Update to the Programs for Grid-Free Object-based Modeling of IHS Sets

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Two GSLIB style FORTRAN codes called `IHSSIM` and `IHSRAST` were developed in 2010 CCG report to implement grid-free algorithm for application of generating IHS sets of the McMurray Formation. This report explains new features added to the programs.

1. Introduction

The main idea of the grid free object-based modeling is to store all the geo-objects and geological sequences in the model without relating them to the Cartesian grid system. Implementation of grid free object-based modeling involves setting up three main components. For the application of Inclined Heterolithic Stratification (IHS) modeling in the grid free mode, two FORTRAN codes were developed; `IHSSIM`, and `IHSRAST`. `IHSSIM` is the simulation engine and the `IHSRAST` is the rasterization engine. These programs have been improved to generate better and more robust grid-free and gridded IHS facies models. These improvements include: changes in the IHS size parameterization, introducing the object hierarchy in the simulation and rasterization, conditional simulation algorithm, shale drape simulation, and more rasterization options.

2. Object Hierarchy

In the previous version of `IHSSIM`, objects were not linked together based on their hierarchy. This feature is added to the new version of `IHSSIM` and `IHSRAST`. Figure 1 shows the object hierarchy chart. Each element is this hierarchy chart carries some properties that are consistent in all the lower level elements.

In this hierarchy chart, model which contains all the information is at the top hierarchy level. Each model may contain several realizations. Within each realization there are several aggradation levels. Channel line is the next hierarchy level. Several channel lines may present at each aggradation level. Each channel line consists of several IHS sets and each IHS sets composed of five architectural elements.

All the objects coordinates are represented relative to the upper hierarchy level coordinates. This hierarchy scheme makes it easier to manipulate objects by simple changing the properties of the higher level hierarchy element. For example, each channel line is parameterized by its start location coordinates and azimuth angle of its main direction. By changing these two parameters, all the channel line's associated IHS sets can easily been transformed or rotated. This has been shown in Figure 2. Transformation and rotation of objects can be used for fast well conditioning. This is discussed in the next section.

Based on this hierarchy scheme, new keywords are introduced in the output grid-free file. Descriptions of these keywords are tabulated in Table 1.

3. Updates to the `IHSSIM` Program

`IHSSIM` program is a GSLIBE style program that is developed to generate both conditional and unconditional IHS facies realizations in the grid-free simulation mode. New parameter file for `IHSSIM` is shown in Figure 3.

One of the new features of `IHSSIM` program is the conditional simulation algorithm. It only consider three main facies for the conditioning; cross-stratified sand as the background, IHS set, and mud-filled channel. Well data should be specified in terms of intervals. Each interval is defined by a base a top elevation. **Line 1** reads the well data file name. Columns for well ID, well coordinates, interval and the facies code are specified in **line 2**.
The program checks thicknesses of conditioning data before conditioning. If the thickness is more than possible IHS thickness, then the interval is divided into several reasonable intervals. Then all data are sorted based on their top elevation. Simulation starts from the bottom of the model so the lower elevation data gets priority for simulation. All data are assigned to the appropriate aggradational level based on their top elevations. Data are also sorted based on the proximity to the source line. Well conditioning is expanded up in the paper 114 of this report.

Table 1: Updated Keywords for `IHSSIM`.

Keyword	# of Variables	Description
MODEL	7	Identifies number of realizations in the model and the model size in the format of xmin, xmax, ymin, ymax, zmin, zmax
REALIZATION	5	realization number, total number of Levels, total number of channels, total number of IHS sets, maximum number of shale drapes
LEVEL	3	Level number, level elevation, number of channel lines in this level
CHANNEL	9	Channel number, x coordinates, y coordinates, azimuth angle, irregularity angle, relative top elevation, thickness, dip angle of IHS sets, number of IHS sets
IHS_SET	2	IHS number, number of shale drapes
{	0	Indicates the start of IHS parameters block
}	0	Indicates the end of IHS parameters block
BODY	12	Shows (x,y) coordinates of top six control points of IHS body
BOX	4	Indicates the IHS bounding box corner relative coordinated in the format of xmn xmx ymn ymx
ANCHOR	2	relative anchor points coordinates in the format of xm ym
PROFILE	2	Profile top slope, and bottom slope
TOP_SHALE	1	Top shale thickness
BRECCIA	1	Breccias thickness
DRAPE	10	Indicates (x,y) relative coordinates of top four points of shale drape, and thickness at top, and the vertical length

IHS Size

In the previous `IHSSIM` program, IHS set size was specified by meander wavelength, meander amplitude to wavelength ratio, and width to wavelength ratio. For some cases where small meander wavelength is specified, unrealistic IHS sets may be generated.

Meander wavelength is closely related to the channel bankfull width. According to the study by Leeder (1973), point bar width (in this case, meander wavelength) is almost eleven times of the channel bankfull width in the meander fluvial channels. The channel width can be calculated by the IHS thickness and the dipping angle.

In new program, meander wavelength is replaced by the channel sinuosity. **Line 9** in the parameter file asks for the sinuosity of channel in terms of its severity. Value of -1 refers to the lowest possible sinuosity and 1 shows highest possible sinuosity. Zero sinuosity in this program relates to the case where the meander wavelength of channel is exactly eleven times of the channel width. This ratio changes linearly between 7 to 15 for the highest and the lowest sinuosity cases, respectively.

Other new IHS set size parameters called IHS length and width are specified in the **line 10** and **11**. These two parameters are the replacement for the amplitude to wavelength ratio and width to wavelength ratio in the previous version.

Shale drape placement

According the Thomas et al (1987), three different types of shale drapes are expected to exist in the IHS sets: 1) irregular discontinuous, 2) distal attached discontinuous and 3) continuous (see Figure 4).

In the previous version of `IHSSIM` all the shale drapes are placed parallel to each other along the IHS strike direction. Discontinuous and distal attached drapes can also be generated in the new version by selecting option 1 in **line 18** of the `IHSSIM` parameter file. Figure 5 shows examples of single IHS sets generated with two shale drape options.

4. Update to the IHSRAST Program

IHSRAST is the rasterization engine that has been developed to generate the gridded facies model of IHS sets. Figure 6 shows the default parameter file for IHSRAST.

The only new feature added to the IHSRAST program is to select which architectural elements to rasterize. In **line 6** of the parameter file where it asks for the facies code, if a negative value is specified for an element, then that element is not rasterized and therefore not included in the final gridded model. This option enables the user to generate models that has selected architectural elements. For example if one is interested to generate a model including only meander channels, then this would be possible by specifying all the architectural elements facies code other than the CHF by a negative values. Figure 7 shows some examples of new rasterization features in the IHSRAST program.

Future Work

Some future works can be expected to improve both IHSSIM and IHSRAST programs. One of them would be to add an option to simulate isolated IHS sets. This should be very useful for generating training images. The other future work is to change the channel line parameterization from a single straight line to multiple connected lines. This will very helpful for well conditioning as it induces more flexibility to place a channel line.

References

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Leeder, M.R. 1973. Fluviatile fining-upward cycles and magnitude of palaeochannels. Geological Magazine, v. 110, p. 265–276.

Thomas, R.G., Smith, D.G., Wood, J.M., Visser, J., Calverley-Range, E.A. and Koster, E.H., 1987, Inclined heterolithic stratification - terminology, description, interpretation and significance. Sedimentary Geology, v. 53, pp. 123-179.

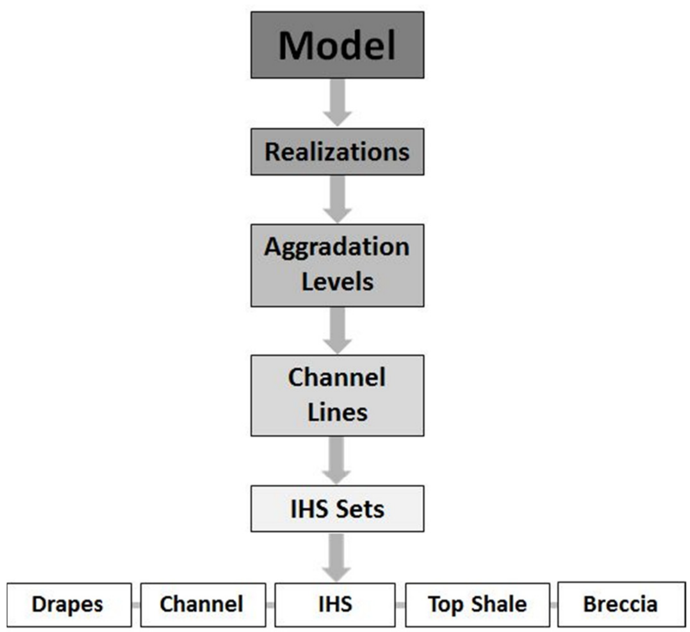

Figure 1: Object Hierarchy chart used in the IHSSIM and IHSRAST programs.

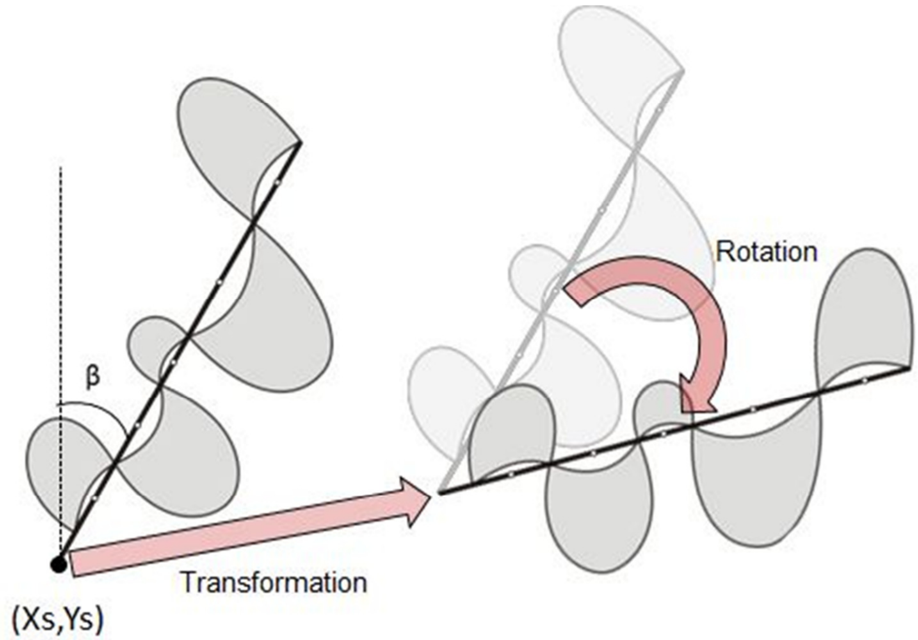

Figure 2: Transformation and Rotation of IHS sets by changing the channel line parameters.

Parameters for IHSSIM
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Line	START OF PARAMETERS:	
1	well.dat	-file for well data
2	1 2 3 4 5 6	- column for well ID, x, y, ztop, zbot, facies code
3	ihssim.gfm	-file for output grid-free model
4	0.0 5000.0	-xmn, xmx
5	0.0 5000.0	-ymn, ymx
6	0.0 50.0	-zmn, zmx
7	2500 100 0 10	-CH source: mx, stdevx, my, stdevy
8	0 30	-CH azimuth angle: m, stdev
9	0	-CH sinuosity: 1=highest, -1=lowest
10	500 50	-IHS Length: m, stdev
11	500 50	-IHS width: m,stdev
12	20 5	-IHS thickness: m, stdev
13	10 2	-IHS dip: m, stdev
14	2000	-max. number of accretion surfaces
15	4 15 25 35 45	-number of levels, level elevations
16	5 7 5 10	-number of channel in each level
17	0.1 0.2 0.3 0.4	-shale drape frequency in each level
18	1	-shale drape option: 1=realistic, 2=,parallel
19	10 5	-top shale thickness(% of IHS thickness): m, stdev
20	10 5	-breccia thickness(% of IHS thickness): m, stdev
21	0.6 0.3 0.1	-profile probability for: sigmoidal, convex-up, concave-up
22	75079	-random number seed
23	1	-number of realization to generate

Figure 3: Parameter file for the updated version of `IHSSIM`.

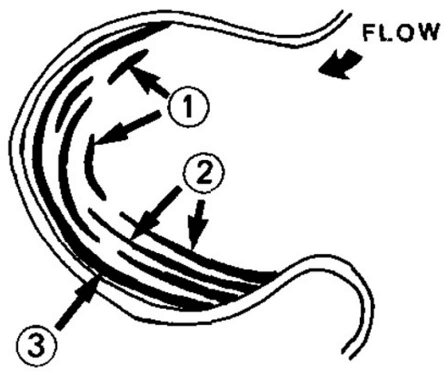

Figure 4: Plan view of a single IHS set showing possible shale drape configurations: 1) irregular discontinuous, 2) distal attached discontinuous and 3) continuous (Thomas et al (1987)).

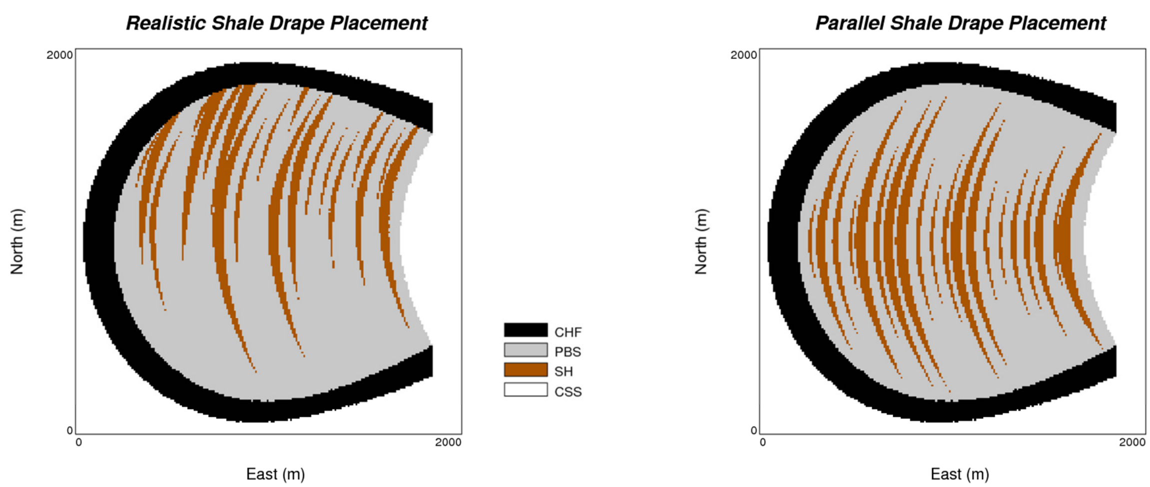

Figure 5: Realistic shale drape placement (left) and the parallel shale drape placement (right).

Parameters for IHSRAST
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Line	START OF PARAMETERS:	
1	Ihssim.gfm	-file for grid-free model
2	Ihsrast.out	-file for output gridded model/cross sections
3	500 5 10	-nx,xmn,xsiz
4	500 5 10	-ny,ymn,ysiz
5	50 0.5 1	-nz,zmn,zsiz
6	0 1 2 3 4	-facies code for CSS,SH,PBS,BR, and CHF (negative codes to skip rasterization of the element)
7	1	-realization number
8	2 40	-rasterization option(1=3D model,2=xy slice,3=xz slice,4=yz slice) , slice number if > 1
9	5 5 1	-discretization in x,y,and z if rasterization option > 1

Figure 6: Parameter file for the `IHSRAST`.

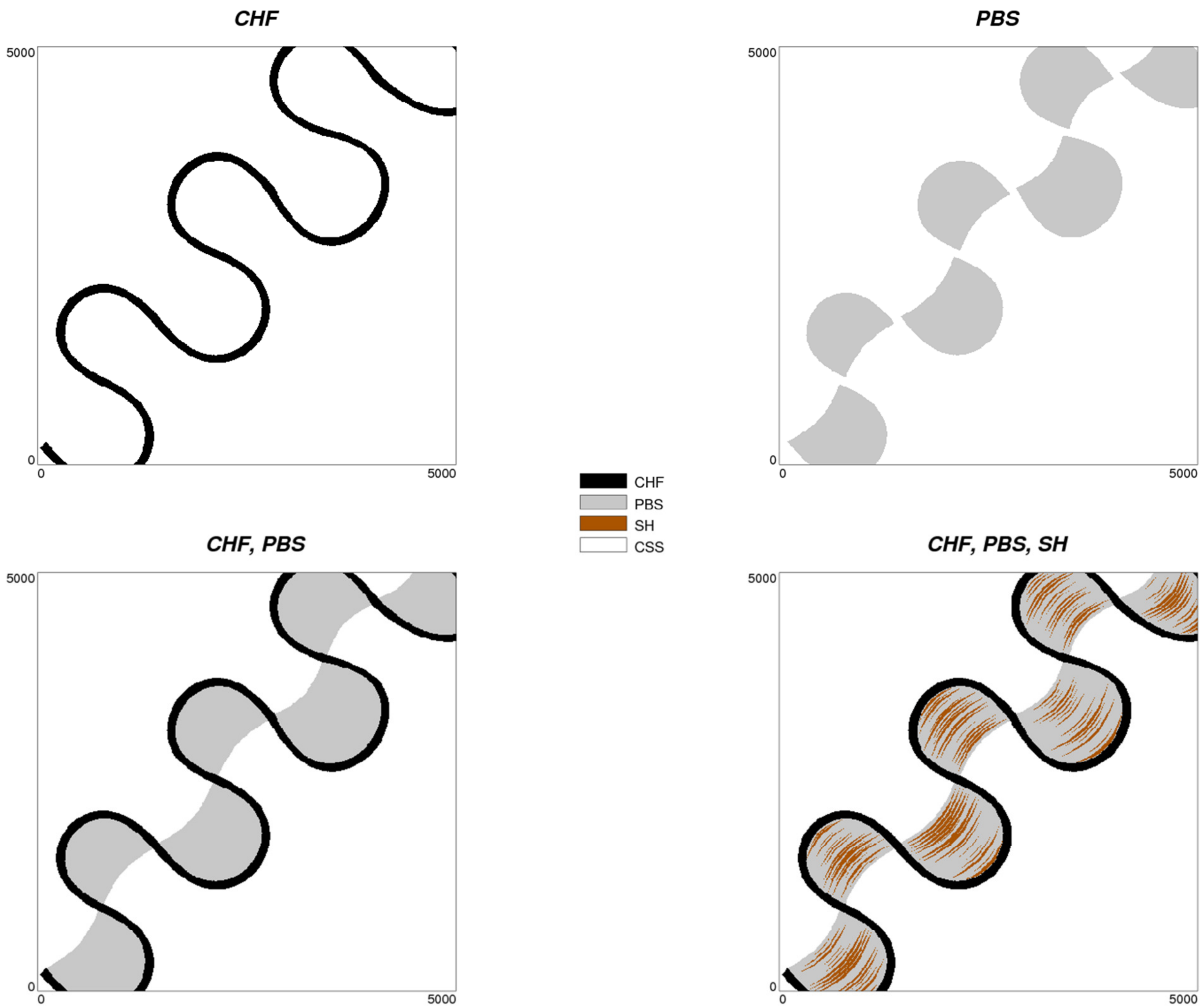

Figure 7: Rasterization option added to the IHSRAST program to rasterize specific architectural elements from the grid-free model.