UDOMORE Depth

User Manual - Version 2016

SEISQUARE

Attention :

For any additional information regarding UDOMORE
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1 Introducing UDOMORE Depth

This section describes target users, target operations, and key features of UDOMORE Depth.

1.1 Target users

UDOMORE Depth provides Geophysicists with seamless control on velocity and structural depth modeling in the Petrel* E&P platform. This plug-in:

- Makes market-leading stochastic technology seamlessly accessible to the geoscience community thanks to a clean-cut, user-friendly interface;
- Enables robust, interactive control on velocity model parameterization;
- Delivers best estimated structural depth maps with maximum accuracy and reliable, quantified, confidence intervals;
- Saves time thanks to parallel computing capability.

1.2 Target operations

UDOMORE Depth matters when an asset team needs to derive structural depth models with maximum possible accuracy and reliable confidence intervals in view of prospect ranking and implementing new exploration/development wells.

1.3 Key features

1.3.1 Input data/parameters

2D time interpretation maps (+ attached uncertainty)
Well depth markers (+ attached uncertainty)
Interval velocity trends/residuals (+ attached uncertainty)

1.3.2 Computations

Simultaneous (multilayer) computations of interval velocity maps + depth maps + uncertainty maps. Advanced algorithms applied to co-kriging depths of seismic interpreted horizons with seismic time related external drifts, and under Bayesian control of external drift coefficients.

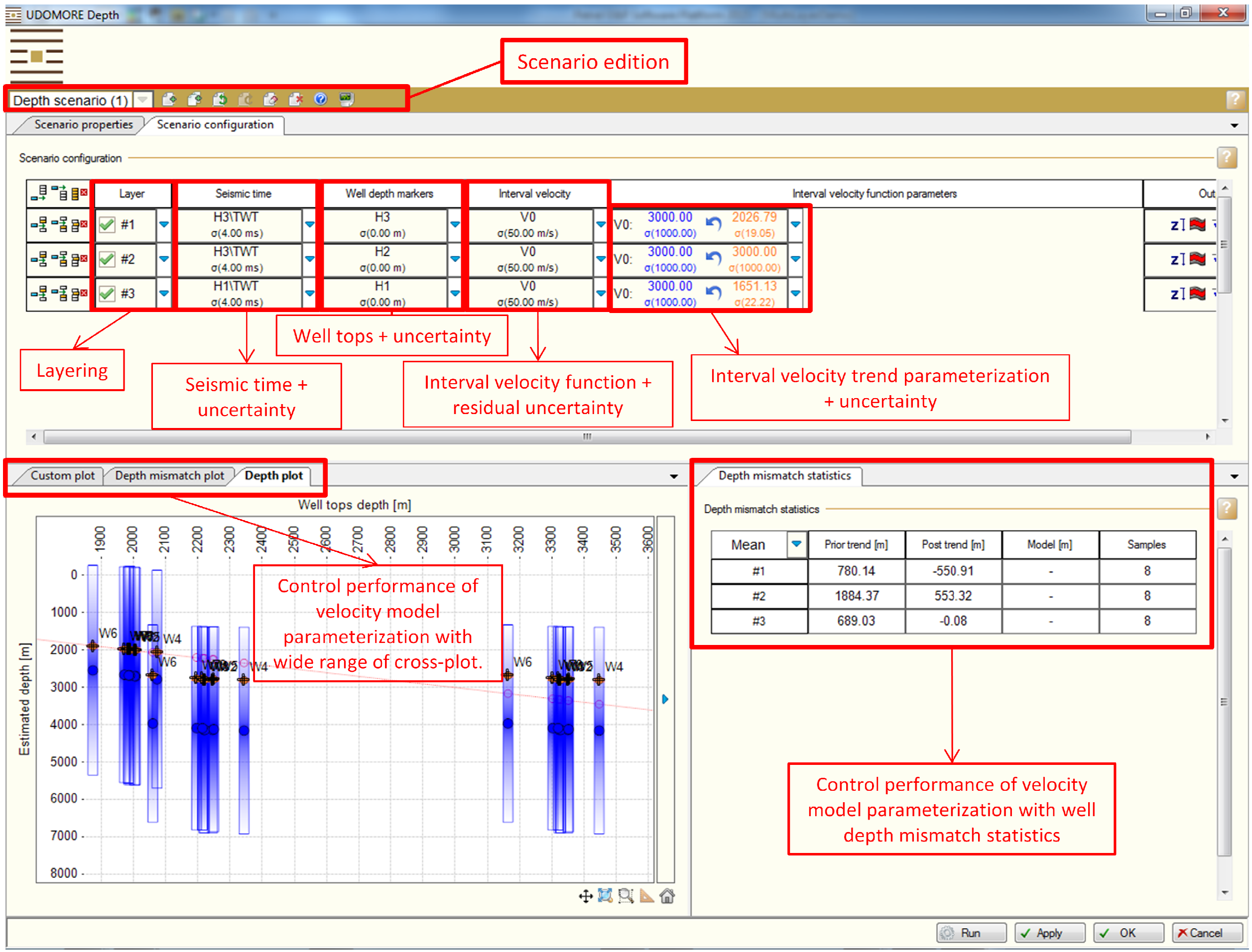
1.3.3 Output

Prior depth trend maps computed with prior parameters (not tied to the wells)
Post depth trend maps computed from post parameters (multilayer + not tied to the wells)
Post depth residuals maps computed from post parameters (multilayer)
Estimated depth maps (multilayer + tied to the wells)
Estimated depth standard deviation maps (multilayer)
Multiple depth realizations inside estimated depth standard deviation maps
Resulting interval velocity maps (multilayer + not tied to the wells)
Resulting interval velocity standard deviation maps (multilayer)
Estimated interval thickness maps (multilayer + tied to the wells)
Estimated interval thickness standard deviation maps (multilayer)

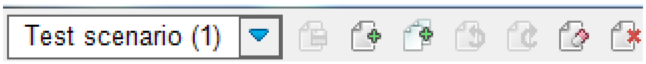
2 Introducing the user interface

This section delivers an overview of the UDOMORE Depth user interface.

2.1 Overview



2.2 Scenario edition



2.2.1 Create a scenario

Create alternative UDOMORE Depth scenarios. Note that all scenario configuration data + parameters + results are saved in your Petrel* E&P project under your scenario name.

2.2.2 Duplicate selected scenario

Duplicate Target Configuration from an existing scenario. Note that all scenario configuration data + parameters are saved in the UDOMORE module and actual results are saved in your Petrel* E&P project under your duplicated scenario name.

2.2.3 Undo/Redo

Undo to cancel changes applied on scenarios. Redo to restitute changescanceled by undo command. Note that all scenario editions (configuration data + parameters are saved in the UDOMORE module and actual results are updated in your Petrel* E&P project under your scenario name.

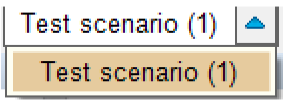
2.2.4 Reset a scenario

Edit existing UDOMORE Depth scenarios. Note that all scenario editions (configuration data + parameters + results) are updated in your Petrel* E&P project under your scenario name.

2.2.5 Delete a scenario

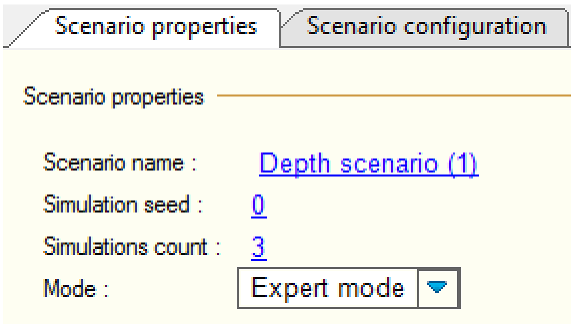
Delete existing UDOMORE Depth scenarios. Note that one a scenario is deleted, all scenario configuration data + parameters are deleted. However, results remain available in your Petrel* E&P project.

2.2.6 Retrieve a scenario



Retrieve existing UDOMORE Depth scenarios. All scenario editions (configuration data + parameters + results) are automatically refreshed in the user interface.

2.3 Scenario properties



2.3.1 Scenario name

Enter/edit your scenario name. Scenario names help you keep track of and benchmark alternative UDOMORE Depth scenarios. Note that all scenario name editions are updated in your Petrel* E&P project.

2.3.2 Simulation seed

Enter simulation seed values to "root" the depth simulations you wish to perform. Changing seed values enables you to compute independent sets of simulations. One given scenario will produce one given set of simulations.

2.3.3 Simulations count

Enter the number of depth simulations you wish to perform. By default, the number of simulations is set at 3. This enables initial testing of your simulations. Experience shows that performing 100 to 500 simulations is a good approach for further analysis.

2.3.4 Mode

Select the mode in which you wish to operate UDOMORE Depth: "Safe" mode or "Expert" mode. The difference between "Safe" and "Expert" modes lies in parameterization and storage capabilities. Note that by default, the plug-in is set in "Safe" mode.

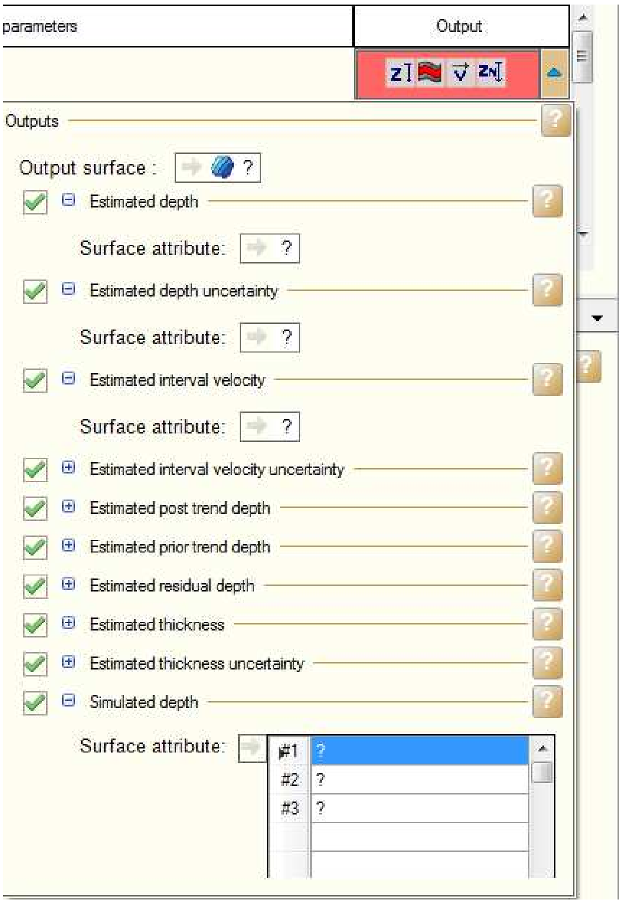
- Parametrization capability: in "Safe" mode, the parameterization capability is restrained in order to constrain the modelling process; in "Expert" mode, the parameterization capability is much wider, meaning there is less constraint on the modelling process. For details on parameterization capabilities in "Safe" and "Expert" models, please see table below:

	Safe mode		Expert mode		
Parameter	Min	Max	Min	Max	Unit
A	-10000	+10 000	-1e11	+1e11	(1)
σ	0	+1 000	0	+1e11	
B	-10000	+10 000	-1e11	+1e11	(m/s)
σ	0	+1 000	0	+1e11	
V0	0	+10 000	0	+1e11	(m/s)
σ	0	+1 000	0	+1e11	
Vint0	0	+10 000	0	+1e11	(m/s)
σ	0	+1 000	0	+1e11	
K	-4	+4	-1 000	+1 000	(1/s)
σ	0	+4	0	+100	
alpha	-20000	+20 000	-1e11	+1e11	(m/s-²)
σ	0	+10 000	0	+1e11	

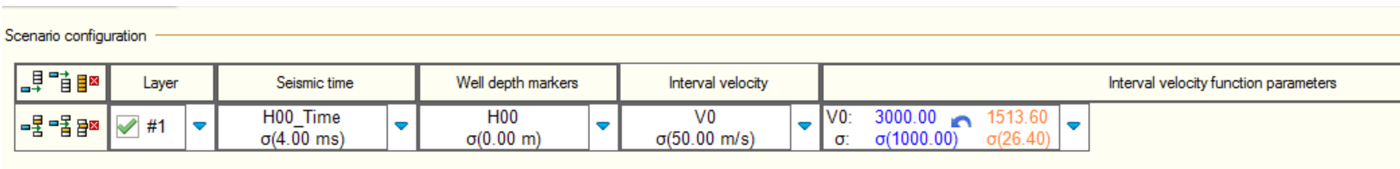
Sigma time	0.1	1 000	1^{e-11}	$+1^{e11}$	(ms)
Spatial range	1	10 000 000	1^{e-11}	$+1^{e11}$	(m)
Sigma depth	0	10 000	0	1^{e11}	(m)

Note: UDOMORE Depth automatically translates Units according to your Petrel project.

- Storing outputs in your Petrel* E&P project: in “Safe” mode, UDOMORE Depth outputs are stored by default in Petrel as Surface Attributes attached to each layer that is considered for depth conversion; in “Expert” mode, UDOMORE Depth outputs may be stored within any designated Surface, as any designated Attribute.



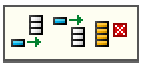
2.4 Scenario configuration



- Specify layering.
- Enter layer names (optional).

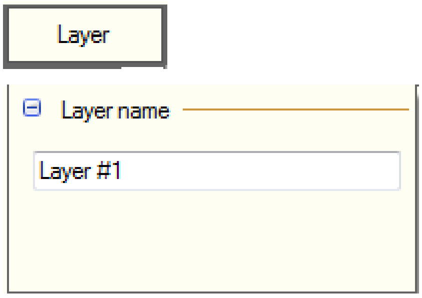
- Upload input data: TWT maps + Well tops if available.
- Select and parameterize interval velocity functions (incl. seismic velocity or V0 maps if relevant).
- Control performance of the velocity model with robust cross-plots and statistics.

2.4.1 Layering



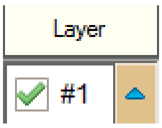
Specify layering with the insert below / insert above / delete buttons. Note that UDOMORE Depth performs simultaneous, multilayer parameterization of interval velocity functions. This means that any parameterization update on any given layer will impact the entire velocity model.

2.4.2 Layer names



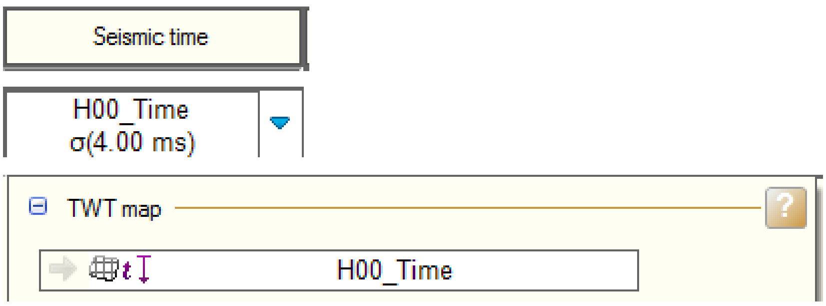
Enter the name you wish to associate to your layer (optional for ease of use only).

2.4.3 Target layers



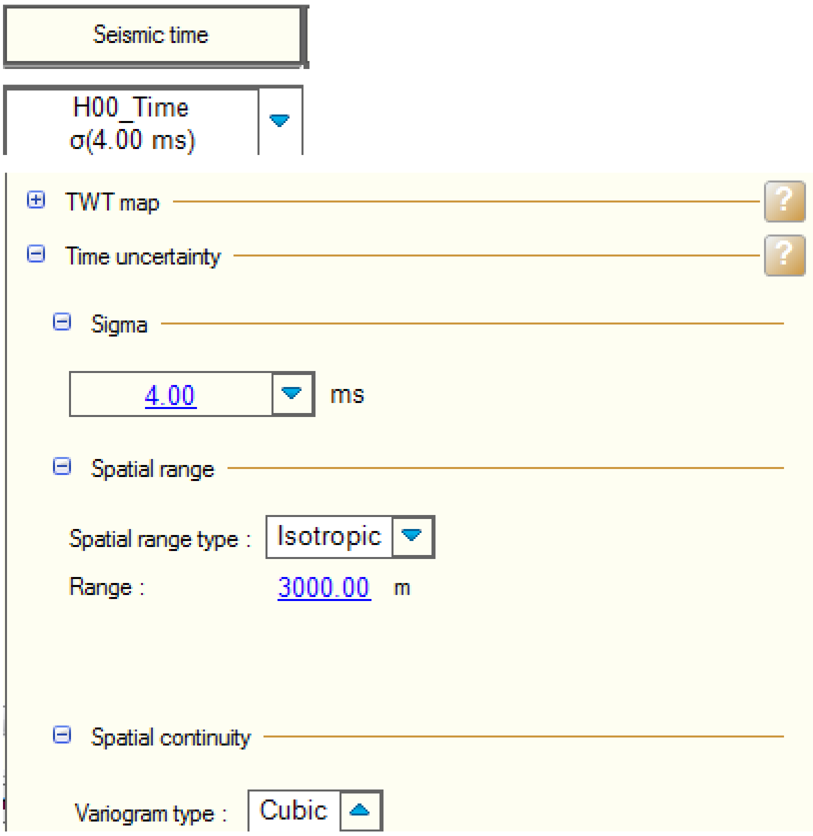
Select/deselect target layers. The selected target layers are displayed on the cross-plots.

2.4.4 Seismic time



Upload 2D seismic time interpretation maps associated to considered layers. Your 2D seismic time interpretation maps must be available in your Petrel* E&P project as TWT attributes to considered layers (Petrel template = General or Elevation Time. See Annex 1 for more information).

2.4.5 Seismic time uncertainty

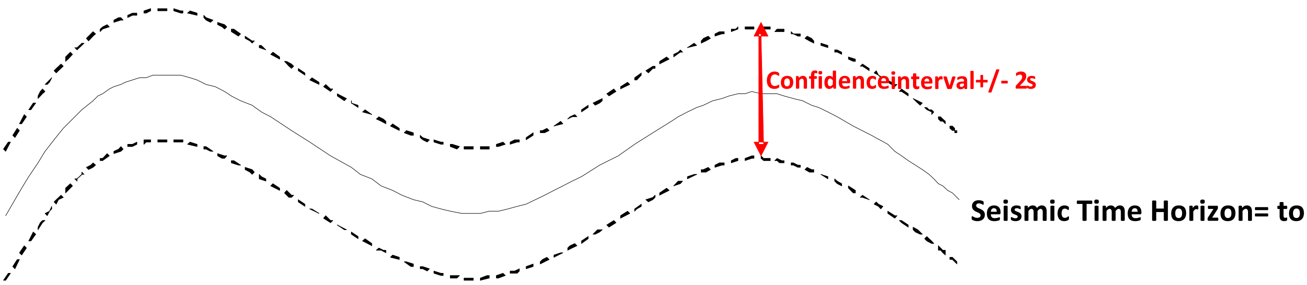


Time picking and calibration errors occur in the context of manual and/or automatic time interpretation processes. UDOMORE Depth enables you to handle these errors consistently in the context of the depth conversion process, and derive best estimate velocity and structural depth models with reliable confidence intervals.

- Non-expert users may rely on default time uncertainty values. Sigma value is set at 2 mstwt constant standard deviation (i.e. +/- 4 mstwt time interpretation error); isotropic spatial range is set at 3000 meters; spatial continuity is defined with a cubic variogram.
- Users with expertise may adjust time uncertainty values: sigma, spatial range, and spatial continuity.

2.4.5.1 Seismic time sigma

Sigma value corresponds to time interpretation uncertainty.



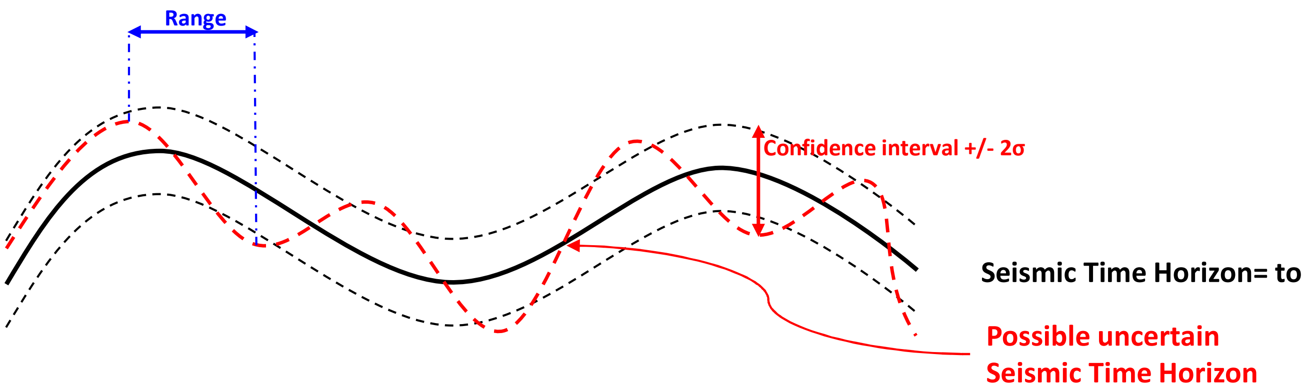
You have two options:

- Enter a constant sigma value (mstwt) based on your a priori knowledge about the subsurface.
- Enter a variable sigma value by uploading a time interpretation uncertainty map from your Petrel* E&P project (Petrel template = General or Thickness Time, See Annex 1 for more information).

For additional information, see Address seismic time sigma.

2.4.5.2 Seismic time spatial range

Spatial Range values corresponds to the seismic time sigma correlation distance.



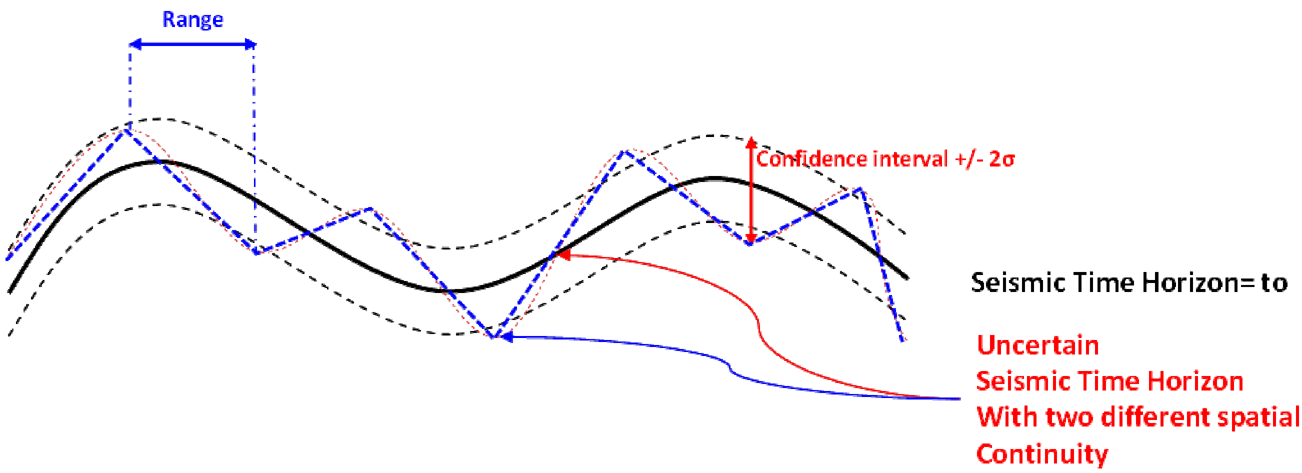
You have two options:

- Enter an isotropic range: same correlation distance in every direction
- Enter an anisotropic range: different correlation distances for the two main directions + azimuth that fits the geology of the target you are working on.

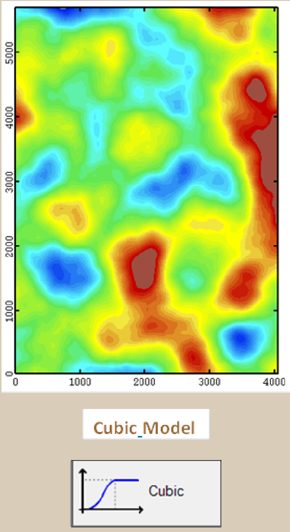
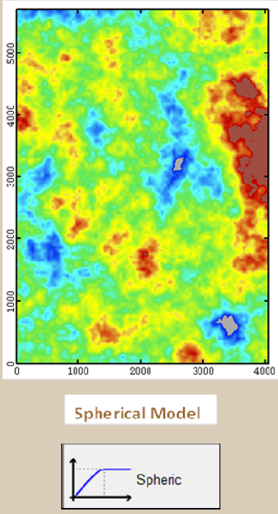
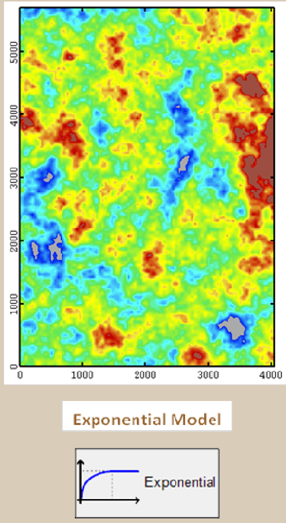
For additional information, see Address seismic time spatial range.

2.4.5.3 Seismic time spatial continuity

Spatial Continuity corresponds to the variogram model applied to the seismic time sigma correlation distance.



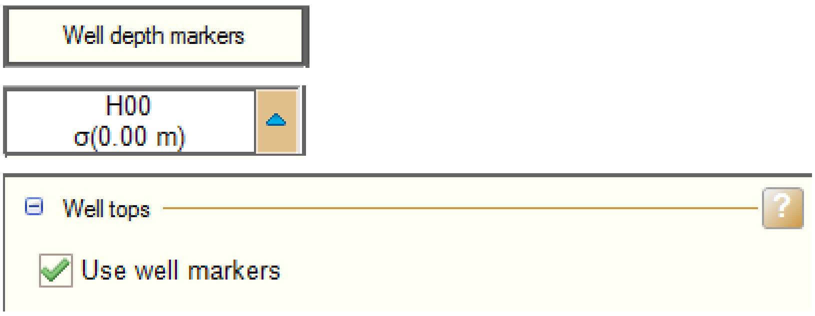
You have three options:

Cubic Model	Spherical model	Exponential model
		

For additional information, see Address seismic time spatial continuity.

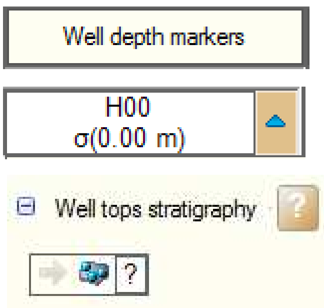
2.4.6 Well depth markers

2.4.6.1 Option to use well depth markers



UDOMORE depth is able to performing computations with and without well depth markers. To upload well tops, check the “Use well markers” box.

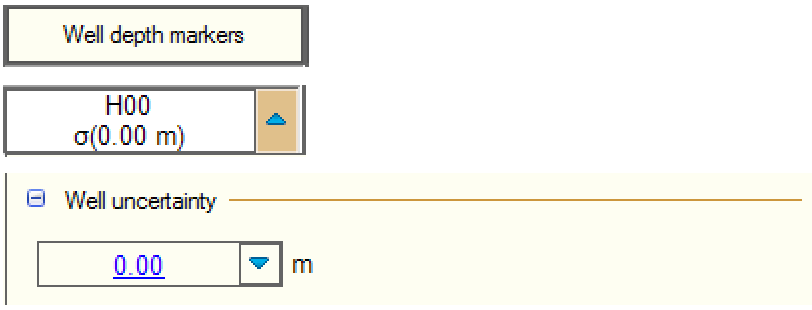
2.4.6.2 Well tops stratigraphy



Upload well tops associated to the considered layers. Your well tops must be available in your Petrel* E&P project with a stratrigraphy linked to the relevant horizon. Please also note the following recommendations before uploading well tops into UDOMORE Depth:

- Well tops must be correctly linked to the well trajectory. Verify (and possibly make adjustments) in Petrel* (well filter folder), using “Connect to Trace”.
- Well marker data must not be duplicated (e.g. well duplicate / side-track). Verify (and possibly make adjustments) in Petrel* (well filter folder), using « Well Tops Spreadsheet ».

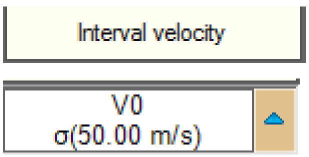
2.4.6.3 Well tops uncertainty

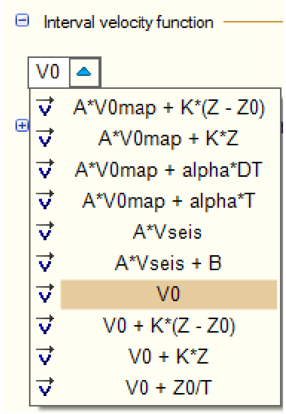


Depth errors may occur in the context of well depth interpretation. UDOMORE Depth enables you to handle these errors consistently in the context of the depth conversion process, and derive best estimate velocity and structural depth models with reliable confidence intervals.

- When confident in well depth interpretations, users may rely on default well tops uncertainty values (constant uncertainty value is set at 0).
- When in doubt with well depth interpretations, users may adjust well uncertainty values: constant uncertainty corresponds to uncertainty on well tops (meters or feet) that is constant in space between well tops; variable uncertainty corresponds to uncertainty on well tops (meters or feet) that varies between well tops (Petrel template = Thickness Depth, See Annex 1 for more information).
- For additional information, see Address well tops uncertainty.

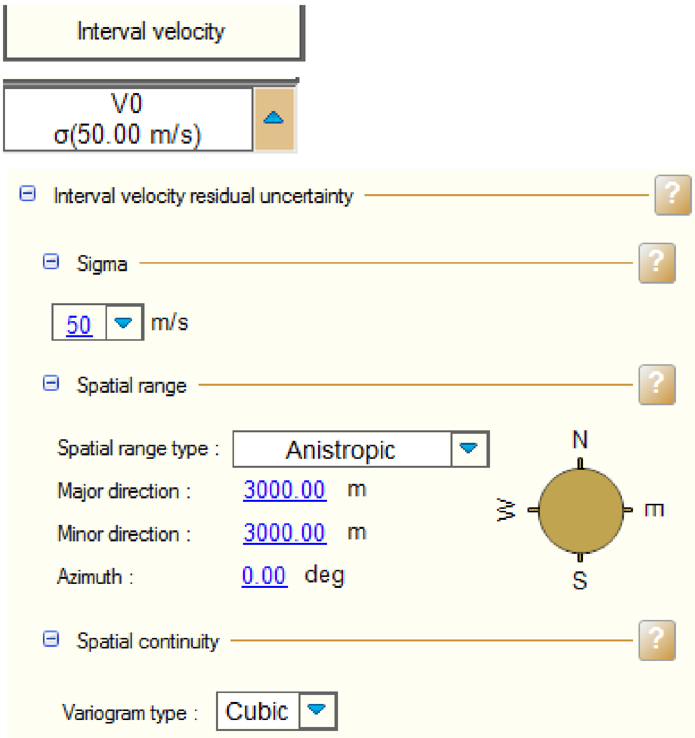
2.4.7 Interval velocity function





Select relevant interval velocity functions for each layer from the scroll down menu. Selecting interval velocity functions is a choice based on your a priori knowledge about the geology (e.g. previous analysis of well velocity profiles). For additional information, see Select interval velocity function. Contact Seisquare support if you would like to see additional functions added to the existing list.

2.4.8 Interval velocity residual uncertainty



Velocity functions are never perfect representations of subsurface reality: there is always uncertainty on velocity function residuals. UDOMORE Depth consistently addresses interval velocity residual uncertainties in order to derive best estimate velocity and structural depth models with reliable confidence intervals.

- Non-expert users may rely on default interval velocity residual uncertainty parameters: constant sigma value is set at 20 m/s standard deviation (i.e. +/- 40 m/s interval velocity residual variations); isotropic spatial range is set at 3000m; spatial continuity is defined with a cubic variogram.

- Users with expertise may adjust interval velocity residual uncertainty parameters: sigma, spatial range, and spatial continuity.

2.4.8.1 Interval velocity residual uncertainty sigma

Sigma value corresponds to interval velocity residual uncertainty. You have two options:

- Enter a constant sigma value (meter/s or feet/s) based on your a priori knowledge about the subsurface.
- Enter a variable sigma value by uploading a velocity uncertainty map from your Petrel* E&P project (Petrel template = General or Velocity interval).

For additional information, see Address interval velocity residual uncertainty sigma.

2.4.8.2 Interval velocity residual uncertainty spatial range

Spatial Range values corresponds to the interval velocity sigma correlation distance.

You have two options:

- Enter an isotropic range: same correlation distance in every direction
- Enter an anisotropic range: different correlation distances for the two main directions + azimuth that fits the geology of the target you are working on.

For additional information, see Address interval velocity residual uncertainty spatial range.

2.4.8.3 Interval velocity residual uncertainty spatial continuity

Spatial Continuity corresponds to the variogram model applied to the interval velocity sigma correlation distance.

You have three options:

<table>
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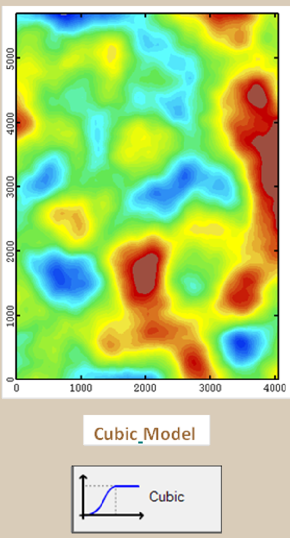
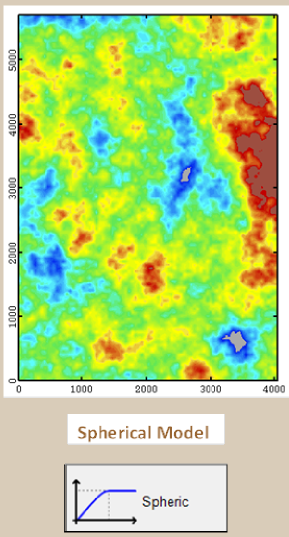
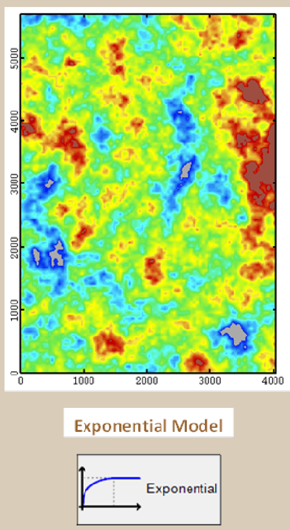
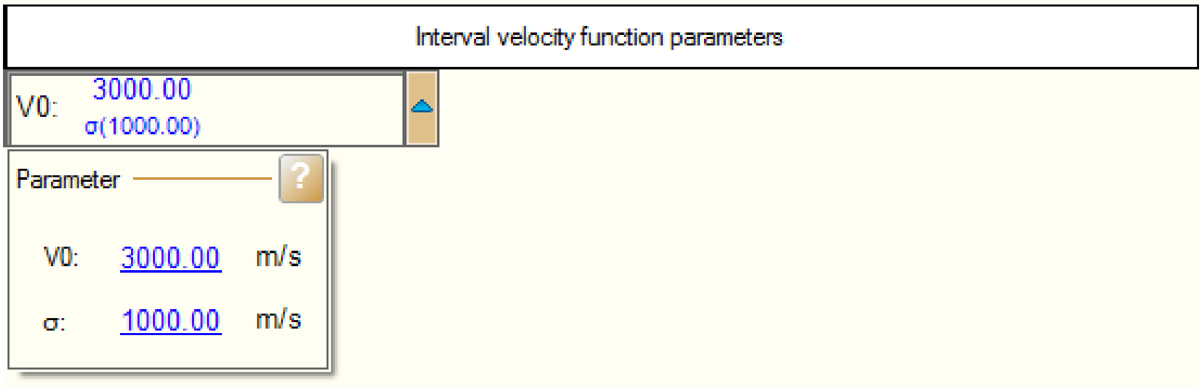
<tr><td>
</td><td>
</td><td>
</td></tr>
</table>

For additional information, see Address interval velocity residual uncertainty spatial continuity.

2.4.9 Interval velocity function parameters



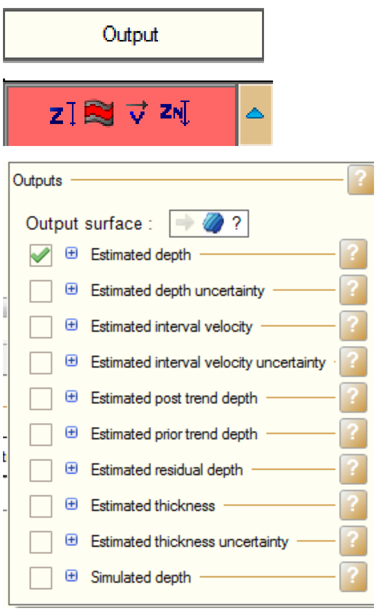
Velocity functions are never perfect representations of subsurface reality: there is always uncertainty on the velocity function trend. UDOMORE Depth consistently addresses interval velocity trend uncertainties in order to derive best estimate velocity and structural depth models with reliable confidence intervals.

- Once you have selected an interval velocity function for a given layer, enter “a priori” interval velocity function parameter values to define your interval velocity trend. These a priori values are based on your knowledge about the subsurface. If there is no well data available, it is recommended to rely on a priori knowledge about the geology; if there is well data available, it is recommended to rely on measured interval velocity. Once you have entered a priori interval velocity function parameter values, enter the corresponding a priori uncertainty values (sigma), also based on your knowledge about the subsurface.

- Once a priori parameterization is performed, click on the blue arrow, and UDOMORE Depth automatically computes “post” interval velocity function parameters (associated with minimized well depth mismatch values).

For additional information, see Parameterize interval velocity function trend.

2.4.10 Outputs

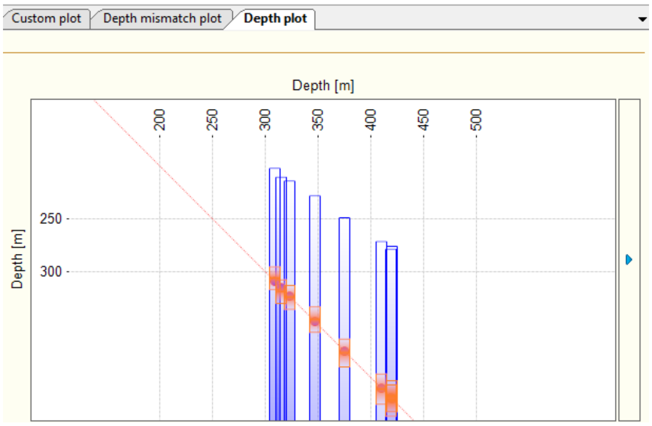


Select the outputs you wish to compute for a given layer. All outputs are computed based on “post” velocity model parameterization (except for the “prior depth trend” maps, which are computed with “prior” velocity model parameterization). Once computed, all outputs are available in your Petrel* E&P project as horizon attributes (except for the “depth realizations”, which are available as independent surfaces). Note: if you select “depth realizations”, make sure you’ve entered relevant parameters in the “Scenario properties” pane. In particular, the number of simulations you choose to perform will affect computing time. For additional information, see list.

2.5 Cross-plots

Interactively anticipate on and control the performance of your velocity model, with a smart set of cross-plots: depth plot; depth mismatch plot; and custom plots.

2.5.1 Depth plot



The depth plot is set in the depth domain for X and Y axes:

- Measured depth in red along the first bisector line;
- Prior trend depth in blue vs. measured depth with associated uncertainty range;
- Post trend depth in orange vs. measured depth with associated uncertainty range.

The depth plot can be used to:

- Control your velocity model: try to align post trend depth around first bisector line (or Measured Depth);
- Measure the impact of velocity model parameterization by comparing prior and post trend depth.

2.5.2 Depth mismatch plot

The depth mismatch plot is set by default as well index vs. horizon index:

- Prior depth mismatch in blue;
- Post depth mismatch in orange.

The depth mismatch plot can be used to:

- Spot layers with important residuals or a systematic bias (too deep/shallow);
- Observe specific bias for one or several wells along different layers.

2.5.3 Custom plot

The custom plot is set by default as a basemap with well positions. You may customize this cross-plot according to your operational needs.

2.6 Depth mismatch statistics

Max	Prior trend [m]	Post trend [m]	Model [m]	Samples
#1	416.62	2.12	-	8
#2	1076.84	42.70	-	8
#3	-	-	-	0

Interactively anticipate on and control the performance of your velocity model, with robust spatial statistics. The depth mismatch table displays:

- Experimental statistics computed on depth mismatches between well depth marker values and estimated prior/post depth trend values, to quantify the level of performance of your velocity model;

- Modeled RMSD statistics correspond to the standard deviation of depth residuals (i.e. local depth residuals around estimated depth trend values), and enables to quantify the level of confidence on your estimated depth trend maps.

Tips on depth mismatch statistics:

- Experimental mean post depth trend values must converge towards 0 (i.e. average depth mismatches = 0);

- Experimental RMSD (standard deviation) post depth trend values must converge towards the lowest possible values;

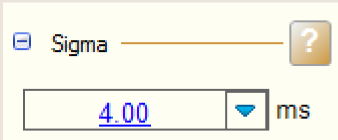
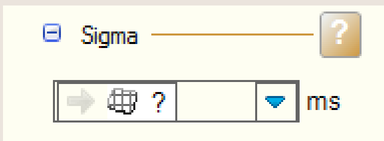
- Modeled RMSD statistics must be slightly higher than experimental RMDS (standard deviation) post depth trend values.

Note: depth mismatch statistics are relevant only if 10 wells or more are involved in your depth conversion scenario. With less than 10 well markers (or “Samples”), statistics can only be treated as informative. For additional information, see Control interval velocity function parameterization.

3 Address seismic time uncertainty

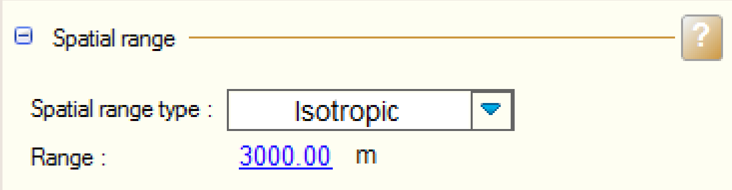
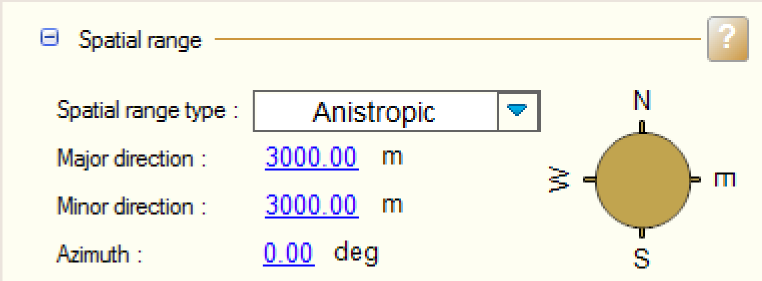
This section specifies how UDOMORE Depth consistently addresses seismic time uncertainty: sigma, spatial range, and spatial continuity.

3.1 Address seismic time sigma

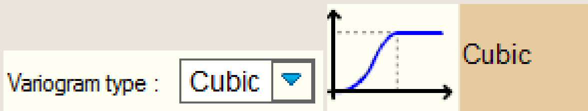
Constant vs. variable sigma	
Constant	Constant seismic time uncertainty corresponds mostly to time picking and calibration uncertainty that is constant in space (standard deviation). Example: 1mstwt standard deviation = +/- 2 mstwt time picking (or calibration) error. Define constant seismic time uncertainty values based on analysis from your interpretation team. Click here to enter constant seismic time uncertainty values: 
Variable	Variable seismic time uncertainty corresponds mostly to time picking and calibration uncertainty that varies in space (standard deviation). Example: at the top of your structure, 1mstwt standard deviation = +/- 2 mstwt time picking (or calibration) error, and on the flank of your structure, 4 mstwt standard deviation = +/- 8 mstwt time picking (or calibration) error. Produce a seismic time uncertainty map (with variable seismic time uncertainty values) in your Petrel* E&P project, based on analysis from your interpretation team. This map must be available in your Petrel* E&P project as an attribute to the relevant horizon. Click here to upload your uncertainty map (Petrel template = General or Thickness Time, See Annex 1 for more information) : 

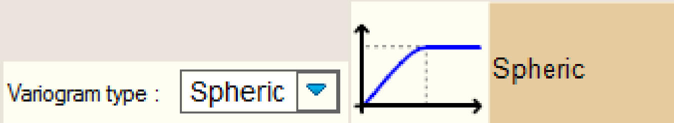
3.2 Address seismic time spatial range

Spatial range	
Isotropic	Spatial range correspond to the size/shape of your main target structure: in the case of isotropic range, your structure has an approximately circular shape, with the same distance in every direction. Define Isotropic (X) spatial range values (meters / feet) based on analysis from your interpretation team and a priori geological knowledge about the subsurface. Click here to enter

<table>
<tr><td></td><td>isotropic (X) range:
</td></tr>
<tr><td>Anisotropic</td><td>Spatial range correspond to the size/shape of your main target structure: in the case of anisotropic range, your structure has an approximately ellipsoidal shape, with the two different distances in the two main directions, and, possibly, an azimuth. Define anisotropic (X,Y) spatial range values (meters / feet) based on analysis from your interpretation team and a priori geological knowledge about the subsurface. Click here to enter anisotropic (X,Y) ranges:
</td></tr>
</table>

3.3 Address seismic time spatial continuity

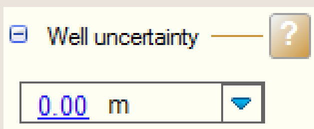
<table>
<tr><td colspan="2">Spatial continuity</td></tr>
<tr><td>Cubic variogram</td><td>Spatial continuity corresponds to the roughness factor of your main structure: in the case of a cubic variogram, the roughness factor is small. It is recommended to select cubic variogram when your seismic time data set presents strong spatial continuity between data values. Also, cubic variograms are very stable for kriging computations and very relevant for depth simulations.

For additional information, see Cubic variogram.</td></tr>
<tr><td>Spheric variogram</td><td>Spatial continuity corresponds to the roughness factor of your main structure: in the case of a spheric variogram, the roughness factor is medium. It is recommended to select cubic variogram when your seismic time data set presents medium spatial continuity between data values (i.e. the experimental variogram of the data exhibits linear behavior at the origin, appropriate for representing properties with a medium level of short</td></tr>
</table>

	range variability).  For additional information, see Spheric variogram.
Exponential variogram	Spatial continuity corresponds to the roughness factor of your main structure: in the case of a exponential variogram, the roughness factor is high. It is recommended to select exponential variogram when your seismic time data set presents low spatial continuity between data values (i.e. the experimental variogram of the data exhibits exponential behavior at the origin, appropriate for representing properties with a high level of short range variability).  For additional information, see Exponential variogram.

4 Address well tops uncertainty

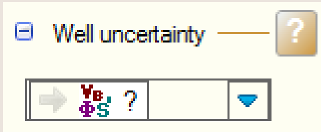
This section specifies how UDOMORE Depth consistently addresses well tops uncertainty: constant and variable.

4.1 Address constant well tops uncertainty

Constant	Well tops constant uncertainty value corresponds to uncertainty on well tops (meters / feet) that is constant in space between well tops. Example: 1m standard deviation from real top to interpreted top = +/- 2 m depth interpretation error. Click here to enter constant well tops uncertainty values: 

4.2 Address variable well tops uncertainty

Sigma	Well tops sigma uncertainty values correspond to uncertainty on well tops (meters / feet) that is variable in space between well tops. Example: 1m standard deviation from real top A to interpreted top A = +/- 2 m depth

	interpretation error; and 2m standard deviation from real top B to interpreted top B = +/- 4 m depth interpretation error. To enter sigma well tops uncertainty values, produce a well tops sigma uncertainty attribute in your Petrel* E&P project. This attribute must be available in your Petrel* E&P project for each relevant well top. Click here to enter sigma well tops uncertainty values (Petrel template = General or Thickness Depth, See Annex 1 for more information): 

5 Select interval velocity function

This section specifies the list of available interval velocity functions available in UDOMORE Depth.

5.1 V0

Function type	Interval velocity is a constant.
Definition of parameters	V0 = constant velocity (assumption that velocity does not vary inside the considered layer). For additional information, see Time to depth conversion formulae.
Operational applications	Useful when layers are very homogeneous and/or when there is a limited amount of well data available.

5.2 V0 + alpha*T

Function type	Instantaneous velocity is a function of time.
Definition of parameters	V0 = constant velocity factor. Alpha = constant acceleration factor. T = bottom seismic time of the layer. For additional information, see Time to depth conversion formulae.
Operational applications	Useful when geology presents non-linear compaction from the surface.

5.3 A*V0 map+ alpha*T

Function type	Instantaneous velocity is a function of a velocity map and time.
Definition of parameters	A = constant factor. V0 map = velocity map. Alpha = constant acceleration factor. T = bottom seismic time of the layer. For additional information, see Time to depth conversion formulae.
Operational applications	Same as V0 + alpha*T model, introducing an additional V0map parameter. You may consider alpha to be relatively constant for a considered layer, and V0 to be variable. Introducing a V0map with possible spatial variation, linked with seismic information, enables to minimize well depth mismatches.

5.4 V0 + alpha*DT

Function type	Instantaneous velocity is a function of time isopach.
Definition of parameters	V0 = constant velocity factor. Alpha = constant acceleration factor. DT = DT isopach time (automatically computed by UDOMORE Depth as the difference between the time interpretation map at the top of the considered layer and the time interpretation map at the top of the layer immediately above). For additional information, see Time to depth conversion formulae.
Operational applications	Same as V0 + alpha*T, except that V0 is linked to the top of the considered layer. Useful when you are in a layered model and the V0 at reference datum does not reflect a possible change of V0 values at the top of the layer. For example, when there is an important dip effect at the top of the layer

5.5 A* V0 map + Alpha*DT

Function type	Instantaneous velocity is a function of a velocity map and time isopach.
Definition of parameters	A = constant rescaling factor. V0map= velocity map. Alpha = constant acceleration factor. DT = DT isopach time (automatically computed by UDOMORE Depth as the

	difference between the time interpretation map at the top of the considered layer and the time interpretation map at the top of the layer immediately above). For additional information, see Time to depth conversion formulae.
Operational applications	Same as V0 + alpha*DT, introducing an additional V0map parameter. You may consider alpha to be relatively constant for a considered layer, and V0 to be variable. Introducing a V0map with possible spatial variation, linked with seismic information, enables to minimize well depth mismatches. For example, you can introduce a seismic V0 map based on your available seismic velocity map.

5.6 V0 + K*Z

Function type	Instantaneous velocity is a function of depth. This function introduces a linear increase in velocity as depth values increase.
Definition of parameters	V0 = constant velocity factor (instantaneous velocity at the surface). K = constant compaction factor. For additional information, see Time to depth conversion formulae.
Operational applications	Useful when geology presents linear compaction (often confirmed by measurements at least in clastic environments).

5.7 A*V0map + K*Z

Function type	Instantaneous velocity is a function of depth and V0 map.
Definition of parameters	A = constant factor. V0map = velocity map. K = constant compaction factor. For additional information, see Time to depth conversion formulae.
Operational applications	Same as V0+k*Z model, introducing an additional V0map parameter. You may consider k to be relatively constant for a considered layer, and V0 to be variable. Introducing a V0map with possible spatial variation, linked with seismic information, enables to minimize well depth mismatches. For example, you can introduce a seismic V0 map based on your available seismic velocity map.

5.8 V0 + K*(Z-Z0)

Function type	Instantaneous velocity is a function of layer isopach.
Definition of parameters	V0 = constant velocity factor (instantaneous velocity at the top of the

	considered layer). K = constant compaction factor. Z0= depth of the top of the considered layer. For additional information, see Time to depth conversion formulae.
Operational applications	Same as V0+k*Z, except that V0 is linked to the top of the considered layer. Useful when you are in a layered model and the V0 at reference datum does not reflect a possible change of V0 values at the top of the layer. For example, when there is an important dip effect at the top of the layer.

5.9 A*V0map + K*(Z-Z0)

Function type	Instantaneous velocity is a function of layer isopach and V0 map.
Definition of parameters	A = constant factor. K = constant compaction factor. V0map = velocity map. Z0= depth of the top of the considered layer. For additional information, see Time to depth conversion formulae.
Operational applications	Same as V0+k*(Z-Z0), introducing an additional V0map parameter. You may consider k to be relatively constant for a considered layer, and V0 to be variable. Introducing a V0map with possible spatial variation, linked with seismic information, enables to minimize well depth mismatches. For example, you can introduce a seismic V0 map based on your available seismic velocity map.

5.10 A*Vseis

Function type	Interval velocity is subject to rescaling of seismic interval velocities.
Definition of parameters	A = constant rescaling factor. Vseis = seismic interval velocity map. For additional information, see Time to depth conversion formulae.
Operational applications	Useful when seismic velocities are available and rescaling is required for coherence with well velocities.

5.11 A*Vseis +B

Function type	Interval velocity is subject to rescaling and shifting of seismic interval velocities.
Definition of parameters	A = constant rescaling factor.

	B = constant shifting factor. Vseis = seismic interval velocity map. For additional information, see Time to depth conversion formulae.
Operational applications	Useful when seismic velocities are available and rescaling is required for coherence with well velocities. Adding a shift to the seismic velocities enables to introduce seismic time as a correcting factor for the seismic velocities. This is relevant if you think that the seismic velocities do not properly capture geological velocity variations.

5.12 V0 + Z0/T

Function type	Depth is a function of time (this is an interval velocity function – not an instantaneous velocity function).
Definition of parameters	V0 = constant velocity factor. Z0 = depth factor. T = bottom seismic time of the layer. For additional information, see Time to depth conversion formulae.
Operational applications	Can also be read as Z=V0*T+Z0; useful when the depth of the given horizon appears as a simple linear transformation of seismic time. This is a simple model which can be used for reference or large scale basin study.

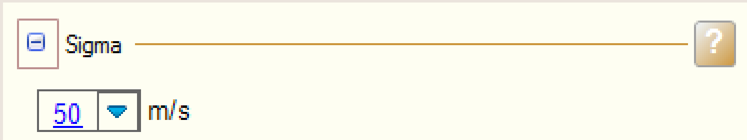
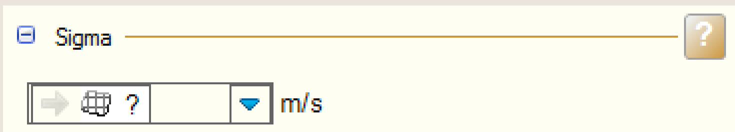
5.13 Alpha*DT+Vint0

Function type	Interval velocity is a linear function of isopach time.
Definition of parameters	A= acceleration factor. Vint0= constant interval velocity factor. DT = DT isopach time (automatically computed by UDOMORE Depth as the difference between the time interpretation map at the top of the considered layer and the time interpretation map at the top of the layer immediately above). For additional information, see Time to depth conversion formulae.
Operational applications	Useful when there is a relation due to the opposition between fast and slow faciès in an aggradational basin.

6 Address interval velocity residual uncertainty

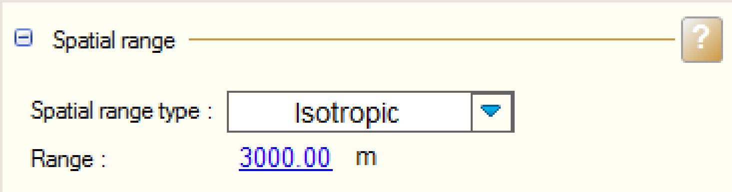
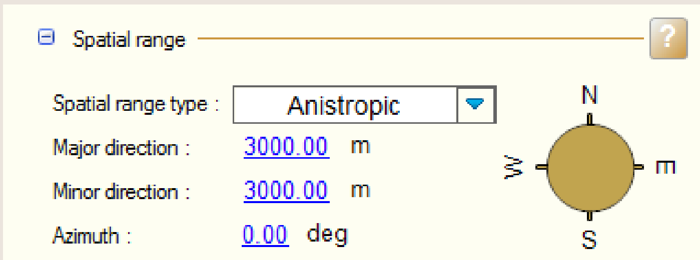
This section specifies how UDOMORE Depth consistently addresses interval velocity residual uncertainty: sigma, spatial range, and spatial continuity.

6.1 Address interval velocity residual uncertainty sigma

Constant vs. variable sigma	
Constant	Uncertainty that is constant in space (standard deviation). Example: 20 m/s standard deviation = +/- 40 ms interval velocity residual variations. Define constant interval velocity residual uncertainty values based on your analysis of the considered horizon (mostly: analysis of sonic well logs, seismic interval velocities). Click here to enter constant interval velocity residual uncertainty values: 
Variable	Uncertainty that varies in space (standard deviation). Example: at the top of your structure, 20 m/s standard deviation = +/- 40 ms interval velocity residual variations, and on the flank of your structure, 40 m/s standard deviation = +/- 80 ms interval velocity residual variations. Produce a interval velocity residual uncertainty map (with variable interval velocity residual uncertainty values) in your Petrel* E&P project, based on your analysis of the considered horizon (mostly: analysis of sonic well logs, seismic interval velocities). This map must be available in your Petrel* E&P project as an attribute to the relevant horizon. Click here to upload your uncertainty map (Petrel template = General or Velocity interval, See Annex 1 for more information): 

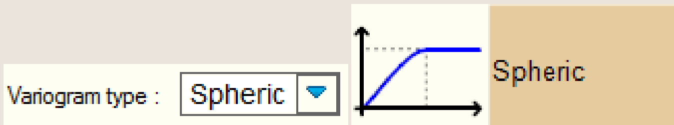
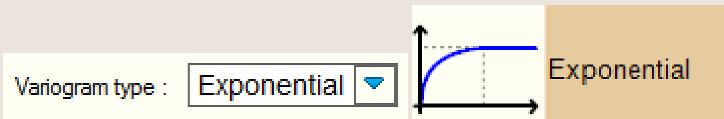
6.2 Address interval velocity residual uncertainty spatial range

Spatial range	
Isotropic	Spatial range correspond to the size/shape of your main target structure: in the case of isotropic range, your structure has an approximately circular

	shape, with the same distance in every direction. Define Isotropic (X) spatial range values (meters / feet) based on your analysis of the considered horizon (mostly: analysis of sonic well logs, seismic interval velocities) and a priori geological knowledge about the subsurface. Click here to enter isotropic (X) range: 
Anisotropic	Spatial range correspond to the size/shape of your main target structure: in the case of anisotropic range, your structure has an approximately ellipsoidal shape, with the two different distances in the two main directions, and, possibly, an azimuth. Define anisotropic (X,Y) spatial range values (meters / feet) based on your analysis of the considered horizon (mostly: analysis of sonic well logs, seismic interval velocities) and a priori geological knowledge about the subsurface. Click here to enter anisotropic (X,Y) ranges: 

6.3 Address interval velocity residual uncertainty spatial continuity

Spatial continuity	
Cubic variogram	Spatial continuity corresponds to the roughness factor of your main structure: in the case of a cubic variogram, the roughness factor is small. It is recommended to select cubic variogram when your seismic time data set presents strong spatial continuity between data values. Also, cubic variograms are very stable for kriging computations and very relevant for depth simulations.  For additional information, see Cubic variogram.

Spheric variogram	Spatial continuity corresponds to the roughness factor of your main structure: in the case of a spheric variogram, the roughness factor is medium. It is recommended to select cubic variogram when your seismic time data set presents medium spatial continuity between data values (i.e. the experimental variogram of the data exhibits linear behavior at the origin, appropriate for representing properties with a medium level of short range variability).  For additional information, see [Spheric variogram].
Exponential variogram	Spatial continuity corresponds to the roughness factor of your main structure: in the case of a exponential variogram, the roughness factor is high. It is recommended to select exponential variogram when your seismic time data set presents low spatial continuity between data values (i.e. the experimental variogram of the data exhibits exponential behavior at the origin, appropriate for representing properties with a high level of short range variability).  For additional information, see [Exponential variogram].

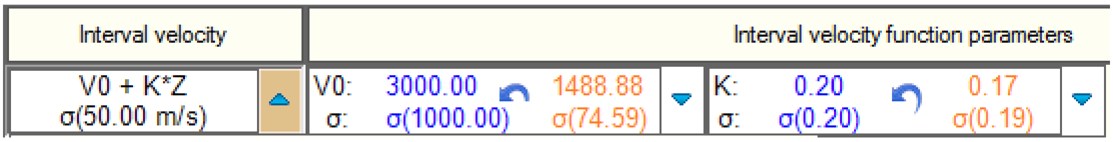
7 Parameterize interval velocity function trend

This section specifies how to parameterize your interval velocity trend and associated uncertainty ranges: prior vs. post values.

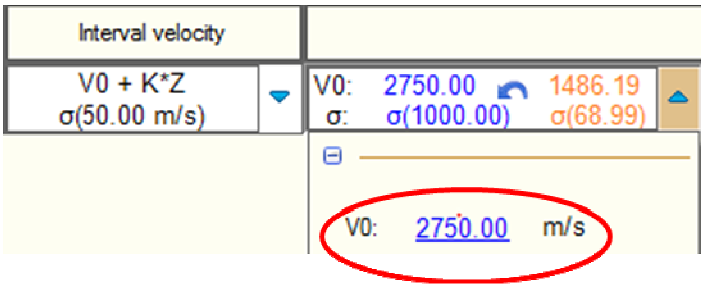
7.1 Enter prior parameter values and associated uncertainty ranges

Once you have selected an interval velocity function for a given layer you need to enter prior parameter values to define your interval velocity trend :

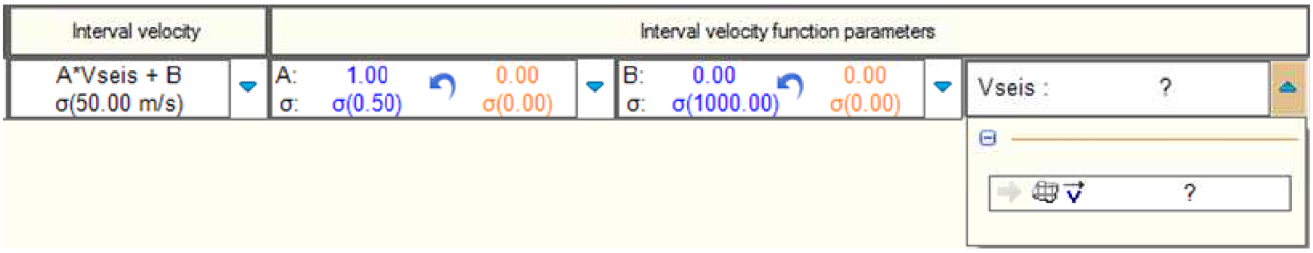
- You may use a set of default prior interval velocity function parameter values (+ associated uncertainty).For example: in case of a V0 + k*Z type interval velocity function, UDOMORE Depth considers the following default parameters: k = 0.2 (σ = 0.1); V0 = 3000 (σ = 500). Based on these default parameters, UDOMORE Depth looks for the optimal set of post V0 and k parameters (+ associated uncertainty) that minimize well depth mismatches.



- You may enter custom prior interval velocity function parameter values (+ associated uncertainty) based on your analysis of the considered horizon (mostly: analysis of sonic well logs, seismic interval velocities, depth vs. time cross plots …) and a priori geological knowledge about the subsurface. For example, in case of a V0 + K*Z type interval velocity function, the statistical analysis of the different available sonic logs enables to derive assumptions for V0 and K values (+ associated uncertainty) that make sense from a geophysical point of vue. Click here to enter a priori interval velocity function parameters (+ associated uncertainty):



- When relevant, depending on the interval velocity function you select, you are required to upload 2D seismic interval velocity maps or V0maps. For example, if you select A*Vseis + B: first, enter a priori A and B rescaling and reshifting parameters (the easiest way to define rescaling and shifting factors can be to analyze the relation between well interval velocity, or pseudo well interval velocity, versus the corresponding seismic interval velocity in the considered layer); then upload 2D seismic interval velocity map; this map must be available in your Petrel* E&P project as an attribute to the relevant horizon (Petrel template = General, Velocity or Velocity Interval), corresponding to the bottom of the considered layer:



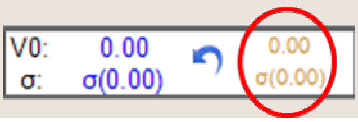
7.2 Compute post parameter values and associated uncertainty ranges

Once prior parameterization is performed, click on the blue arrow, and UDOMORE Depth automatically computes post interval velocity function parameters. UDOMORE Depth enables robust estimations of interval velocity function parameter values (+ associated uncertainty ranges), driven towards minimization of well depth mismatches, using an advanced Bayesian Kriging algorithm. For additional information, see Bayesian kriging.

- Click here to compute post interval velocity function parameter values (+ associated uncertainty ranges):

- Click again for subsequent iteration…

- Systematically converge towards best possible parameterization (+ associated uncertainty ranges). Example, in case of a V0 + K*Z type interval velocity function:

Prior vs. Post parameter values (+ associated uncertainty range)	
Prior	Read here for prior V0 parameter value (+ associated uncertainty range): 
Post	Read here for post V0 parameter value (+ associated uncertainty range): 

8 Control interval velocity function parameterization

This section specifies how to interactively control interval velocity function parameterization using statistics, and converge towards your best estimate velocity and depth models.

Time to depth conversion velocity model will always generate well depth mismatches between measured depth and estimated depth trend. UDOMORE Depth prior vs. post parameterization aims to systematically minimize these mismatches. Note: depth mismatch statistics are relevant only if 10 wells or more are involved in your depth conversion scenario. With less than 10 wells, statistics can only be treated as informative. The well-depth mismatch table displays:

- Experimental statistics computed on depth mismatches between well depth marker values and estimated depth trend values, to quantify the level of performance of your velocity model:

Experimental prior	Depth mismatches between well depth marker values and prior depth trend values (i.e. computed from prior parameterization values).
Experimental post	Depth mismatches between well depth marker values and post depth trend values (i.e. computed from post parameterization values).
Tips	"Experimental Post" values should be lower that "Experimental Prior" values, demonstrating minimization of well-depth mismatches.

- Experimental statistics may be displayed in terms of standard deviation ("RMSD") of depth mismatches:

RMSD	Standard deviation of depth mismatches between measured depth and estimated depth trend values.
Tips	RMSD values should be as low as possible to ensure optimal accuracy of your interval velocity model.

- Experimental statistics may be displayed in terms of mean value of depth mismatches:

Mean	Average value of depth mismatches between measured depth and estimated depth trend values.
Tips	"Mean" values should as close as possible to 0 to ensure that interval velocity model doesn't lead to systematic over/under estimation of layer depth.

- Experimental statistics may be displayed in terms of minimum and maximum values of depth mismatches:

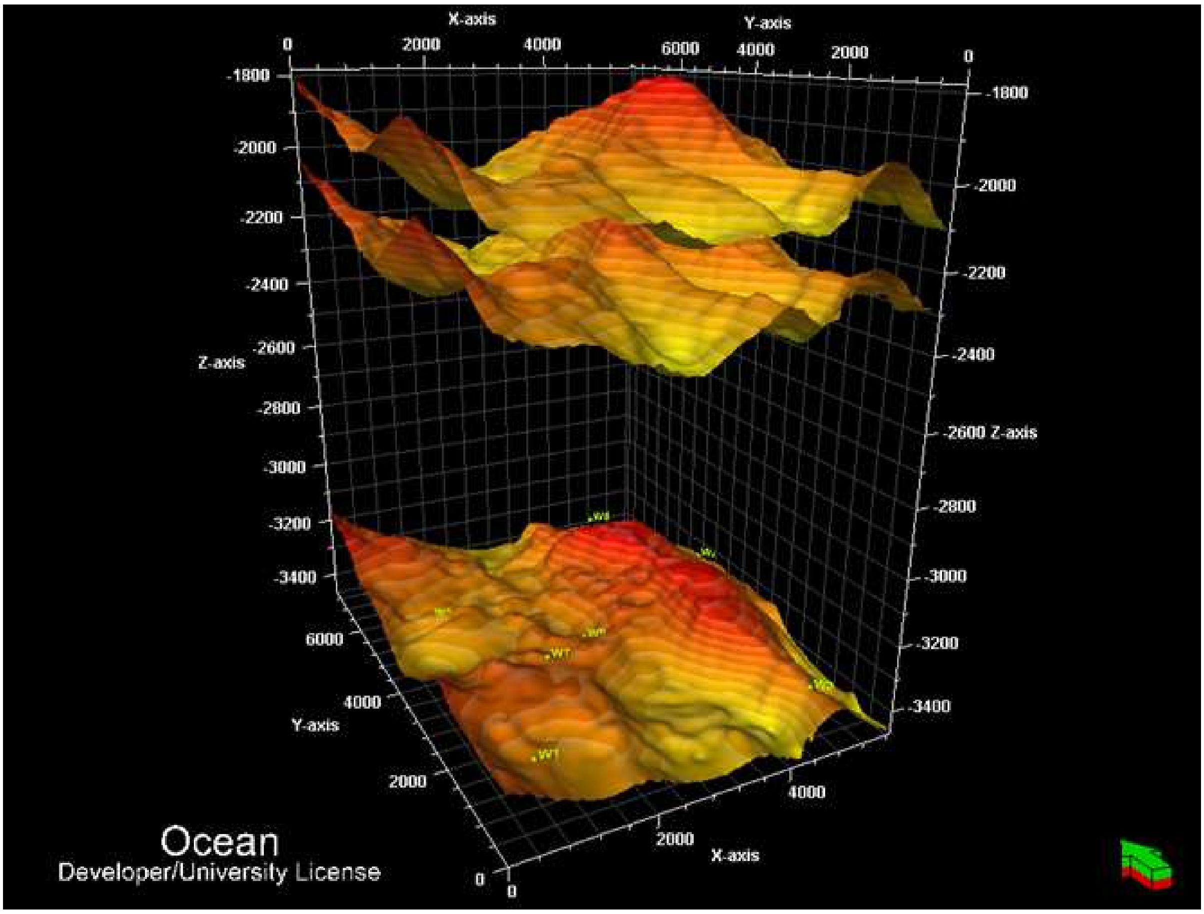
Minimum	Minimum value of depth mismatches between measured depth and estimated depth trend values.
Maximum	Maximum value of depth mismatches between measured depth and estimated depth trend values.
Tips	The range between minimum and maximum depth mismatch values should be reduced to the maximum possible extent.

- Modeled standard deviation of well-depth mismatches (i.e. local well-depth mismatches around estimated depth trend values), to quantify the level of confidence on your estimated depth trend:

Modeled RMSD	Modeled standard deviation corresponds to the confidence range around the estimated depth trend, derived (or “modeled”) from time uncertainty values and residual interval velocity uncertainty values (i.e. without reference to measured well depth). For additional information, see Model.
Tips	Check that the modeled RMSD values (i.e. confidence range without reference to measured well depth) are consistent with the experimental RMSD statistics (i.e. direct reference to measured well depth): modeled RMSD values should be equal or higher than the experimental RMSD values.

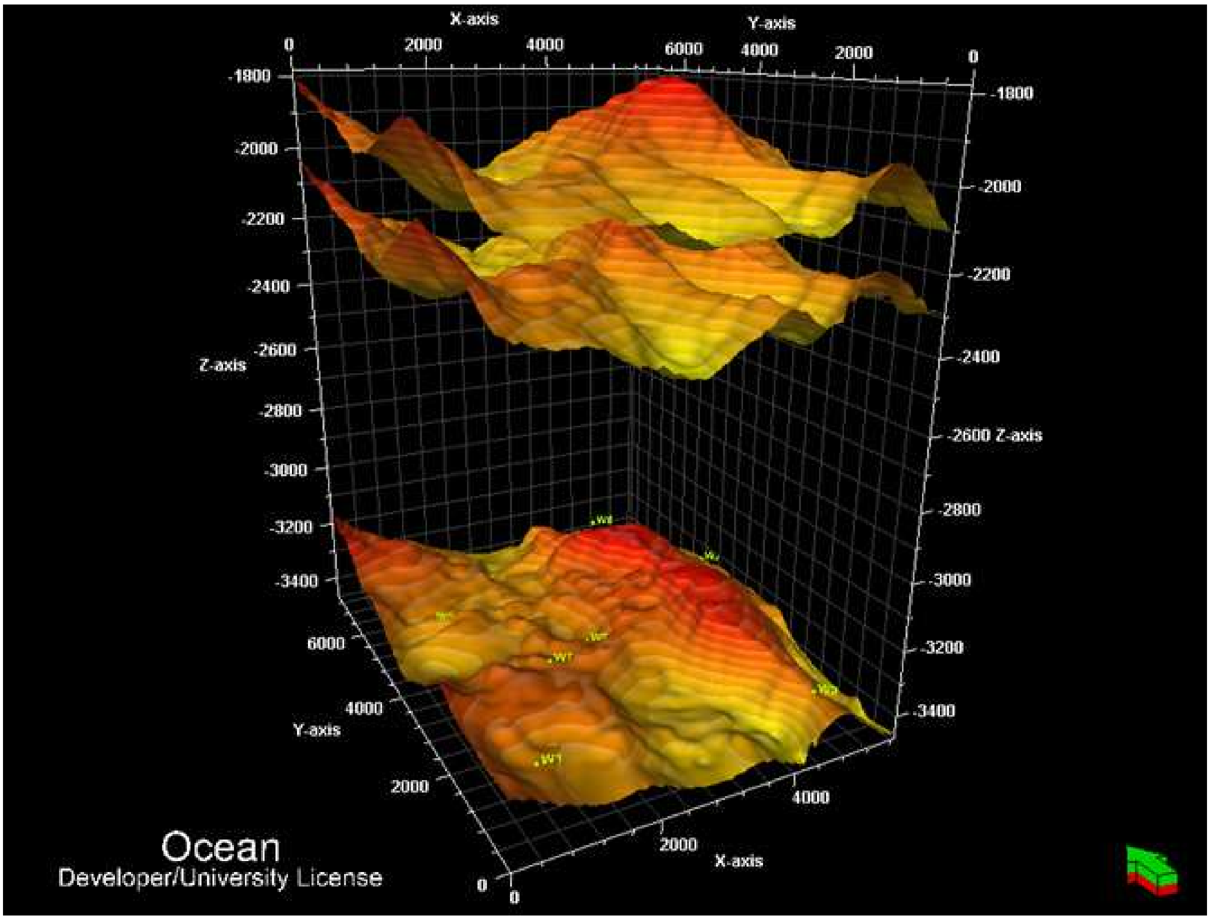
9 Outputs

9.1 Prior trend depth maps



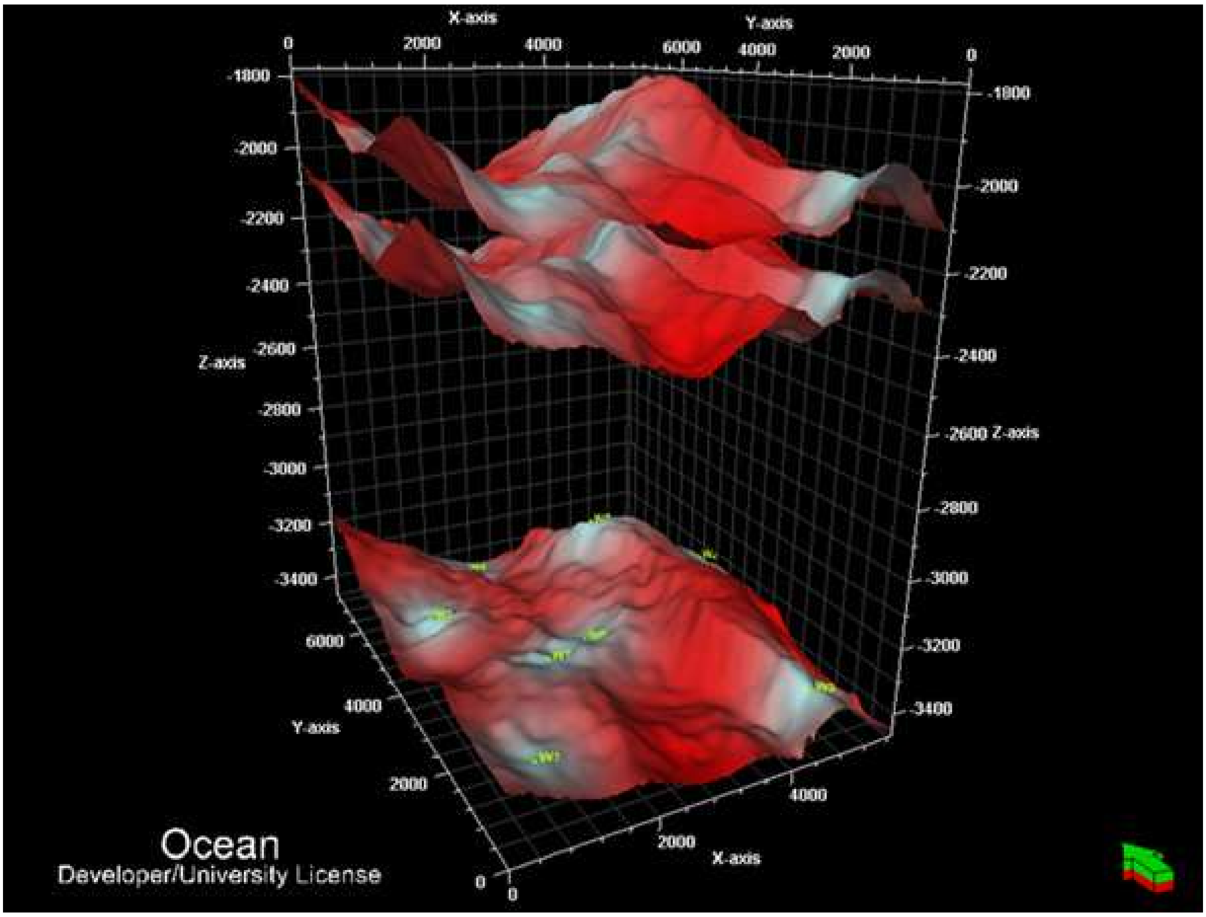
Definition	Product of 2D seismic time interpretation maps by interval velocity functions prior to UDOMORE Depth parameterizations.
Characteristics	Multilayer. Not tied to the wells.
Applications	Reference map for your depth conversion scenario. You can appreciate parameterizations performed by UDOMORE Depth by comparing the prior depth trend maps with the post depth trend maps.

9.2 Post trend depth maps



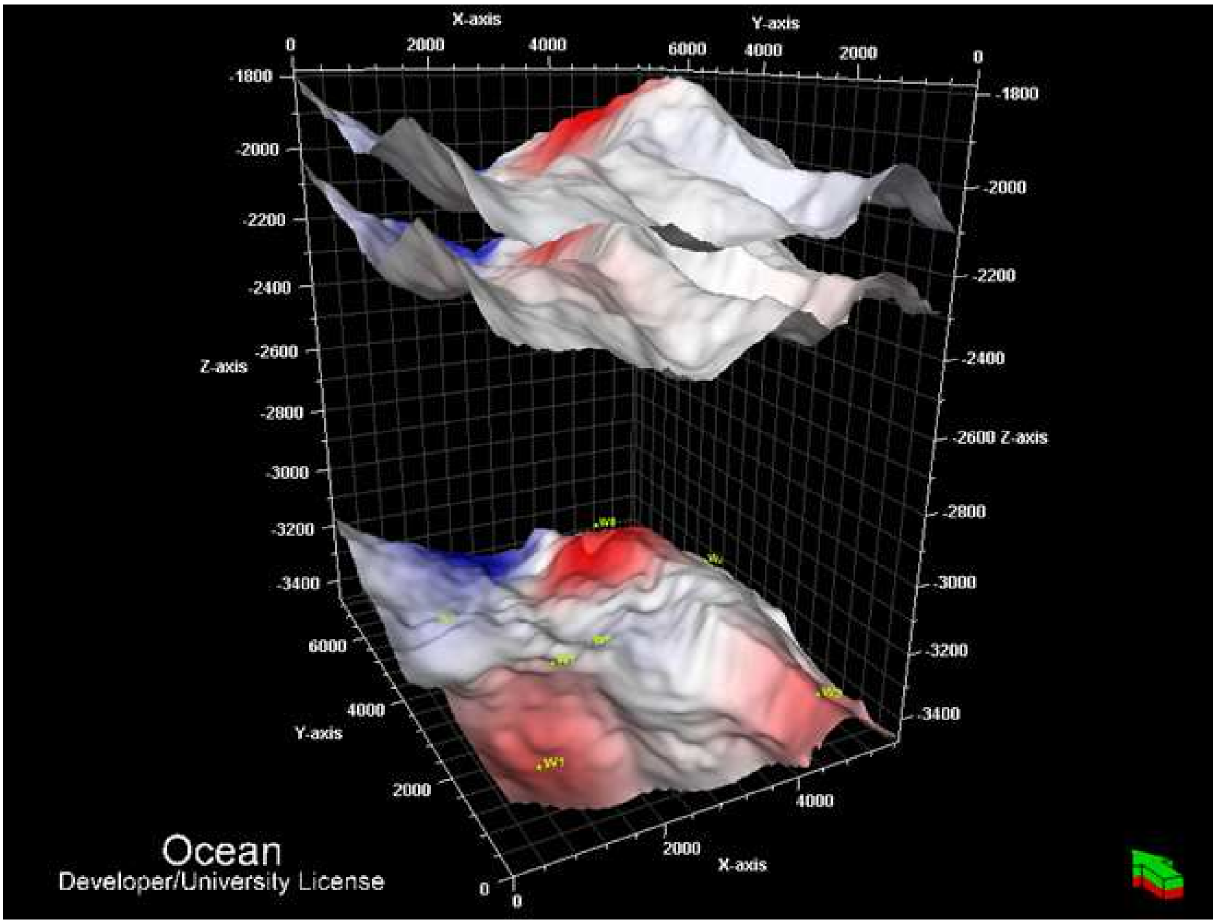
Definition	Product of 2D seismic time interpretation maps by interval velocity functions after UDOMORE Depth parameterizations.
Characteristics	Multilayer. Not tied to the wells. Well-depth mismatches are minimized to best possible extents.
Applications	Reference map for your depth conversion scenario. You can appreciate parameterizations performed by UDOMORE Depth by comparing the prior depth trend maps with the post depth trend maps.

9.3 Estimated depth standard deviation maps



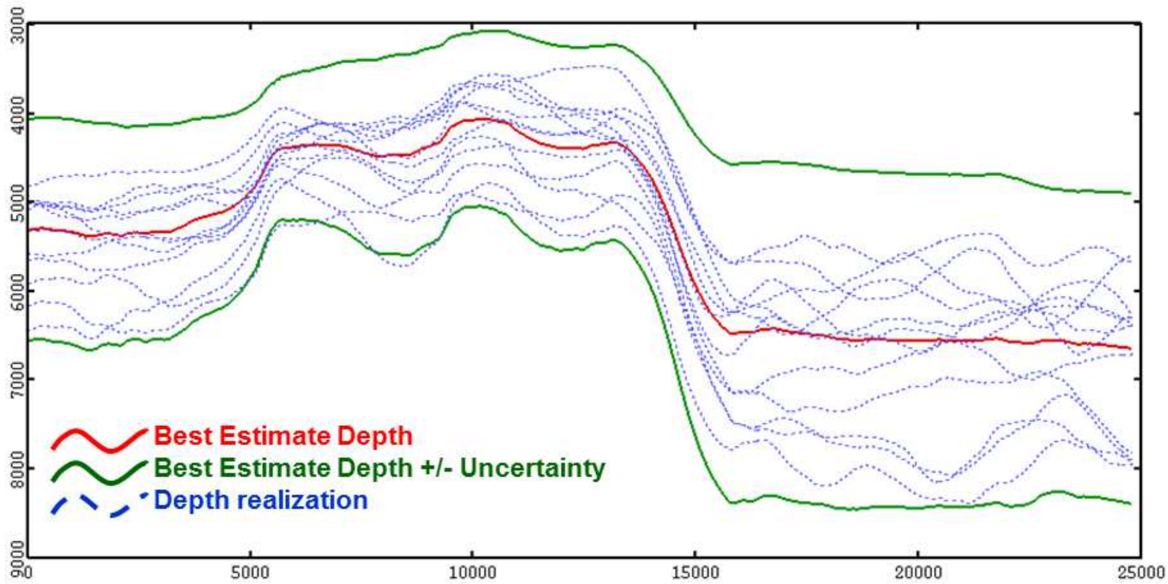
Definition	Depth uncertainty map (expressing the standard deviation around estimated depth map).
Characteristics	Multilayer. Standard deviation = 0 at well locations. Computed using advanced stochastic estimation algorithm: co-kriging depth with external drifts related to time interpretations and under Bayesian control on the drift coefficient.
Applications	Helps to appreciate the accuracy of your estimated depth map. The lower the standard deviation value, the higher your confidence. Standard deviation is cornerstone to depth realization computations: most of depth realizations (95.5% on a Gaussian assumption) are computed between estimated depth and +/- 2 time the standard deviation.

9.4 Post depth residuals maps



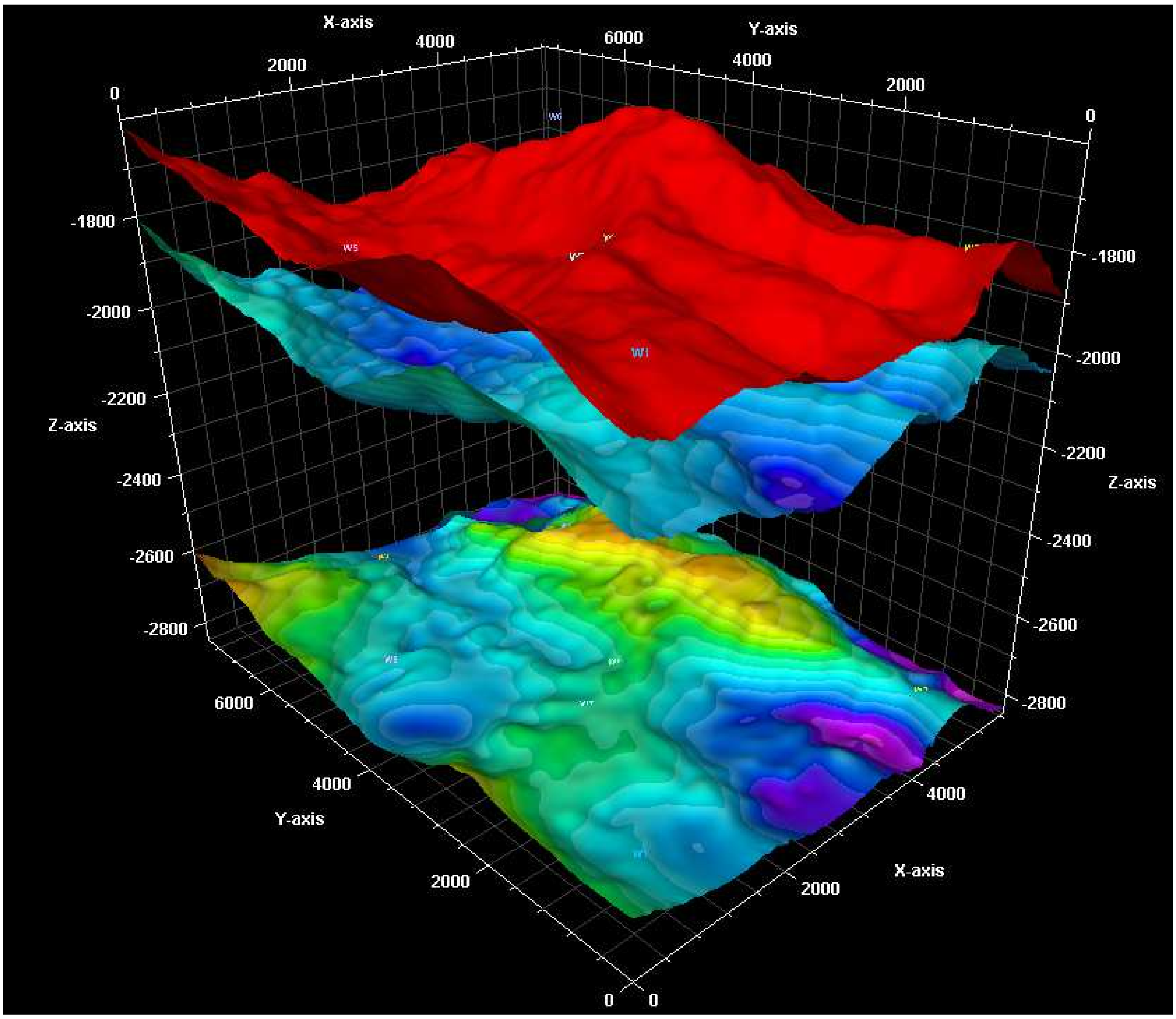
Definition	Difference between the estimated depth map and the post depth trend map.
Characteristics	Multilayer.
Applications	Helps to appreciate the accuracy of your estimated depth map. You are able to verify the impact of the well-depth mismatches on your estimated depth map. You may also verify is there is any remaining organization in your residuals (ex: clear geographical trend E/W or N/S).

9.5 Depth realizations



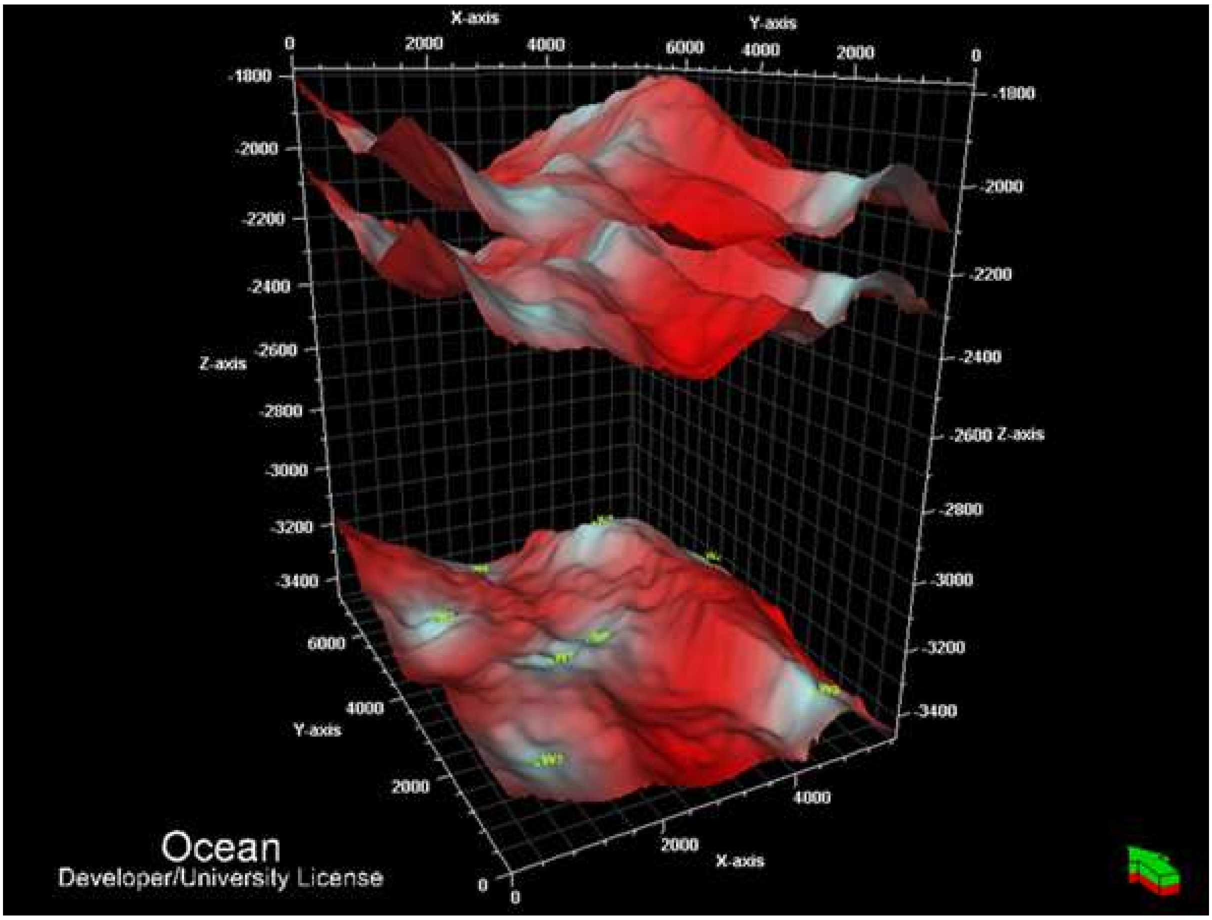
Definition	Depth realizations are computed using an advanced stochastic Bayesian simulation algorithm. For additional information, see Stochastic
Characteristics	Computed on selected layer. Tied to the wells.
Applications	Depth realizations allow you to enter into volumetric computations for field appreciation. Studying specific realizations (around P10/P50/P90) is useful to understand possible reservoir geometry.

9.6 Estimated thickness maps



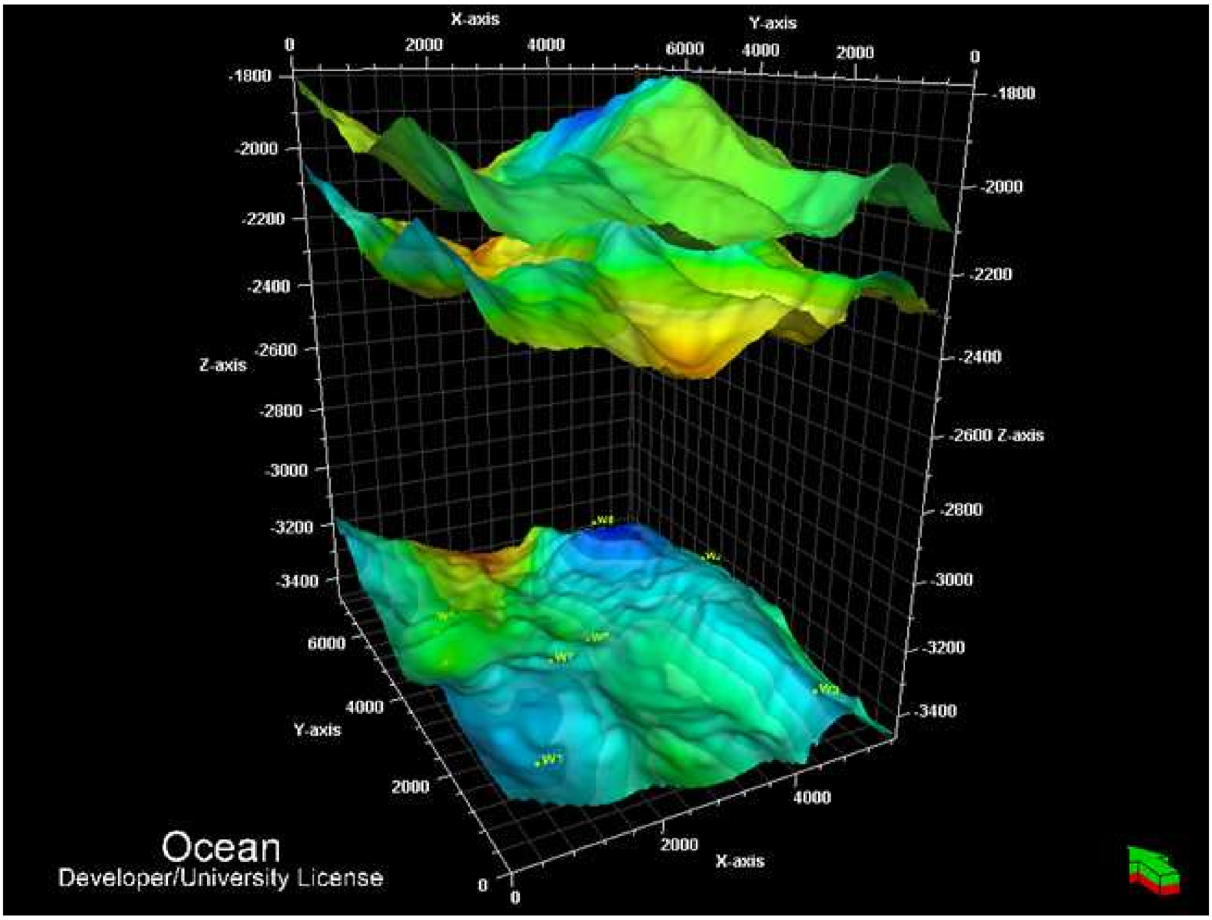
Definition	Best estimate thickness map. Corresponds to the difference between top and bottom estimated depth maps.
Characteristics	Multilayer. Tied to the wells.
Applications	Thickness Base Case, to be used as reference to analyze depth simulations.

9.7 Estimated thickness standard deviation maps



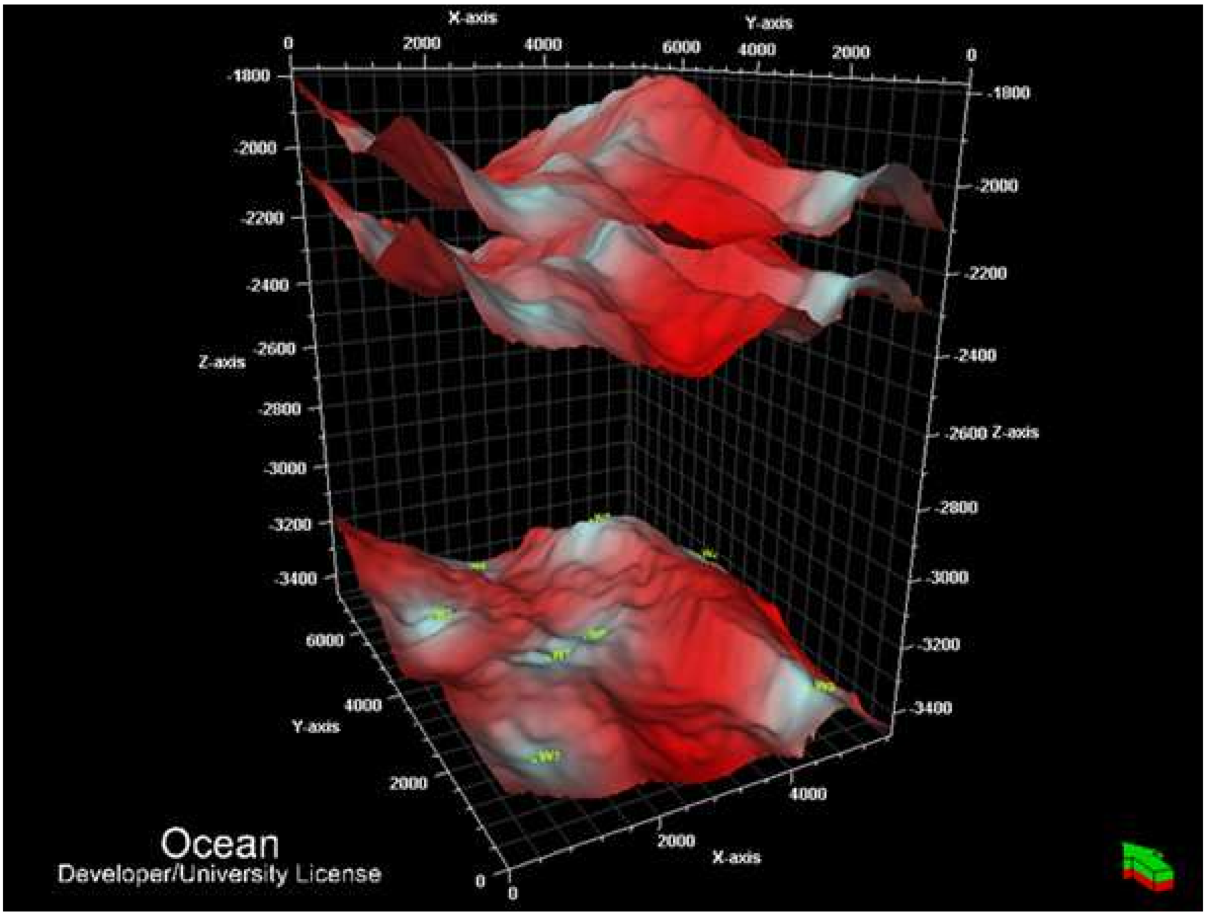
Definition	Thickness uncertainty map (expressing the standard deviation around estimated thickness map).
Characteristics	Multilayer. Standard deviation = 0 at well locations.
Applications	Helps to appreciate the accuracy of your estimated thickness map. The lower the standard deviation value, the higher your confidence.

9.8 Resulting interval velocity maps



Definition	Resulting interval velocity map. Corresponds to the estimated thickness maps divided by the seismic time isopach.
Characteristics	Multilayer. Tied to the wells.
Applications	Consistent input to your 3D velocity model.

9.9 Resulting interval velocity standard deviation maps



Definition	Resulting interval velocity uncertainty map (expressing the standard deviation around resulting interval velocity map).
Characteristics	Multilayer. Standard deviation = 0 at well locations.
Applications	Helps to appreciate the accuracy of your resulting interval velocity map. The lower the standard deviation value, the higher your confidence.

10 Technical references

This section provides technical detail on the stochastic processes implemented in UDOMORE Depth.

10.1 Bayesian kriging

From a geostatistical point of view, the time-to-depth conversion of seismic horizons is a classical estimation problem involving one or more secondary variables $S_l(x) \to \{S_0 = 1, l = 1, \cdots L\}$, (S_1= time-migrated horizon in time units) and well markers corresponding to the interpreted horizon $Z(x_i) \to \{i = 1, \ldots N\}$ (in depth units).

Different kriging methods are used for this estimation problem such as Simple Kriging (SK), Kriging with External Drift (KED). As all kriging methods, they provide the depth mapping and an estimation of associated uncertainty. These kriging methods are based on the dichotomy of the spatial random variable $Z(x)$ (Matheron, 1963) in two parts the mean $m(x)$ and the residual $Z_R(x)$. The mean function is generally done by a linear combination:

$$m(x) = \sum_{l=0}^{L} b_l \cdot S_l(x)$$

In the case of SK the mean $m(x)$ is assumed to be known and defined as a time-depth regression fit based on well markers. In the case of kriging with external drift (Wackernagel**,** 1995), the drift coefficients are evaluated in the KED process (called "geo-regression"). All these kriging based estimators are of course conditioned by the data and are model-driven but the only tuning parameter is the variogram model. The drift coefficients are either fixed or estimated. However we can have the a-priori information about the velocity model and for that reason, the Bayesian approach is well adapted to provide a framework for the integration of this a-priori knowledge.

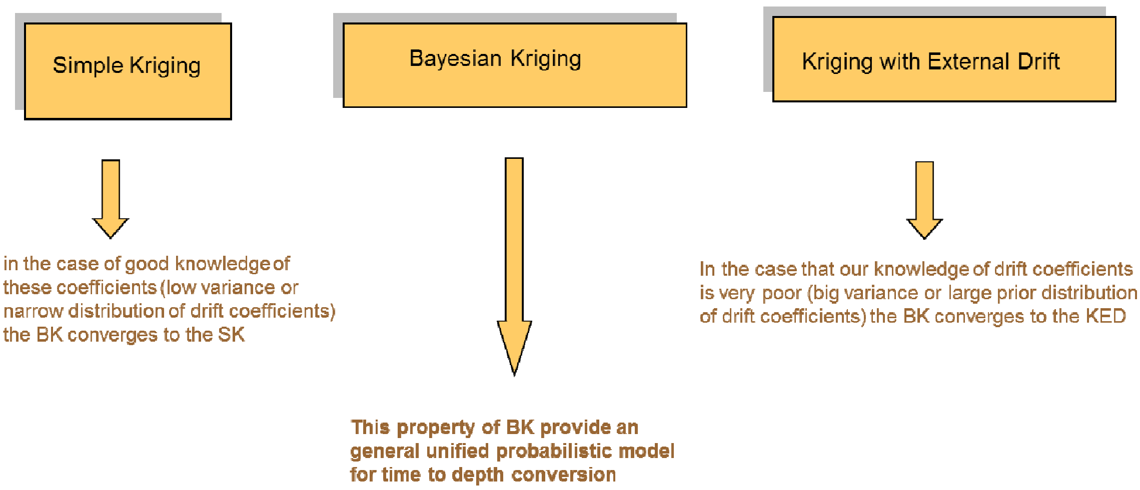
In the linear Bayesian approach we replace the set of regression linear coefficients b_l by random variables B_l characterized by a known a-priori join distribution. The a-priori knowledge of time-depth relationship or the prior distribution of drift coefficients in Gaussian case can be fully determined by two first moments: the prior expectation vector $\mu_l = E[B_l]$ and associated covariance matrix $Cov(B_l, B_k) = \sigma_{lk}$. The Bayesian extension of KED provides an estimator which is more general and introduces the notion of uncertainty of the mean (or trend) prediction. The kriging formalism is generalized thanks to a Bayesian inference and provide a local estimation with an associated variance of estimation and posterior distribution of drift coefficients (Omre 1987, Omre and al. 1989). The Bayesian Kriging system is then defined as:

$$\sum_{i=1}^{N} \lambda_i \left\{ C_{Z|B}(x_i - x_j) + \sum_{l=0}^{L}\sum_{k=0}^{L} \sigma_{lk} S_l(x_i) S_k(x_j) \right\} = C_{Z|B}(x_0 - x_j) + \sum_{l=0}^{L}\sum_{k=0}^{L} \sigma_{lk} S_l(x_0) S_k(x_j)$$

Where $C_{Z|B}(x_i - x_j)$ is the conditional covariance which can be modeled from experimental variogram of residuals (the trend is computed using prior). Considering the Gaussian distribution of drift coefficients, the first two moments of posterior distribution can be obtained by the following equations:

$$E[B|Z] = \mu + (S\Sigma)^T (C + S\Sigma S^T)^{-1} (Z - S\mu)$$
$$Cov[B|Z] = \Sigma - (S\Sigma)^T (C + S\Sigma S^T)^{-1} S\Sigma$$

Where: µ is the vector of drift coefficients, S is the drift matrix $S = [S_i(x_j)]$ (seismic time or seismic depth at well markers), $\Sigma = [\sigma_{ij}]$ is the matrix of the covariance of drift coefficients, C is the covariance matrix between data points and Z is the vector of sample depth measurements. The Bayesian Kriging (BK) stands between Simple Kriging (SK) and Kriging with external Drift (KED). In the case that our knowledge of drift coefficients is very poor (big variance or large prior distribution of drift coefficients) the BK converges to the KED and in the case of good knowledge of these coefficients (low variance or narrow distribution of drift coefficients) the BK converges to the SK. This property of BK provide an general unified probabilistic model for time to depth conversion that can be applied in three mentioned M0, M1 and M2 scenarios and as all kriging estimators Bayesian Kriging provide also a quantification of the depth uncertainty by the kriging variance of estimation.



10.2 Model Value

The model value is a key parameter of UDOMORE depth conversion computations; it enables to properly handle uncertainties on the time picking and interval velocity model, and maximize the confidence in the depth model. The model value is derived from the Bayesian kriging model of all layers at the layer considered as follows :

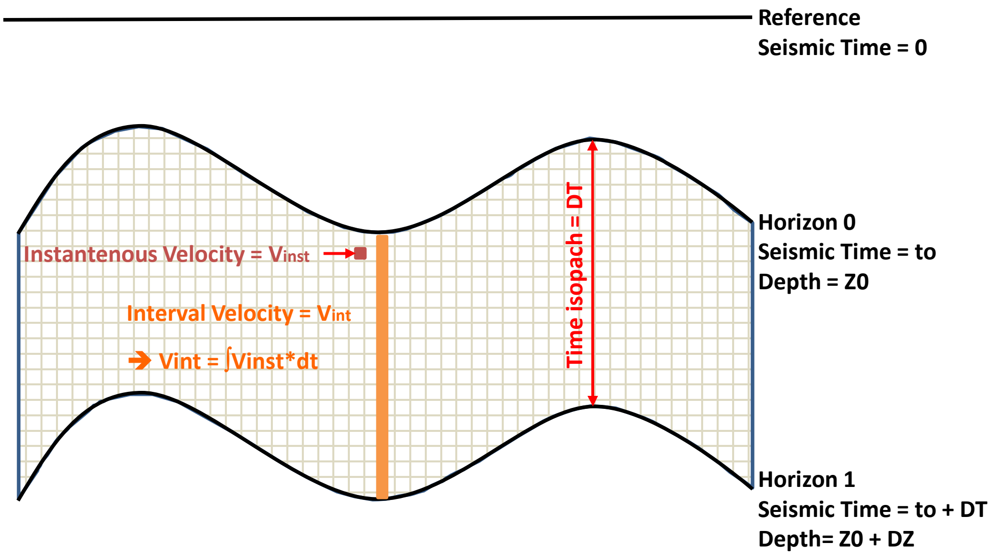
$$\sigma_{RZ_l} = \left(\frac{1}{Nw_l} \sum_{i=1}^{Nw_l} \left(\sum_{j=1}^{l} \Delta t_j(x_i)^2 \cdot \sigma_{RV_j}^2(x_i) + \overline{V_l}(x_i)^2 \cdot \sigma_{RT_l}^2(x_i) \right) \right)^{\frac{1}{2}}$$

Where :

- V is the mean velocity at the wells and t the mean of time at the wells
- σ_{RZ_l} Is the average standard deviation of the modeled residual depth of the layer l
- Nw_l Is number of well-tops corresponding to the layer l
- $\Delta t_j(x_i)$ Is the one-way time interval of the layer j at the ith well-top

- $\sigma^2_{RV_l}(x_i)$ Is the local variance of residual velocity of the layer l at the ith well-top
- $\overline{V_l}(x_i)$ Is the trend velocity of the layer l at the ith well-top
- $\sigma^2_{RT_l}(x_i)$ Is the local variance of residual time of the horizon l at the ith well-top

10.3 Time to depth function formulae



- **V0**

$V_{int} = V0$
$DZ = V0 * DT$

- **V0 + alpha*T or A*V0 map+ alpha*T**

$V_{inst} = V0 + alpha * t$
$DZ = \int_{t_0}^{t_0+DT} V_{inst} dt = \int_{t_0}^{t_0+DT} (V0 + alpha * t) * dt$
$DZ = \left(V0 + alpha * t_0 + \frac{alpha}{2} * DT\right) * DT$
$V_{int} = V0 + alpha * t_0 + \frac{alpha}{2} * DT$

- **V0 + alpha*DT or A* V0 map + Alpha*DT**

$V_{inst} = V0 + alpha * (t - t_0)$
$DZ = \int_{t_0}^{t_0+DT} V_{inst} dt = \int_{t_0}^{t_0+DT} (V0 + alpha * (t - t_0)) * dt$
$DZ = \left(V0 + (alpha - 1) * t_0 + \frac{alpha}{2} * DT\right) * DT$
$V_{int} = V0 + (alpha - 1) * t_0 + \frac{alpha}{2} * DT$

- **V0 + K*Z or A*V0map + K*Z**

$V_{inst} = V0 + k * Z$
$\Rightarrow Hypothesis\ 1: \ Z = Z(t)$
$\Rightarrow Vinst(t) = V0 + k * Z(t)$
$\Rightarrow \frac{DZ(t)}{dt} = V0 + k * Z(t) \quad \equiv \boldsymbol{first\ order\ differential\ equation}$
$\Rightarrow General\ solution\ \ Z(t) = Ce^{kt} - \frac{V0}{k}$
$With\ \ Z(0) = 0 = C - \frac{V0}{k} \Longrightarrow C = \frac{V0}{k}$
$Z(t) = \frac{V0}{k}(e^{kt} - 1)\& \qquad V_{inst} = V0e^{kt}$
$\boldsymbol{DZ = \int_{t_0}^{t_0+DT} V_{inst} dt = \int_{t_0}^{t_0+DT} V0 * e^{kt} dt}$
$\boldsymbol{DZ = \frac{V0}{k} e^{kt_0} * (e^{kDT} - 1)}$

$$\boldsymbol{V_{int} = \frac{V0}{k * DT} e^{kt_0} * (e^{kDT} - 1)}$$

- **V0 + K*(Z-Z0) or A*V0map + K*(Z-Z0)**

$V_{inst} = V0 + k * (Z - Z0)$
$\Rightarrow Hypothesis\ 1: \ Z = Z(t)$
$\Rightarrow Vinst(t) = V0 + k * (Z(t) - Z0)$
$\Rightarrow \frac{DZ(t)}{dt} = (V0 - k * Z0) + k * Z(t) \quad \equiv \boldsymbol{first\ order\ differential\ equation}$
$\Rightarrow General\ solution\ \ Z(t) = Ce^{kt} - \frac{V0}{k} + Z0$
$With\ \ Z(t_0) = Z0 = Ce^{kt_0} - \frac{V0}{k} + Z0 \implies C = \frac{V0}{k} e^{-kt_0}$
$Z(t) = \frac{V0}{k}\left(e^{k(t-t_0)} - 1\right) + Z0 \qquad \& \qquad V_{inst} = V0e^{k(t-t_0)}$
$\boldsymbol{DZ = \int_{t_0}^{t_0+DT} V_{inst}dt = \int_{t_0}^{t_0+DT} V0 * e^{k(t-t_0)}dt}$
$\boldsymbol{DZ = \frac{V0}{k} * (e^{kDT} - 1)}$
$\boldsymbol{V_{int} = \frac{V0}{k * DT} * (e^{kDT} - 1)}$

- **A*Vseis**

$V_{int} = A * V_{seis}$
$DZ = V_{int} * DT = \ A * V_{seis} * DT$
$DZ = A * DZ_{seis}$

- **A*Vseis +B**

$V_{int} = A * V_{seis} + B$
$DZ = V_{int} * DT = (A * V_{seis} + B) * DT$
$DZ = A * DZ_{seis} + B * DT$

- **V0 + Z0/T**

$$V_{int} = V0 + \frac{Z0}{DT}$$
$$DZ = V_{int} * DT = (V0 + \frac{Z0}{DT}) * DT$$
$$DZ = V0 * DT + Z0$$

- **Vint = Vint0+ Alpha*DT**

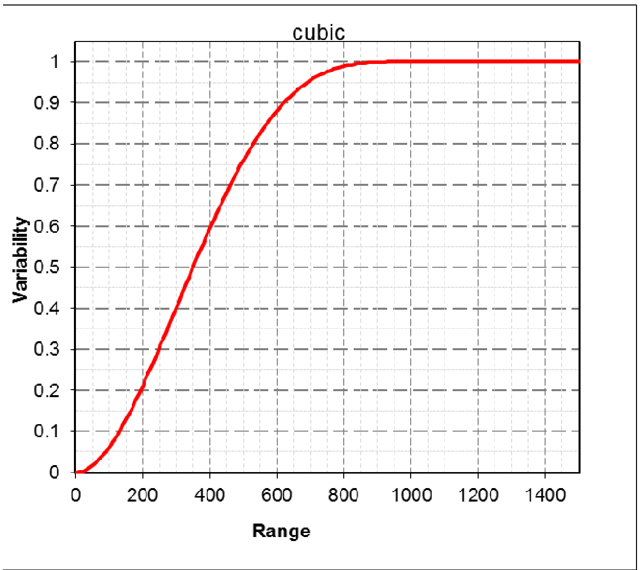
$$V_{int} = V_{int0} + Alpha * DT$$
$$DZ = V_{int} * DT = (Alpha * DT + V_{int0}) * DT$$
$$DZ = Alpha * DT^2 + V_{int0} * DT$$

10.4 Spatial continuity

10.4.1 Cubic variogram

Cubic	
$h \leq a$	$\gamma(h) = C\left[7\left(\frac{h}{a}\right)^2 - \frac{35}{4}\left(\frac{h}{a}\right)^3 + \frac{7}{2}\left(\frac{h}{a}\right)^5 - \frac{3}{4}\left(\frac{h}{a}\right)^7\right]$
$h > a$	$\gamma(h) = C$

h = separation distance
C = sill - Nugget
a = effective range



10.4.2 Exponential Variogram

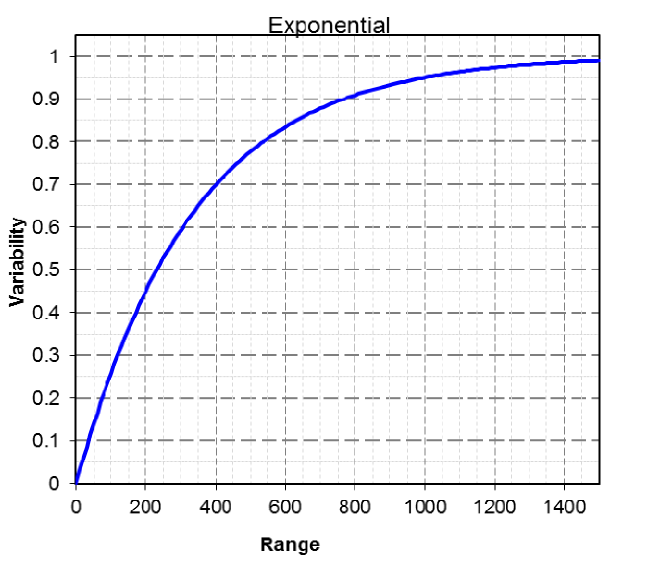
Exponential

$$\gamma(h) = C\left[1 - \exp\left(-\frac{\delta h}{a}\right)\right]$$

$\delta = 2.996$

The effective range (a) is defined as the distance at which (h) = 0.95C.

h = separation distance
C = sill - Nugget
a = effective range
δ = scaling factor



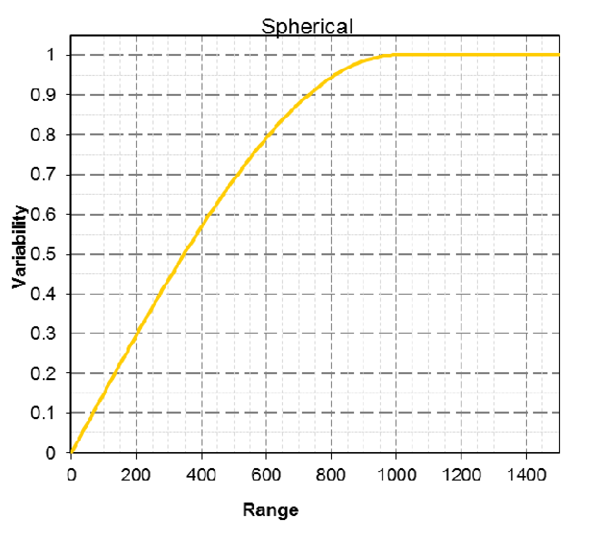
10.4.3 Spheric variogram

Spherical

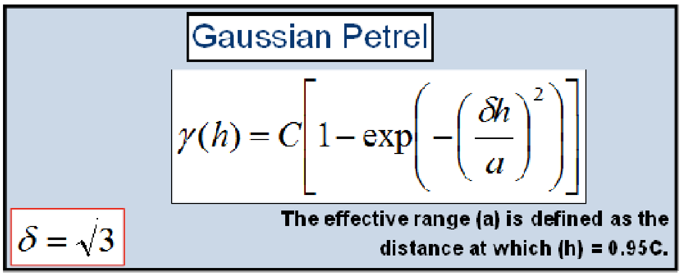
$h < a$: $$\gamma(h) = C\left[\frac{3}{2}\left(\frac{h}{a}\right) - \frac{1}{2}\left(-\frac{h}{a}\right)^3\right]$$

$h \geq a$: $\gamma(h) = C$

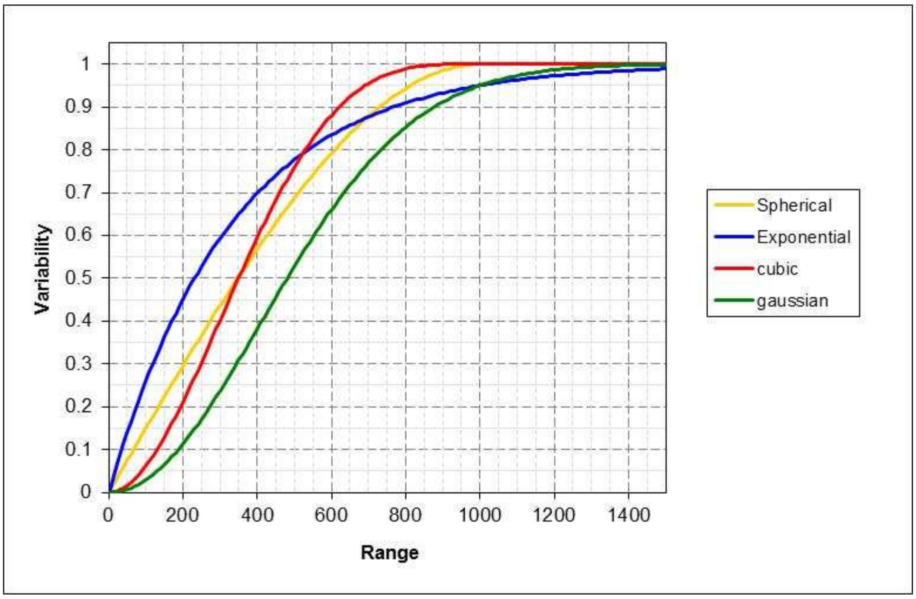
h = separation distance
C = sill - Nugget
a = effective range



10.4.4 Gaussian variogram



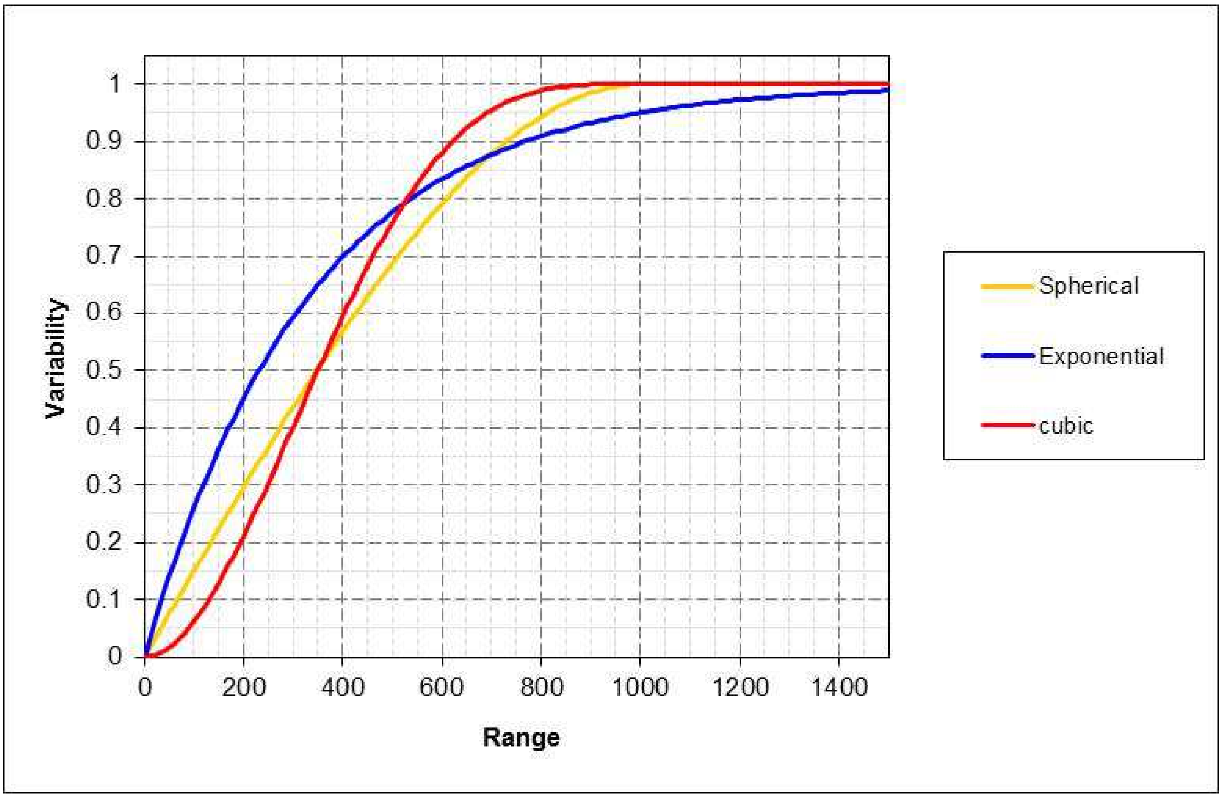
h = separation distance
C = sill - Nugget
a = effective range
δ = scaling factor

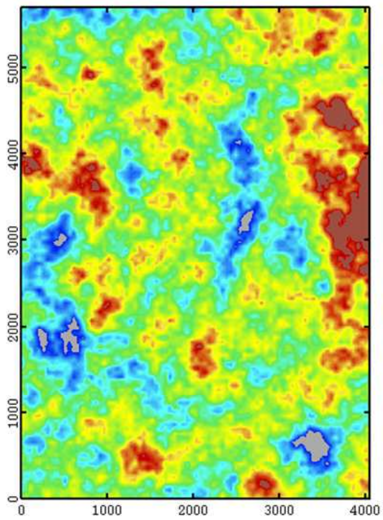


Gaussian variogram is not included as an option in UDOMORE Depth, for a number of reasons: using Gaussian variogram model (infinitely differentiable for h=0) is suitable for data sets showing extreme spatial continuity which is seldom the case. In the case of time to depth conversion, small depth differences between adjacent wells (short distance in space) will introduce numerical instabilities in the kriging equation system, because the variogram model assumes a spatial continuity that is not verified by experimental data values. The numerical “tip” is then to introduce a small “nugget” effect in the variogram model but this prevent to properly tie the depth maps to the wells.

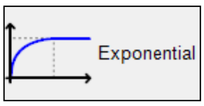
10.4.5 Variogram mapping comparison

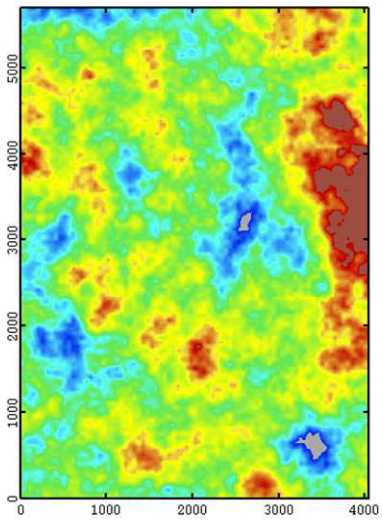
This section contains some illustrations build by stochastic simulations to illustrate the different type of continuity available under the plug-in. Each realizations have the same range and sill, only the type of continuity (Exponential Spherical, Cubic) change.



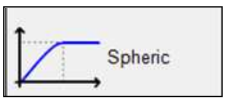


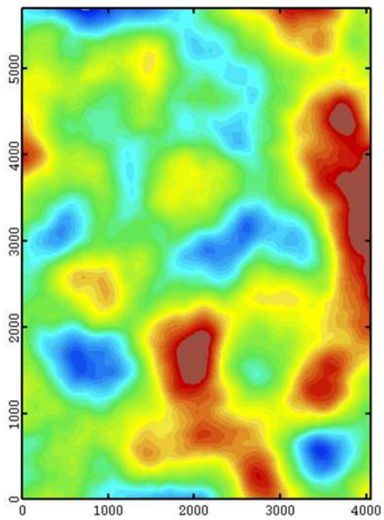
Exponential Model



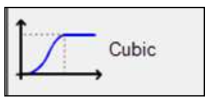


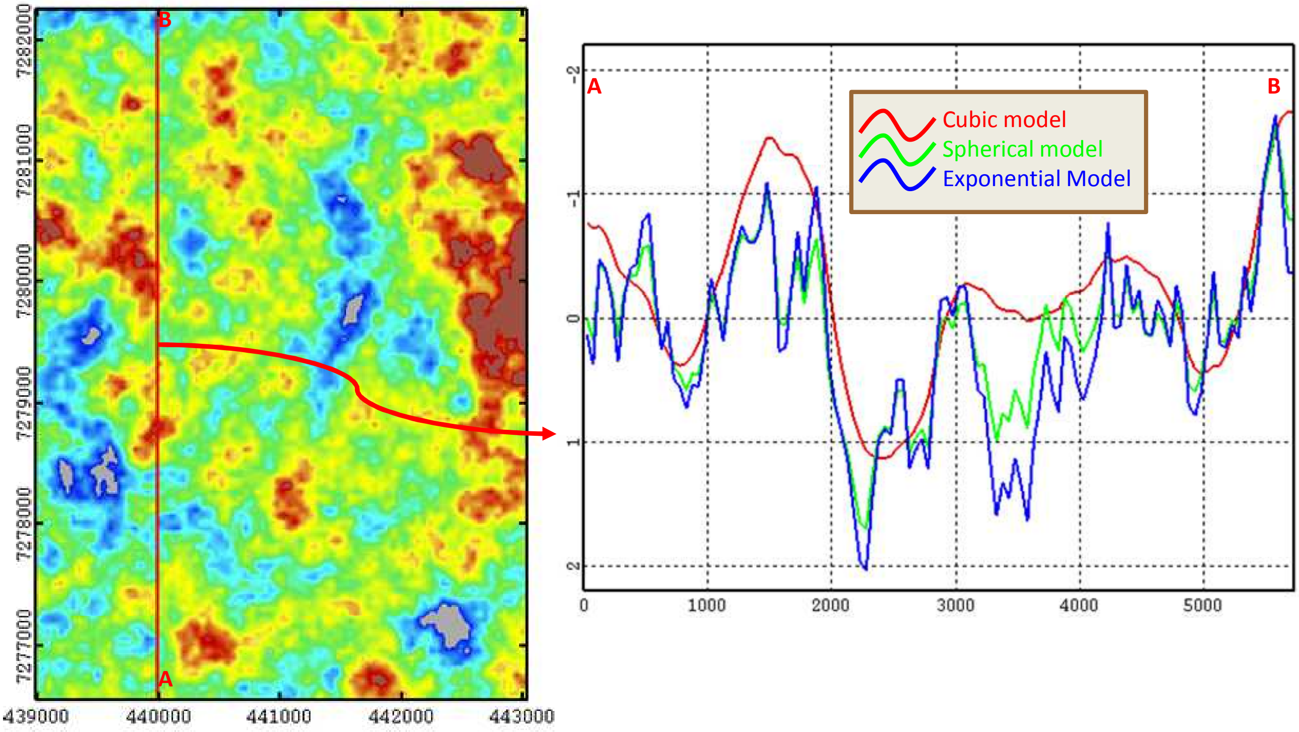
Spherical Model





Cubic_Model



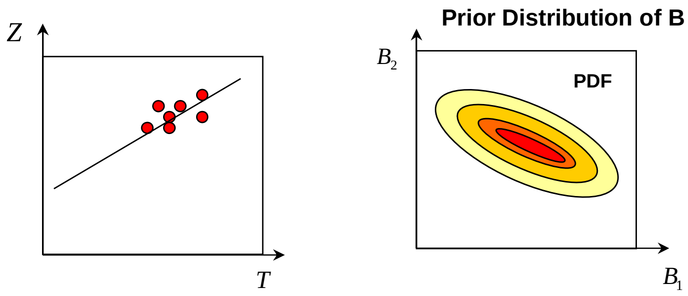


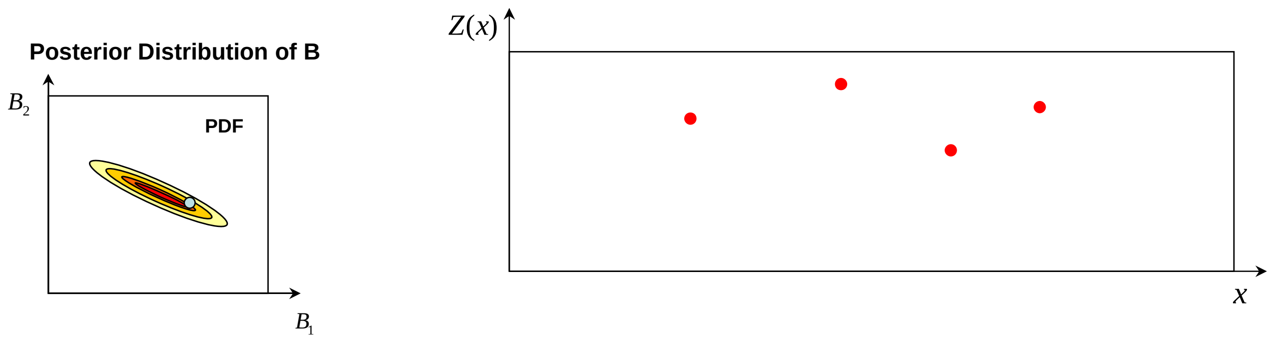
10.5 Stochastic simulations

Stochastic simulations workflow breaks down as follows:

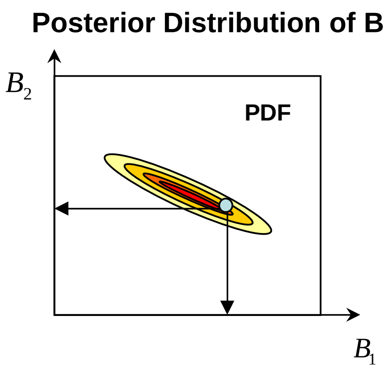
- Draw drift coefficients from posterior distribution;
- Compute simulated trend;
- Add a simulated unconditional field with given covariance;
- Compute residual with data points;
- Apply Bayesian kriging of residuals.

Illustration for an interval velocity function with one parameter B :

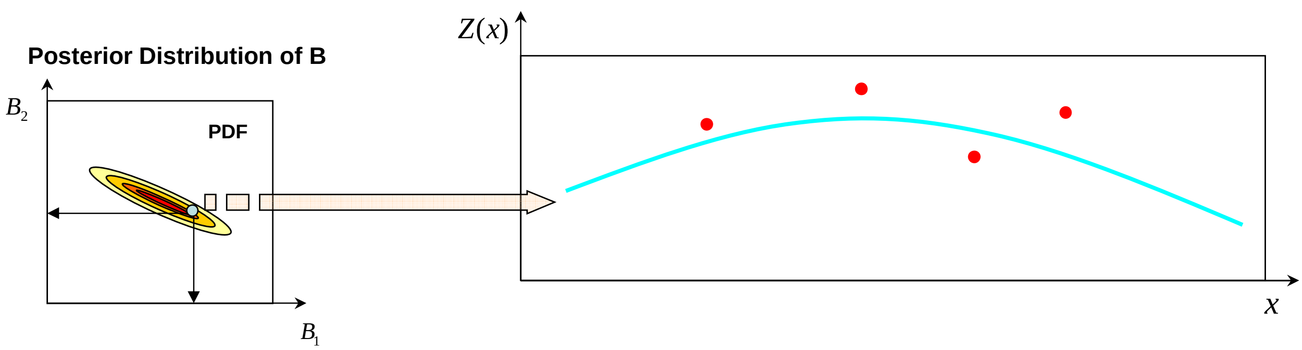




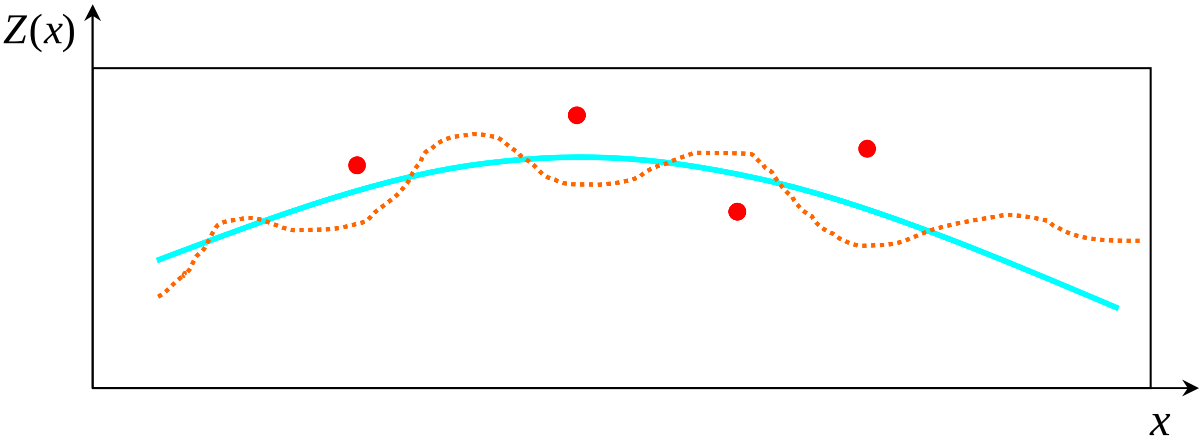
- Draw drift coefficients from posterior distribution



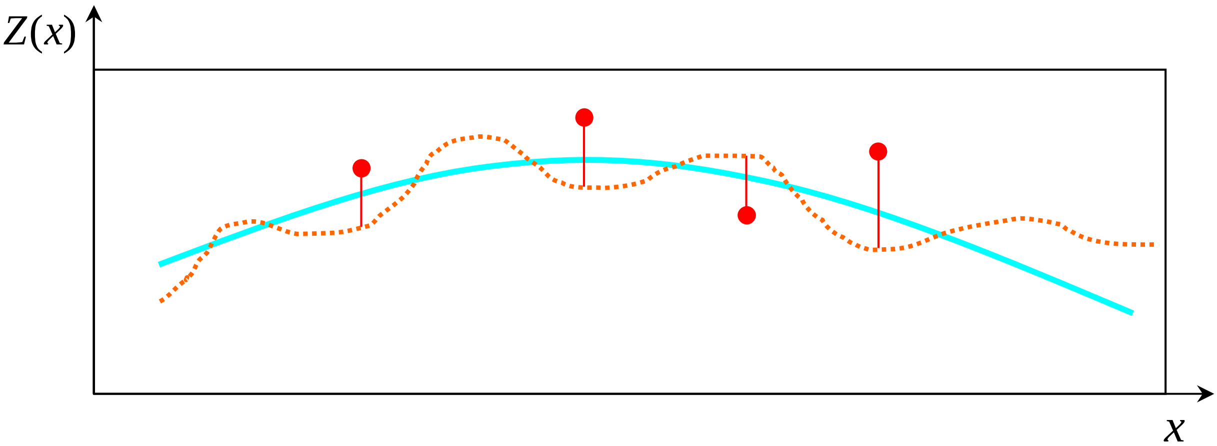
- Compute simulated trend



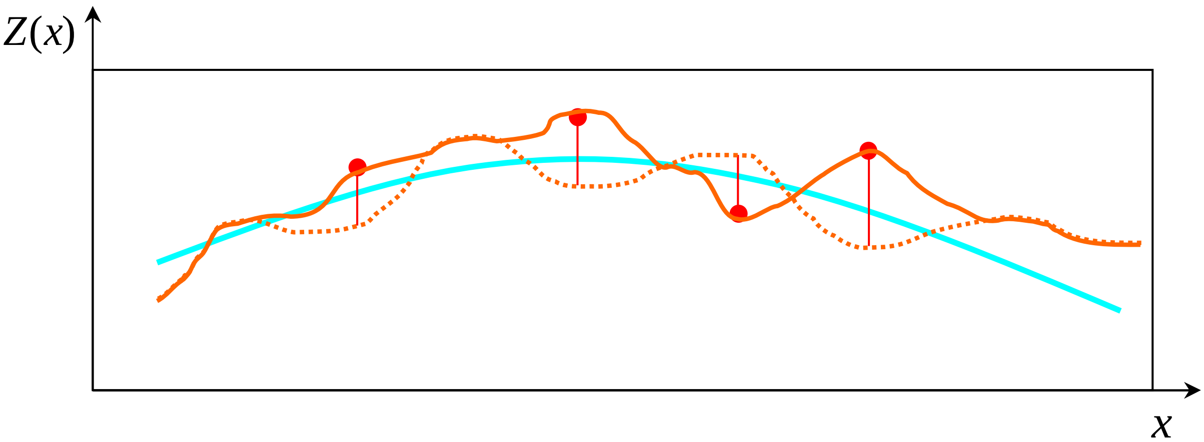
- Add a simulated unconditional field with given covariance



- Compute residual with data points



- Apply Bayesian kriging of residuals



Annex 1 - UDOMORE Depth data types Vs Petrel Templates

Udomore data type	Petrel Template
Depth	Elevation depth
Depth uncertainty	Thickness depth
Time	General, Elevation Time
Time uncertainty	General, Thickness time
Thickness	Thickness depth
Thickness uncertainty	Thickness depth
Velocity	General, Velocity, Velocity Interval
Velocity uncertainty	General, Velocity interval