National Aeronautics and Space Administration

Long-Term Trends in Space-Ground Atmospheric Propagation Measurements

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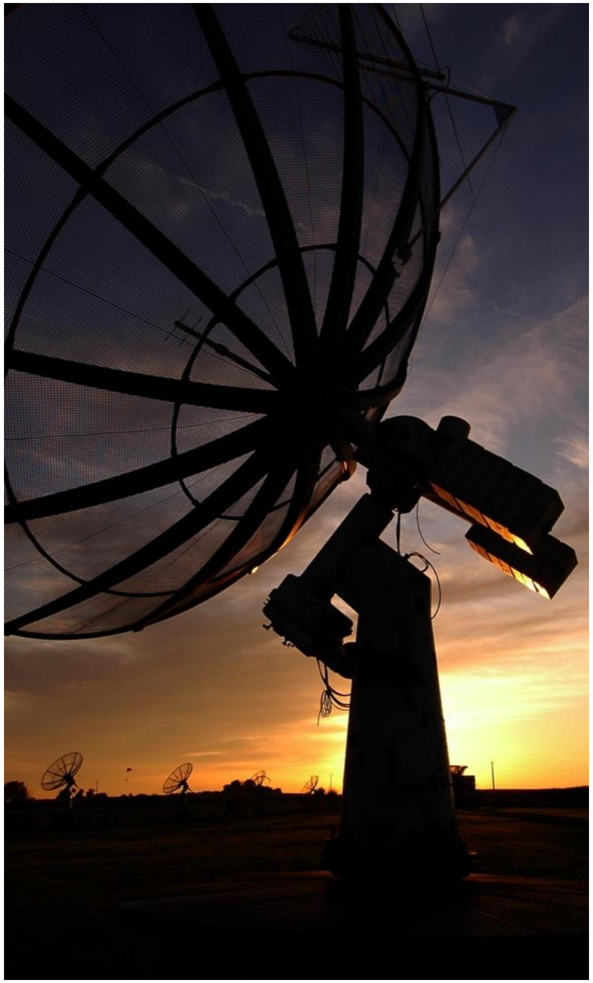
Presentation Overview



1. Technical Motivation
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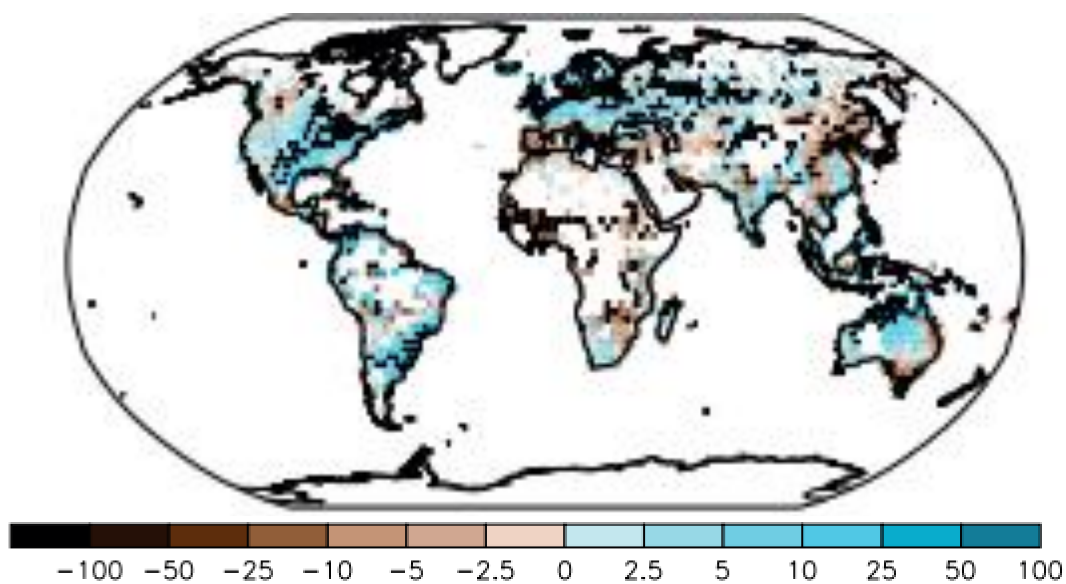
Technical Motivation

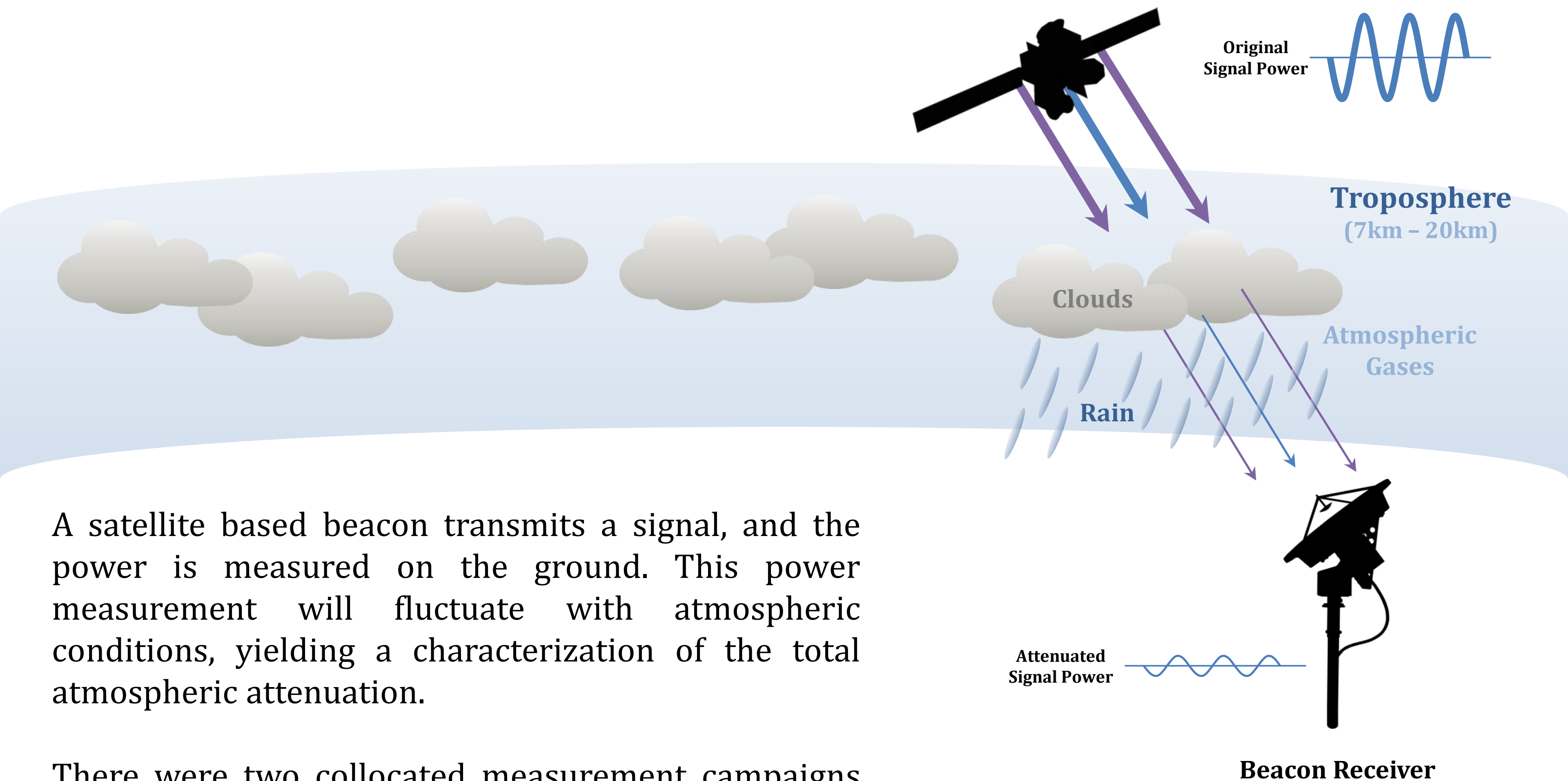
Long-term trends of propagation data may be impacted by global changes in rain patterns. Rain fade is the most dominant factor in determining site attenuation statistics, and it has been observed that rain events over the past 50 years have trended toward increased frequency, intensity, and rain height.

Global Trends in Annual Precipitation
Since 1951



Deviation [mm/yr]

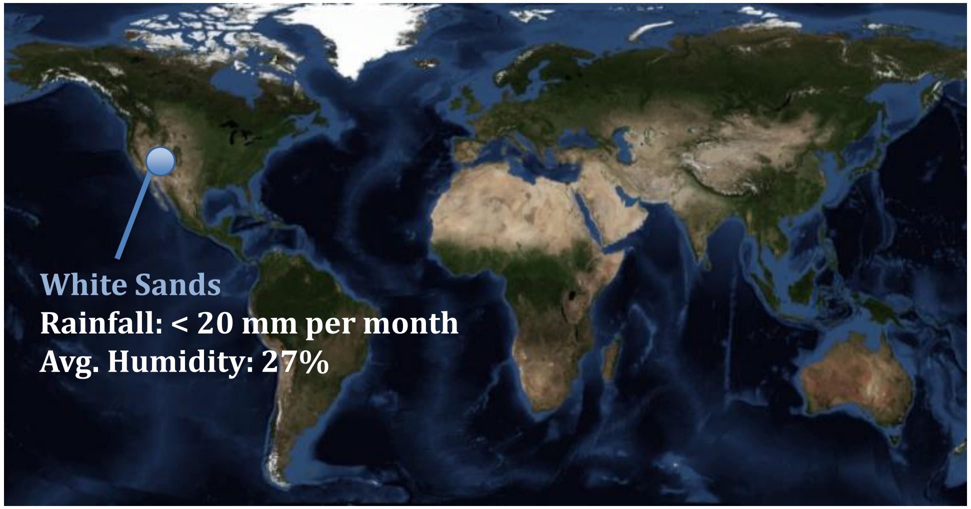
Experiment Description



A satellite based beacon transmits a signal, and the power is measured on the ground. This power measurement will fluctuate with atmospheric conditions, yielding a characterization of the total atmospheric attenuation.

There were two collocated measurement campaigns conducted in White Sands facility in New Mexico, the first from 1994 -1999 and the second 2009 -2014.

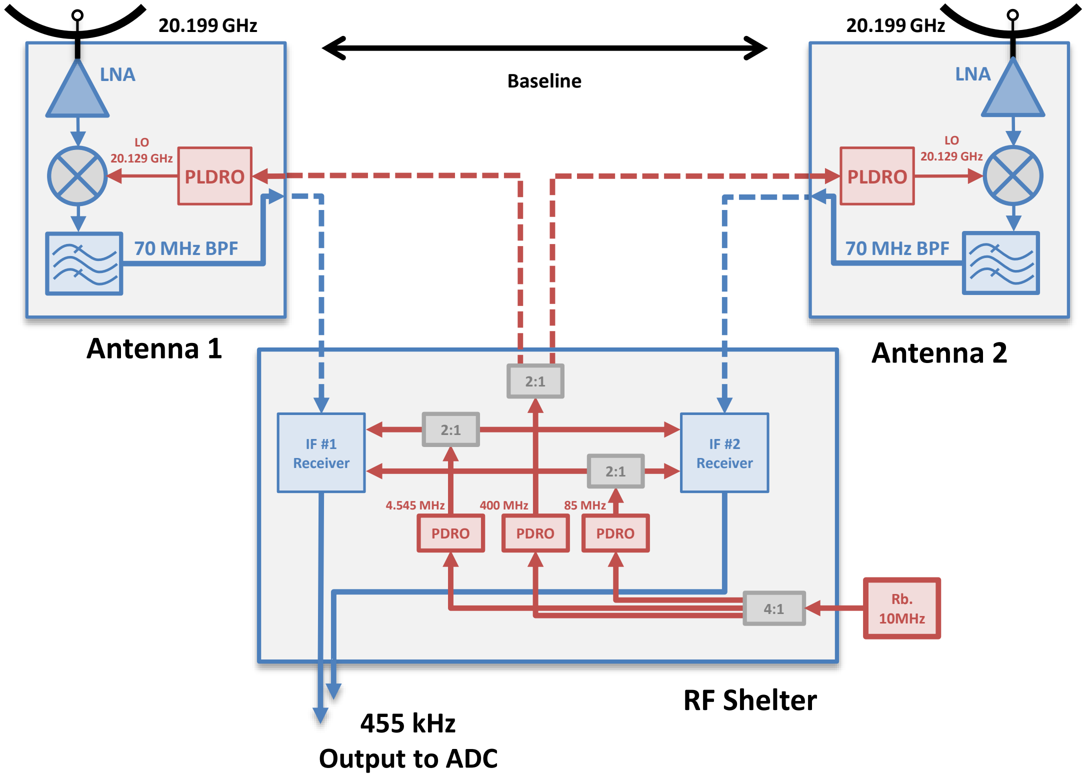
Site Information



		White Sand, NM
Site	Installation Date	February 2009
	Latitude	45.4787° N
	Longitude	9.2327° E
	Altitude	1469 m
Satellite	Name	Anik F2
	Elevation	51.8°
	Azimuth	188.3°
	Beacon Freq.	20.199GHz

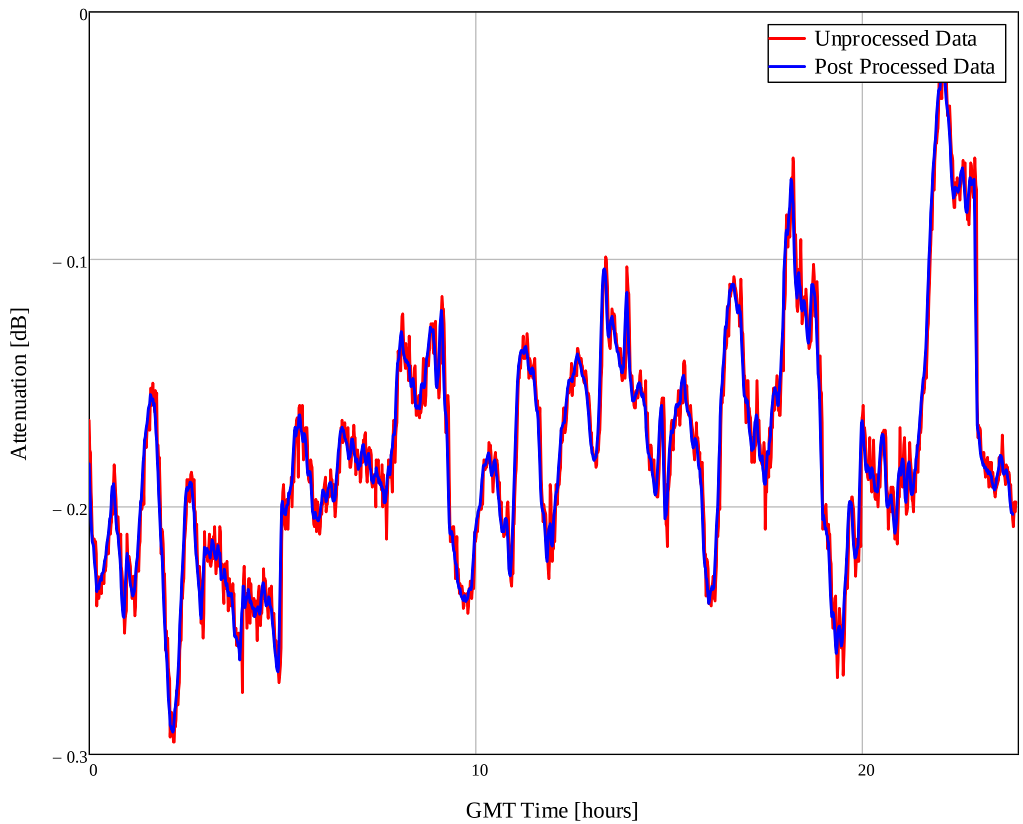
Receiver Design

System Specifications	
Downconversion	2-step down to 455 kHz
Sampling Rate	3.64 MHz
Integration Time	144 ms
Time Series Output Rate	1 Hz
Phase Noise Floor	< 1.8° RMS or 0.34 ps

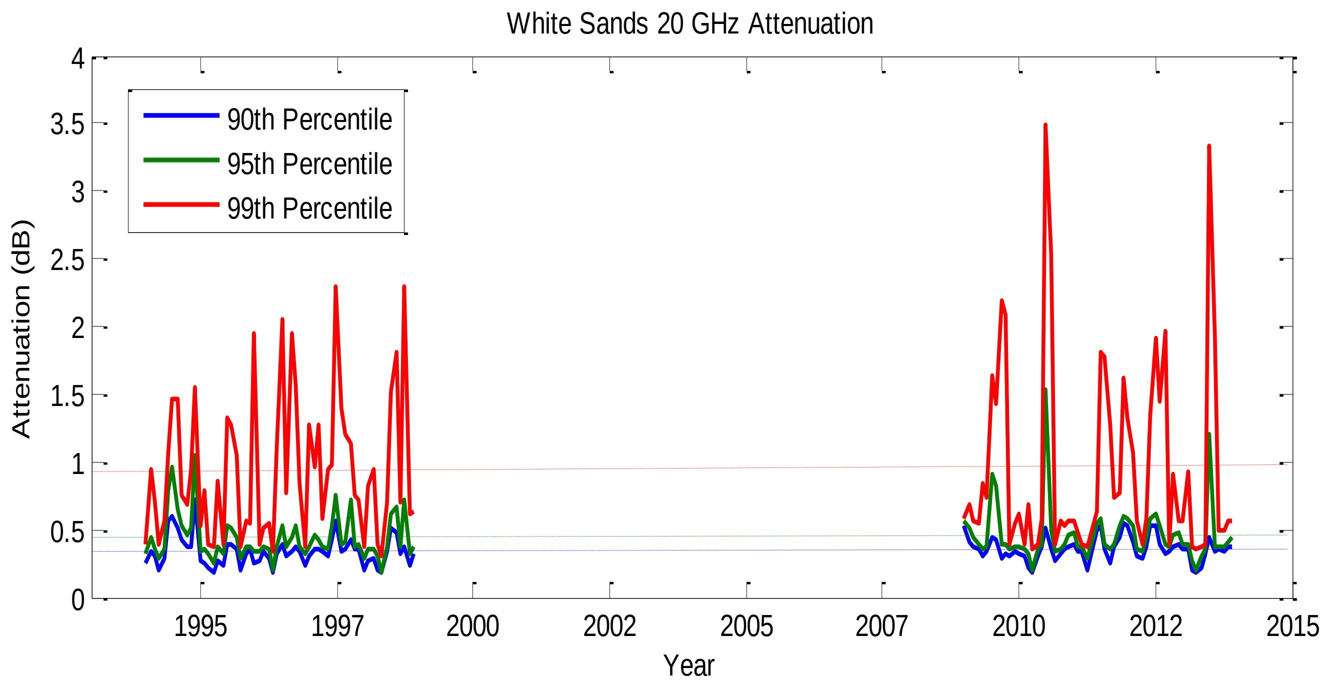


Data Processing Procedure

Both data sets (1994-1998 and 2009-2015) were normalized by taking a 5 minute moving average and subtracting the peak value of the moving average from the non-averaged data before processing.

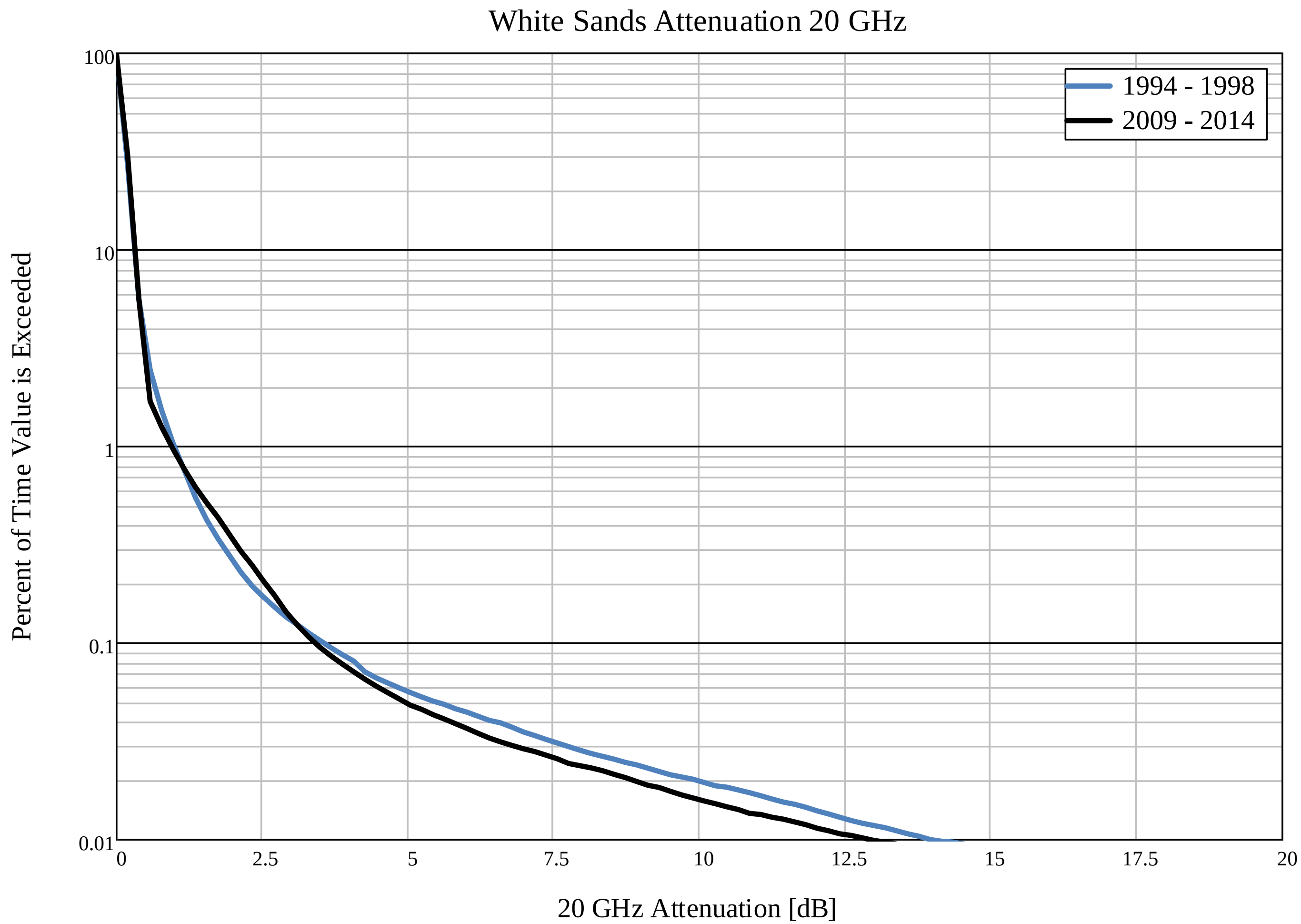


Results



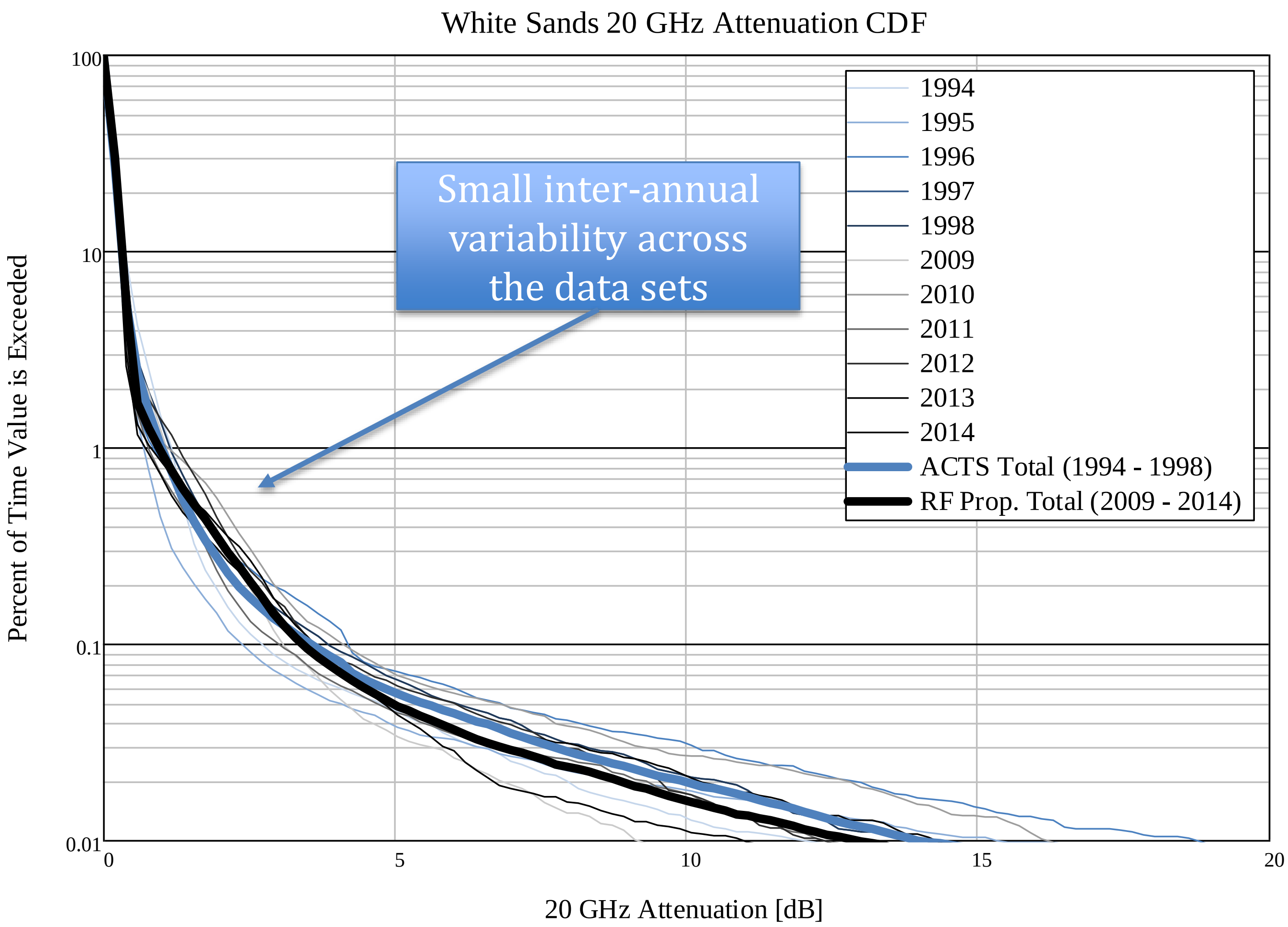
White Sands 20 GHz Attenuation
Attenuation (dB)
4
3.5
3
2.5
2
1.5
1
0.5
0
90th Percentile
95th Percentile
99th Percentile
1995
1997
2000
2002
2005
2007
2010
2012
2015
Year

Results



Minimal impact on average statistics, although the mean attenuation shows a small increase, the standard deviation is more variable, which is also evident by increase in high attenuation months

Results



White Sands 20 GHz Attenuation CDF
Percent of Time Value is Exceeded
100
10
1
0.1
0.01
0
5
10
15
20
20 GHz Attenuation [dB]
1994
1995
1996
1997
1998
2009
2010
2011
2012
2013
2014
ACTS Total (1994 - 1998)
RF Prop. Total (2009 - 2014)
Small inter-annual variability across the data sets

Conclusions

The Statistics Indicate:

- Slight Increasing Trend in Attenuation
- Variability in Standard Deviation

Impact is negligible unless designing above 99.9% availability, however this phenomena needs to be explored in a variety of rain zones and over longer time scales for a complete analysis.

Acknowledgements

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- James Nessel

References

[1] IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp, doi:10.1017/CBO9781107415324 [2] D. H. Rogstad, A. Mileant, and T. T. Pham, Antenna Arraying Techniques in the Deep Space Network. Pasadena, CA, Hoboken, NJ: Wiley, 2003.

[2] K. S. Paulson, “The Effects of Climate Change on Microwave Telecommunications,” 11th Int. Conf. on Telecom., Graz, Austria. Jun. 2011.

[3] C. Riva, “Seasonal and diurnal variations of total attenuation measured with the ITALSAT satellite at Spino d’Adda at 18.7, 39.6 and 49.5 GHz,” Int. J. Satell. Commun. Network., vol, 22, pp. 449 – 476, 2004. [5] "The Proposer's Guide for the Green Bank Telescope," National Radio Astronomy Observatory, 2013.

[4] J. M. Garcia-Rubia, et al., “Rain Attenuation Variability Calculated From a Slant-Path Ka-Band Experiment,” 8th European Conference on Antennas and Propagation, The Hague, Netherlands, Apr. 6-11 2014.

[5] R. K. Crane, “ACTS Propagation Experiment: Experiment Design, Calibration, and Data Preparation and Archival,” Proc. IEEE, vol. 85, no. 6, pp. 863-878, Jun. 1997.

[6] R. J. Acosta, M. J. Zemba, J. R. Morse, and J. A. Nessel, "Two Years of Simultaneous Ka-Band Measurements: Goldstone, CA; White Sands, NM; and Guam, USA," in 18th Ka and Broadband [2] K. S. Paulson, “The Effects of Climate Change on Microwave Telecommunications,” 11th Int. Conf. on Telecom., Graz, Austria. Jun. 2011.

[7] R. K. Crane, "Propagation Phenomena Affecting Satellite Communication System Operating in the Centimeter and Millimeter Wavelength Bands," Proc. IEEE, vol. 59, no. 2, pp. 173-188, Feb. 1971.

[8] Paulson, K.; Al-Mreri, A., "Trends in the incidence of rain height and the effects on global satellite telecommunications," Microwaves, Antennas & Propagation, IET , vol.5, no.14, pp.1710,1713, November 18 2011

[9] Paulson, K.S., "The effects of climate change on microwave telecommunications," Telecommunications (ConTEL), Proceedings of the 2011 11th International Conference on , vol., no., pp.157,160, 15-17 June 2011

[10]] R. S. Bradley, Keimig, F. T., Diaz H. F. and Hardy, D. R.,“ Recent changes in freezing level heights in the Tropics with implications for the deglacierization of high mountain regions”, Geophysical Research Letters, 2009, 36, L17701,doi:10.1029/2009GL037712, 2009.