Operational Mitigation of Ground Clutter Using Information from Past and Near-Future Radar Scans

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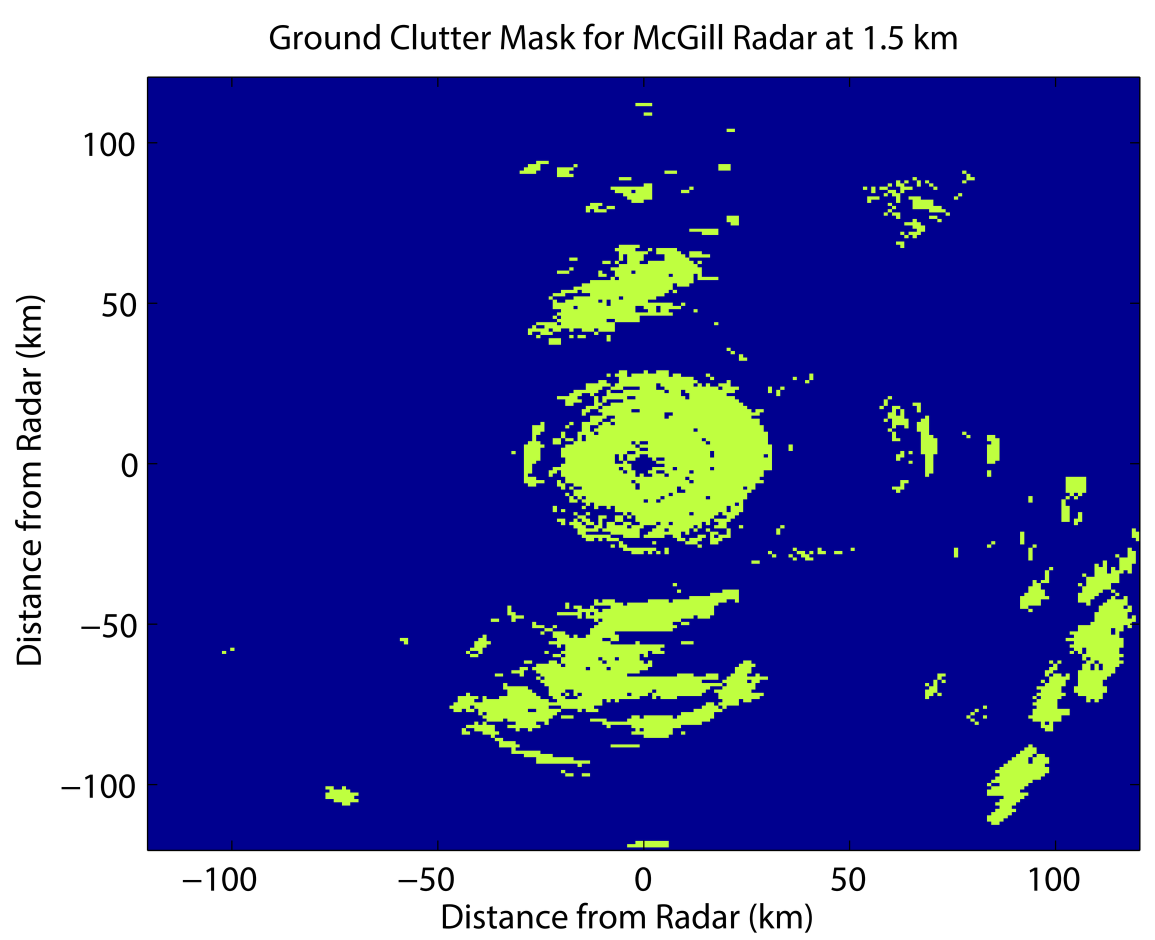
1) Ground Clutter and the Correction of Contaminated Pixels

Ground clutter: echoes produced by fixed objects close to the transmitter

- Can be identified by looking for persistent, stationary clear-air radar returns



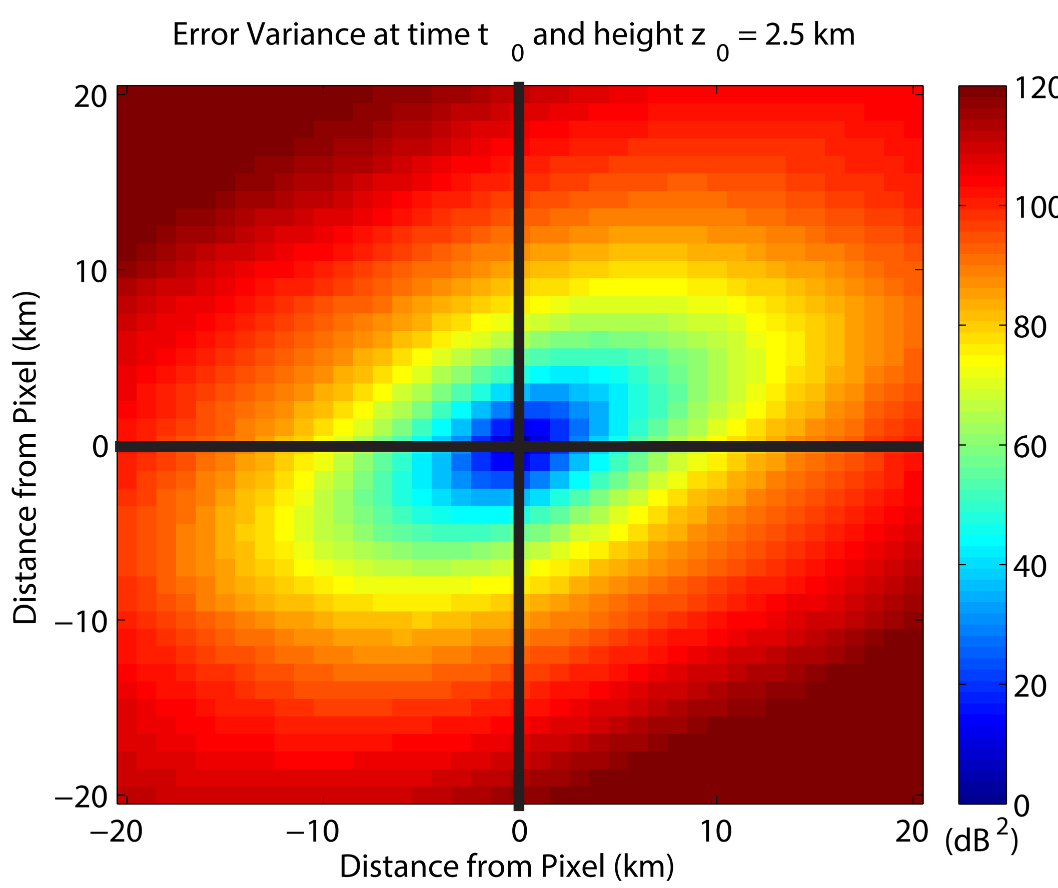
Actual ground clutter present at the McGill radar (green pixels indicate ground clutter, blue pixels indicate uncluttered data). Each pixel is 1 km x 1 km.

What is the best possible way to fill these gaps?

2) The Single-Pixel Replacement Problem

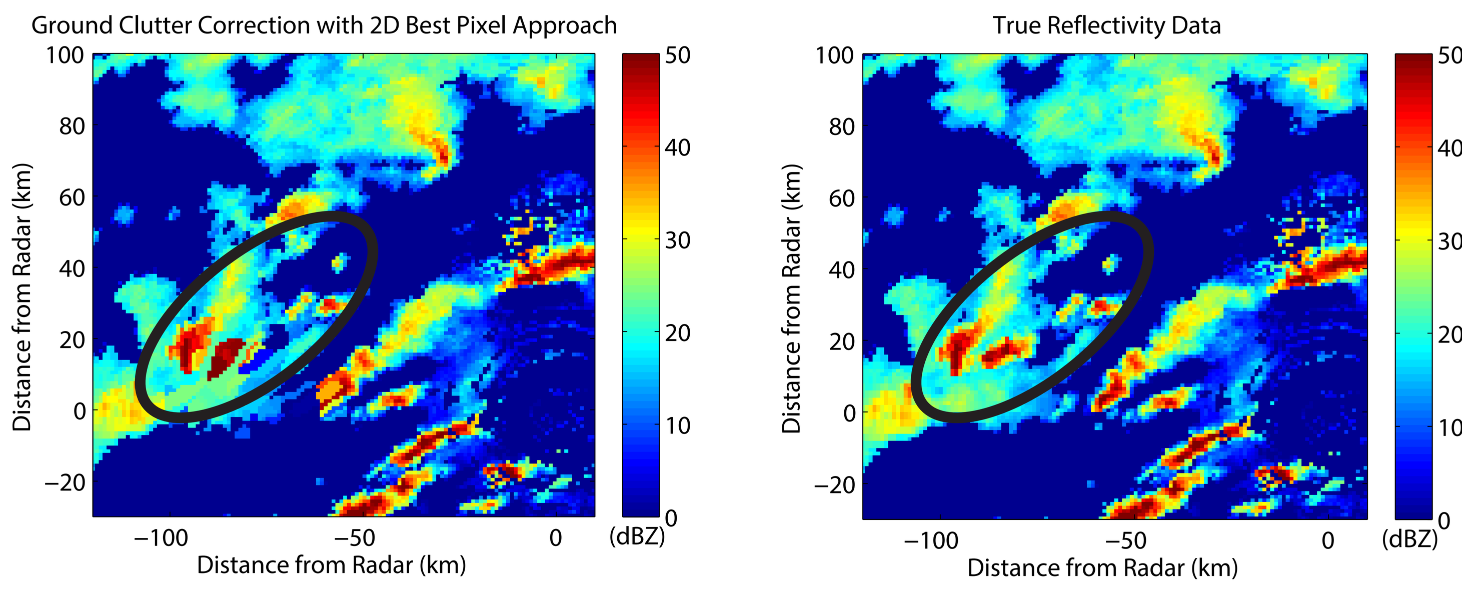
- Simplify the problem to start: given a single contaminated pixel, which pixel from its surroundings would make the best replacement (i.e., which pixel would give the lowest error)?

Variograms: visual representations of the error structure (variance) that results if a given contaminated pixel is to be replaced by a single pixel from its surroundings



A variogram (depiction of the mean variance as a function of distance from a pixel contaminated by ground clutter) for a convective precipitation event at the McGill radar. This figure gives a 2D picture of the error that would result if we were to replace a contaminated pixel with another pixel from its surroundings.

- We can now use a "best pixel" approach, where each contaminated pixel is replaced by the pixel with the lowest variance
- To evaluate this approach, blot out part of a radar scan and treat it as though it has been contaminated with ground clutter



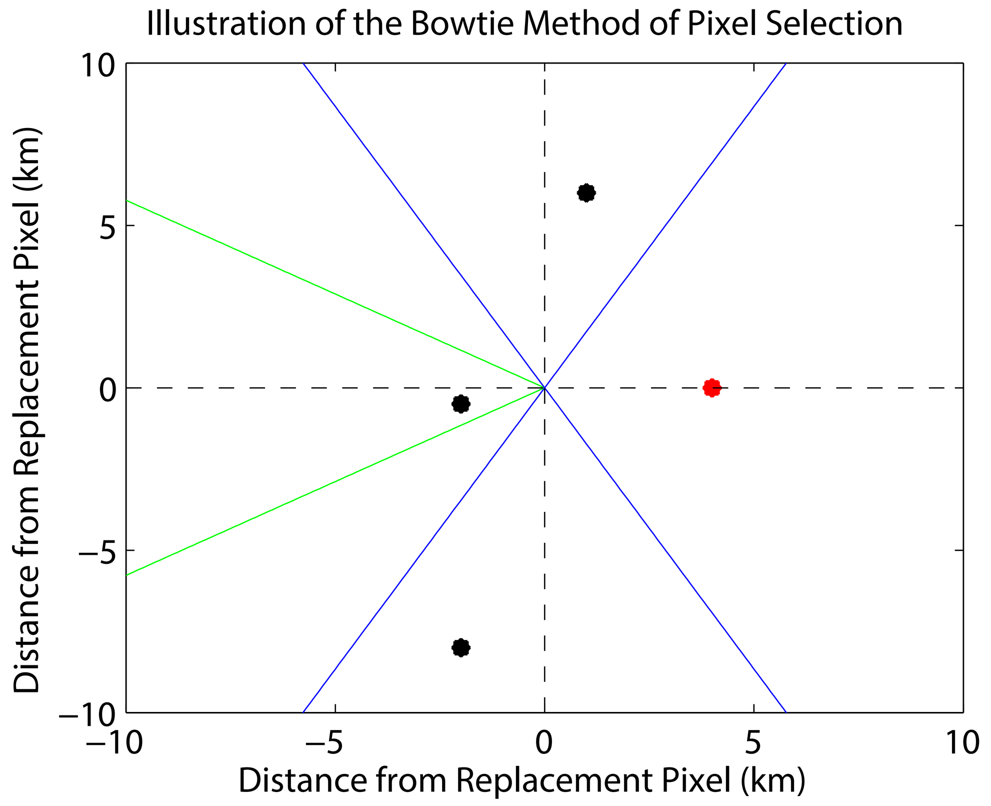
Replace each pixel within a region of false (created) ground clutter with an uncluttered pixel from the same radar scan that has the lowest available variance (left) and compare with the true reflectivity data (right) to evaluate the "best pixel" method.

3) Information Blending for Clutter Correction

Why stop at a single replacement pixel?

- Rather than replacing each ground clutter pixel with a single pixel from its surroundings, we can replace ground clutter using some blend of the surrounding data

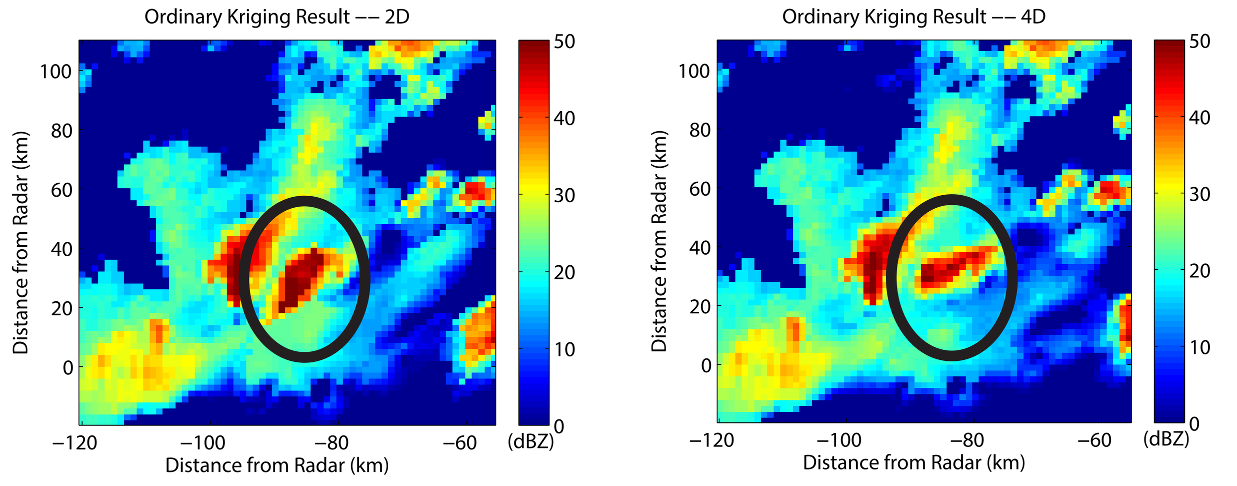
Ordinary Kriging: geostatistical method that replaces a cluttered pixel with the mean of several surrounding pixels, weighted using the error structure (i.e., the variogram)



We developed a "smart" ordinary kriging method that reduces the number of spatially redudant pixels being averaged by requiring that each pixel be at least 30 degrees from any other pixel.

Why stop at a single radar scan?

- Data from different heights also contribute useful knowledge that could provide more valuable clutter-correction information than horizontal data alone (especially in the case of a vertically developed convective precipitation event)
- In operational settings, we frequently ignore data from past and near-future radar scans, despite the fact that these data could contribute a large amount of valuable information



Qualitative depiction of the value added by including pixels from different heights and times. Nearly the entirety of the storm cell circled was blotted out by ground clutter, and these figures show the results of the ordinary kriging algorithm with two different pools of possible replacement pixels: 2D only (left) and fully 4D (right). When compared with the true intensity and size of this cell, the 4D algorithm, making use of data from different heights and from different times, was a very close match.

4) Conclusions

Method		
Nearest Neighbour	2D	5.3
Best Pixel	2D	5.3
	3D	5.2
	3.5D	4.9
	4D	4.9
Ordinary Kriging	2D	4.4
	3D	4.4
	3.5D	4.1
	4D	4.0
Smart Ordinary Kriging	2D	4.3
	3D	4.3
	3.5D	3.0
	4D	2.9

Mean standard deviations of radar reflectivity (dB) for the convective precipitation event illustrated in the preceding figures.

Better gap-filling can thus be achieved by:

- **Increasing the complexity of the pixel-replacement algorithm.**
- **Increasing the pool of possible replacement pixels.**

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