

# **Diversity Benefits for Millimeter Wave Satellite Communications, with Cloud Correlation Functions**

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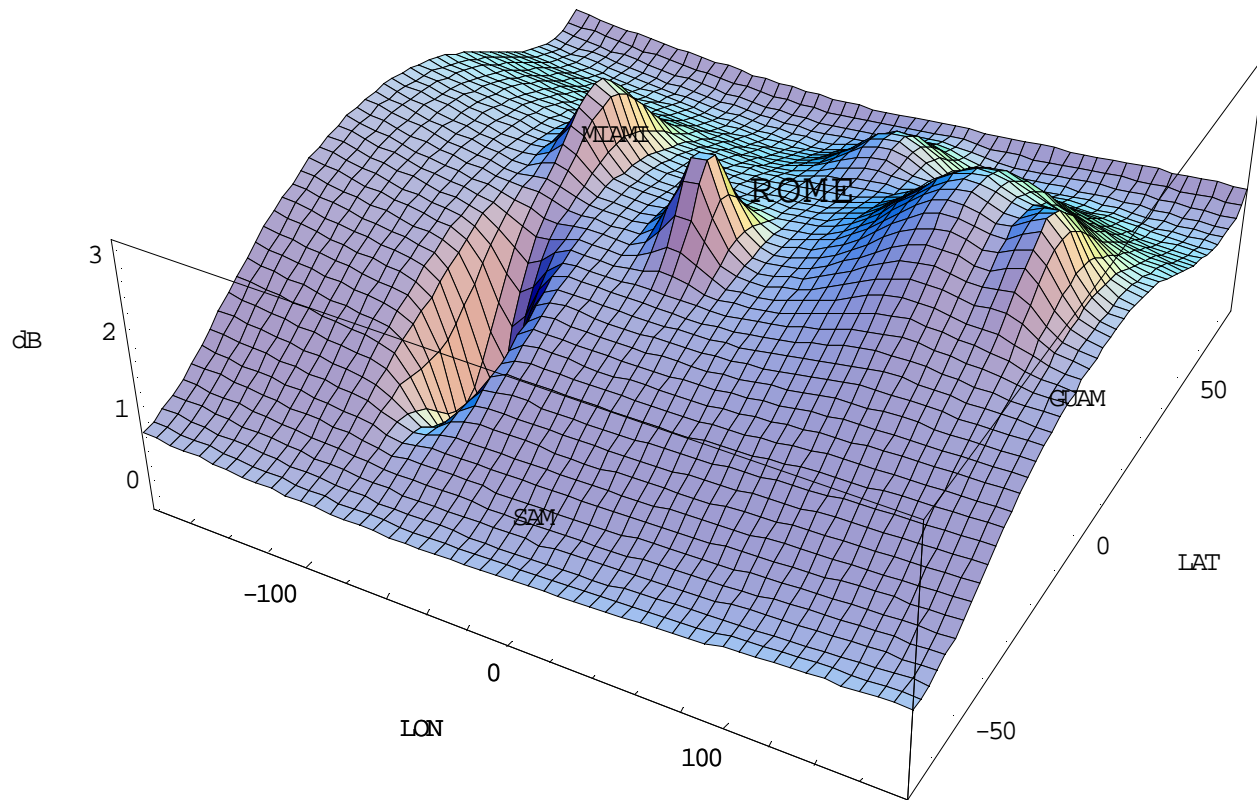
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# Outline

- **Barbaliscia's 49/22 GHz Worldwide Attenuation maps**
- **New 6 to 100 GHz Function, for new maps**
- **Compare GEO, Molniya Att'n at 30 GHz**
- **Examine Molniya GEO at 30- 45, 90-100 GHz for Iceland, NY, and Rio.**
- **Discuss Soviet Cloud Correlation Functions**
  - Use to predict site diversity advantages,  
with modest attenuation, good reliability at 90 GHz  
(Rain Correlation Functions, Appendix)

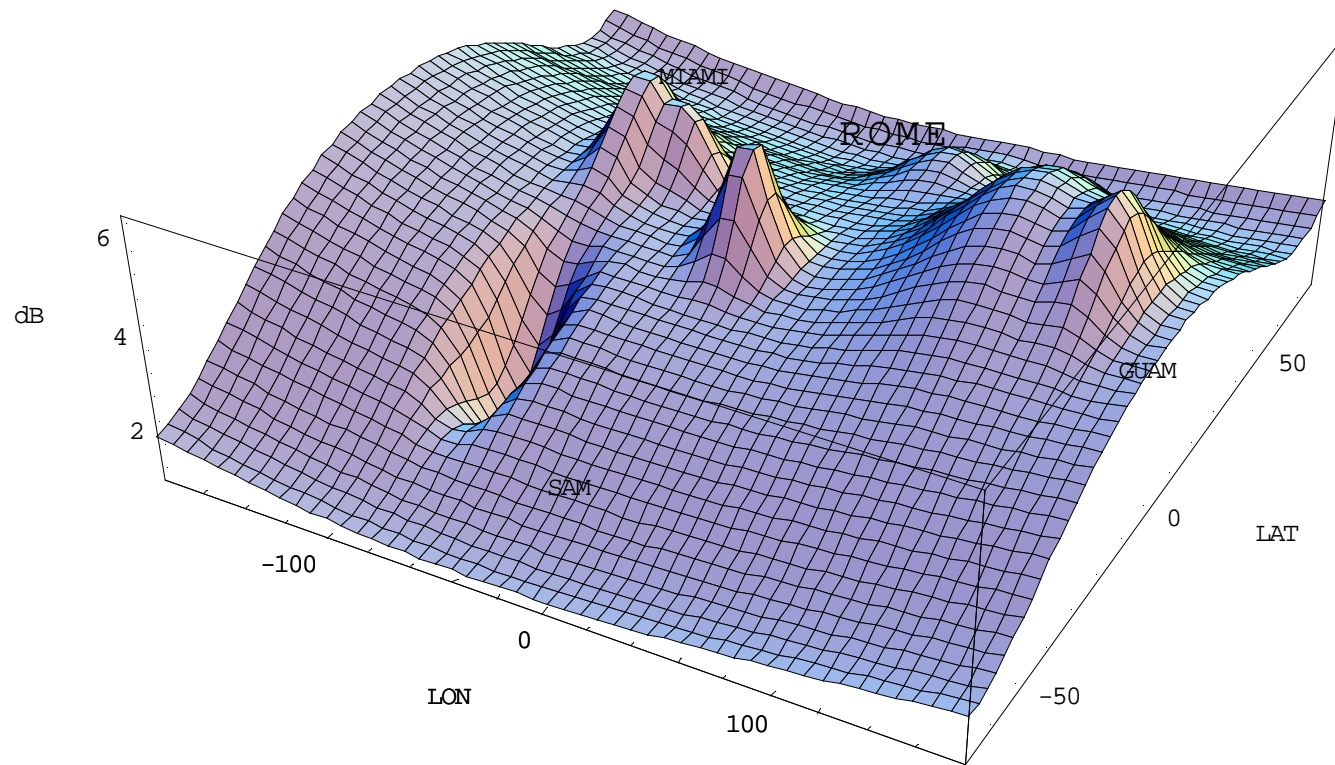
# Barbaliscia's 99% Non Rainy Zenith Attenuation at 22.2 GHz World Wide (note ROME, Miami, S.America)

Barbaliscia 's 22.2 GHz Zenith Attenuation for N.Hemisphere

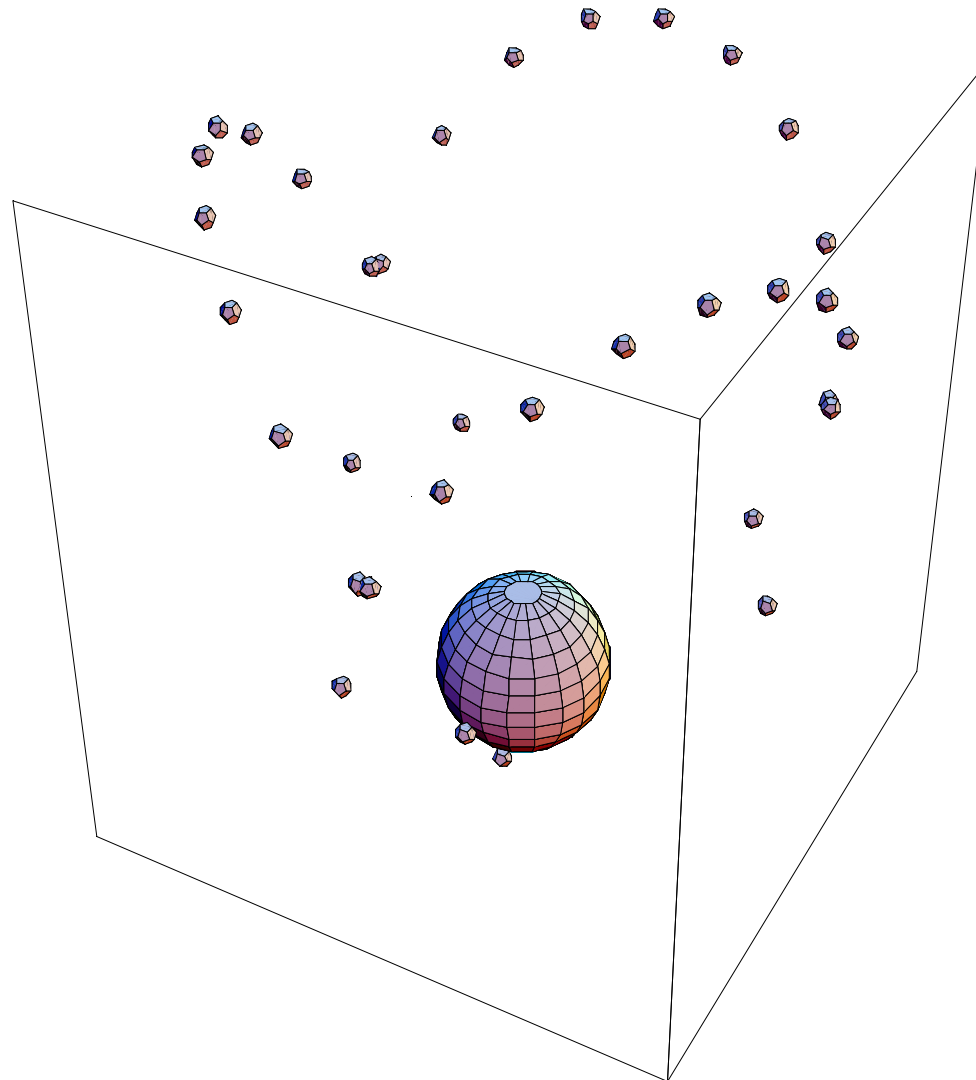


# Barbaliscia's 99% Non Rainy Zenith Attenuation at 49.5 GHz vs LON, LAT

49.5 GHz Zenith Attenuation for N.Hemisphere

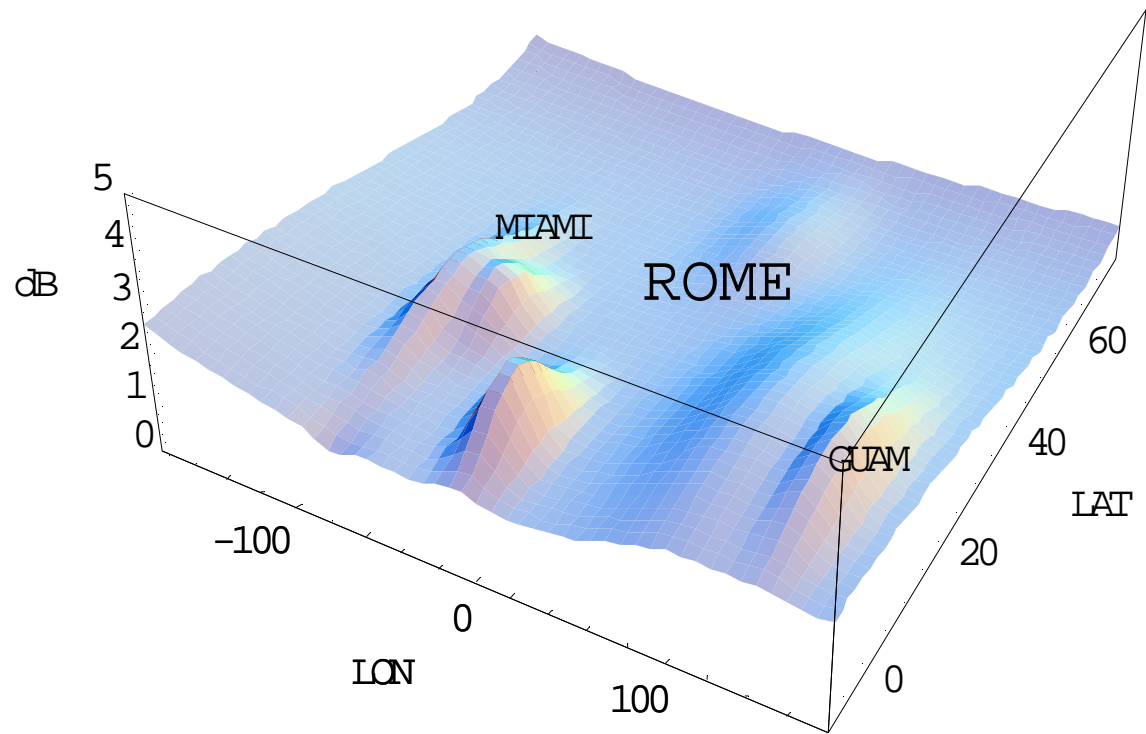


## 3 Phased Molniya for Continuous Coverage

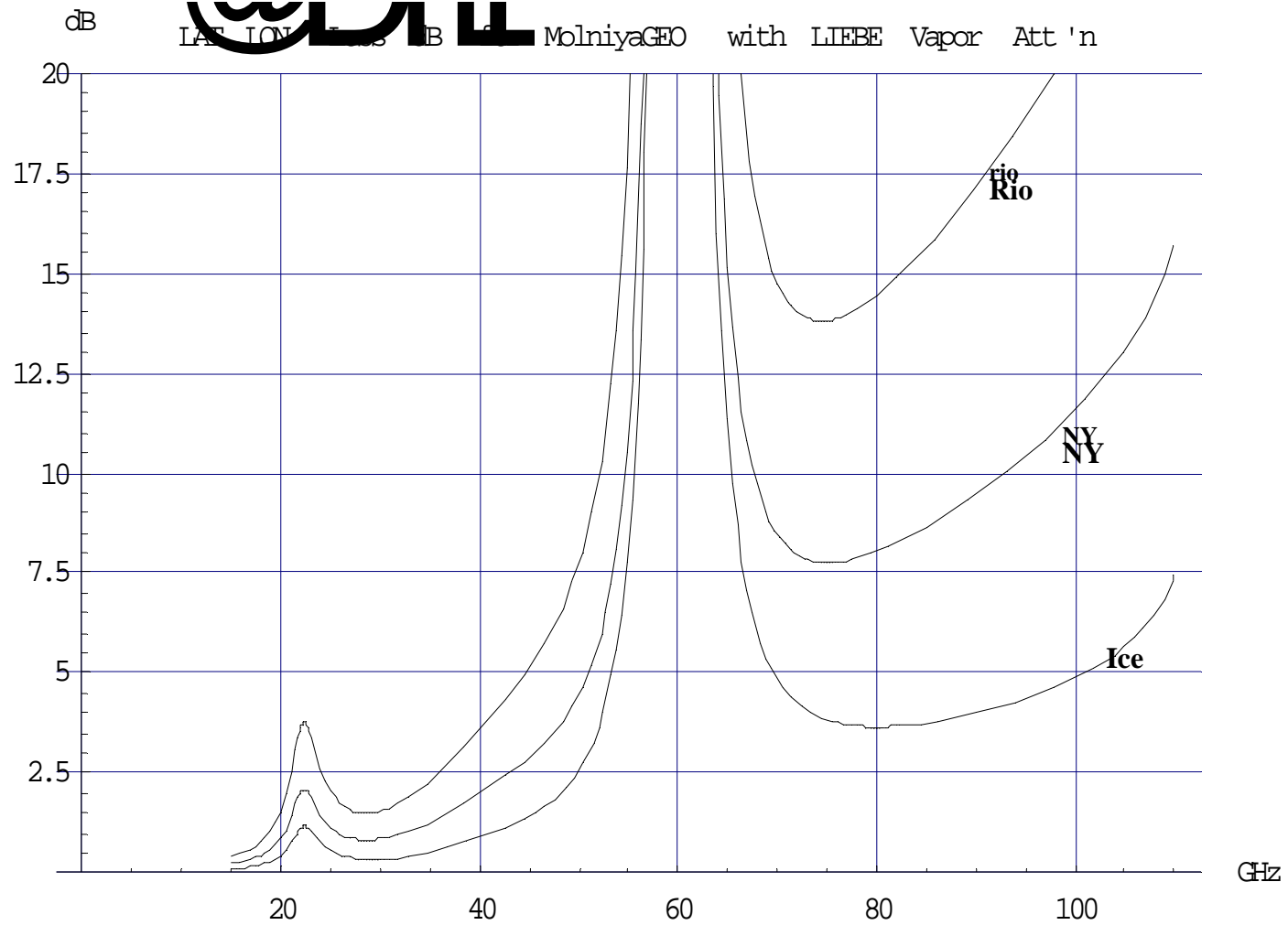


# MolniyaGEO Attenuation at 30 GHz

MolniyaGEO Attenuation for N.Hemisphere at F= GHz ,by  
Barbaliscia ,LIEBE

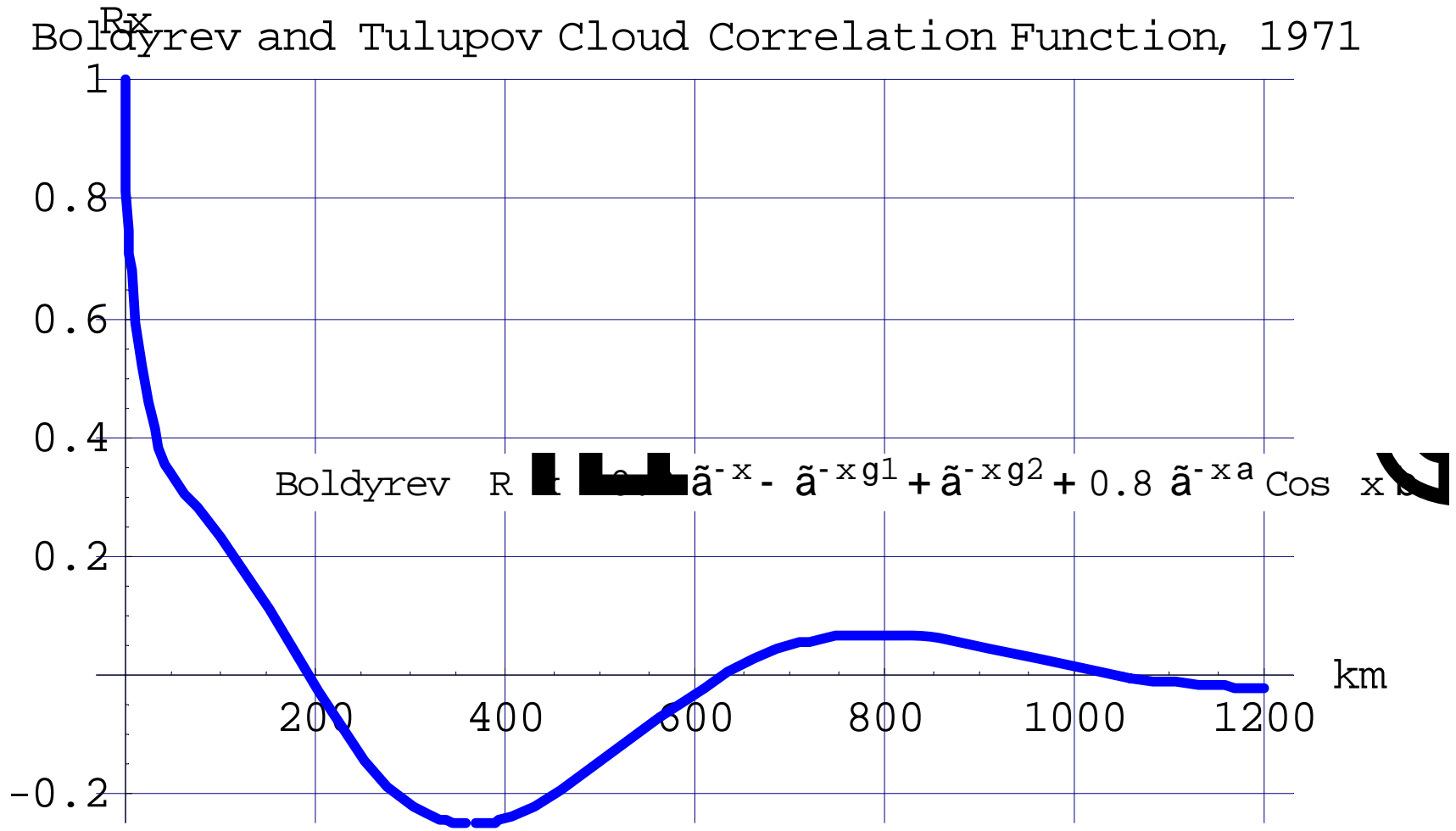


# MolniyaGEO Attenuation at Rio, NY, Iceland



# Soviet Cloud Autocorrelation Function v. Distance (km)

## Boldyref and Tulupov





## Observations on Soviet Cloud Autocorrelation Function

- **R(x) drops to ZERO at 200 km**
  - and NEGATIVE at 300 km**
  - as observed by strong switched diversity results against rain**  
**(Hatsuda, Baltimore APS, 96)**
  - Not accounted for with ITU diversity attenuation**
- **R(x) drops to 0.4 at 32-40 km**
  - Good cloud relief for Millimeter Wave Satellite Systems**

# Availability from Boldyrev and Tulupov Cloud Correlation Function

Availability with 2 sites=

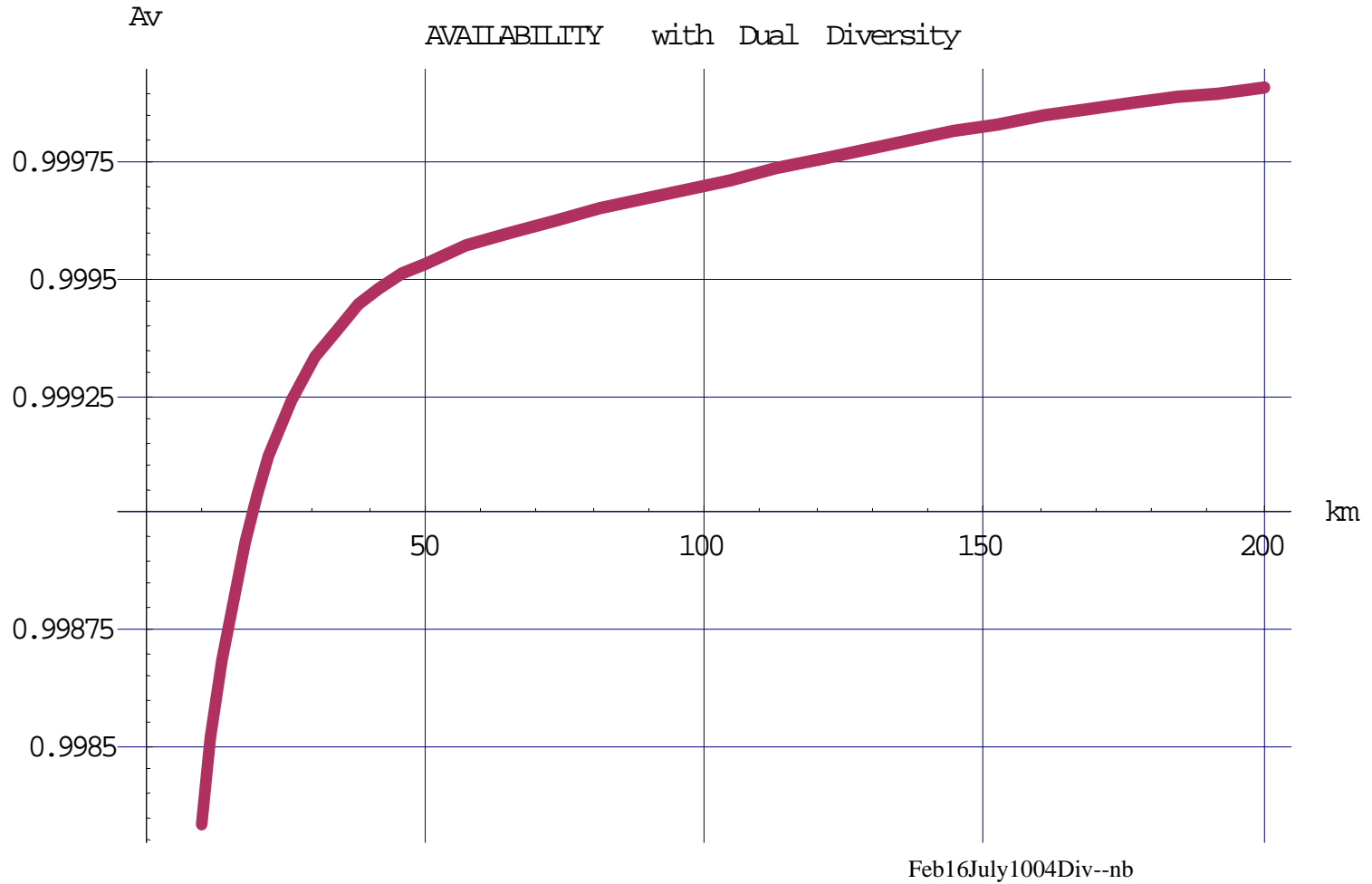
$A_{V2} =$

$$1 - (1 - a_{v1})^{2 - 0.2 e^{-x} - e^{-0.036 x} + e^{-0.015 x} - 0.8 e^{-0.003 x} \cos[0.0075 x]}$$

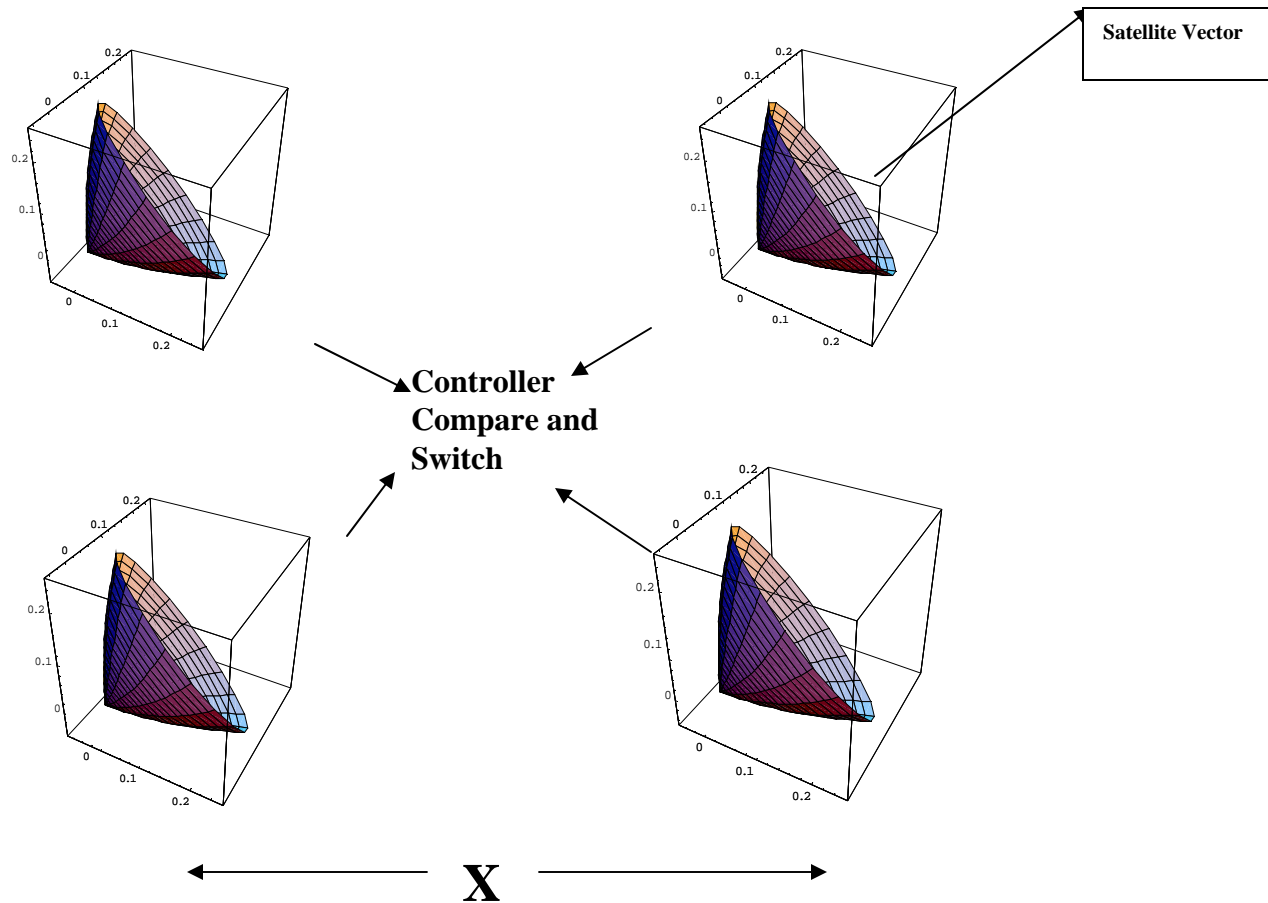
Where  $x$ =site separation, km

with  $a_{v1}$ =availability with 1 site= 0.90 for typical 90 GHz satellite link  
 $a_{v2}$ = availability with 2 separated, switched diversity sites

# --b. and Much Higher Availability with 0.99 Single Link

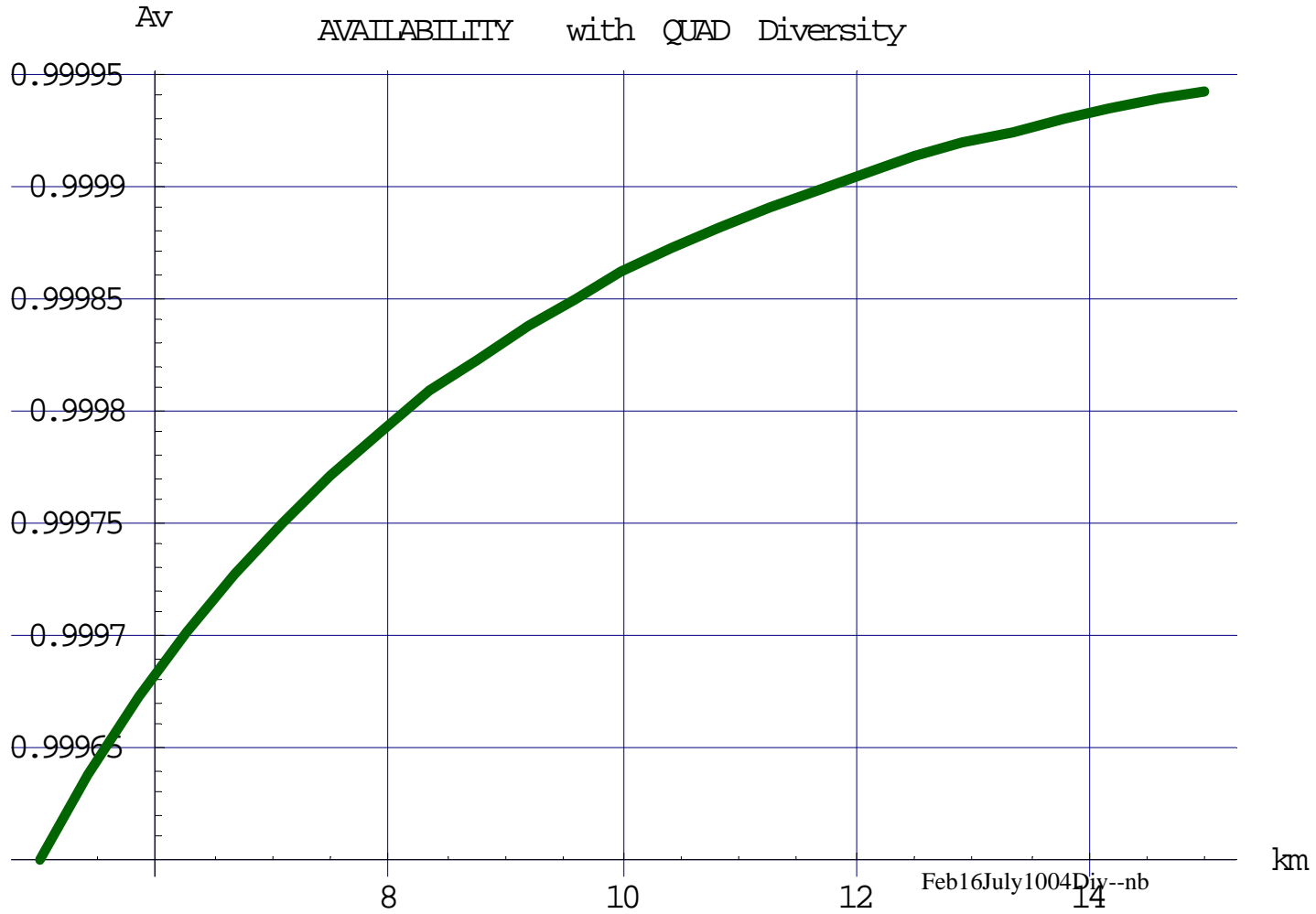


# Superior Availability with 4 Sites



$$1 - \left( (1 - av1)^{2-0.2 e^{-x} - e^{-0.036 x} + e^{-0.015 x} - 0.8 e^{-0.003 x} \cos[0.0075 x]} \right)^{2-0.2 e^{-x} - e^{-0.036 x} + e^{-0.015 x} - 0.8 e^{-0.003 x}}$$

# --and Much Higher Availability with 0.99 Single Link as 3dB at 45 GHz; 9dB at 90 GHz



## Conclusions for Diversity Discussion

- **Barbaliscia's non-rainy attenuation results were invaluable, as basis for deriving estimates of zenith attenuation for 6-100 GHz.**
- **Constellations with high elevation allow the low attenuation to be realized.**
  - both Molniya and GEO are well understood, and behaved.
- **Boldyrev and Tulupov's cloud correlation function (Slide 7) allowed high availability (>0.999) to be achieved with modest diversity**
  - e.g, 45 GHz, 25 km dual sites, 3 dB; 90GHz, 25 km, 9 dB
  - and, the site separation combats rain; R(x) as 8km (Appendix)
- ***Your cloud correlation functions will be of interest.***