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A physics based framework for geologic sedimentation

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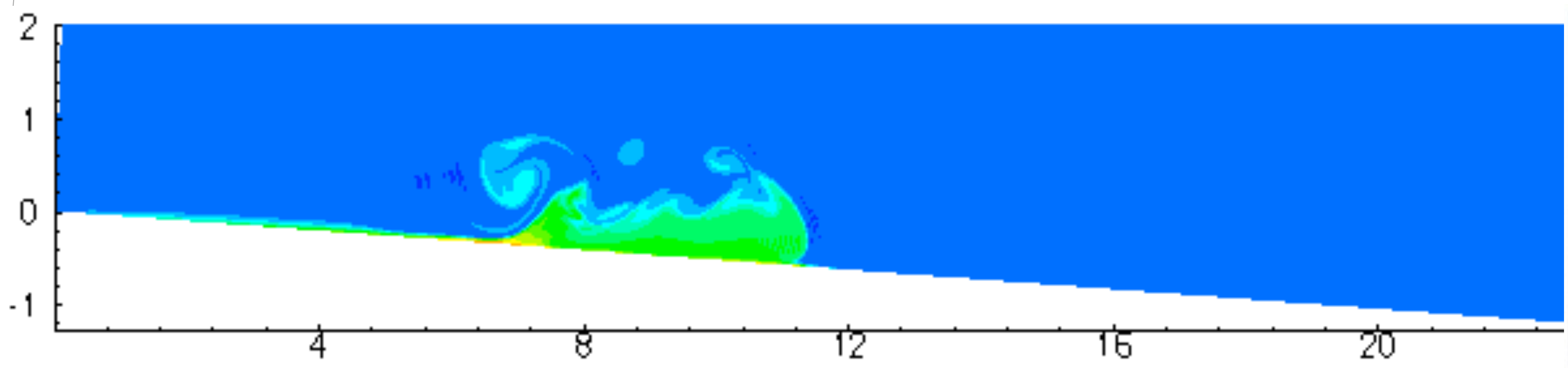
"Winter Mountain Sunset" -- sunset on the Sangre de Cristo Mountains near Santa Fe, New Mexico, USA

Bold scientific aspiration

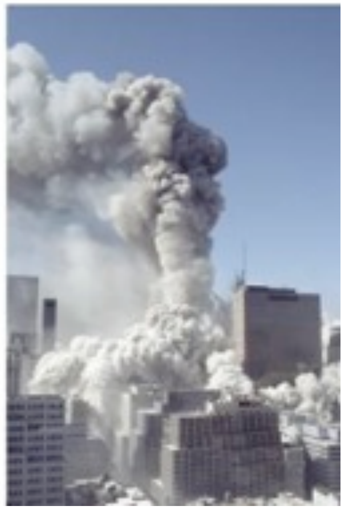
- As plate tectonics gave a physics based framework for understanding and prediction of structural geology, we aspire to provide a physics based framework for geologic sedimentation
- Outline
  - inspiration
  - vision
  - theoretical framework

Two phases of turbidite propagation

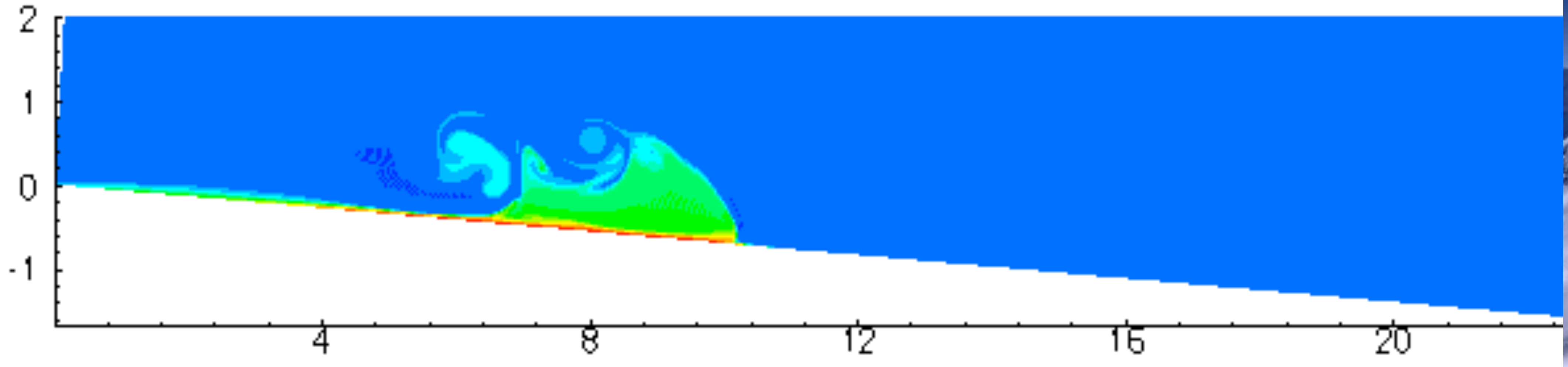
slope angle= 3 degrees, deposition outweighs erosion, decaying tubidity current



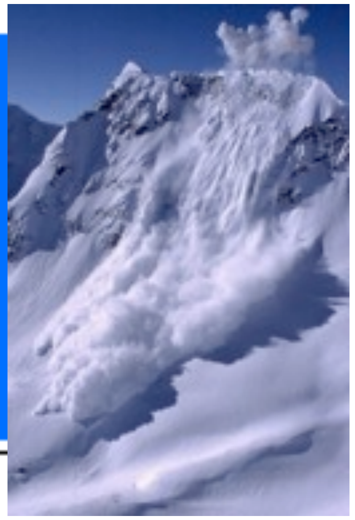
collapsing building



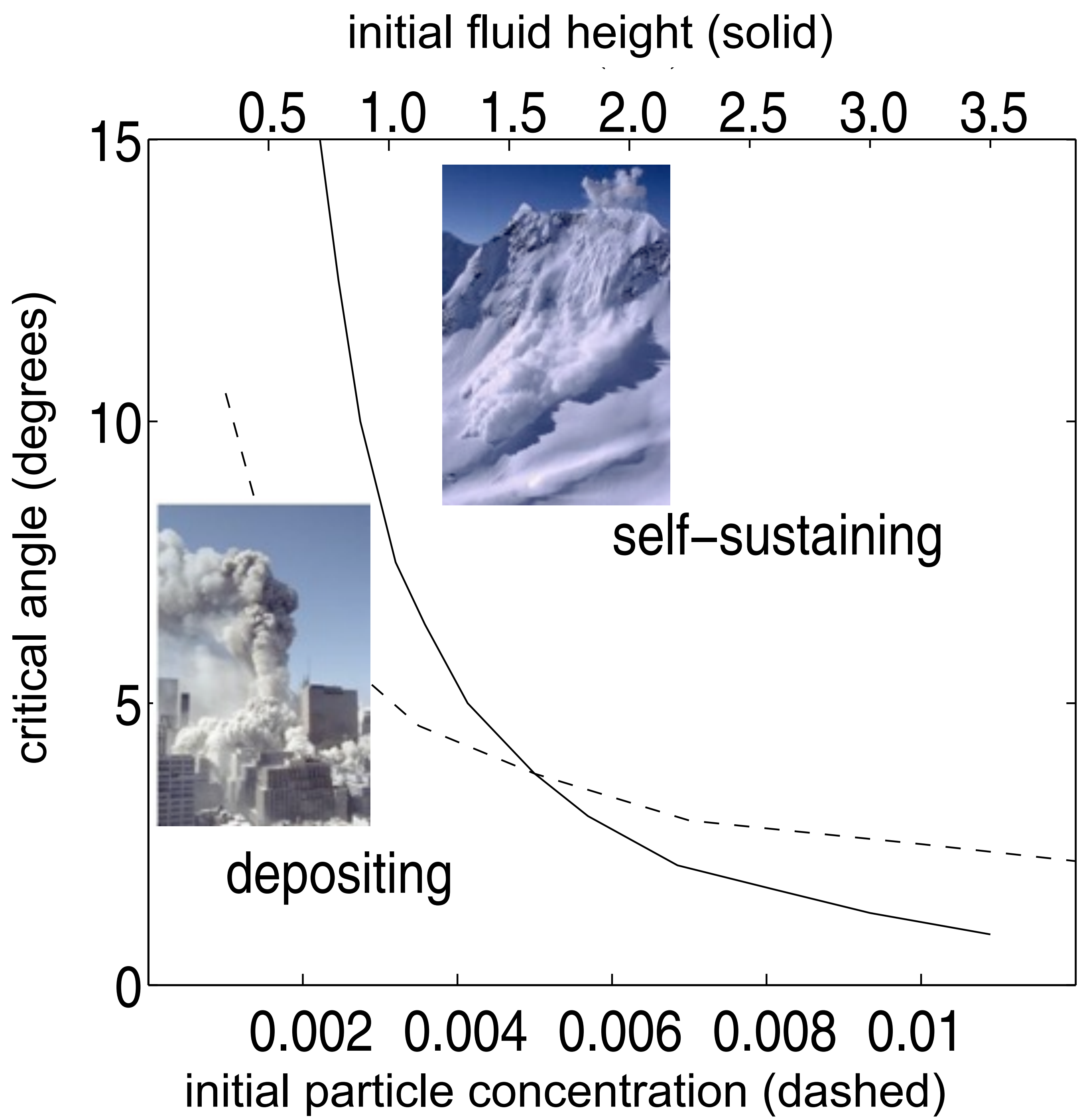
slope angle= 4 degrees, erosion outweighs deposition, growing tubidity current



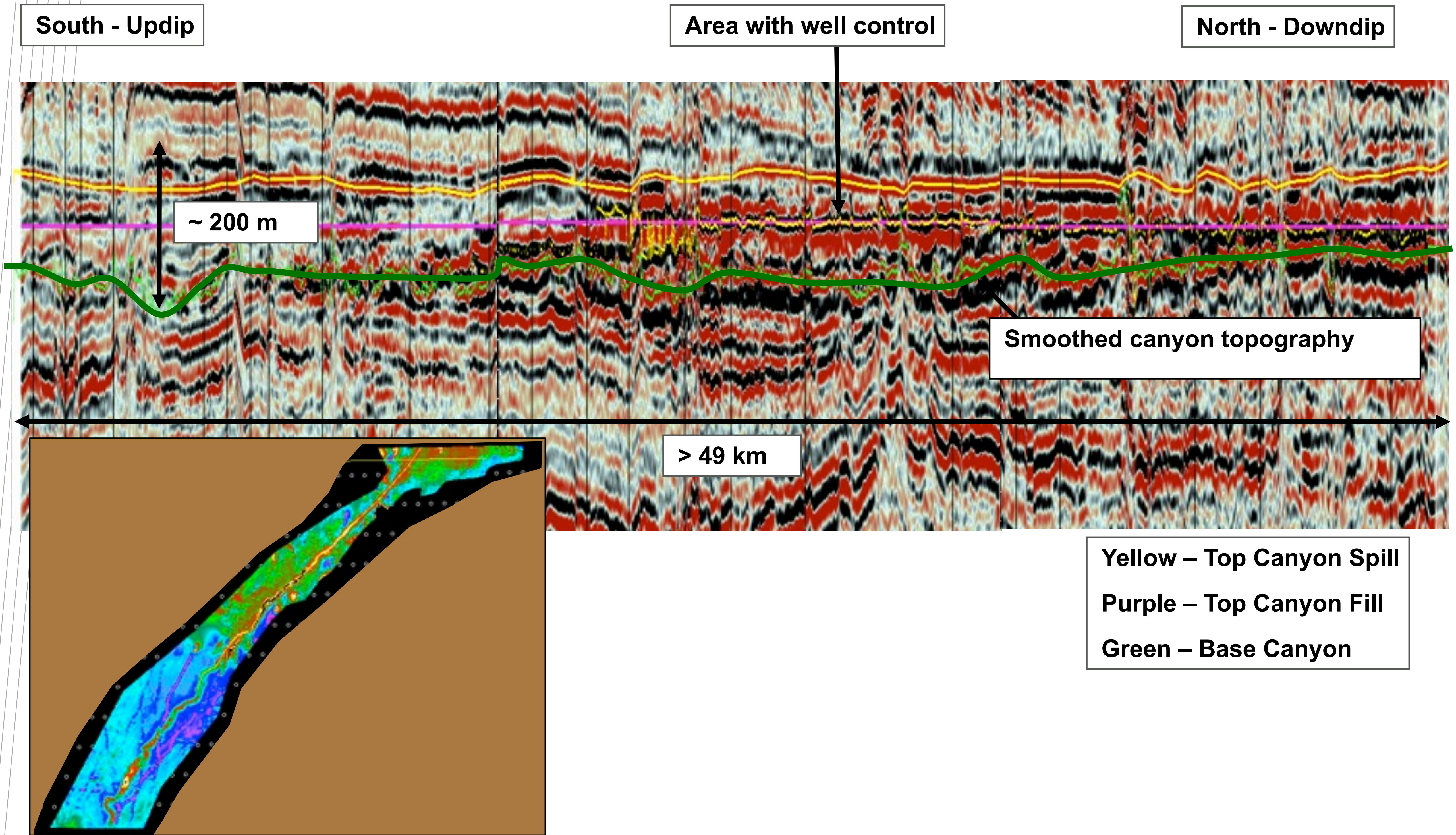
avalanche



The phase space of turbidite propagation



Turbidite deposition in canyon shows remarkable self organisation

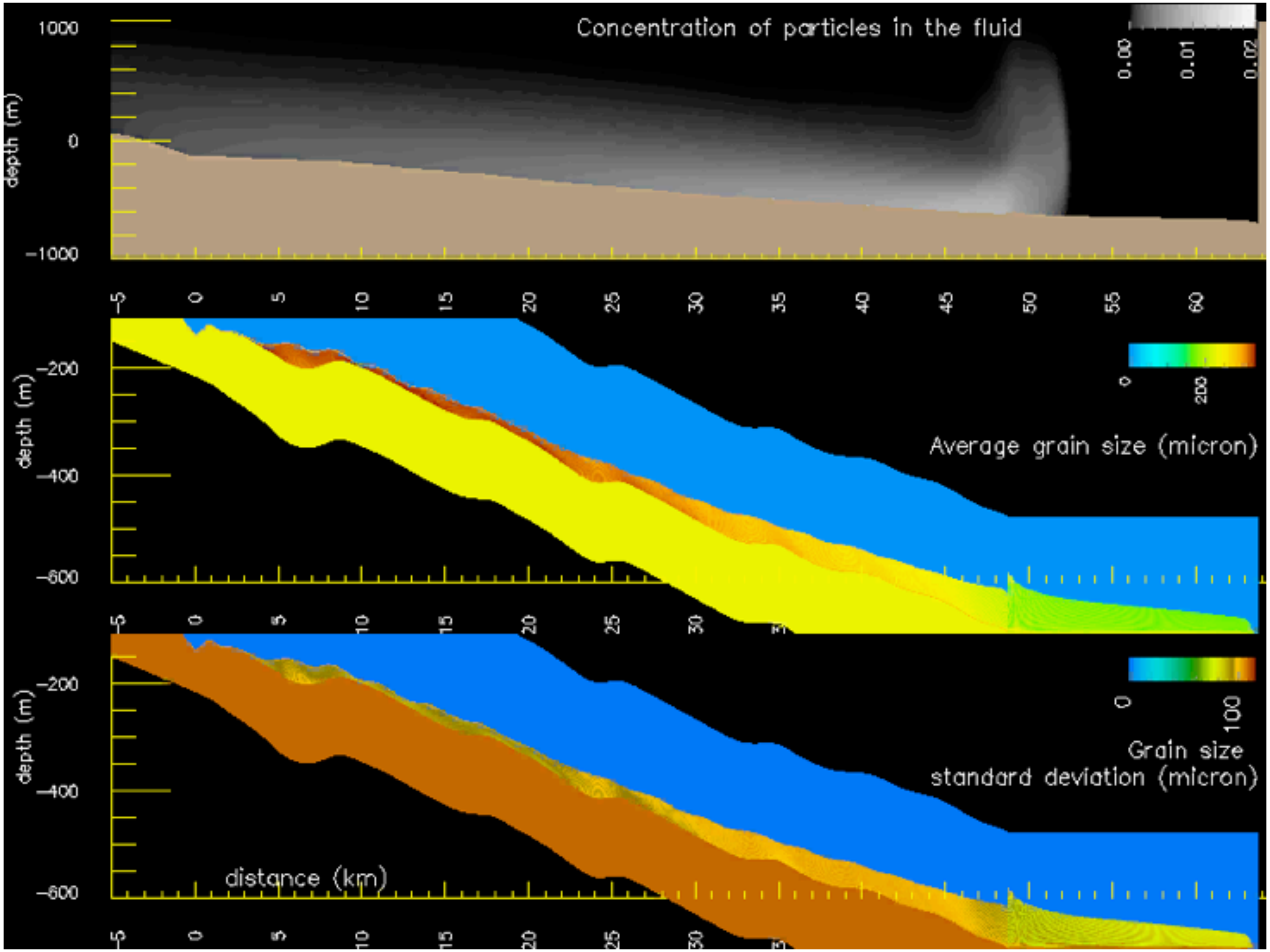


Yellow – Top Canyon Spill

Purple – Top Canyon Fill

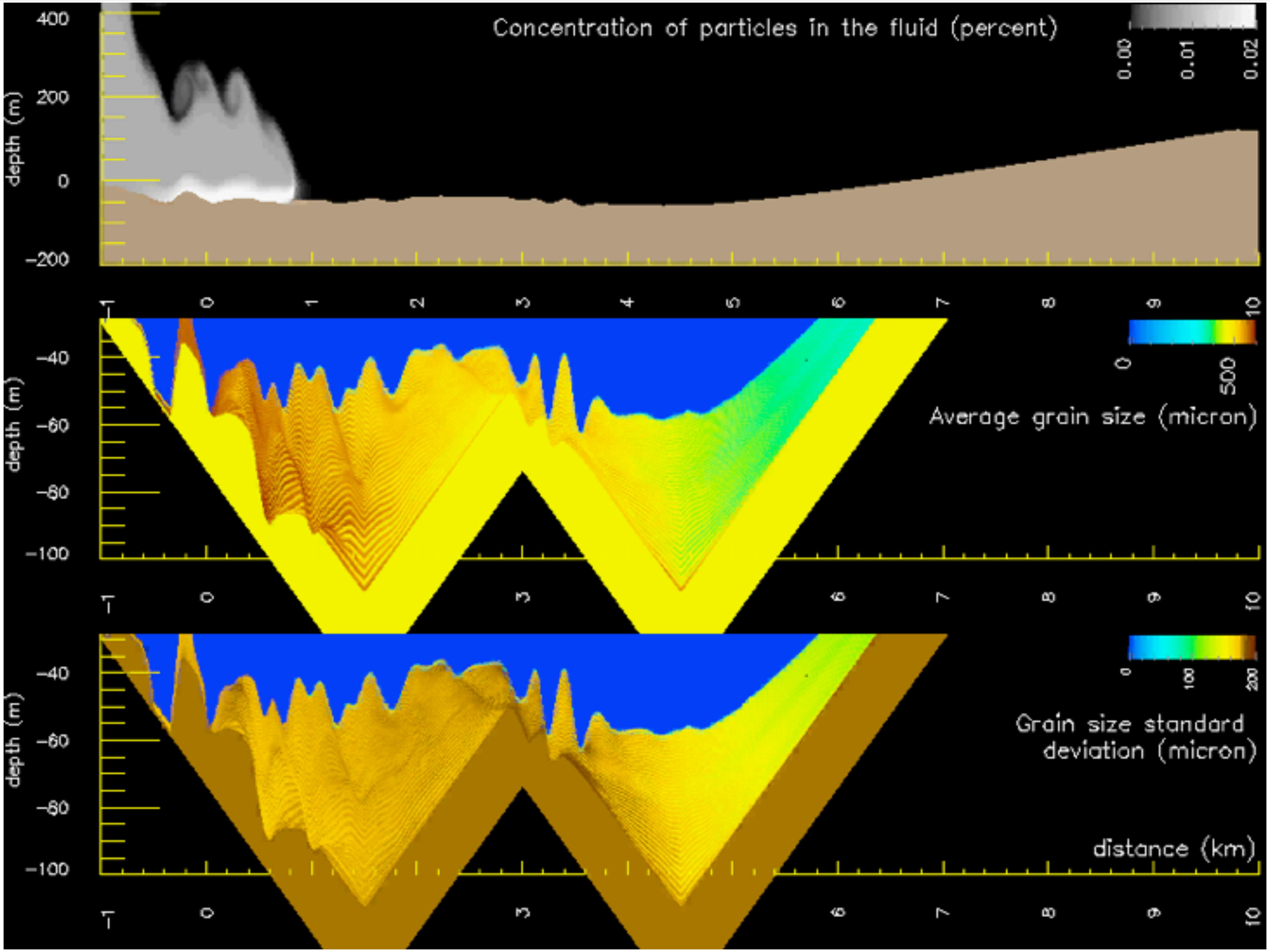
Green – Base Canyon

Movie of deposition in 2D canyon



deposits on slope and propagates to fan only for paleo dips of 0.75 to 1.25 degrees.
Paleo dip estimated to be 0.75 degrees from overlying delta

Movie of formation of sediment waves, shows a more complex self organisation



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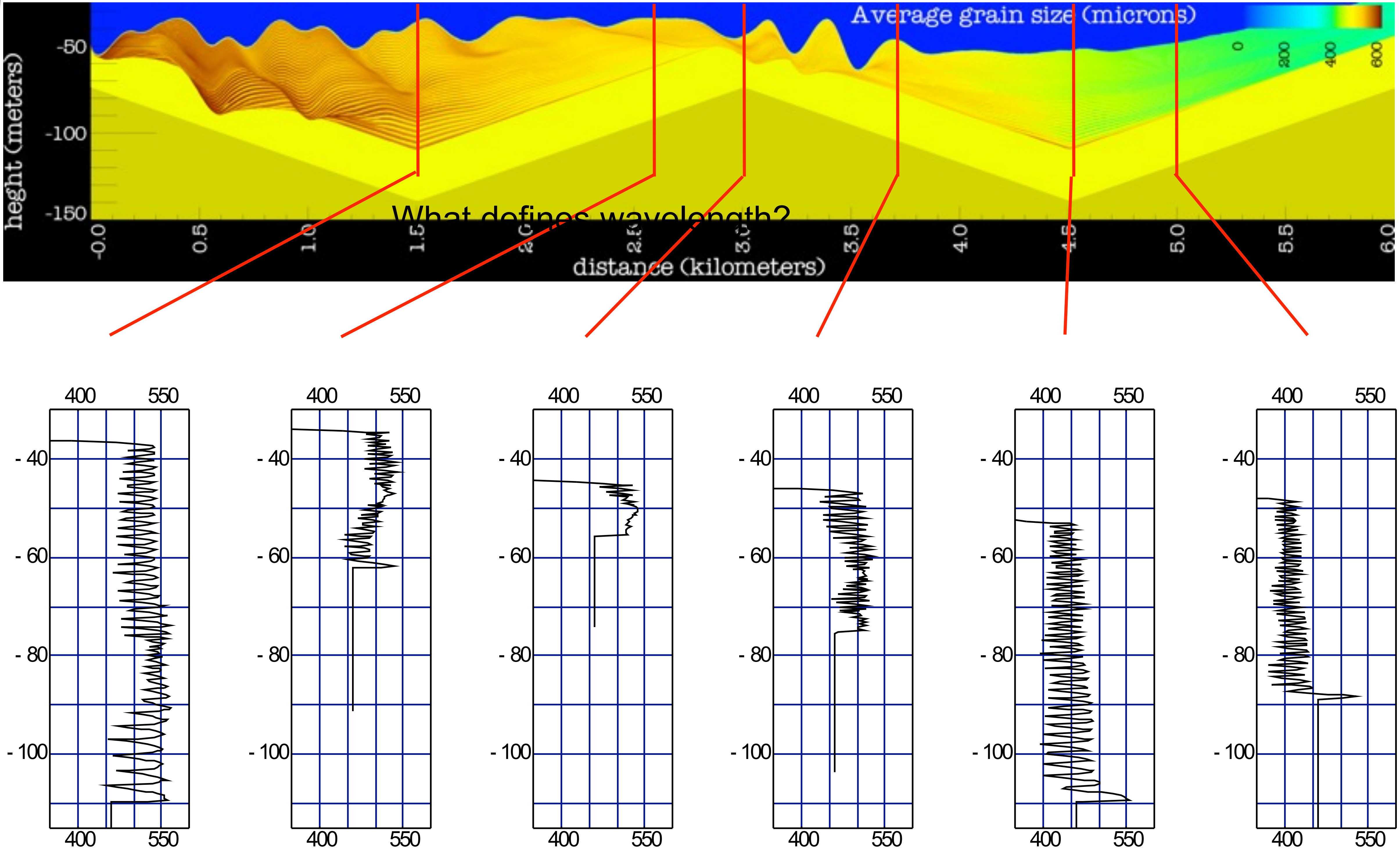
A closer look at the more complex self organisation -- geologic texture



Complex systems approach

small handful of parameters

source conditions
(boundary and initial conditions)

+

known functional with infinite number of parameters

physics
(Partial Differential Equations)

gives

geologic prediction
(self organisation, correlation of complex system)

potentially high dimensional result, but determined by small handfull of parameters

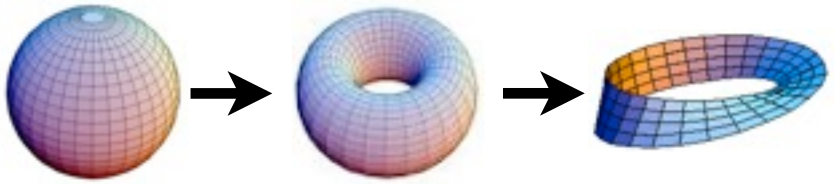
It is about dynamics, not statistics

Dissipative systems collapse to low dimensional submanifolds in phase space

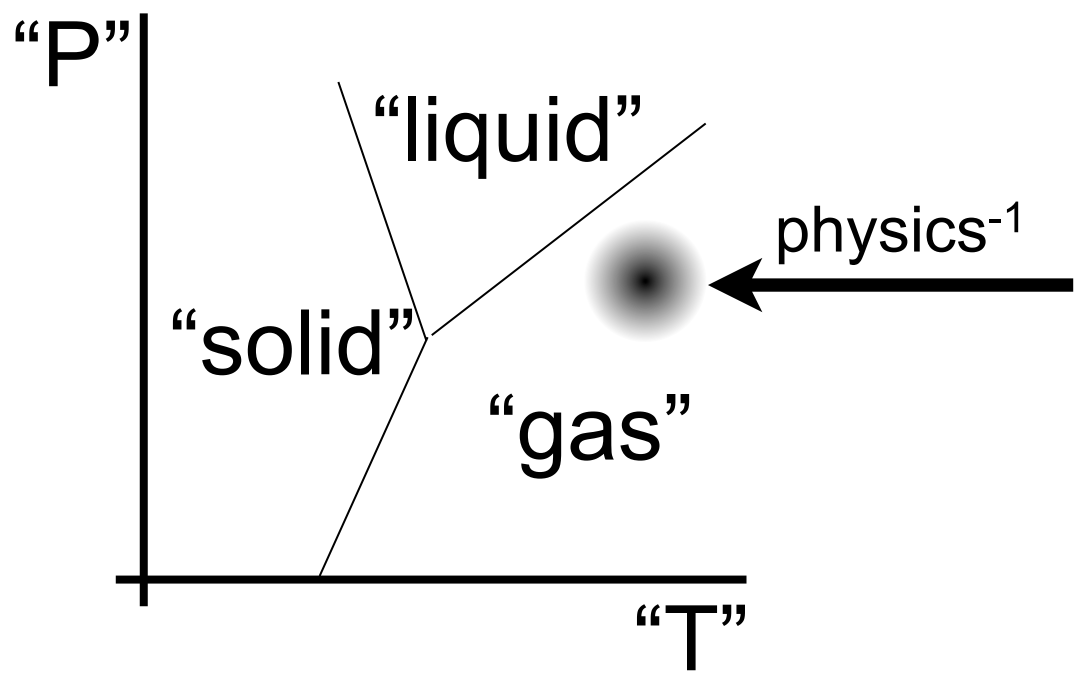
Motion is chaotic on this submanifold

What is important are the “actions” determining the submanifold, not the chaotic “phase” of where one is on the submanifold

phase transitions happen at bifurcations in the singularity structure leading to different topologies of the submanifold, that is textures of the self organisation



Type of depositional body correlation is depositional phase (stratigraphy)



limited observation w/ error

boundary & initial conditions "actions"

↓ physics, dynamics

self organization, correlation submanifold topology

- temperature
- pressure

- flow size
- grain size
- sorting
- source position

- solid
- liquid
- gas

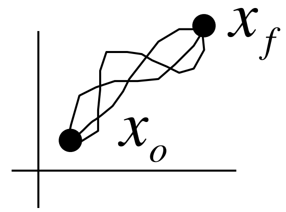
- channel
- levee
- fan

Theoretical physics techniques from quantum field theory key -- gives texture's fingerprint

Start with path integral formulation of data assimilation problem

$$P(x_f \mid y) = \int \left[\int_{x_o}^{x_f} e^{-A[x_f, x_o, y]} D[x(t)] \right] P(x_o)\, dx_0 = \int e^{-A_{cl}} F_{QM}(x_f, x_o) P(x_o) dx_o$$

wave function or probability density function

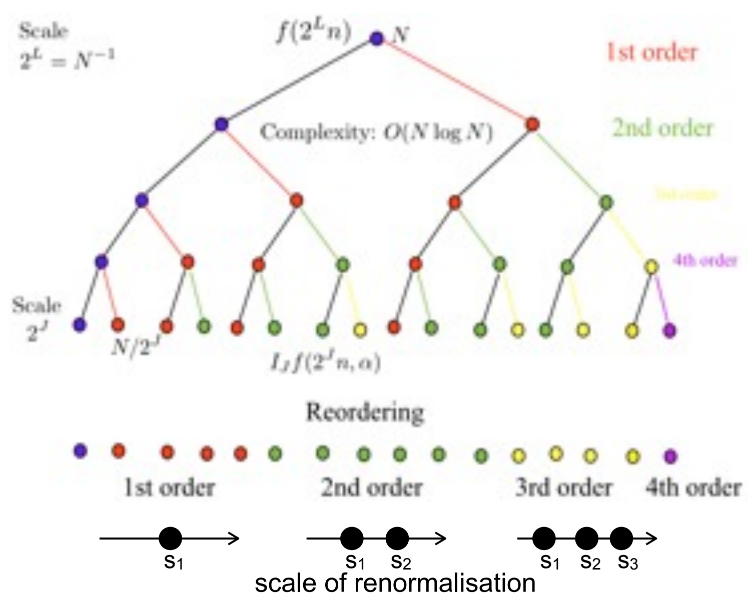


action or probability of observed data, classical path dependant

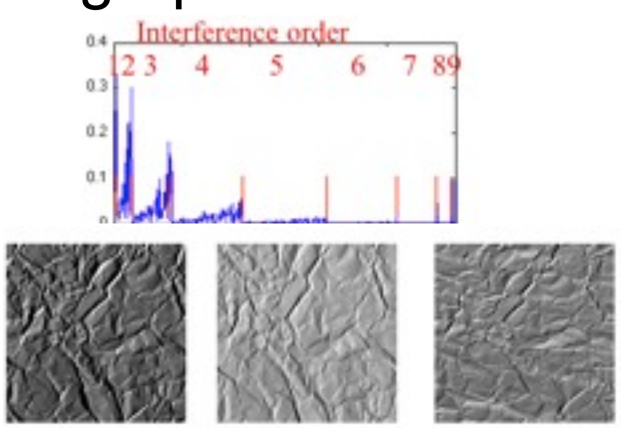
quantum fluctuations or uncertainty in forward model physics, path independent

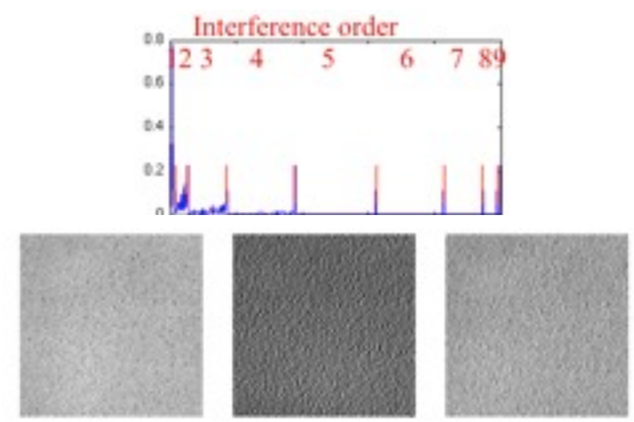
expand in recursive wavelet renormalisation

Evaluate with Feynman expansion in terms of the complexity of the interaction about a group symmetry using method of steepest decent (constant phase)



unique action fingerprint of texture





independent of chaotic "phase"

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  - Vivek Sarkar, computational science from Rice University
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  - Chevron SEED project
  - Woodside 10/11 budgeted technology project

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