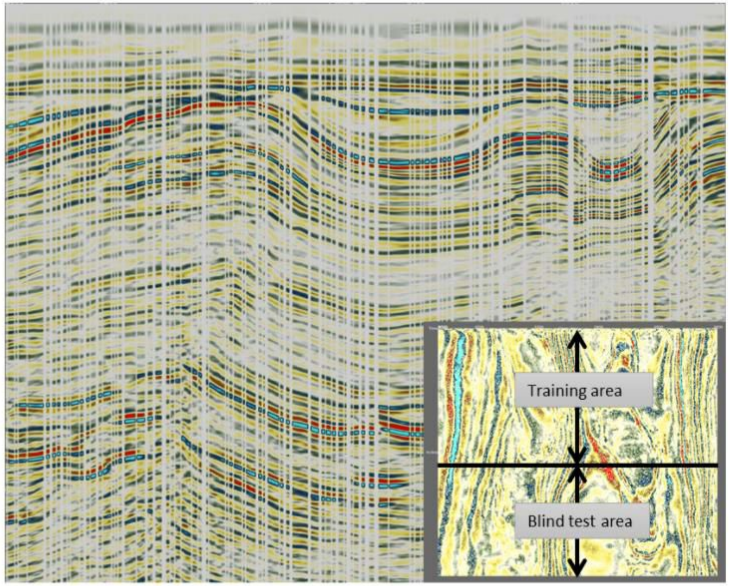
Exercise objective:

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’sattribute engine to randomly blank +/-33% of all traces
- We select examples from one side of thevolume 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 exercisewe train a 2D Unetbut you can equally well train a 3D Unet. The differences between 2D and 3D Unetsare 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 tracesworkflow:

To train our 2D Unetregression 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'sAttribute 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/QCresults before and after prediction.

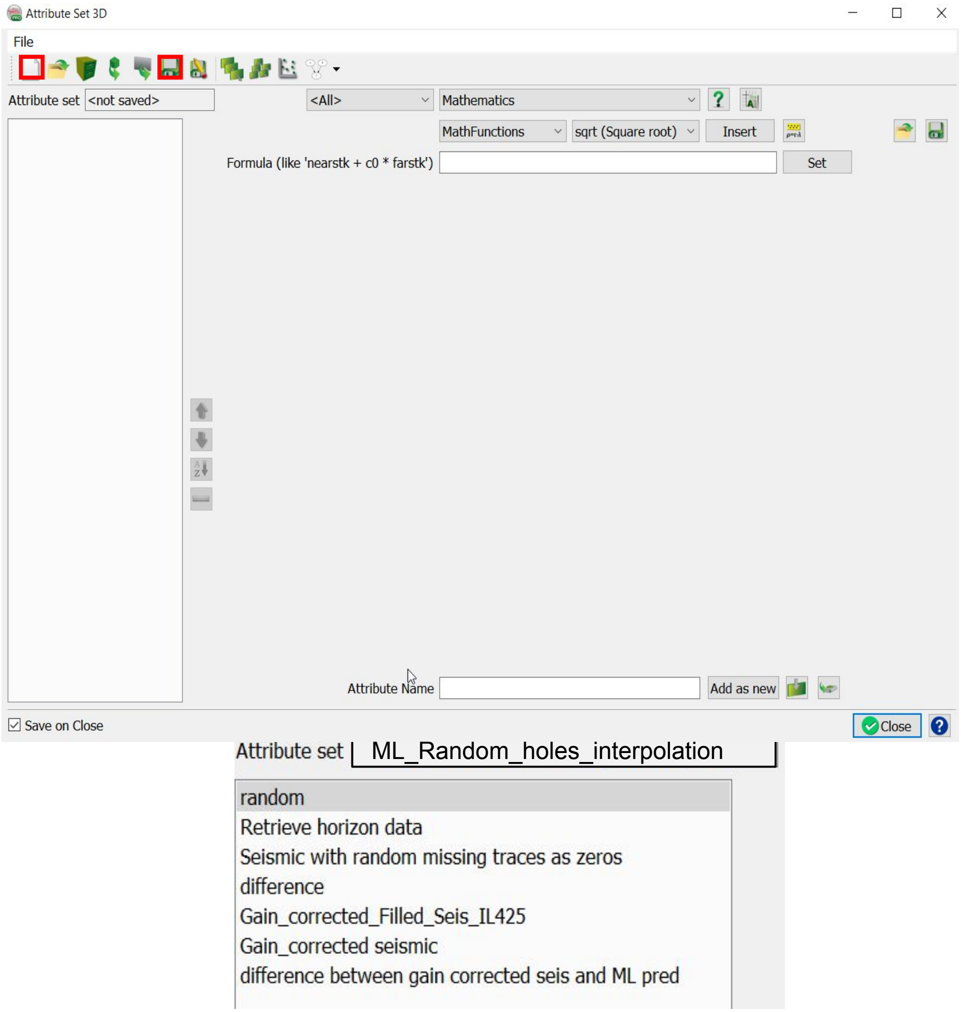
Randomly blank tracesworkflow:

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
Theseattributes that will be explained in the next steps.

3. **Save**as attribute set with the name ‘ML_Random_holes_interpolation’.

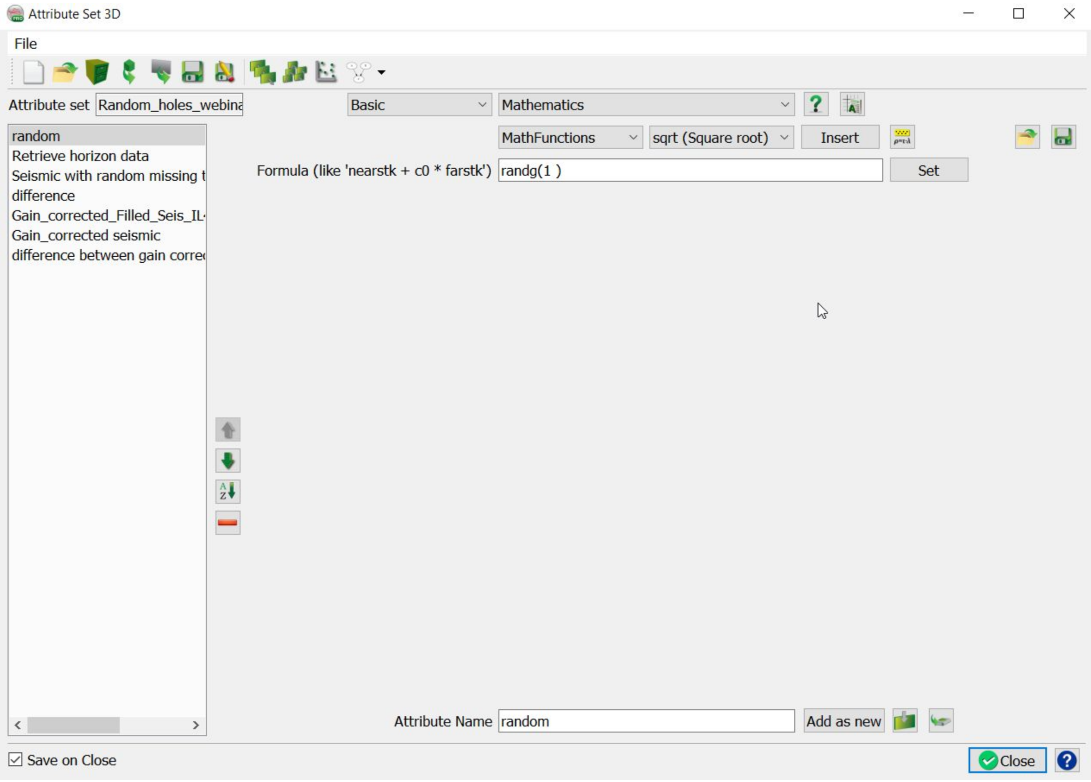


Randomly blank tracesworkflow:

4. Create1st attribute with name 'random' as indicated in the attribute set windowand **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 tracesworkflow:

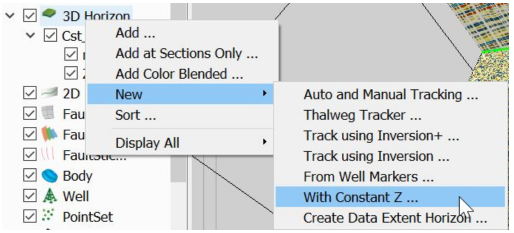
Createa seismic horizon at Z = 1 s. Then apply the random attribute to this horizon and save this as horizon data. This horizon data will beused in the attribute that does the actual blanking.

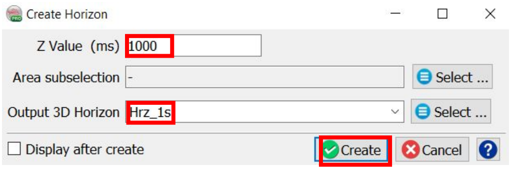
6. Createa constant seismic horizon at Z = 1s.

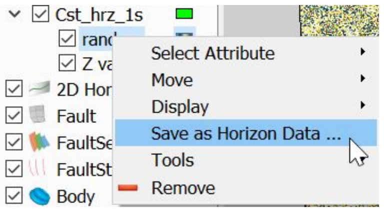
7. Right mouse click on the 3D Horizon < New < With constant Z.

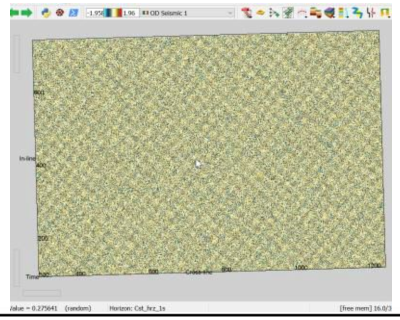
8. EnterZ value (ms)= 1000. Type an Output 3D Horizon name e.g. Hrz_1s. **Hit**Create.

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









Randomly blank tracesworkflow:

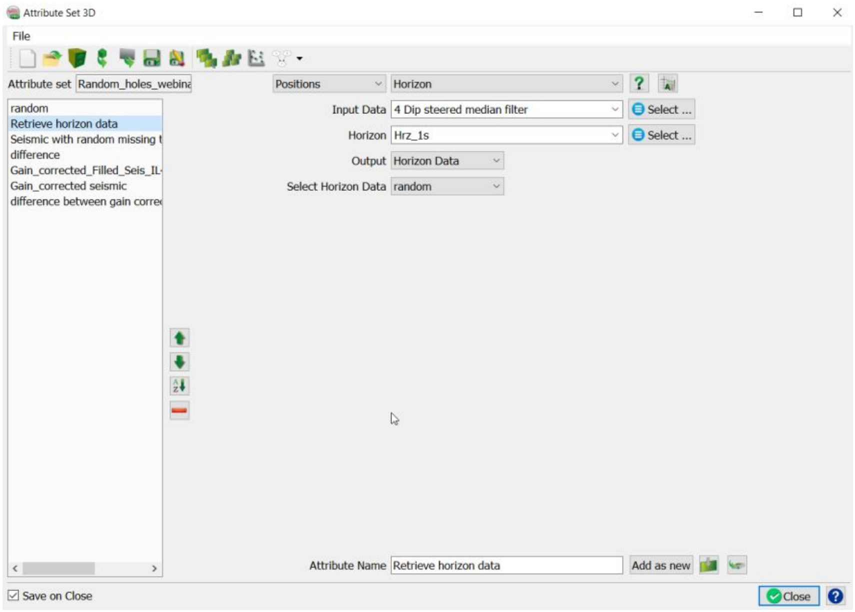
Create an horizon attribute that retrieves the random values from the saved horizon data. The horizon attribute replaces a value at an inline, crossline position with the value extracted from the given horizon.

10. **Create** 2nd attribute ''Retrieve horizon data'' as indicated in the attribute set windowand **Hit** 'Add as new'.

11. Selectthe Input Data that will be blanked '4 Dip steered Median filter'.

12. Selectthe constant horizon ''Hrz_1s'' created in the previous step.

13. **Select** Output ''Horizon Data'' and Horizon Data ''random''.



Randomly blank tracesworkflow:

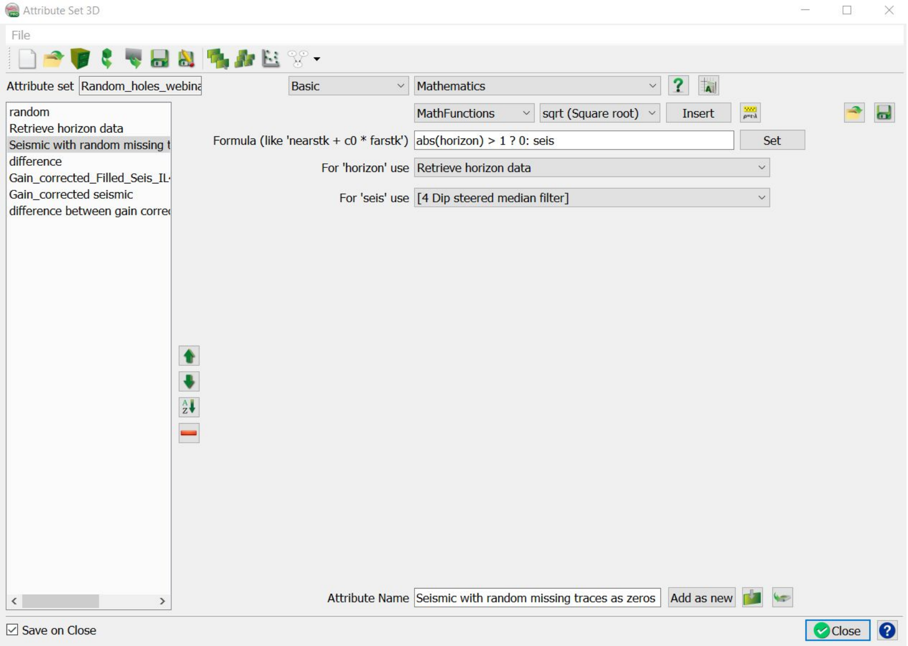
Create an attribute that willrandomly blank traces as zeros in the input seismic.

14. Create3rdattribute ‘Seismic with random missing traces as zeros’ as indicated in the attribute set windowand **Hit**‘Add as new’.

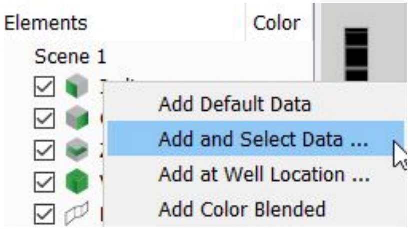
15. Seta Math attribute with formula: “abs(value)> 1 ? 0: seis”. Thisassign the retrieved horizon data to the variable “value” and the seismic data to “seis”. This attribute assigns values larger than the absolute value of 1 standard deviation to zero while all other values are given the value of the seismic data.

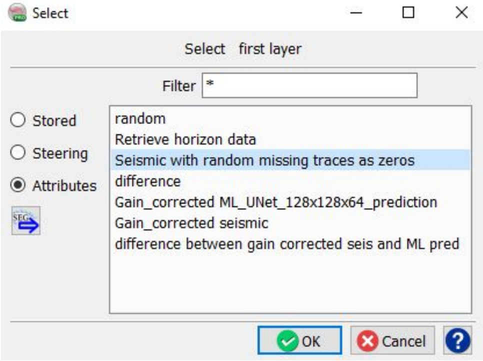
16. Selectthe previously created attribute ‘Retrieve Horizon Data’ in the ‘For Horizon to use’.

17. Selectthe seismic you wish to blank in the ‘seis’ (e.g. 4_Dip steered median filter).



Blank traces workflow cont'd:

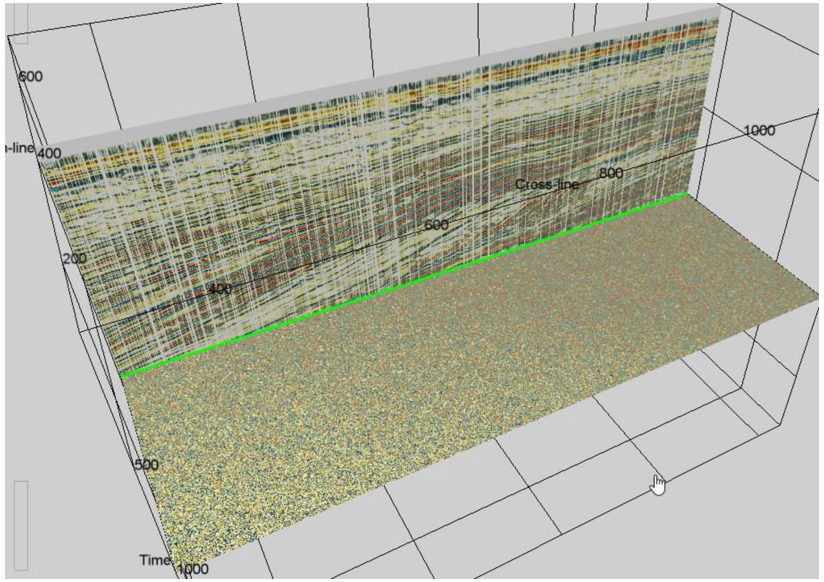




18. Display the new seismic attribute with blanked traces. **Right mouse click**on the In-line. **Select**''Add and Select Data''

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 :

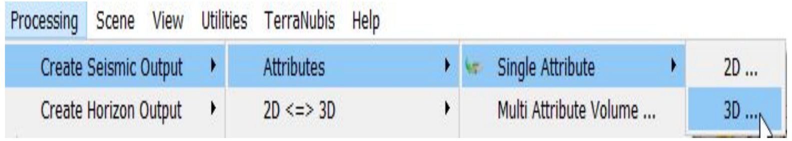
20. **Select**, ''Create a Seismic Output'' from the attribute –Seismic with random missing traces as zeros.

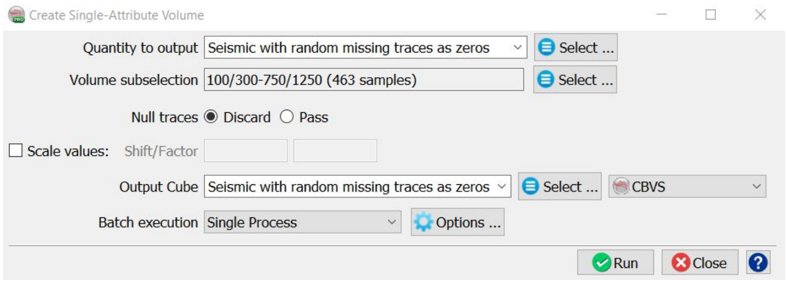
21. In the ''Create Single Attribute Volume'' window, keep the default parameters. **Type**an Output name (e.g. Seismic with random missing traces as zeros) and **Run**.

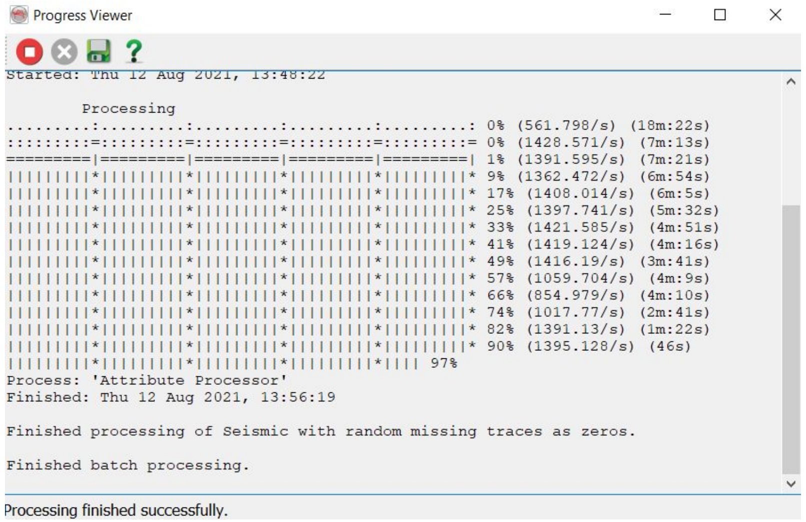
22. **Close**the progress window when the processing finish

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

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



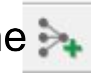




Exercise objective:

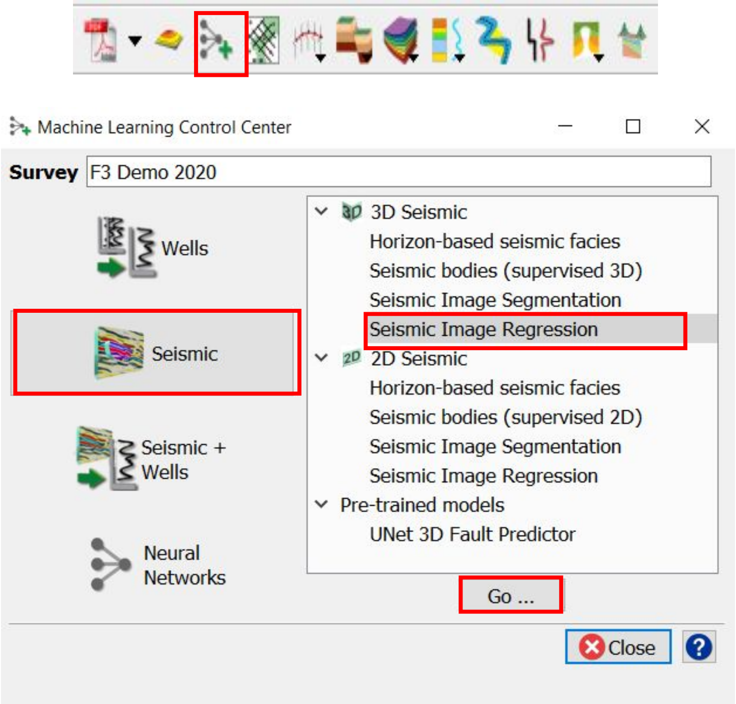
To fill blank seismic traces using the ‘Seismic Image Regression’’ tool which is part of the machine learning plugin. The model will have to learn how to recreate an image from example images containing blank traces.

Workflow:

1. **Open** the Machine Learning Control Center with the  icon.

2. **Click** on Seismic.

3. **Select** the ‘Seismic Image Regression’ and **Hit** Go.



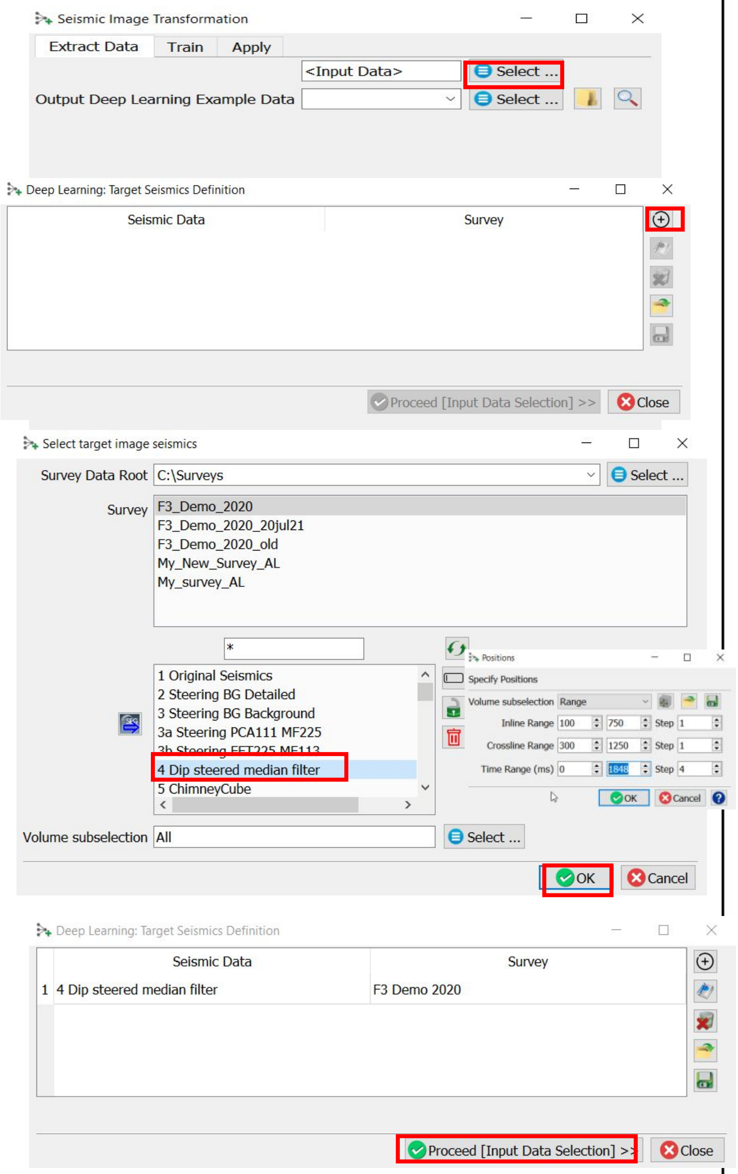
Workflow cont'd:

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:

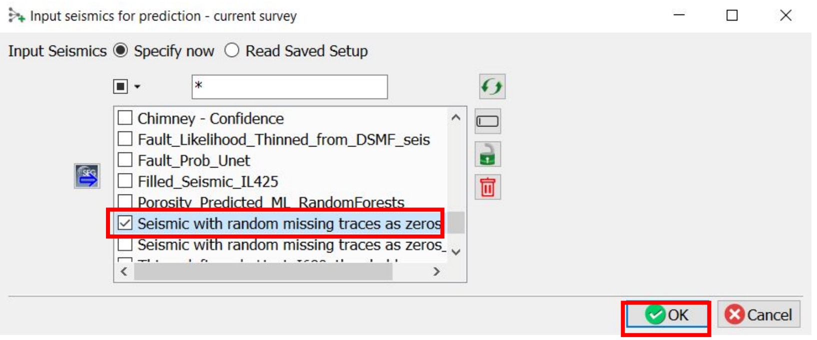
7. **Select**the input seismic data (i.e. the seismic with the missing traces as zeros) and **PressOK**.

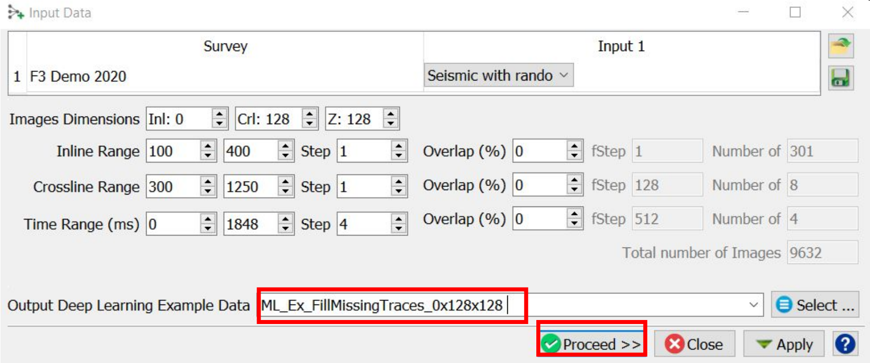
8. In the "Input Data" window set the dimensions of the input features.To minimize processing time for this exercise, **Set**the Images dimension to: 0x128x128, overlap: 0x0x0 and Inline range: (100 –400).

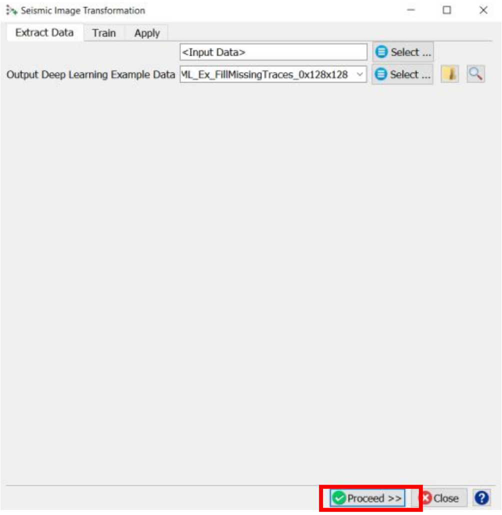
Note: If the current HW has large amount of GPU and CPU/computing power, the recommended Image Dimensions are128x128x128.

9. Specifythe name of theOutput Deep Learning Example Data(e.g. ML_Ex_FillMissingTraces_0x128x128) and **PressProceed**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:

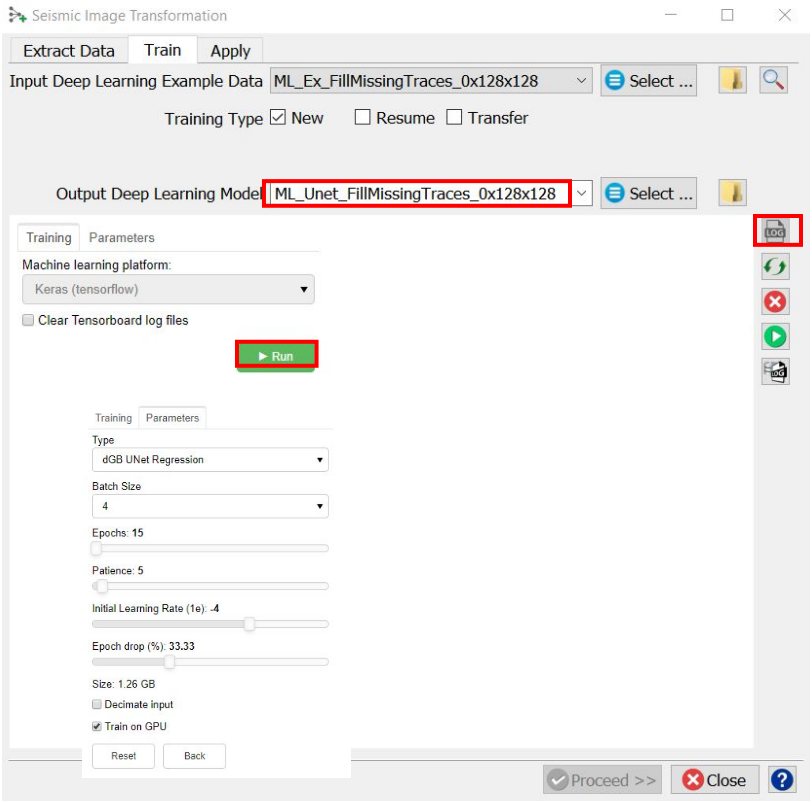
11. After the training data is selected the available models are shown. For seismic image workflows we use**Keras(TensorFlow)**.

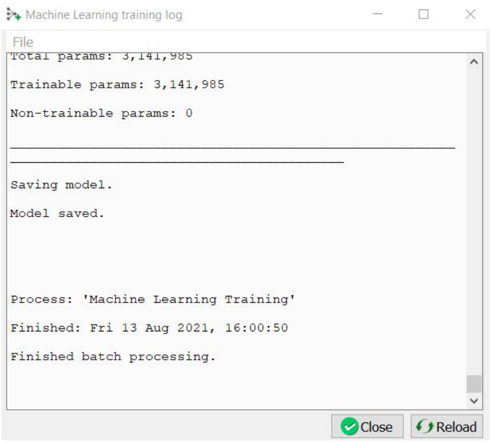
12. **Check**the**Parameters**tab to see which models are supported and which parameters can be changed.

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:

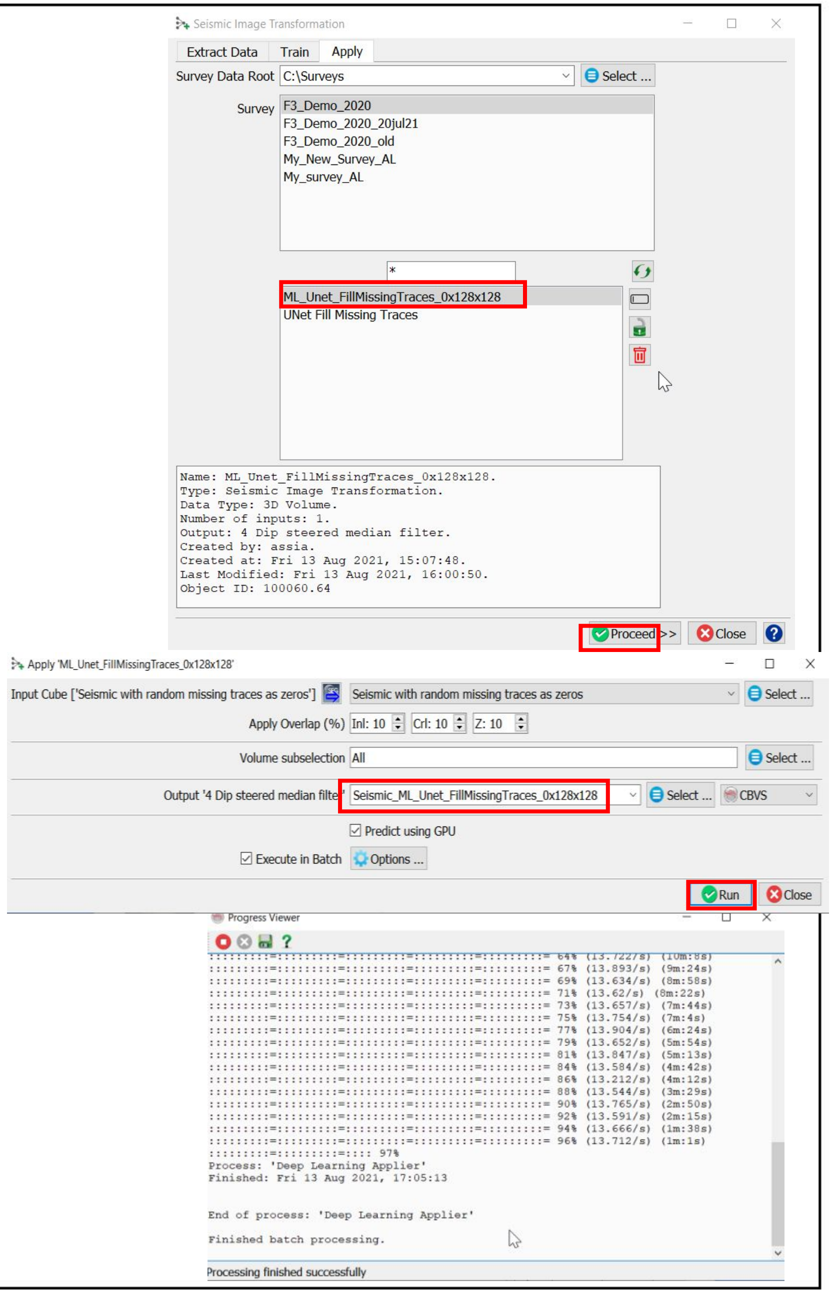
16. Once the Training is done, the trained model can be applied. **Select** the trained model and **PressProceed.**

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.**PressRun**to create the desired output.

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



Workflow cont'd:

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

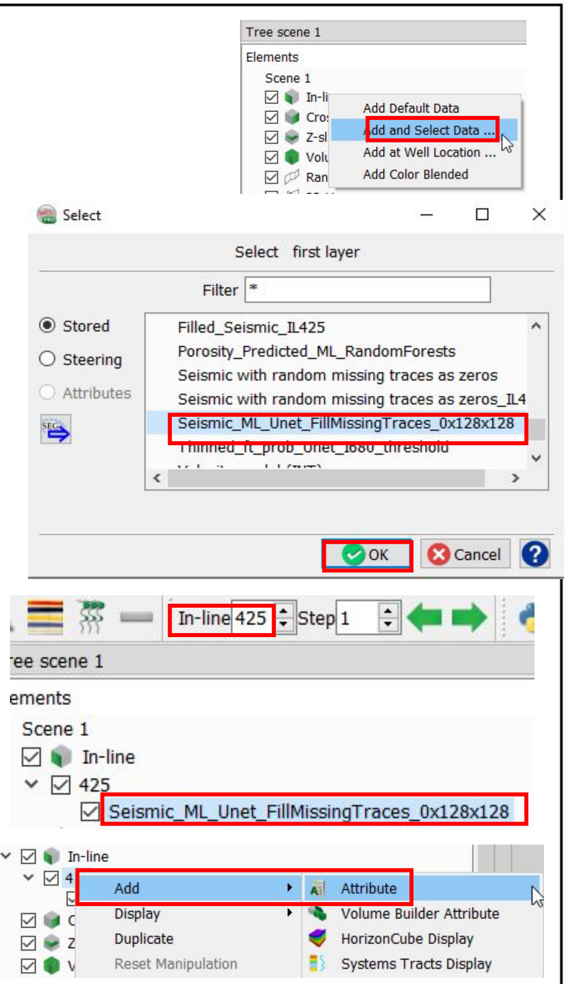
20. ***Right Mouse Click*** *on In-line > Add and select Data*
> Store. ***Select****the created Filled Seismic*
(e.g. ML_Unet_FillMissingTraces_0x128x128), and **Hit**OK.

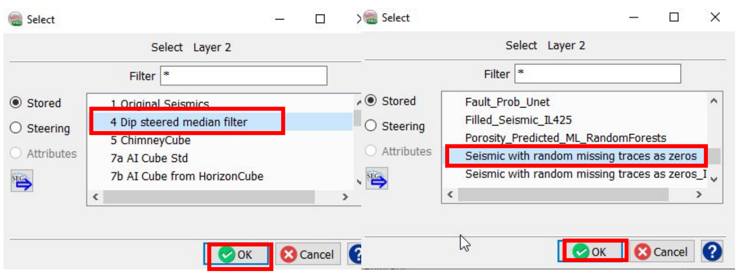
21. ***Type*** *inthe Inline field: 425, and* **Hit**Enter.

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.



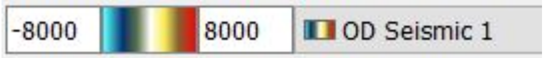


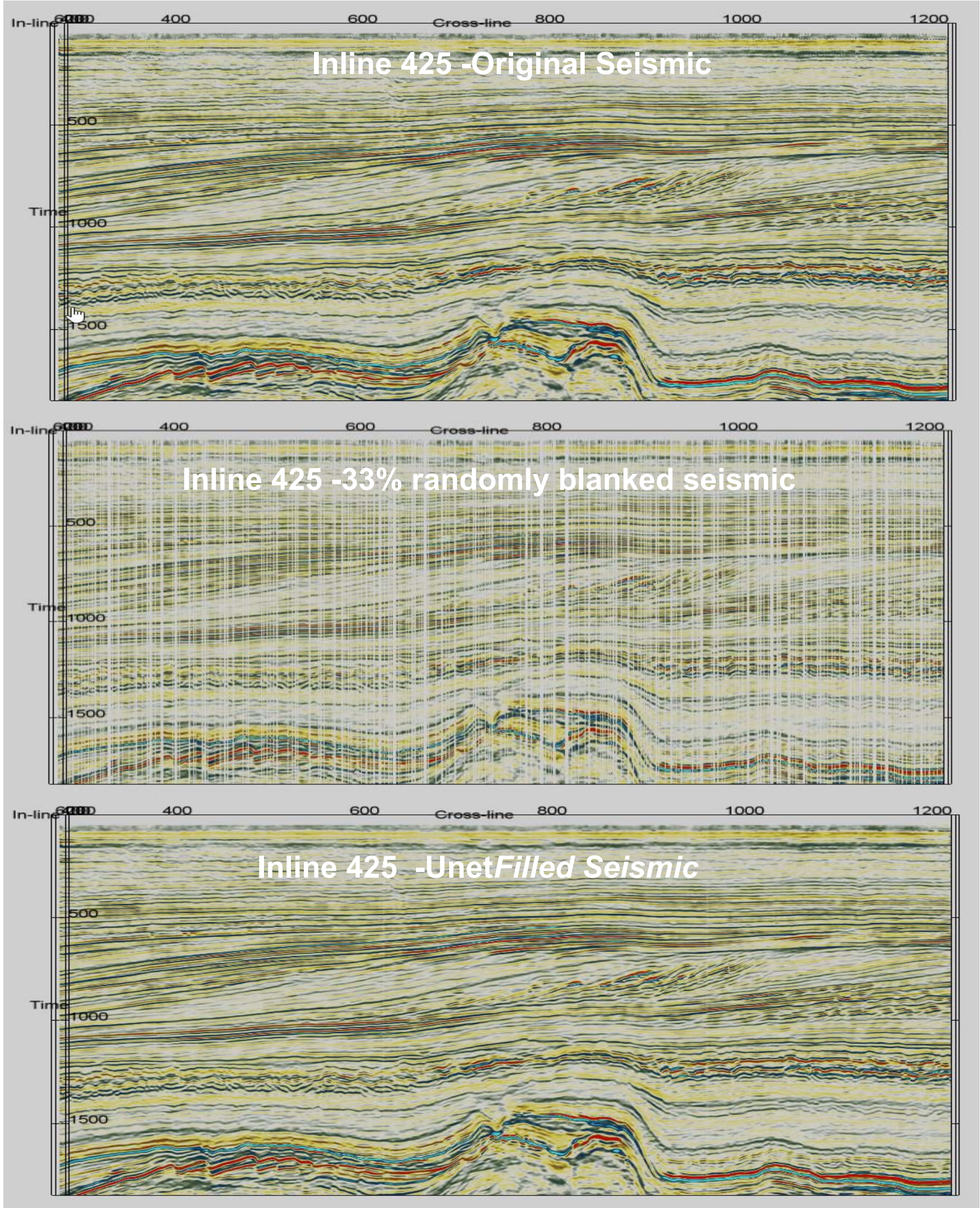
Workflow cont'd:

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)
- *Unetfilled seismic (ML_Unet_FillMissingTraces_0x128x128)*

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).*





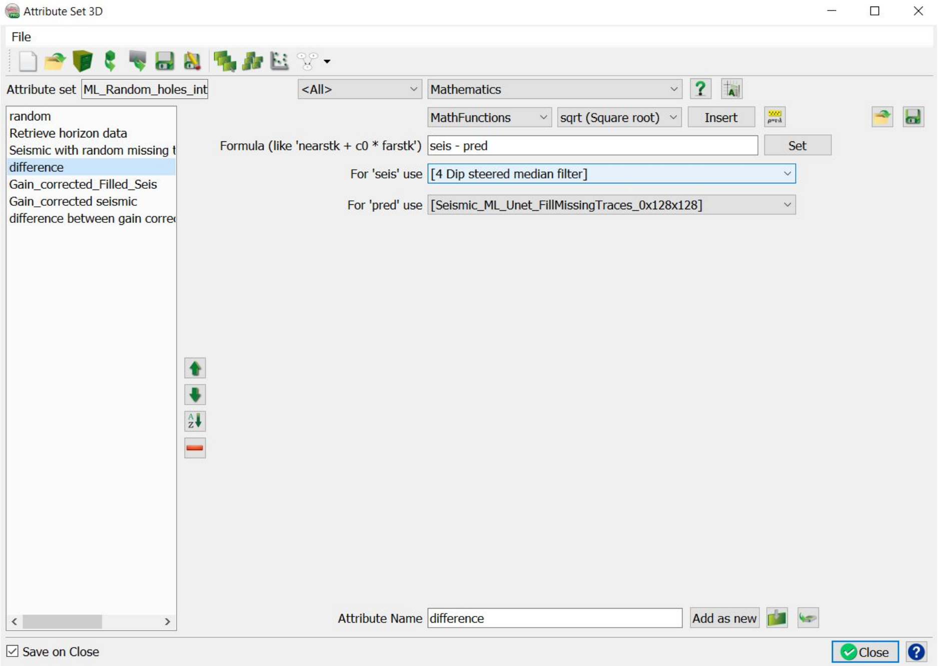
Workflow cont'd:

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

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

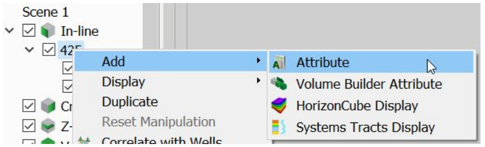
27. **Create**a 4thattribute ''difference'' as indicated in the attribute set window and **Hit** 'Add as new'.

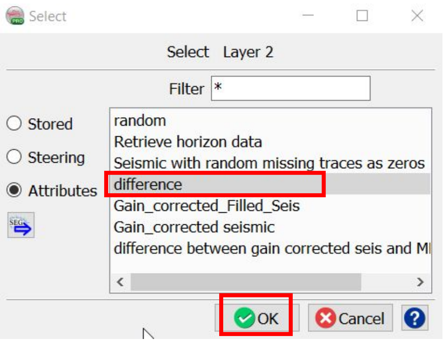
28. Selectthe Original seismic (e.g. *4 Dip steered median filter) for 'Seis', and the predicted seismic (e.g. ML_Unet_FillMissingTraces_0x128x128) for 'pred'*

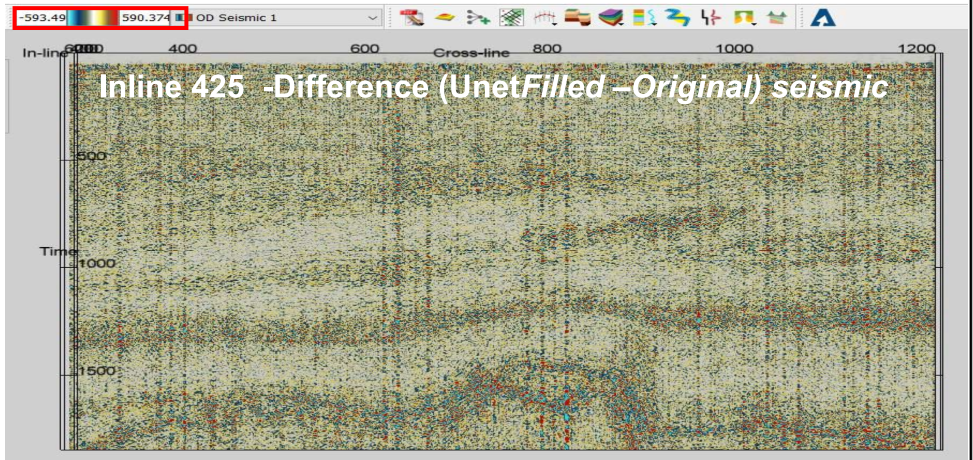


Workflow cont'd:

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

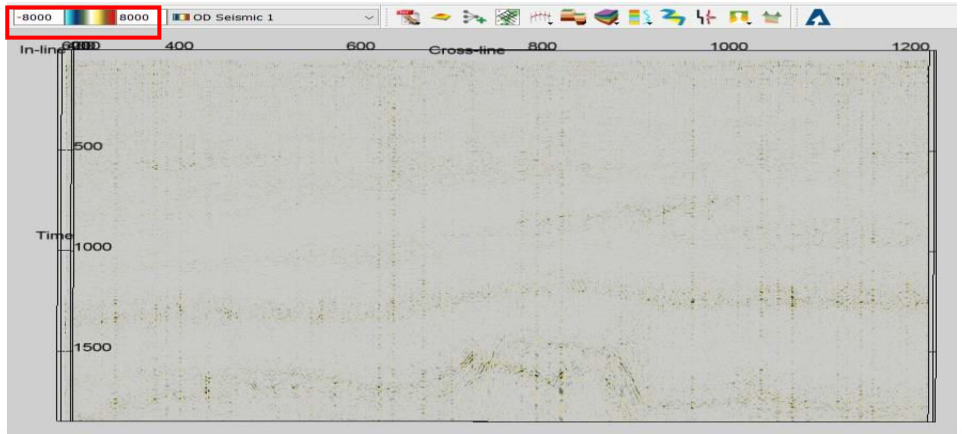






29. Right-Click*on Inline 425 > Add > Attribute.* ***Select****the attribute 'difference'', and* **Hit**OK.

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]

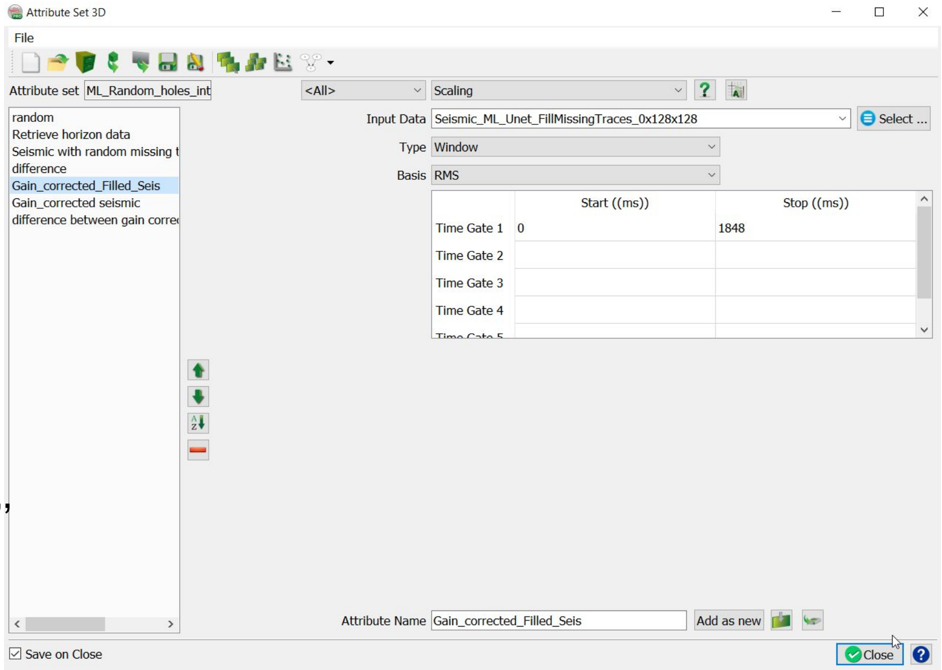
Workflow cont'd (Optional):

For more accurate comparison, apply an RMS gain scaled correction to the original and predicted seismic, than compute the difference.
Create a new Gain correction attributes to be applied on the original and predicted seismic.

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

32. Createa 5thattribute "Gain_corrected_Filled_Seis" as indicated in the attribute set windowand **Hit** 'Add as new'

33. Selectthe Input Data "Seismic_ML_Unet_FillMissingTraces_0x128x128"



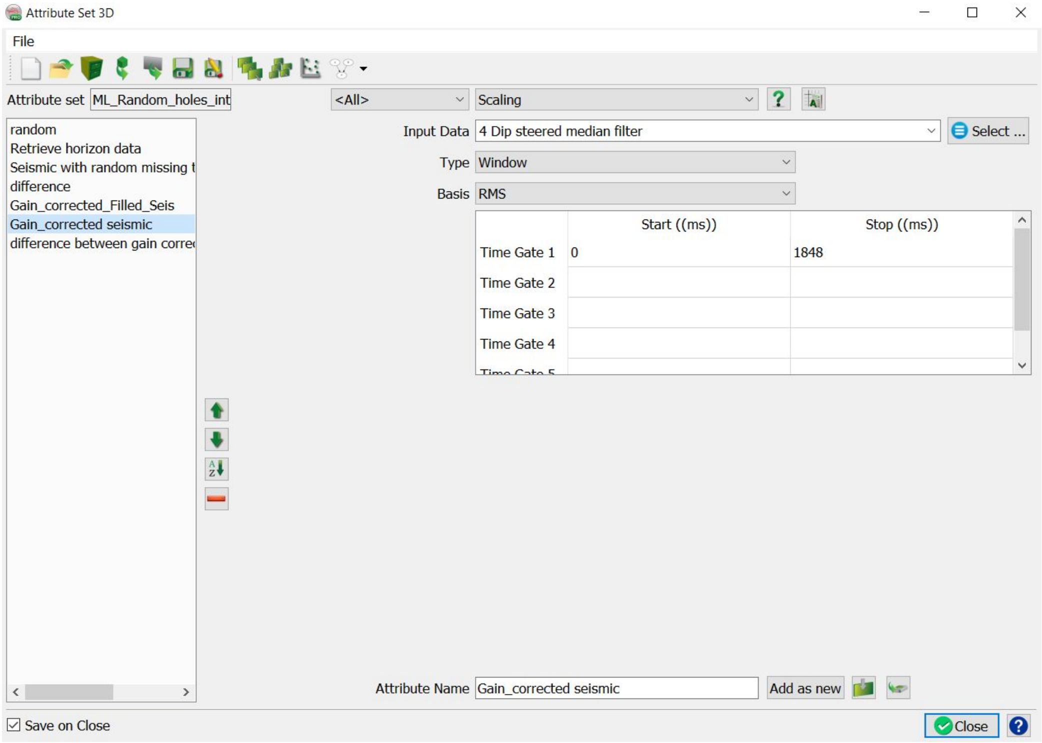
Workflow cont’d (Optional):

For more accurate comparison, apply an RMS gain scaled correction to the original and predicted seismic, than 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 6thattribute ‘’Gain_corrected seismic’’ as indicated in the attribute set windowand **Hit** ‘Add as new’

36. **Select**the Input Data ‘Gain_corrected seismic’’



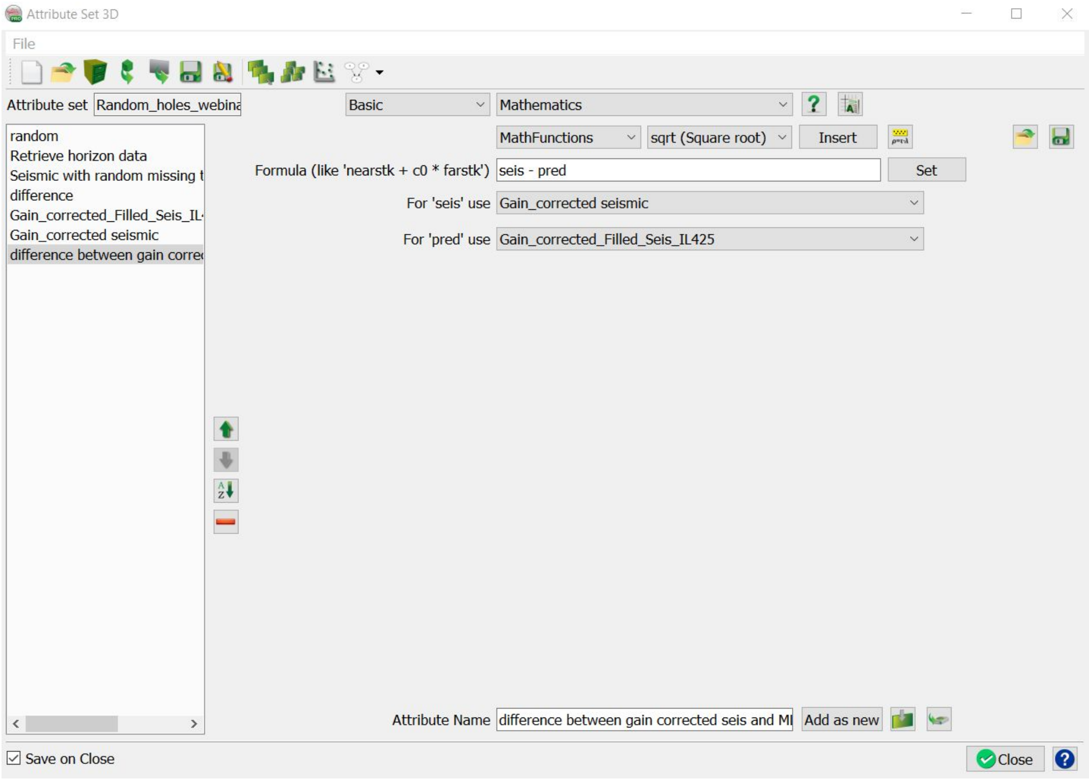
Workflow cont'd (Optional):

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

37. Selectthe 3D attribute icon . **Open**the attribute set . **Select**the attribute set ''ML_Random_holes_interpolation''

38. Createa 7th attribute ''difference between gain corrected seis and ML pred'' as indicated in the attribute set windowand **Hit**'Add as new'.

39. **Select**the ''Gain_correctedseismic'' as input for 'seis' and the ''Gain_corrected_Filled_Seis'' as input for 'pred'

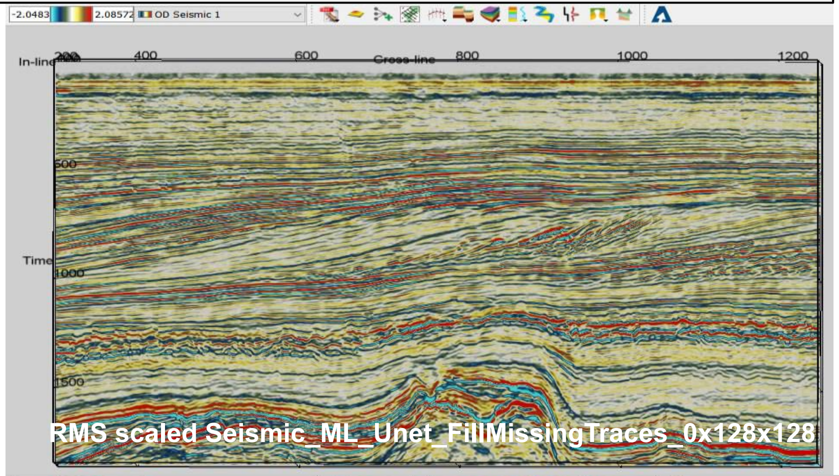


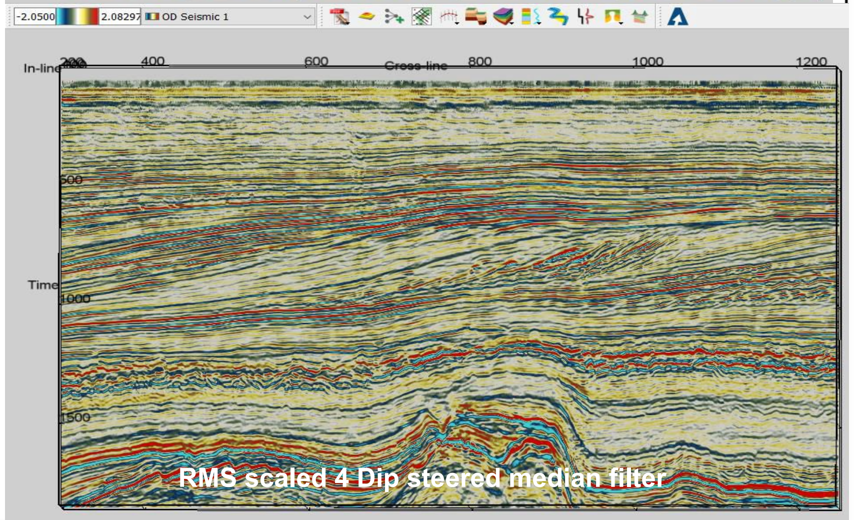
Workflow cont'd (Optional):

Display the attribute ''Gain_corrected_Filled_Seis'' (RMS scaled Seismic_ML_Unet_FillMissingTraces_0x128x128) and the ''Gain_correctedseismic''(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*.*

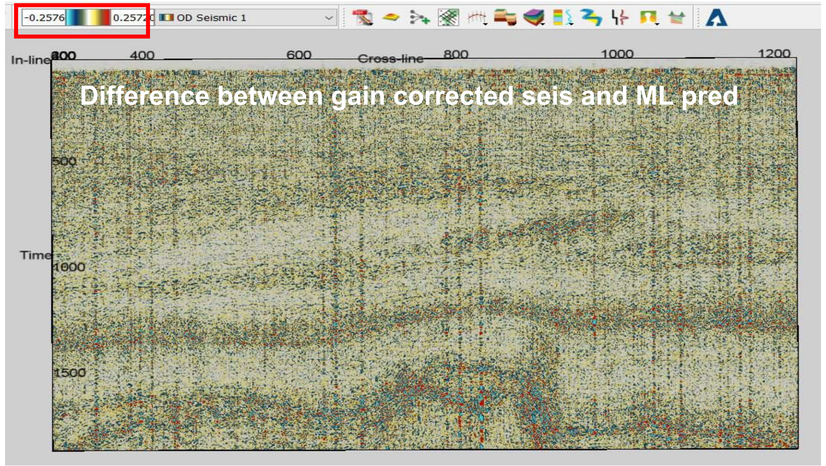
41. Right-Click*on Inline 425 > Add > Attribute.* ***Select****the attribute* 'Gain_correctedseismic'', *and* **Hit**OK*.*





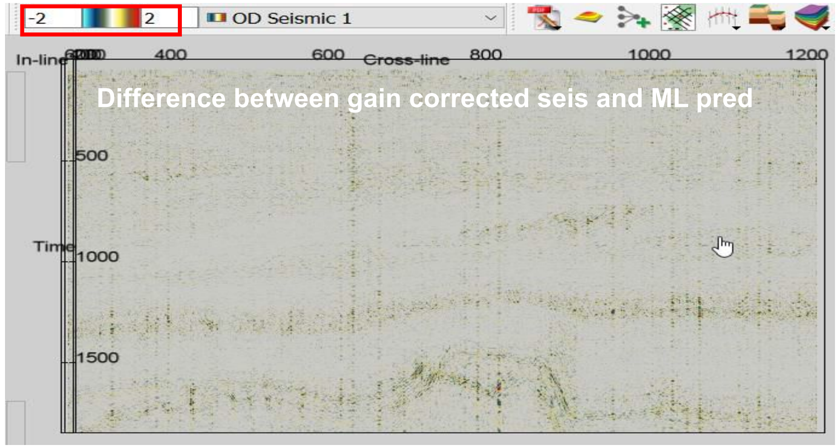
Workflow cont'd (Optional):

Comparequantitatively in the blind test area theRMS 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].*