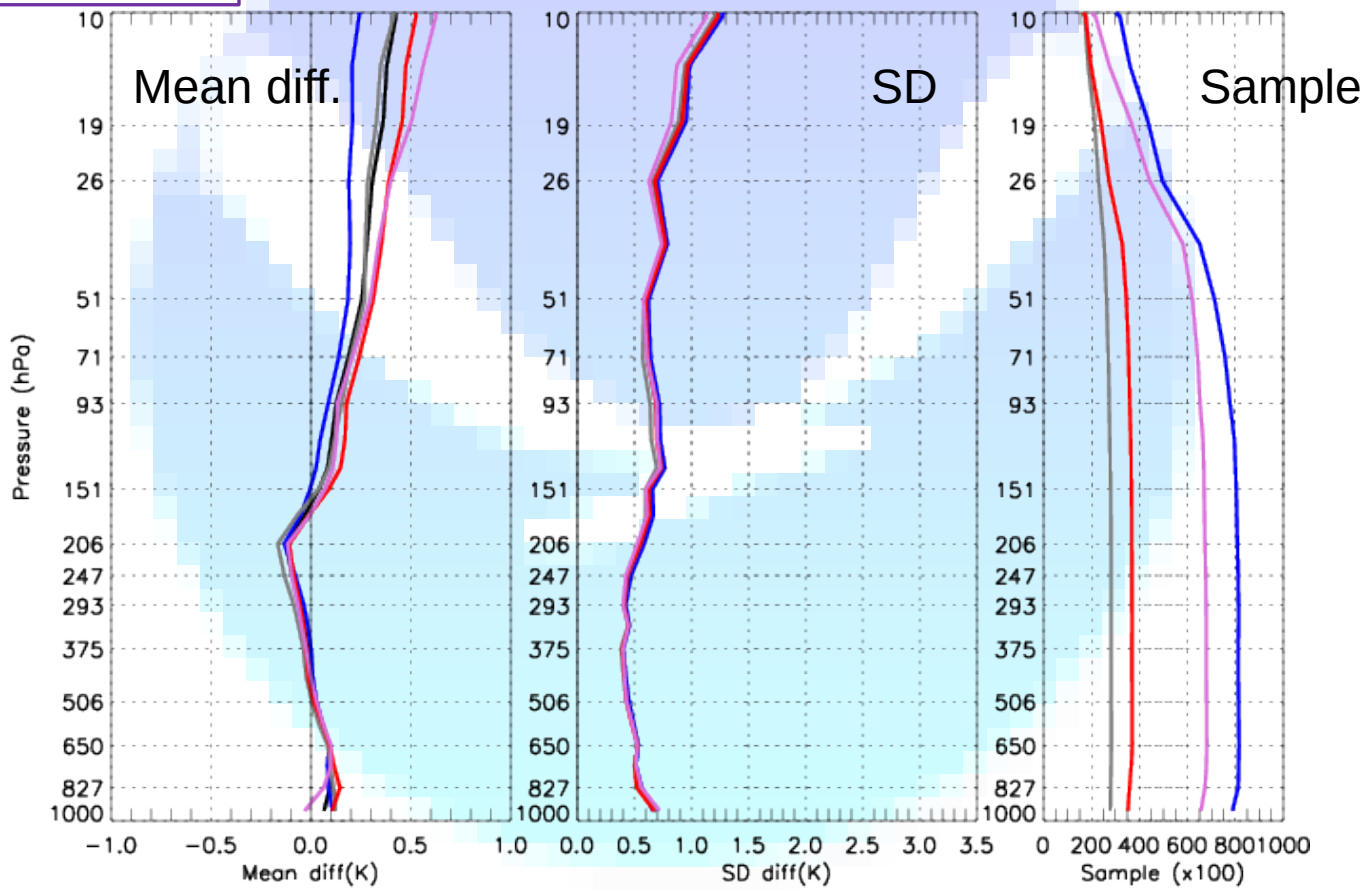
Solar Elevation Categories

- NIGHT (<−7.5 deg)
- DAWN/DUSK (−7.5 – 7.5 deg)
- LOW (7.5 – 22.5 deg)
- HIGH (>22.5 deg)

Sun, B., A. Reale, S. Schroeder, D. J. Seidel, and B. Ballish, 2013: "Toward improved corrections for radiation-induced biases in radiosonde temperature observations". JGR, Vol 118, 1-13, doi:10.1002/jgrd.50369.

RS92-minus-ECMWF ANALYSIS
Global (1hr/50km)

Solar Elevation Categories
- NIGHT (<−7.5 deg)
- DAWN/DUSK (−7.5 – 7.5 deg)
- LOW (7.5 – 22.5 deg)
- HIGH (>22.5 deg)



RS41-minus-ECMWF ANALYSIS
Global (1hr/50km)

Solar Elevation Categories
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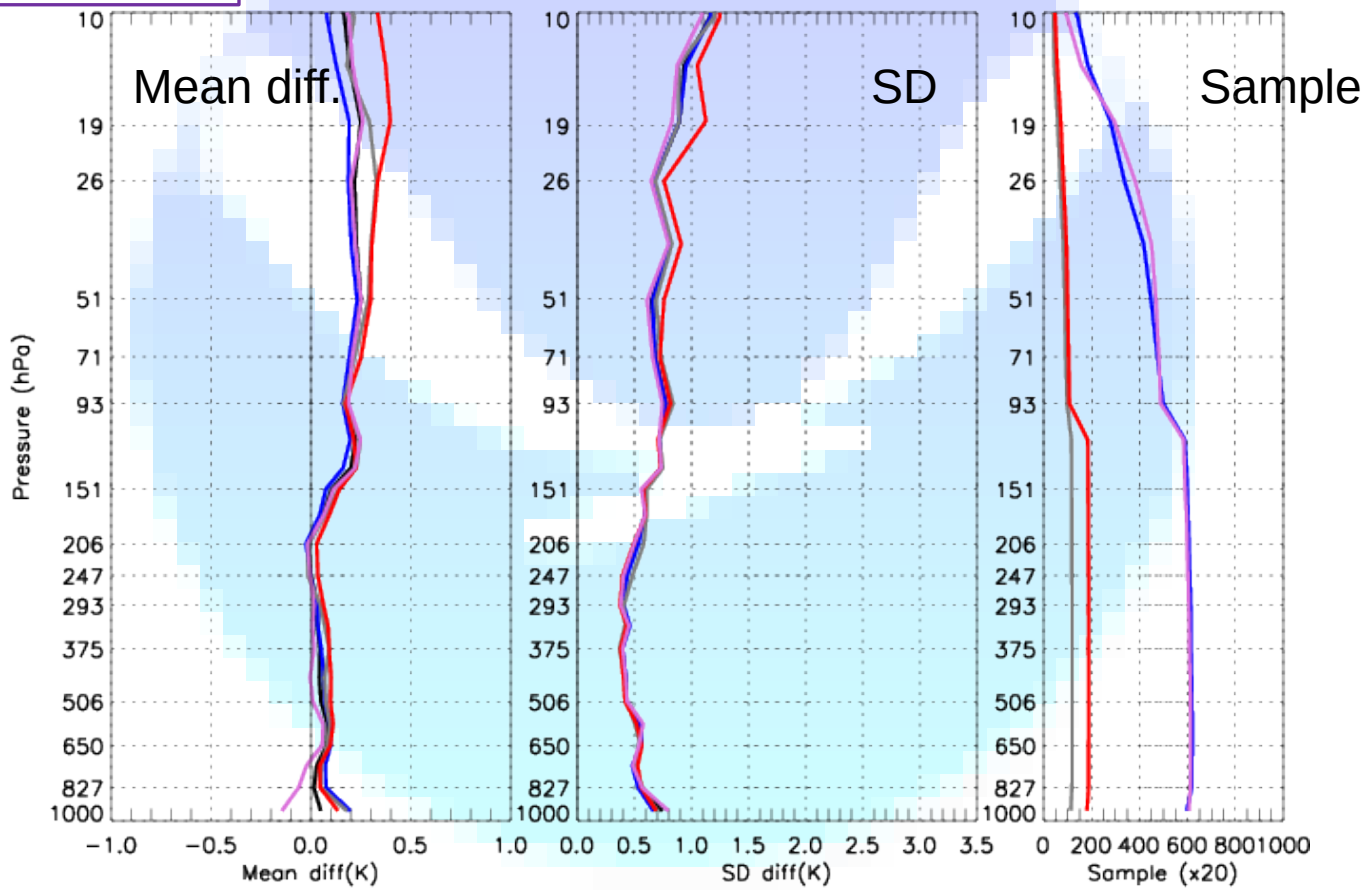
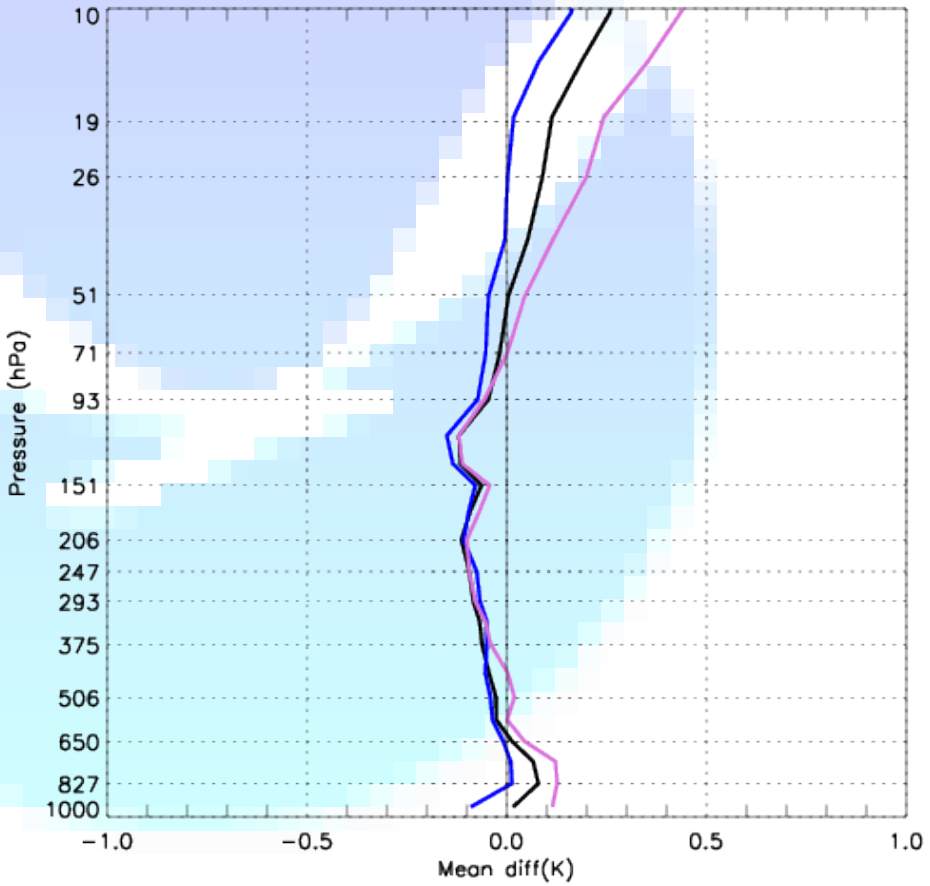


(RS41-EC) -minus- (RS41-EC)

Solar Elevation Categories
- NIGHT (<−7.5 deg)
- DAWN/DUSK (−7.5 – 7.5 deg)
- LOW (7.5 – 22.5 deg)
- HIGH (>22.5 deg)

For 21-32 hPa
Night 0.00 K
High Solar Elevation 0.20 K

For 32-43 hPa
Night -0.01 K
High 0.11 K



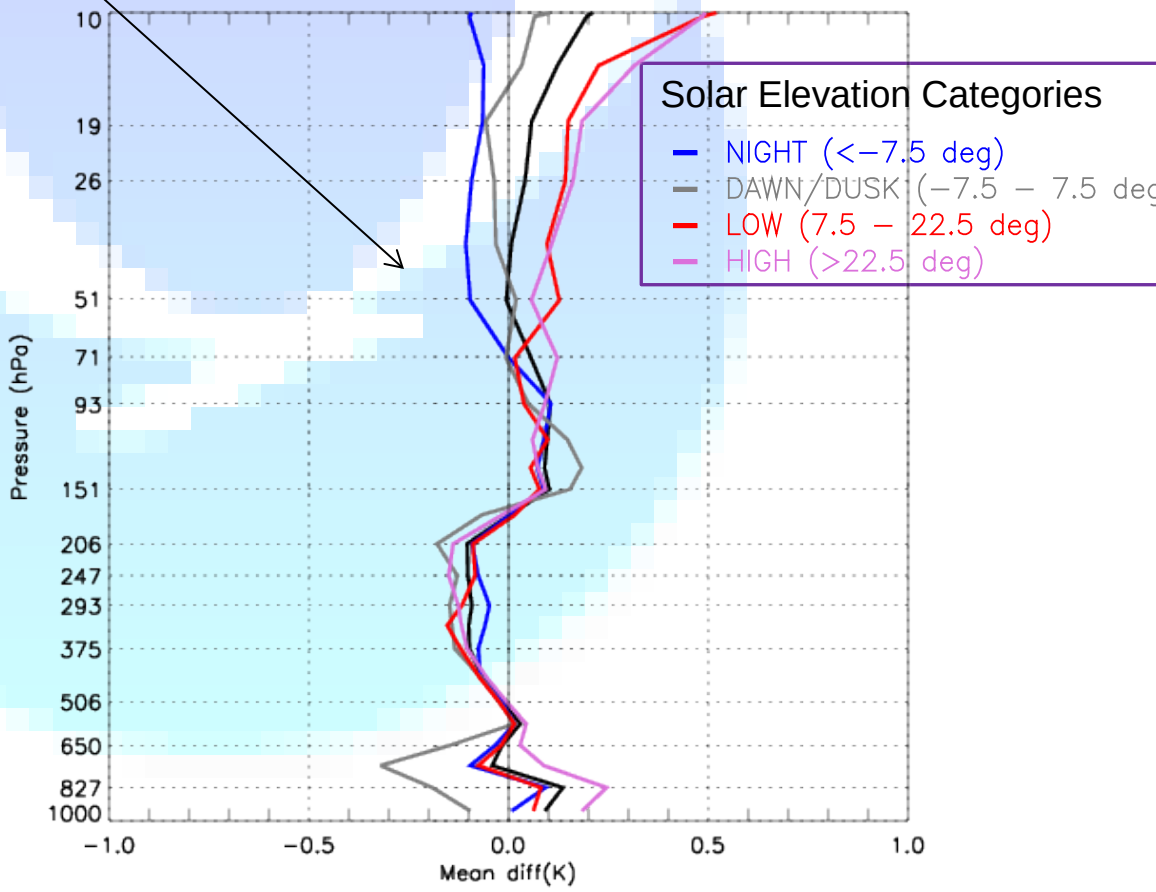
(RS92-EC92) – (RS41-EC41)
= (RS92-RS41) – (BG92-EC41)

RS92-RS41 = {(RS92-EC92) – (RS41-EC41)} + (EC92-EC41)

RS92-minus-RS41 = {(RS92-BG92) –minus- (RS41-BG41)} – (BG92-BG41)

For 21-32 hPa
Night -0.09 K
High Solar Elevation 0.16 K

For 32-43 hPa
Night -0.11 K
High 0.11 K

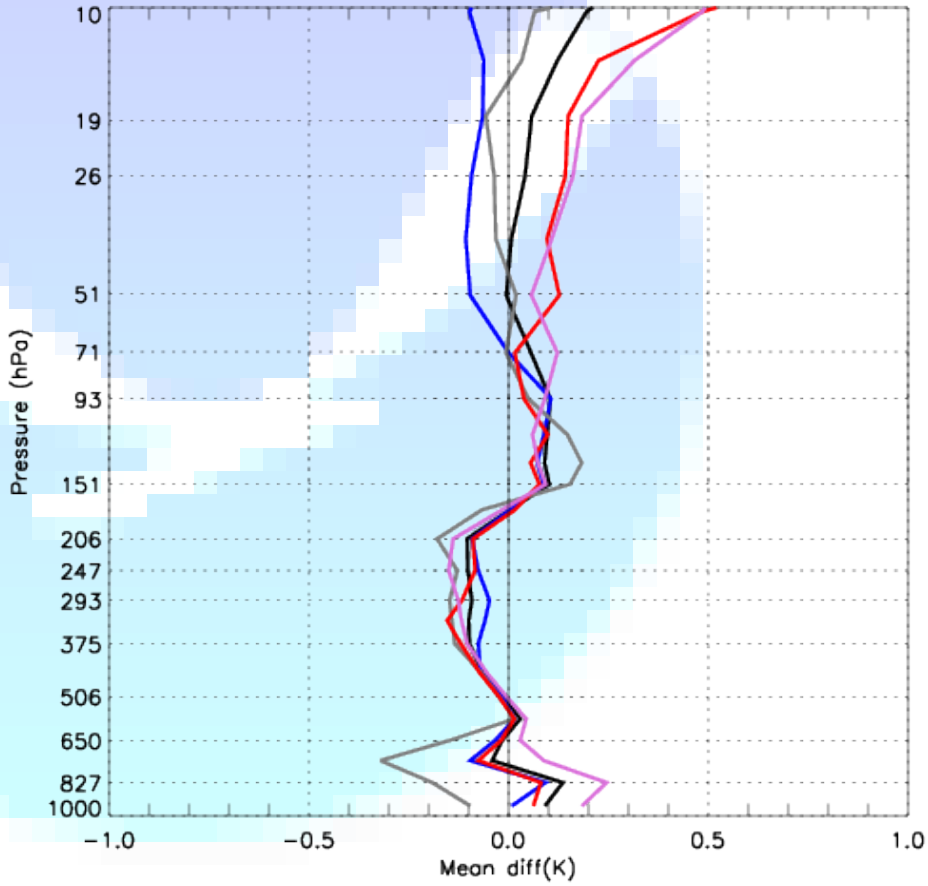


(RS92-BG) –minus- (RS41-BG)

Solar Elevation Categories
- NIGHT (<−7.5 deg)
- DAWN/DUSK (−7.5 – 7.5 deg)
- LOW (7.5 – 22.5 deg)
- HIGH (>22.5 deg)

For 21-32 hPa
Night -0.09 K
High Solar Elevation 0.16 K

For 32-43 hPa
Night -0.11 K
High 0.11 K

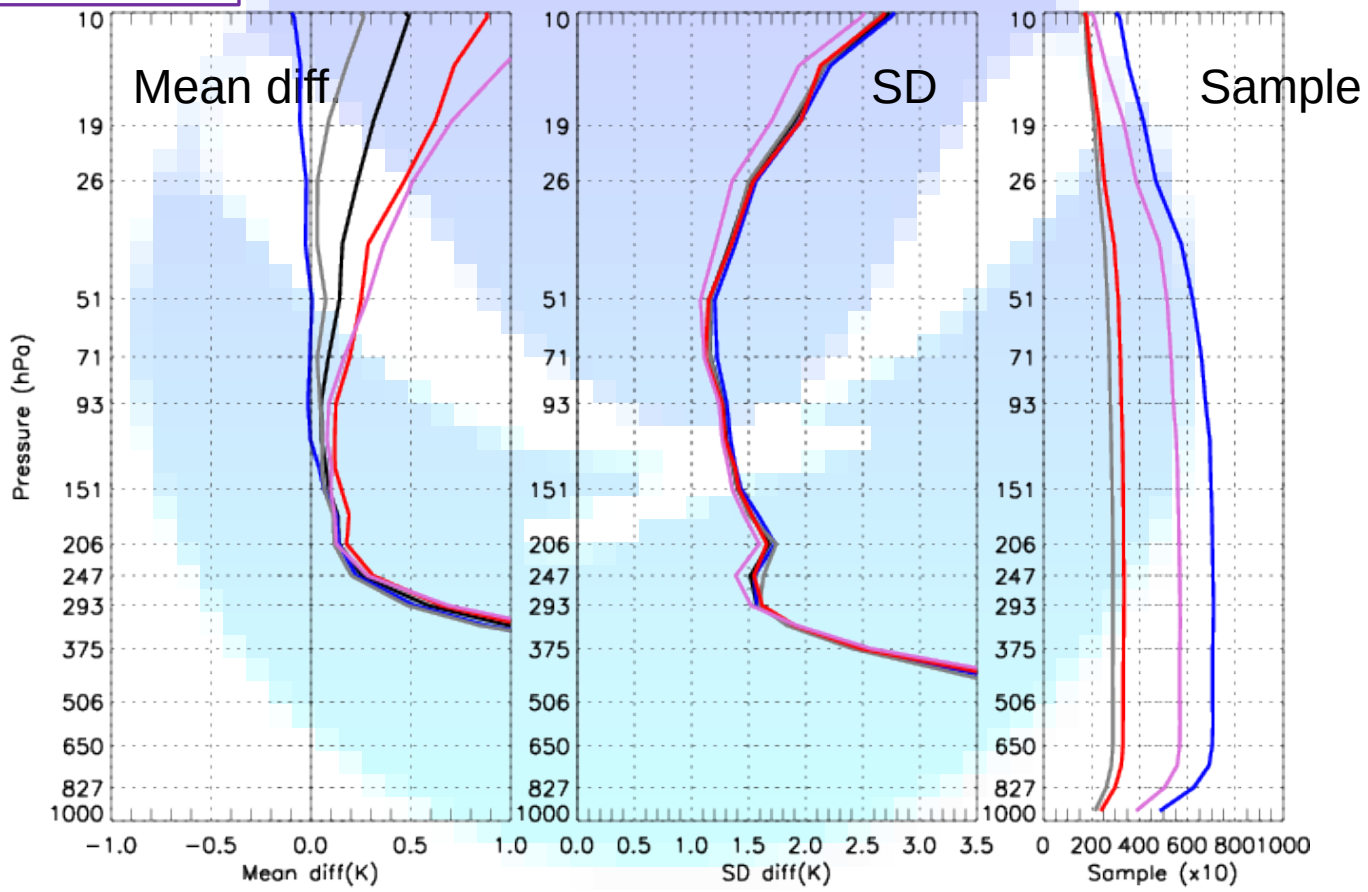


(RS92-BG92) – (RS41-BG41)
= (RS92-RS41) – (BG92-BG41)

RS92-RS41 = {(RS92-BG92) – (RS41-BG41)} + (BG92-BG41)

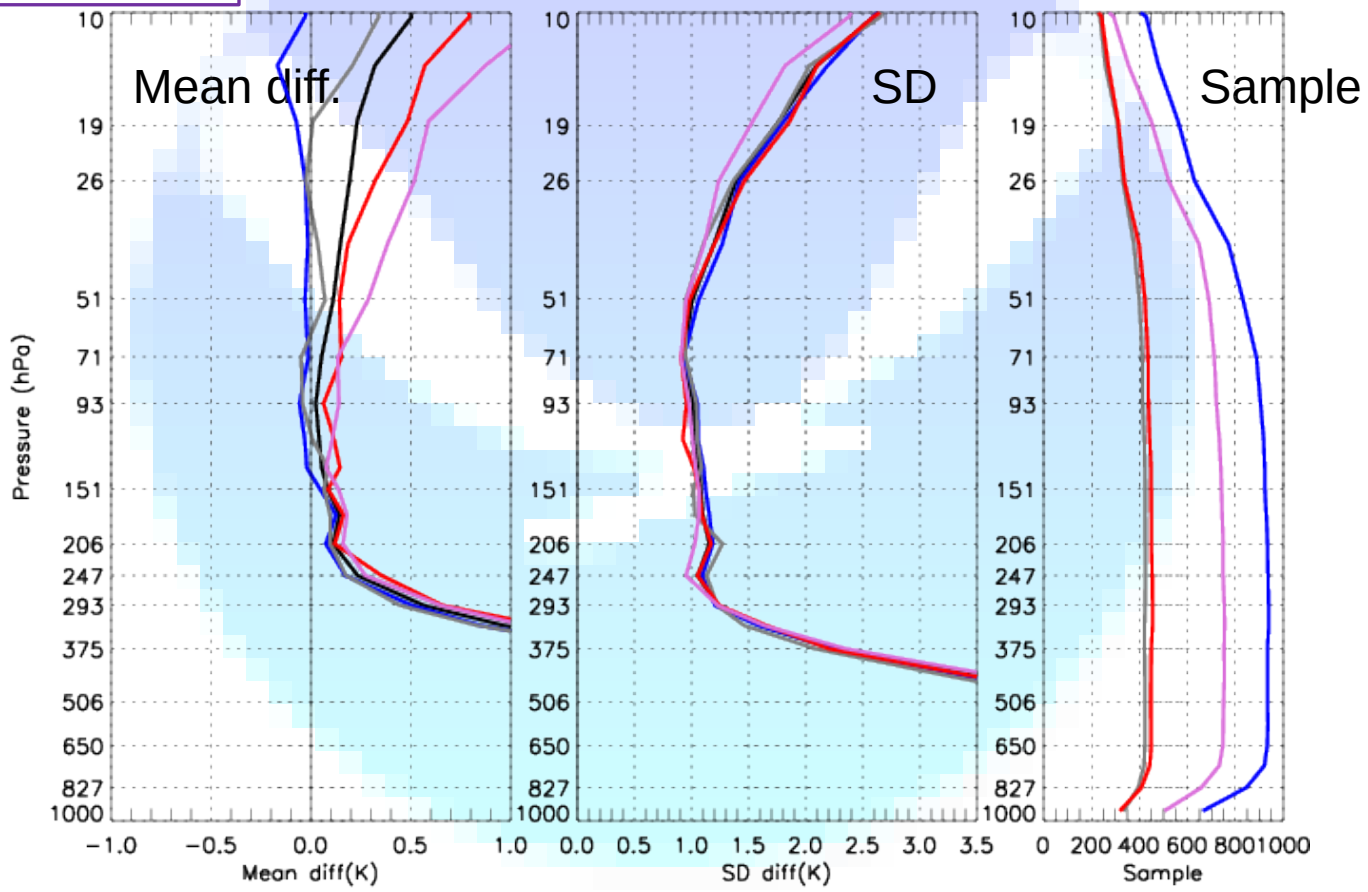
RS92-minus-Tdry COSMIC Global (3hr/250km)

Solar Elevation Categories
- NIGHT (<−7.5 deg)
- DAWN/DUSK (−7.5 – 7.5 deg)
- LOW (7.5 – 22.5 deg)
- HIGH (>22.5 deg)



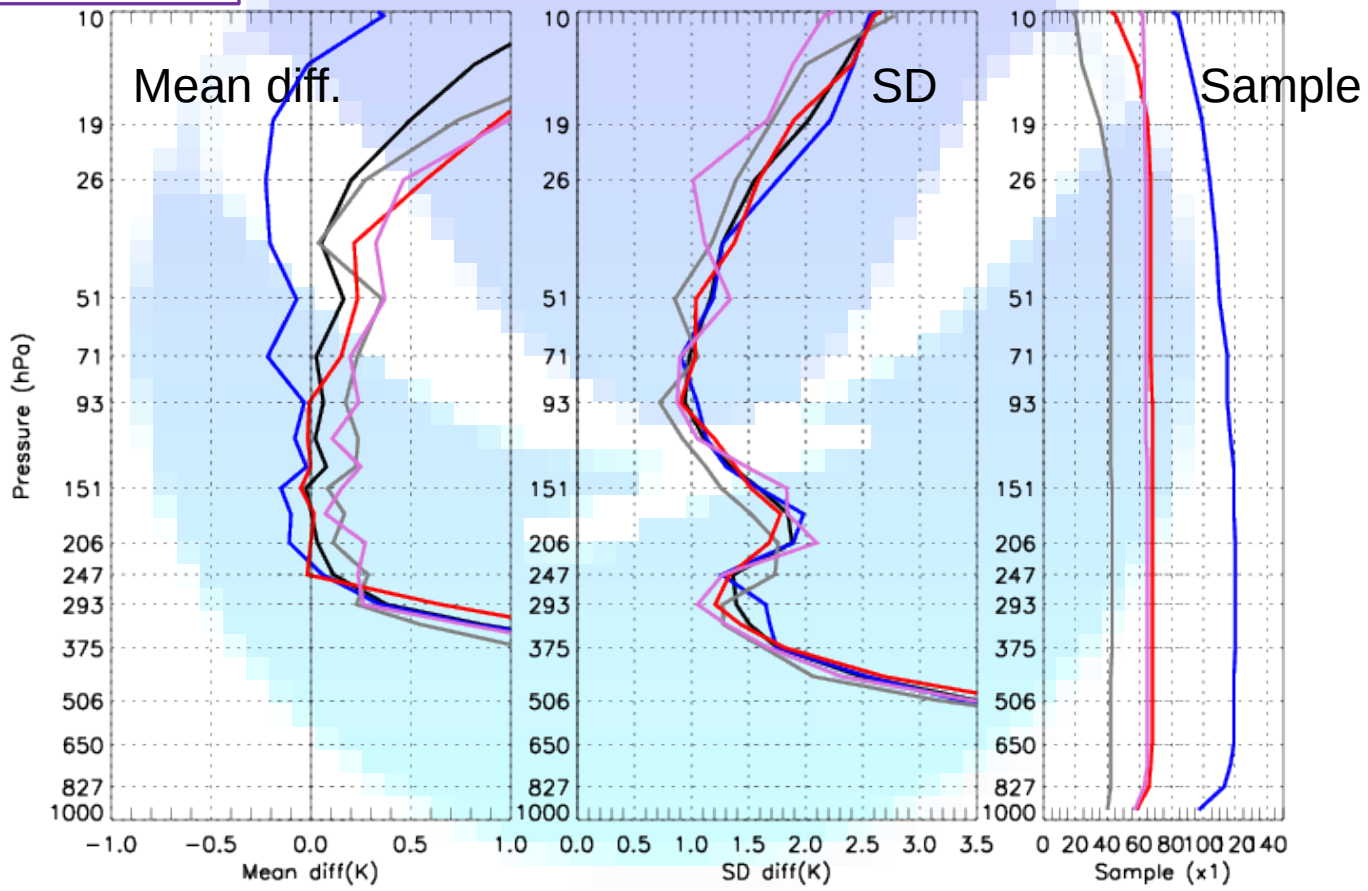
RS41-minus-Tdry COSMIC Global (1hr/150km)

Solar Elevation Categories
- NIGHT (<−7.5 deg)
- DAWN/DUSK (−7.5 – 7.5 deg)
- LOW (7.5 – 22.5 deg)
- HIGH (>22.5 deg)

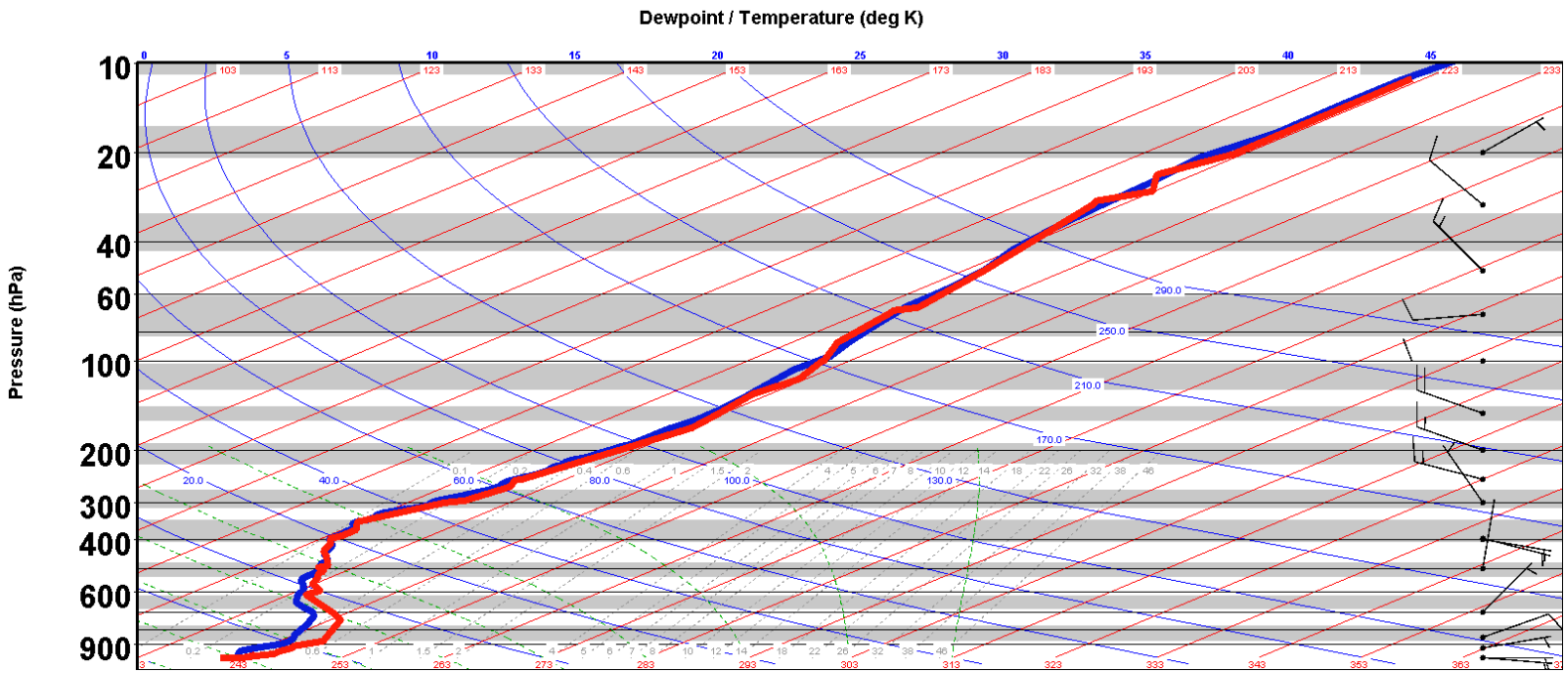


RS92-minus-Tdry COSMIC Lindenberg (3hr/250km)

Solar Elevation Categories
- NIGHT (<−7.5 deg)
- DAWN/DUSK (−7.5 – 7.5 deg)
- LOW (7.5 – 22.5 deg)
- HIGH (>22.5 deg)



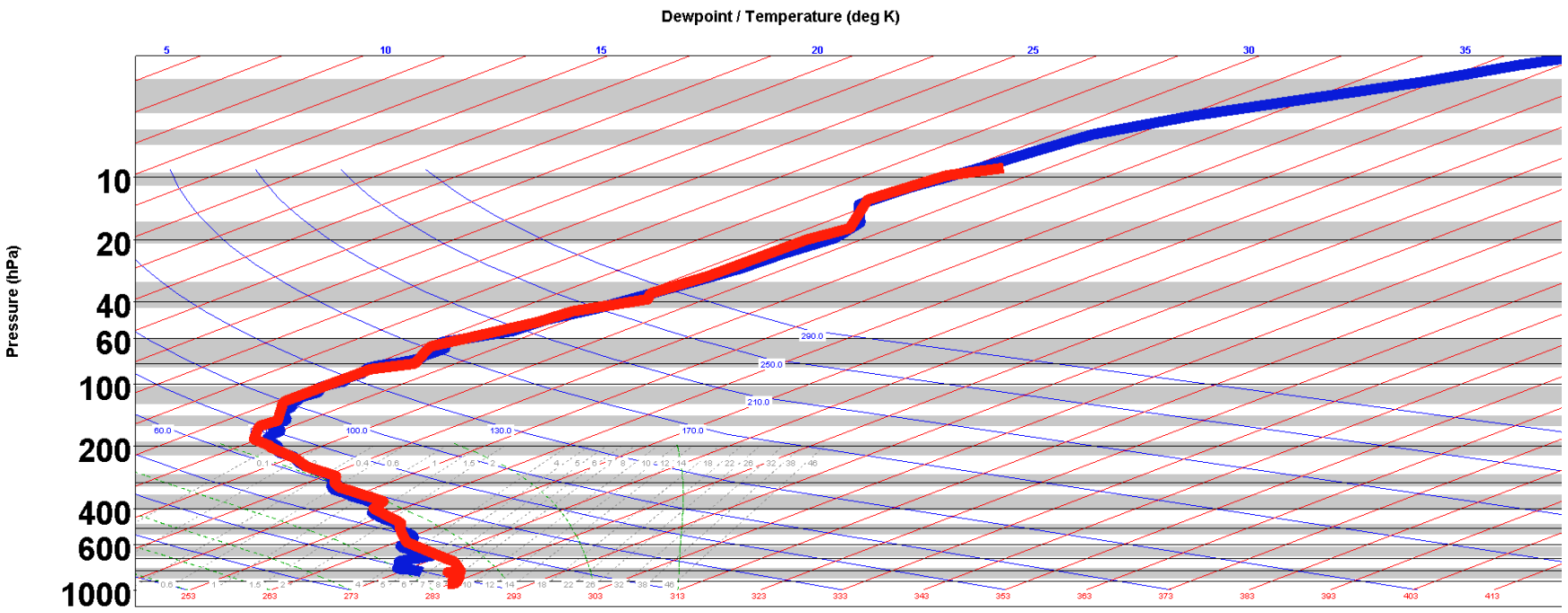
NOAA Products Validation System (NPROVS)



SONDE 71915 (80) SONDE 1/30/2015 23:25:00Z 64.2 N / 83.4 W

COSMIC UCAR Raw Dry 1/30/2015 22:41:48Z (-0.7 hours) 64.9 N / 84.2 W (84.5 km)

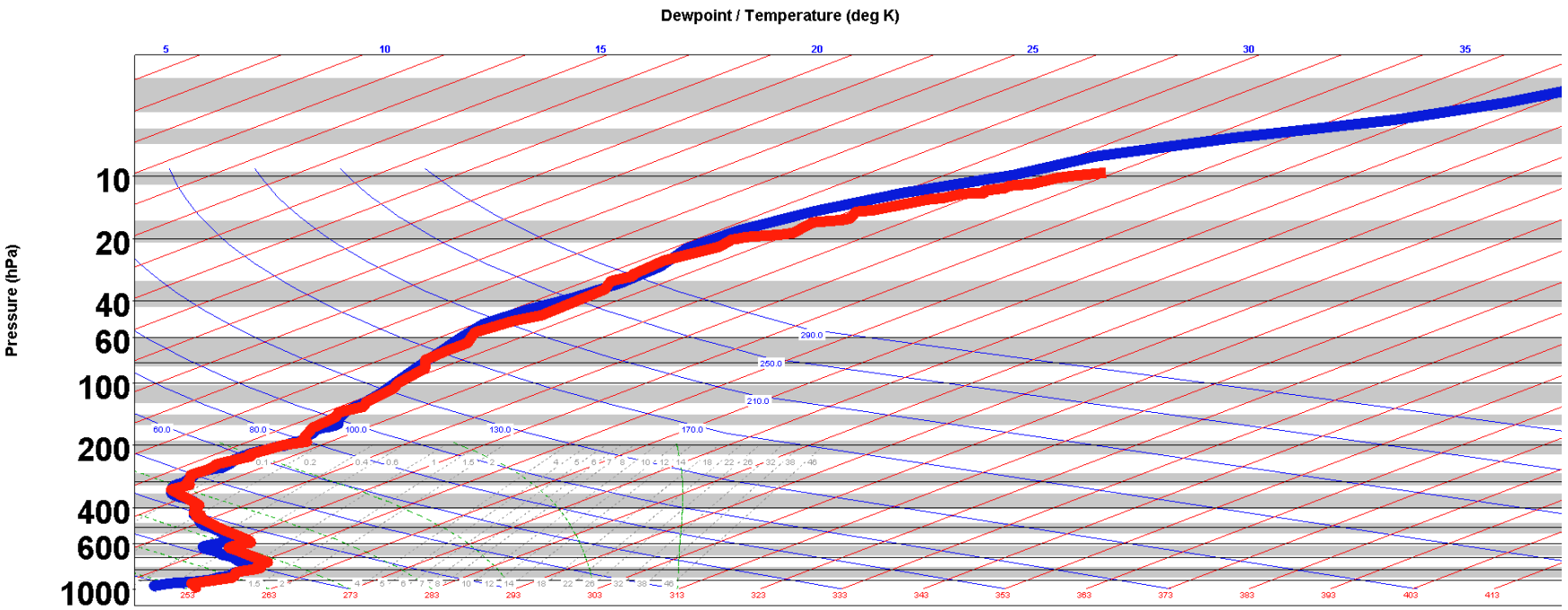
NOAA Products Validation System (NPROVS)



SONDE 40375 (80) SONDE 1/5/2015 22:05:00Z 28.4 N / 36.6 E

COSMIC UCAR Raw Dry 1/5/2015 21:55:17Z (-0.2 hours) 27.7 N / 34.3 E (235.9 km)

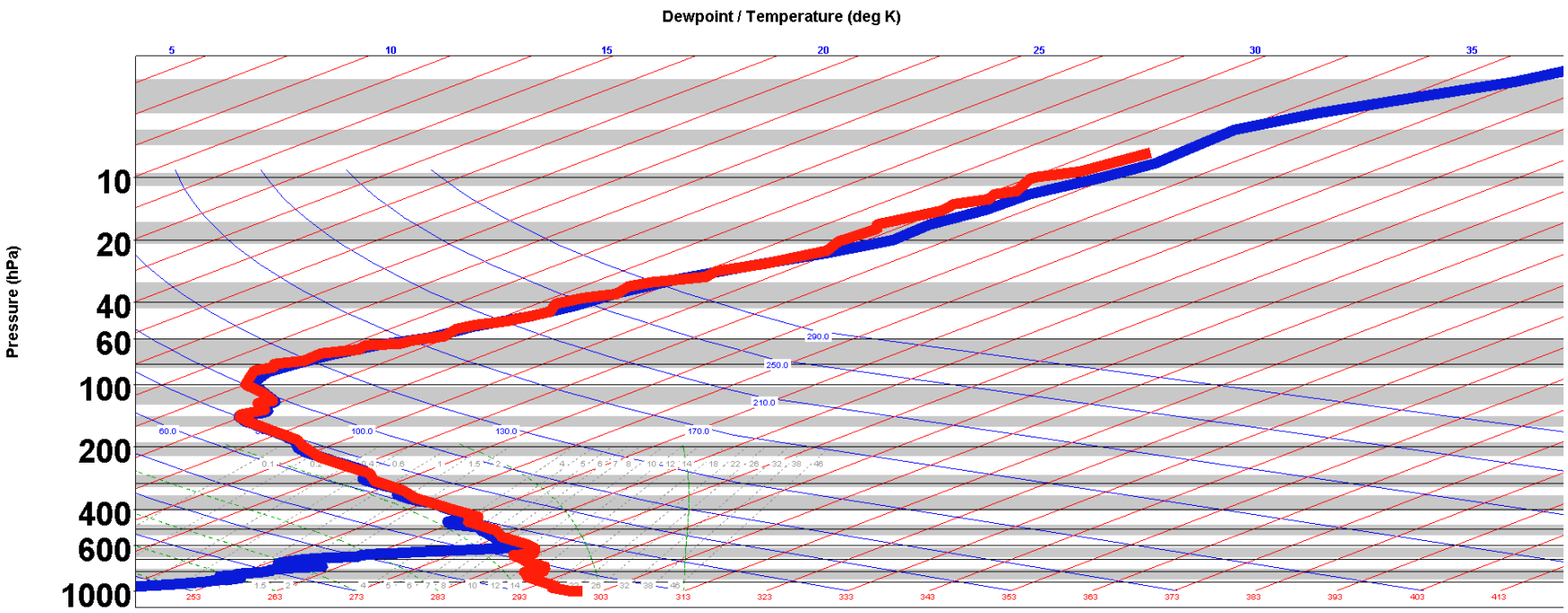
NOAA Products Validation System (NPROVS)



SONDE 72747 (152) SONDE 1/5/2015 23:16:00Z 48.6 N / 93.4 W

COSMIC UCAR Raw Dry 1/5/2015 23:37:31Z (0.3 hours) 48.7 N / 94.4 W (74.4 km)

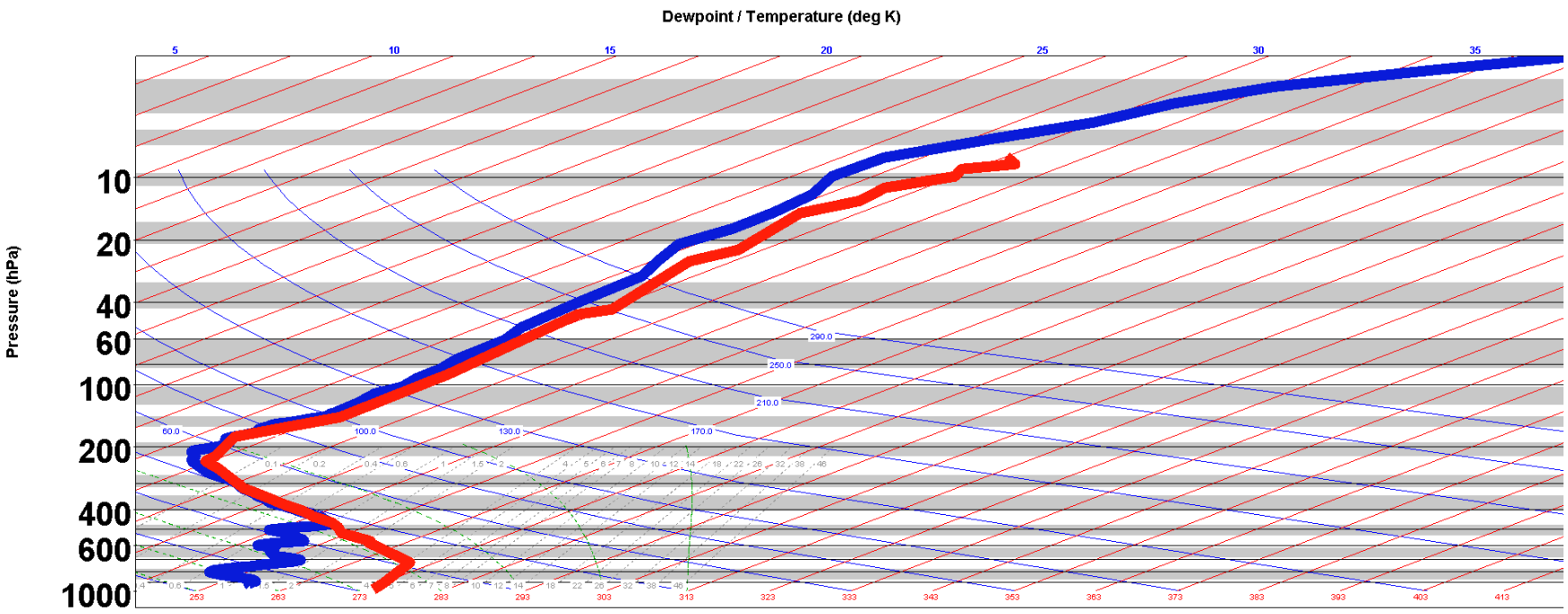
NOAA Products Validation System (NPROVS)



SONDE 91212 (152) SONDE 1/14/2016 23:14:00Z 13.5 N / 144.8 E

COSMIC UCAR Raw Dry 1/14/2016 22:34:55Z (-0.6 hours) 14.1 N / 145.1 E (80 km)

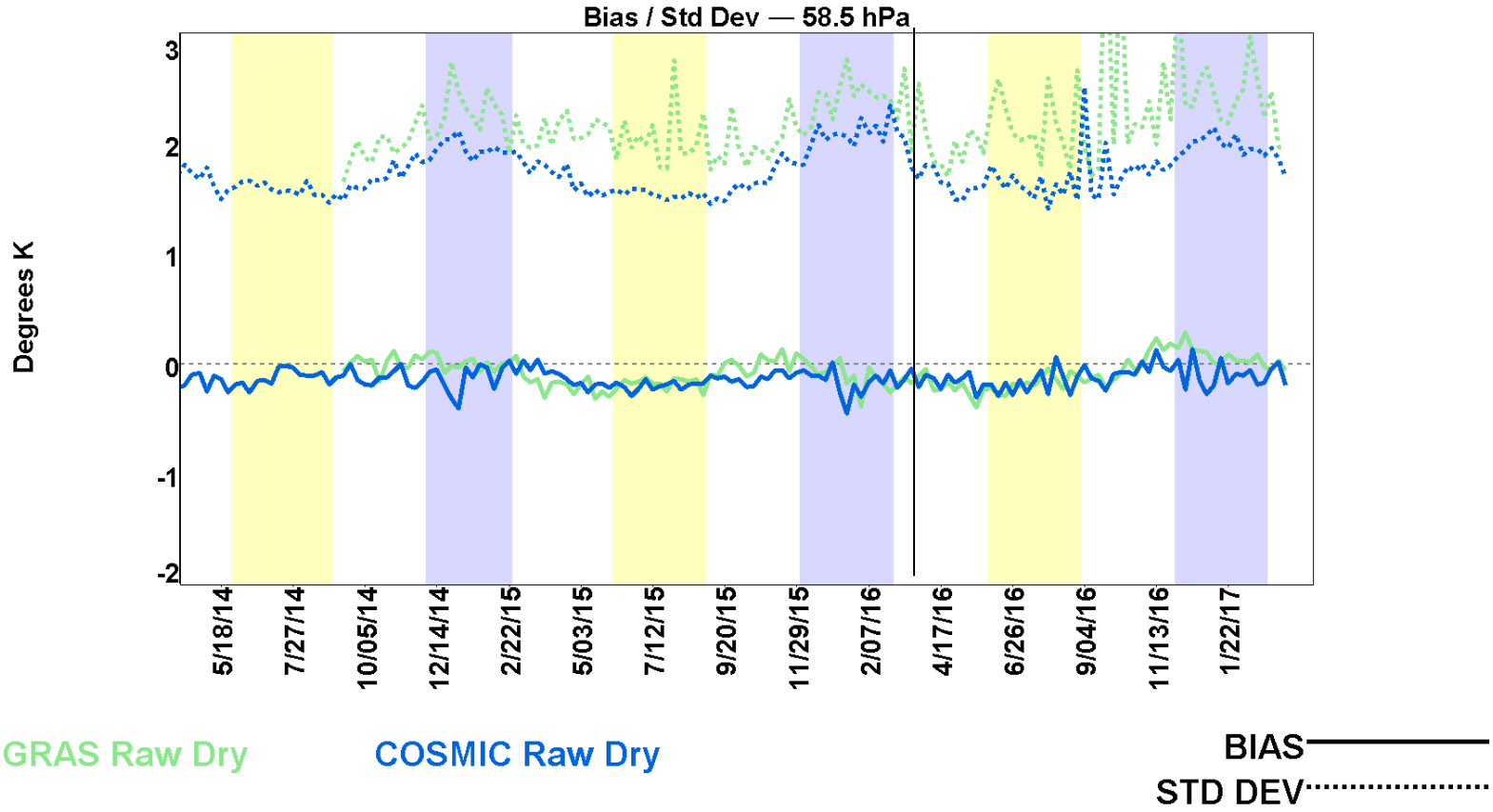
NOAA Products Validation System (NPROVS)



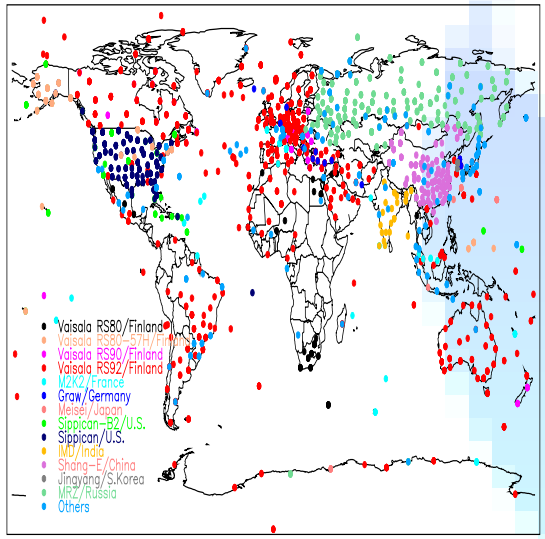
SONDE 11520 (80) SONDE 1/1/2015 11:15:00Z 50 N / 14.5 E

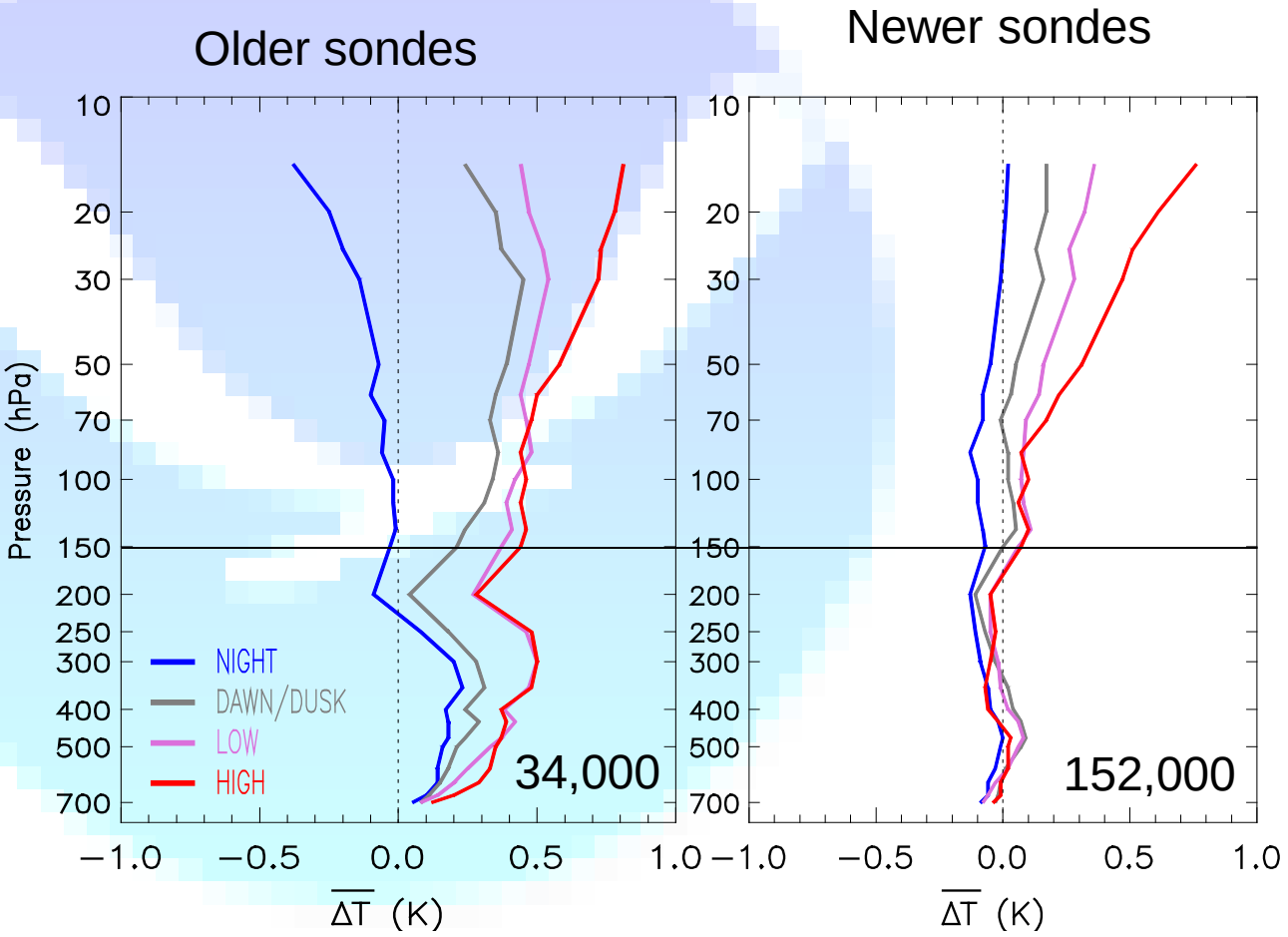
COSMIC UCAR Raw Dry 1/1/2015 10:03:51Z (-1.2 hours) 49.2 N / 13.3 E (122.7 km)

Difference from collocated raobs



RAOB-minus-Tdry diff. for 2008-11





Sun et al. (2013, JGR): “Toward improved correction for radiation-induced biases in radiosonde temperature observations”