How do you tell how big something is without direct measurement?

Estimating grain size using an image's spectrum

Daniel Buscombe **David M. Rubin**

http://walrus.wr.usgs.gov/seds/grainsize/

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Indirect vs Direct Sizing of Objects

- Most geophysical techniques measure something by measuring something else, e.g.
  - size of bubbles in water
  - size of particles in hydrosols and aerosols

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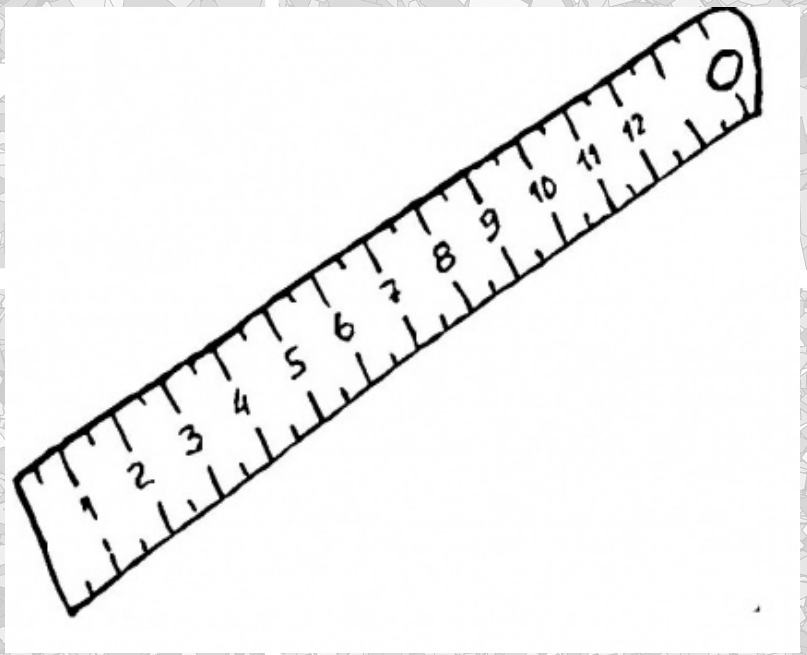
Indirect vs Direct Sizing of Objects



- When you can see what you're measuring, direct *and* indirect measurements are possible

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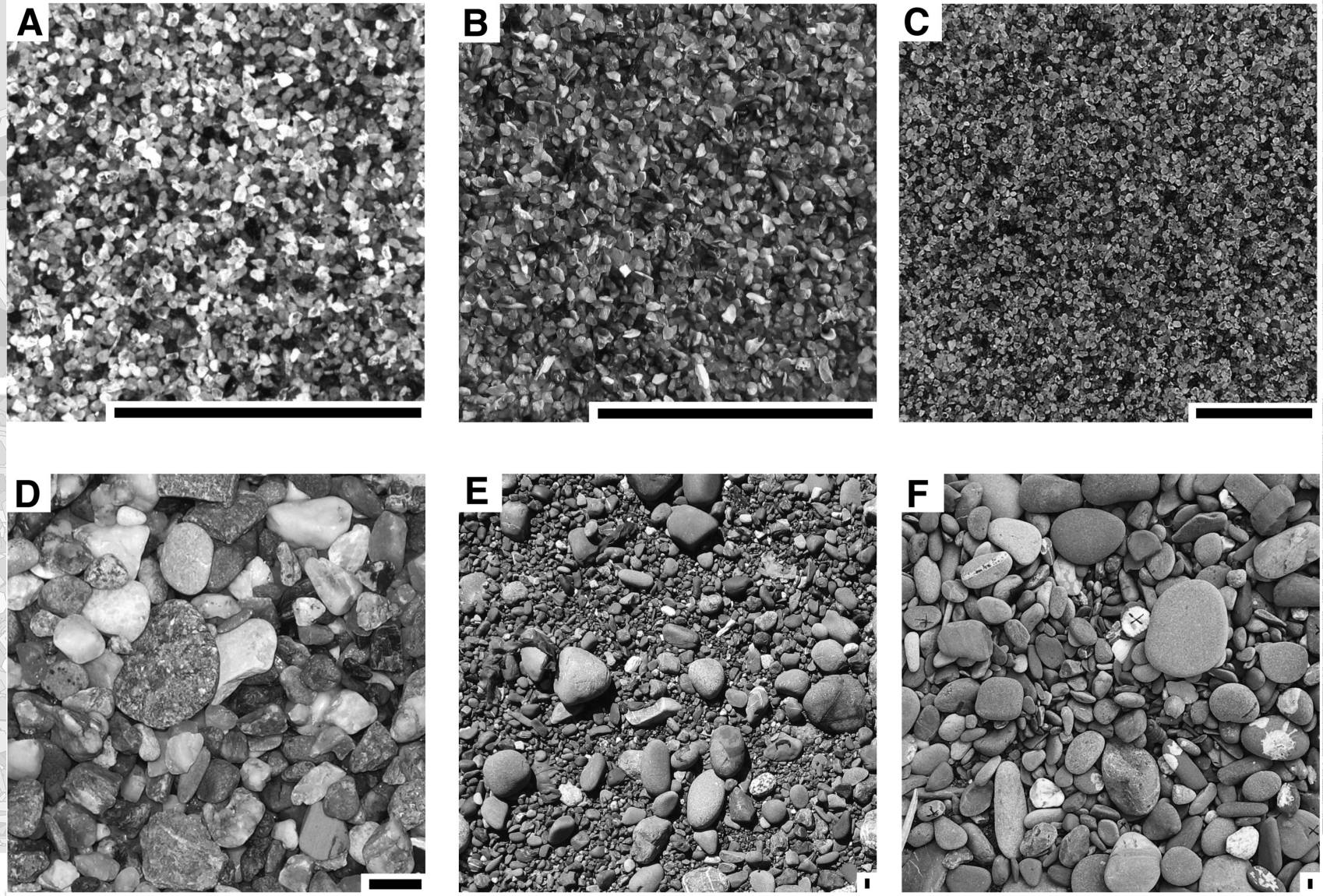
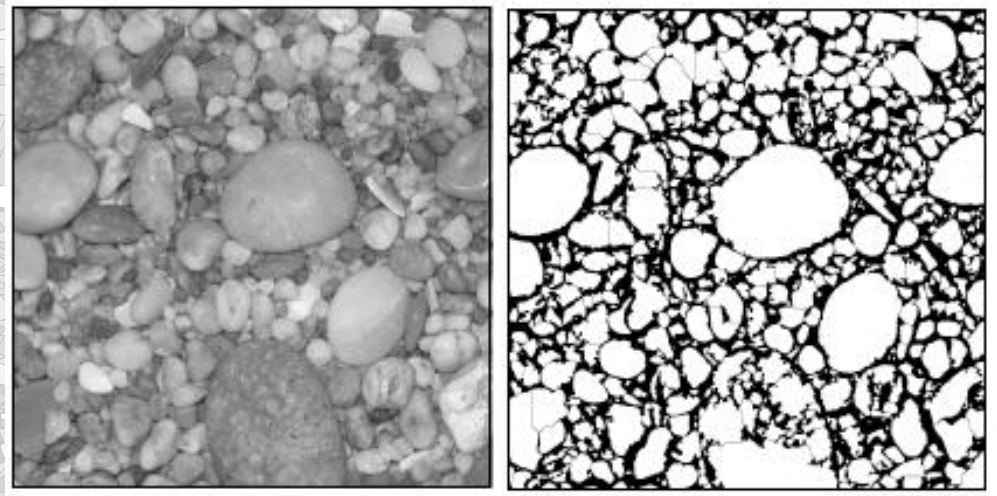
Direct Approach



Direct Approach to Sizing Grains

Segmentation Algorithm

- Operator-defined filters, coefficients, search scales
- Sensitive to sequence of operations
- Hard to make truly transferable



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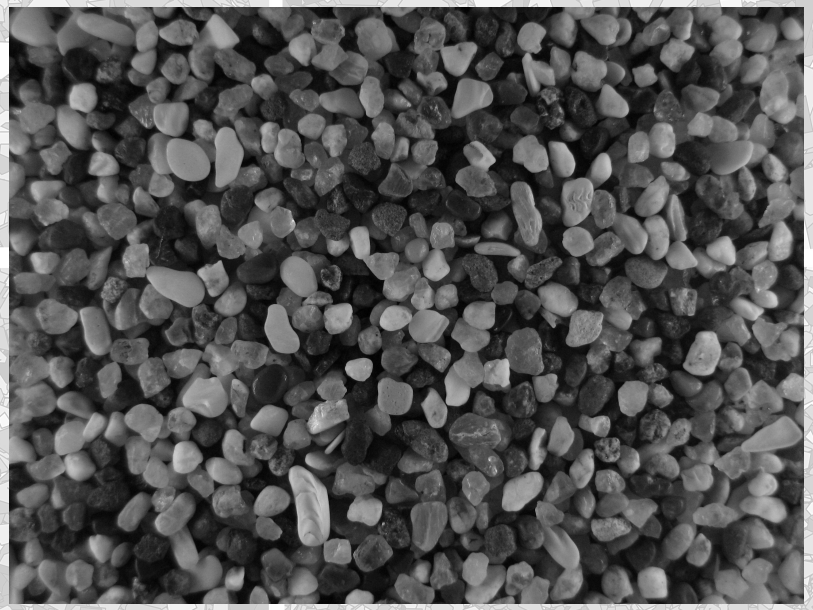
Indirect Approach to Sizing Grains

- Simple Fourier-optical techniques can reveal particle size



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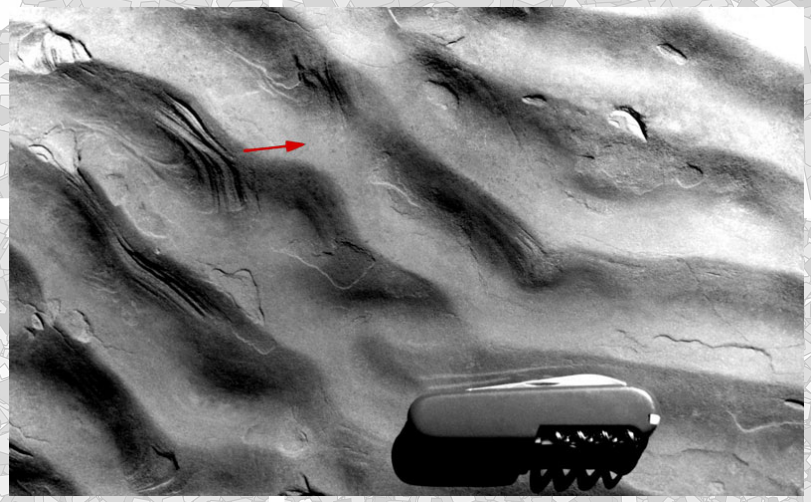
Indirect Approach to Sizing Grains

- Exploit the stochastic properties of the image of sediment



Source: http://walrus.wr.usgs.gov/seds/bedforms/photo_pages

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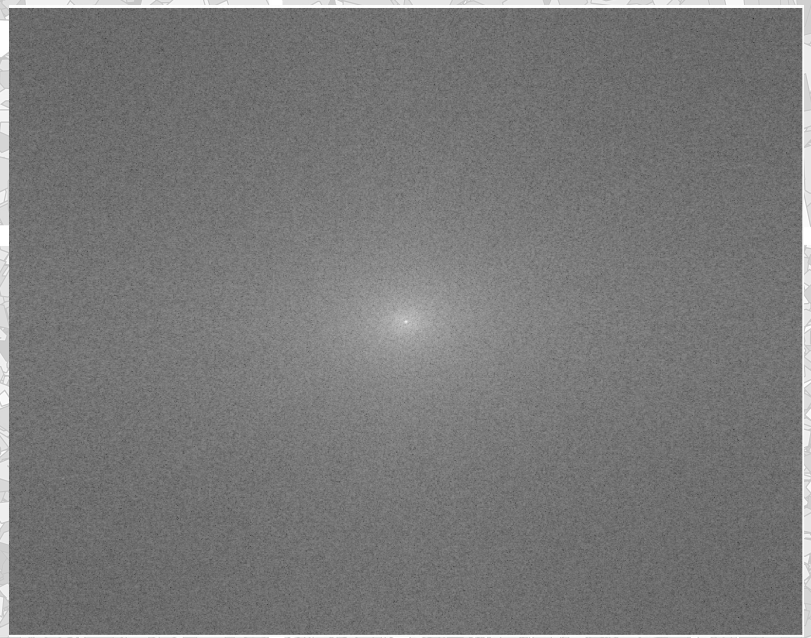
Indirect Approach to Sizing Grains

- Fourier transform captures all scales of variability



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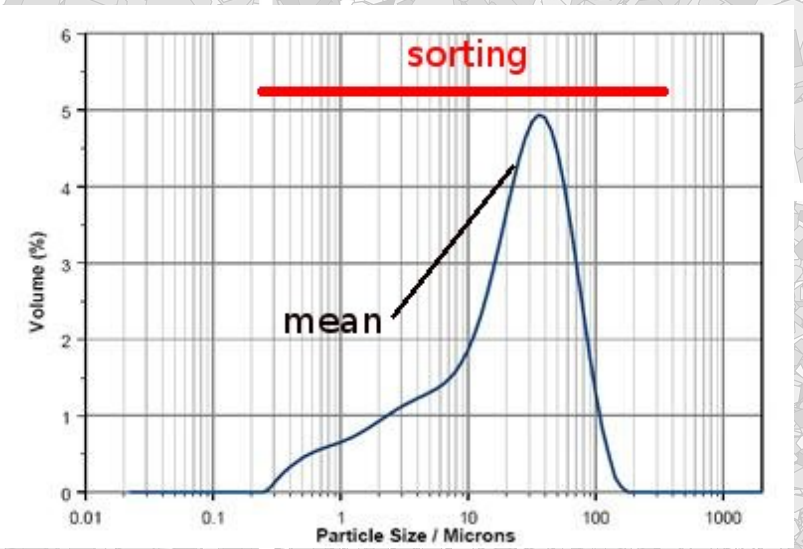
Indirect Approach to Sizing Grains



- Mean and standard deviation estimated directly
- No tunable parameters or empirically derived coefficients

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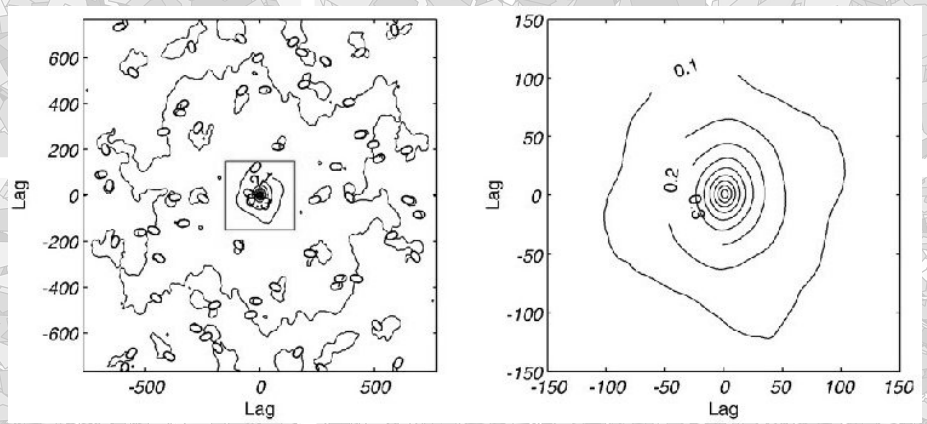
Mean Grain Size

Mean

$\mu = 2\pi / k_R r$

- k_R = lag at which $R(l)$=0.5
- r is image resolution (length/pixels)



2D autocorrelation

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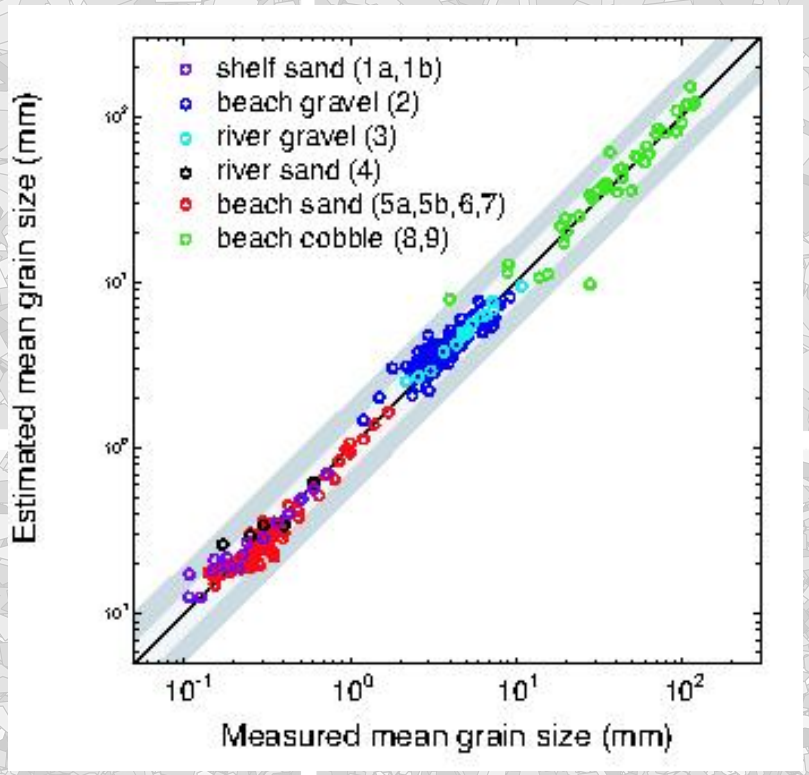
Mean Grain Size

Mean

$$\mu = 2\pi / k_R r$$

- k_R = lag at which $R(\ell) = 0.5$
- r = radius of circle

- 10 different 'populations' (500 images)
- Range of sizes 0.1 —150mm



500 images of sediment, RMS error ≈16%

Buscombe et al. (2010) *Journal of Geophysical Research - Earth Surface* 115, F02015

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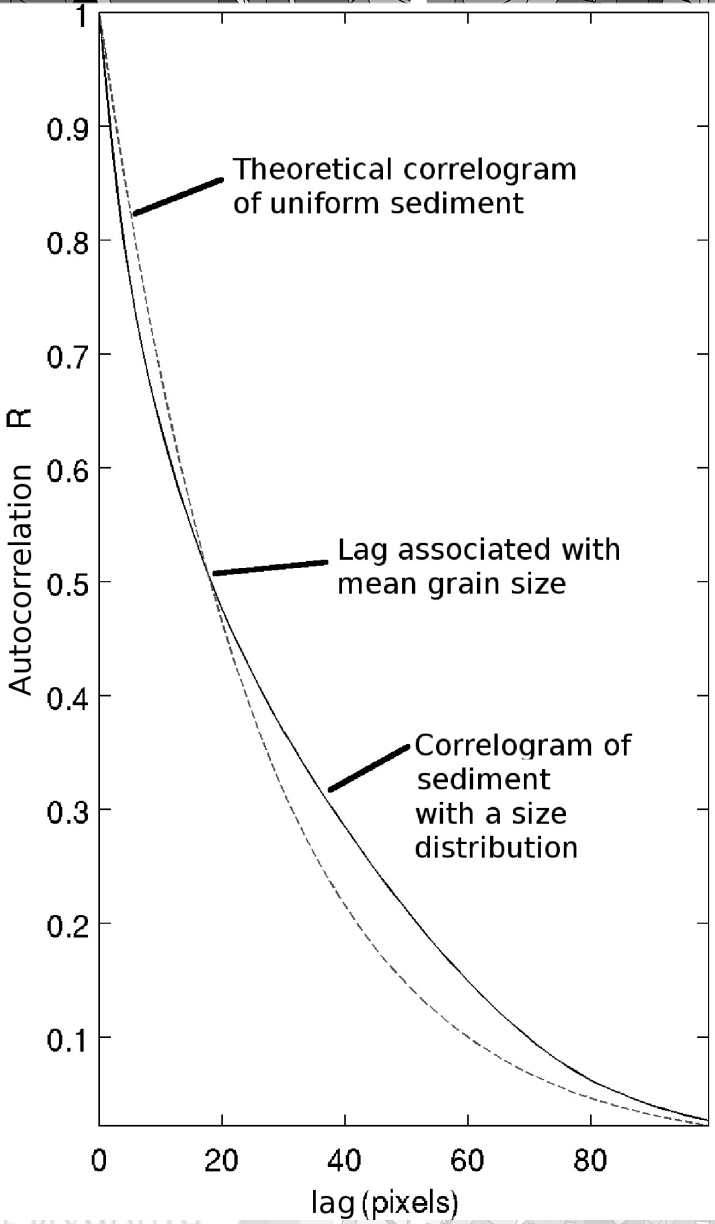
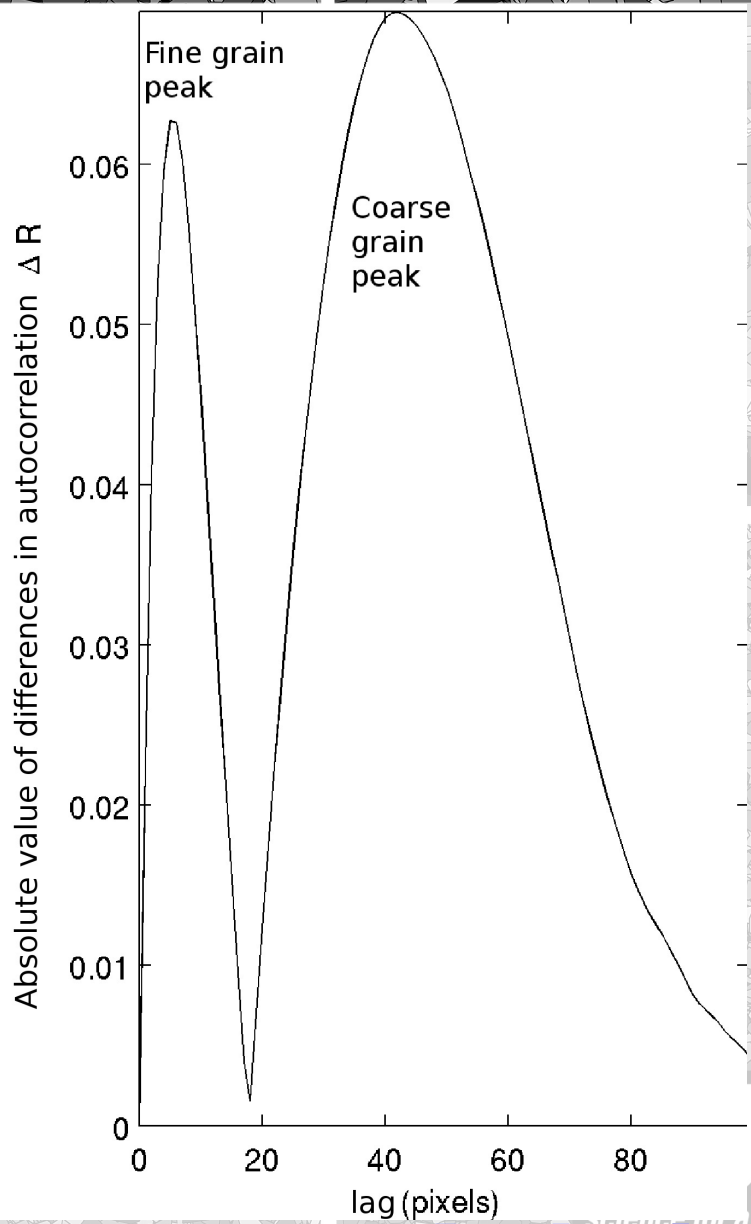
Standard Deviation of Grain Sizes





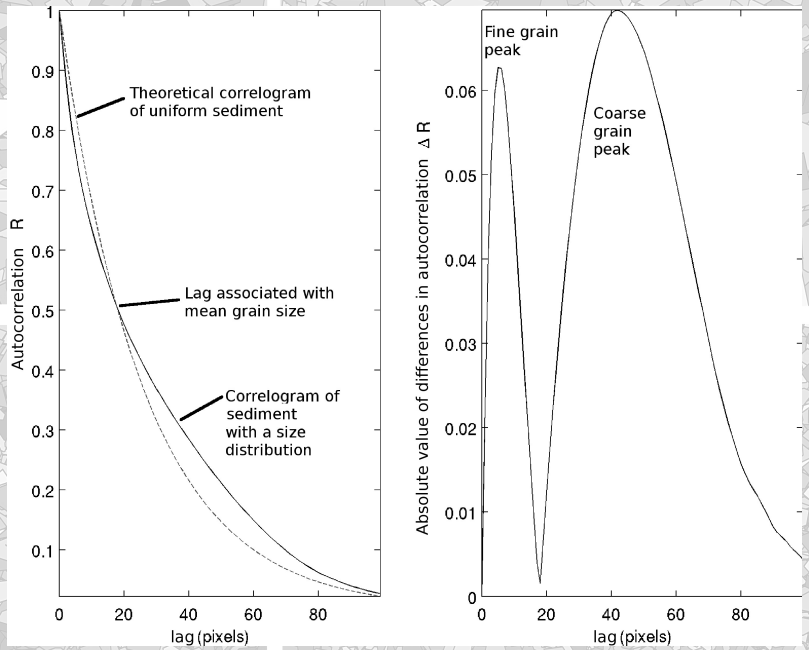
Standard Deviation of Grain Sizes

Standard Deviation

$$\sigma = c \int_{L_0} [|R(l) - R_u| dl]$$

Correlogram Idealised Sediment

$$R_u = e^{-k_R^2 l^2}, c = 2\pi$$



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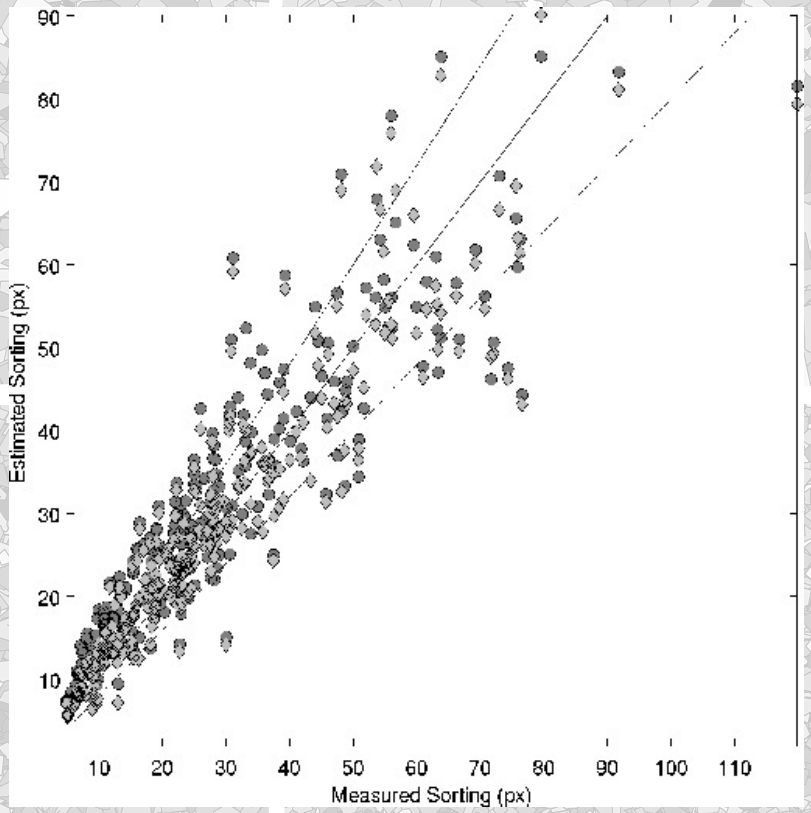
Standard Deviation of Grain Sizes

Standard Deviation

$$\sigma = c \int_{L_0} [|R(l) - R_u| dl]$$

- r.m.s error ≈30%



262 sediment images from 8 populations

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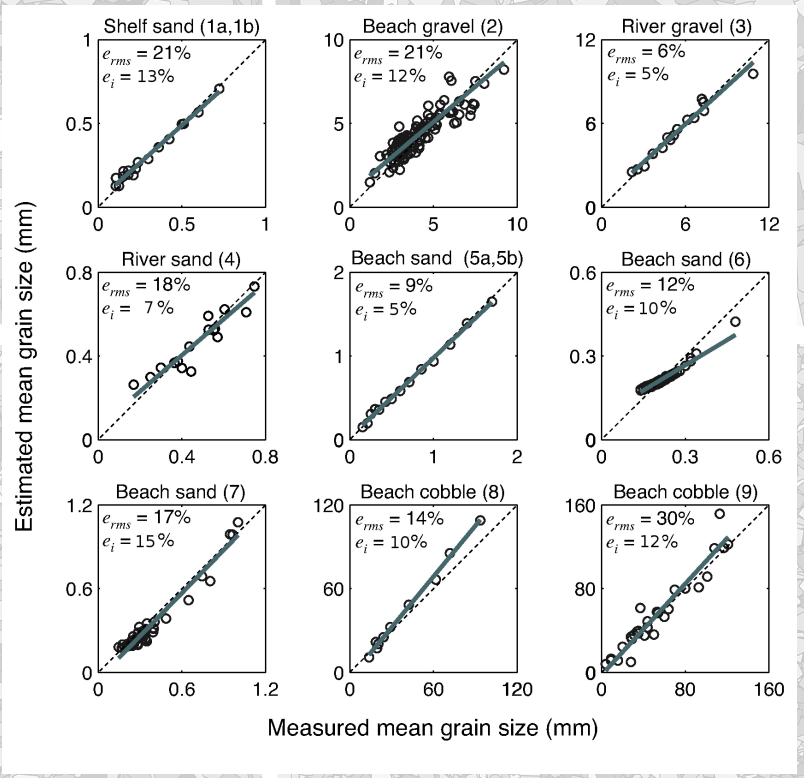
Standard Deviation of Grain Sizes

- r.m.s. error ≈30%

- estimates for mean and sorting reduce when corrected for bias



individual populations

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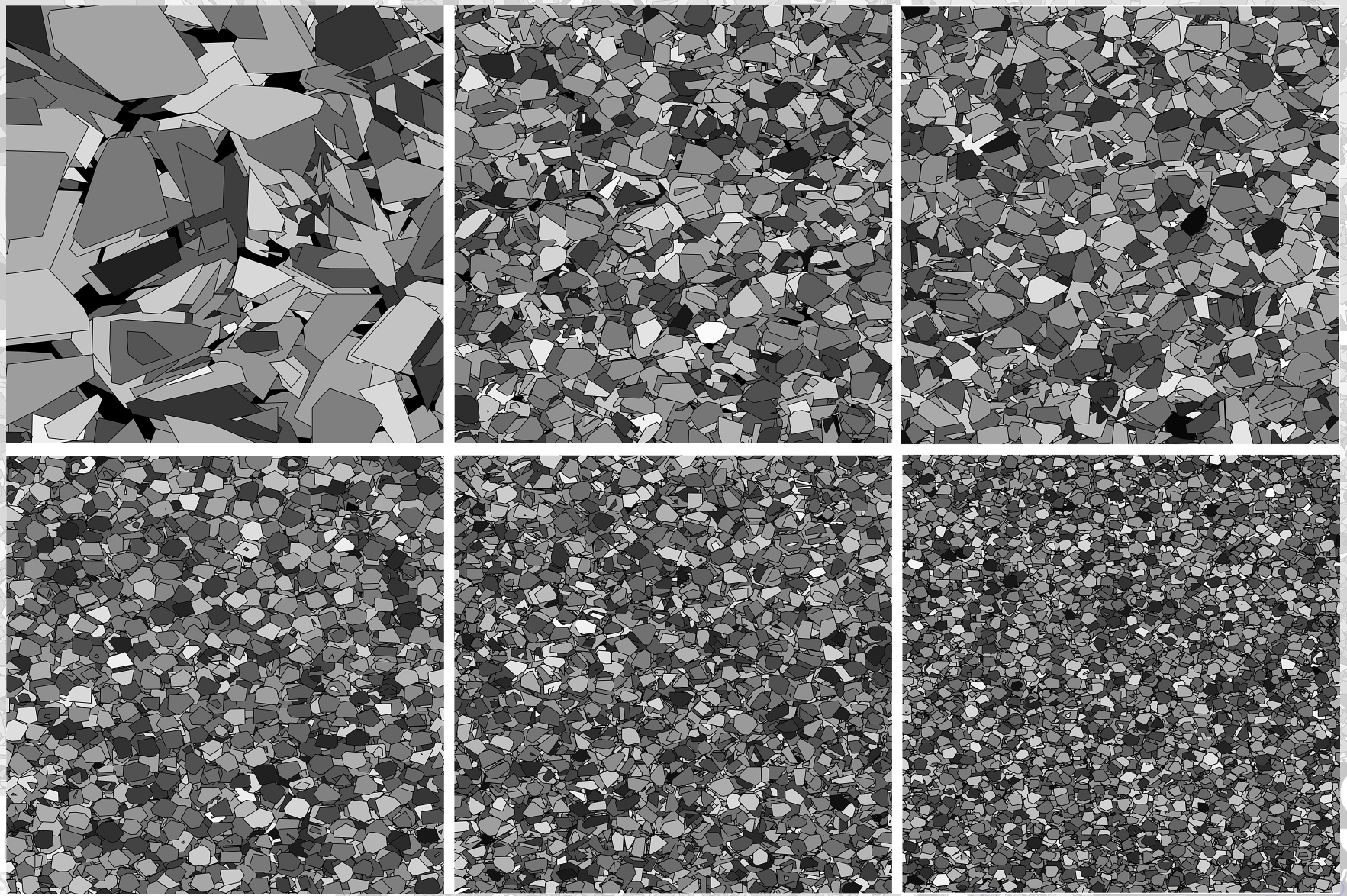
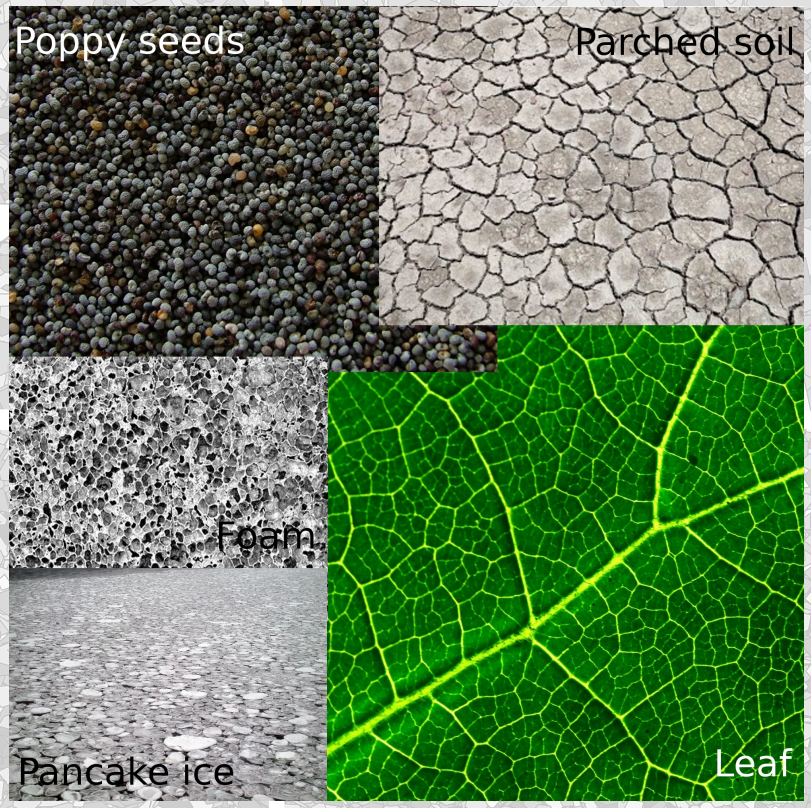
Model for Granular Material



Is it useful for Other Natural Patterns?

- Only one type of object



Sources: *http://www.123rf.com*
http://www.koepp.de
http://en.wikipedia.org/wiki/
http://www.utsa.edu/lrsg/Antarctica/SIMBA/

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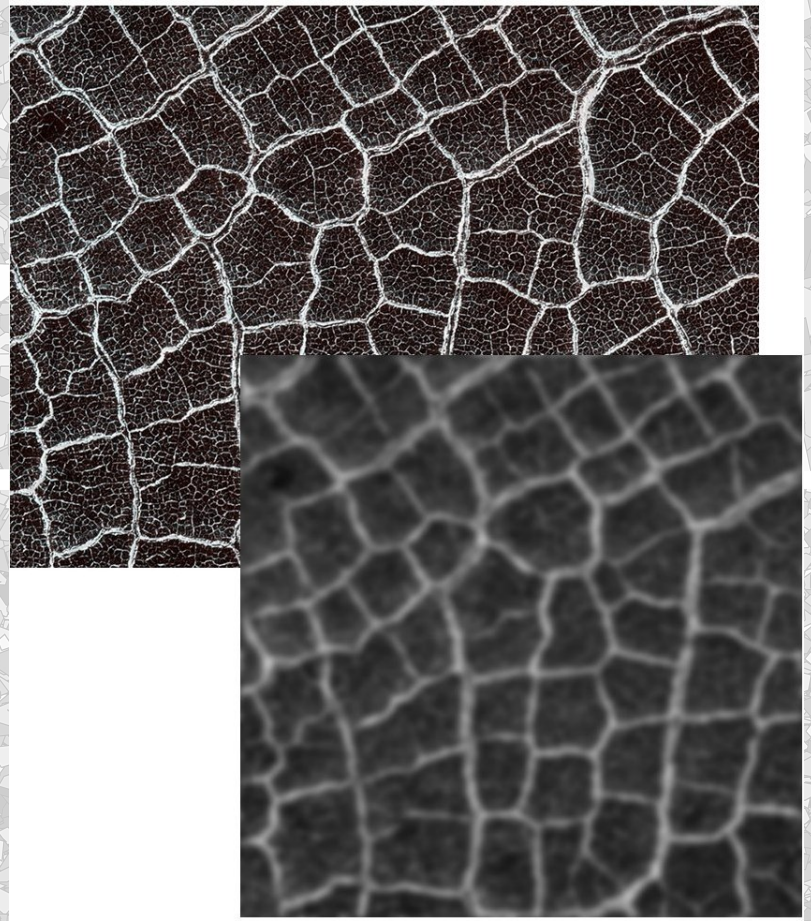
Is it useful for Other Natural Patterns?

- Size is fairly homogeneous in space, but multiple scales possible



Patterned ground (Source: `http://hirise.lpl.arizona.edu`)
Algorithm predicts the smaller scale (10 pixels).
Gaussian low pass filtered image
Algorithm reveals the larger scale (65 pixels).

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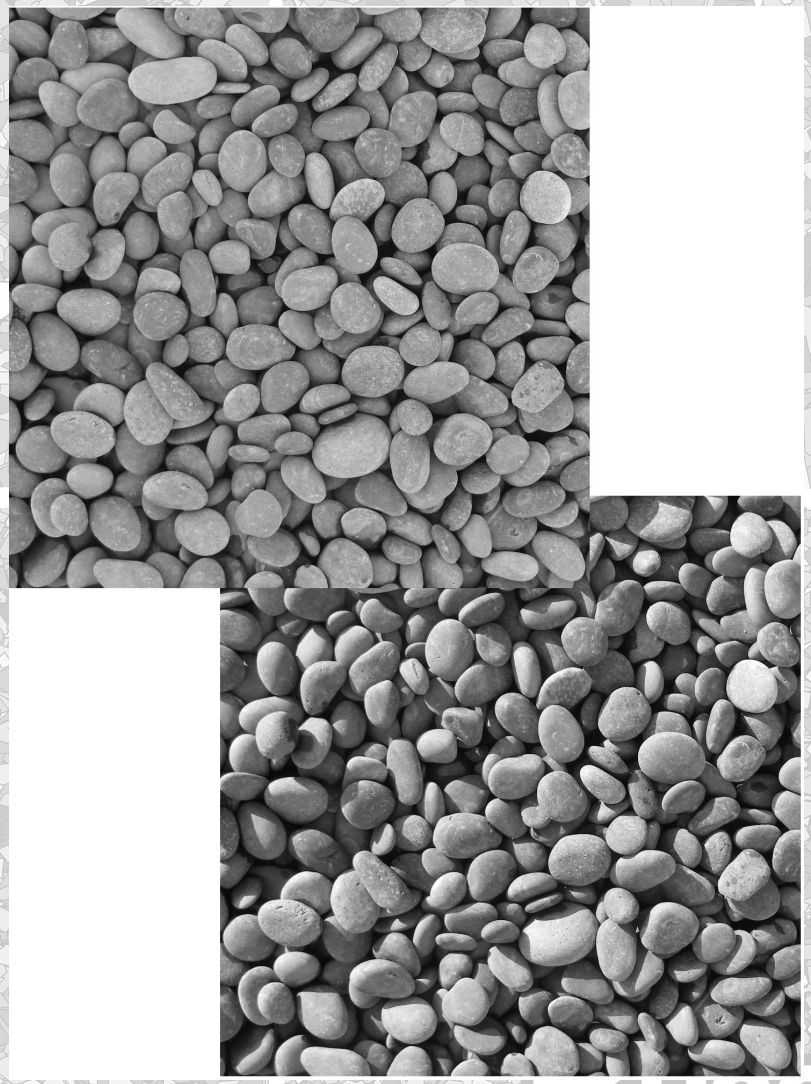
Is it useful for Other Natural Patterns?

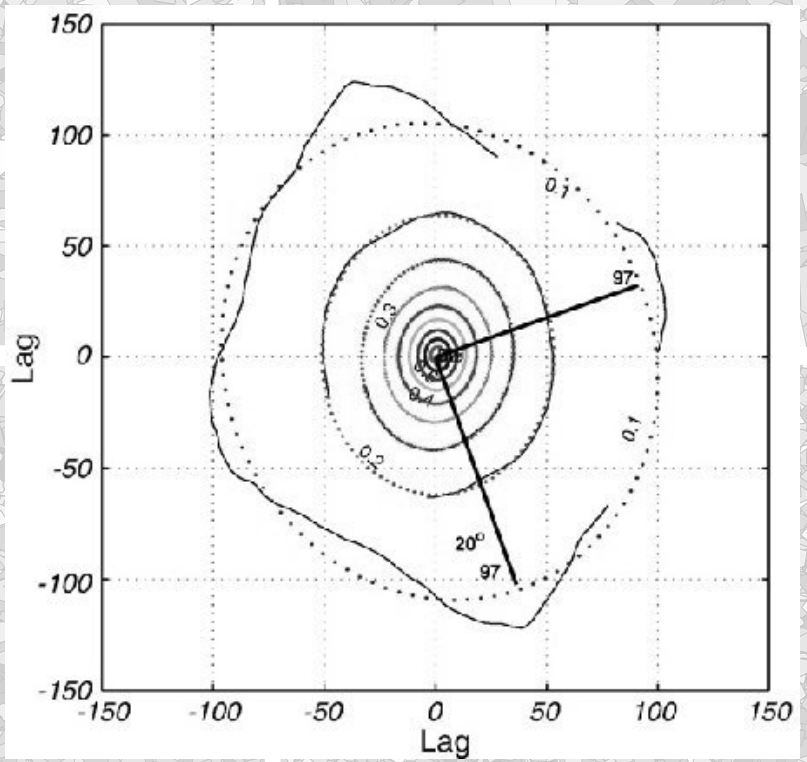
- Large shading introduces errors. Filtering required.



Error up to 30%. Filtering reduces error by about half.

Is it useful for Other Natural Patterns?

- Dominant orientation captured



Orientation of the ellipse fit to the contour

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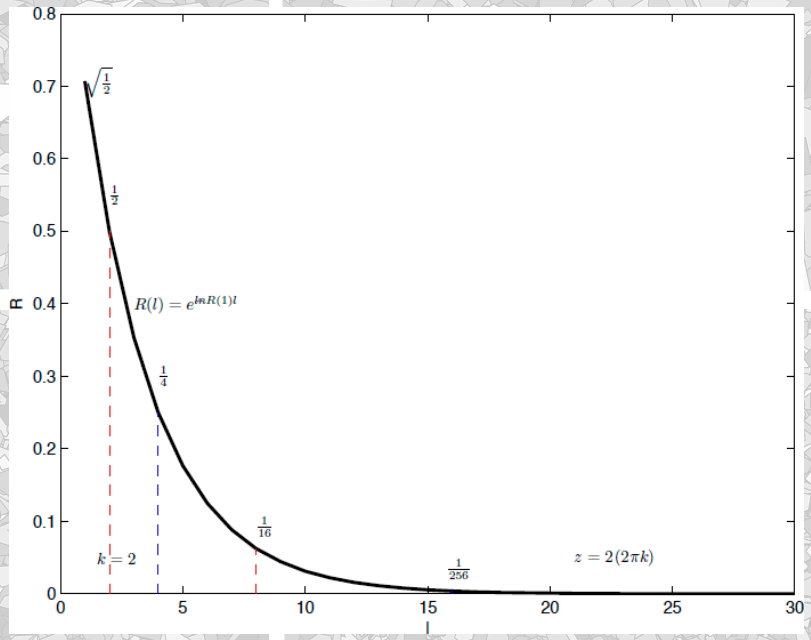
Is it useful for Other Natural Patterns?

- Only one type of pattern
- Size is fairly homogeneous in space, but multiple scales possible
- Shape is not homogeneous
- A note on resolution



Smallest grain $>$ *2 pixels.* $R(1) > \sqrt{0.5}$

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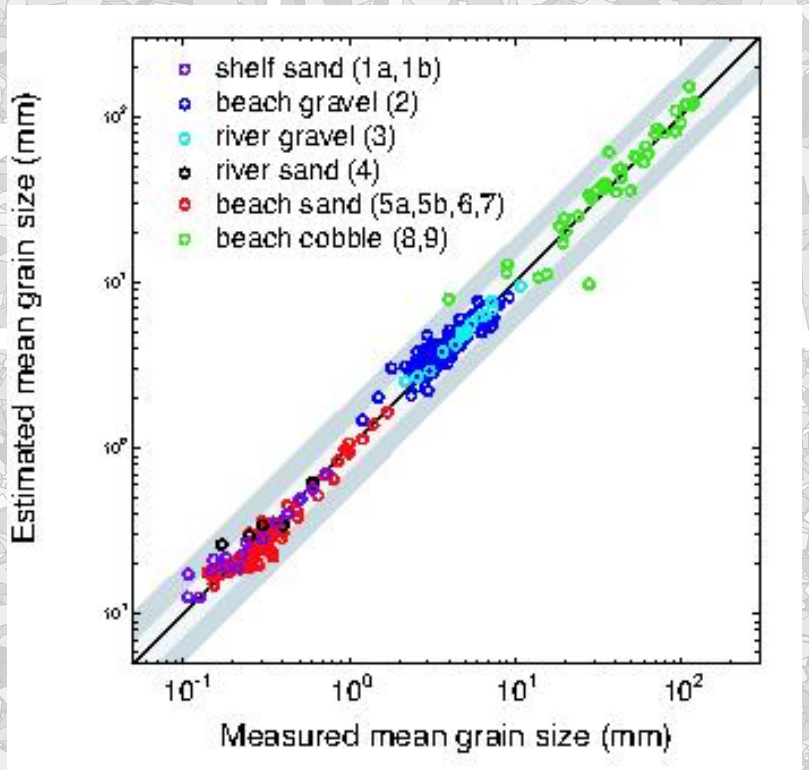
Summary

- Particle size directly from image spectrum
- Viable alternative to thresholding-based techniques



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Summary

- Particle-size directly from image spectrum
- Viable alternative to threshold-based techniques
- Development of models for granular materials
- Similar methods useful for other natural patterns?

Follow up:

- daniel.buscombe@plymouth.ac.uk
- Code available: http://walrus.wr.usgs.gov/seds/grainsize/
- Buscombe et al. (2010) *JGR-Earth Surface* 115, F02015
- Buscombe and Rubin (in review) *JGR-Earth Surface*

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Why Does it Work?