Stanford Telecom / New Mexico State University

ACTS Propagation Measurements Program

Data Analysis Summary

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Agenda

- **Introduction**
  - ➢ Experiment objectives and configuration
- **NM ACTS K_A band measurements and analysis**
  - ➢ Four years (12/93-11/97) of propagation statistics
  - ➢ Annual model comparisons
  - ➢ Seasonal statistics
  - ➢ Almost five years (12/93-8/98) of propagation statistics
- **Summary and future activities**

STel ACTS Propagation Experiment Objectives

- **Measure and evaluate K_A band propagation effects and link performance for New Mexico**
- **Develop long-term statistics and prediction modeling techniques for the New Mexico climate region to be used for advanced satellite system planning and design**

New Mexico APT

- **Measured parameters**
  - ➢ Beacons: 20.185 GHz and 27.505 GHz
  - ➢ Radiometers: 20 GHz and 27.505 GHz
  - ➢ Rain rate (CRG, TBG)
  - ➢ Temperature, Relative Humidity, Wind Vector, Barometric Pressure
- **Rain Region:**
  - ➢ Crane Region: F
  - ➢ ITU Region: E
- **Site Specific Geometrical Parameters:**
  - ➢ Elevation Angle: 51°
  - ➢ Polarization Tilt: 79°
  - ➢ Altitude: 1.459 km
  - ➢ Latitude: 32° 32' 40'' N & Longitude: 106° 36' 48'' W

Definition of Attenuation Terms

- **AFS: Attenuation wrt Free Space**

  Difference between the received beacon level and the received level if in a vacuum. AFS includes attenuation due to atmospheric absorption, rain, clouds, and scintillation.

- **ARD: Radiometrical Derived Attenuation**

  Attenuation measurements from radiometers. Comparable to AFS.

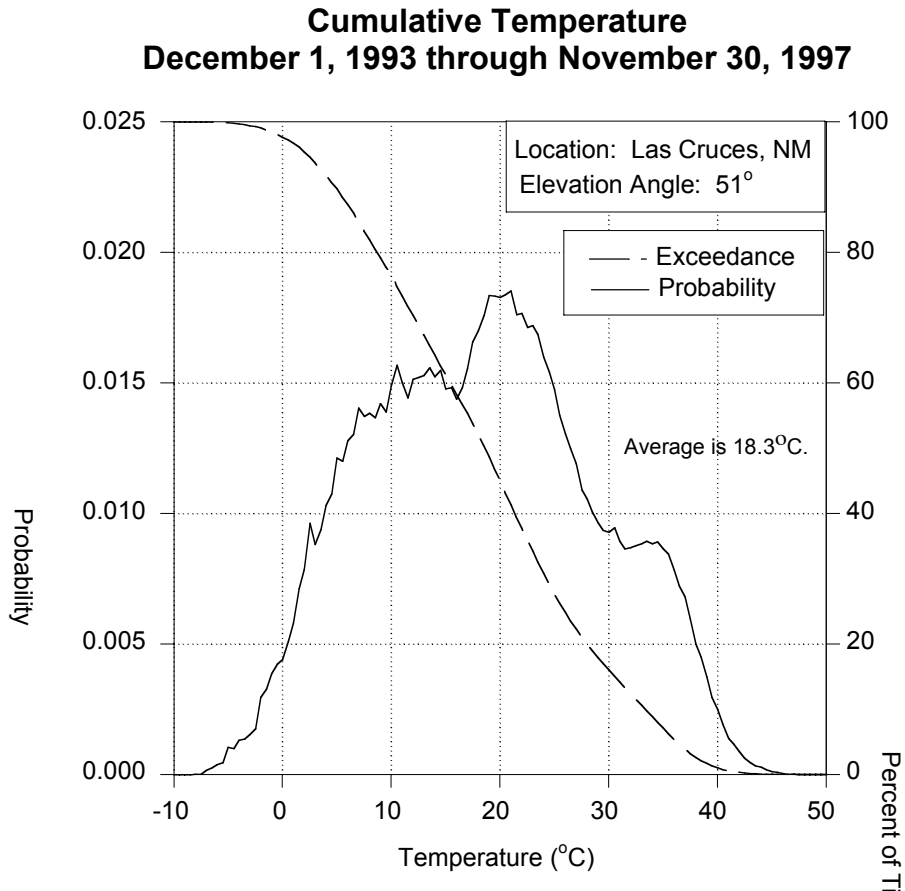
- **ACA: Attenuation wrt Clear Air**

  The difference between the received beacon level and the expected level due to atmospheric absorption (AGA). ACA includes rain, clouds, and scintillation. ACA=AFS-AGA.

- **ARS: Statistical Attenuation Ratio**

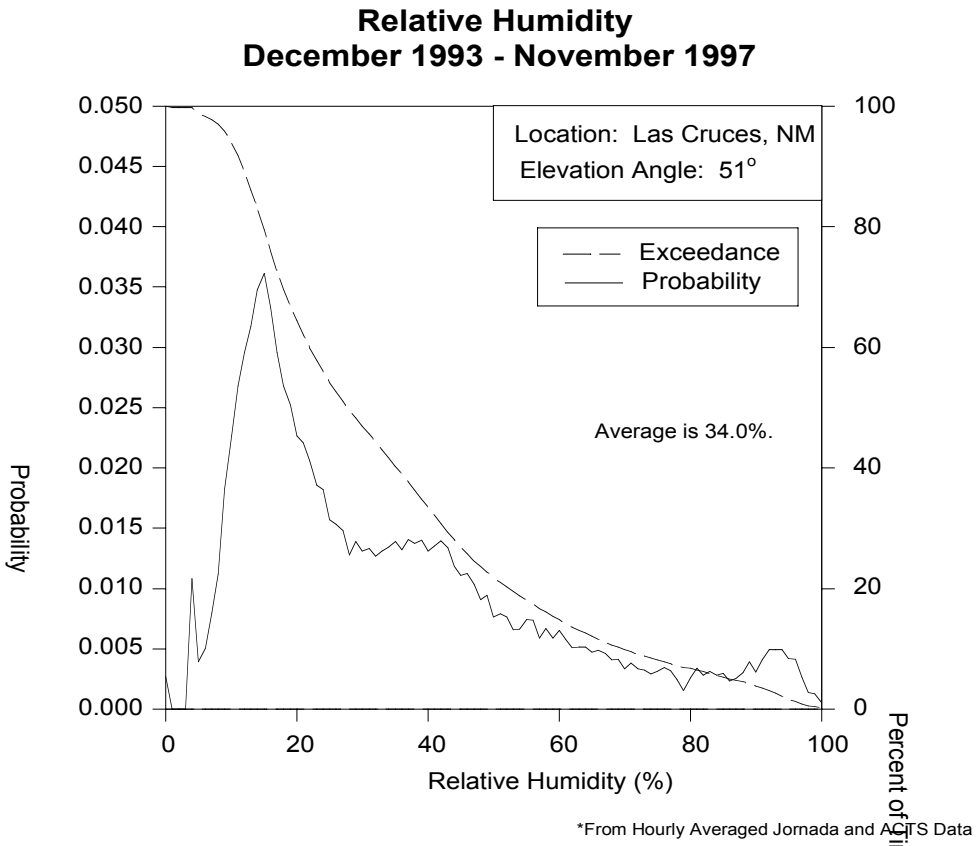
  Ratio of equiprobable attenuation levels at two frequencies of interest.

Cumulative Surface Temperature



- Historical weather data shows the average annual temperature for the New Mexico site to be 17ºC.

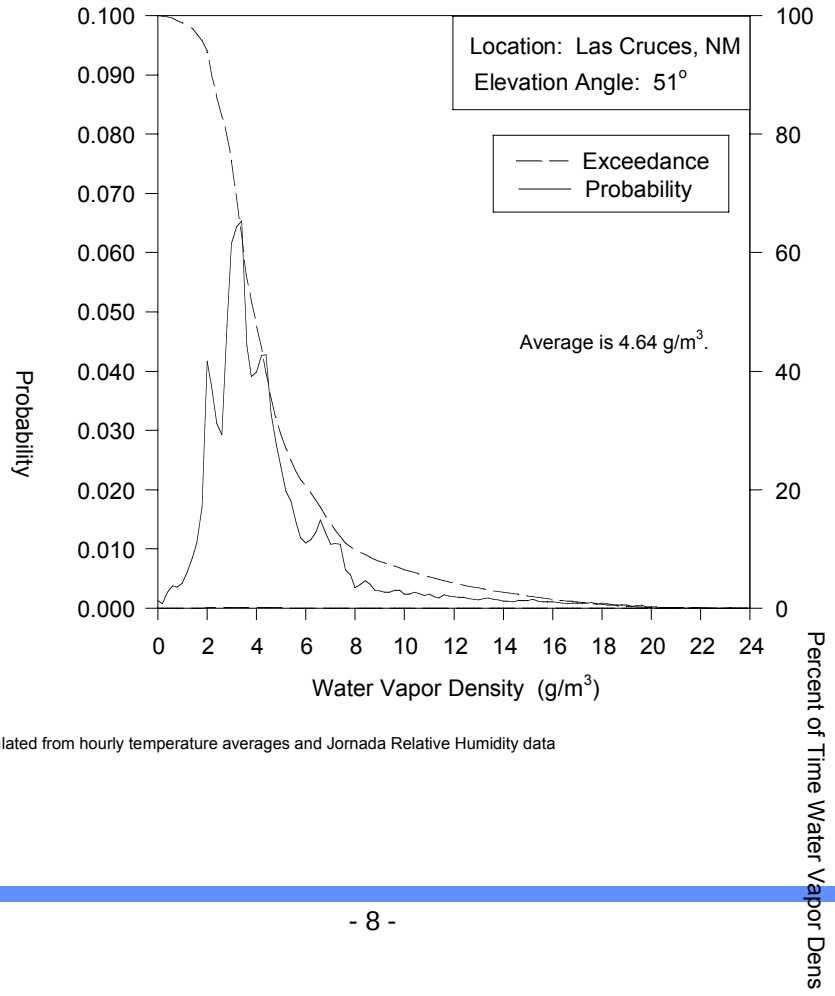
Cumulative Relative Humidity



- Historical weather data shows the average annual relative humidity for the New Mexico site to be 47%.

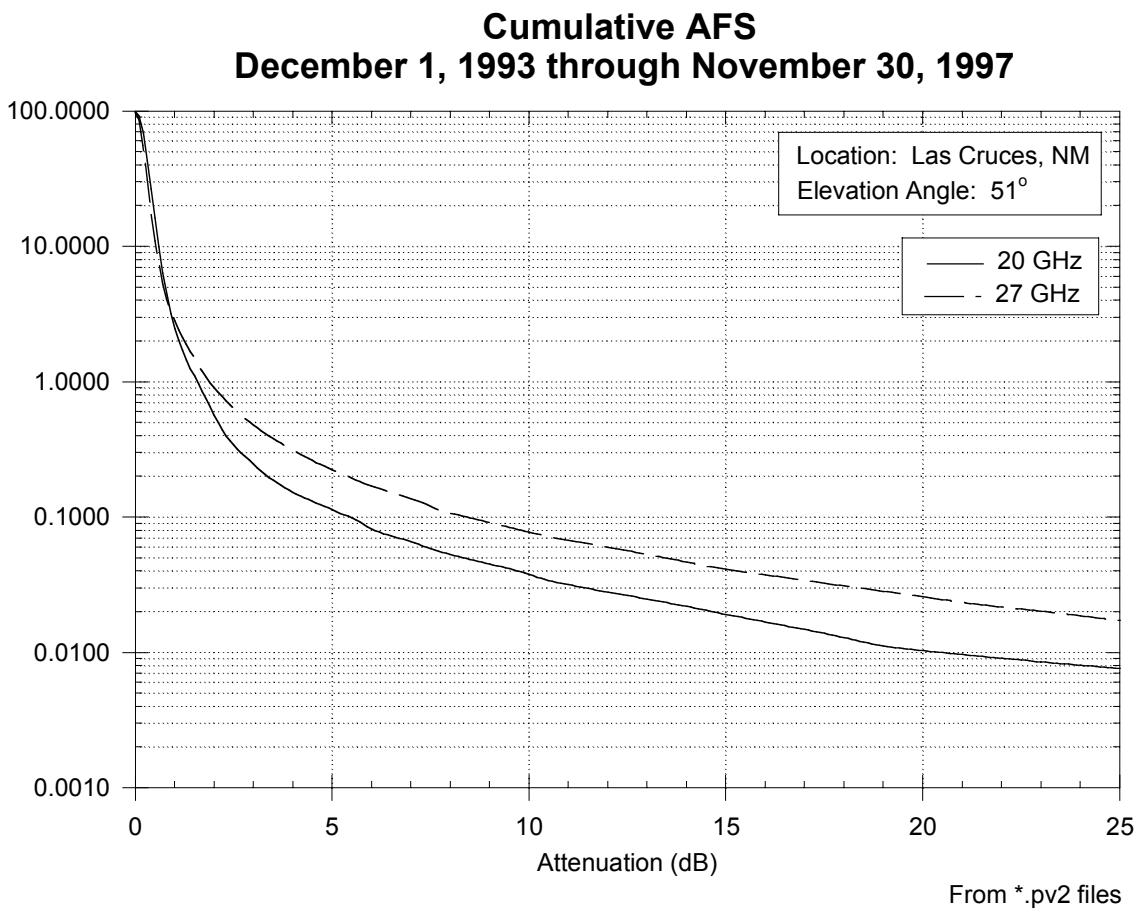
Cumulative Water Vapor Density

Water Vapor Density
December 1993 - November 1997

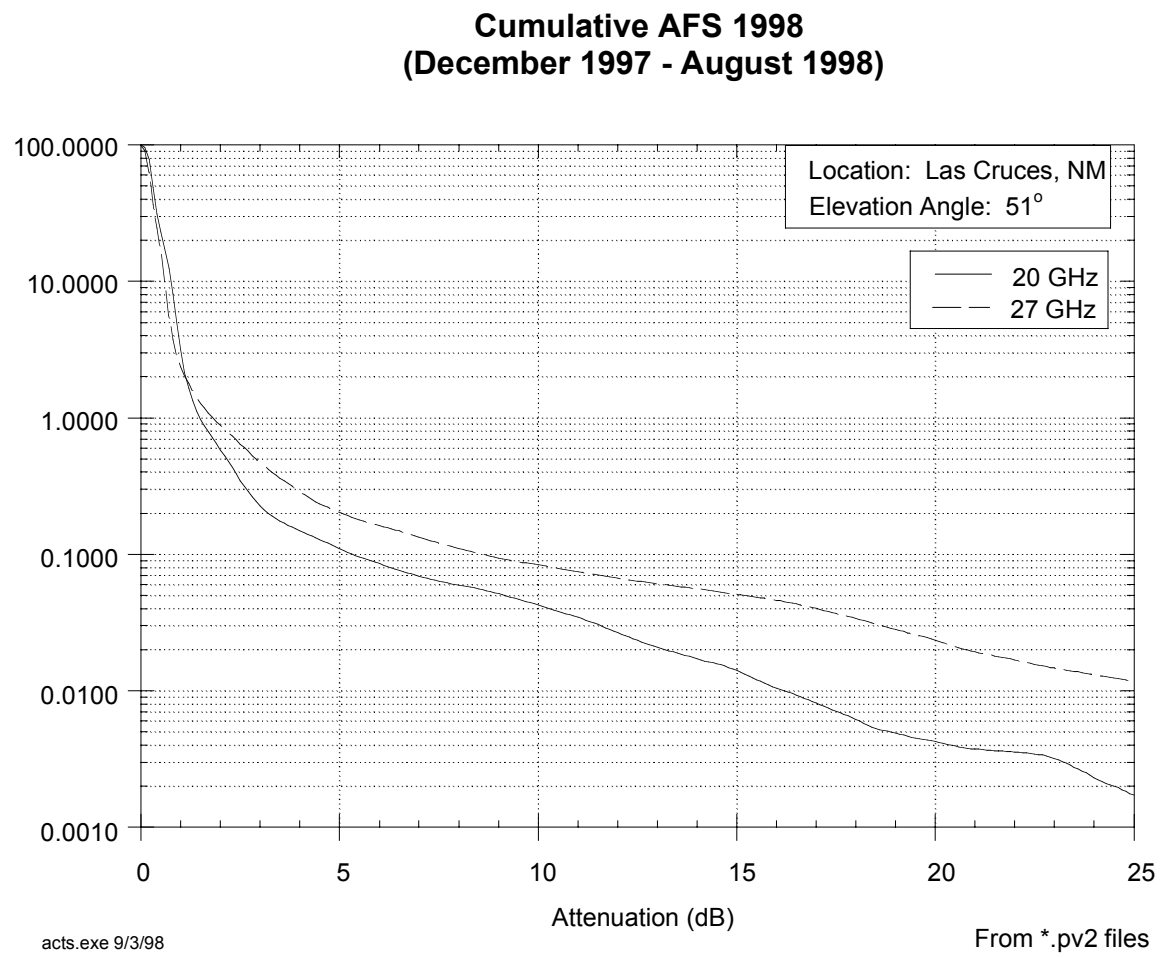


*Calculated from hourly temperature averages and Jornada Relative Humidity data

Attenuation wrt Free Space (AFS)



Attenuation wrt Free Space (AFS)



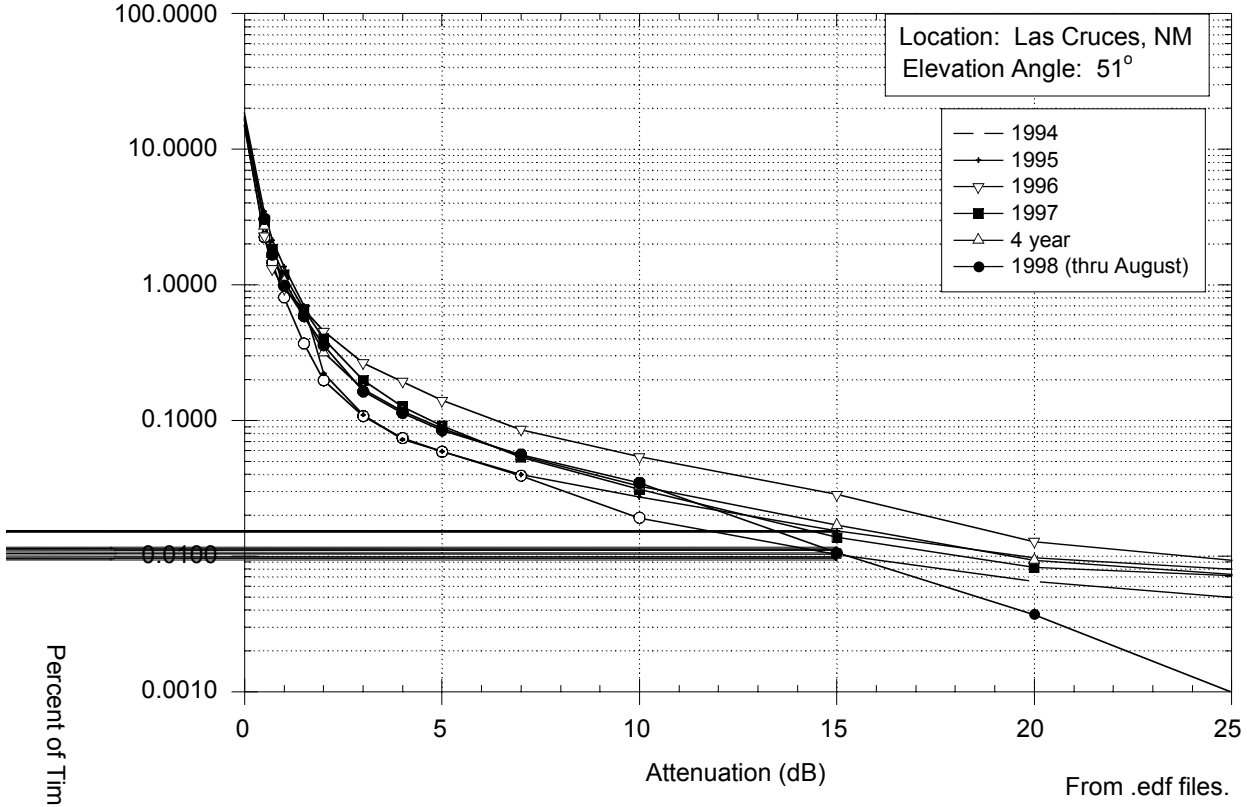
New Mexico ACTS Statistics Summary (Cont.)

- **Measured Link Performance for 12/93-8/98 (*.pv2)**

		20.2 GHz		27.5 GHz	
	% Availability	99.9	99.99	99.9	99.99
	% Outage Time	0.1	0.01	0.1	0.01
Attenuation	1994	5.4 dB	17.2 dB	8.5 dB	>25.0 dB
	1995	3.7 dB	19.4 dB	6.0 dB	>25.0 dB
	1996	6.3 dB	>25.0 dB	10.0 dB	>25.0 dB
	1997	5.3 dB	18.2 dB	9.3 dB	>25.0 dB
	4 Year	**5.4 dB**	**20.0 dB**	**8.4 dB**	**>25.0 dB**
	1998	5.2 dB	16.0 dB	8.6 dB	>25.0 dB

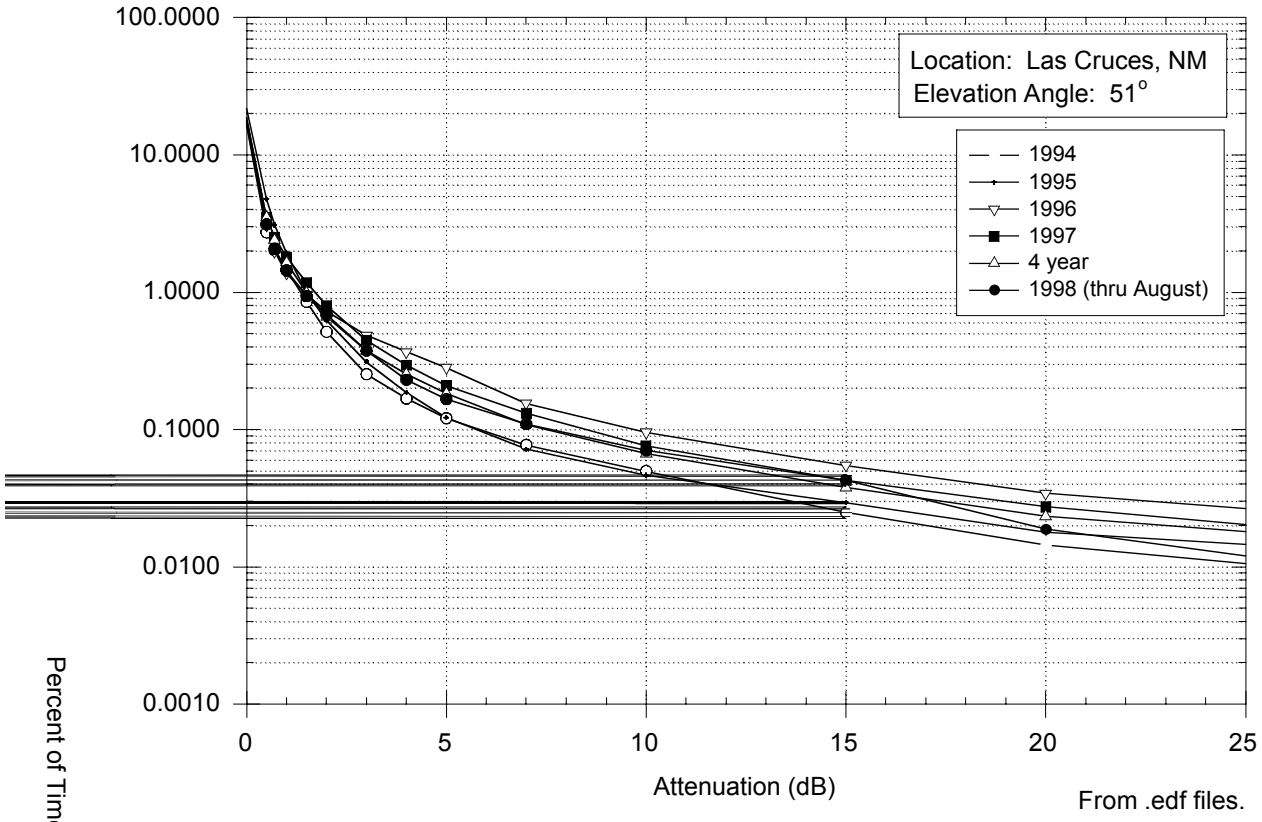
Annual ACA Empirical Distributions (20 GHz)

ACA for December 1993- August 1998
(20GHz)



Annual ACA Empirical Distributions (27 GHz)

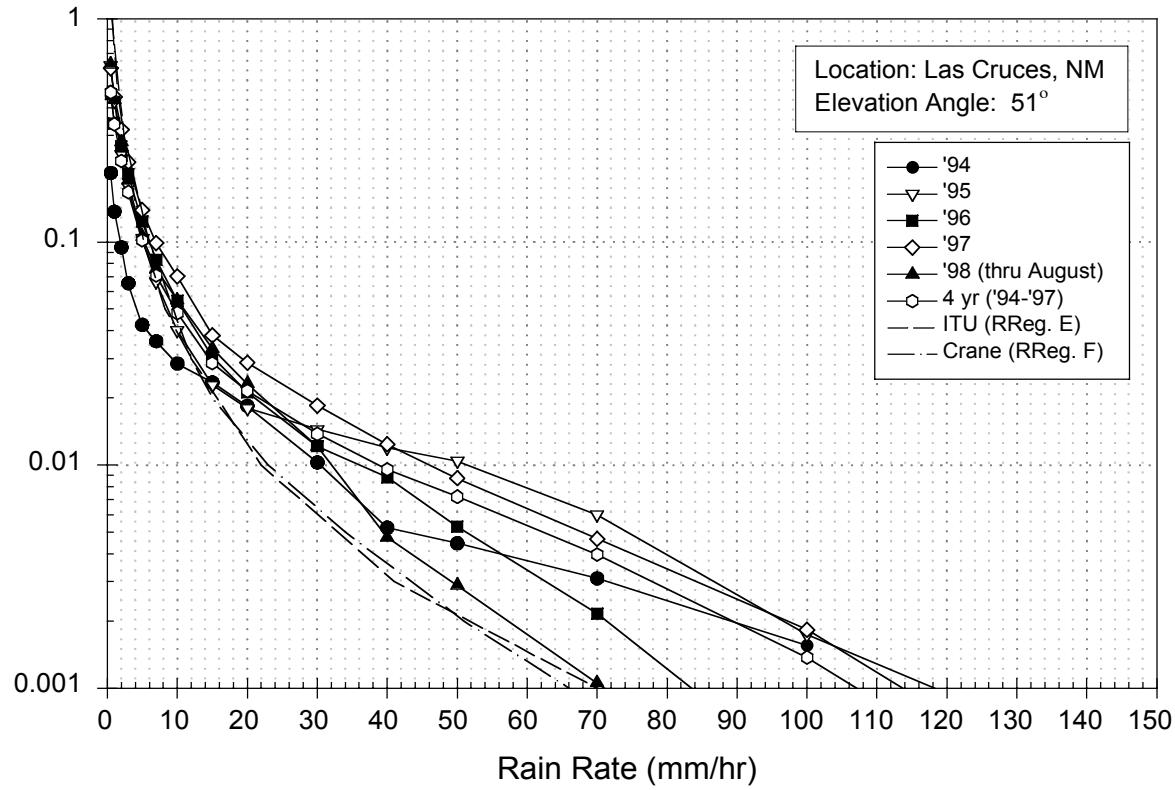
ACA for December 1993- August 1998
(27 GHz)



Percent of Time Attenuation is E

Annual Rain Rate Empirical Distributions from the Tipping Bucket

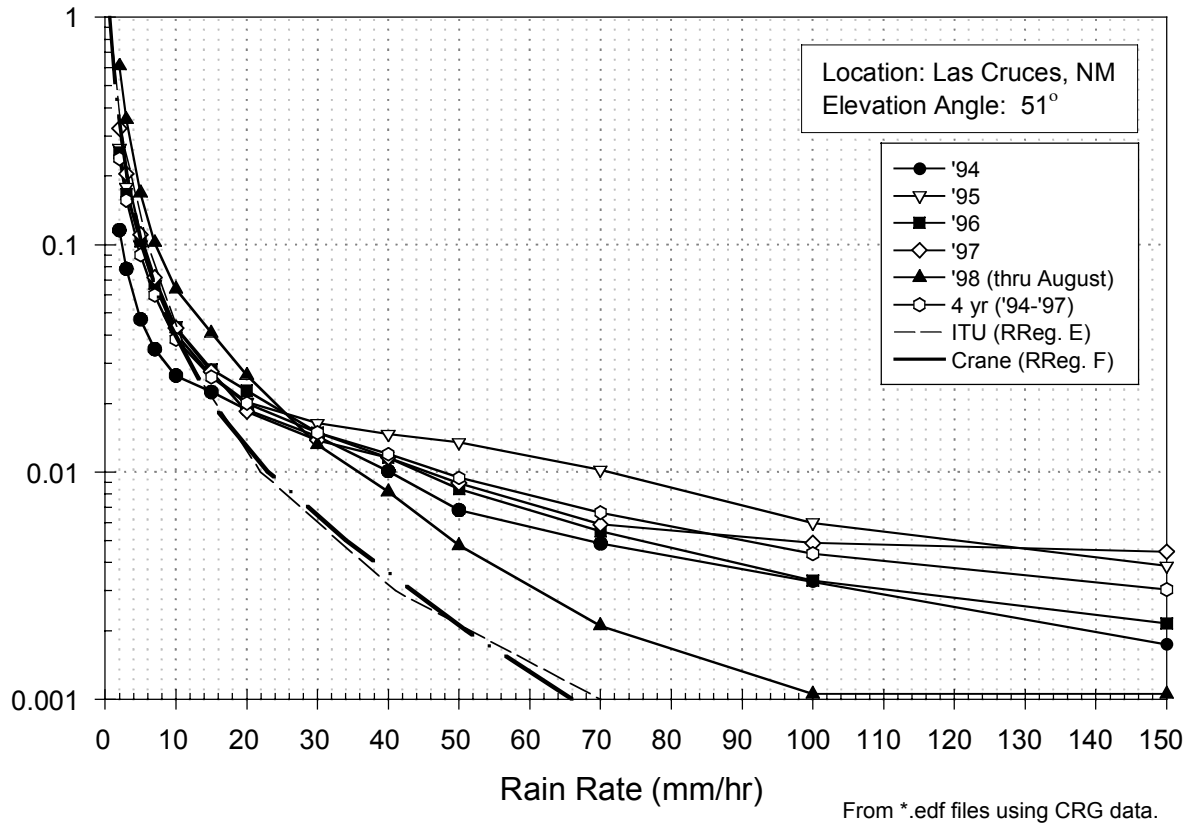
Annual Rain Rates for
December 1993 - August 1998



From *edf files using tipping bucket.

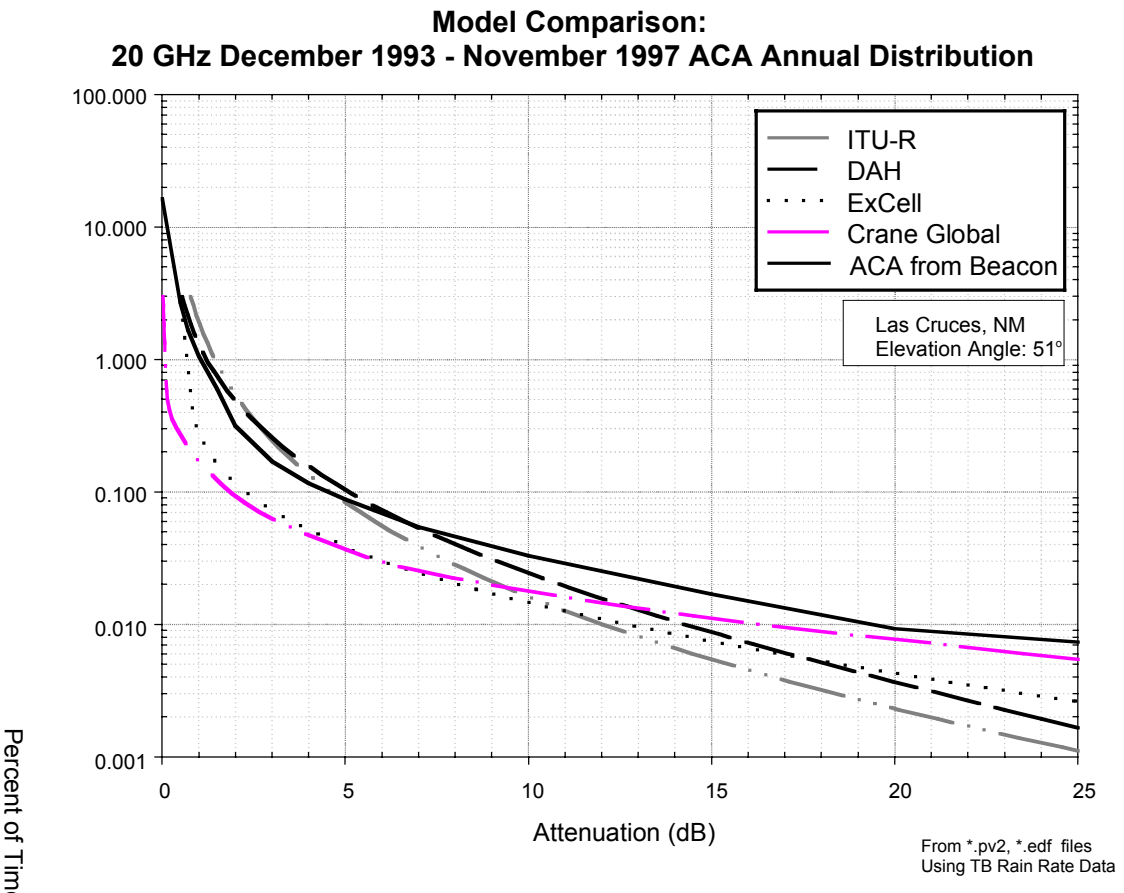
Annual Rain Rate Empirical Distributions from CRG

Annual Rain Rates for
December 1993 - August 1998



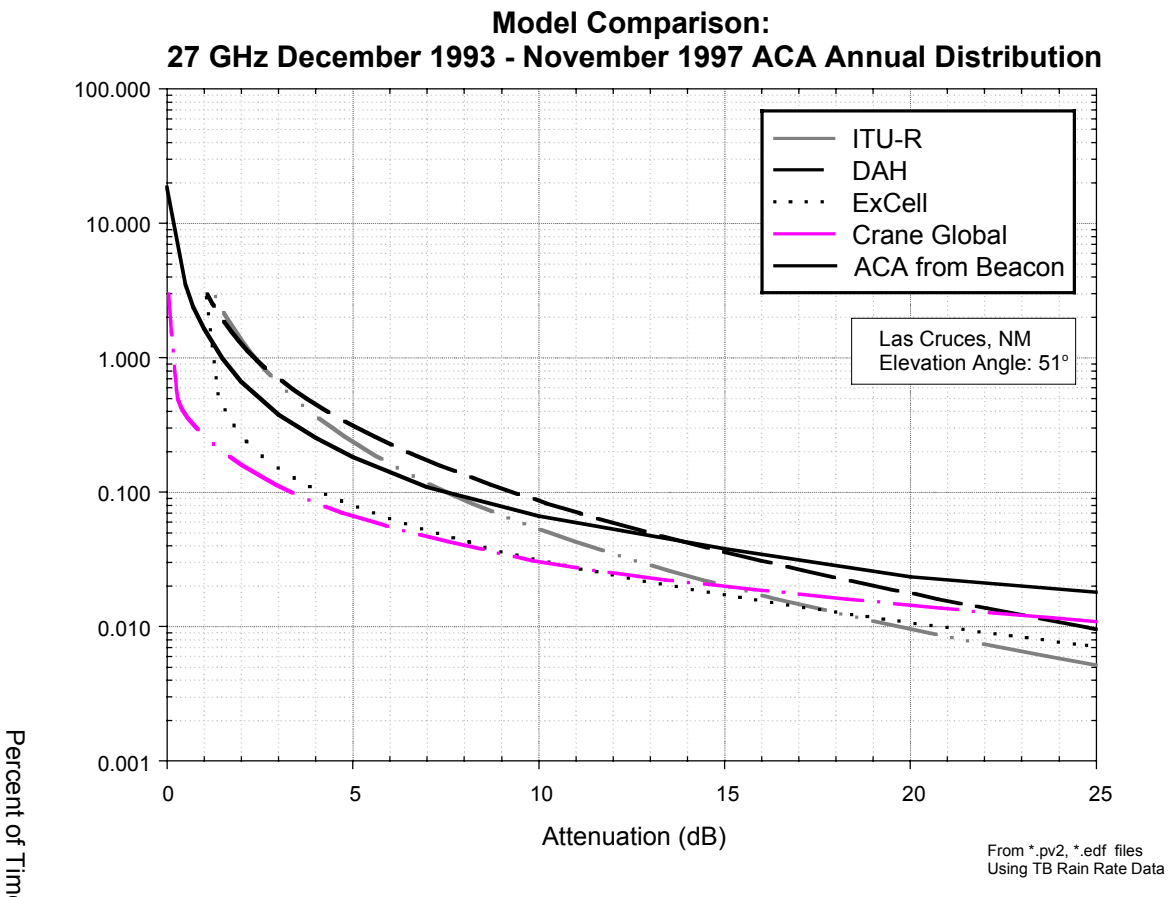
From *.edf files using CRG data.

Model Comparison: ACA 4yr Distribution (20 GHz)



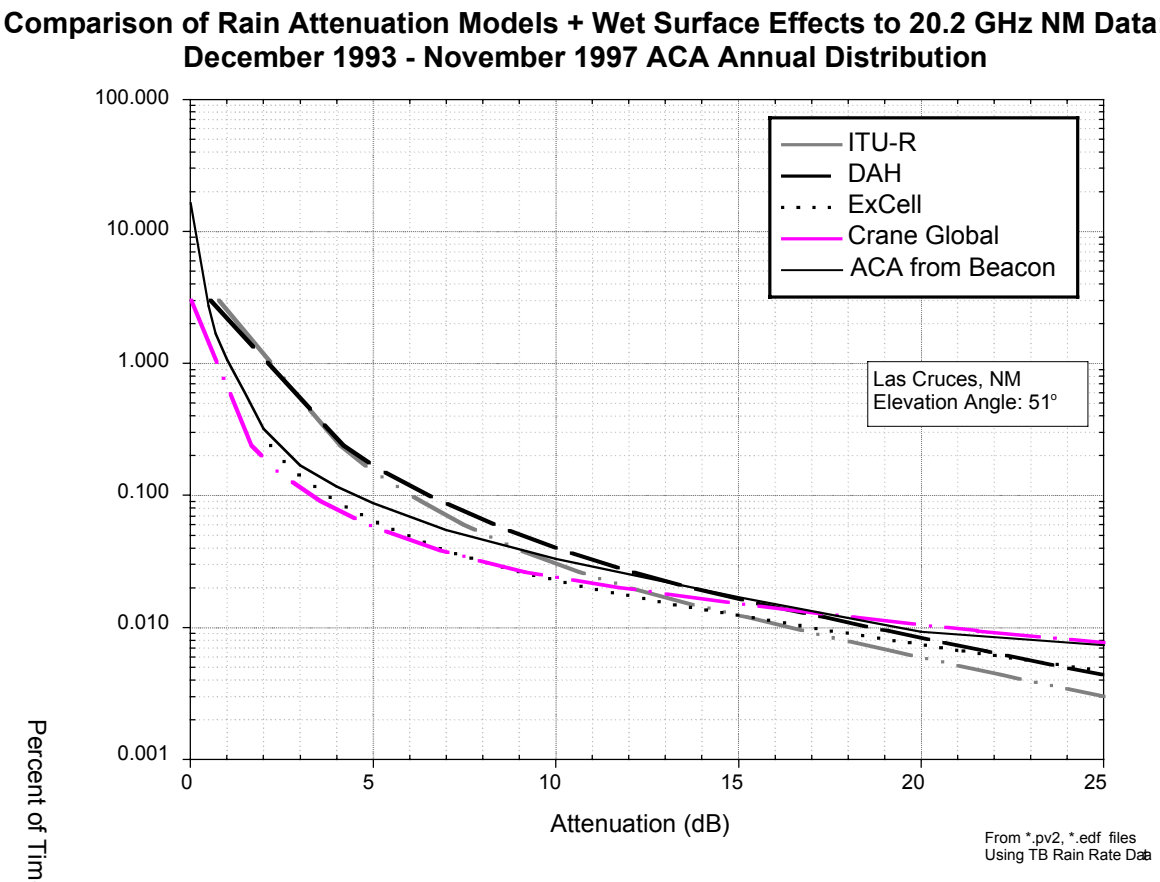
✣ Rain rates used come from tipping bucket data.

Model Comparison: ACA 4yr Distribution (27 GHz)



✣ Rain rates used come from tipping bucket data.

Model Comparison + Wet Surface Effects (20 GHz)



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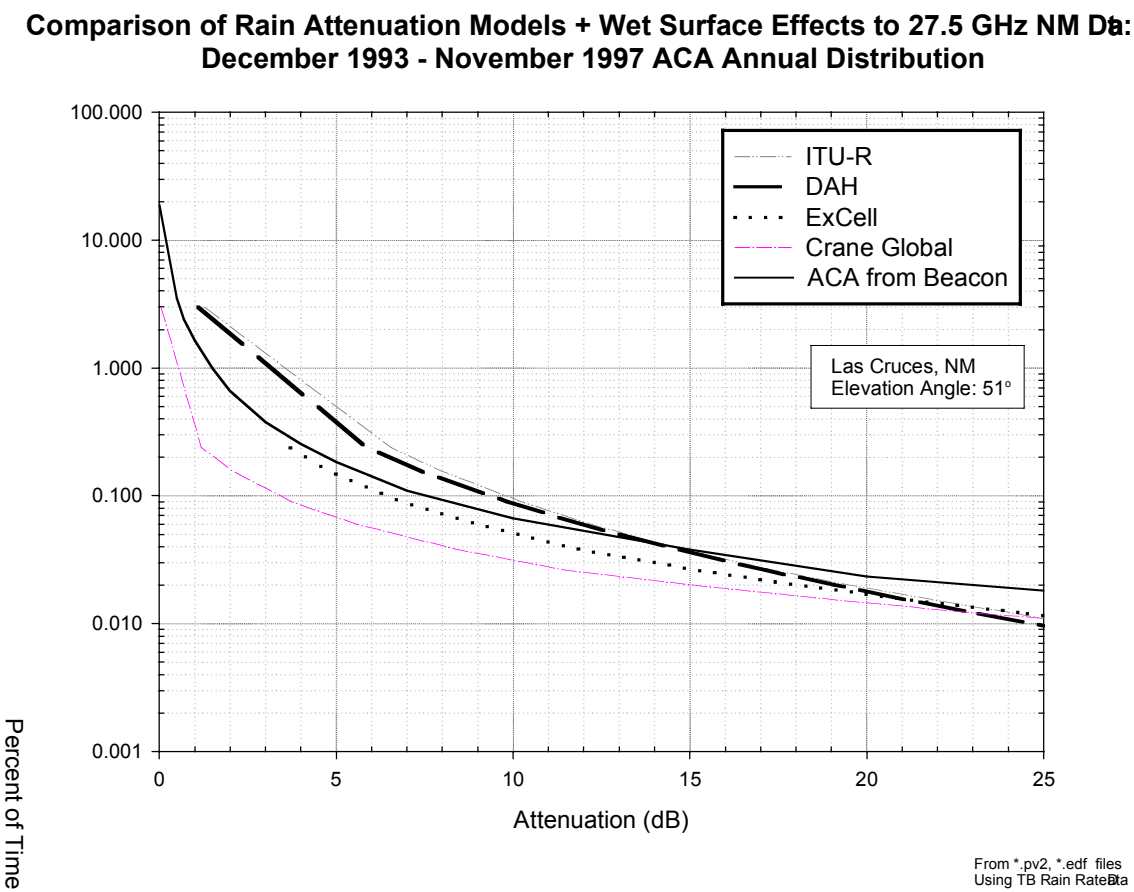
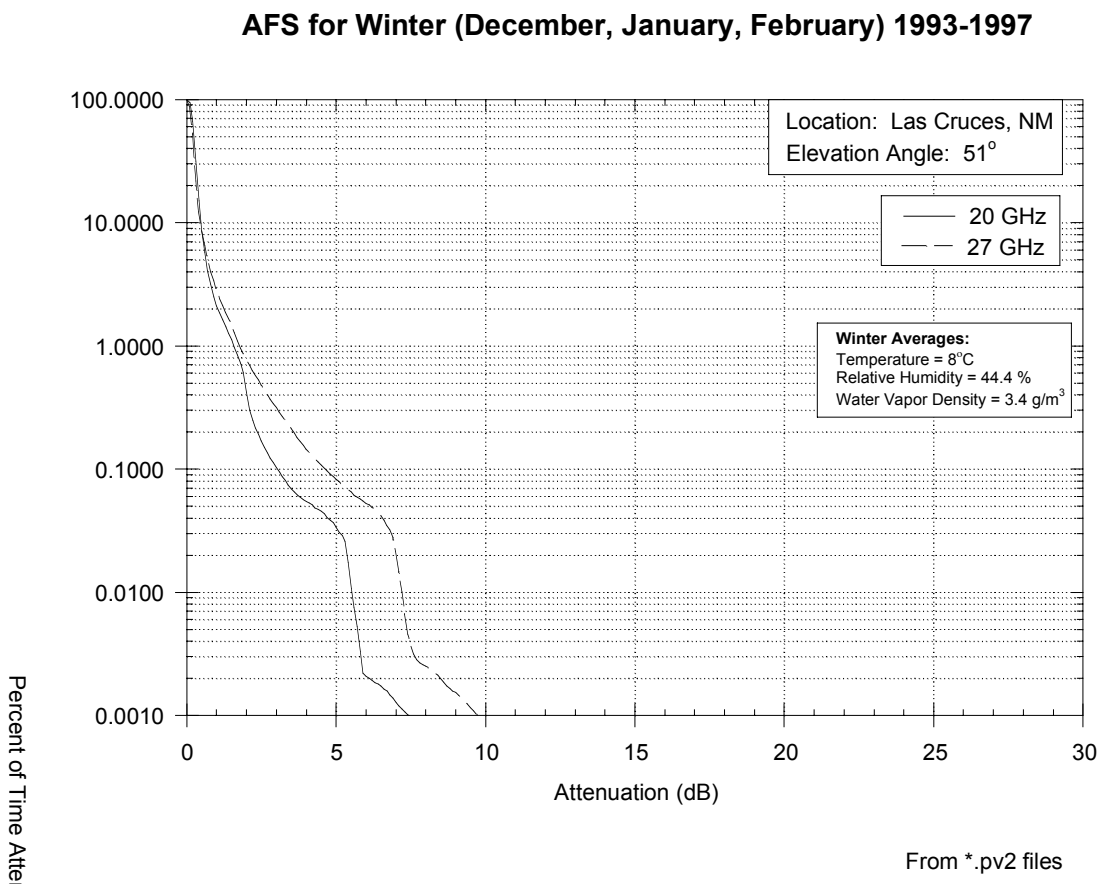
Model Comparison + Wet Surface Effects (27 GHz)



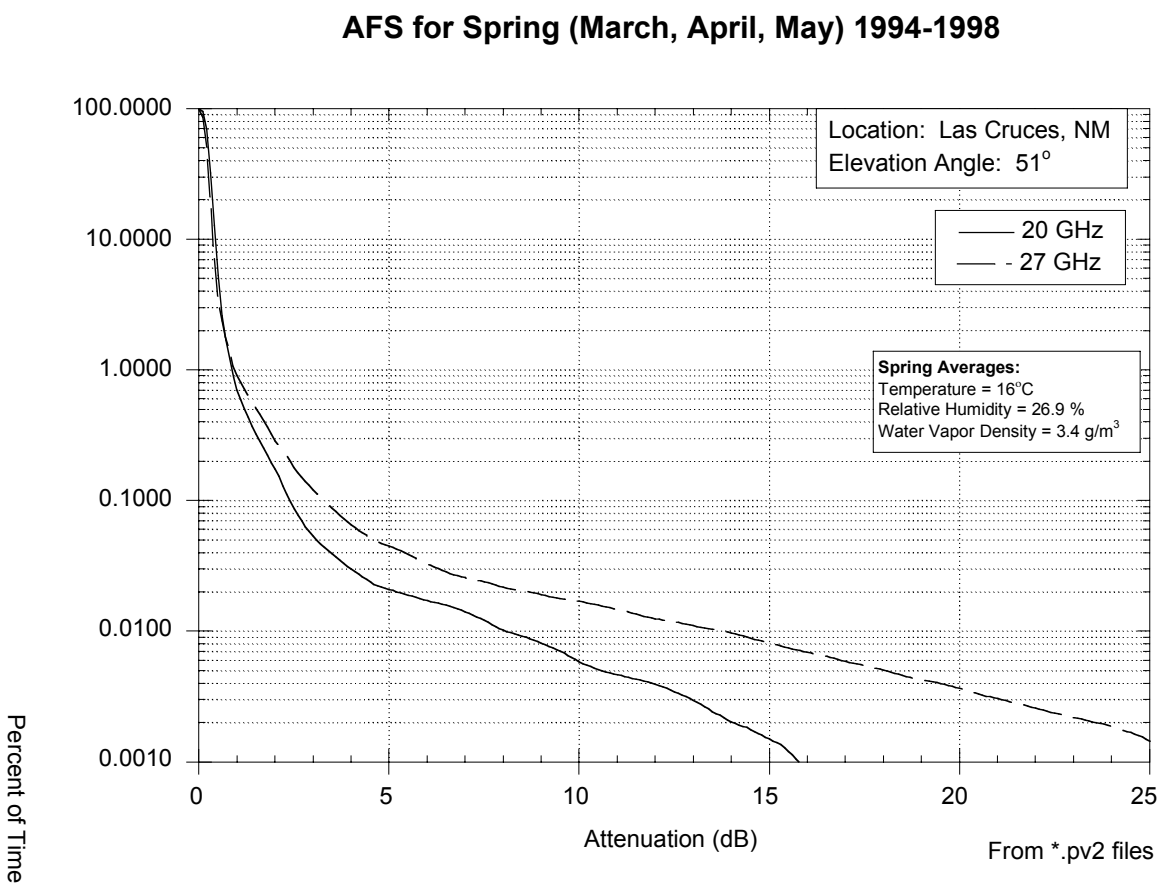
✣ Rain rates used come from tipping bucket data.

Five Year Winter AFS Statistics



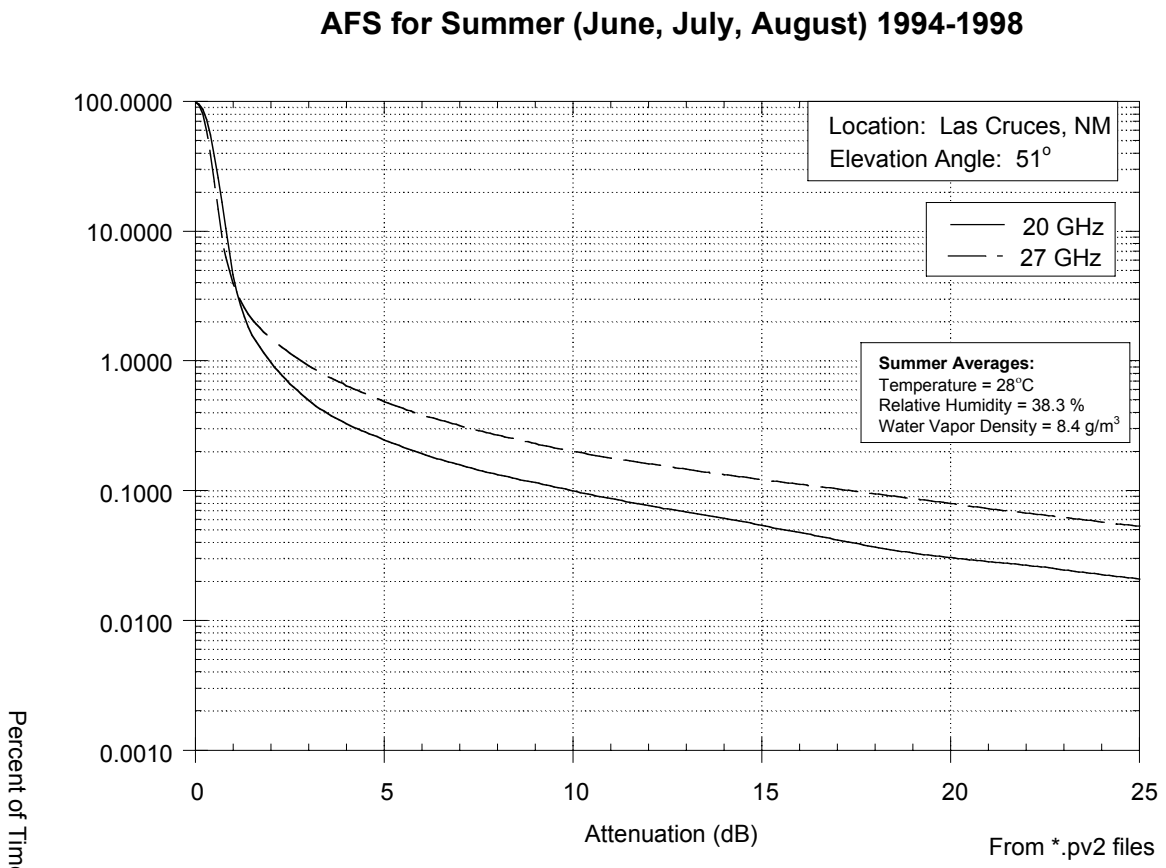
- Historical weather data for the New Mexico site: For Winter, the average temperature is 7.7ºC and the average relative humidity is 40.6%.

Five Year Spring AFS Statistics



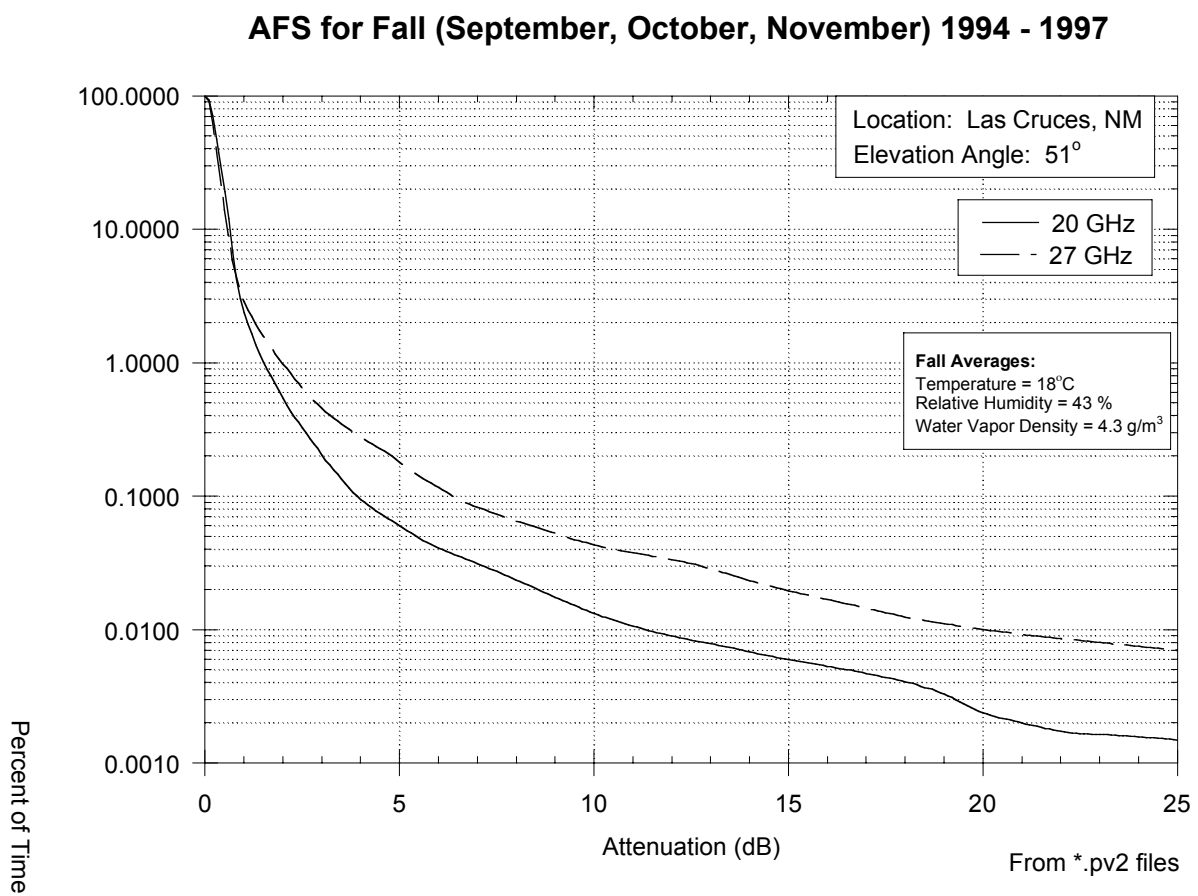
✦ Historical weather data for the New Mexico site: For Spring, the average temperature is 16.9ºC and the average relative humidity is 26.3%.

Five Year Summer AFS Statistics



- Historical weather data for the New Mexico site: For Summer, the average temperature is 27ºC and the average relative humidity is 41.3%.

Four Year Fall AFS Statistics



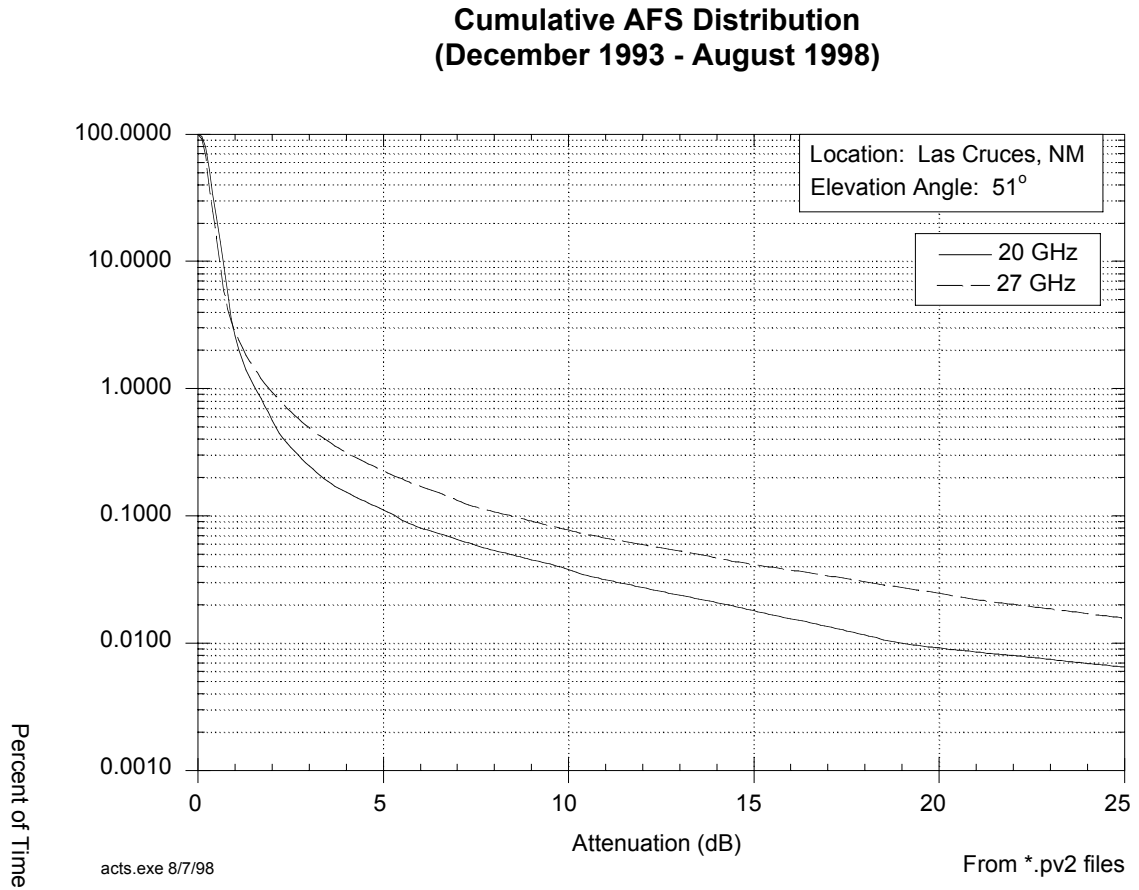
- Historical weather data for the New Mexico site: For Fall, the average temperature is 17.7ºC and the average relative humidity is 42.3%.

Summary of Seasonal Statistics

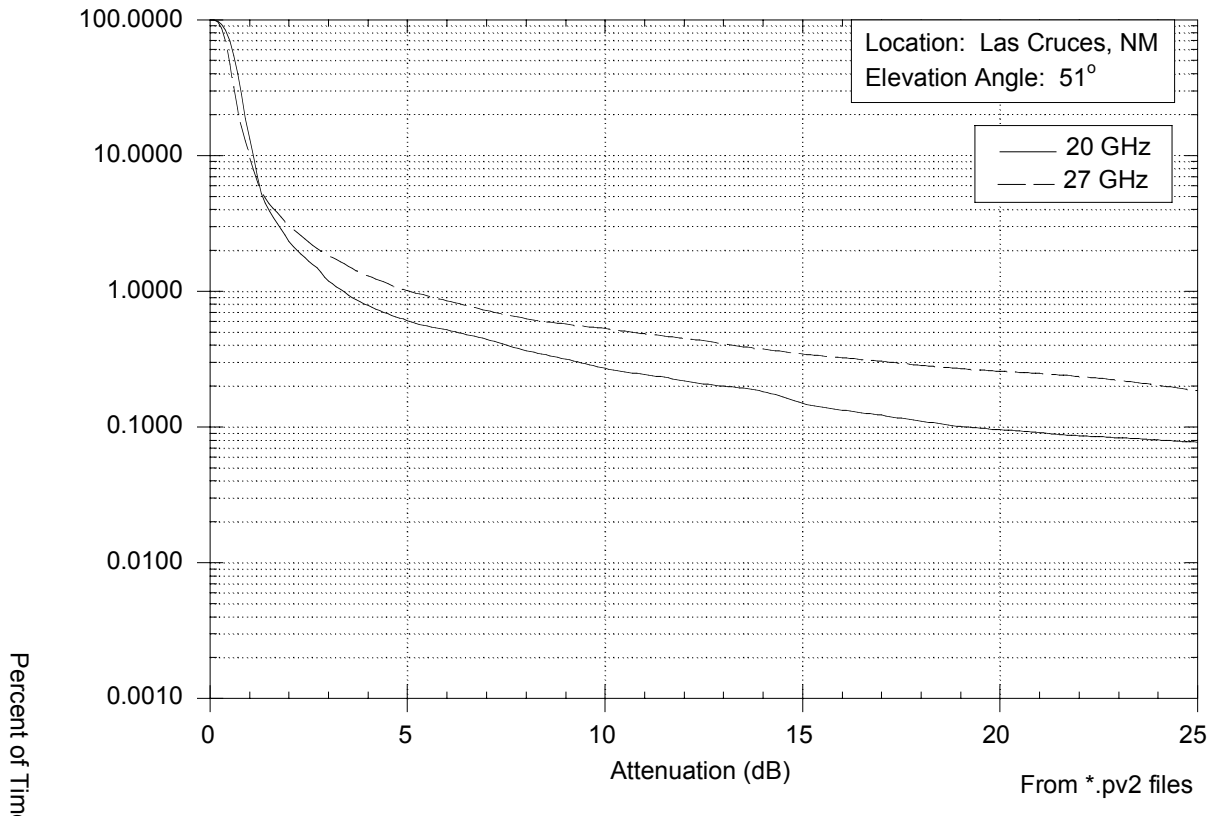
- **Measured Link Performance for 12/93-8/98 (*.pv2):**

		20.2 GHz		27.5 GHz	
	% Availability	99.9	99.99	99.9	99.99
	% Outage Time	0.1	0.01	0.1	0.01
Attenuation	Winter(5-yr)	3.0 dB	5.5 dB	4.4 dB	7.3 dB
	Spring(5-yr)	2.4 dB	8.0 dB	3.3 dB	13.3 dB
	Summer(5-Yr)	10.0 dB	>25.0 dB	17.3 dB	>25.0 dB
	Fall(4-yr)	3.9 dB	11.2 dB	6.4 dB	20.0 dB

57 Month Cumulative Attenuation wrt Free Space(AFS)



Actual Worst Month: July 1997 Attenuation wrt Free Space (AFS)



New Mexico ACTS Statistics Summary

- **Seasonal Statistics**
  - ➢ Majority of Large Fades occur in summer months.
- **Rain attenuation model prediction comparisons**
  - ➢ All the rain models match the empirical data fairly well
  - ➢ Adding wet surface effects to the rain attenuation models improves the models significantly.
- **Worst actual month (in 57 months): July 1997**

STel Future ACTS Activities

- Complete 5 year cumulative distributions from *.pv0 preprocessing
- Complete 5 year cumulative distributions from *.pv2 preprocessing
- Complete the 5 year final report