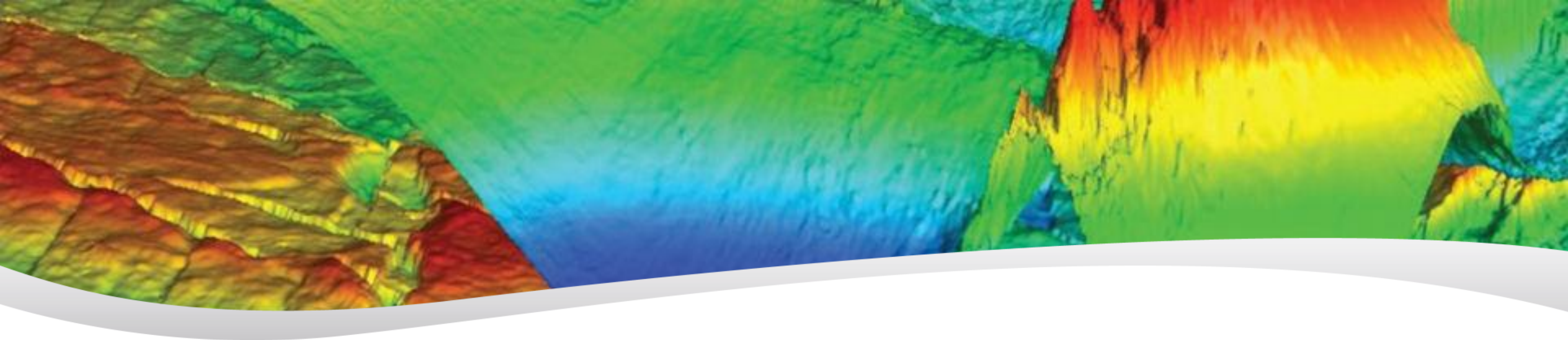

Real-time advanced AVO seismic processing QCs for validation of key processing steps

FORCE Seminar

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Stavanger,
27th of January 2016

Passion for Geoscience

Introduction (1/2):

- Advanced seismic processing QCs were implemented during the seismic imaging project in order to monitor the AVO behavior of the seismic data after key processing steps;

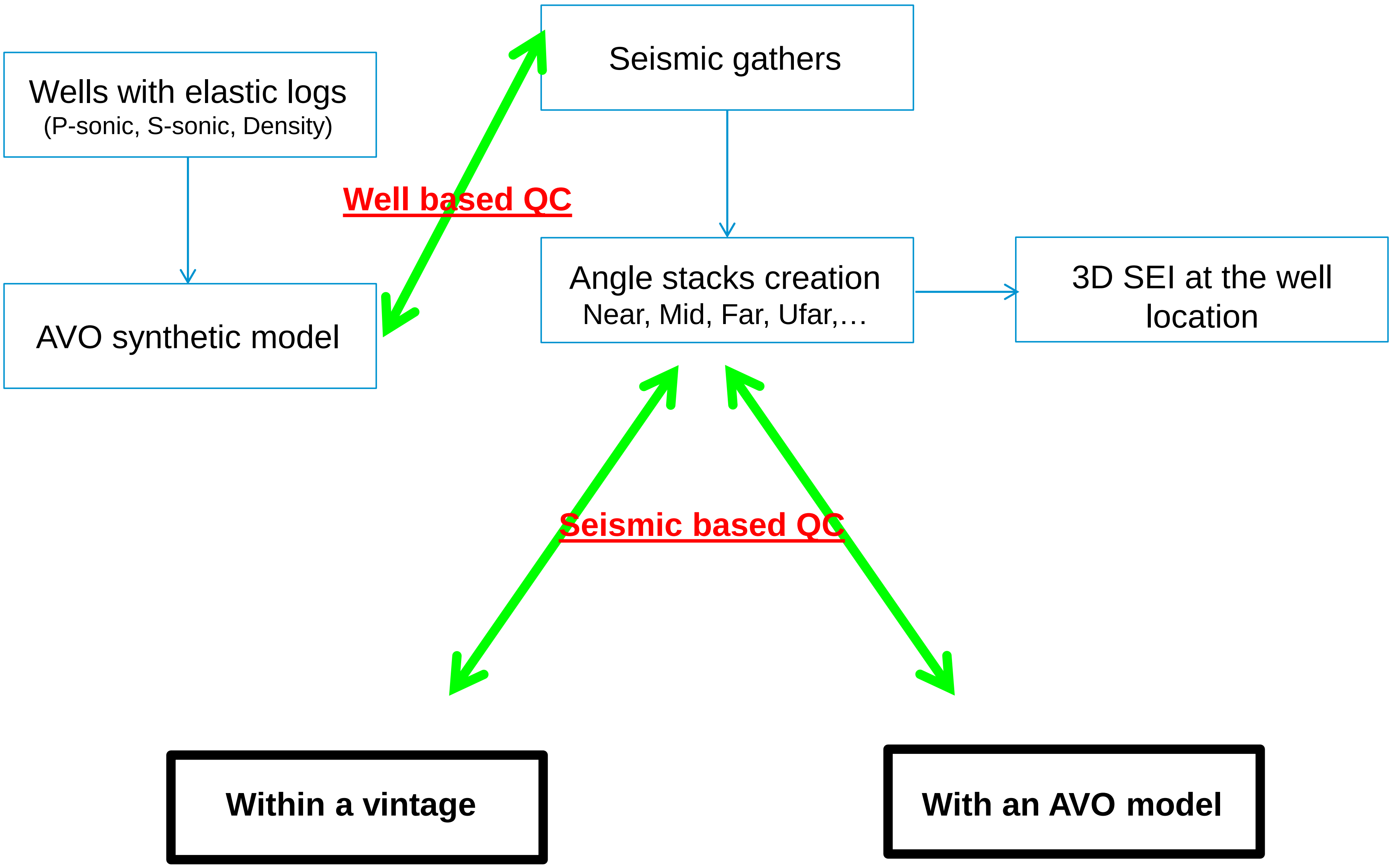
- Conducted on the CGG Multi-Client New Ventures Horda 2014 dataset;

- Objective: is the Zoeppritz compliancy of the data preserved or improved so that accurate quantitative interpretation of processing outputs can be attempted following the seismic processing?

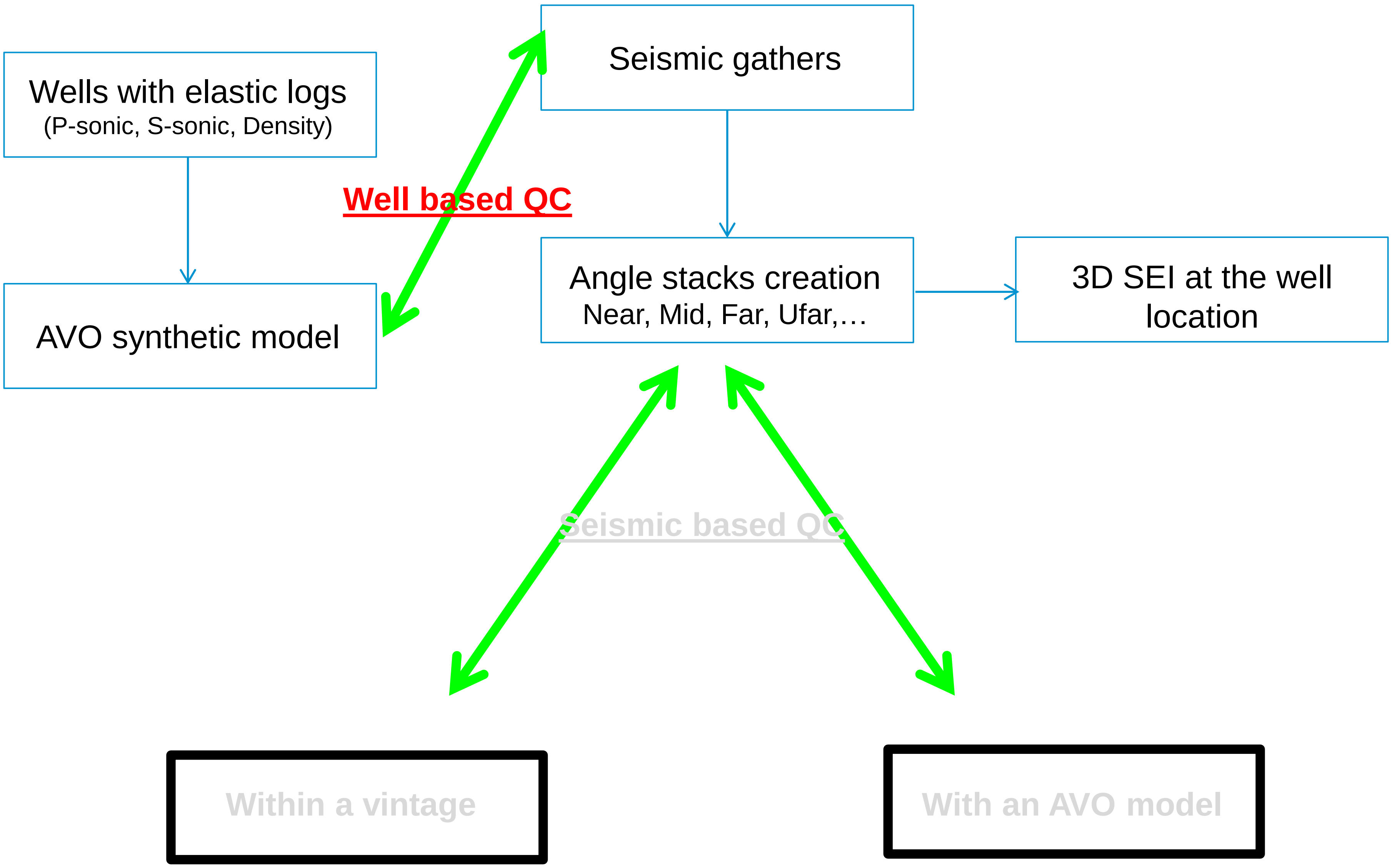
Introduction (2/2):

- 4 different key processing steps were selected during the course of the signal processing to conduct these QCs:
  - Step 1: after pre-migration Radon;
  - Step 2: after 5D signal enhancement (far trace denoise + destriping, shot/channel amplitude correction, common offset denoise + demultiple and intrabed multiple attenuation);
  - Step 3: after F-XY denoise;
  - Step 4: after dip filtering and RMO correction.

Advanced seismic QCs results proposed in this presentation:



Advanced seismic QCs results proposed in this presentation:

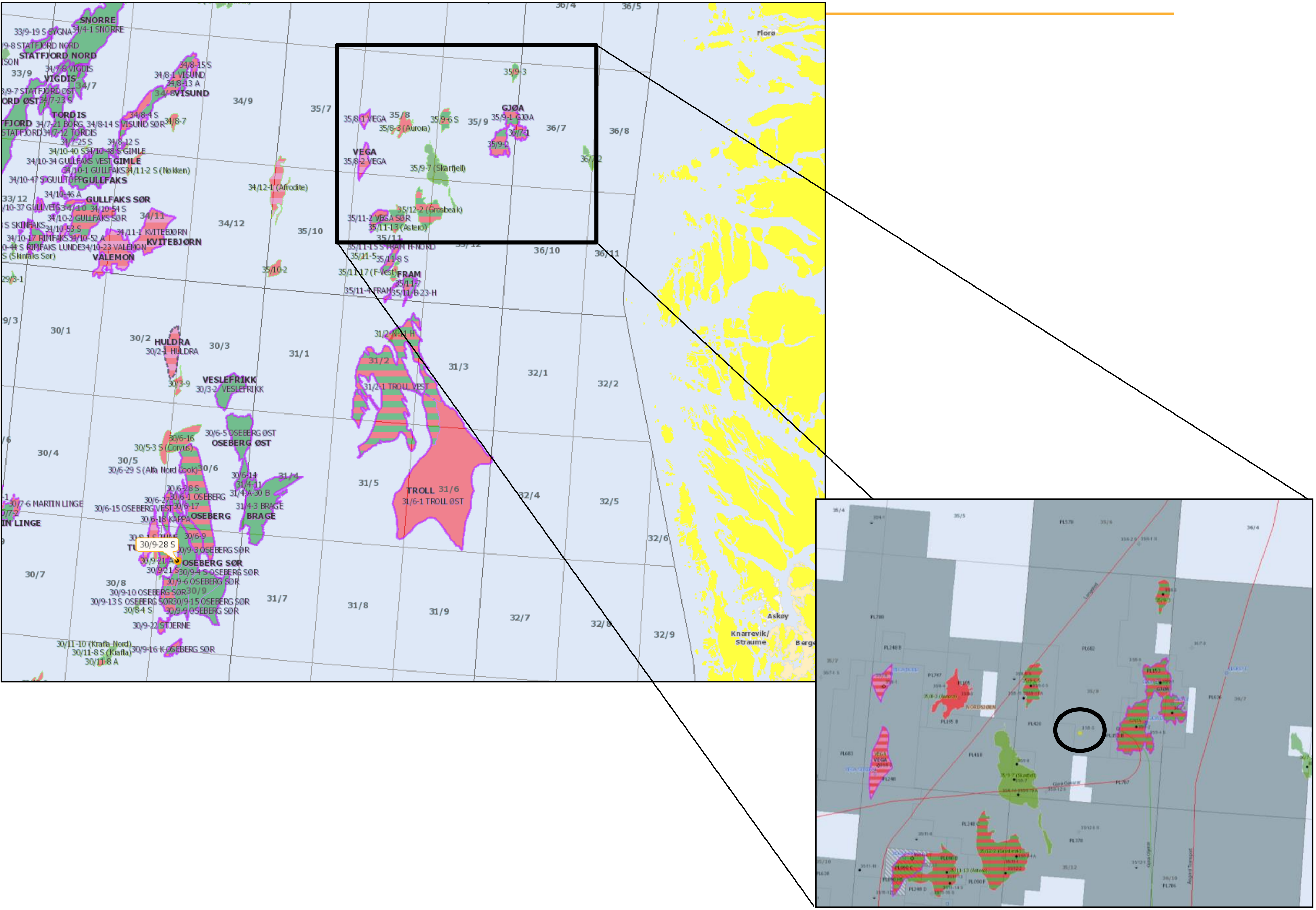


Objective and key observations to be done during those QCs:

- **AVO synthetic versus offset gathers**:
  - Is the seismic AVO trend consistent with the synthetic AVO trend?
  - Do we observe an increase of the correlation between the seismic AVO fit and the AVO synthetic?

- **Inversion analysis at the well location:**
  - Does the correlation between inverted attributes and well logs increase?

Well 35/9-5: location



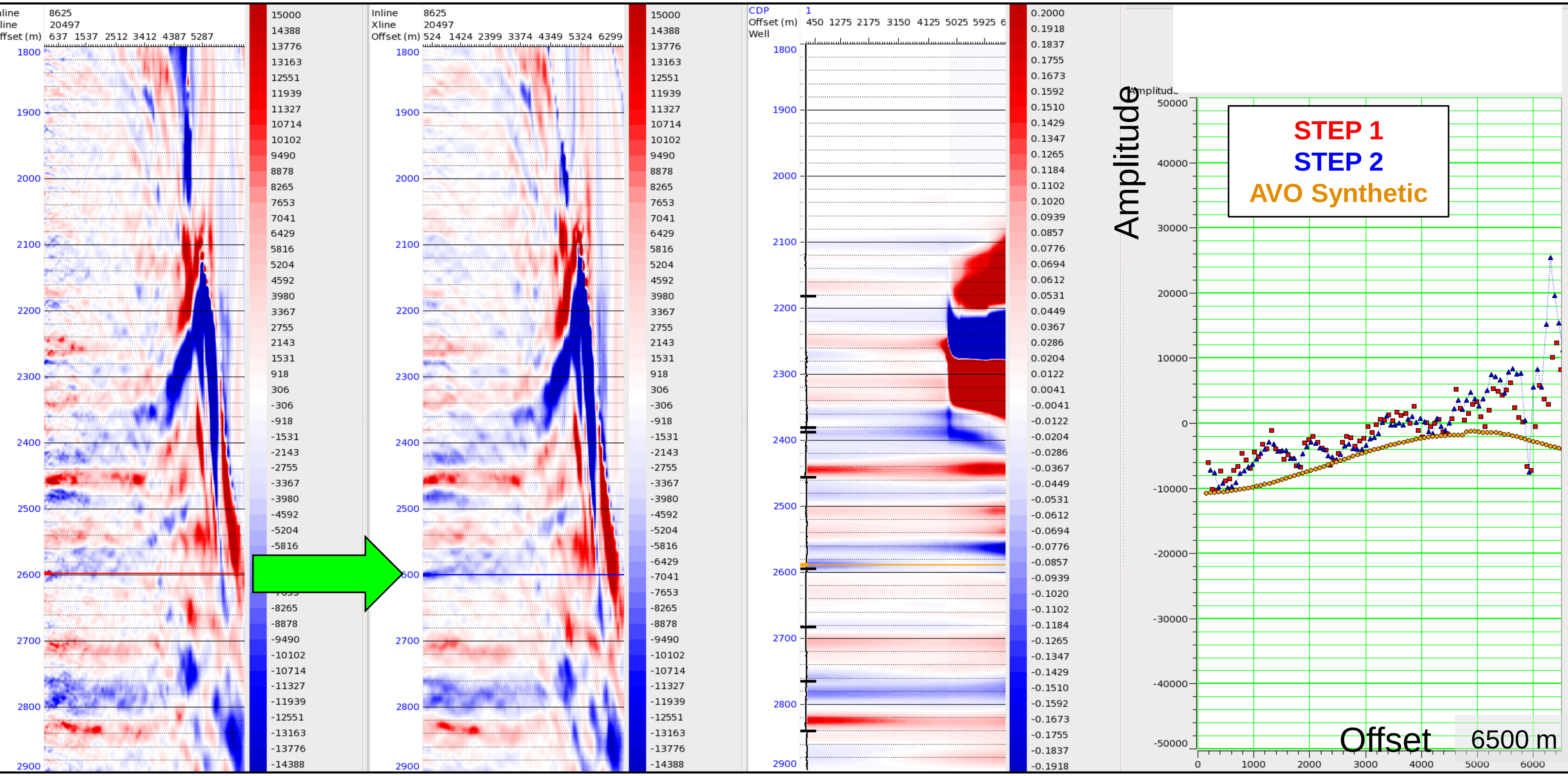
Well 35/9-5 results, from NPD website:

- Drilled in 2010;
- Full suite of logs available (Vp, Vs and Density);
- **Main objective**: evaluate the hydrocarbon potential of the Middle Cretaceous Agat Formation sandstone;
- **Results**: very little sand preserved in the Agat Formation, described here as a sandy limestone to calcareous sand; no shows to confirm hydrocarbons in the Agat Formation or in any other part of the well;
- Permanently abandoned as a dry well.

TWT= 2600 ms

(near Top Agat)

STEP 1 **STEP 2** **AVO SYNTH**



After pre-mig Radon

After 5D enhancement

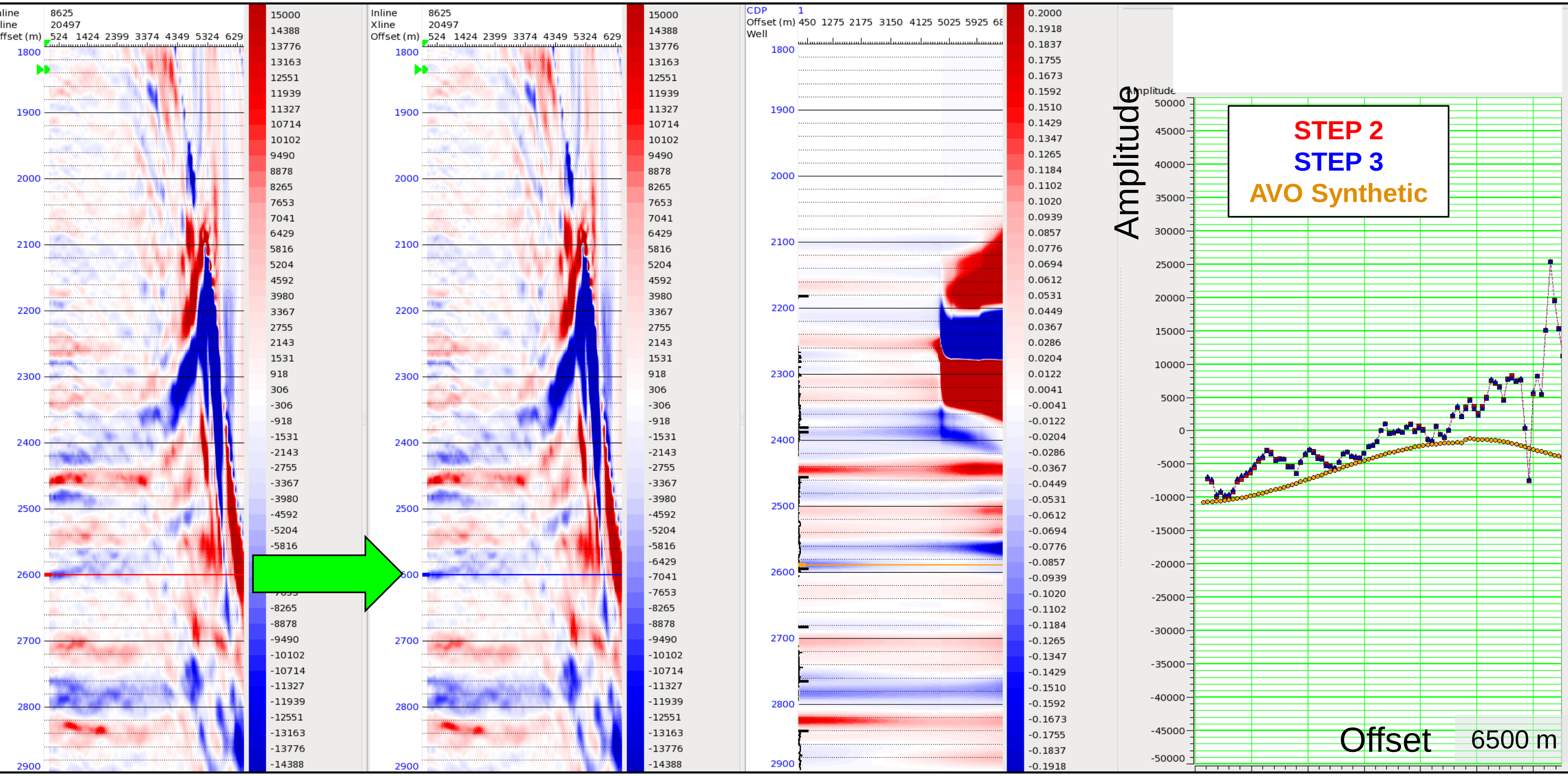
CC, STEP 1 = 68 %

CC, STEP 2 = 72 %

TWT= 2600 ms

(near Top Agat)

STEP 2 **STEP 3** **AVO SYNTH**



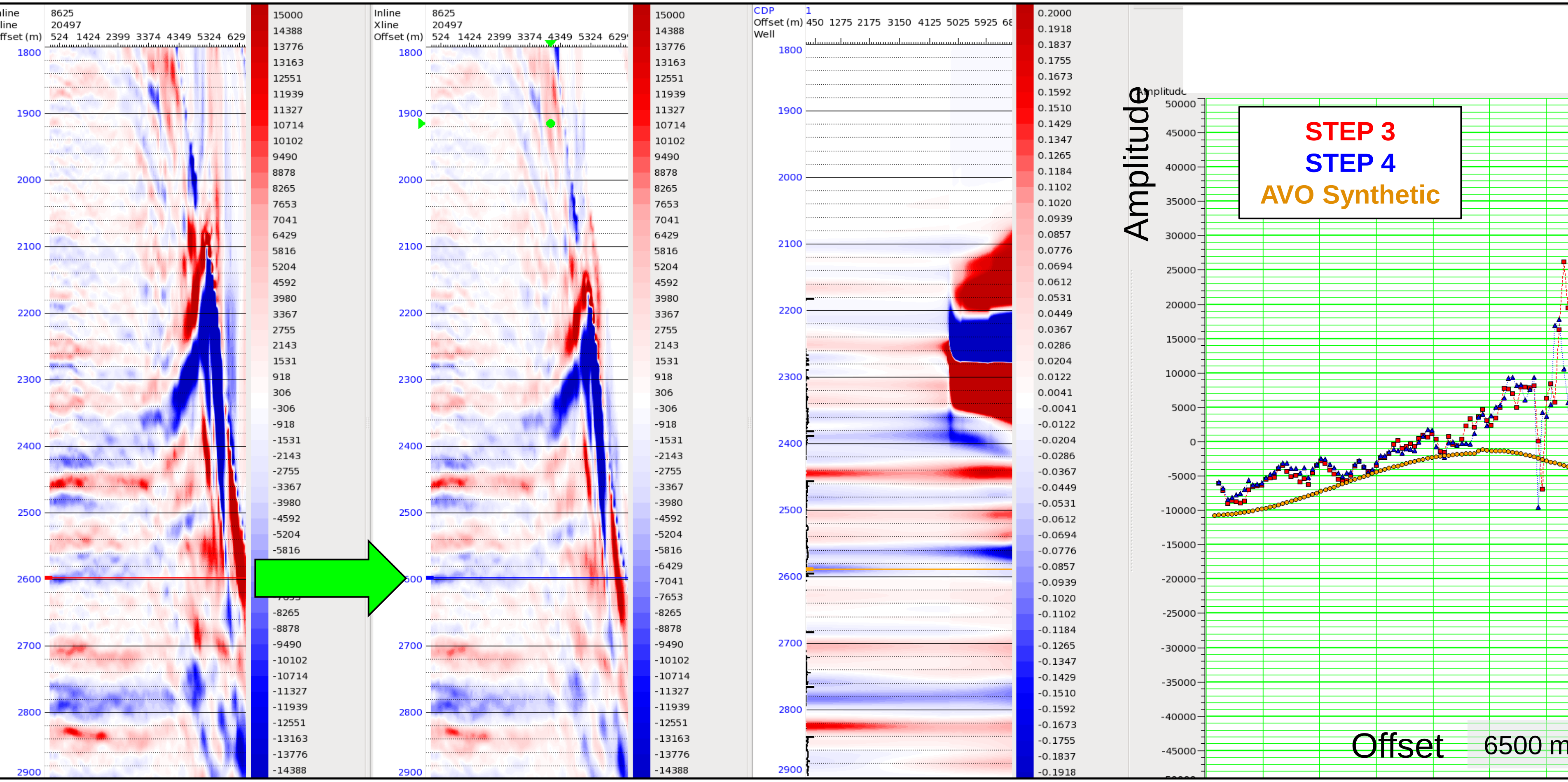
After 5D enhancement

After F-XY denoise

CC, STEP 3 = 74 %

TWT= 2600 ms
(near Top Agat)

STEP 3 **STEP 4** **AVO SYNTH**



After F-XY denoise

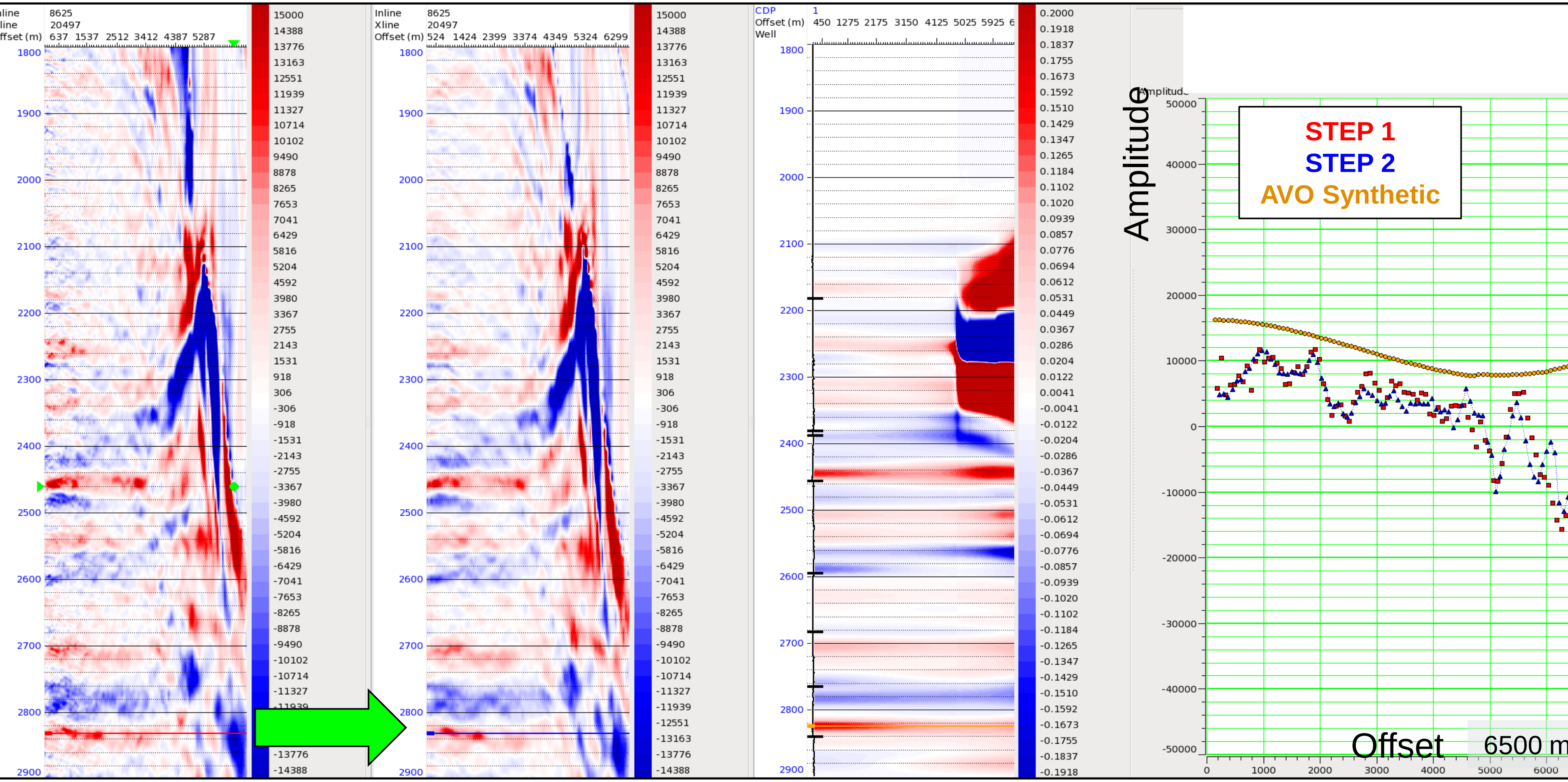
After dip filtering + RMO correction

CC, STEP 4 = 77 %

TWT= 2825 ms

(near Top Krossfjord FM)

STEP 1 **STEP 2** **AVO SYNTH**



After pre-mig Radon

After 5D enhancement

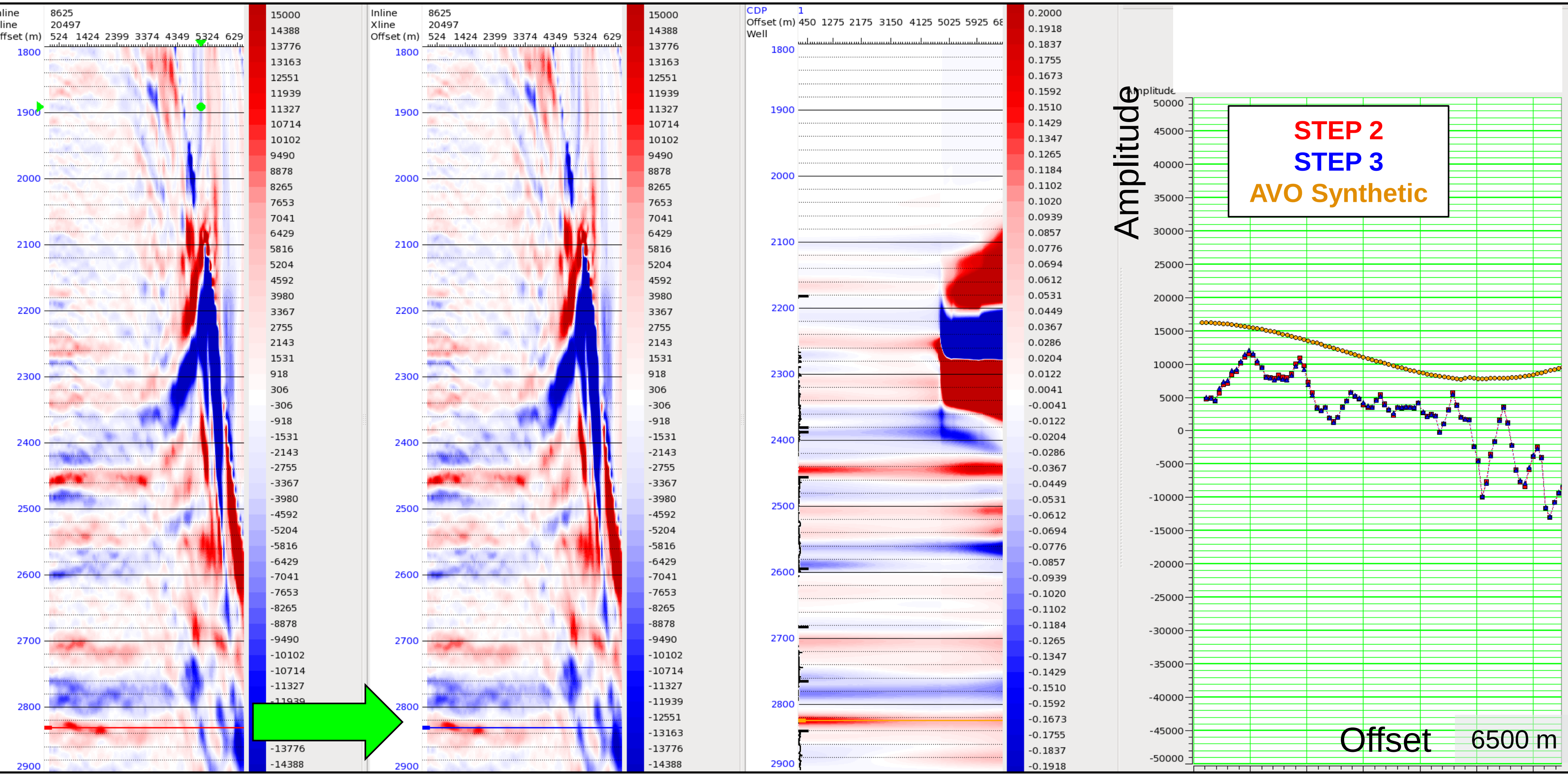
CC, STEP 1 = 69 %

CC, STEP 2 = 71 %

TWT= 2825 ms

(near Top Krossfjord FM)

STEP 2 | **STEP 3** | **AVO SYNTH**



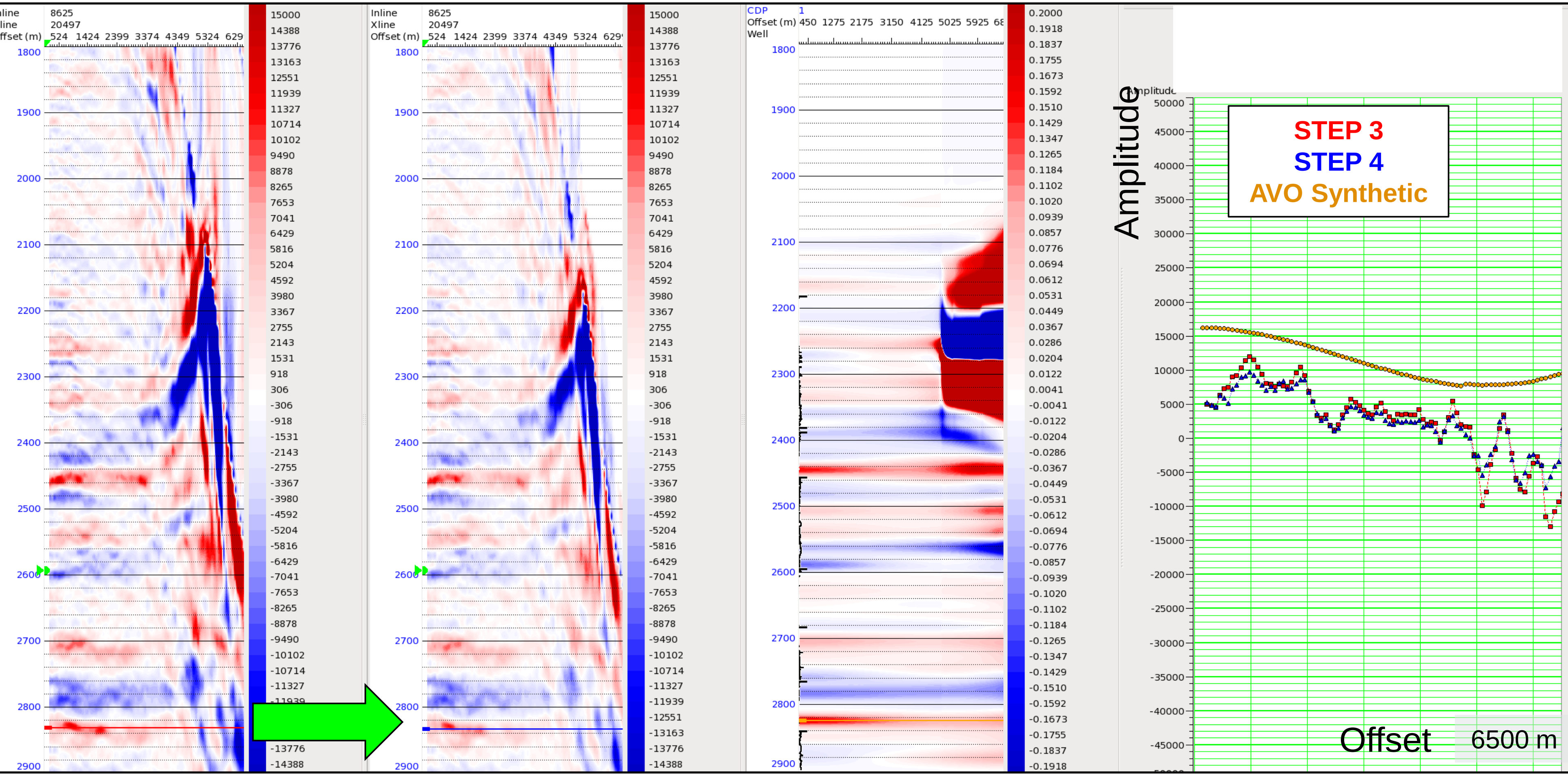
After 5D enhancement

After F-XY denoise

CC, STEP 3 = 72 %

TWT= 2825 ms
(near Top Krossfjord FM)

STEP 3 **STEP 4** **AVO SYNTH**



After F-XY denoise

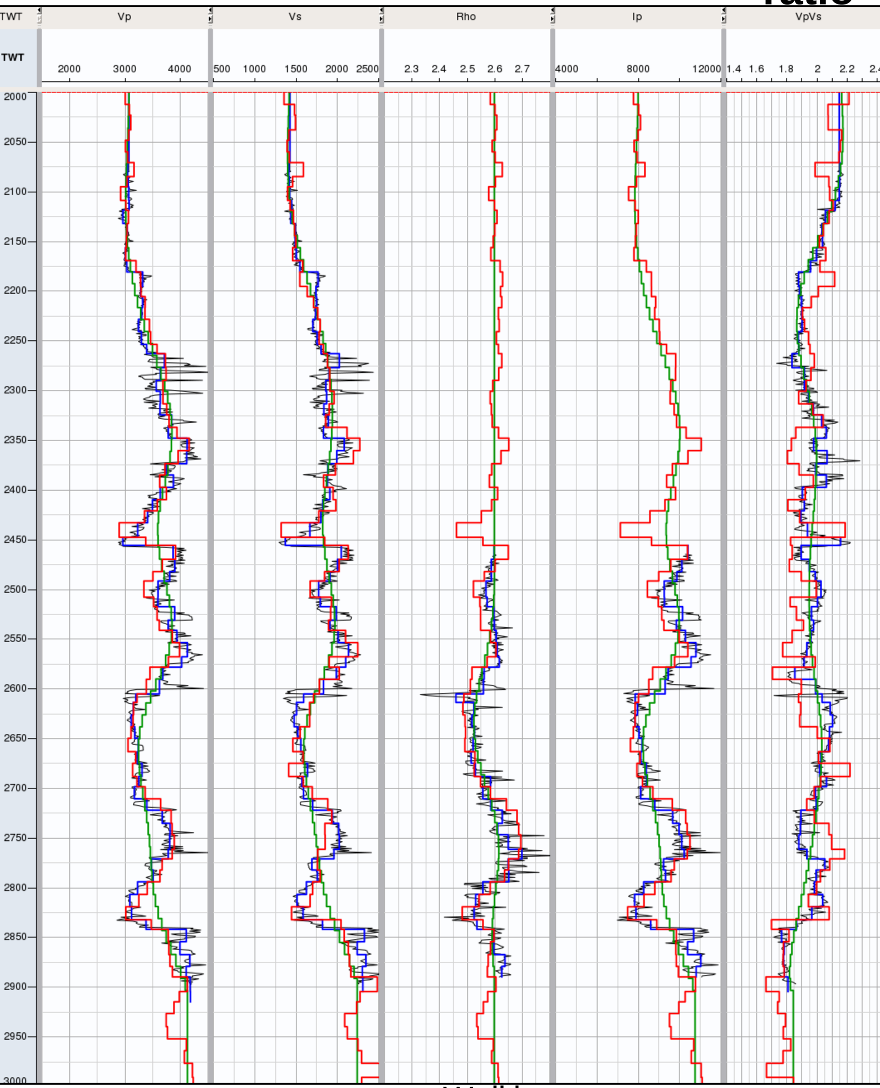
After dip filtering + RMO correction

CC, STEP 4 = 76 %

Inversion analysis at the well location:

Step 1 > pre-mig Radon

Vp **Vs** **Density** **Ip** **Vp/Vs ratio**

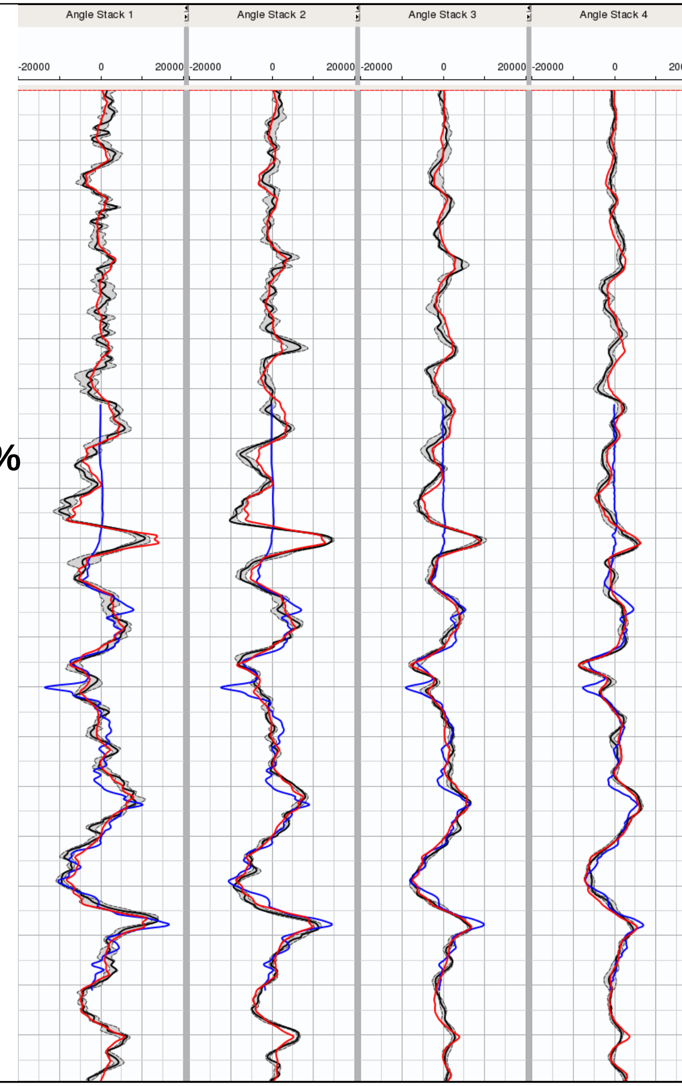


Well logs
Upscaled well logs
Inverted attributes
Initial model

CC
(upscaled well logs versus inverted attributes)

Ip = 83,2%
Vp/Vs ratio = 49,0 %

Near **Mid** **Far** **UFar**

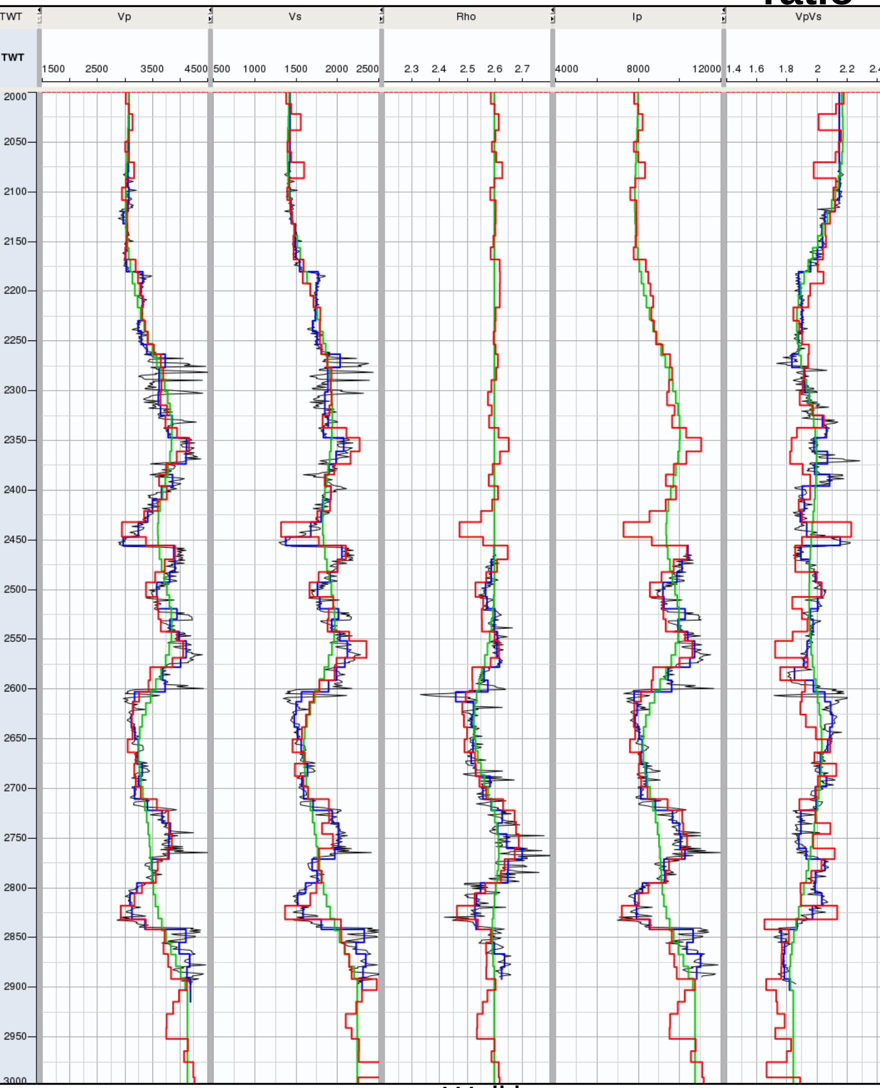


Seismic traces
Synthetic created from well logs
Synthetic from inverted attributes

Inversion analysis at the well location:

Step 2 > 5D signal enhancement

Vp **Vs** **Density** **Ip** **Vp/Vs ratio**

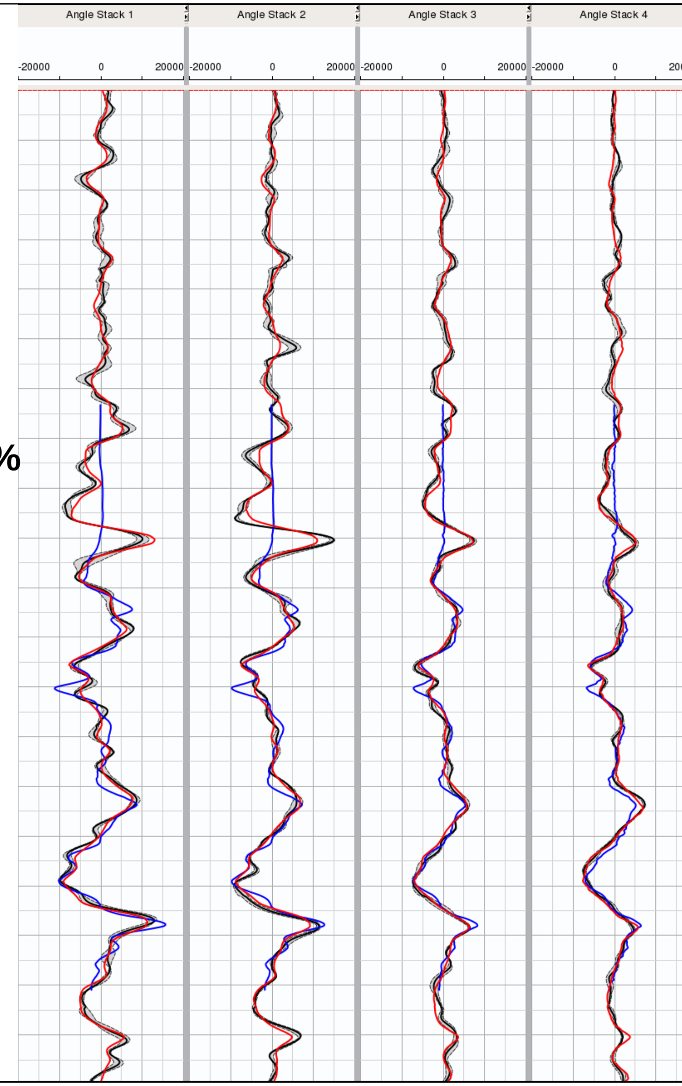


Well logs
Upscaled well logs
Inverted attributes
Initial model

CC
(upscaled well logs versus inverted attributes)

Ip = 85,7%
Vp/Vs ratio = 56,2 %

Near **Mid** **Far** **UFar**

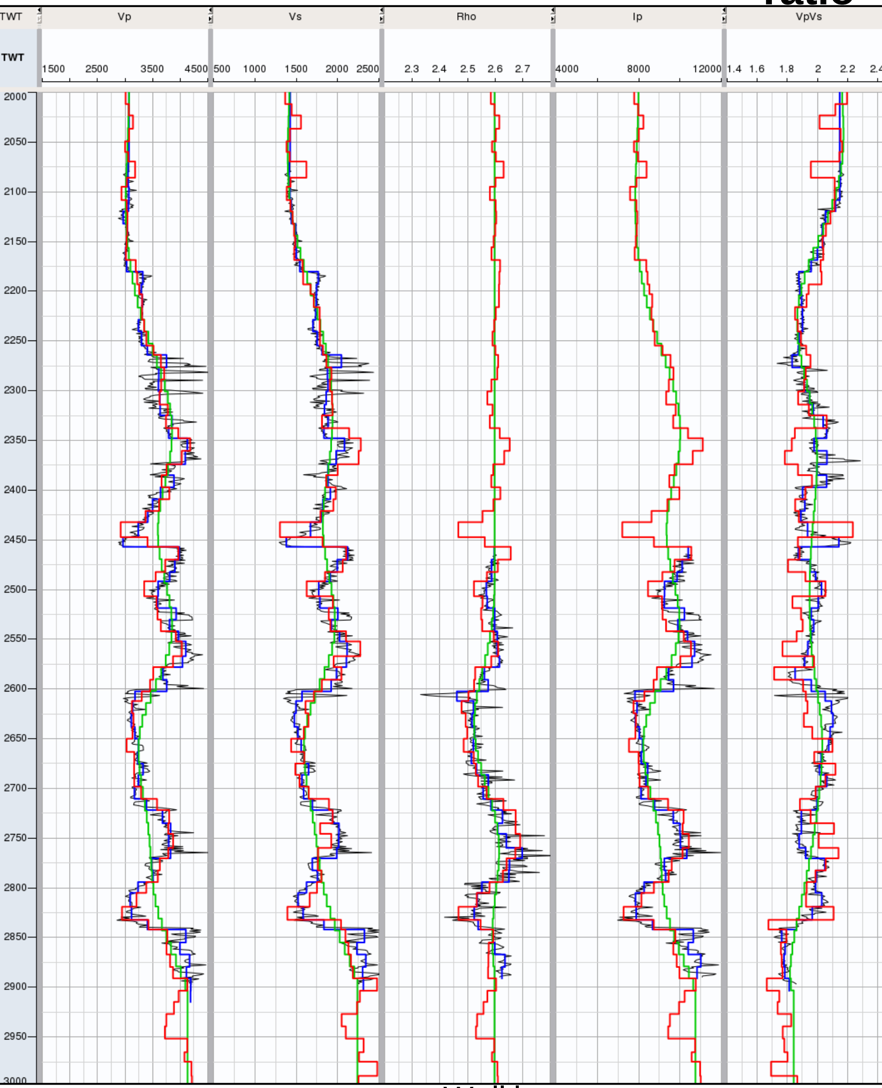


Seismic traces
Synthetic created from well logs
Synthetic from inverted attributes

Inversion analysis at the well location:

Step 3 > F-XY denoise

Vp **Vs** **Density** **Ip** **Vp/Vs ratio**

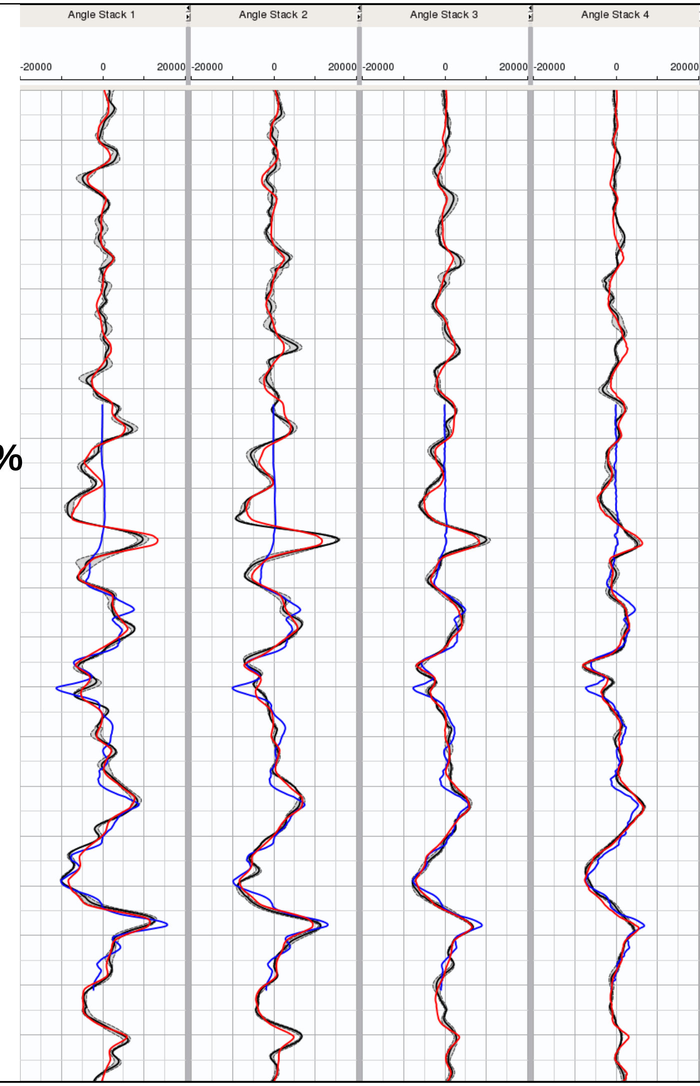


Well logs
Upscaled well logs
Inverted attributes
Initial model

CC
(upscaled well logs versus inverted attributes)

Ip = 85,7%
Vp/Vs ratio = 56,6 %

Near **Mid** **Far** **UFar**

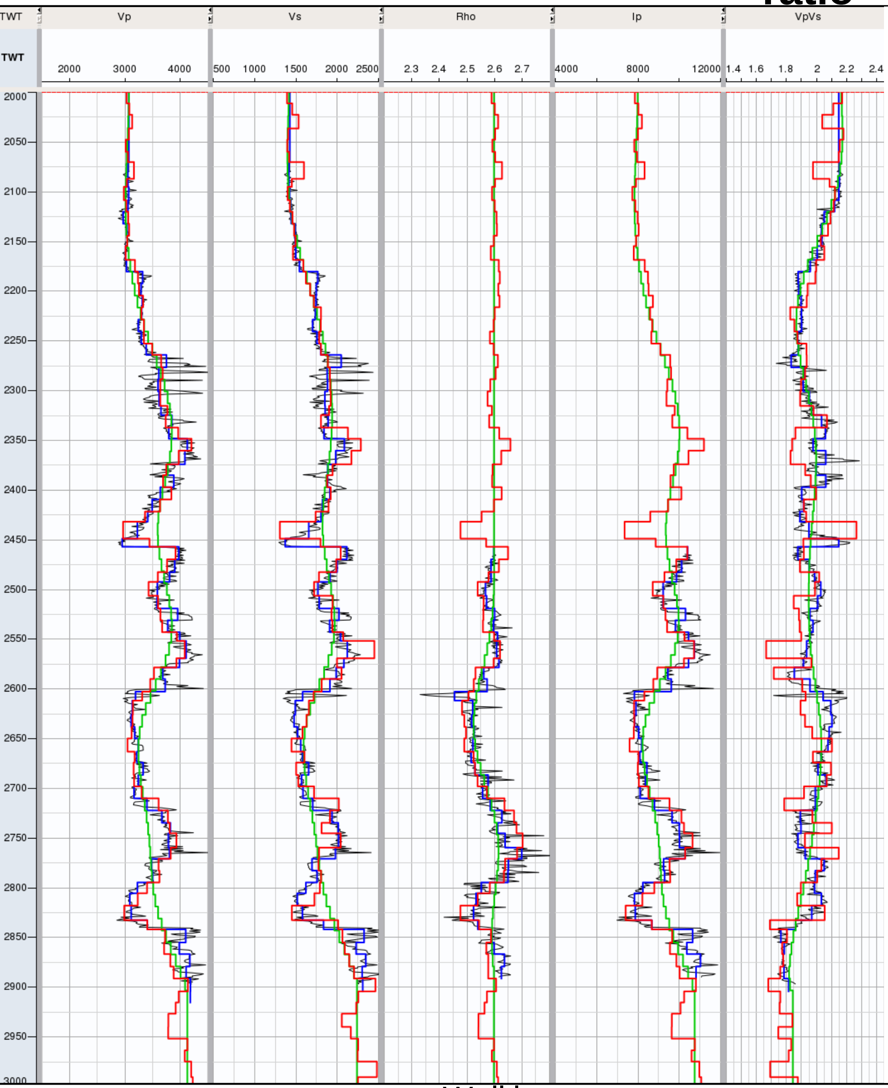


Seismic traces
Synthetic created from well logs
Synthetic from inverted attributes

Inversion analysis at the well location:

Step 4 > Dip filter + RMO corr.

Vp **Vs** **Density** **Ip** **Vp/Vs ratio**

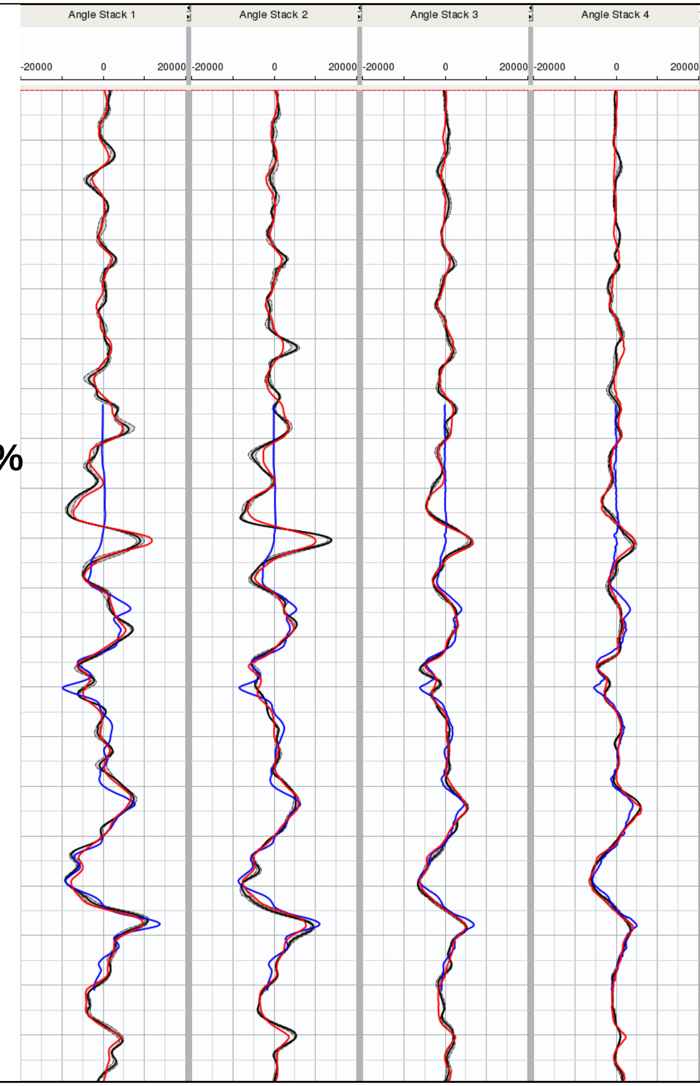


Well logs
Upscaled well logs
Inverted attributes
Initial model

CC
(upscaled well logs versus inverted attributes)

Ip = 86,4%
Vp/Vs ratio = 58,1 %

Near **Mid** **Far** **UFar**

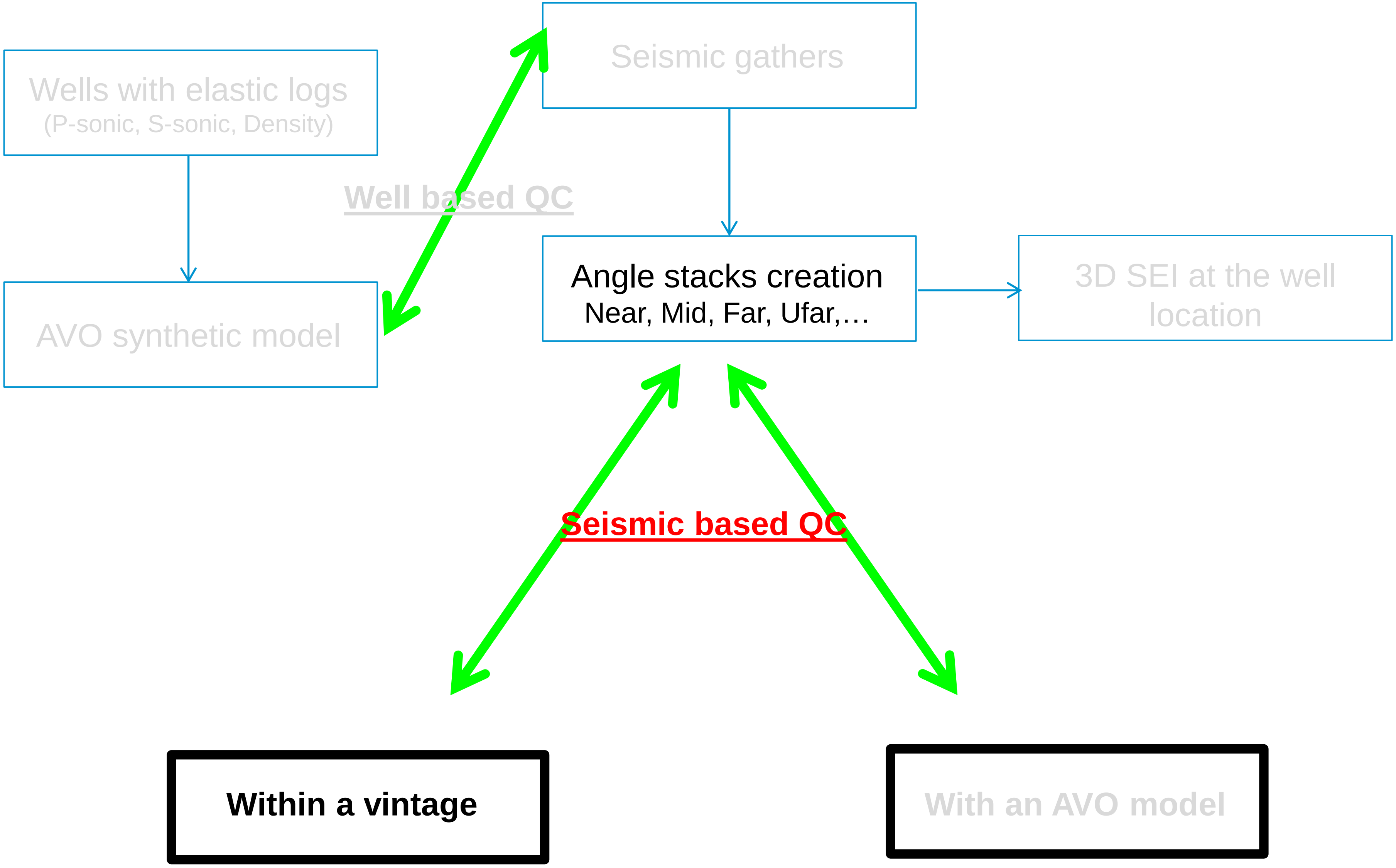


Seismic traces
Synthetic created from well logs
Synthetic from inverted attributes

Observations/Conclusions:

- Less amplitude dispersion as we proceed through the processing sequence;
- Amplitude trend consistent with prediction coming from the AVO model;
- Increased correlation between inverted attributes and upscaled well logs;
- Limitation: observation valid only at the well location.

Advanced seismic QCs results proposed in this presentation:

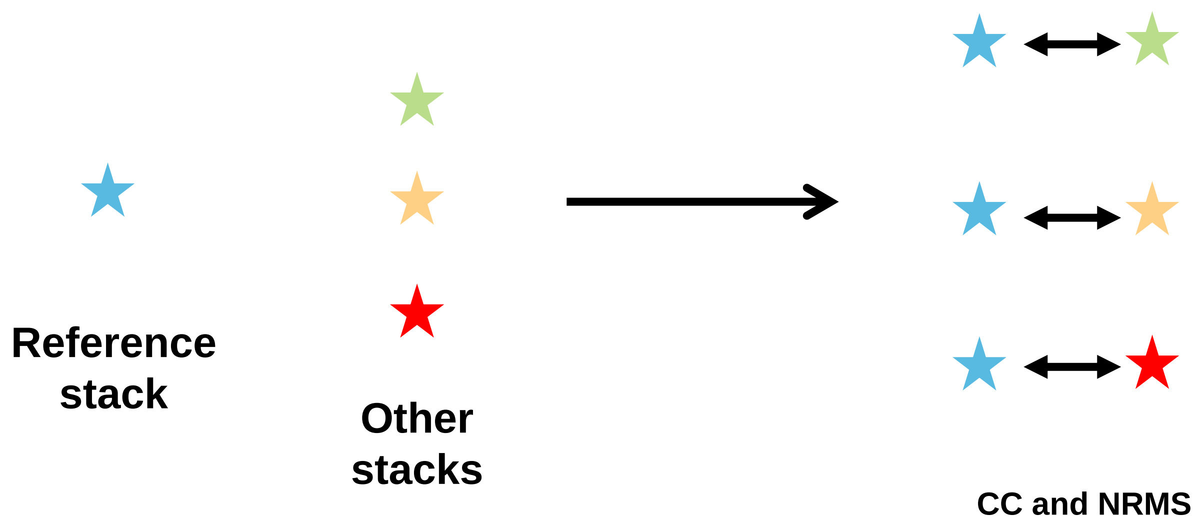


Objective and key observations to be done during those QCs:

- Is the repeatability between angle stacks increasing?
- Is this behaviour seen for a «statistically meaningful» population of traces?

Methodology:

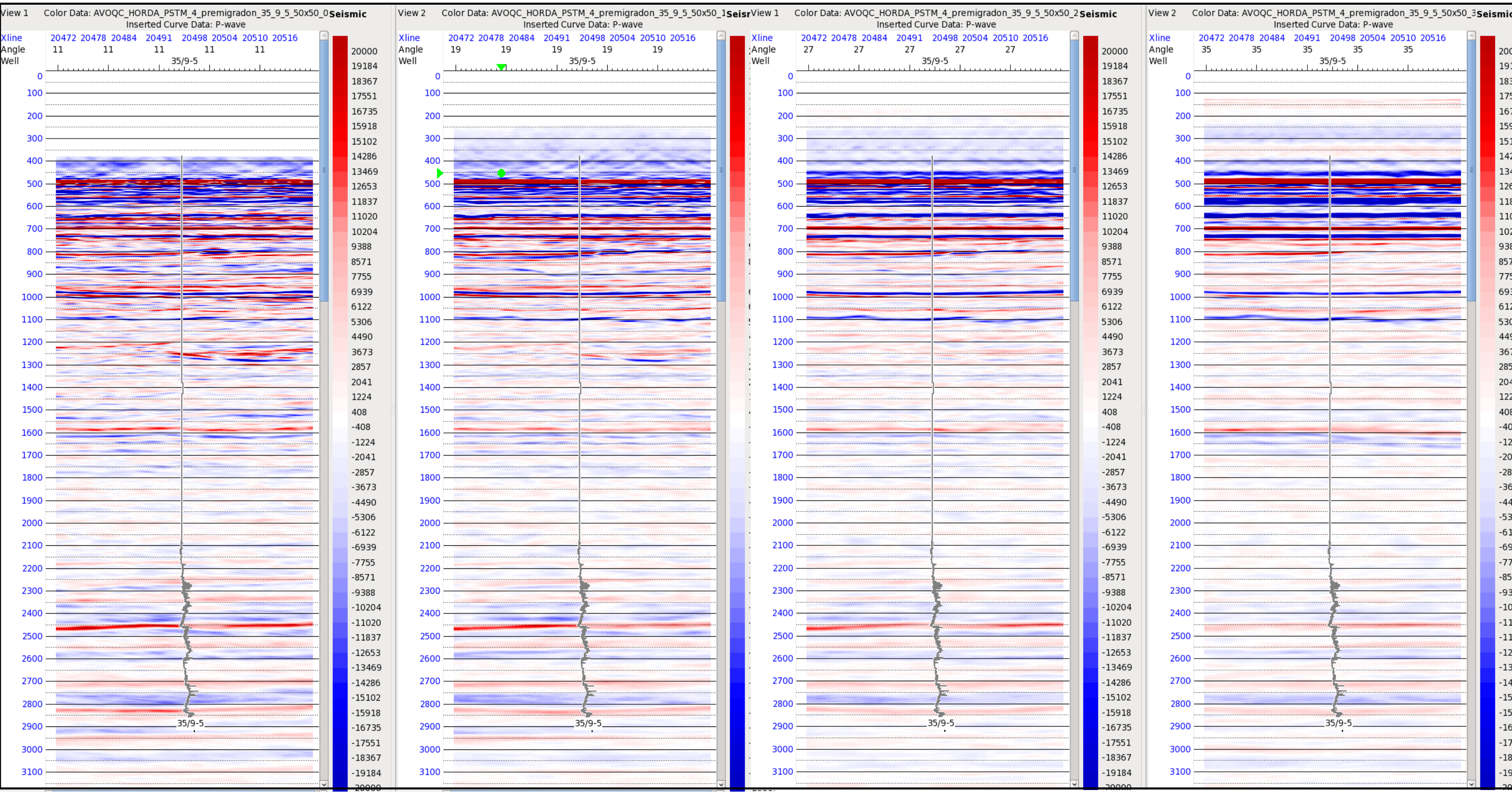
- Comparison between one reference angle stack and other angle stacks:



Angle stacks:

Step 1 > pre-mig Radon

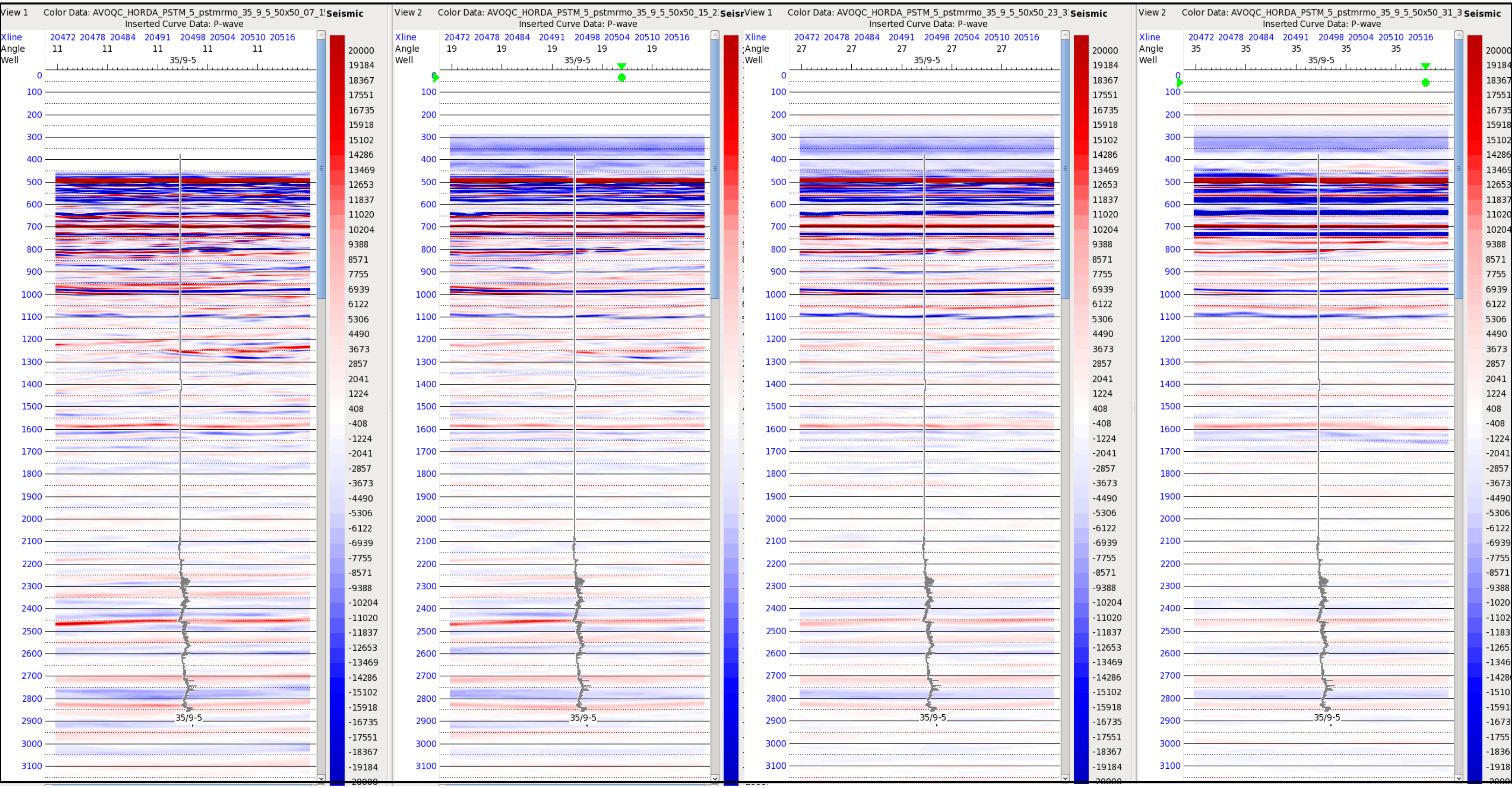
Near	Mid	Far	Ufar



Angle stacks:

Step 4 > Dip filter + RMO corr.

Near **Mid** **Far** **Ufar**



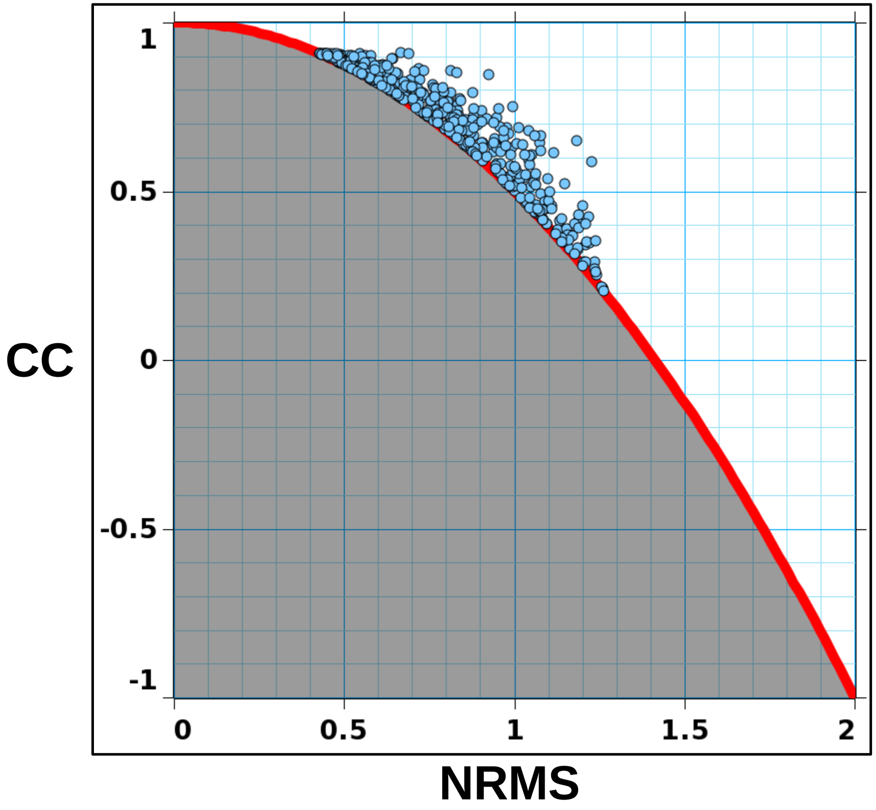
Statistical measurements:

- **C**orrelation **C**oefficient:

$$CC(A,B) = \frac{Cov(A,B)}{\sigma(A)\sigma(B)}$$

- **N**ormalized **R**oot **M**ean **S**quare:

$$NRMS(A,B) = \frac{2\,RMS(A-B)}{RMS(A)+RMS(B)}$$

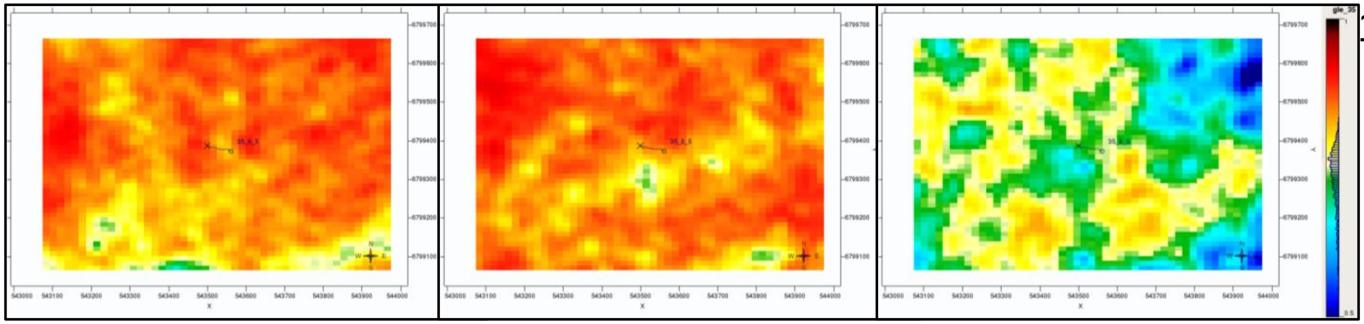


Couple of traces to be compared

Lower Bound: $CC = 1 - \frac{NRMS^2}{2}$

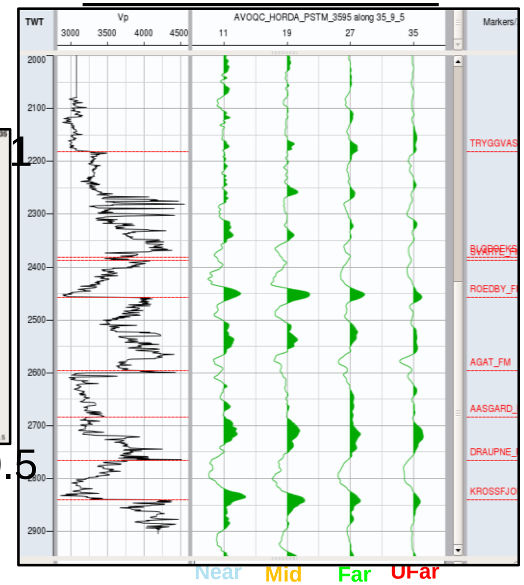
Step 1: pre-mig Radon

CC CC CC

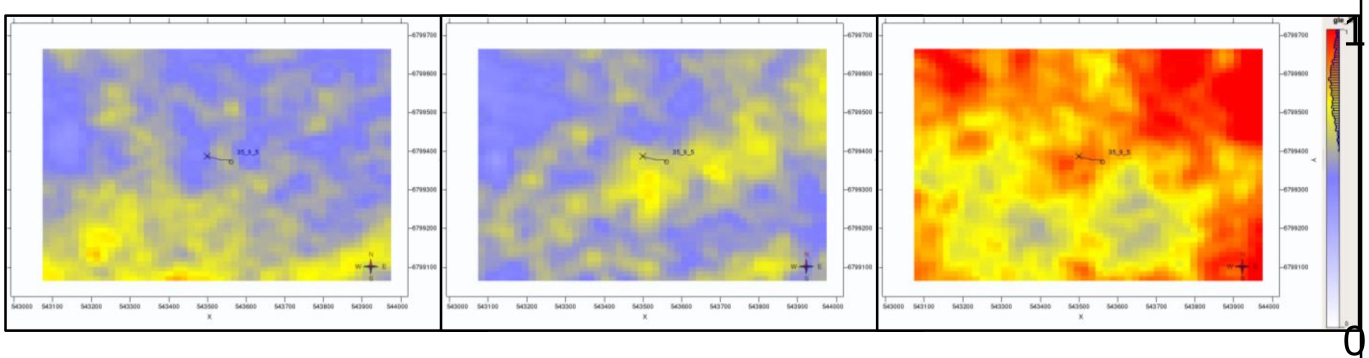


Near <-> Mid   Far <-> Mid   UFar <-> Mid

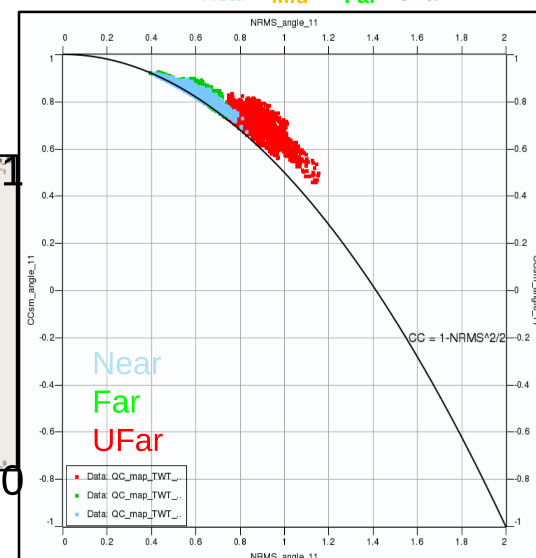
seismic at well location



NRMS NRMS NRMS



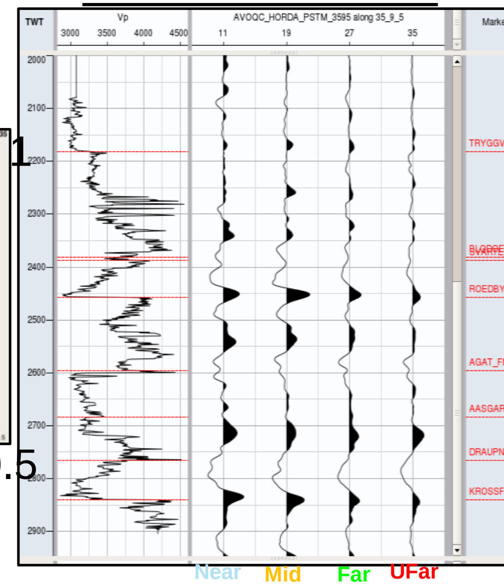
Near <-> Mid   Far <-> Mid   UFar <-> Mid



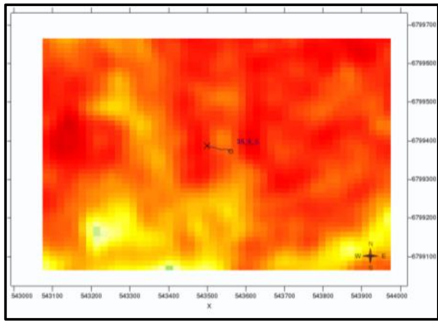
Extraction window size: 1s
Swath of 50 IL x 50 XL around the well

Step 2: 5D signal enhancement

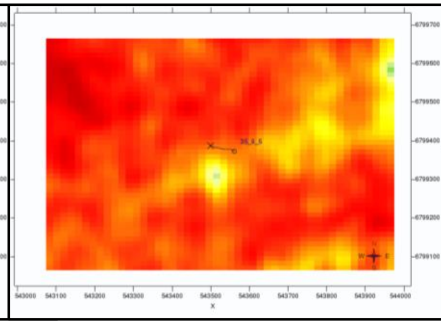
seismic at well location



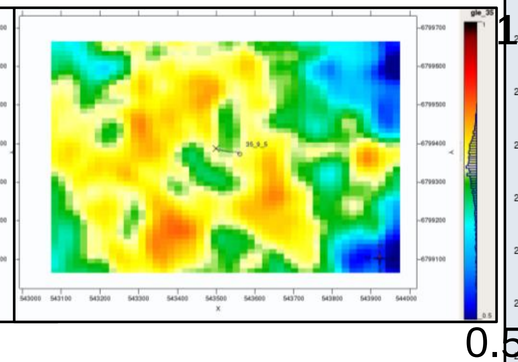
CC



CC



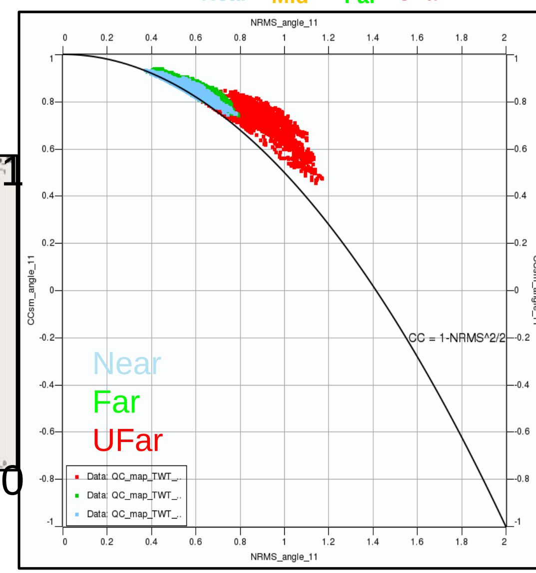
CC



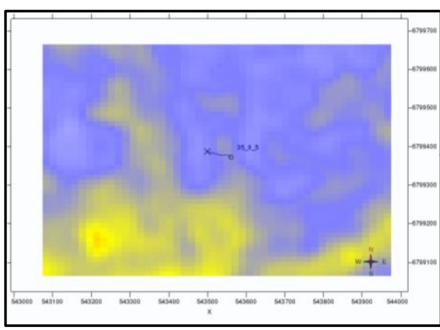
Near <-> Mid

Far <-> Mid

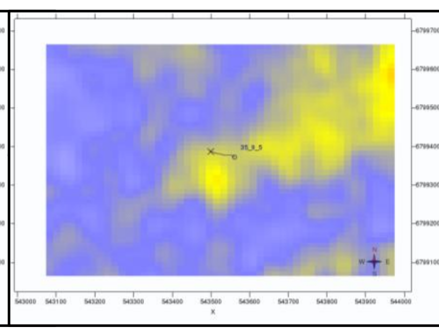
UFar <-> Mid



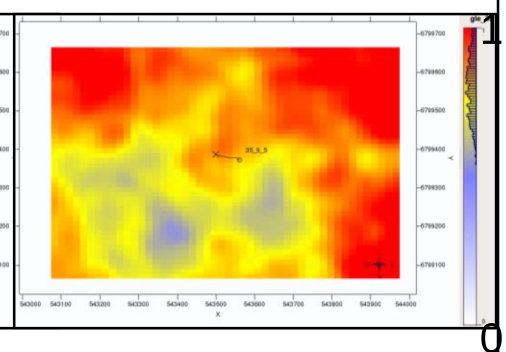
NRMS



NRMS



NRMS



Near <-> Mid

Far <-> Mid

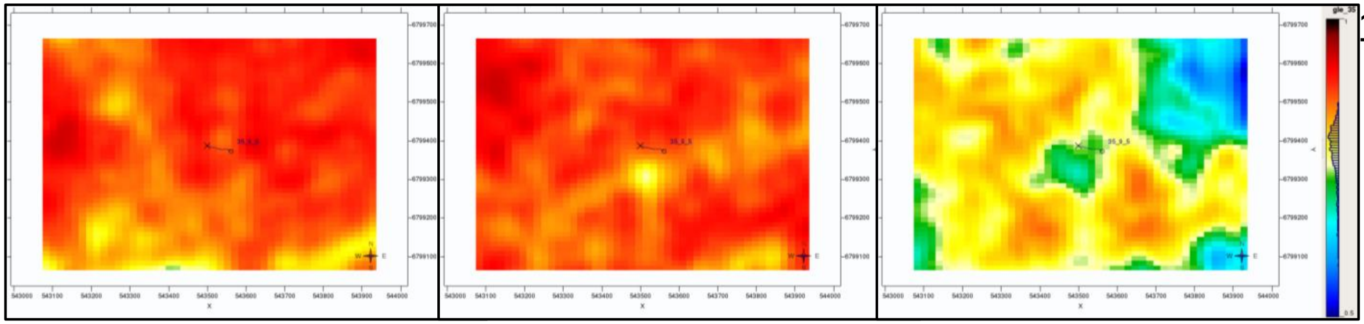
UFar <-> Mid

Extraction window size: 1s

Swath of 50 IL x 50 XL around the well

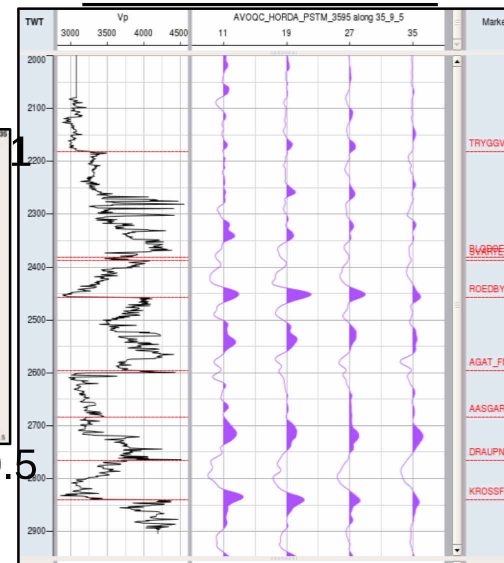
Step 3: F-XY denoise

CC CC CC

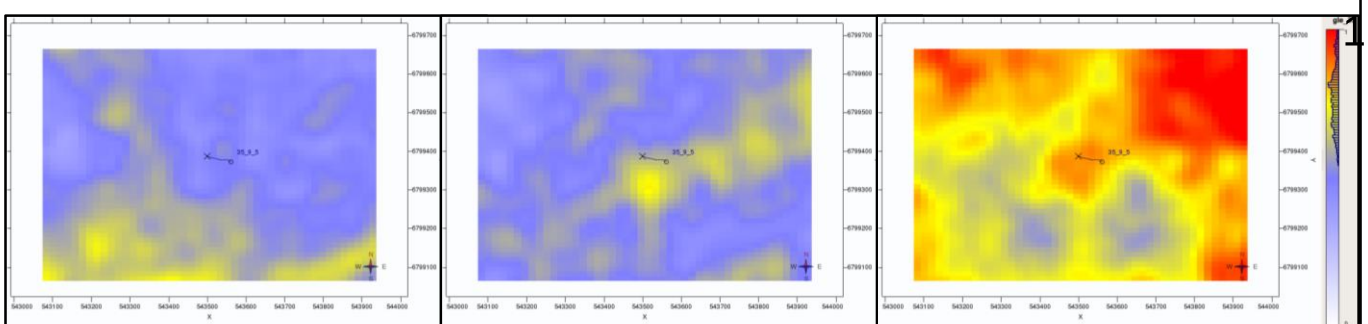


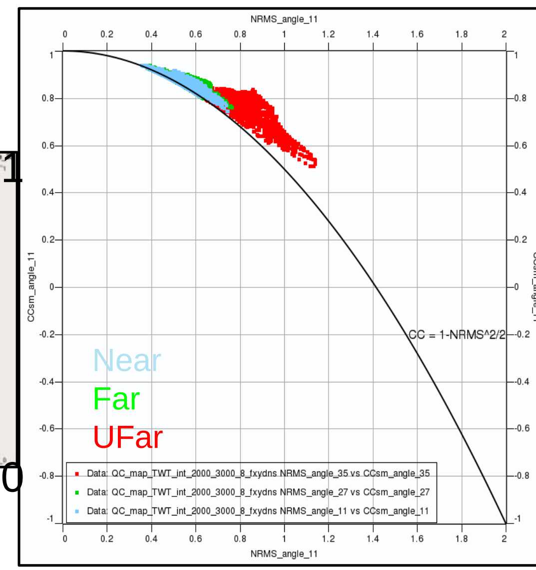
Near <-> Mid Far <-> Mid UFar <-> Mid

seismic at well location



NRMS NRMS NRMS



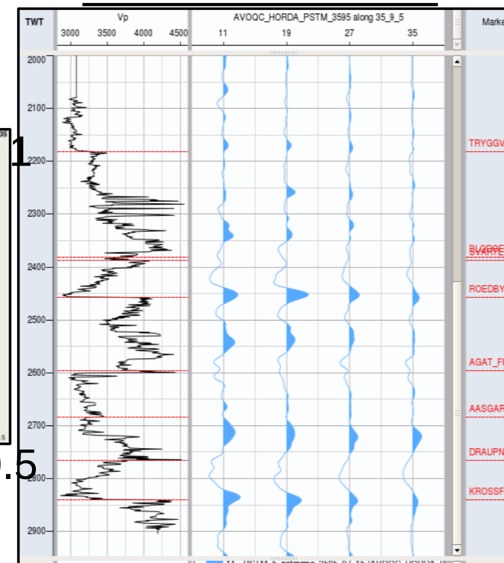


Near <-> Mid Far <-> Mid UFar <-> Mid

Extraction window size: 1s
Swath of 50 IL x 50 XL around the well

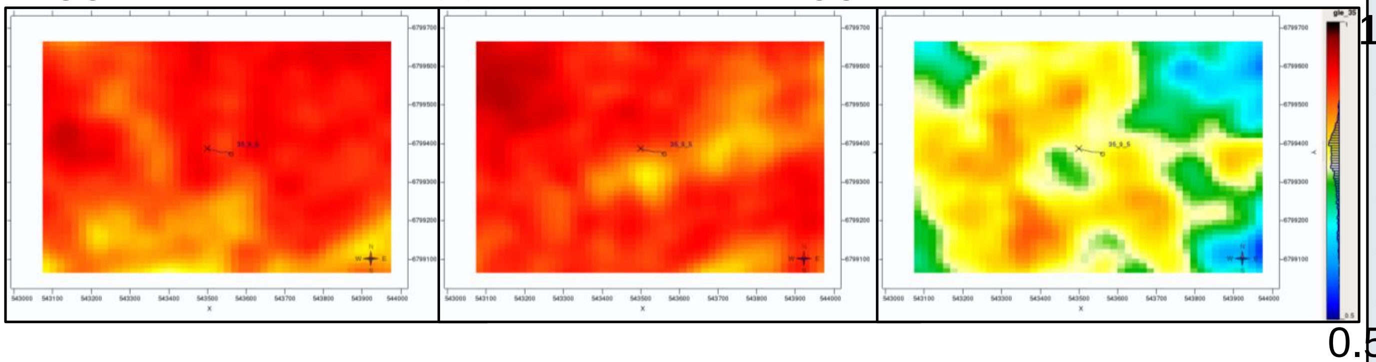
Step 4: Dip filter + RMO corr.

seismic at well location



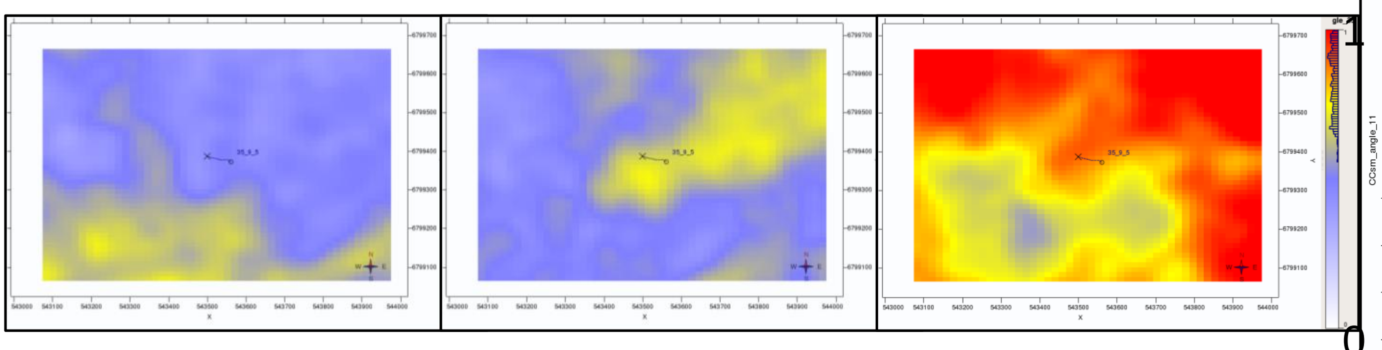
Near Mid Far UFar

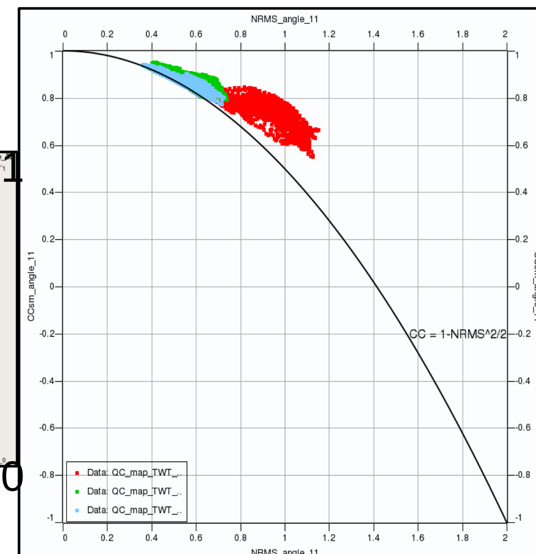
CC CC CC



Near <-> Mid　　Far <-> Mid　　UFar <-> Mid

NRMS NRMS NRMS





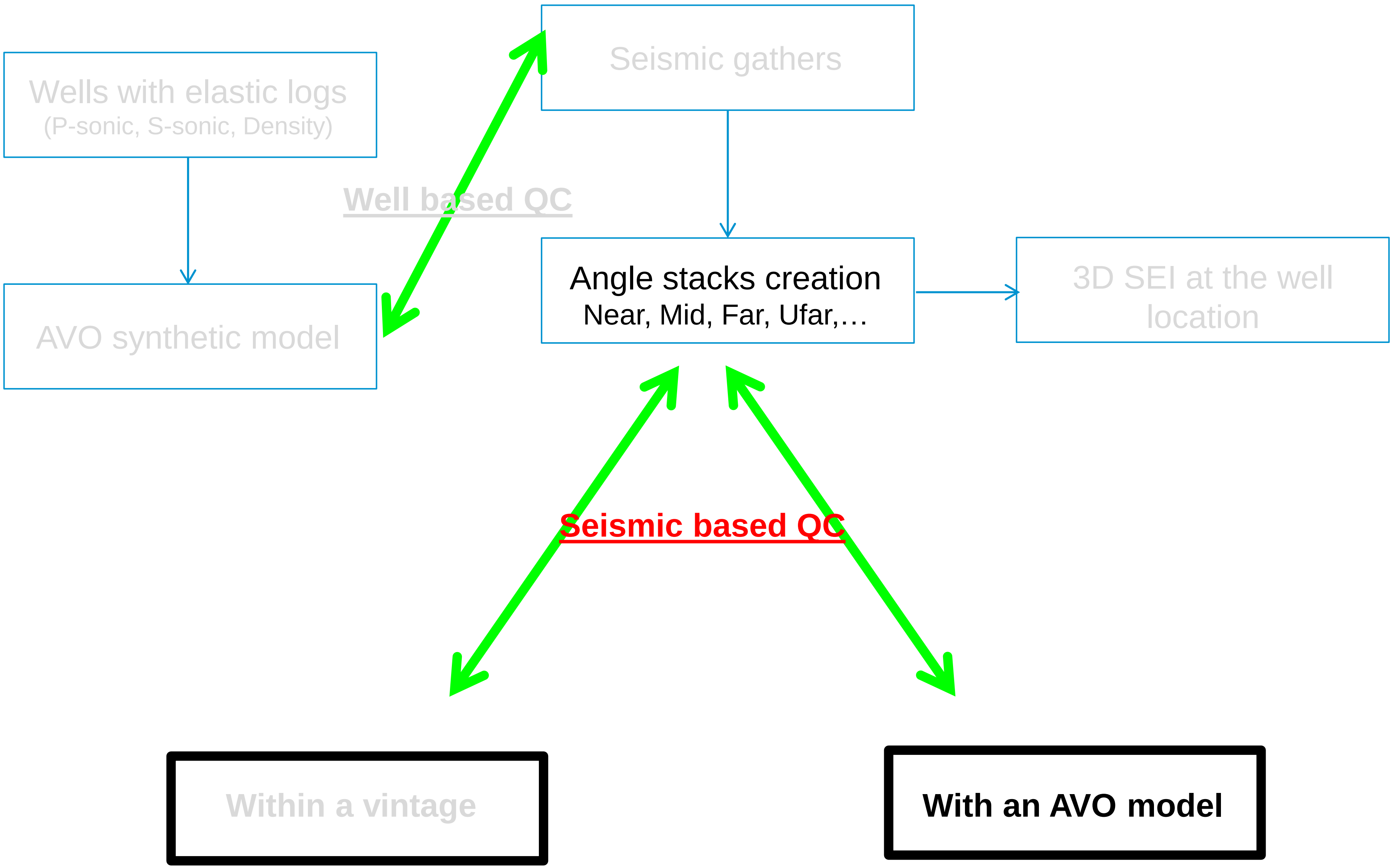
Near <-> Mid　　Far <-> Mid　　UFar <-> Mid

Extraction window size: 1s
Swath of 50 IL x 50 XL around the well

Observations/Conclusions:

- Increased repeatability between angle stacks;

Advanced seismic QCs results proposed in this presentation:

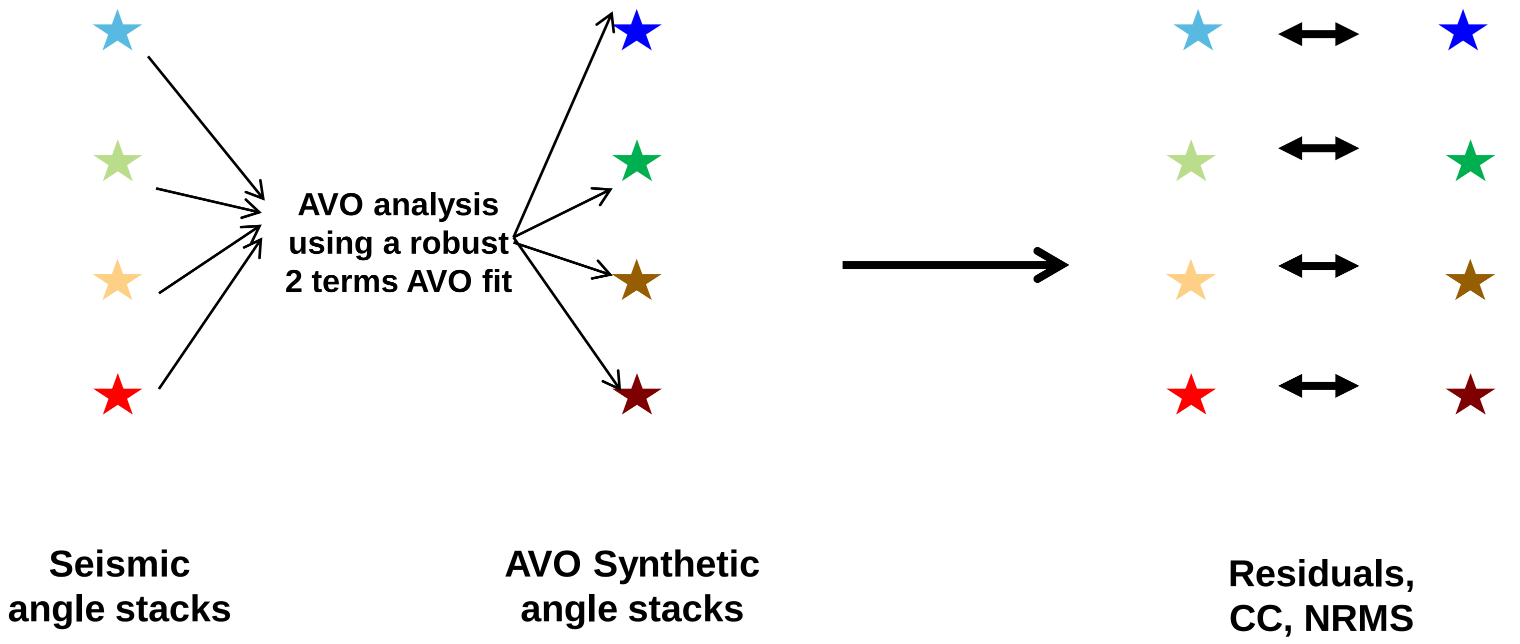


Objective and key observations to be done during those QCs:

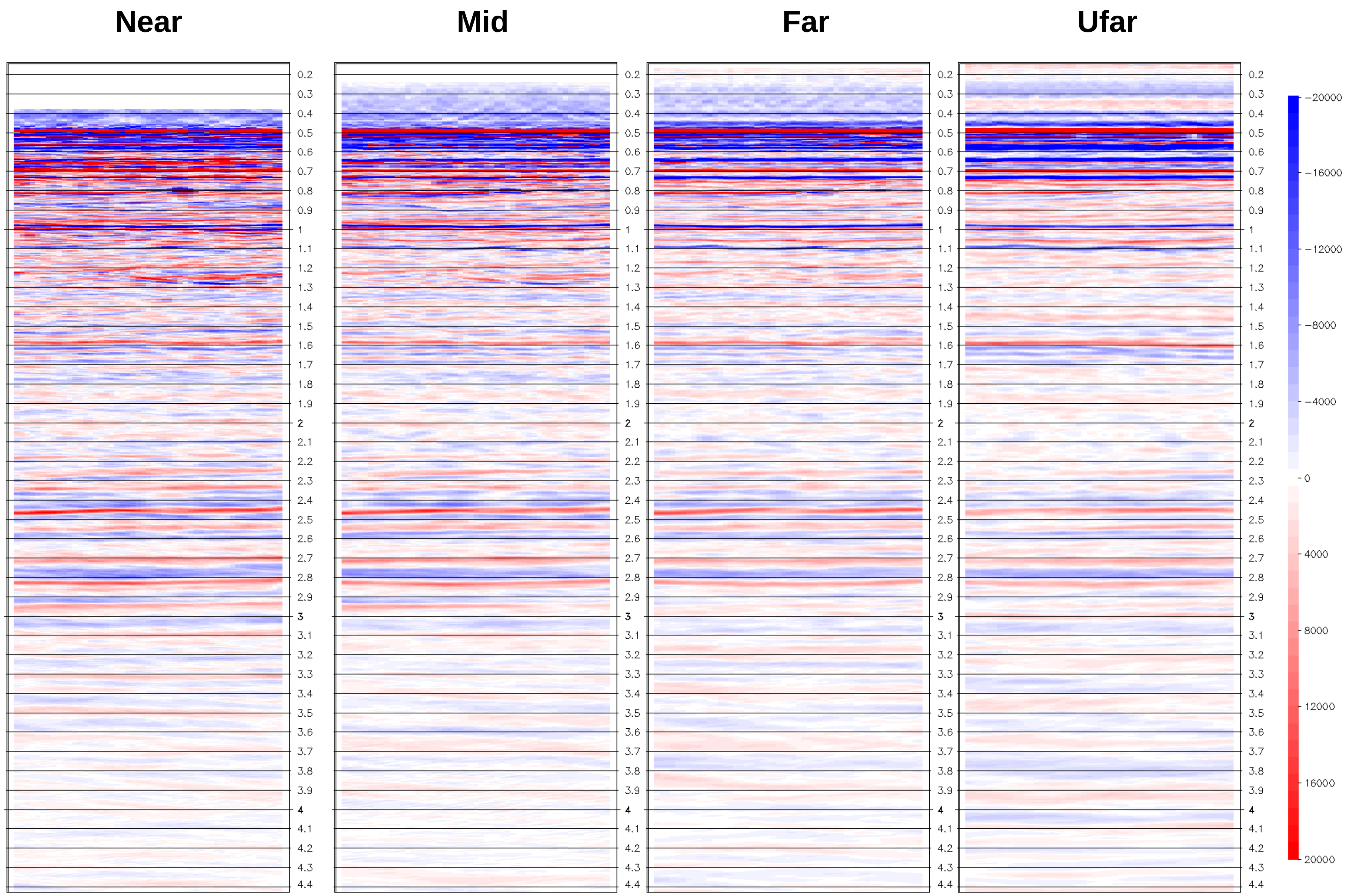
- Is the Zoeppritz compliancy of the seismic data improving during the processing > are less residuals observed between an AVO model and the real seismic data?

Methodology:

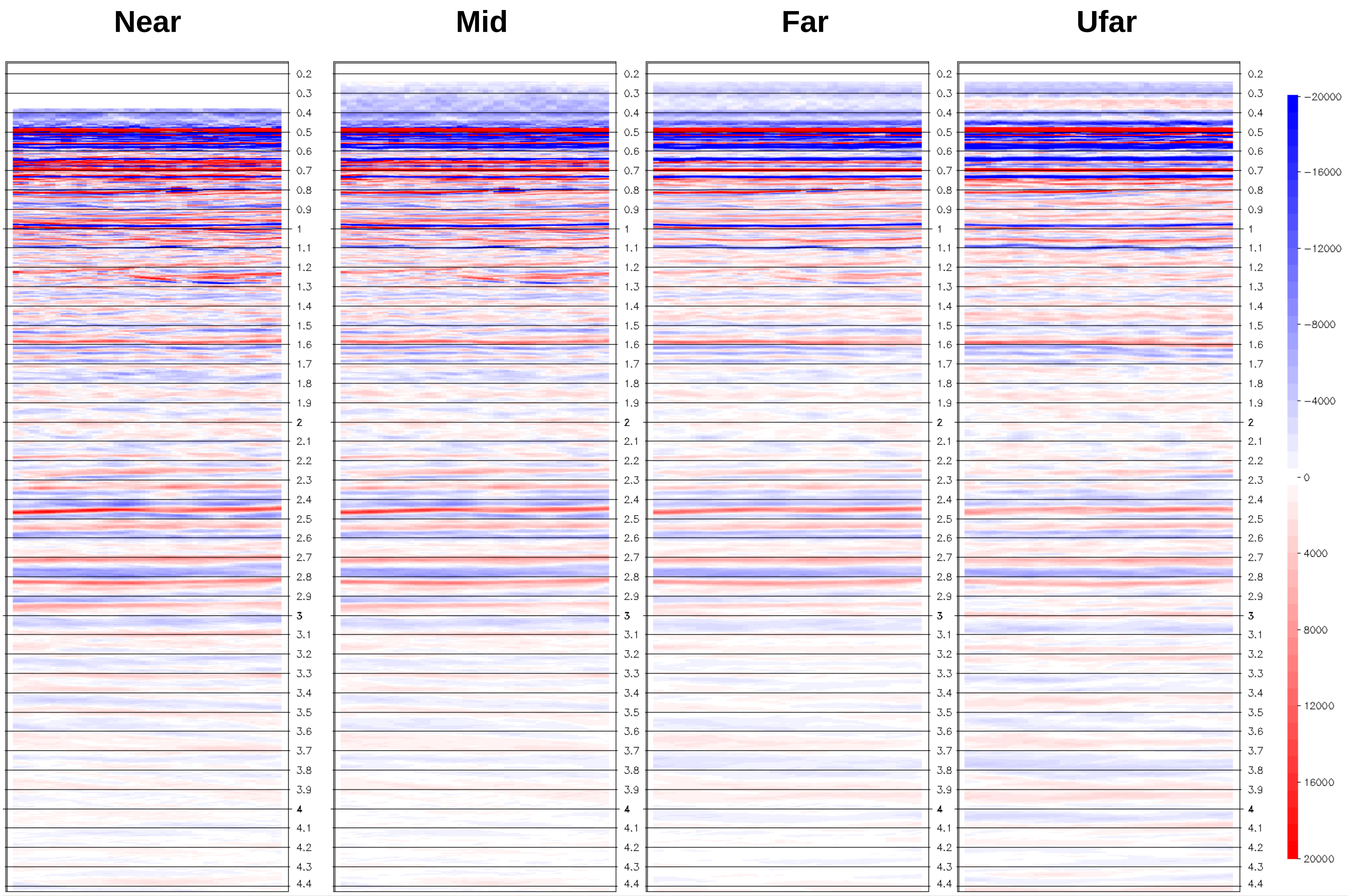
- Comparison between angle stacks and synthetic angle stacks generated from an AVO analysis.



Step 1: pre-mig Radon / «Real» angle stacks

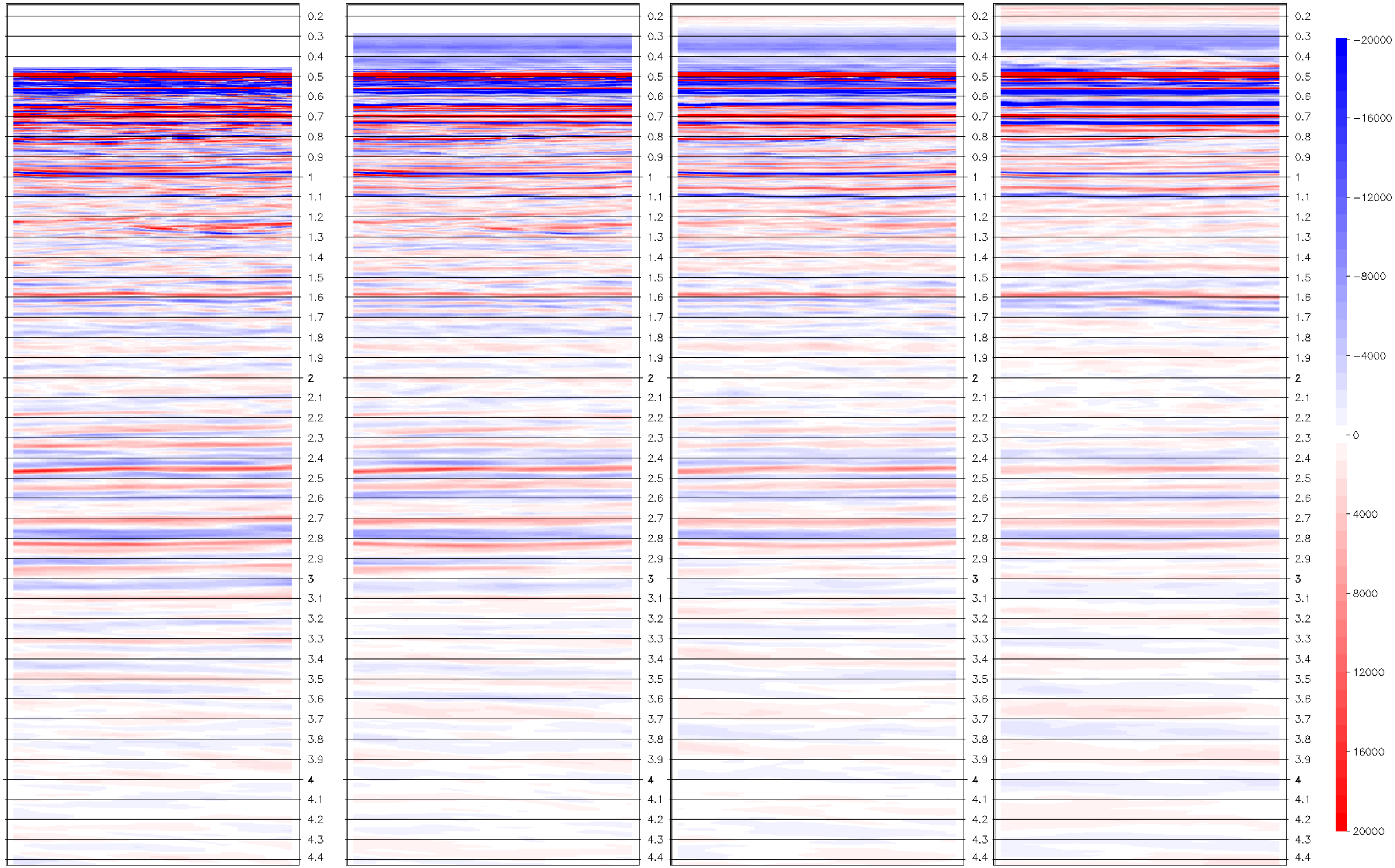


Step 1: pre-mig Radon / Synthetic angle stacks

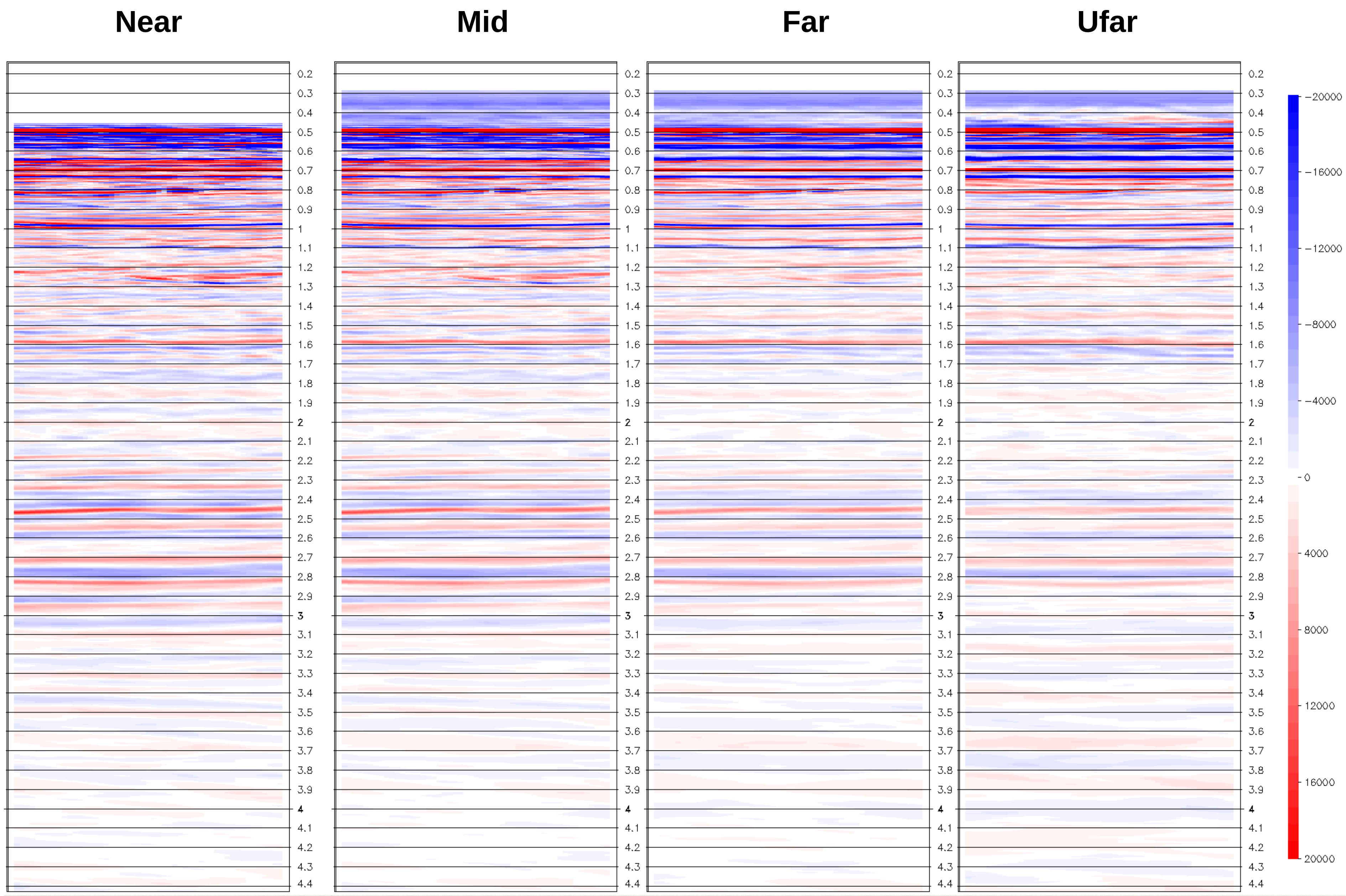


Step 4: Dip filter + RMO corr. / «Real» angle stacks

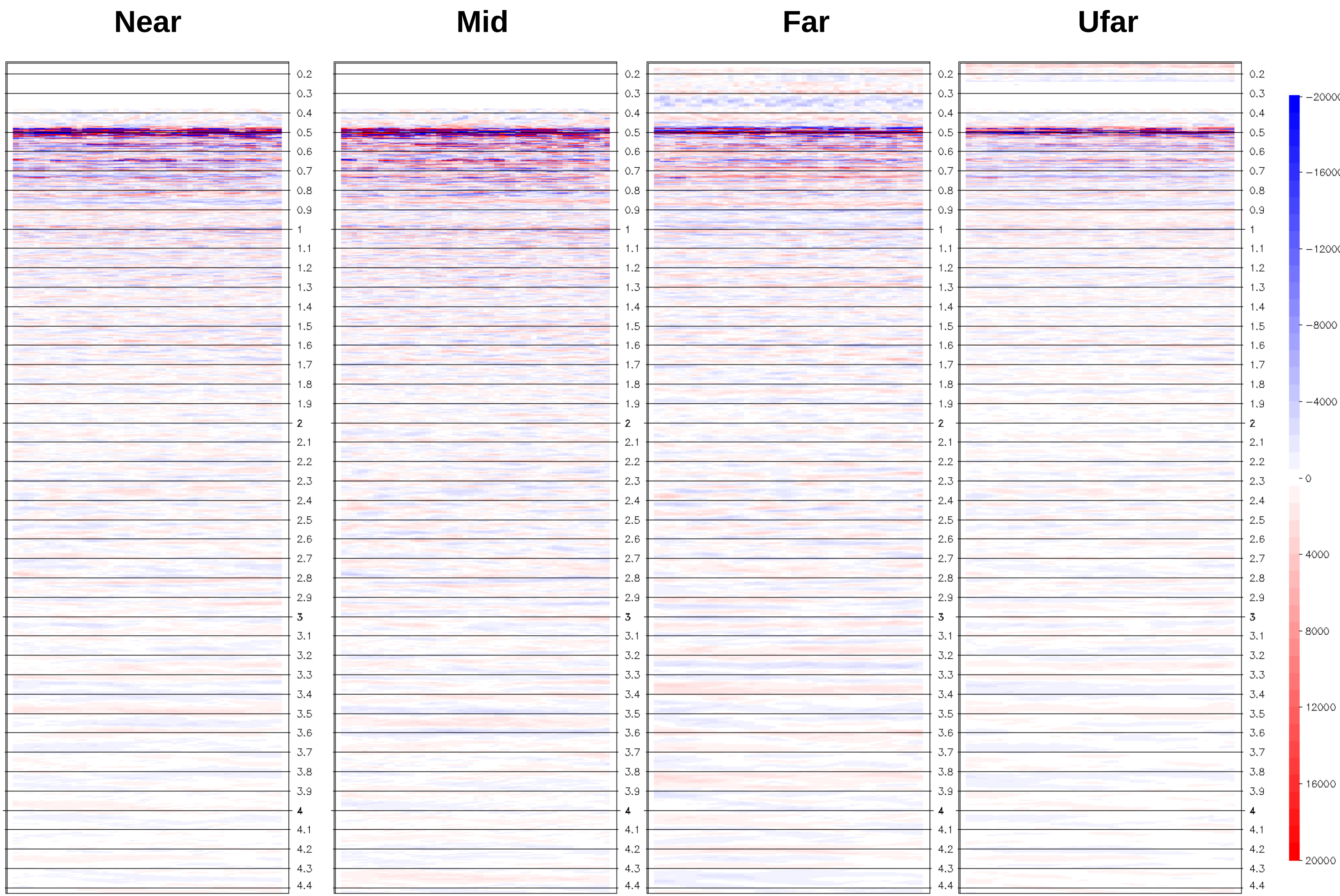
Near | **Mid** | **Far** | **Ufar**



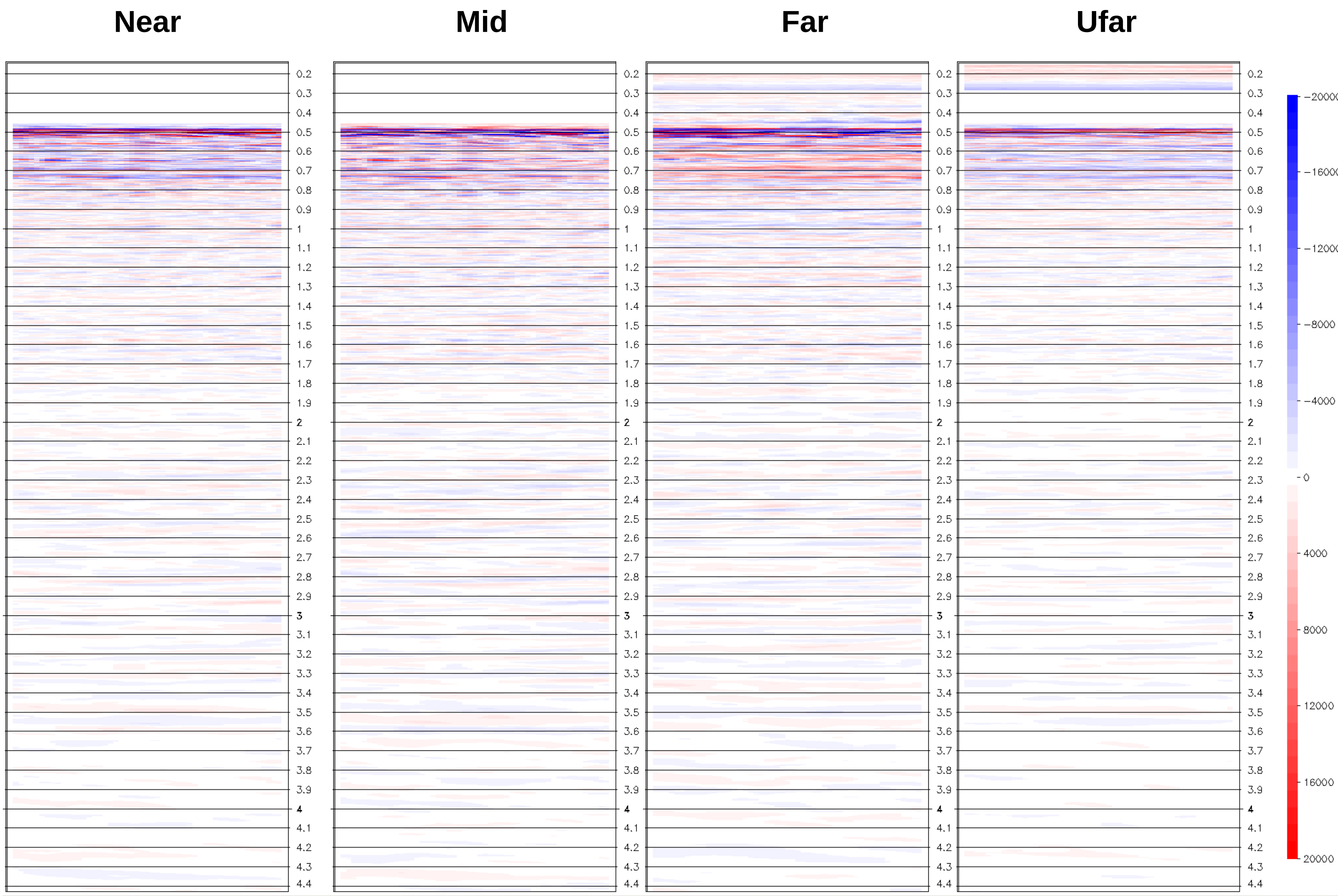
Step 4: Dip filter + RMO corr. / Synthetic angle stacks



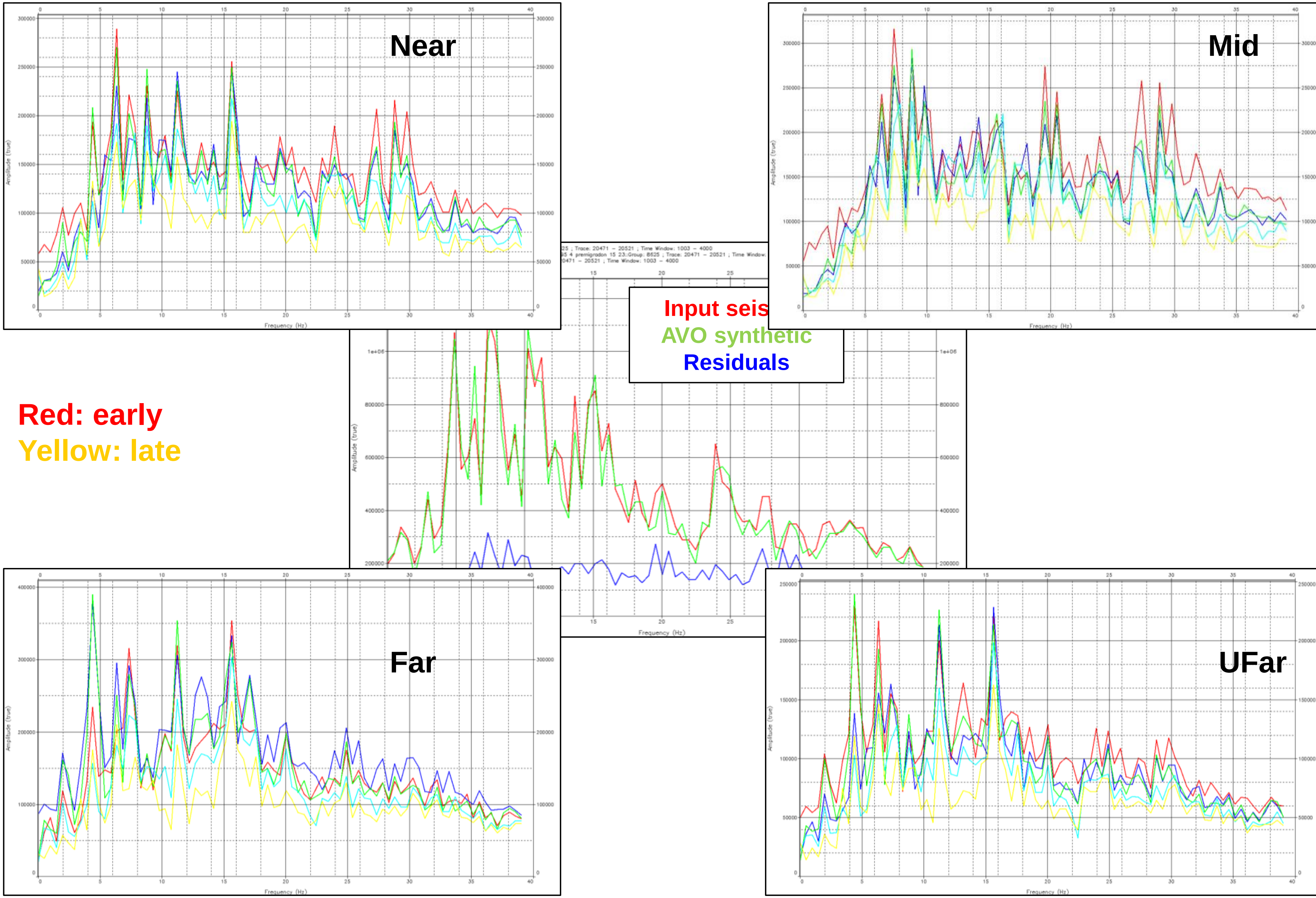
Step 1: pre-mig Radon / Residuals



Step 4: Dip filter + RMO corr. / Residuals



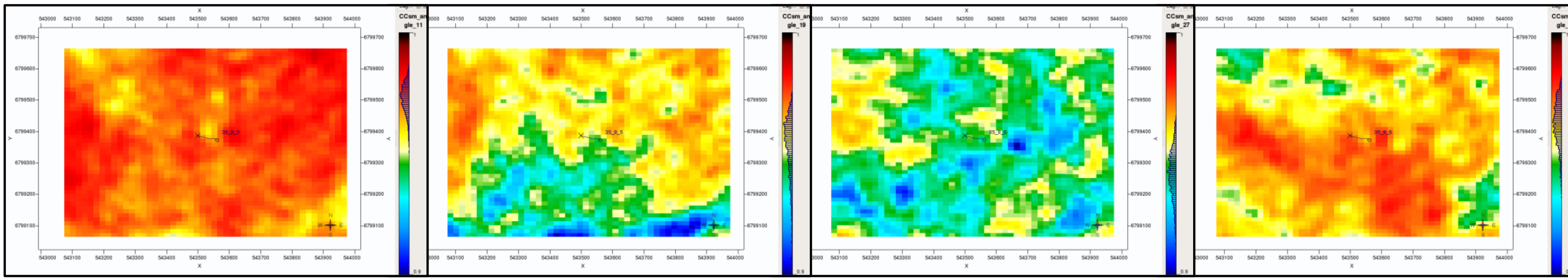
Amplitude spectra of the residuals:



Red: early
Yellow: late

Step 1: pre-mig Radon

CC



1.0

0.9

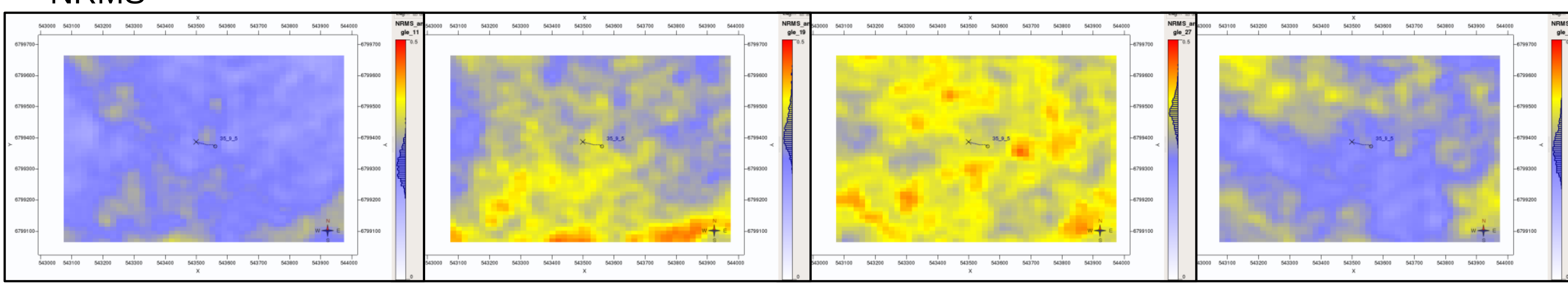
Near seismic<->
Near synthetic

Mid seismic<->
Mid synthetic

Far seismic<->
Far synthetic

UFar seismic<->
UFar synthetic

NRMS



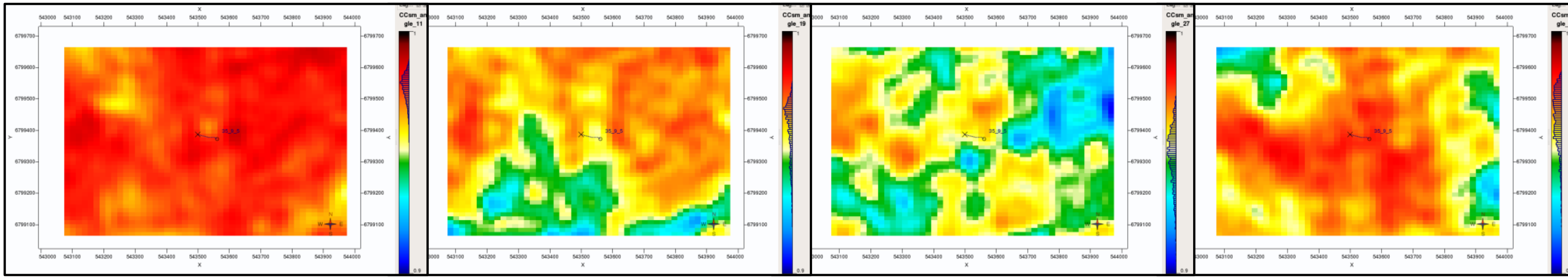
0.5

0.0

Extraction window size: 1s
Swath of 50 IL x 50 XL around the well

Step 2: 5D signal enhancement

CC



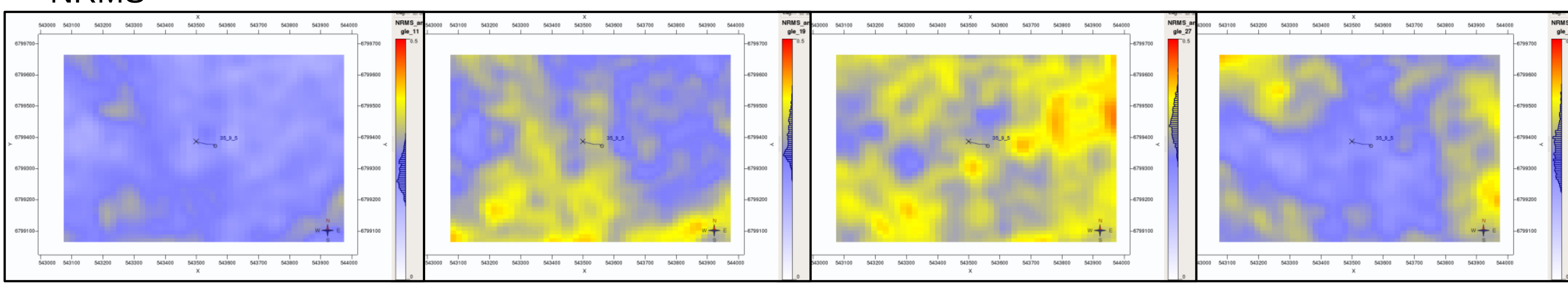
Near seismic<-> Near synthetic

Mid seismic<-> Mid synthetic

Far seismic<-> Far synthetic

UFar seismic<-> UFar synthetic

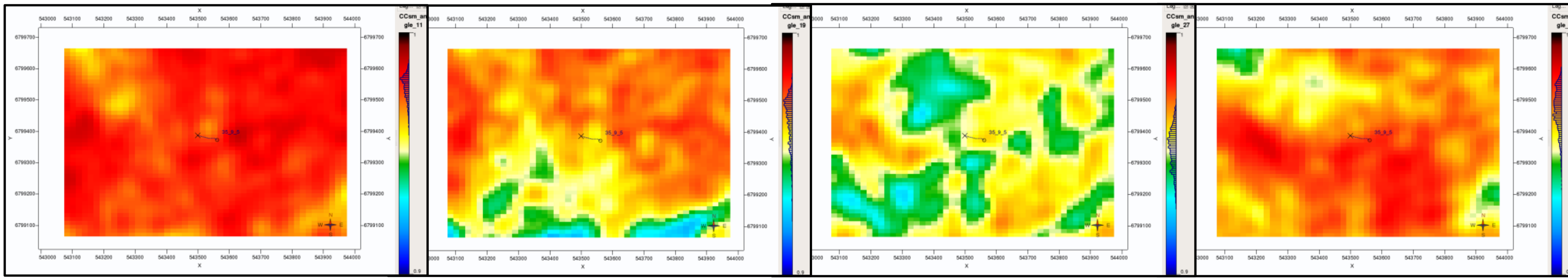
NRMS



Extraction window size: 1s
Swath of 50 IL x 50 XL around the well

Step 3: F-XY denoise

CC



1.0

0.9

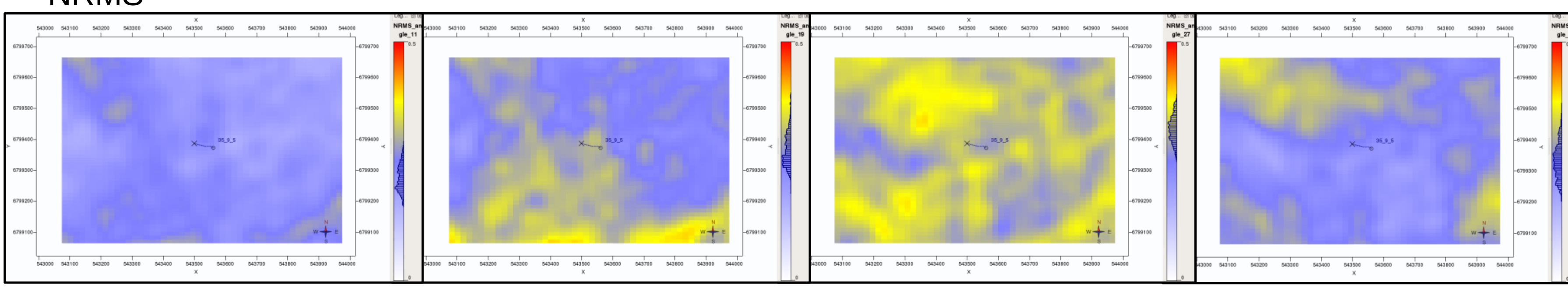
Near seismic<-> Near synthetic

Mid seismic<-> Mid synthetic

Far seismic<-> Far synthetic

UFar seismic<-> UFar synthetic

NRMS



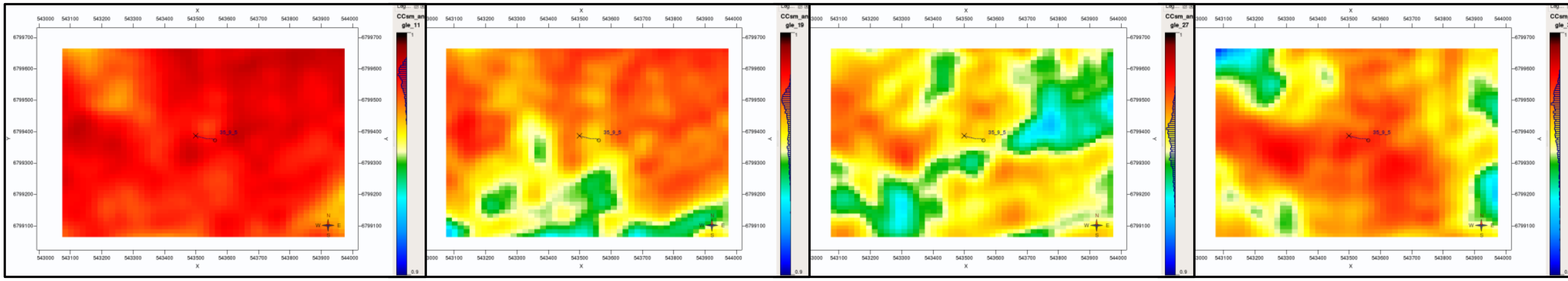
0.5

0.0

Extraction window size: 1s
Swath of 50 IL x 50 XL around the well

Step 4: Dip filter + RMO corr.

CC



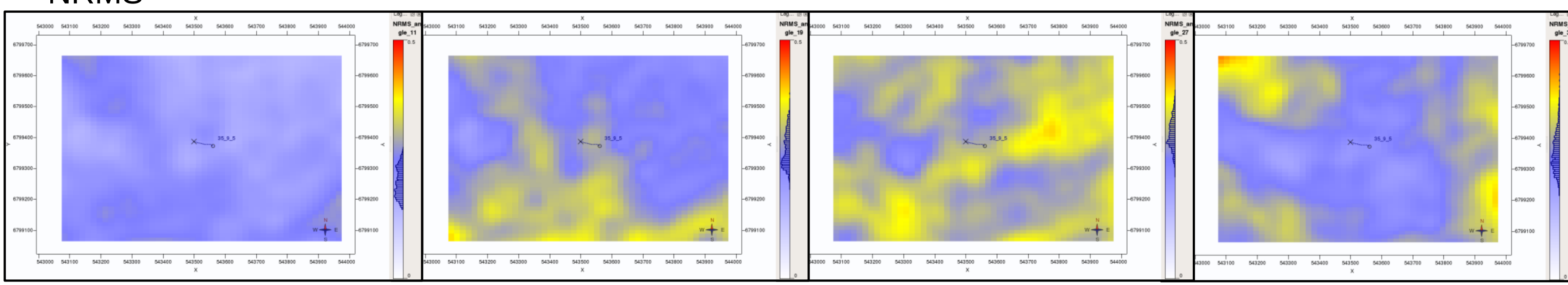
Near seismic<-> Near synthetic

Mid seismic<-> Mid synthetic

Far seismic<-> Far synthetic

UFar seismic<-> UFar synthetic

NRMS



Extraction window size: 1s
Swath of 50 IL x 50 XL around the well

Conclusions:

- Less seismic amplitude dispersion in the pre-stack data;
- AVO compliancy is preserved during the processing;
- Increased correlation between the well logs and inverted attributes; decent match despite having used non-optimized parameters > QI of this dataset should be attempted;

Recommendations:

- These QCs should become standard in any seismic processing project;
- QCs should not be restricted to a few traces at arbitrarily chosen well locations.