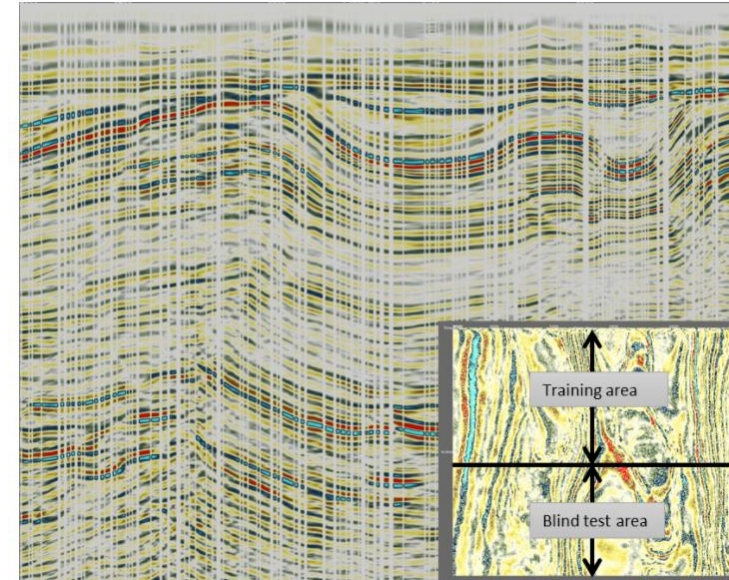


Exercise objective:

To fill blank seismic traces using the ‘Seismic Image Regression’ workflow which is part of the machine learning plugin. The model will have to learn how to recreate an image from example images containing blank traces. Therefore, we need an input data set in which we have deliberately blanked some of the traces.

For the purpose of this exercise:

- We use OpendTect’s attribute engine to randomly blank +/- 33% of all traces
- We select examples from one side of the volume for training the U-Net
- We apply the trained U-Net to the full volume, so that we can validate the interpolation results in the blind test zone



Note: In this exercise we train a 2D Unet but you can equally well train a 3D Unet. The differences between 2D and 3D Unets are as follows:

1. A 2D model trains much faster (hours vs days)
2. 2D models can be trained on workstations with less GPU / CPU capacity
3. Interpolation results are comparable although 2D interpolation may introduce some striping (like a footprint)
4. Application of a trained 3D model is much faster than a trained 2D model (minutes vs hours)

Randomly blank traces workflow:


To train our 2D Unet regression model we create a data set with 33% randomly blanked traces. From this cube we extract examples for training in a restricted area. The trained model is applied to the entire volume, whereby the area from which no examples are extracted acts as blind test area. The real value is of course when we apply the trained model to an area with real missing traces (which we don't have in this case). Random blanking (replacing the values with hard zeros) is done in OpendTect's Attribute engine and can be done in different ways. In this case, we will create an attribute set to perform the following tasks:


1. Math attribute with formula: "randg(1)". This generates random values with a Gaussian distribution and 1 standard deviation;
2. Apply this attribute to a horizon and save as horizon data;
3. Horizon attribute that retrieves the random values from the saved horizon data. A Horizon attribute replaces a value at an inline, crossline position with the value extracted from the given horizon;
4. Math attribute with formula: "abs(value)> 1 ? 0: seis". We assign the retrieved horizon data to the variable "value" and the seismic data to "seis". This attribute assigns values larger than the absolute value of 1 standard deviation to zero while all other values are given the value of the seismic data.
5. Additional attributes in the set are used to compare/QC results before and after prediction.

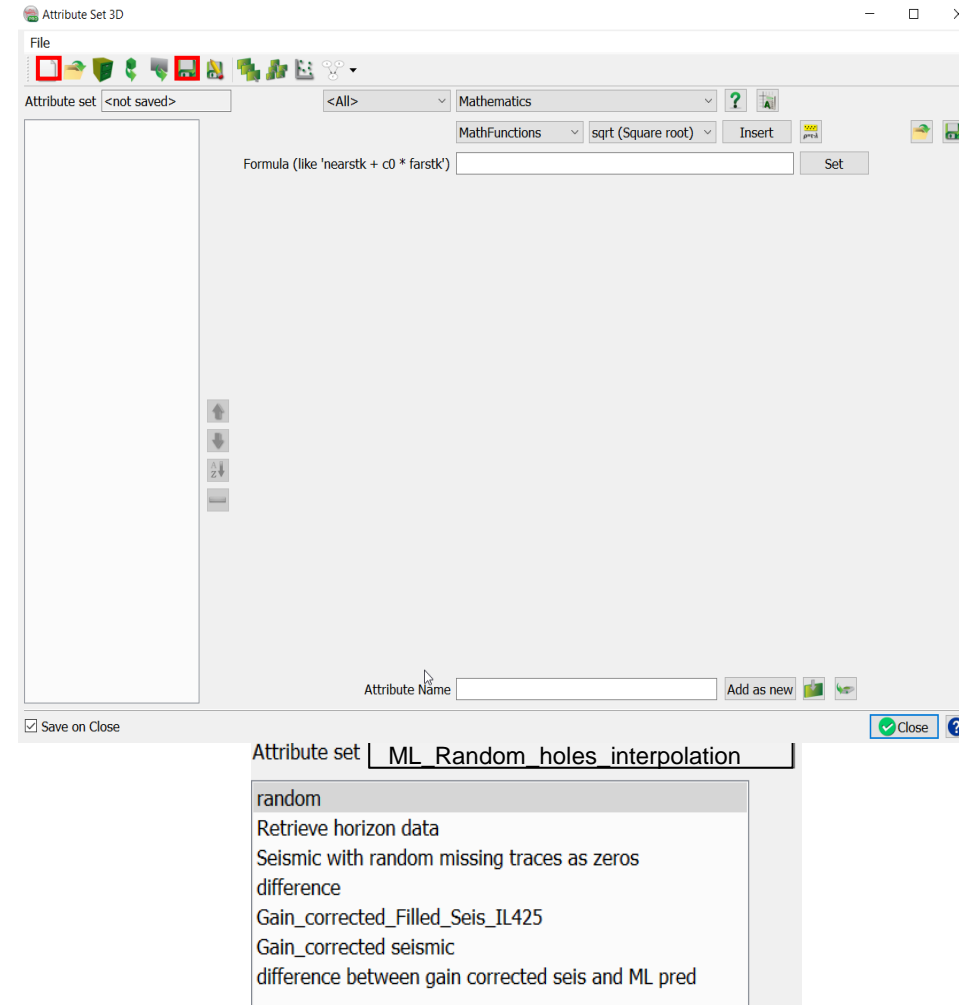
Randomly blank traces workflow:

Create a new 3D attribute set to randomly blank traces as explained in the following steps.

1. **Select** the 3D Attributes engine  icon.

2. **Create** a new 3D attribute set 
These attributes that will be explained in the next steps.

3. **Save** as attribute set  with the name 'ML_Random_holes_interpolation'.



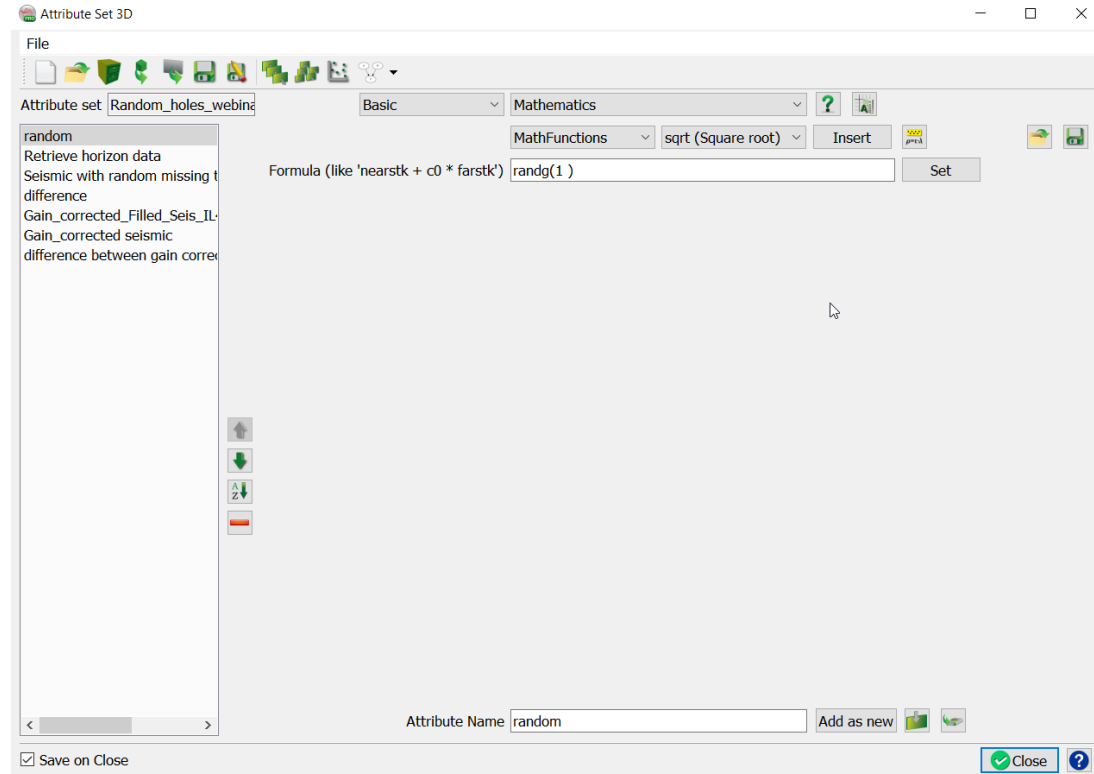
Randomly blank traces workflow:

4. **Create** 1st attribute with name 'random' as indicated in the attribute set window and **Hit** 'Add as new'.

5. **Set** Math attribute with formula: "randg(1)".

This generates random values with a Gaussian distribution and 1 standard deviation;

Apply this attribute to an horizon and save as horizon data as indicated in the next step.



Randomly blank traces workflow:

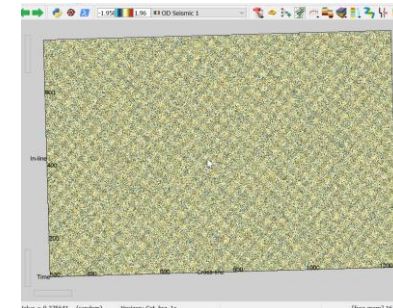
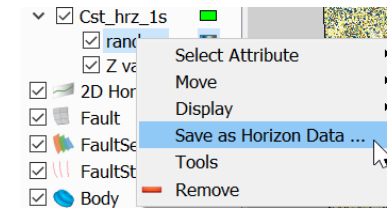
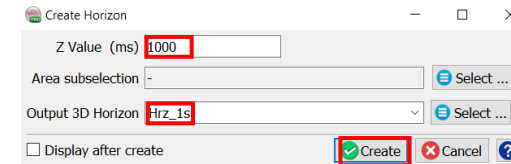
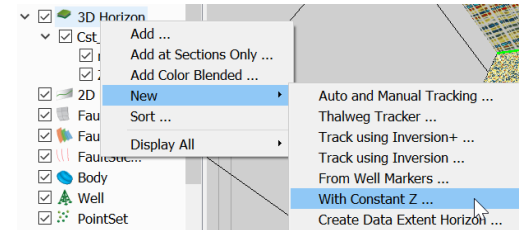
Create a seismic horizon at $Z = 1$ s. Then apply the random attribute to this horizon and save this as horizon data. This horizon data will be used in the attribute that does the actual blanking.

6. Create a constant seismic horizon at $Z = 1$ s.

7. Right mouse click on the 3D Horizon < New < With constant Z.

8. Enter Z value (ms)= 1000. Type an Output 3D Horizon name e.g. Hrз_1s. **Hit** Create.

9. Display the horizon – attribute ‘random’. **Save as** Horizon data.



Randomly blank traces workflow:

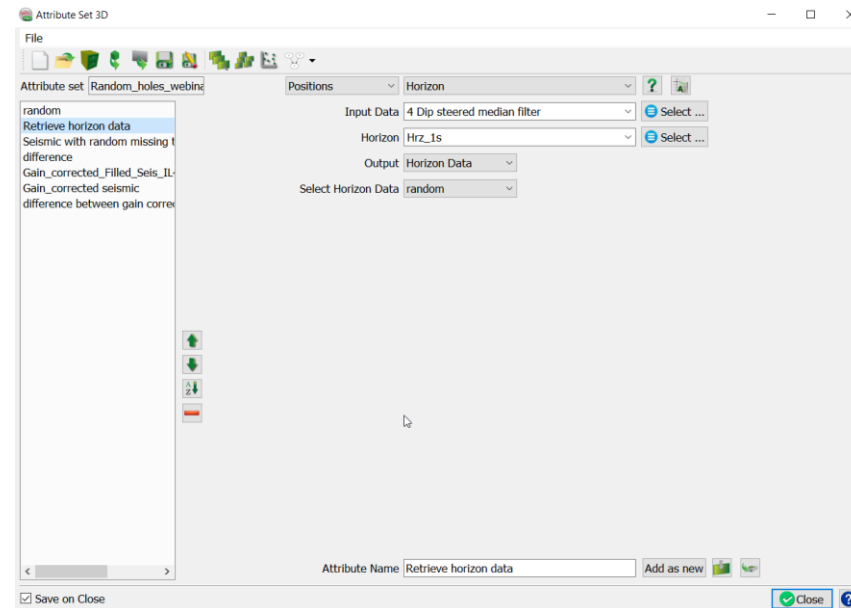
Create an horizon attribute that retrieves the random values from the saved horizon data. The horizon attribute replaces a value at an inline, crossline position with the value extracted from the given horizon.

10. **Create** 2nd attribute “Retrieve horizon data” as indicated in the attribute set window and **Hit** ‘Add as new’.

11. **Select** the Input Data that will be blanked ‘4 Dip steered Median filter’.

12. **Select** the constant horizon “Hrz_1s” created in the previous step.

13. **Select** Output “Horizon Data” and Horizon Data “random”.



Randomly blank traces workflow:

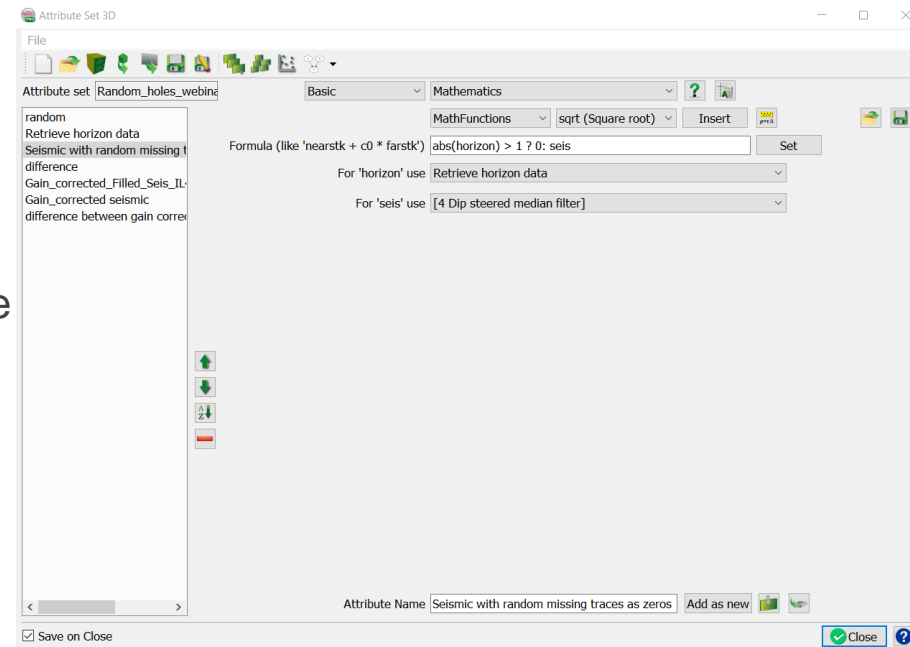
Create an attribute that will randomly blank traces as zeros in the input seismic.

14. Create 3rd attribute 'Seismic with random missing traces as zeros' as indicated in the attribute set window and **Hit** 'Add as new'.

15. Set a Math attribute with formula: " $\text{abs}(\text{value}) > 1 ? 0 : \text{seis}$ ". This assign the retrieved horizon data to the variable "value" and the seismic data to "seis". This attribute assigns values larger than the absolute value of 1 standard deviation to zero while all other values are given the value of the seismic data.

16. Select the previously created attribute 'Retrieve Horizon Data' in the 'For Horizon to use'.

17. Select the seismic you wish to blank in the 'seis' (e.g. 4_Dip steered median filter).

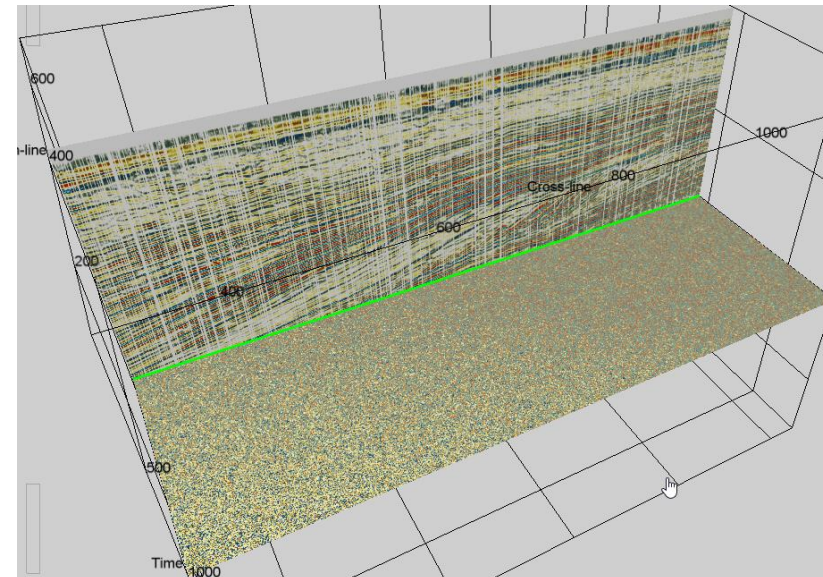
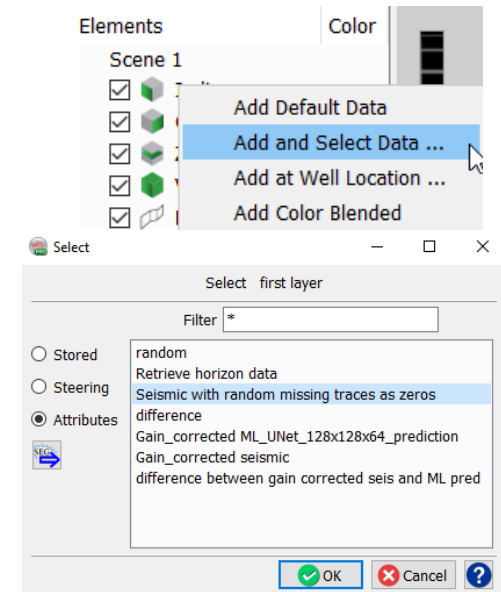


Blank traces workflow cont'd:

18. Display the new seismic attribute with blanked traces. **Right mouse click** on the In-line. **Select** "Add and Select Data"

19. **Select** the attribute "Seismic with random missing traces as zeros" and **Hit** Ok.

Notice that random traces have been blanked.



Blank traces workflow cont'd :

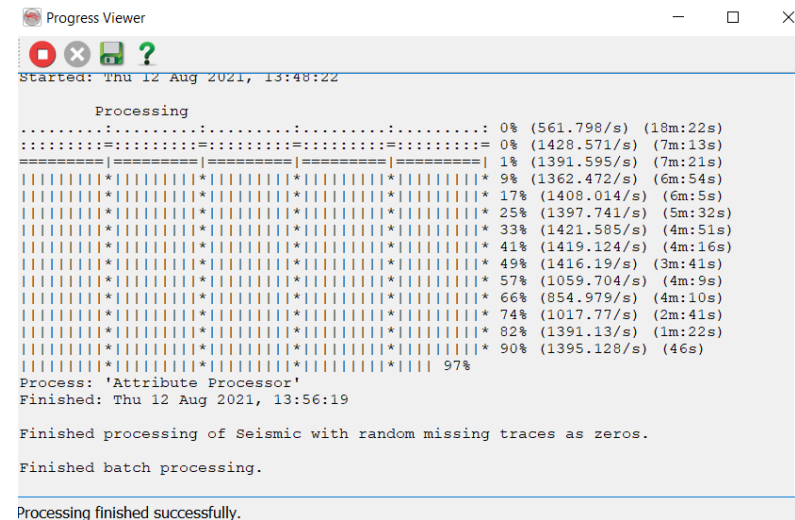
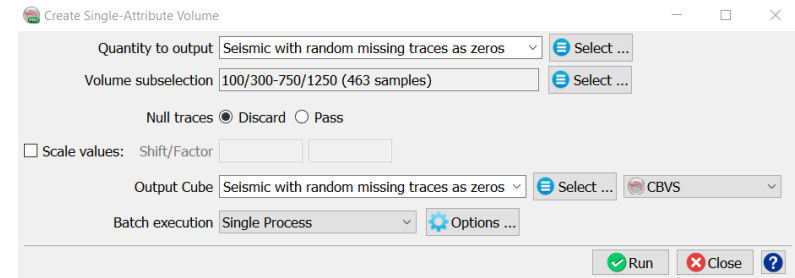
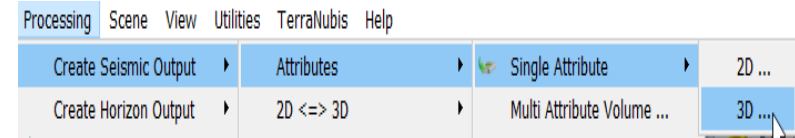
20. **Select**, “Create a Seismic Output” from the attribute – Seismic with random missing traces as zeros.

21. In the “Create Single Attribute Volume” window, keep the default parameters. **Type** an Output name (e.g. Seismic with random missing traces as zeros) and **Run**.

22. **Close** the progress window when the processing finish

23. **Display**/QC the created seismic


This seismic will be used as input for the next step, ML Seismic Image Regression prediction.

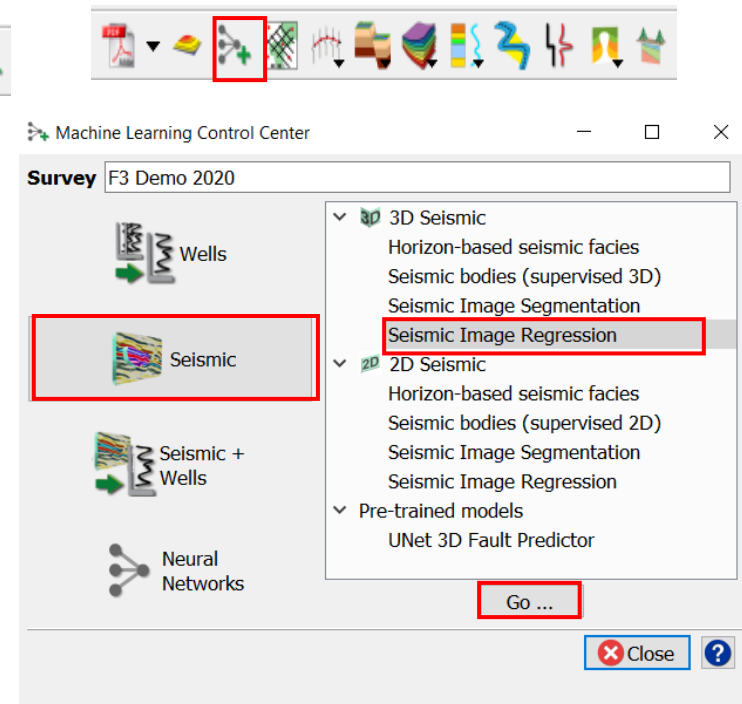


Exercise objective:

To fill blank seismic traces using the ‘Seismic Image Regression’ tool which is part of the machine learning plugin. The model will have to learn how to recreate an image from example images containing blank traces.

Workflow:

1. **Open** the Machine Learning Control Center with the  icon.
2. **Click** on Seismic.
3. **Select** the ‘Seismic Image Regression’ and **Hit** Go.



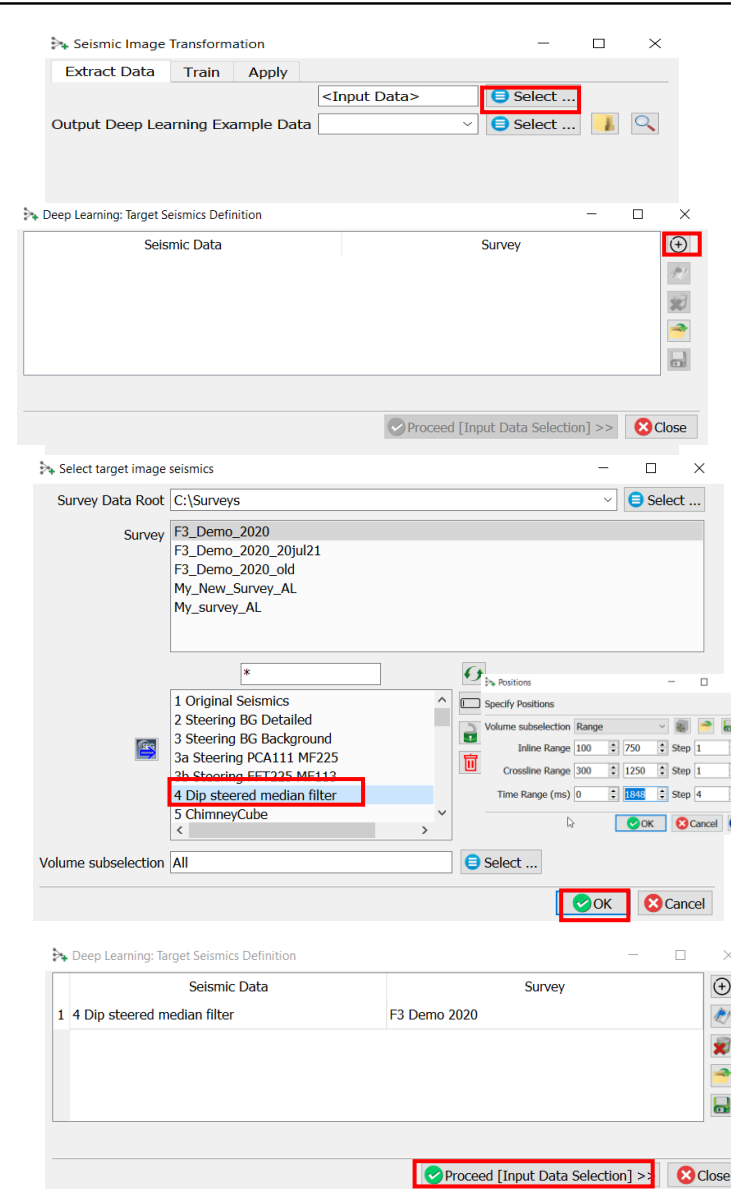
Workflow cont'd:

4. In the 'Extract Data' tab, **Press** the Select button. The "Deep Learning Target Seismic Definition" window pops up.

5. **Press** the + icon and **Select** the target seismic volume (e.g. 4 Dip steered median filter). **And OK.**

***Note:** it is possible to create a Training Set from examples extracted from multiple surveys. To do this, press the + icon again and select the target volume to add to the table below.

6. **Press Proceed [Input Data Selection].** The "Input seismic for prediction" window pops up



* The option to select data from other surveys is available only in commercial projects

Workflow cont'd:

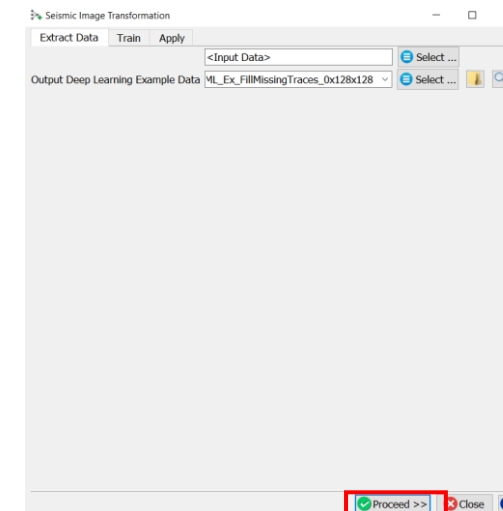
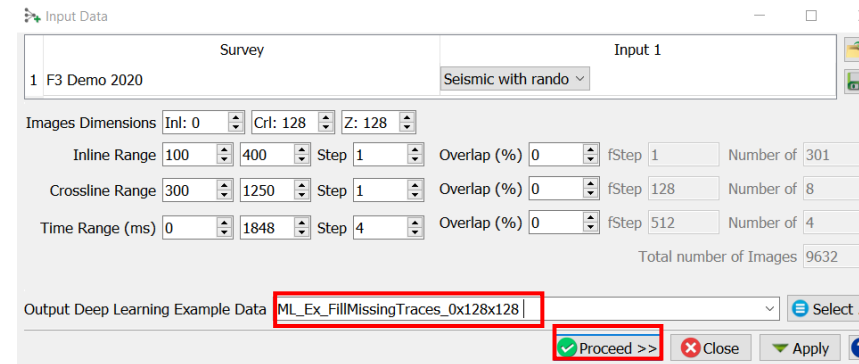
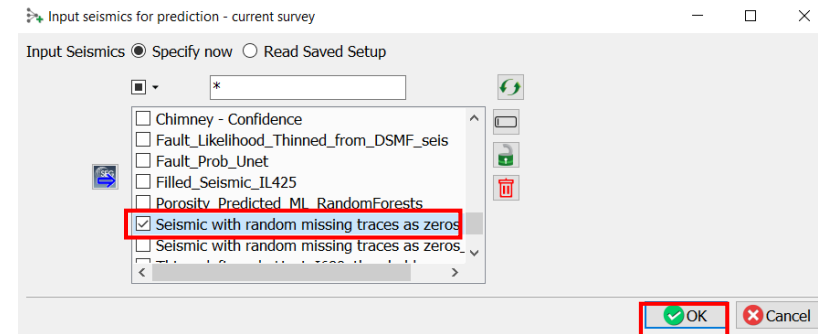
7. **Select** the input seismic data (i.e. the seismic with the missing traces as zeros) and **Press OK**.

8. In the “Input Data” window set the dimensions of the input features. To minimize processing time for this exercise, **Set** the Images dimension to: 0x128x128, overlap: 0x0x0 and Inline range: (100 – 400).

Note: If the current HW has large amount of GPU and CPU/computing power, the recommended Image Dimensions are 128x128x128.

9. **Specify** the name of the Output Deep Learning Example Data (e.g. ML_Ex_FillMissingTraces_0x128x128) and **Press Proceed** to start the extraction process.

10. When this process is finished **Press Proceed** in the “Seismic Image Transformation” window to continue to the Training tab.



Workflow cont'd:

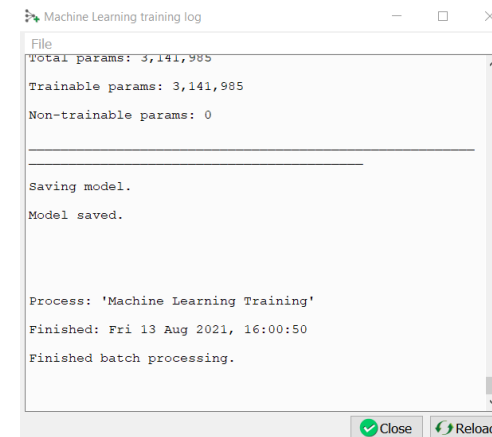
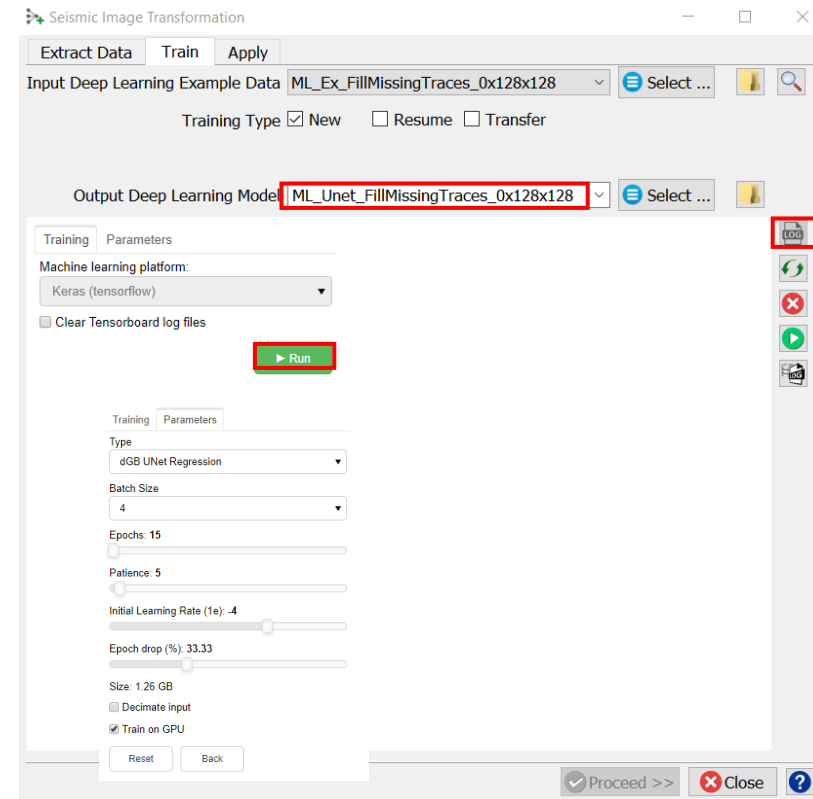
11. After the training data is selected the available models are shown. For seismic image workflows we use **Keras (TensorFlow)**.

12. **Check** the **Parameters** tab to see which models are supported and which parameters can be changed.

13. **Specify** a name for the "Output Deep Learning Model" (e.g. *ML_Unet_FillMissingTraces_0x128x128*).

14. **Hit** Run.

15. **Open** the processing log file to follow the progress. When the log file shows "Finished batch processing", the Proceed button turns green. You can press **Proceed** or **Open** the **Apply** tab.



Workflow cont'd:

16. Once the Training is done, the trained model can be applied. **Select** the trained model and **Press Proceed**.

17. The **Apply** window **pops up**. Here you can optionally apply to a **Volume subselection**. **Type** an Output name (e.g. `Seismic_ML_Unet_FillMissingTraces_0x128x128`)

*Note: You can run on GPU or CPU using the **Predict using GPU** toggle. Running the application on a GPU is many times faster than running it on a CPU.*

18. **Press Run** to create the desired output.

19. **Close** the 'Progress Viewer' window when the processing is finished.

The screenshot displays the 'Seismic Image Transformation' software interface. The main window is titled 'Seismic Image Transformation' and has tabs for 'Extract Data', 'Train', and 'Apply'. The 'Apply' tab is active, showing a list of surveys: 'F3_Demo_2020', 'F3_Demo_2020_20Jul21', 'F3_Demo_2020_old', 'My_New_Survey_AL', and 'My_survey_AL'. Below this list, a model named 'ML_Unet_FillMissingTraces_0x128x128' is selected, with a red box around its name. The 'Proceed' button is highlighted with a red box. Below the model list, a text box contains the following information: 'Name: ML_Unet_FillMissingTraces_0x128x128. Type: Seismic Image Transformation. Data Type: 3D Volume. Number of inputs: 1. Output: 4 Dip steered median filter. Created by: assia. Created at: Fri 13 Aug 2021, 15:07:48. Last Modified: Fri 13 Aug 2021, 16:00:50. Object ID: 100060.64'. The 'Proceed' button is highlighted with a red box.

The 'Apply' window is titled 'Apply ML_Unet_FillMissingTraces_0x128x128' and shows the following settings: 'Input Cube [Seismic with random missing traces as zeros]', 'Apply Overlap (%) Inl: 10, Crl: 10, Z: 10', 'Volume subselection All', 'Output 4 Dip steered median filter Seismic_ML_Unet_FillMissingTraces_0x128x128', 'Predict using GPU' checked, and 'Execute in Batch' checked. The 'Run' button is highlighted with a red box.

The 'Progress Viewer' window shows the progress of the processing. It displays a progress bar and a list of progress indicators for each trace. The progress indicators are as follows:

Trace ID	Progress (%)	Time (s)
65%	13.722/s	110m:58s
67%	13.893/s	9m:24s
69%	13.634/s	8m:58s
71%	13.62/s	8m:22s
73%	13.657/s	7m:44s
75%	13.754/s	7m:4s
77%	13.904/s	6m:24s
79%	13.652/s	5m:54s
81%	13.847/s	5m:13s
84%	13.584/s	4m:42s
86%	13.212/s	4m:12s
88%	13.544/s	3m:29s
90%	13.765/s	2m:50s
92%	13.591/s	2m:15s
94%	13.666/s	1m:58s
96%	13.712/s	1m:1s

The progress bar shows 97% completion. The process is identified as 'Deep Learning Applier' and finished at 'Fri 13 Aug 2021, 17:05:13'. The message 'End of process: 'Deep Learning Applier'' and 'Finished batch processing.' is displayed. The final status is 'Processing finished successfully'.

Workflow cont'd:

Compare the original seismic data with the Unet predicted filled seismic results. The line is extracted from the blind test area.

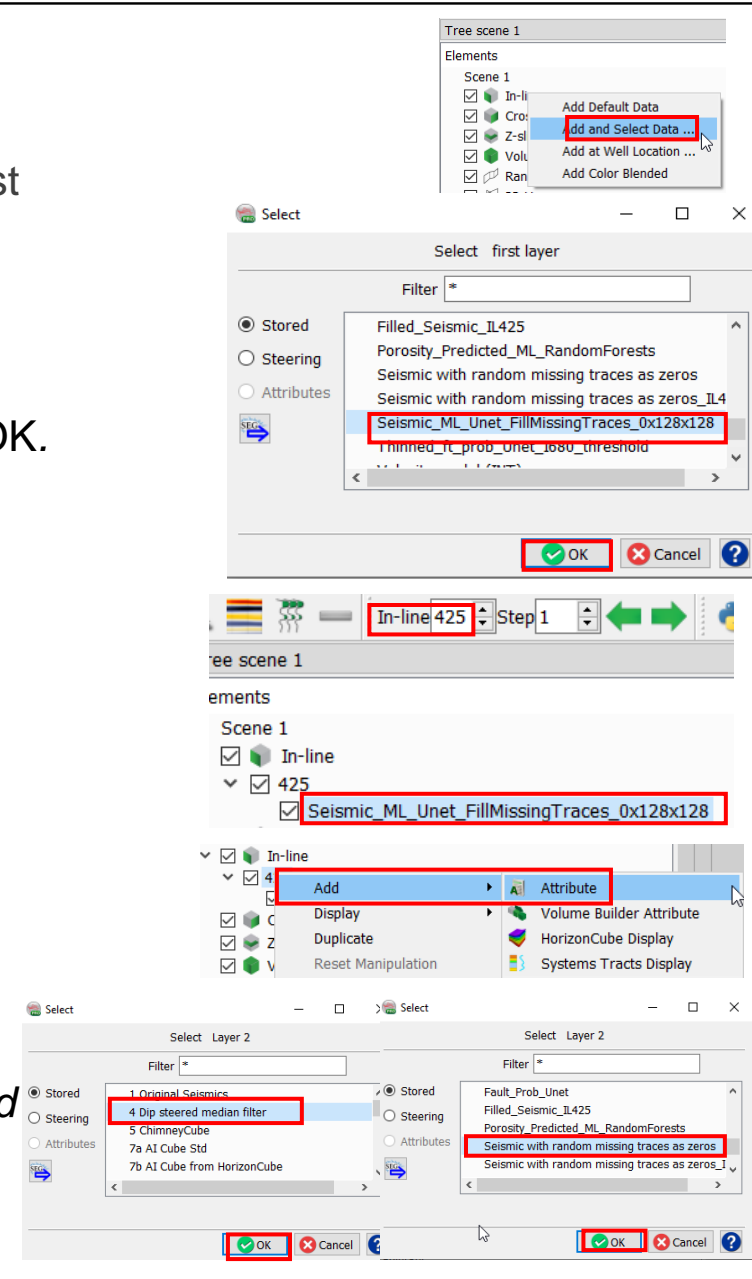
20. **Right Mouse Click** on *In-line* > **Add and select Data** > **Store**. **Select** the created *Filled Seismic* (e.g. *ML_Unet_FillMissingTraces_0x128x128*), and **Hit** OK.

21. **Type** in the *Inline* field: 425, and **Hit** Enter.

The same way, add to the display, the original seismic and seismic with missing traces .

22. **Right-Click** on *Inline 425* > **Add** > **Attribute** > **Stored**. **Select** the original seismic (e.g. *4 Dip steered median filter*), and **Hit** OK.

23. **Right-Click** on *Inline 425* > **Add** > **Attribute** > **Stored**. **Select** the seismic with missing traces (e.g. *Seismic with random missing traces as zeros*), and **Hit** OK.

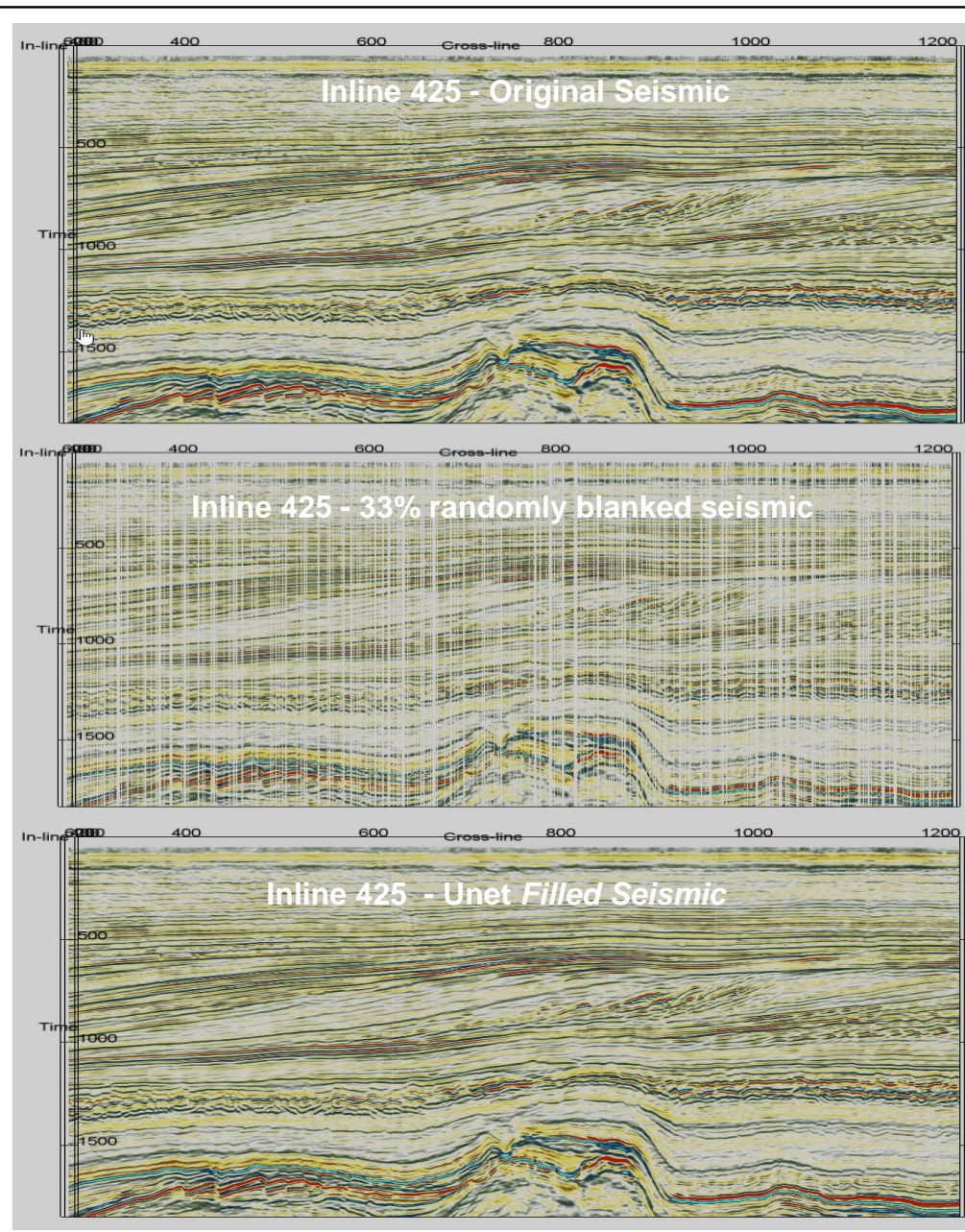
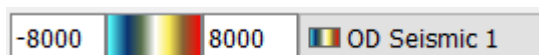


Workflow cont'd:

24. **Compare** visually in the blind test area the:



- *Original seismic (4 Dip steered median filter)*
- *Randomly blanked traces seismic (Seismic with random missing traces as zeros)*
- *Unet filled seismic (ML_Unet_FillMissingTraces_0x1 28x128)*

25. For more accurate comparison, **Set** similar colour range for the 3 seismic cubes. Highlight the seismic cube, Set the colour bar range to (-8000, 8000).



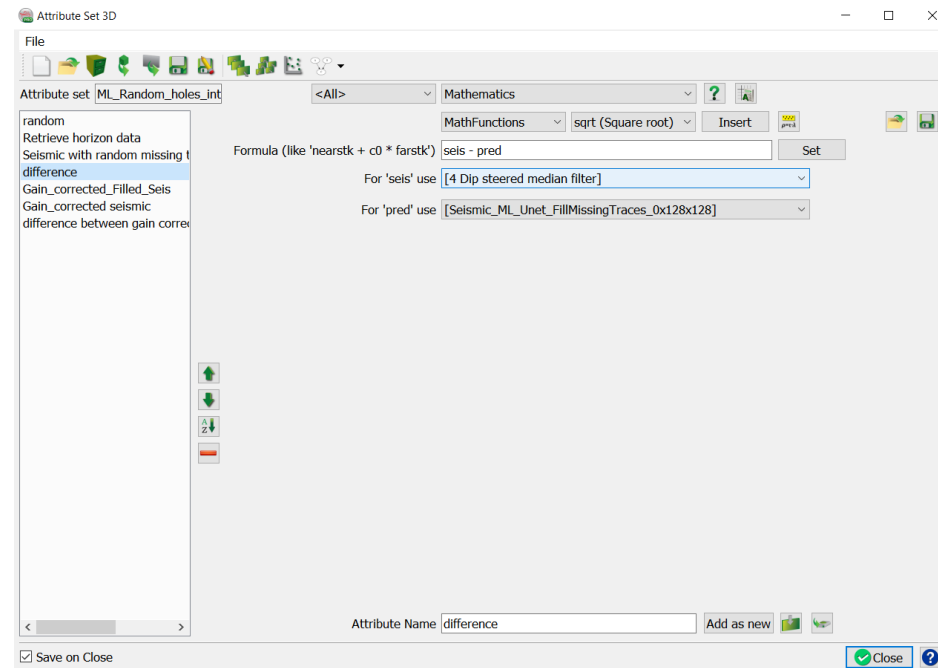
Workflow cont'd:

For a better quantitative comparison, create a new attribute 'difference' that computes the difference between the predicted and the original seismic.

26. Select the 3D attribute icon . **Open** the attribute set . **Select** the attribute set "ML_Random_holes_interpolation"

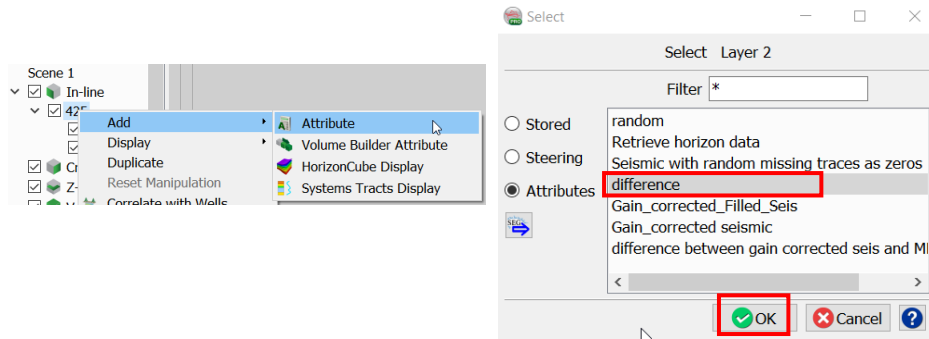
27. Create a 4th attribute "difference" as indicated in the attribute set window and **Hit** 'Add as new'.

28. Select the Original seismic (e.g. *4 Dip steered median filter*) for 'Seis', and the predicted seismic (e.g. *ML_Unet_FillMissingTraces_0x128x128*) for 'pred'



Workflow cont'd:

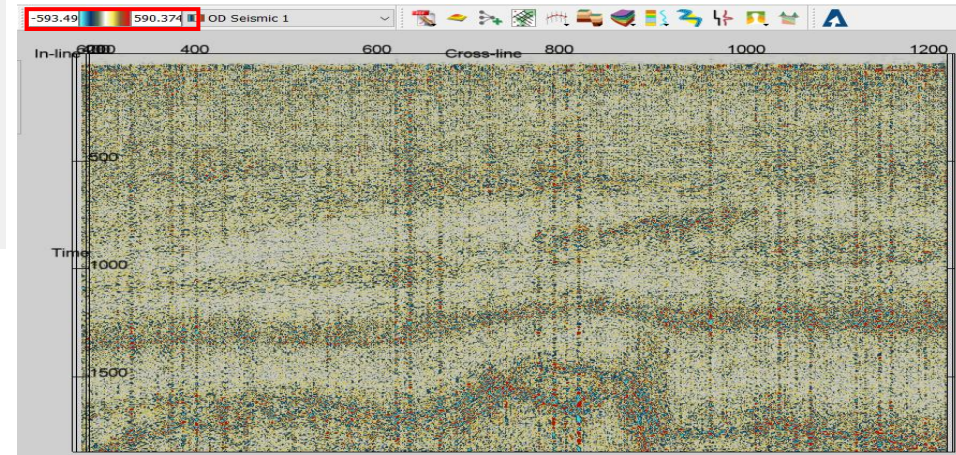
Display/QC the attribute "difference". Difference = Original seismic (4 Dip steered median filter) – Predicted seismic (ML_Unet_FillMissingTraces_0x128x128)



29. **Right-Click** on Inline 425 > Add > Attribute. **Select** the attribute 'difference', and **Hit** OK.

Notice the small values of the difference, range (-593, 590).



30. For more accurate comparison, **Modify** the color range to similar range as the original and predicted seismic [-8000,8000]



Workflow cont'd (Optional):

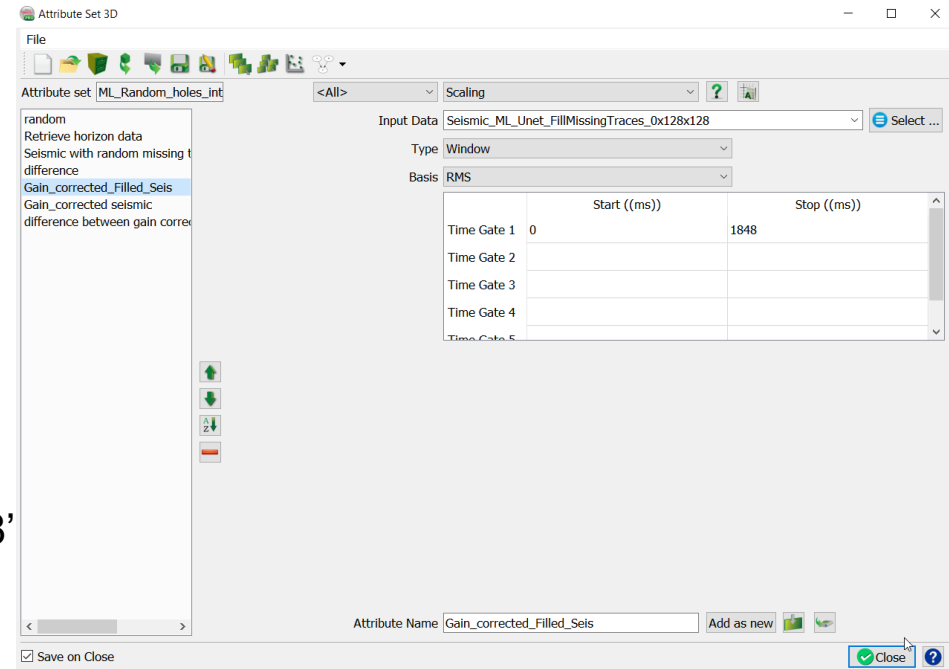
For more accurate comparison, apply an RMS gain scaled correction to the original and predicted seismic, then compute the difference.

Create a new Gain correction attributes to be applied on the original and predicted seismic.

31. Select the 3D attribute icon . **Open** the attribute set . **Select** the attribute set "ML_Random_holes_interpolation"

32. Create a 5th attribute "Gain_corrected_Filled_Seis" as indicated in the attribute set window and **Hit** 'Add as new'



33. Select the Input Data "Seismic_ML_Unet_FillMissingTraces_0x128x128"



Workflow cont'd (Optional):

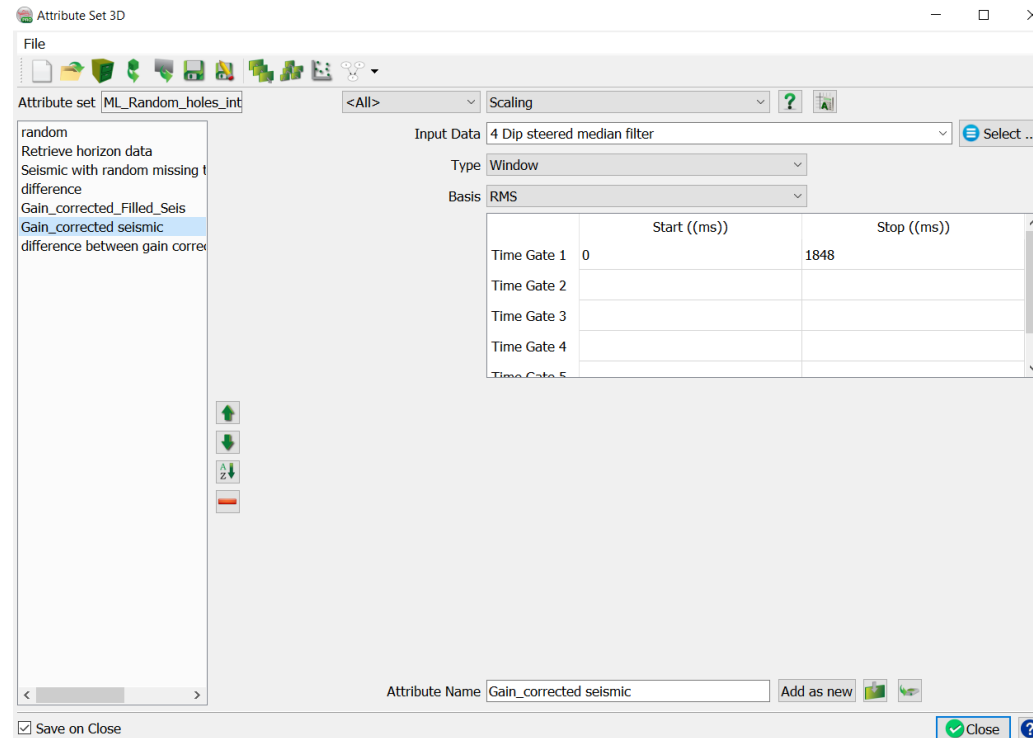
For more accurate comparison, apply an RMS gain scaled correction to the original and predicted seismic, then compute the difference.

Create a new Gain correction attributes to be applied on the original and predicted seismic.

34. Select the 3D attribute icon . **Open** the attribute set . **Select** the attribute set "ML_Random_holes_interpolation"



35. Create a 6th attribute "Gain_corrected seismic" as indicated in the attribute set window and **Hit** 'Add as new'

36. Select the Input Data 'Gain_corrected seismic'



Workflow cont'd (Optional):

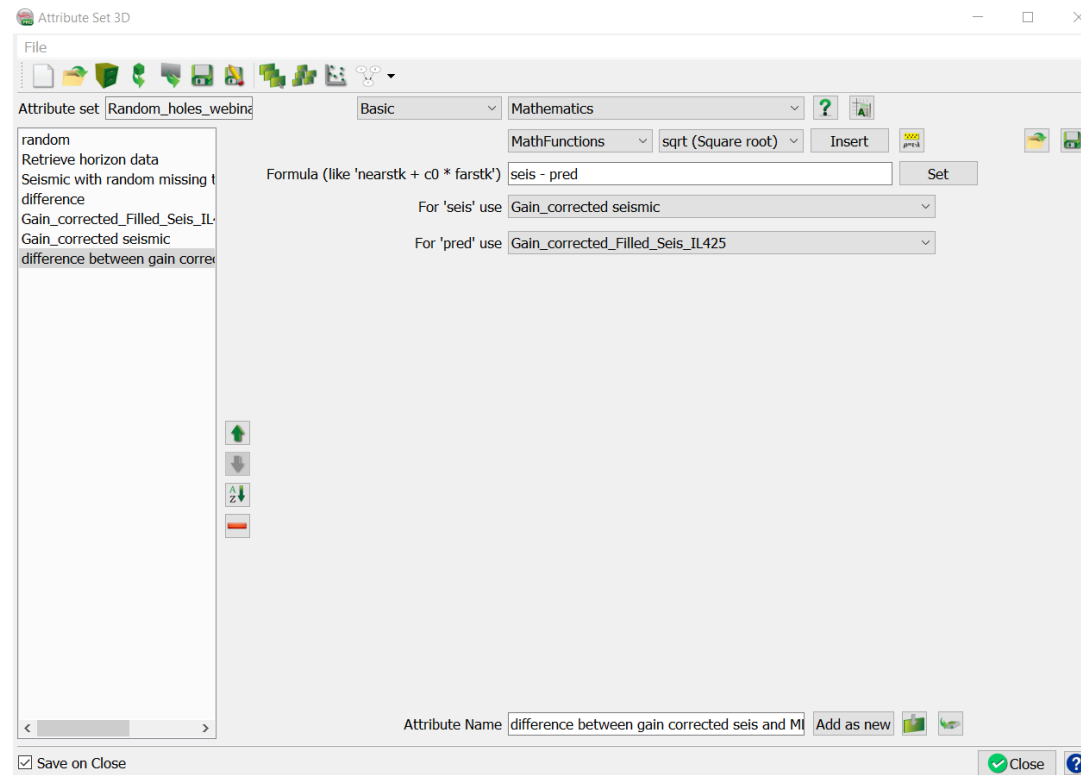
Create a new attribute that will compute the difference between the RMS gain corrected original seismic and ML predicted seismic

37. Select the 3D attribute icon  .
Open the attribute set  . **Select** the attribute set

“ML_Random_holes_interpolation”

38. Create a 7th attribute “difference between gain corrected seis and ML pred” as indicated in the attribute set window and **Hit** ‘Add as new’.

39. Select the “Gain_corrected seismic” as input for ‘seis’ and the “Gain_corrected_Filled_Seis” as input for ‘pred’

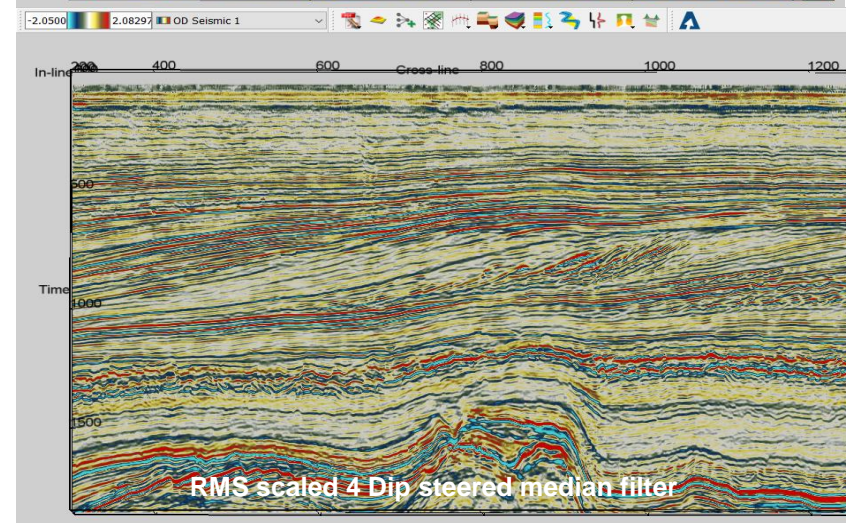
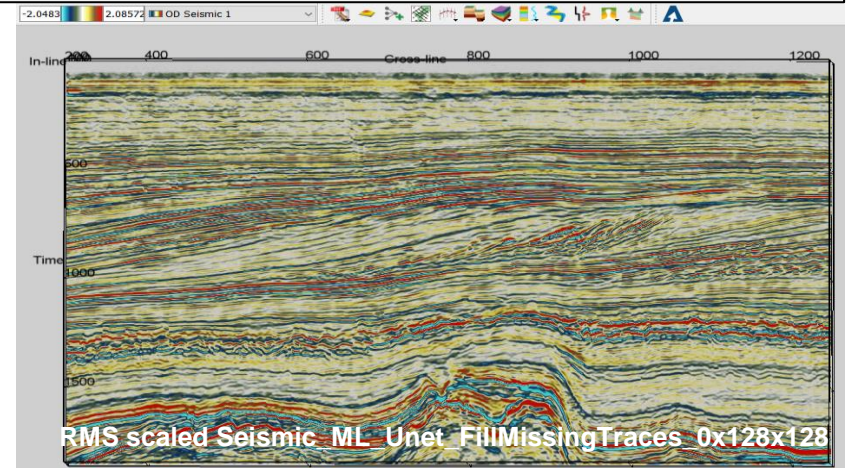


Workflow cont'd (Optional):

Display the attribute "Gain_corrected_Filled_Seis" (RMS scaled Seismic_ML_Unet_FillMissingTraces_0x128x128) and the "Gain_corrected seismic"(RMS scaled 4 Dip steered median filter).

40. Right-Click on *Inline 425 > Add > Attribute*.
Select the attribute "Gain_corrected_Filled_Seis",
and **Hit** OK.

41. Right-Click on *Inline 425 > Add > Attribute*.
Select the attribute 'Gain_corrected seismic', and
Hit OK.



Workflow cont'd (Optional):

Compare quantitatively in the blind test area the RMS gain corrected difference between the *original seismic and the predicted seismic*.

42. **Display** the “difference between gain corrected seis and ML pred” seismic attribute. **Right mouse click** on the In-line 425. **Select** “Add and Select Data”.

43. **Select** the attribute “difference between gain corrected seis and ML pred” and **Hit** Ok.

Notice the very low values of the “difference between gain corrected seis and ML pred”. The range [-0.257, 0.257].

44. *For more accurate comparison, display the difference attribute with similar colour range as the gain corrected original and predicted seismic.* **Highlight** the seismic cube, Set the colour bar range to [-2, 2].

