IMPRINTS

Separating Signal from Noise in Radar-Rainfall Fields

Geoff Pegram, Xavi Llort and Daniel Sempere-Torres

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UNIVERSITY OF KWAZULU-NATAL

CRAHI

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The problem statement

- How do we generate meaningful stochastic ensembles of radar estimates of rainfall?
- How do we avoid variance inflation?

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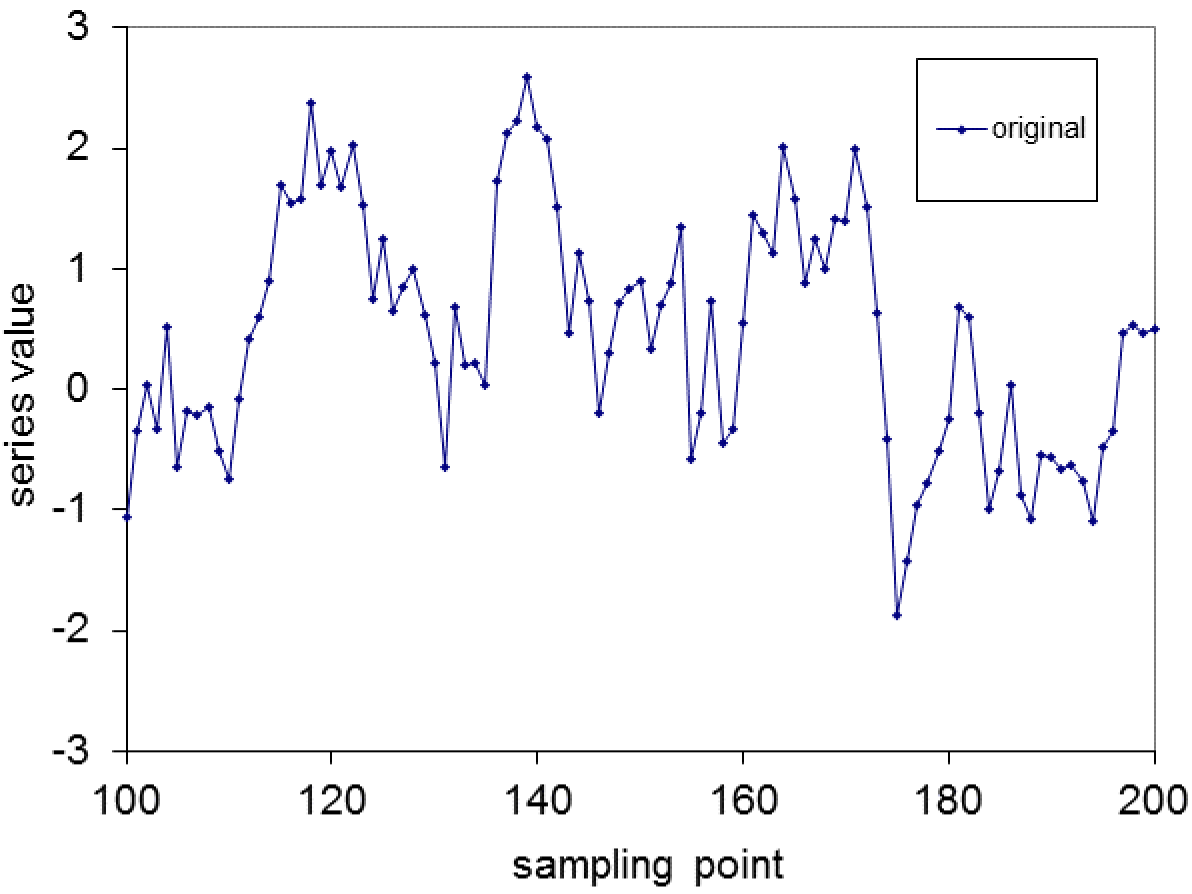
- How do we generate meaningful stochastic ensembles of radar estimates of rainfall?
- How do we avoid variance inflation?
  - [Bias is a separate issue]
  - We need to define signal & noise separation in context

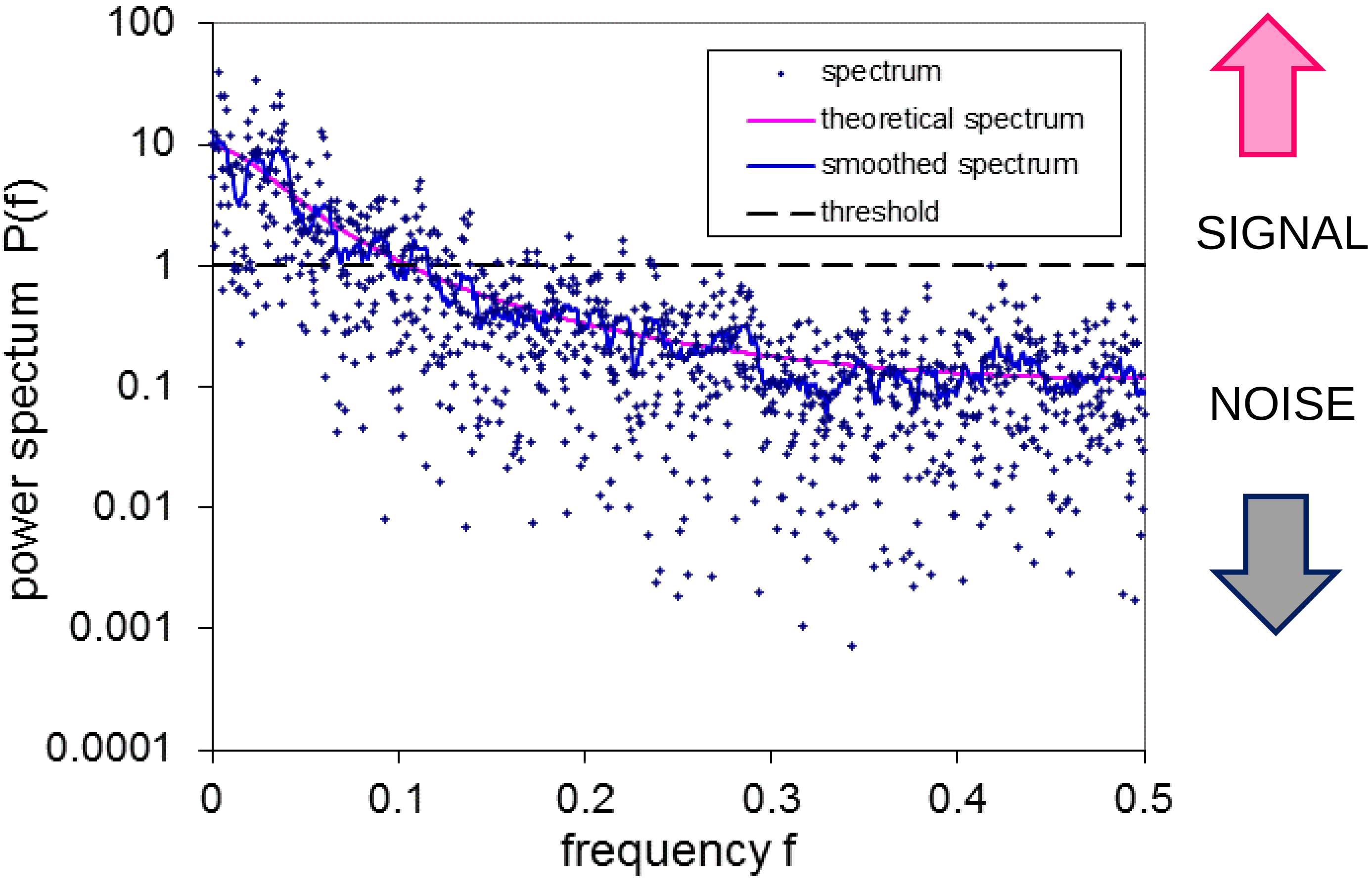
A simple 1-D AR(1) example: $\rho = 0.8$



A 100-unit clip from a 1024 sequence: $X(t) = \rho X(t-1) + a(t)$

Pegram, G., et al., Atmos. Res. (2010),
doi:10.1016/j.atmosres.2010.11.018

Its Spectrum & partitioning



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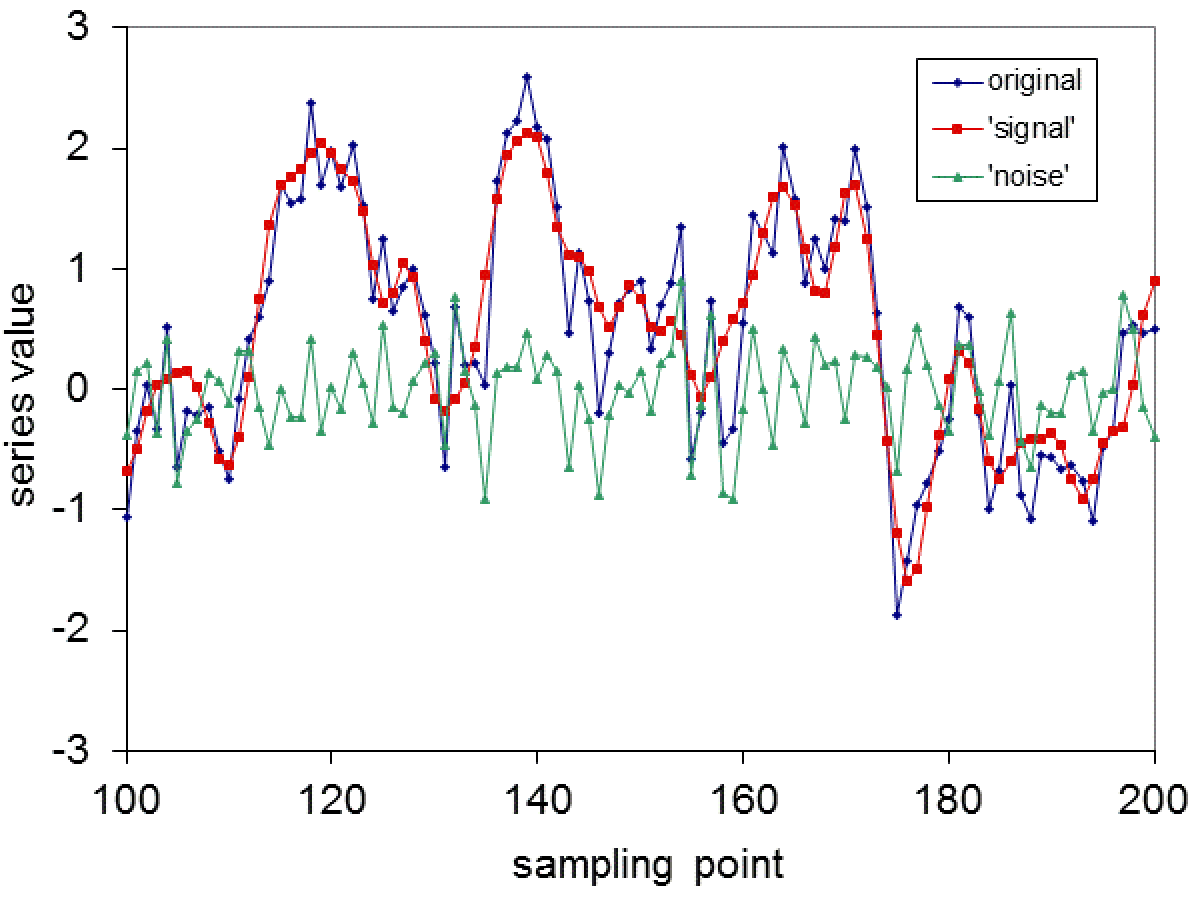
The result after reverse transformation



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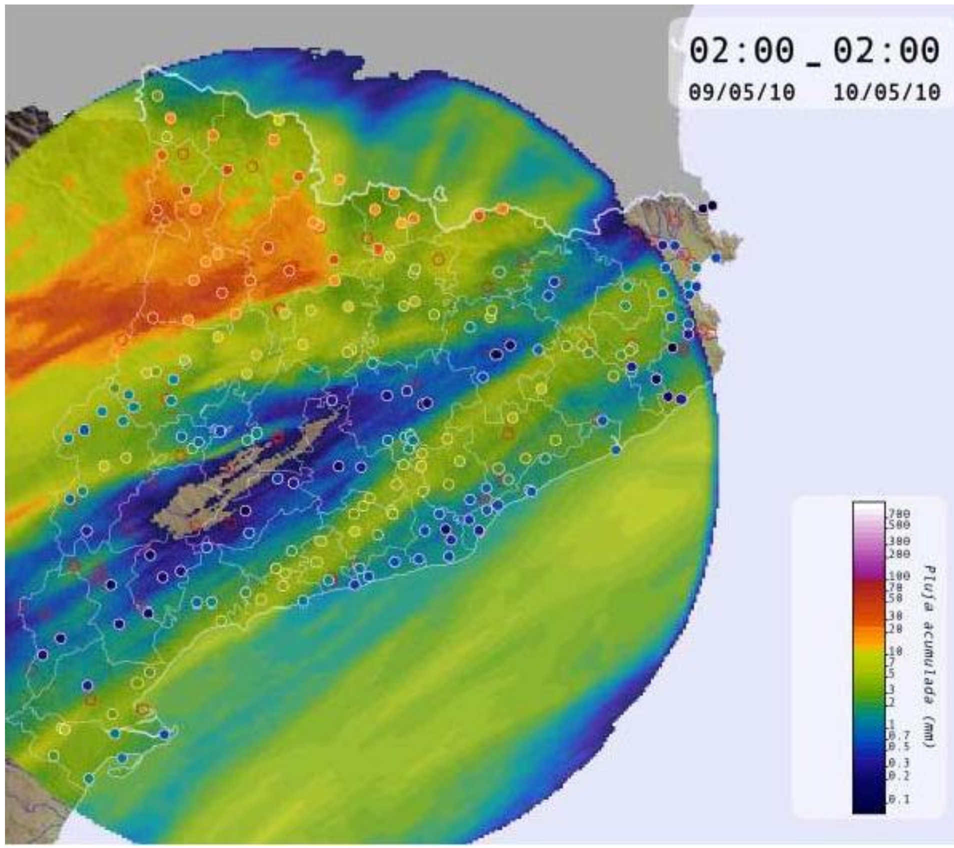
Consider a well-conditioned radar rainfall estimate – where is the error?



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The suggestion:

For each of a sequence of radar rainfall images:

- Use a simple spectral method to ***separate*** each image into signal and noise
- Simulate an alternative noise field, with the same spectrum as the original noise, and combine it with the signal field

  - hence no variance inflation -
- Procedure generates an ensemble member, *with the same stats as original*, to perform sensitivity studies.

Analysis (briefly):

1. Trim radar field Rad(x) at < 18dBZ.
   R(x) = ln[Rad(x)] (or 0). Its mean is m.
   Put Z(x) = R(x) – m.
2. FFT[Z(x)] → Z(s) to get its spectrum and find a suitable *horizontal* noise threshold
3. Split Z(s) into 2 components, signal S(s) & noise δ(s):
   $$Z(s) = S(s) + \delta(s)$$
4. Simulate noise δ*(s) with the same spectrum as δ(s)
5. Add δ*(s) to S(s) to create the alternative to Z(s) as:
   $$E(s) = S(s) + \delta^*(s)$$
6. FFT^{-1}[E(s)] to obtain ensemble member: m + exp{E(x)}

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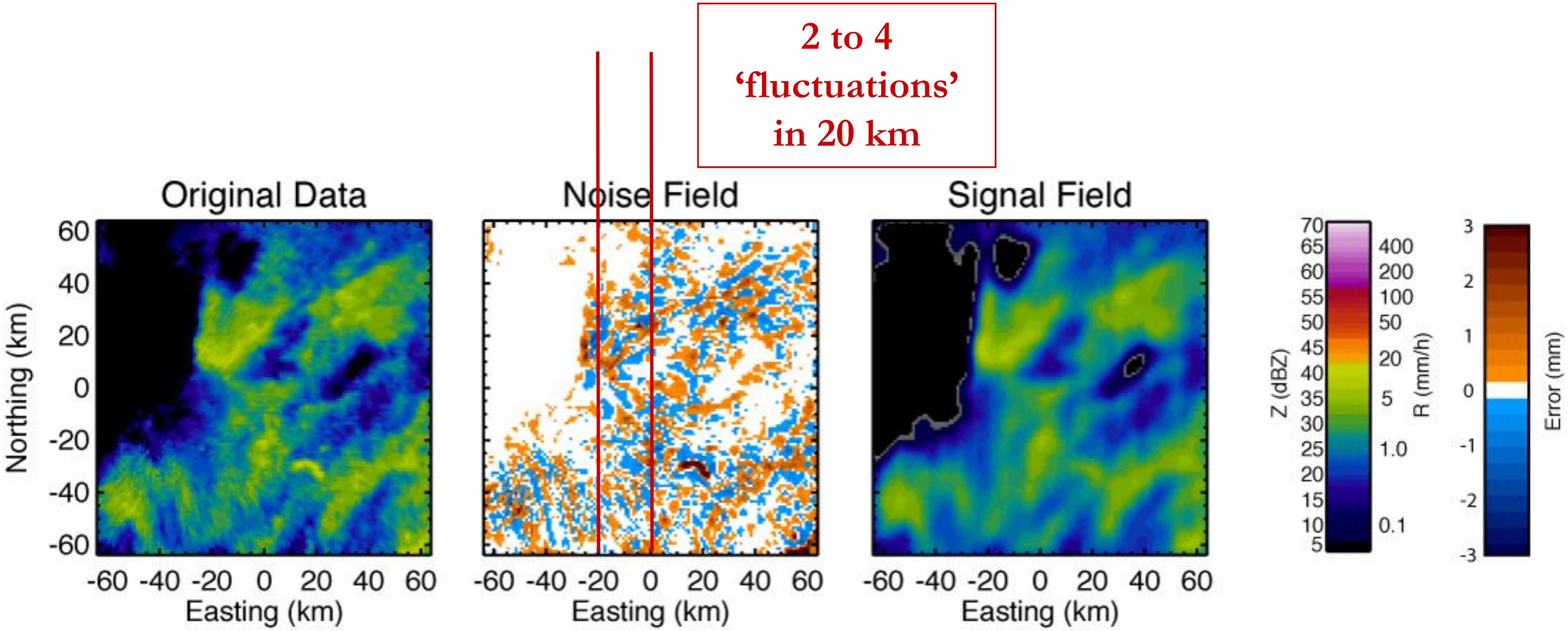
Decomposition



dBZ or mm/h mm/h dBZ or mm/h

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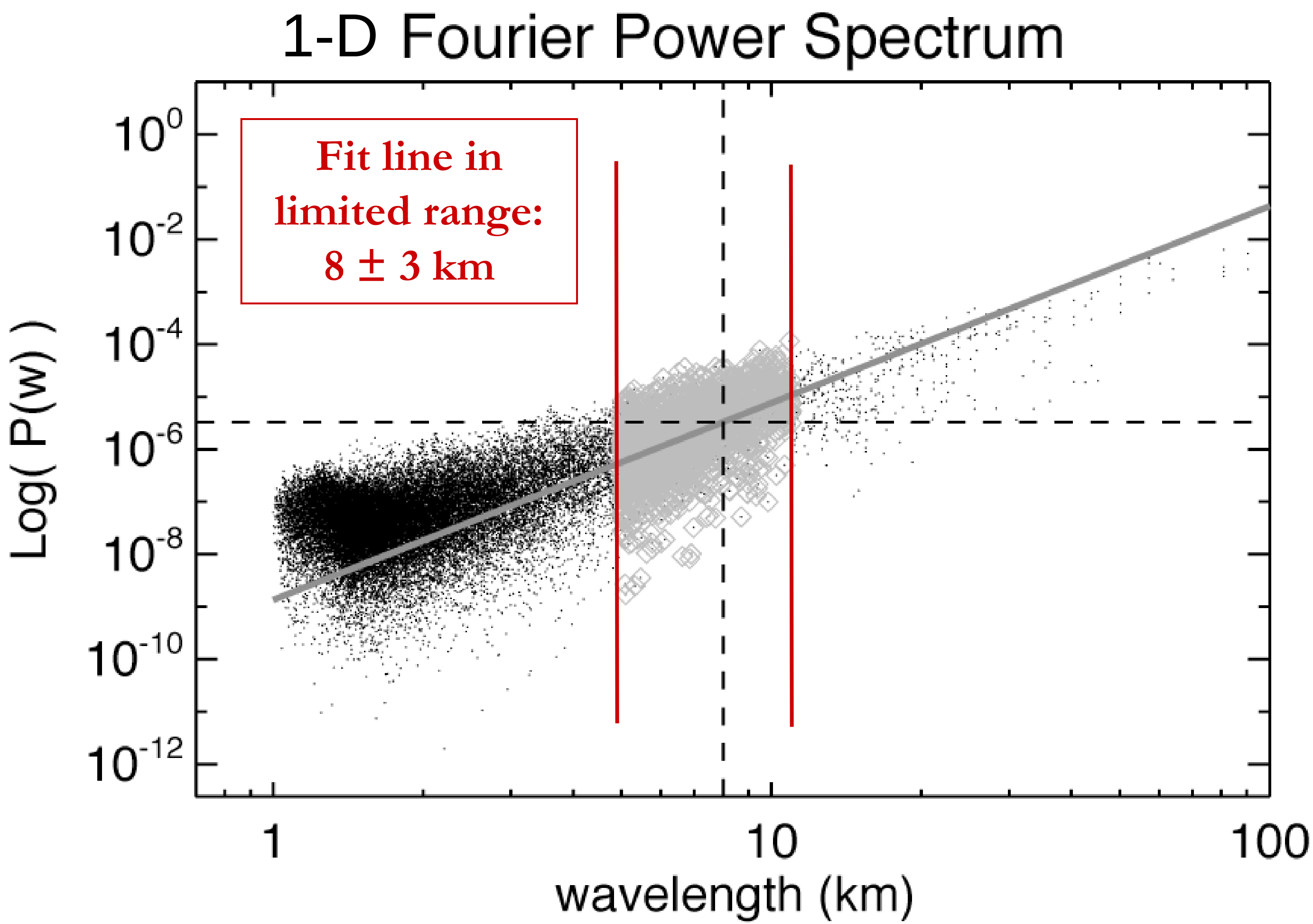
Threshold | wavelength (for low scc)



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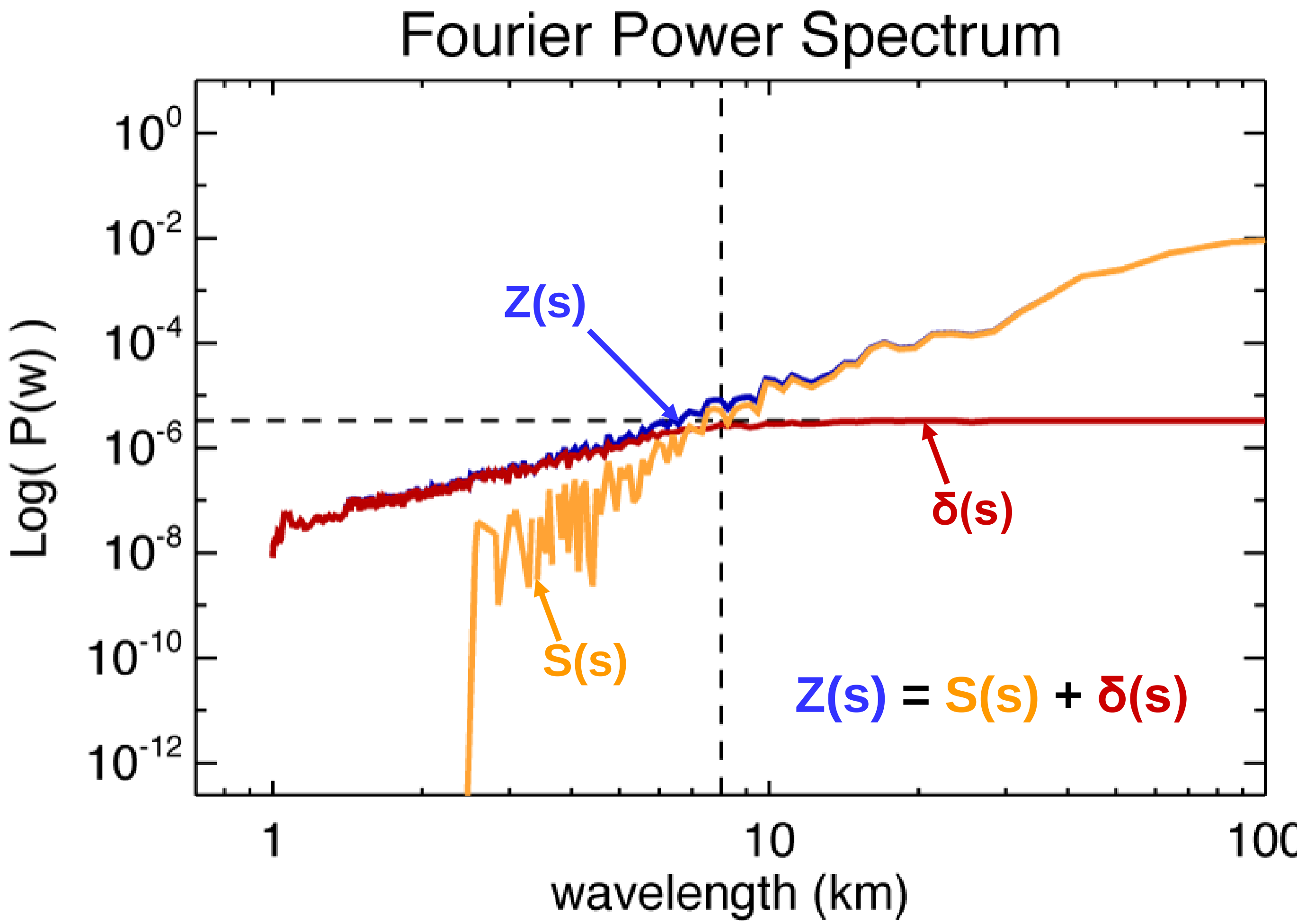
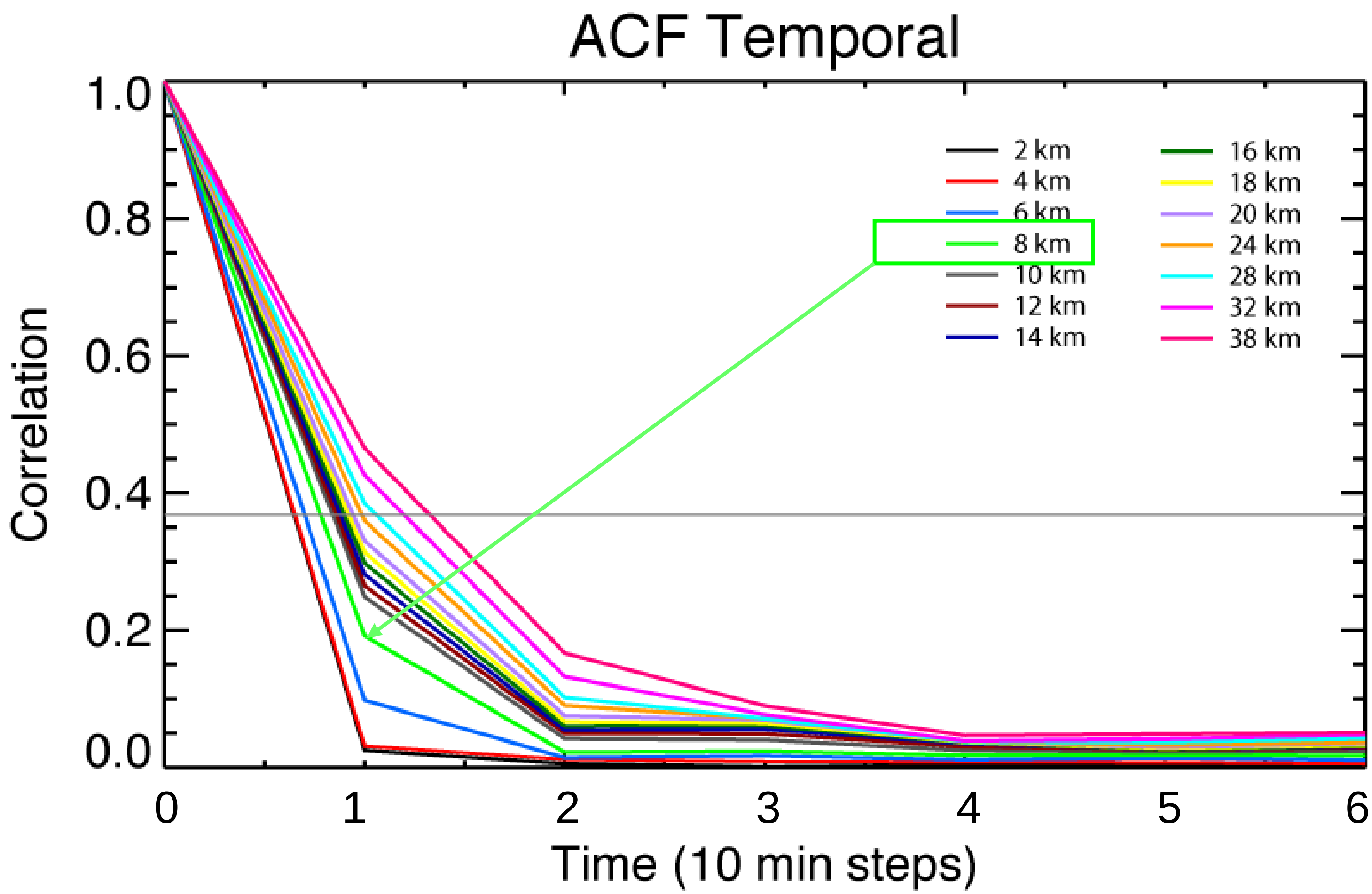
Define threshold in 1D Spectrum



White Noise has a **flat** Spectrum

Pegram, G., et al., Atmos. Res. (2010), doi:10.1016/j.atmosres.2010.11.018

Choose wavelength by SCC of noise



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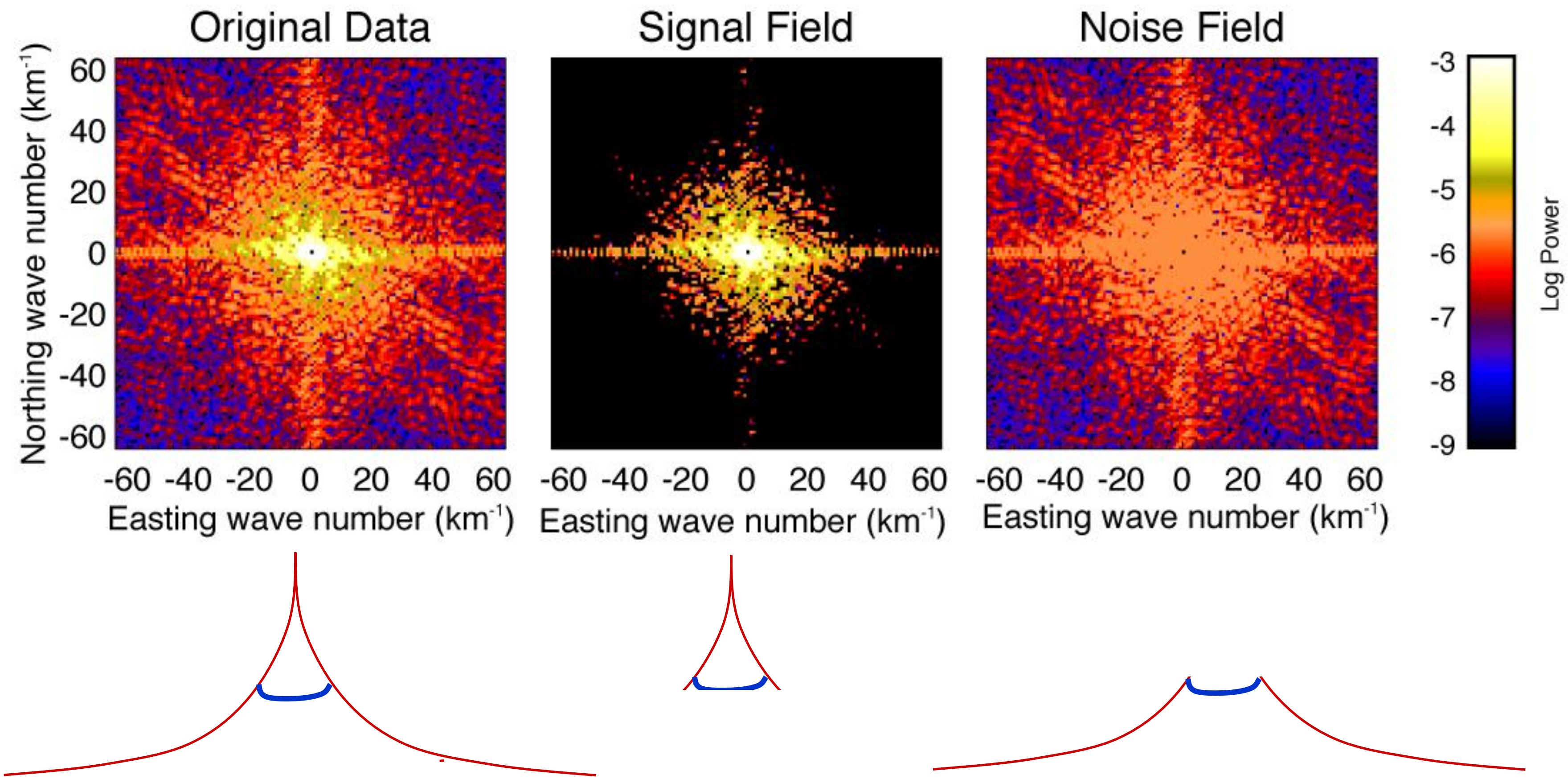
2D spectra of Data, Signal & Noise in frequency domain



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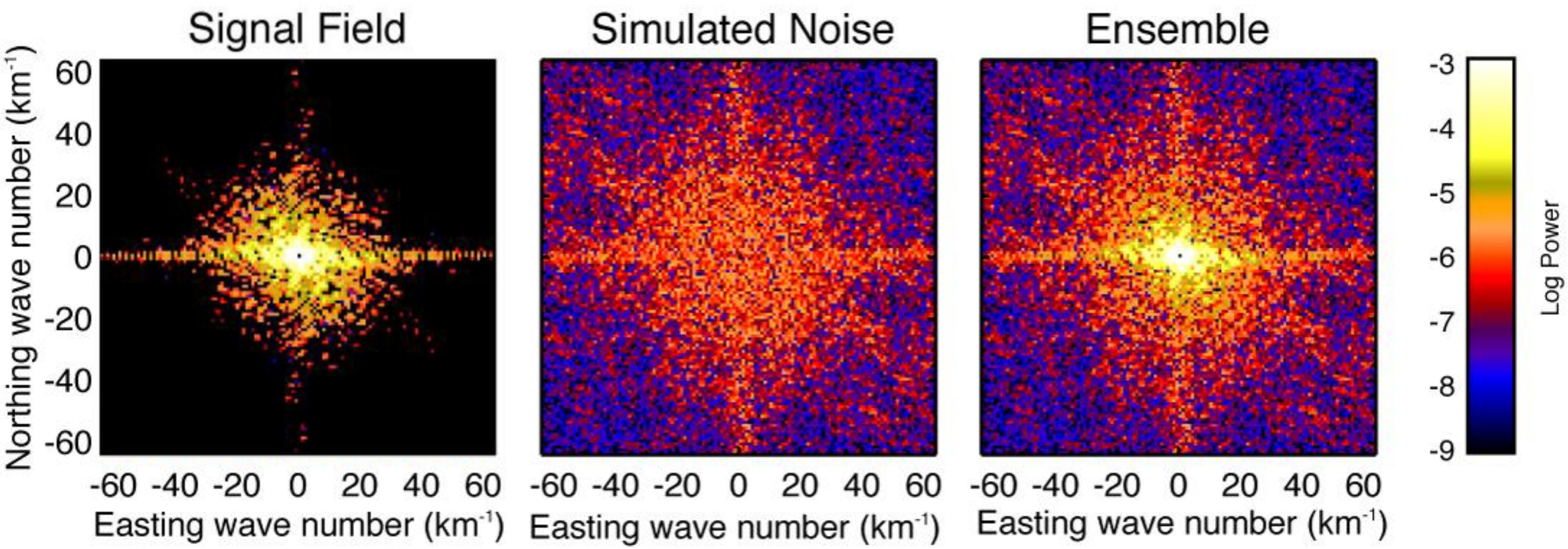
Spectra:
Signal + Simulated Noise = Ensemble



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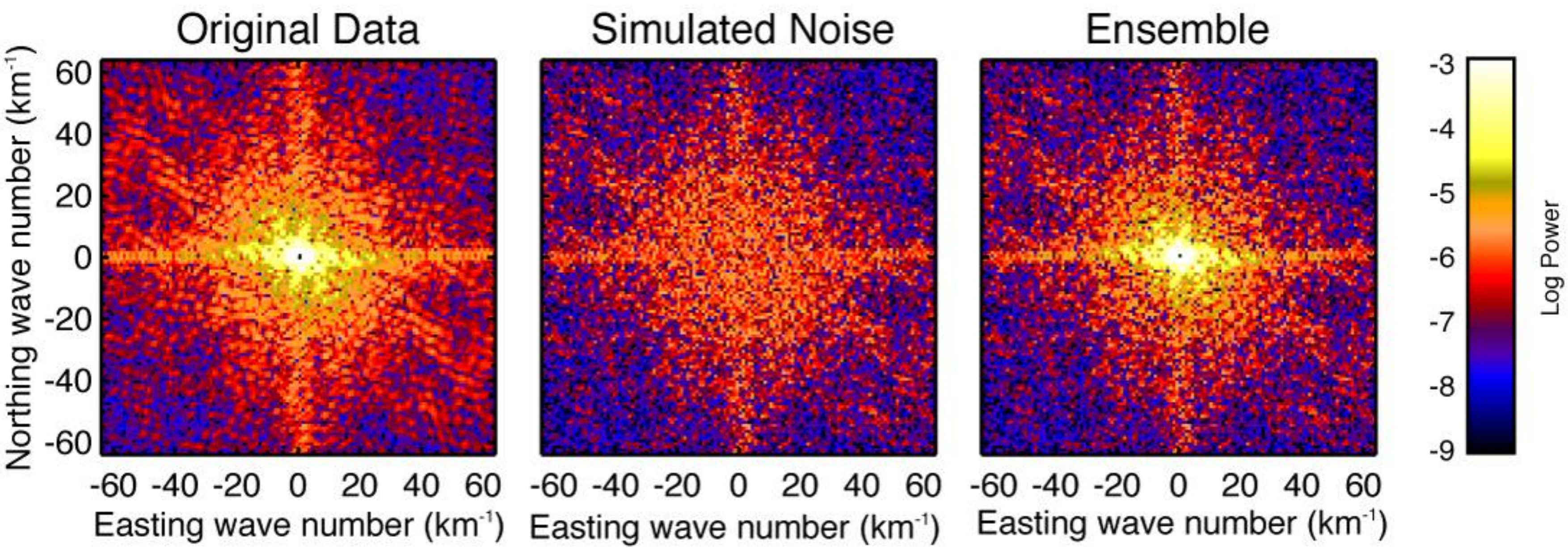
Spectra: comparisons



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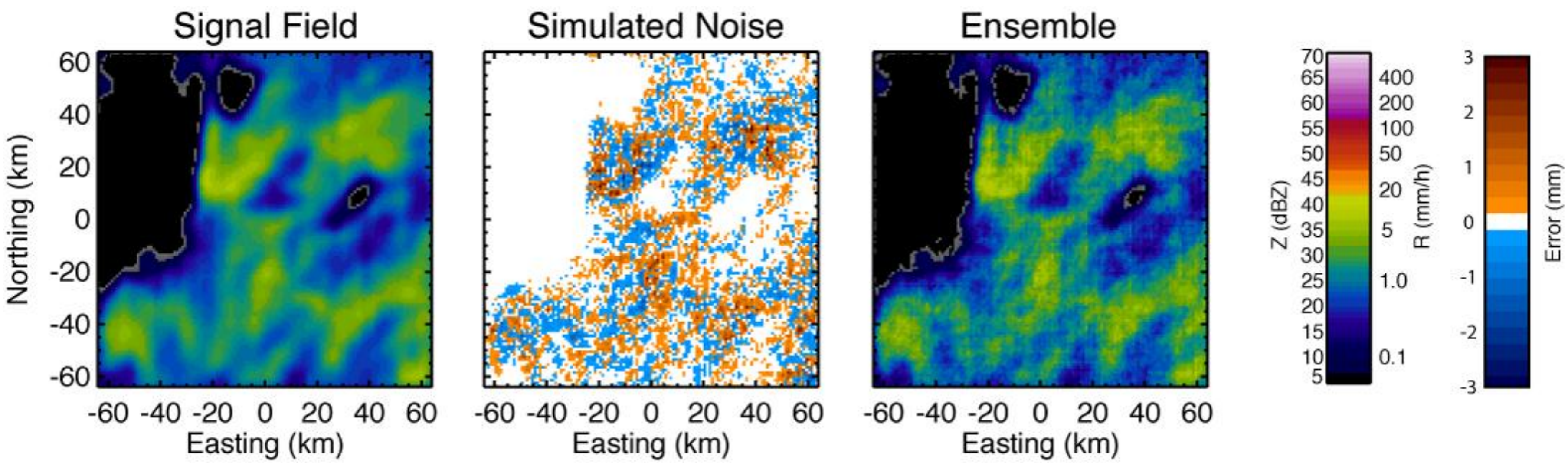
& after Inverse FFT we get …



Non-raining areas not affected

Noise is a bit gridded due to FFT on square

Solved by sampling on the disc

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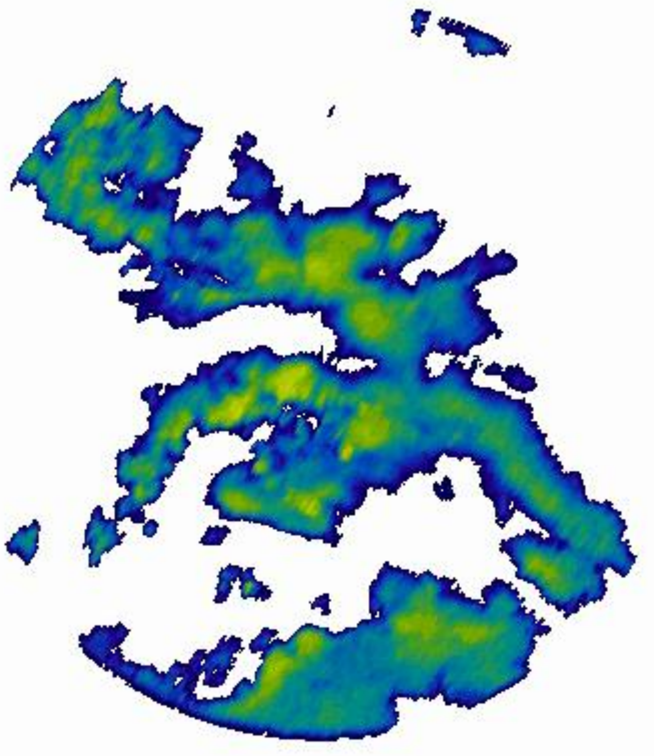
Some movies: The original sequence



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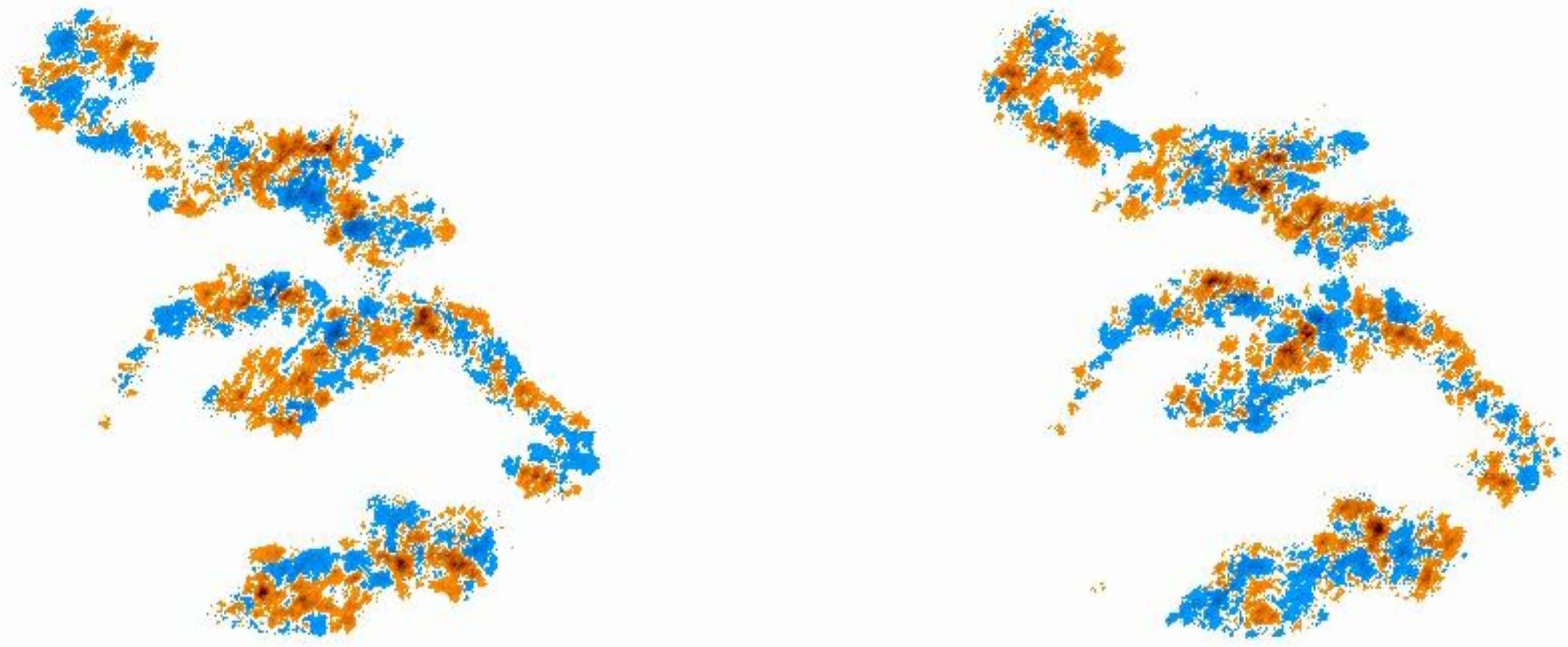
Two generated noise fields (mm/h)



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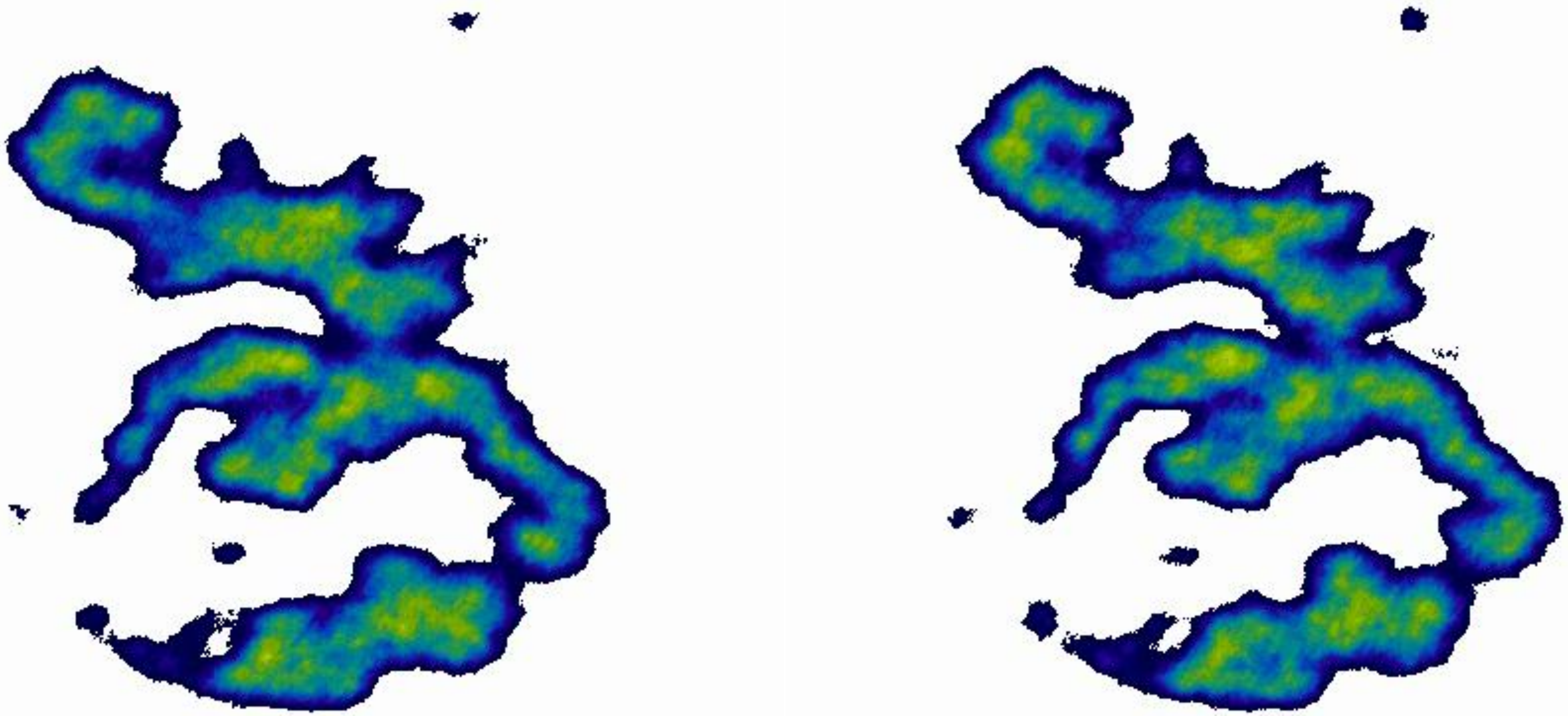
2 Ensembles



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