Summary

Gridded tomography is generally perceived as being very good at resolving velocities down to fine detail, but when it comes to resolving very sharp contrasts, such as at top chalk or top salt levels, it breaks down, giving way to the hybrid approach. In this, gridded tomography is confined to certain velocity domains and another velocity estimation method, such as flooding or vertical update, is used in the problematic domains. While it is not inherently a problem to employ such a hybrid approach it relies on interpreting layers which could bias the final model and subtle intra-layer features may be missed. We show in this presentation that the gridded approach works throughout the entire section in the Nordsjøn Area. This part of the Norwegian North Sea is characterized by shallow heterogeneities and a thin chalk layer at intermediate depths.

High lateral and vertical velocity variations at shallow levels impair the image quality at deeper target levels if not accounted for in the model-building process. Diapirs, channels, gas chimneys, cementation, volcanic and salt intrusions are only a few geological features that can produce artefacts at deeper levels such as pull-ups, push-downs and shadows. Some of these features, such as cemented carbonates or sand intrusions are distributed randomly within the imaging area and not larger than a few hundred meters, which makes them particularly difficult to incorporate in conventional layer-based velocity models. Adequate horizontal and vertical sampling of the velocity model and the velocity analysis grids ensures that gridded tomography captures these features in great detail. The chalk layer is relatively thin (i.e. less than 200m thickness) but well constrained by top and bottom reflections. This allows us to capture the chalk velocities accurately, except in a small area where the chalk thins out below our model-building resolution.

As a result of this approach, a 3D PreSDM volume of a far superior imaging resolution than the vintage data set was produced. Examples from the model-building sequence and the final result are shown.

Figure 1: 3D PreSDM stack and velocity overlay shows the complexities of the Nordsjøn area. Shallow channels diapirs and sand injections at intermediate depth levels, highly folded and faulted basins at greater depths.
Method and results

The gridded approach to model-building is by its nature more data-driven than the layer-based approach. Firstly, a full skeleton of events contributes to the tomographic inversion whereas only a small number of events drive the layer-based tomography. Secondly, the residual move-out is calculated densely within a sliding window of generally small dimensions (a few horizontal and vertical samples) to ensure optimal statistical averaging and pick continuity along one or more directions. And finally, the gridded approach is not burdened as much by interpretational errors. Its challenge consists more in testing the optimal parameters for automatic RMO picking as much as for the inversion that can be “guided” away from local, un-geological solutions by applying a wealth of weights and constraints.

![Figure 2: A full event skeleton lies at the base of gridded tomography. The entire seismic record with amplitudes above a use specified threshold is considered for inversion. Displayed are stack (above) and event skeleton (below).](image)

During the inversion process measured depth errors (stored in the residual move-out (RMO) grid) are back propagated along straight or curved ray-paths to position velocity contrasts accurately. Short wave-length interval velocity information can be extracted directly from the hyperbolic move-out field via a simple differential formula. The approach is an extension to the depth migrated domain and to non-horizontal reflectors of the well known Dix formula. Thereby high resolution tomography succeeds in retrieving (1) the layered structure of the overburden, (2) resolving velocity anomalies of irregularly shaped sand bodies of locally sub-cable dimensions,
(3) finding low velocities associated with shale diapirs, and (4) the retrieving accurate velocity of a thin chalk layer. Figure 3 illustrates the velocity detail achieved by this procedure. Low velocities associated with diapirs can be seen in Figure 1 at intermediate depth levels. Gridded tomography is helped in resolving the thin high velocity layer by a very good signal-to-noise ratio at this level. Both, top and base chalk, are strong reflections with considerable offset coverage. To avoid picking the chalk refraction, which crosses the top chalk reflection at the critical distance, a surgical mute centred on the top chalk was applied.

Figure 3: This second example from the Nordsjøn area shows a structurally and tomographically well resolved section. Resolving the shallower sand intrusions above the thin chalk helps in imaging the chalk with only a minor imprint from the “moustache” reflection.

Conclusions
Application of high resolution gridded tomography to data from the Nordsjøn area succeeds in resolving the velocity structure of the entire subsurface with great accuracy. As a measure of this we show in Figure 4 a very good tie between the final product (3D PreSDM) and well information.

Figure 4: Seismic/well tie shows a very good match.

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