Estimating SRTM terrain-height errors and their effect on profile interpretation

ISART

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D F Bacon

dB Spectrum Services Ltd

Two sources of terrain-height data cover the UK:

National mapping agency (OS)	SRTM
Conventional surveying	Remote sensing
"Bare-earth"	Tends to upper surface
50-m grid intervals	3 arc-seconds

If a propagation software library is switched from OS to SRTM
what difference will it make to the results ?

Define:

$$\Delta_h = H_{SRTM} - H_{OS}$$

where:

H_{OS} = OS height at exact grid point

H_{SRTM} = SRTM height interpolated for the same location

Thus SRTM heights are subject to a small degree of smoothing due to the bi-linear interpolation required to match the exact UK grid point

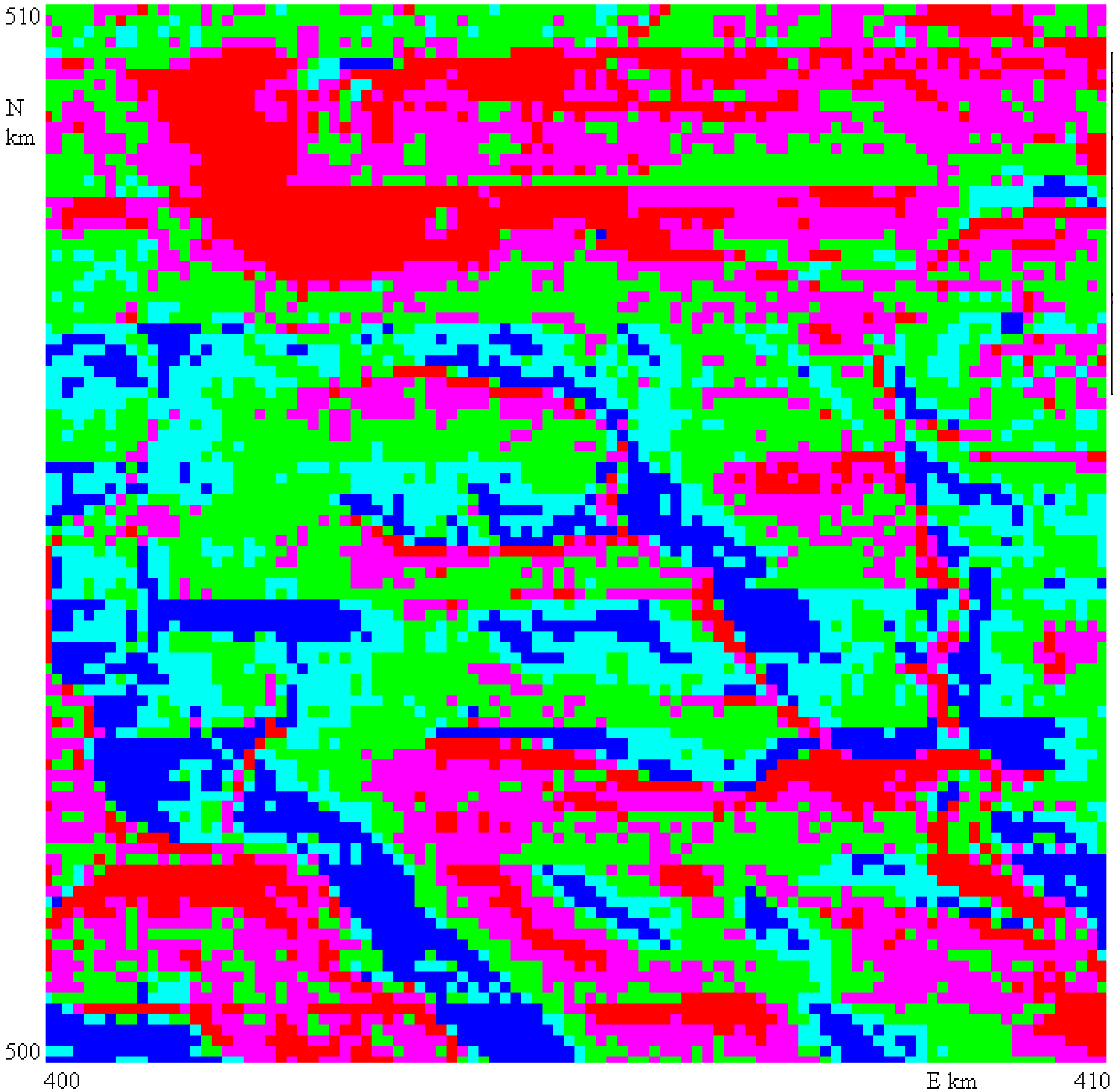
ALL-LAND 10-km TILES:

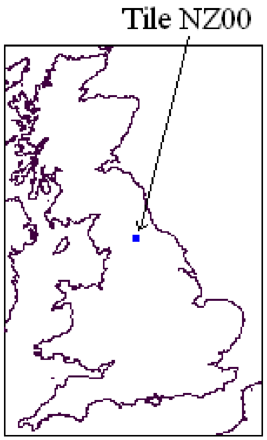
Δ_h was calculated at 100 m intervals of the grid in 10-km square tiles, each of which contains no sea points.

There are 1,899 of these tiles

and thus almost 19 million Δ_h values.

One tile: Δ_h correlation with slope





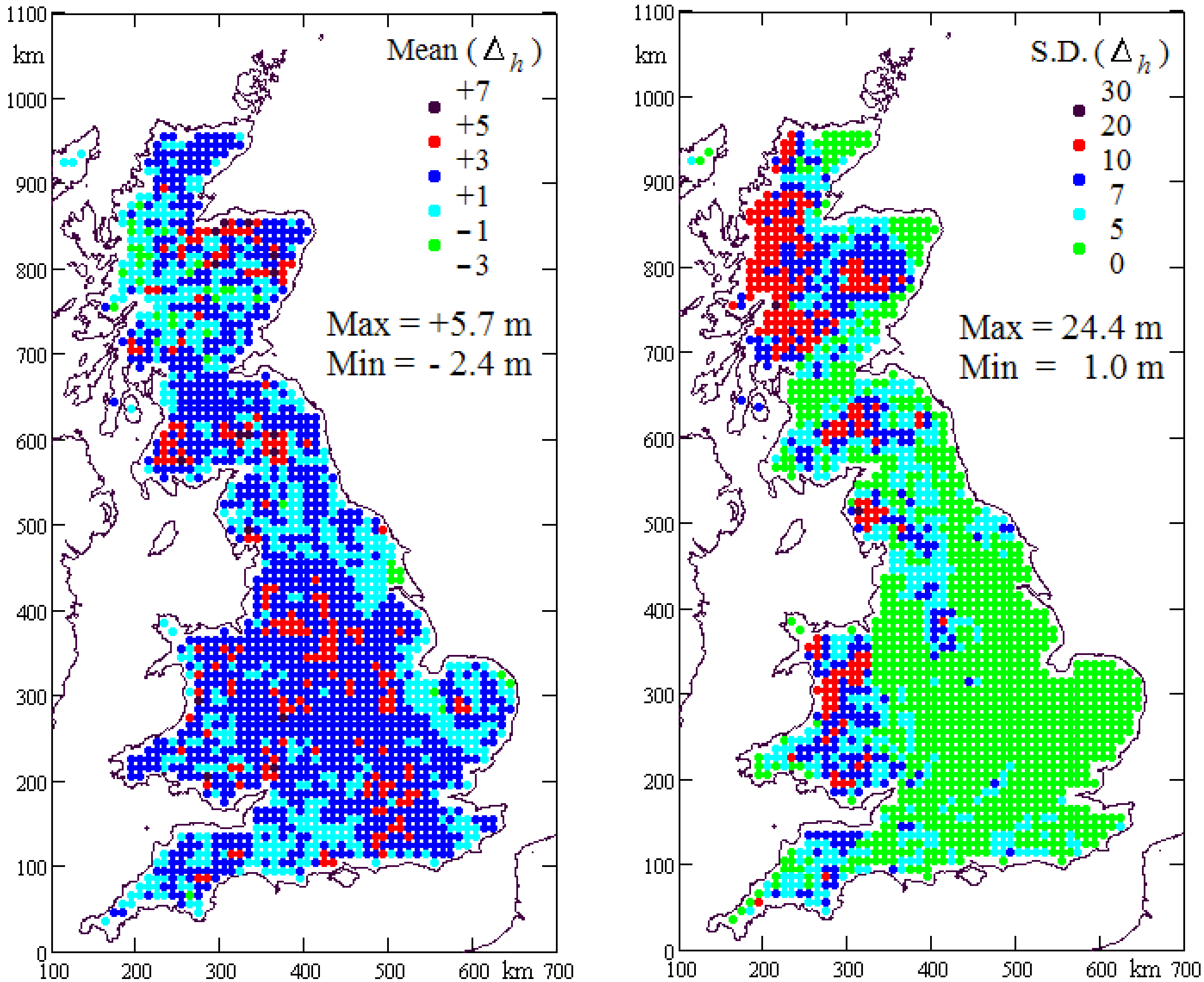
Height range in tile is from about 80 to 560 m asl

Δ_h m

+7
+3
−1
−5

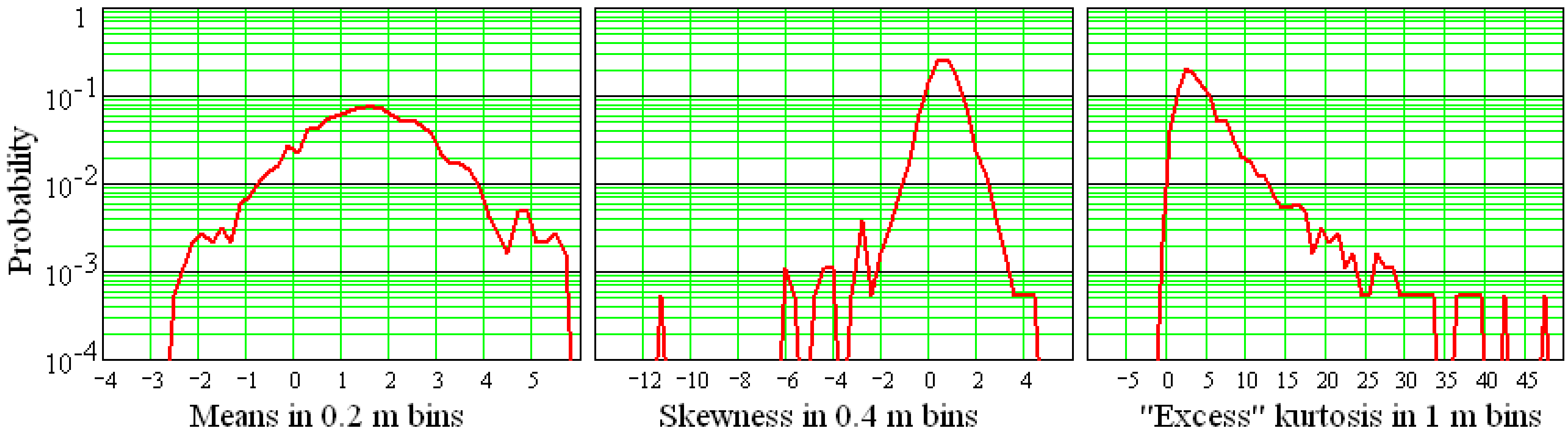
max = + 32
mean = + 1.2
min = − 40

Δ_h means and SDs for all tiles



Distribution of tile Δ_h statistics:

Means | Skewness | "Excess" Kurtosis

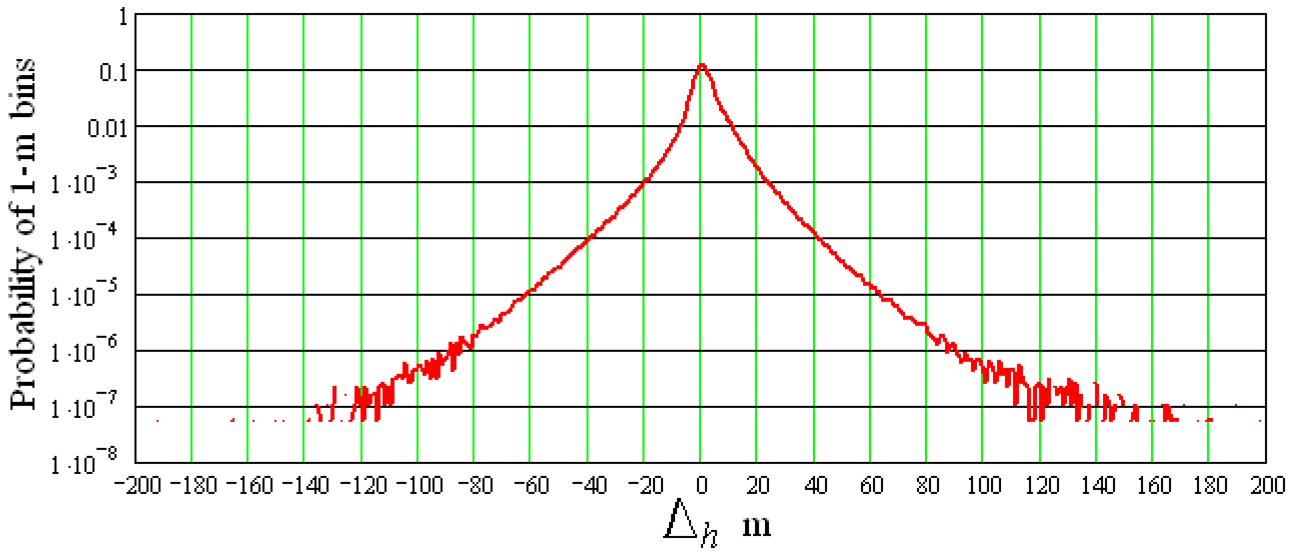


Modes: + 1.7 m | + 0.25 | + 2.5

Note: for "excess kurtosis" 0 = normal, 3 = exponential.

Thus the distribution of tile Δ_h statistics has a mean of +1.7m, small positive skew, and a distribution closer to exponential than to the normal distribution.

A single Δ_h histogram for all 18,990,000 points is consistent with the previous results:



Minimum = -192 m

Maximum = + 198

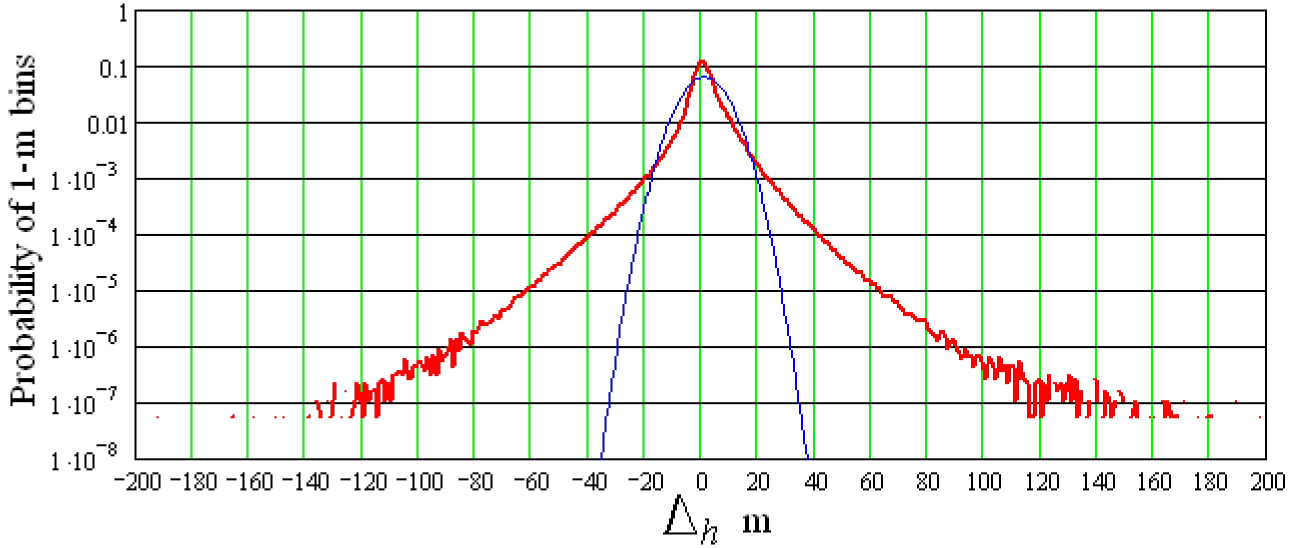
Mean = 1.575 m

Standard deviation = 6.501

Skewness = + 0.253

"Excess" kurtosis = 15.6

A single Δ_h histogram for all points in the tiles plus the normal distribution with the same S.D:



NOTE: The red distribution applies to the discrepancies between the two databases, not to either.

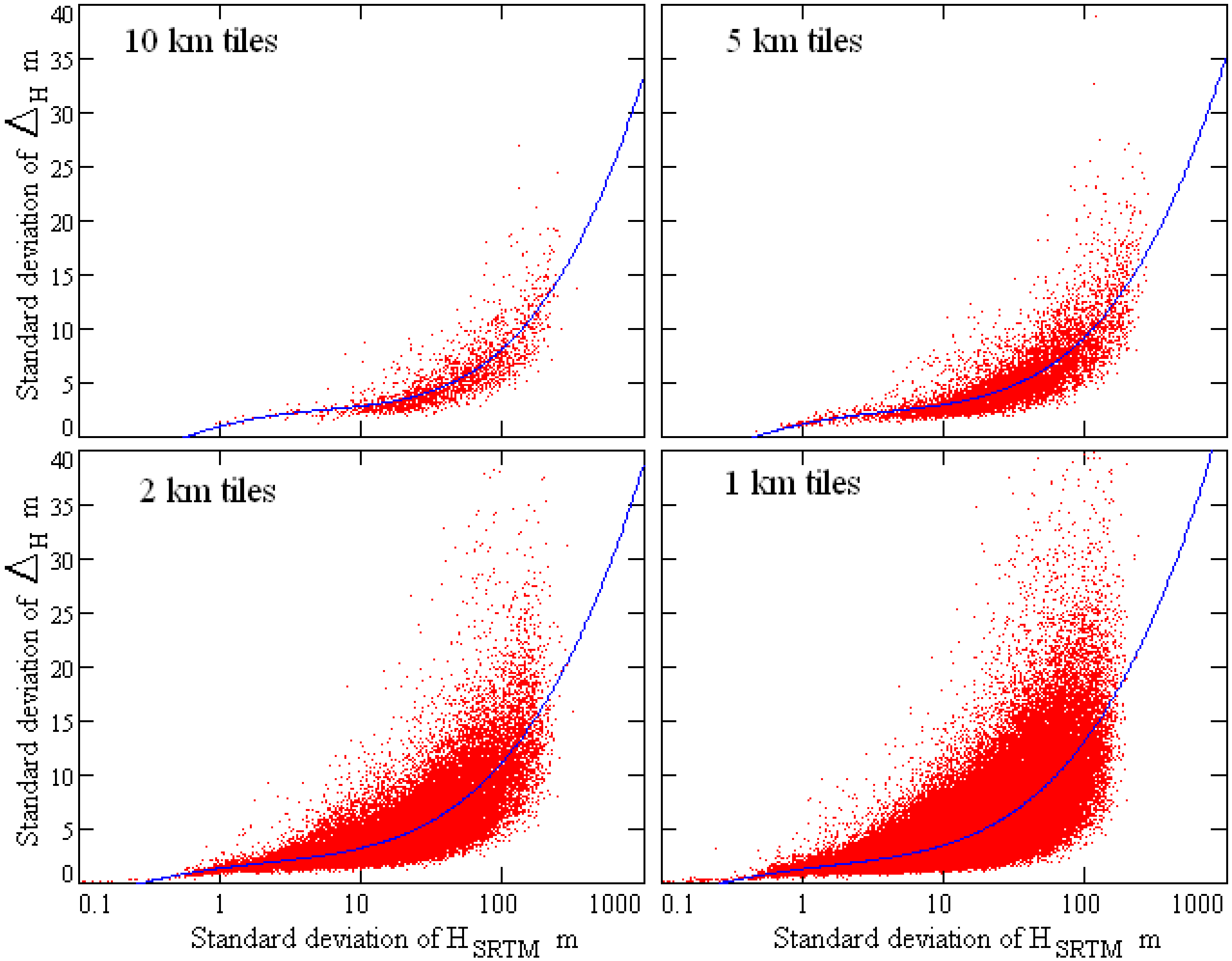
Extreme errors may be due to horizontal discrepancies at steep hillsides or cliffs

The SD of Δ_h correlates with the SD of the heights in the same tile.

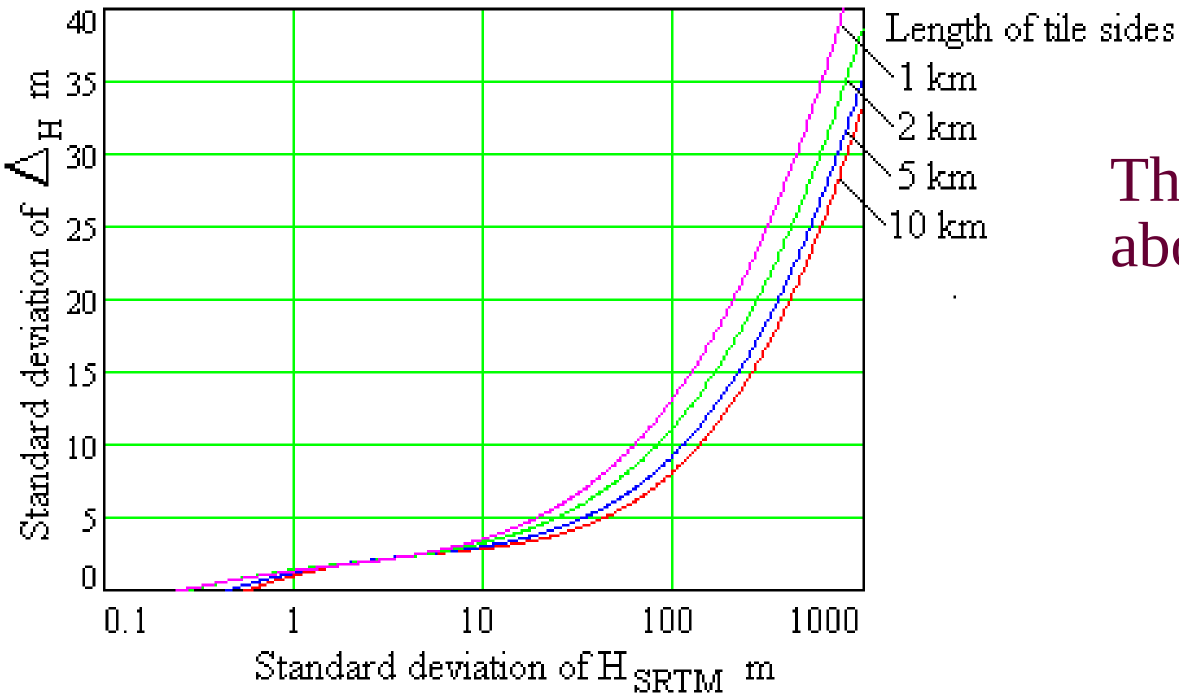
Red points are scatter diagrams of SD(Δ_h) vs log(H_{SRTM})

The blue lines are 4th-order polynomials with log(H_{SRTM}) as the independent variable.

As expected, there is a wider spread of SD(Δ_h) in smaller tiles.



The trend lines for different tile sizes vary relatively little



The lines cross over at about SD(H_{SRTM}) = 3 m

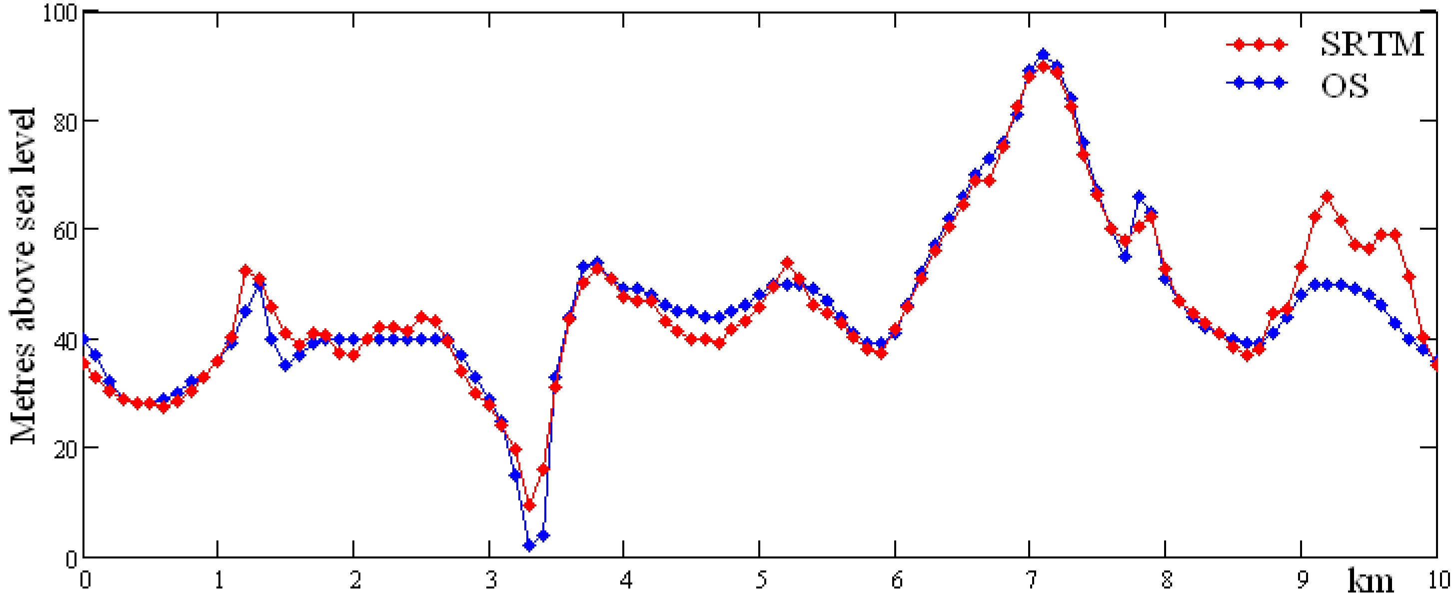
Thus it should be possible to model the distribution of Δ_h as a function of SD(H_{SRTM}) for an appropriately-sized area of terrain.

For profile analysis the model should give a bounded distribution.

CORRELATION OF Δ_h ALONG A PATH PROFILE

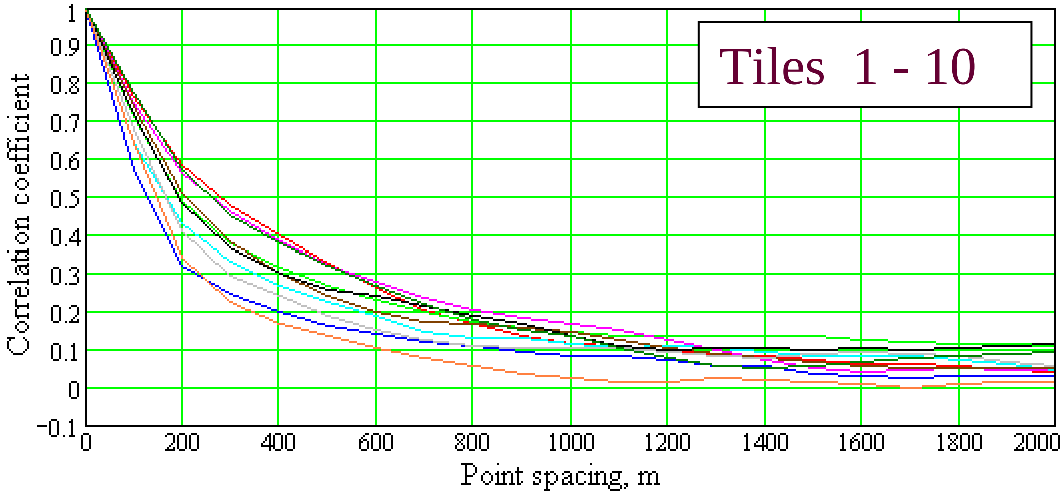
To investigate the effect of height errors on profile interpretation it is useful to know the distance beyond which they will be statistically independent.

Δ_h TENDS TO BE SPATIALLY CORRELATED

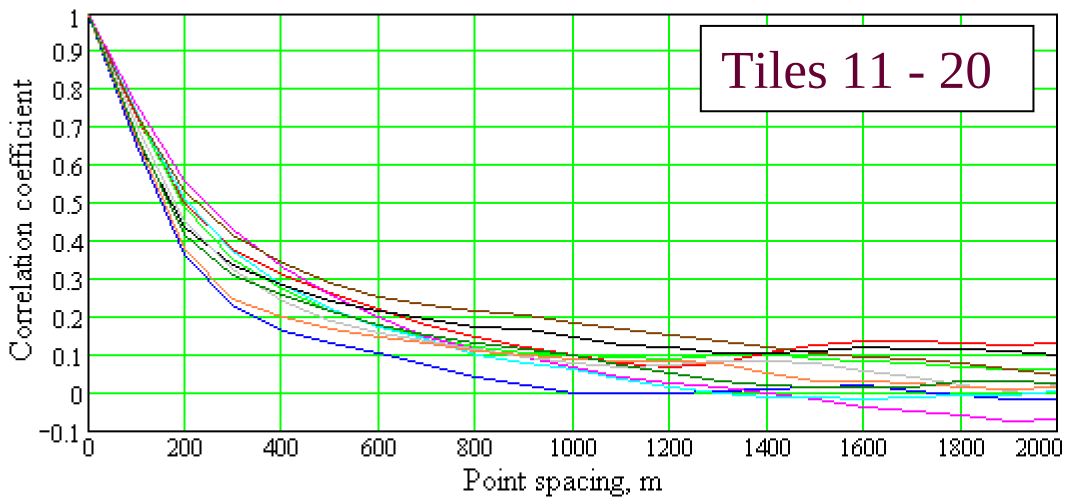


Terrain profiles extracted from both databases show a clear tendency for Δ_h to be correlated for neighbouring points, shown by symbols in the above graph.

Auto-correlation of Δ_h as function of distance

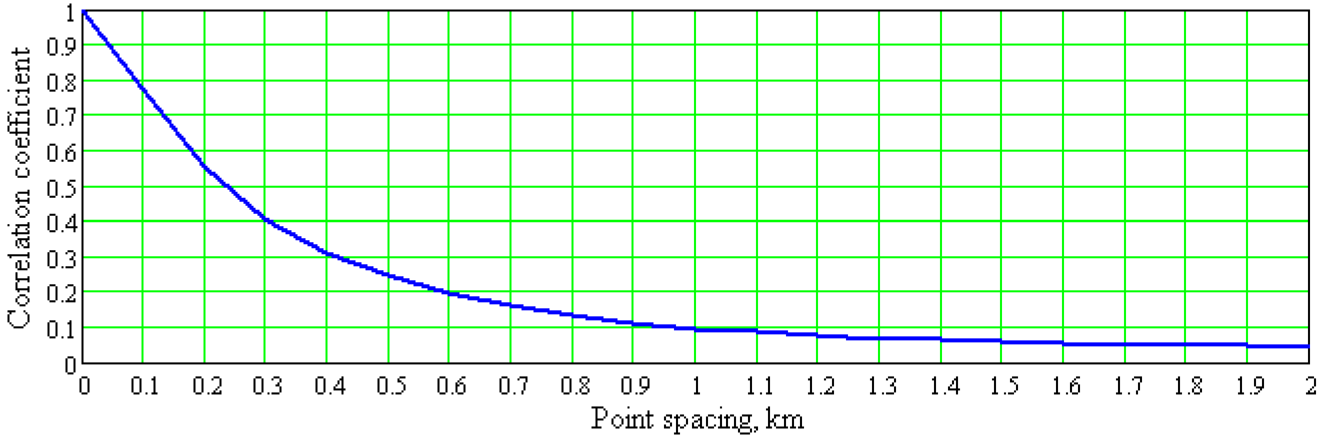


For each 10 km tile the correlations coefficient of Δ_h for all pairs of points with a given spacing were plotted against spacing.



These all show similar decreases with distance, passing through 0.5 in the range 100 to 400 m.

Auto-correlation of Δ_h as function of distance

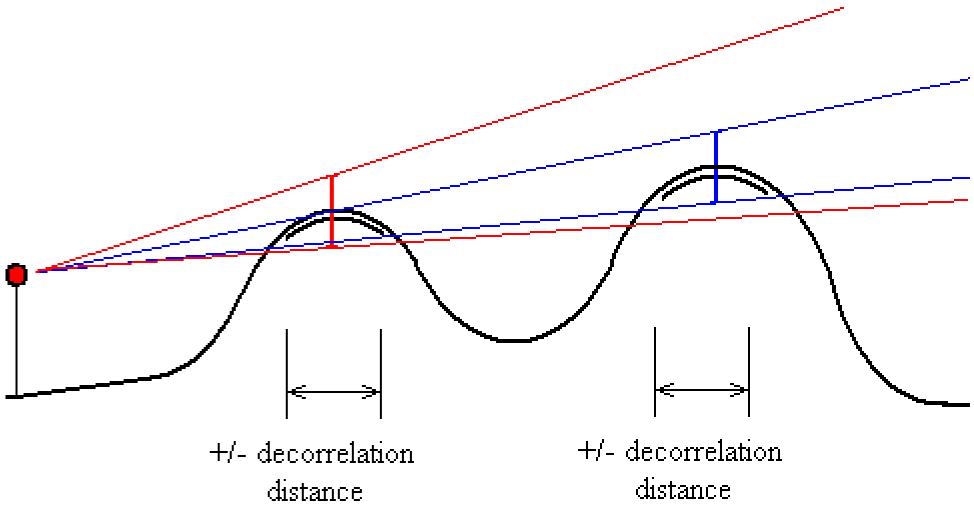


The median of the auto-correlations vs. distance for all tiles shows a smooth decrease passing through 0.5 at 240m.

A simplification is adopted for profile interpretation:

1. Errors within 240 m are assumed to be fully correlated
2. Errors beyond 240 m are assumed to be statistically independent

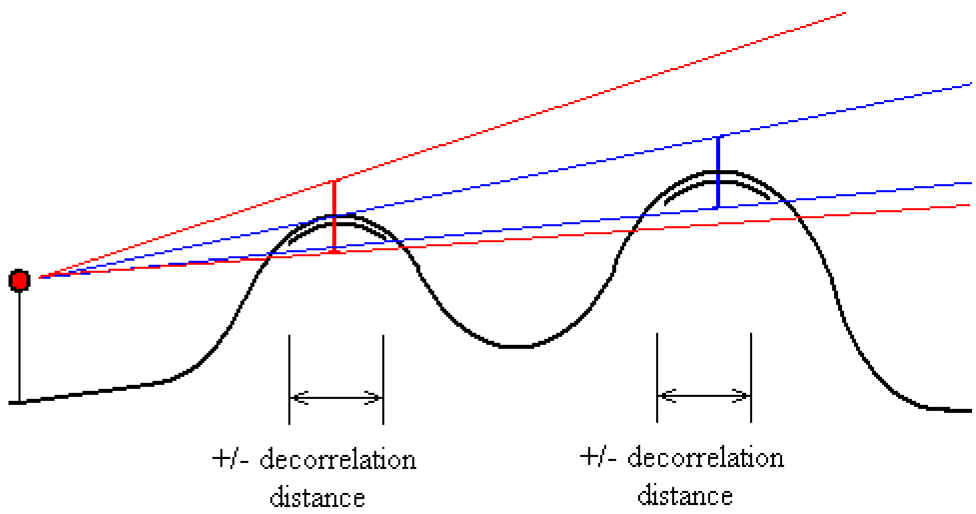
Effect of height errors on horizon angles



The width of the distribution of elevation angle errors depends on skyline distance.

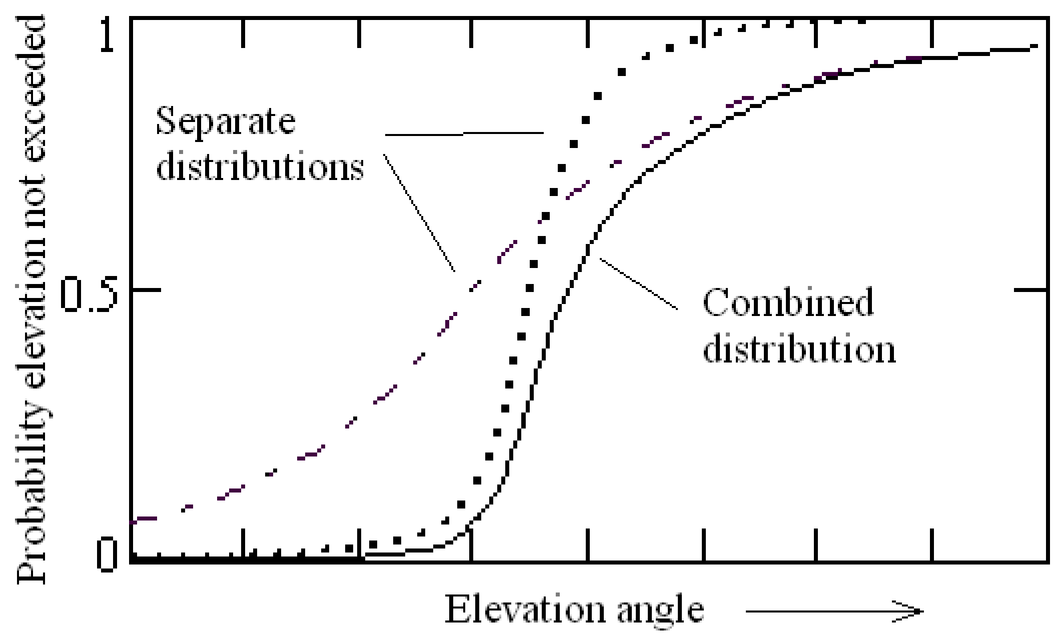
1. Find the horizon point, estimate error distribution at this point, and thus the elevation angle non-exceedance cumulative distribution.
2. Eliminate ± the de-correlation distance from further consideration.
3. Repeat 1 and 2 until there is a gap between distributions.
4. The combined distribution is the product of the separate ones.

Effect of height errors on horizon angles



A set of elevation-angle distributions.

The overall distribution of elevation angle errors is given by the product of the separate elevation angle non-exceedance cumulative distributions

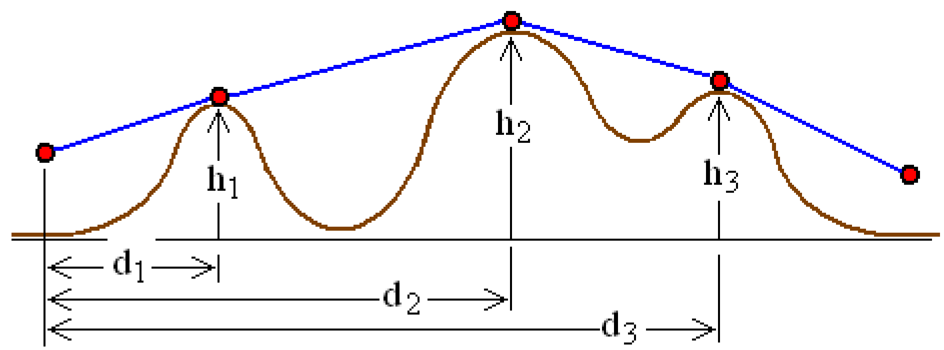


Effect of height errors in diffraction models

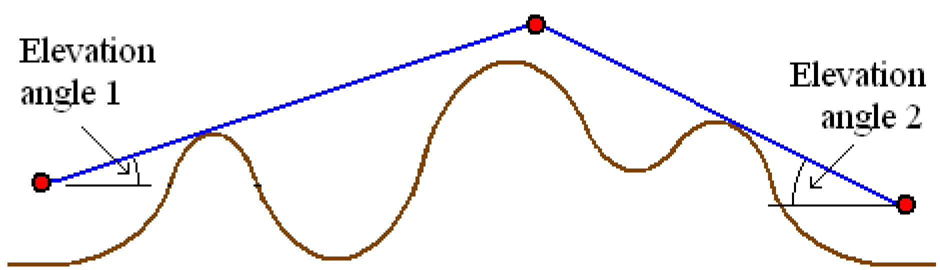
Diffraction models vary in their requirements for terrain information.
For NLOS paths:

a) The 3-edge Deygout method requires three distance/height pairs;

b) The Bullington construction requires only two elevation angles



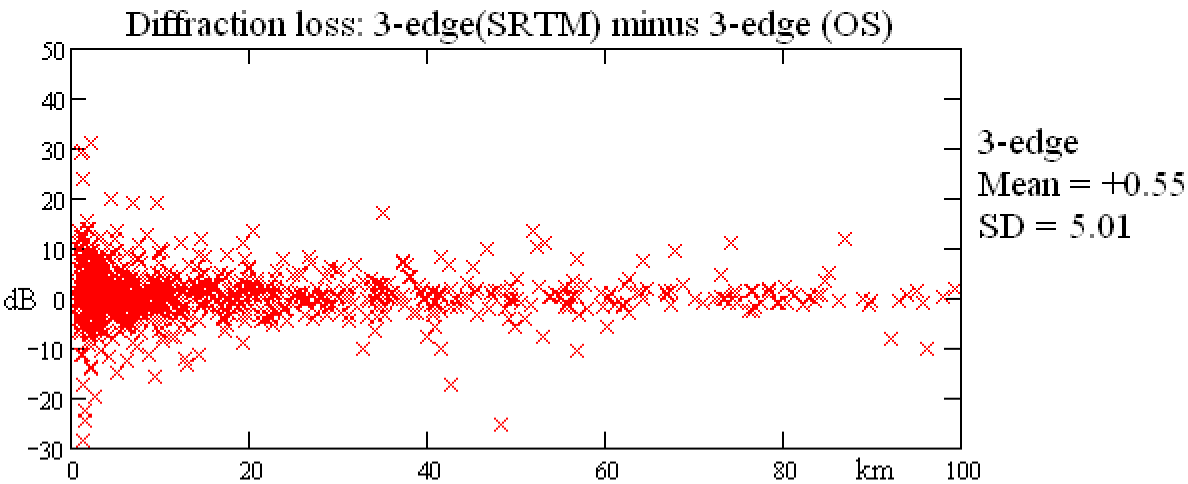
a) 3-edge Deygout construction

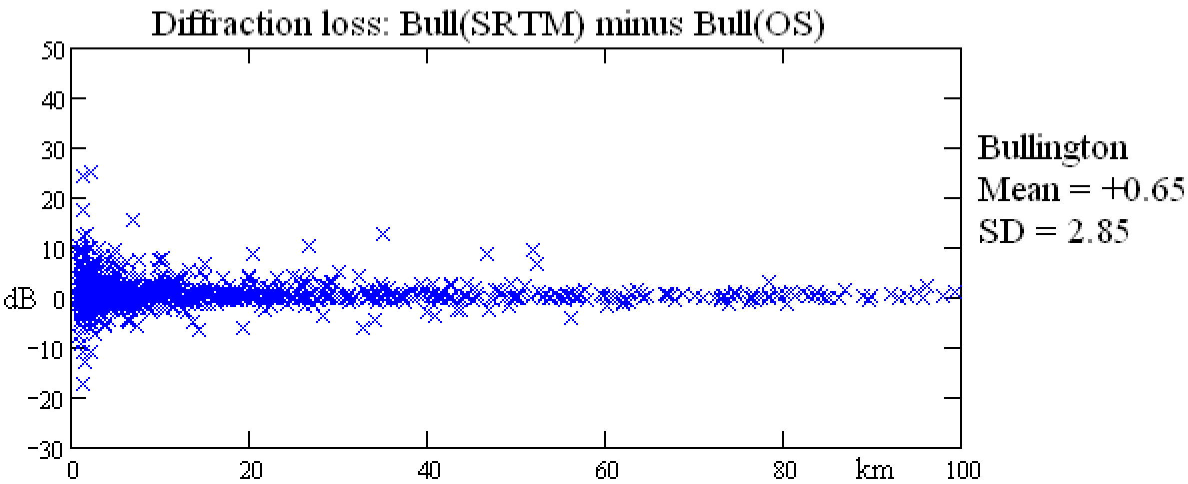


b) Bullington construction

What difference will it make to switch between OS and SRTM ?

Sensitivity to height errors: 300 MHz



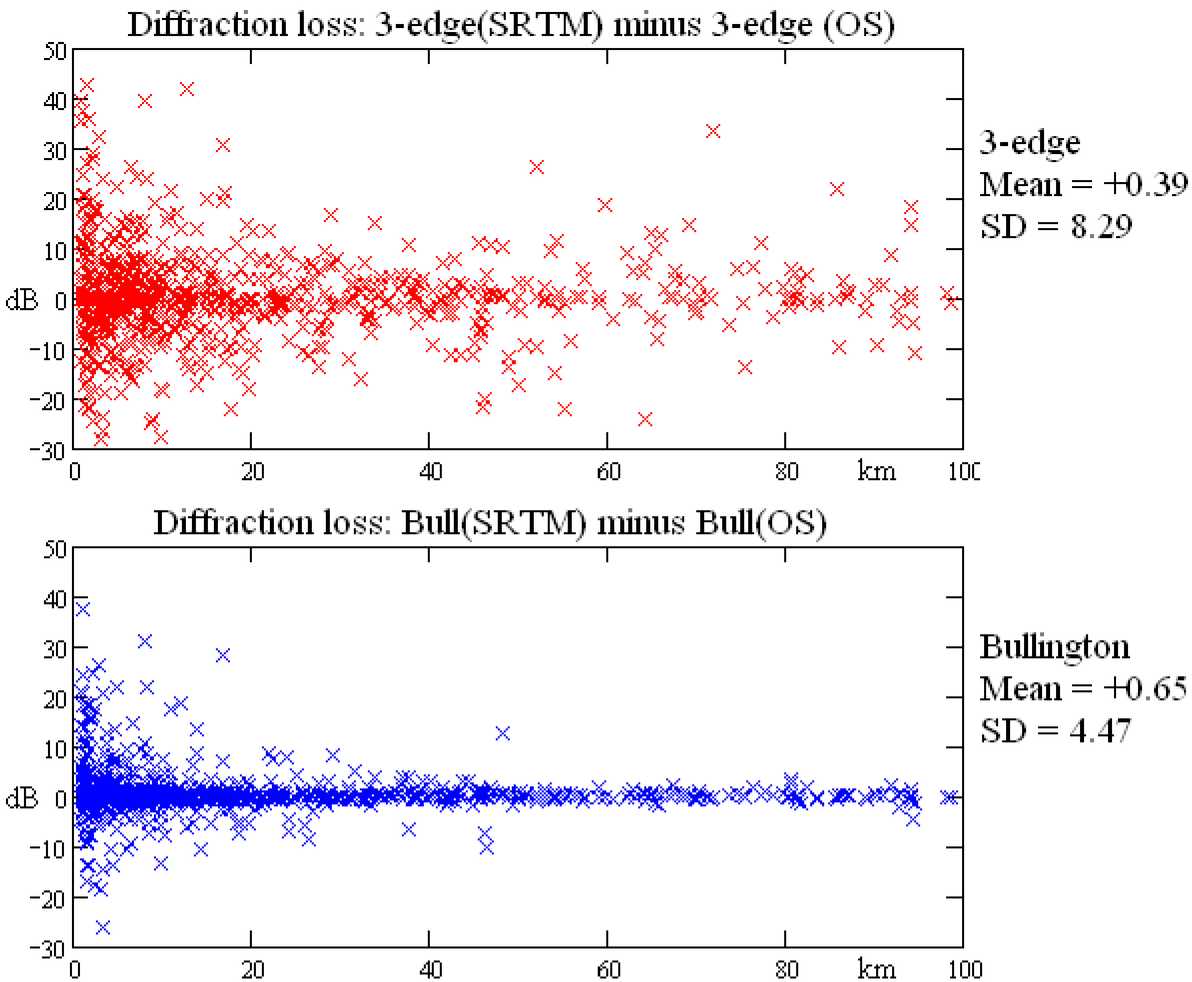


Differences in diffraction losses for identical profile points extracted from SRTM and OS data.

Upper = 3-edge

Lower = Bullington

Sensitivity to height errors: 3 GHz



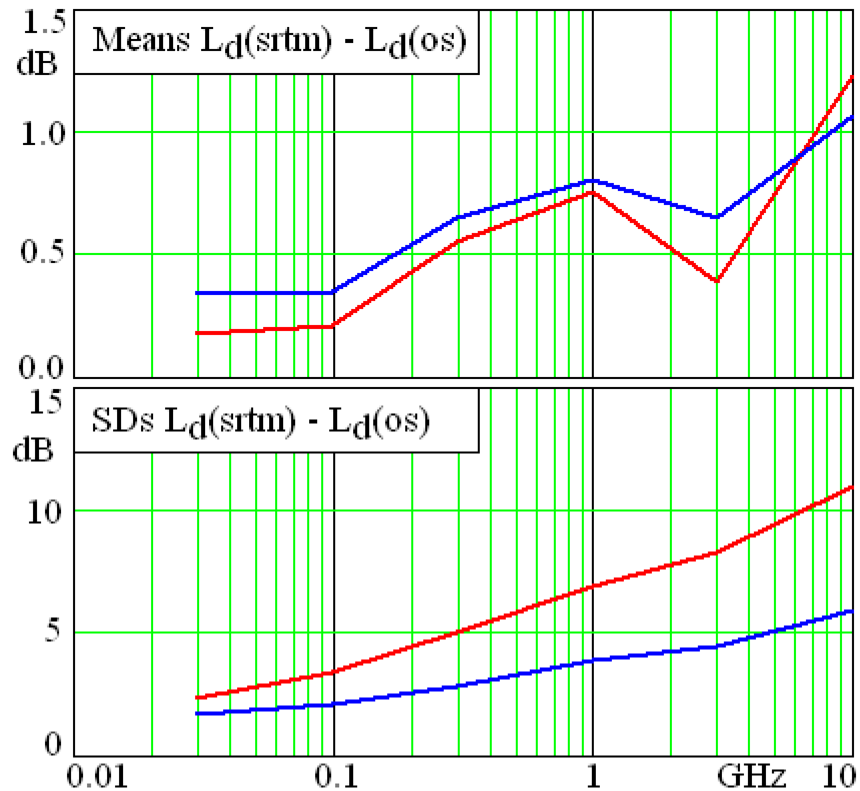
Bullington is less affected than the 3-edge model.

Sensitivity increases with frequency, and at 3 GHz the differences are similar to model accuracy.

Sensitivity to height errors as function of frequency

As expected, Bullington (blue) is less affected by height discrepancies than the 3-edge method (red).

The standard deviation of discrepancies from using the two height databases increases systematically with frequency.



Diffraction modelling above about 3 GHz needs terrain-height data of greater accuracy

Conclusions

1. More attention should, perhaps, be paid to the accuracy of terrain-height data.
2. Propagation models should take account of whether terrain data represents "bare-earth" or "surface".
3. It should be practicable to provide a risk factor for a given level of accuracy, at least for simple propagation models.
4. The lower requirement for terrain information of the Bullington diffraction model is an advantage in reducing the effect of height errors.
5. Diffraction predictions above about 3 GHz based on current terrain-height data should be treated with suspicion.

Further work

1. Predicting Δ_h along profiles rather than over tiles.
2. Predicting propagation modelling errors due to height errors.

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but otherwise
THE END