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Handling non stationarity in Multiple-Point Statistics Simulation with a Hierarchical approach

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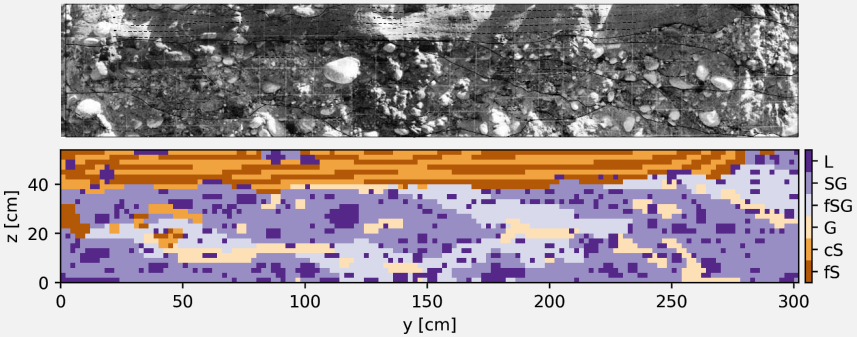
Non-stationarity in MPS

Non-stationarity is in the daily agenda of Geostatistics. . .

- In particular, when dealing with natural outcrops used as training images (TIs)

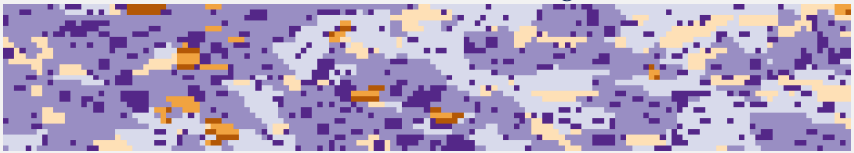


Zappa et al. (2006)

(. . . and you have to care about non-stationarity)

TI (non-stationary)

MPS simulation (TI “as it is”, without taking into account for non-stationarity)



Approaches to deal with non-stationarity in MPS

For example, one can use 👉 *auxiliary variables* maps.

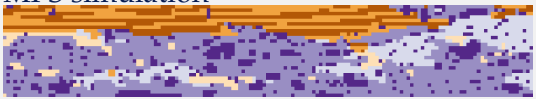
TI

\+

Auxiliary variable (z coordinate)

=

MPS simulation



Many other approaches have been proposed:

- Multiple TIs
- Search-three partitioning
- Spatial similarity. . .
- Transformations. . .

de Vries *et al.* (2009), Honarkhah and Caers (2012), Caers (. . .), Chugunova *et al.* (2008. . .), Boucher *et al.*. . . and many others.

An alternative: the hierarchical approach

Some of the aforementioned approaches to handle non stationarity are not straightforward to apply.
For example, in the absence of soft data (i.e., from geophysics), finding an appropriate auxiliary variable map can be challenging, in particular for complex geometries.

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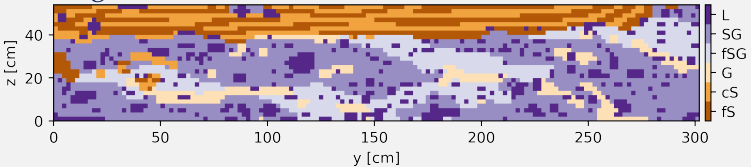
For example, in the absence of soft data (i.e., from geophysics), finding an appropriate auxiliary variable map can be challenging, in particular for complex geometries.

Why don't we tackle non-stationarity with a *hierarchical approach*?

Hierarchical approach

(in Geostatistics, only a little younger than the variogram $\gamma \ldots$)

Starting data set



Aggregated facies `fs+cS` (light blue) and `G+SG+fSG` (orange)

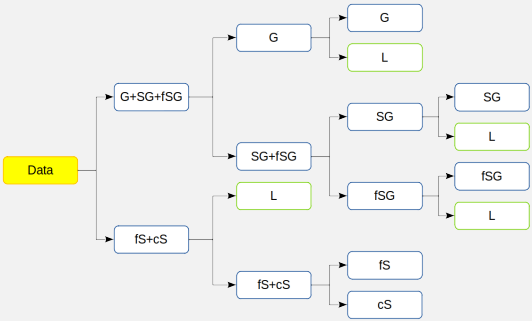
☞ can be used as TI[1] and to separate the simulation grid in two domains.

[1] not the best TI, in this case...

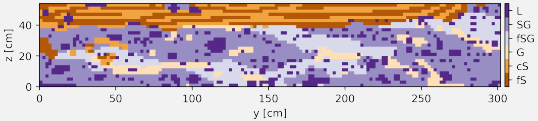
Hierarchical simulation procedure

Binary tree

(for example, based on texture)



Data



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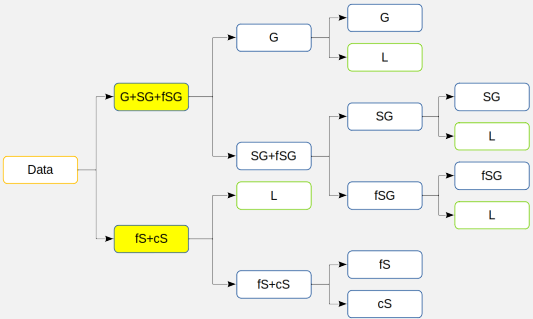
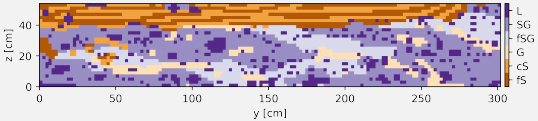
Hierarchical simulation procedure

Binary tree

(for example, based on texture)



Data



Binary TI, obtained through:

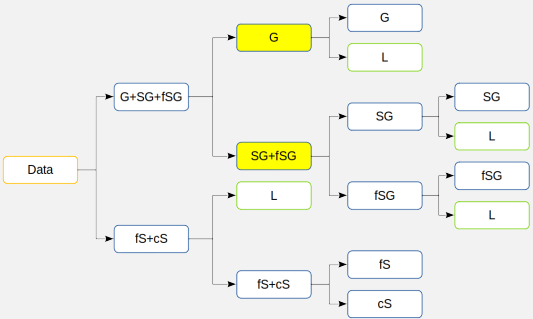
1) data with aggregated facies (fs+cS versus G+SG+fSG)
2) MPS simulation with incomplete data

👍 also used to separate the simulation grid into two sub-domains

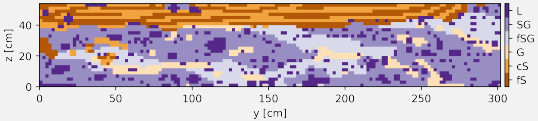
Hierarchical simulation procedure

Binary tree

(for example, based on texture)



Data



Binary TI, obtained through:

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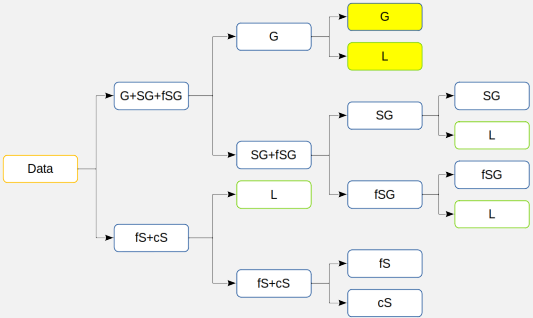
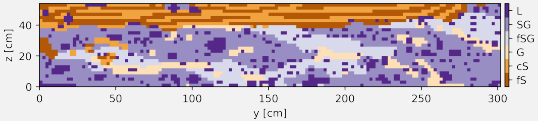
Hierarchical simulation procedure

Binary tree

(for example, based on texture)



Data



Binary TI, obtained through:

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Hierarchical simulation procedure

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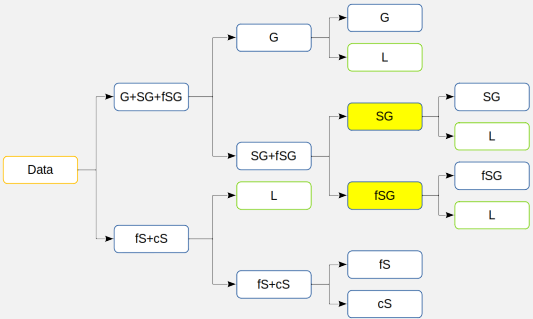
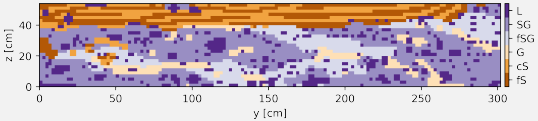


Data



Binary TI, obtained through:

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Hierarchical simulation procedure

Binary tree

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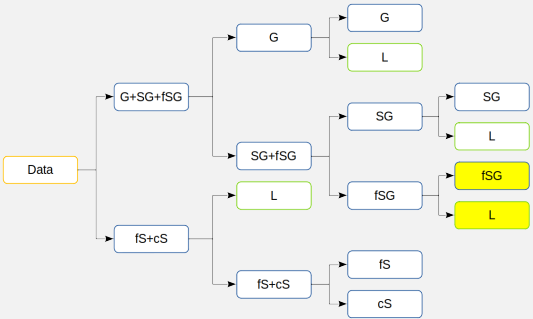
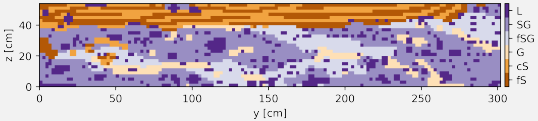


Data



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Hierarchical simulation procedure

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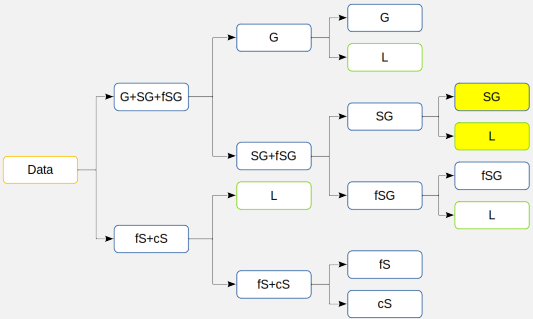
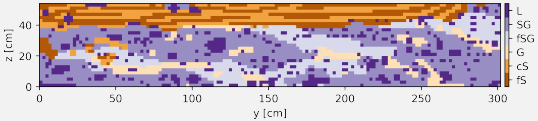


Data



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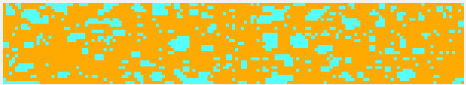

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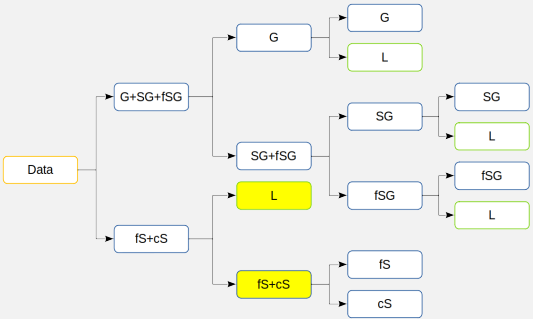
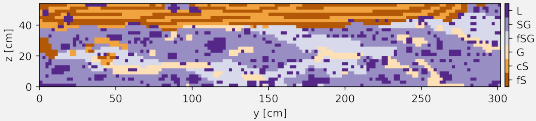


Data



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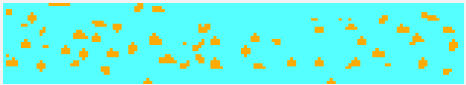

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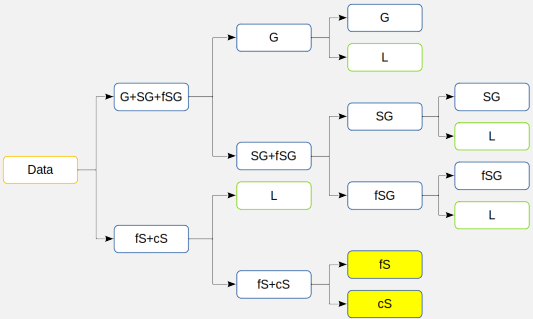
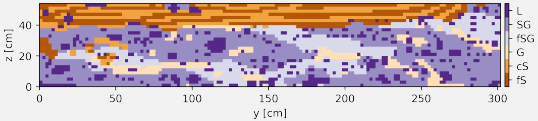


Data



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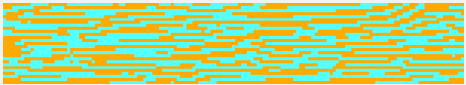
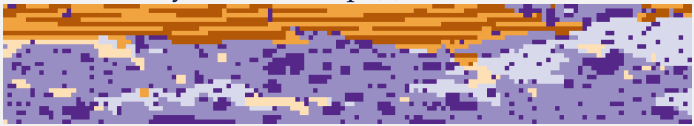


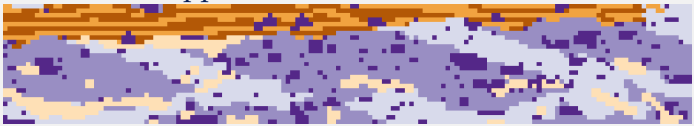
Results (2D) - visual inspection

Reference outcrop

With auxiliary variable map (z)

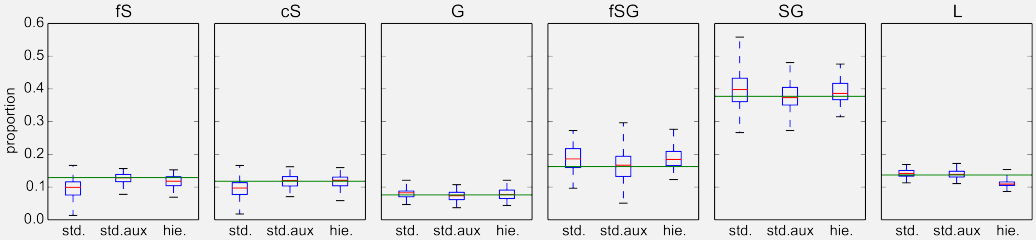


Hierarchical approach



Results (2D) - proportions

Facies proportions



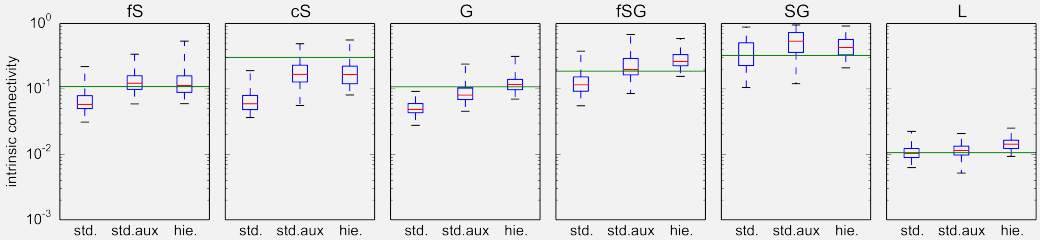
std. "standard" MPS with no auxiliary variables

std.aux "standard" MPS with auxiliary variables

hie. hierarchical MPS (no auxiliary variables)

Results (2D) - connectivity

Intrinsic connectivity indicator



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Some remarks

1) Here MPS only was used in each step. Clearly, one could also use different tools at each step (see i.e. Comunian *et al.*, 2015; or Schorpp *et al.*, 2022)

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2) Tested binary tree with a hierarchy based on textural properties. Other criteria could be tested. . .

Some remarks

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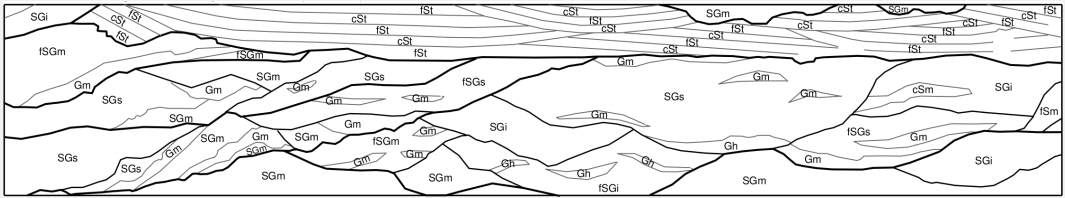
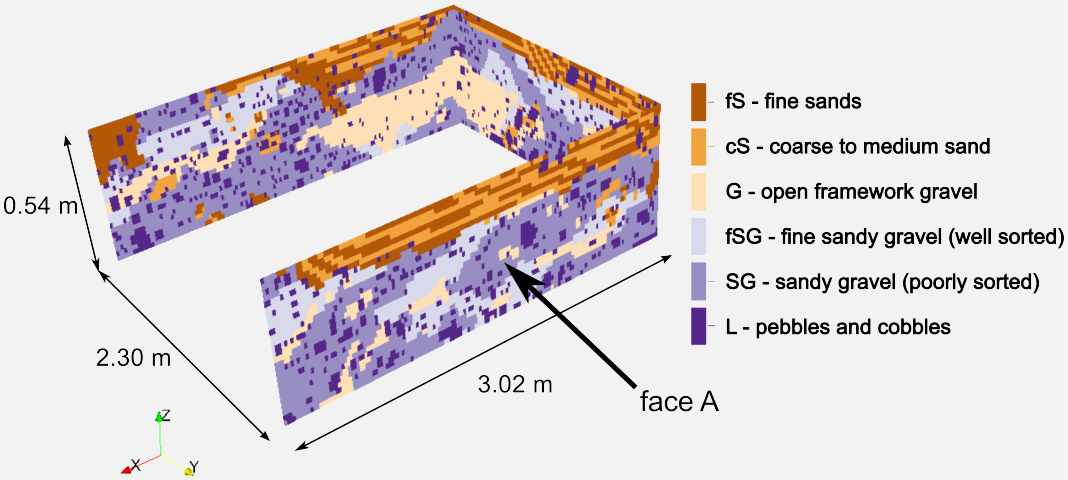
2) Tested binary tree with a hierarchy based on textural properties. Other criteria could be tested. . .
3) Instead of a binary tree, one could also use a "stratigraphic hierarchy", using nested *stratigraphic piles* (Zuffetti *et al.*, 2021; Schorpp *et al.*, 2022)



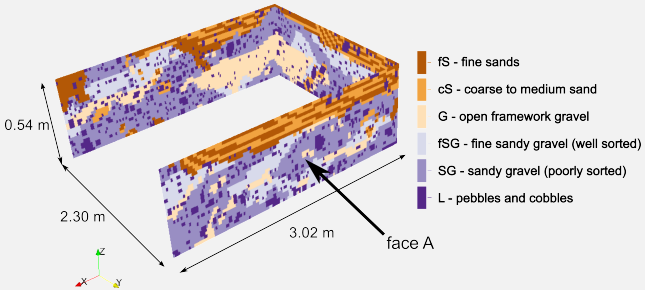
Zappa et al. (2006)

In 3D? The Zappa *et al.* data-set contains much more info...



(+ info about two other "blocks"...)

We can apply the s2Dcd approach



s2Dcd approach,

s sequential

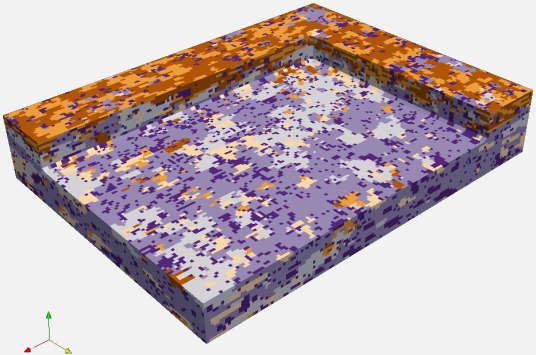
2D two-dimensional (simulations)

cd with conditioning data

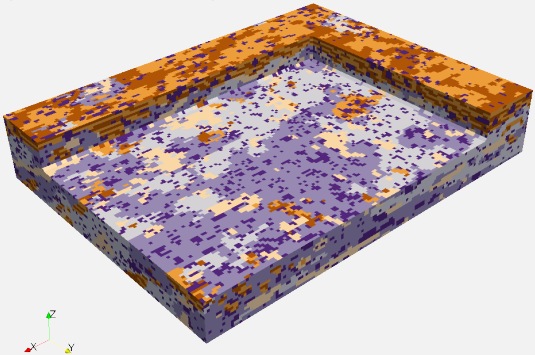
Comunian *et al.* (2012)

Preliminary results in 3D

`s2Dcd` with “standard” MPS
(with aux.variable)



`s2Dcd` with hierarchical MPS
(no aux.variable)



👉 With simpler binary TIs, one could also improve `s2Dcd` performances.

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Conclusions

The proposed hierarchical approach allows to

- further inject “soft knowledge” into the simulation
- obtain results at least comparable (or even better) than “standard” MPS with auxiliary variable maps
- cost: definition of binary tree and implementation
  (but tools exist, see i.e. https://github.com/randlab/ArchPy)

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The proposed hierarchical approach allows to

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TODO

- Test diverse hierarchies
- Improve testing in 3D (`s2Dcd` included)
- Test on other case studies


THANK
YOU!