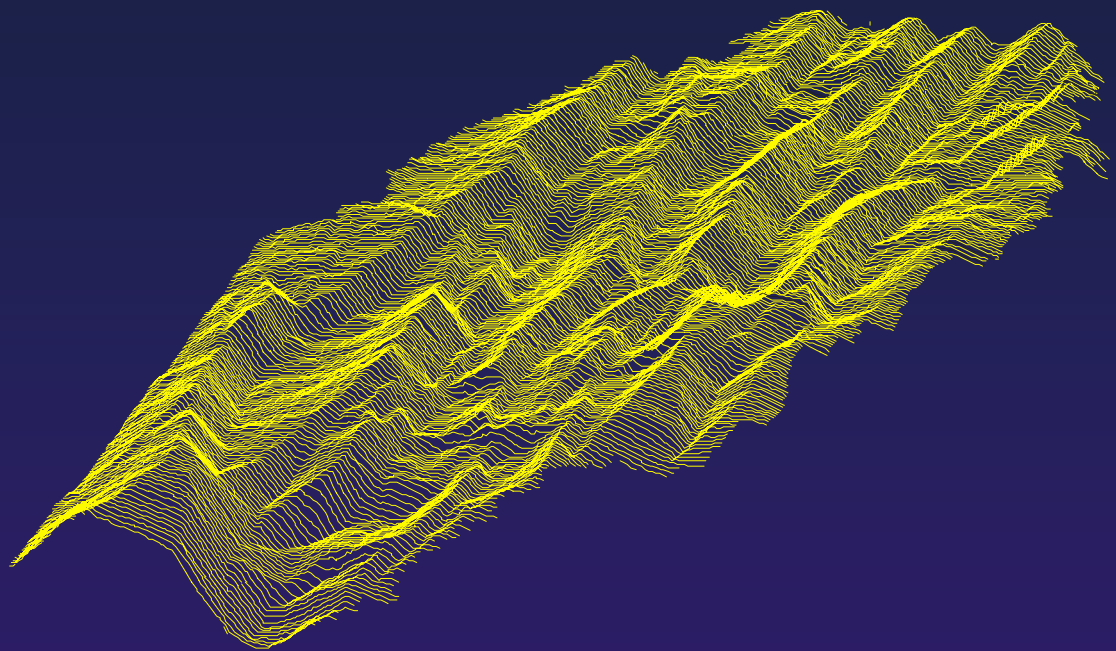
BUILDING, MANAGING, AND HISTORY MATCHING VERY LARGE AND COMPLEX GRIDS

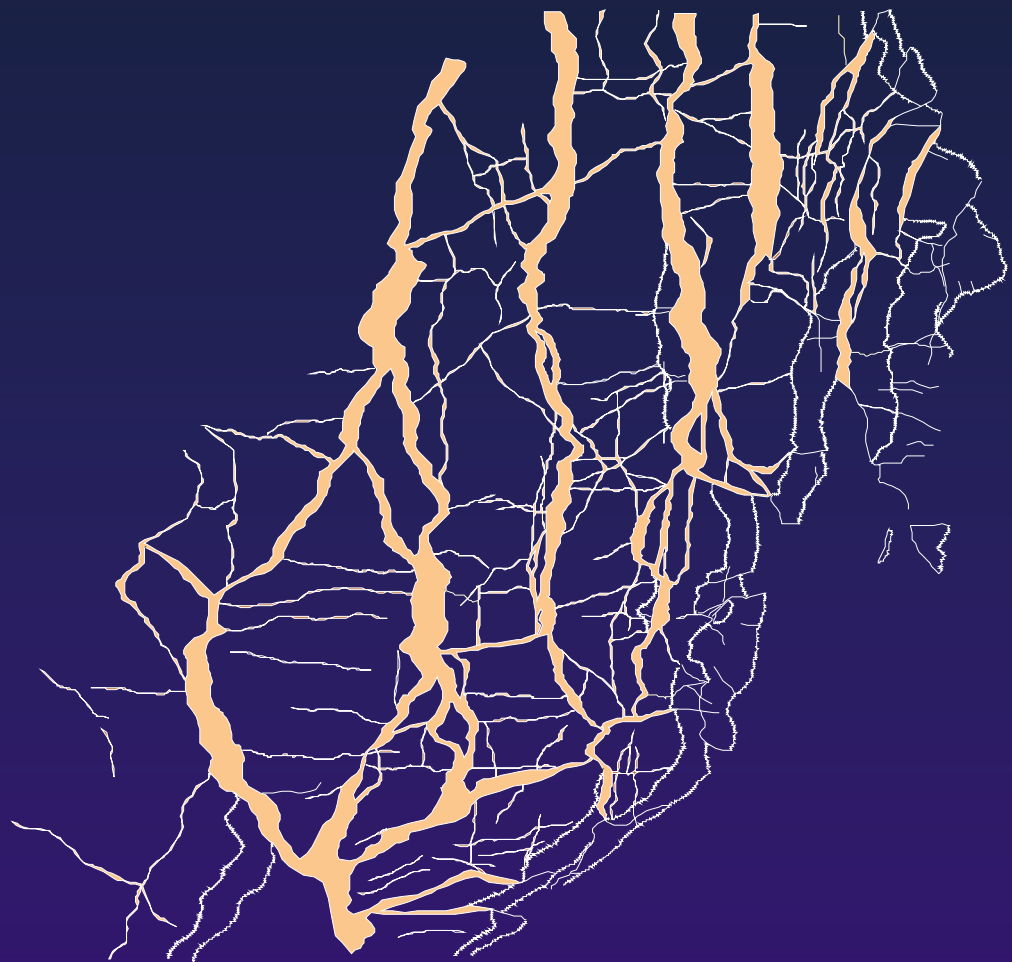


WITH EXAMPLES FROM THE GULLFAKS FIELD

by
Øystein Pettersen

STATOIL

GULLFAKS FAULT MAP



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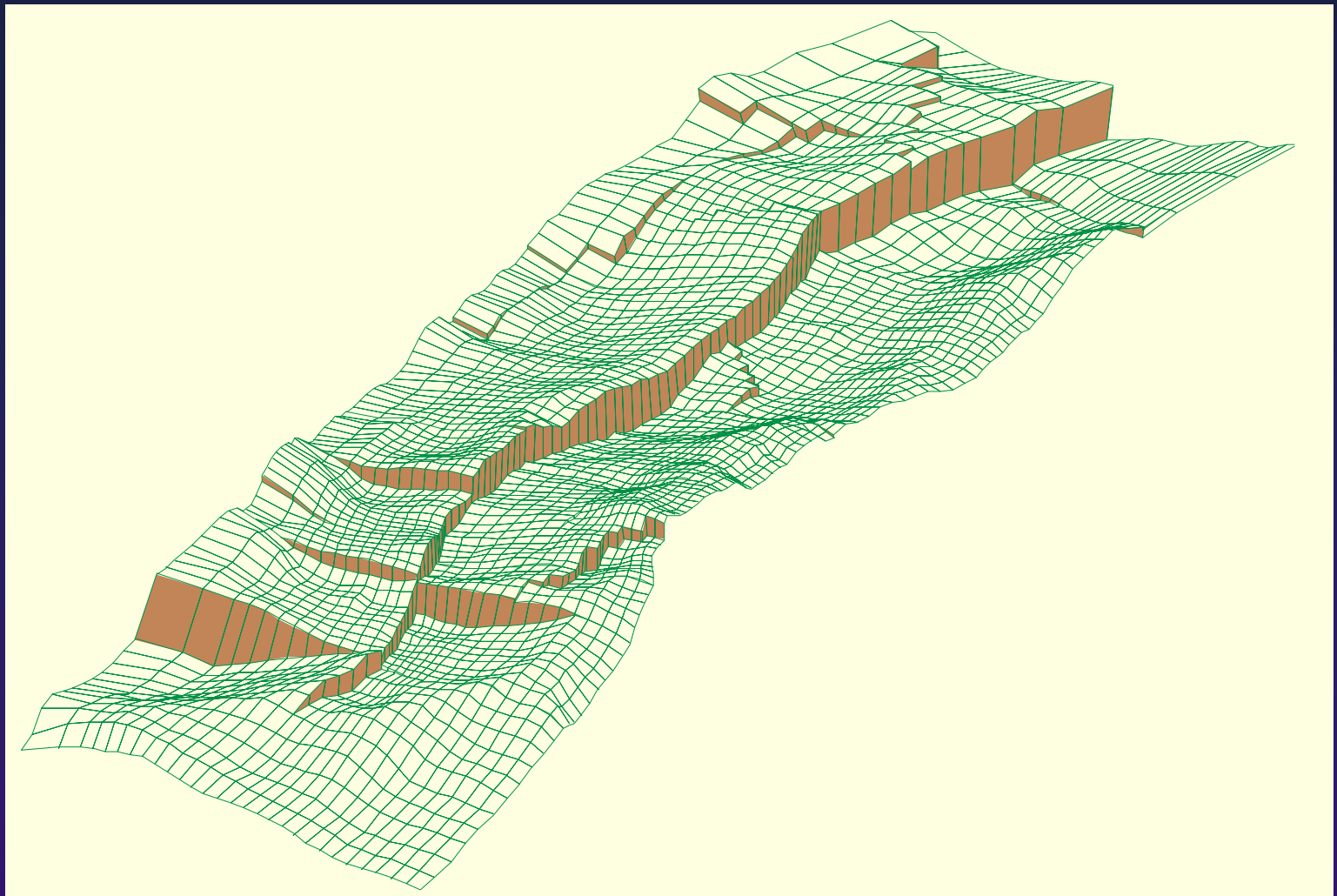
GULLFAKS CENTRAL AREA GRID



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MODEL DEVELOPMENT PROCESS

GRID BUILDING | HISTORY MATCHING | PRED. RUNS

6 mths | 12 mths | 15 mths

RESULT ANALYSIS | EDITING | MACHINE WORK HOURS

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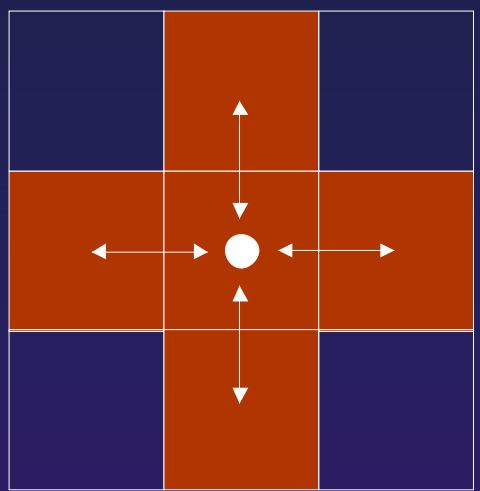
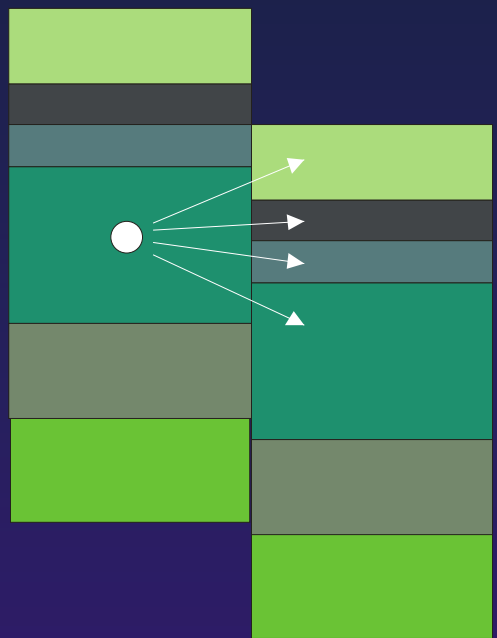
OUTLINE

1. **SLOPING GRIDS - WORTH THE EFFORT?**
2. **ALGORITHMS FOR CONSTRUCTION OF SLOPING GRIDS**
3. **SAMPLING ON VERTICAL AND SLOPING MAPS AND GRIDS**

NON-NEIGHBOUR CONNECTIONS

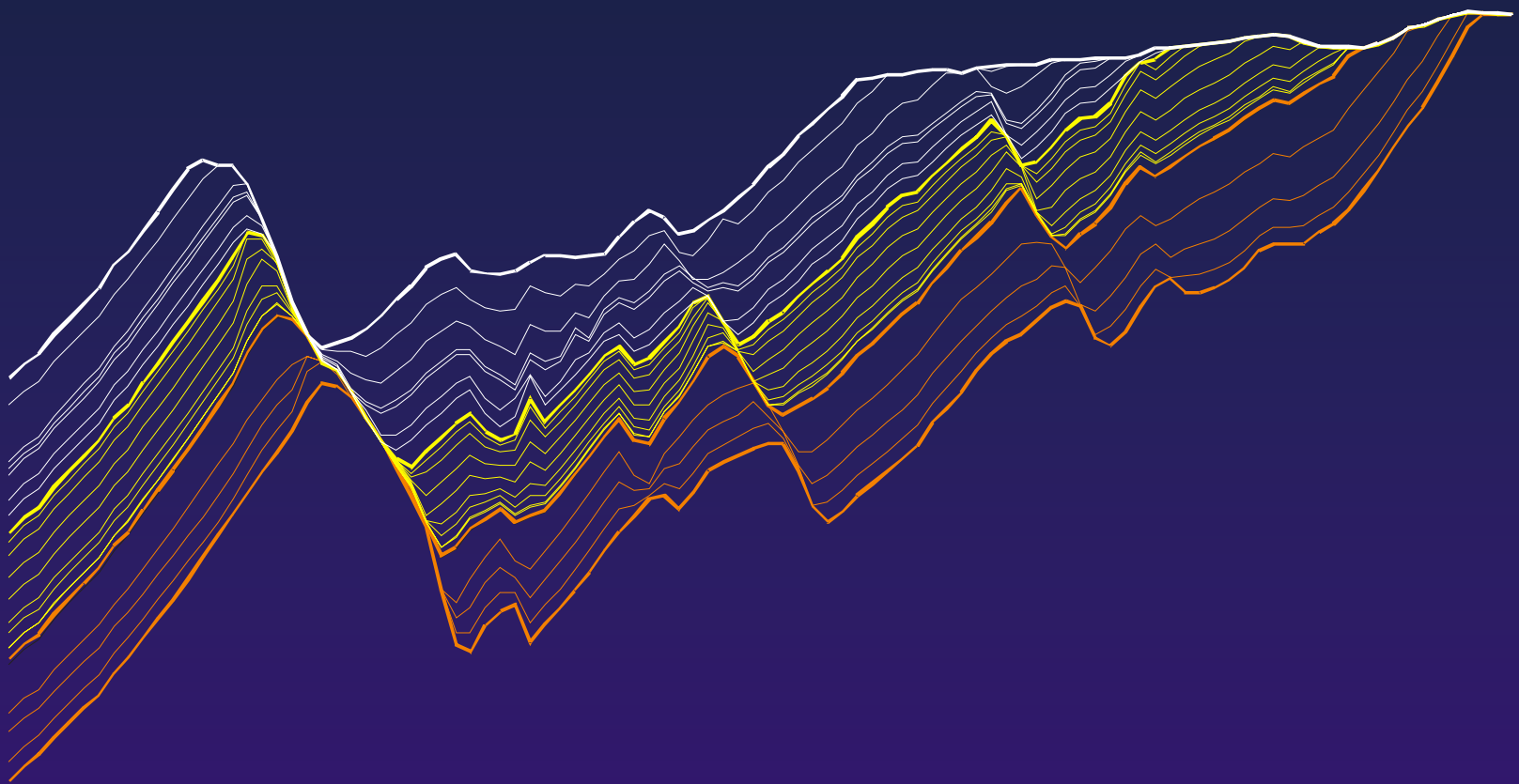


Flow restricted to neighbour blocks



"Normal" Non-Neighbour Flow

TYPICAL X-SECTION MAIN RESERVOIR



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SIMULATOR OPERATES ON PROPERTY MATRIX -- NOT ON GRID

PROPERTY MATRIX: $\mathbf{P}$

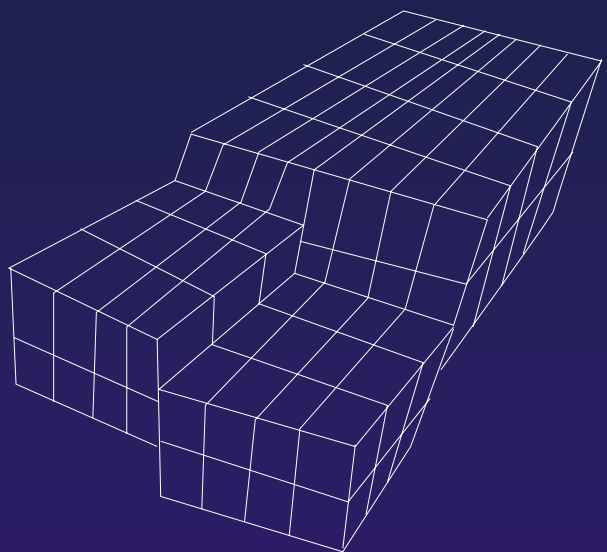
For each grid block (i,j,k)

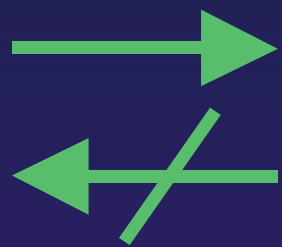
$\mathbf{P}_{ijk}$ = {PORV, P, Fluid data, S_w, (S_o), $\mathbf{T}$}

$\mathbf{T}$ is the transmissibility tensor defining conductivity to all other cells in the grid
For normal connections all but six elements are zero

STATOIL

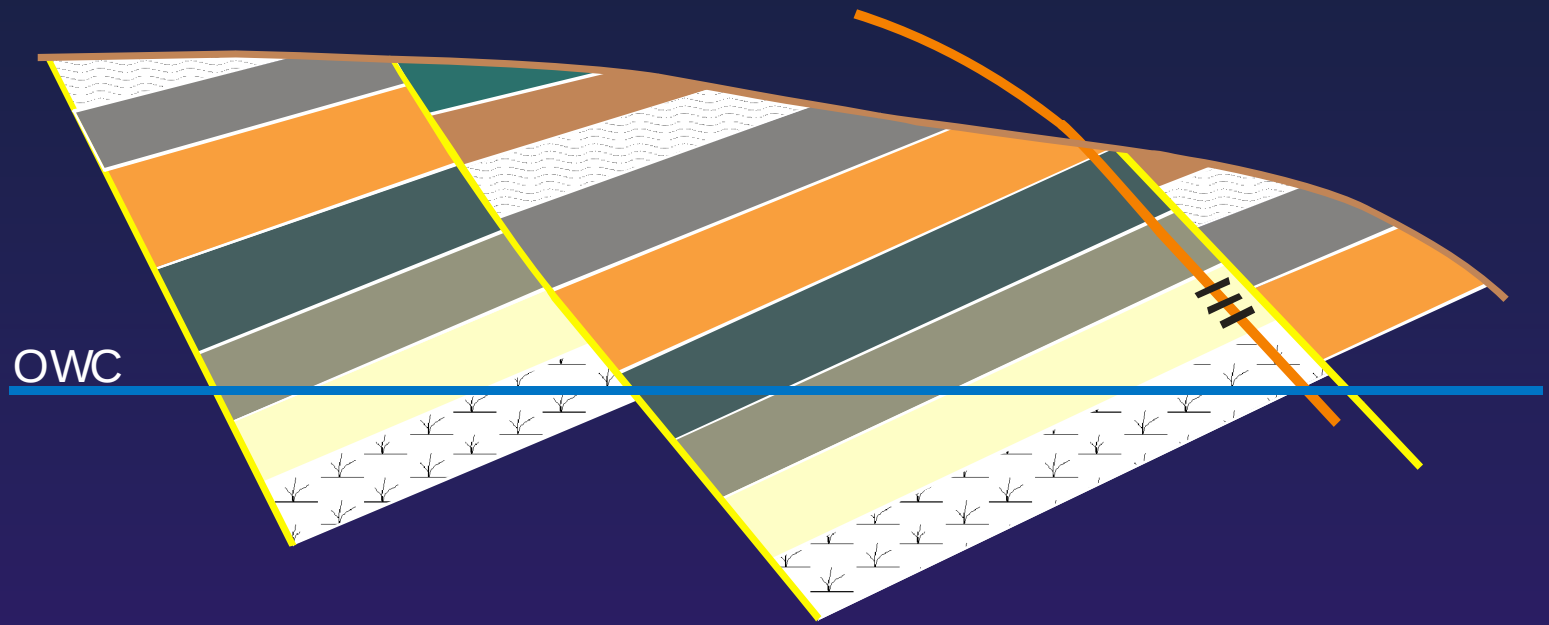
RELATIONSHIP GRID - SIMULATOR





i.e. The Simulator has no Knowledge of the Original Grid

ARE SLOPING GRIDS NECESSARY?



Critical factors:

- Volumes
- Slope vs. absolute pressures
- Relative pressures
- Distances from well to fault, erosion surface
- Distance perforations to OWC
- Well zone depths

STATOIL

GEOMETRY: NUMERICAL ERRORS

General remark: Irregular grids more "dangerous" than Cartesian - false confidence by appearance

Shape: Cartesian blocks "ideal",
errors increase with departure from orthogonal

Ideal Aspect ratio: $dx : dy : dz = U_x : U_y : U_z$ (NOT Cube)

NB: These factors are primarily important in predictive runs with no (or short) history

The numerical errors are tied solely to the Transmissibility Calculations.
The Transmissibility Tensor will be handled as a Degree of Freedom during History Matching anyway

CONSISTENT GRIDS SUMMARY

* A consistent model is a prerequisite for a successful History Match

* A consistent Verticalized Grid is NOT necessarily easier to construct than a sloping grid

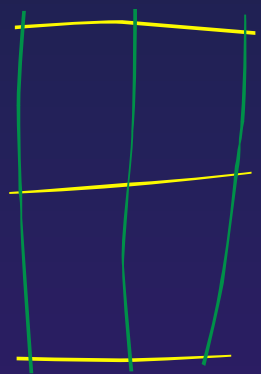
* Improved grid building tools encourage use of sloping grids

* Geometry-dependant numerical errors are not a critical factor in history matching problems

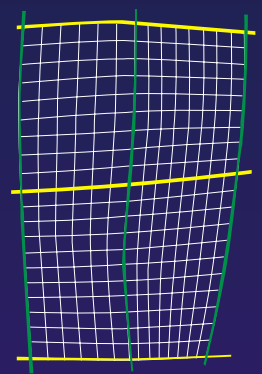
OUTLINE

1. SLOPING GRIDS - WORTH THE EFFORT?
2. ALGORITHMS FOR CONSTRUCTION OF SLOPING GRIDS
3. SAMPLING ON VERTICAL AND SLOPING MAPS AND GRIDS

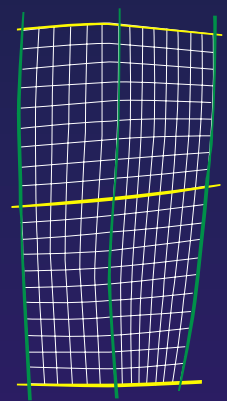
SLOPING GRID CONSTRUCTION PROCESS



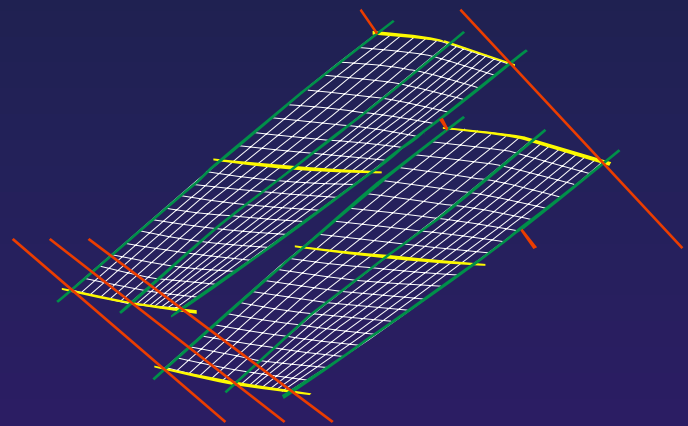
1. Control lines



2. Fill in base grid



3. Same proc. top grid



4. Merge top & base grids

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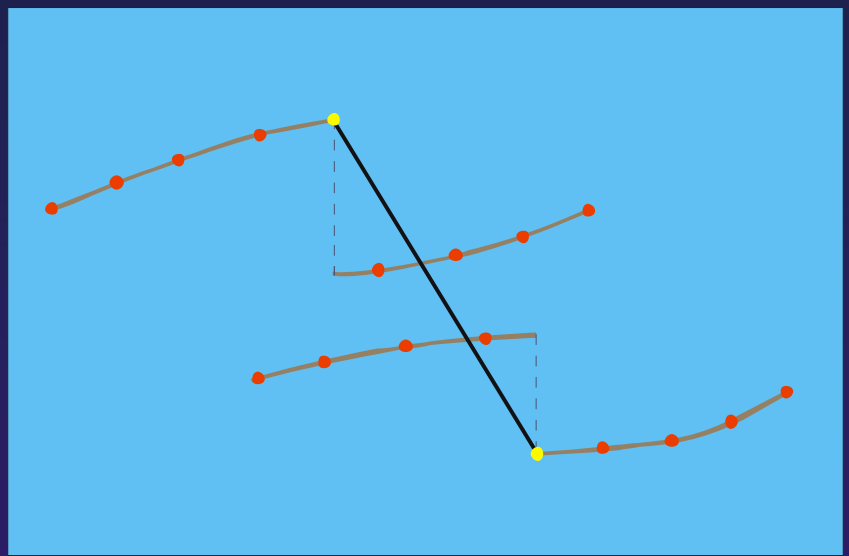
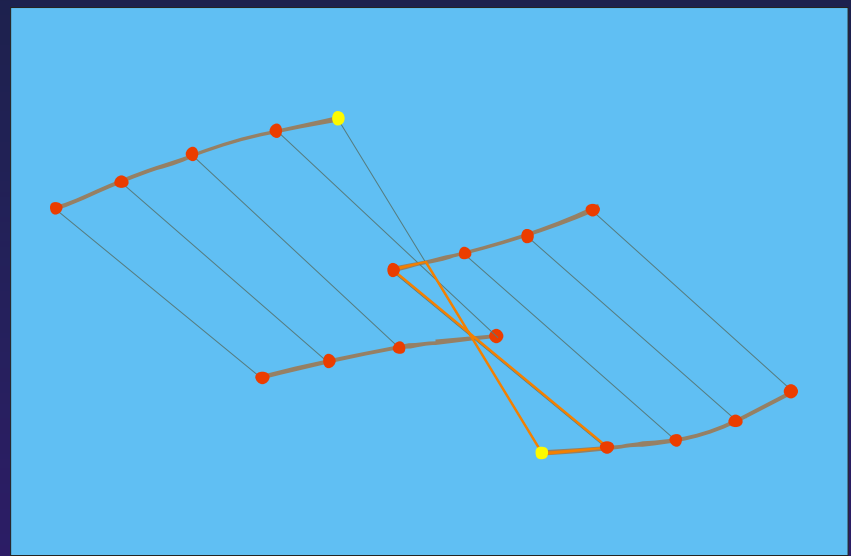
MERGING GRIDS: INSUFFICIENT ALGORITHM





Primary Coordinate Lines determined by faults' top of top and bottom of base

Resulting Grid:
Only Primary Coordinate Lines Correct
Secondary Lines inconsistent w. Primary

BASIC PROBLEM

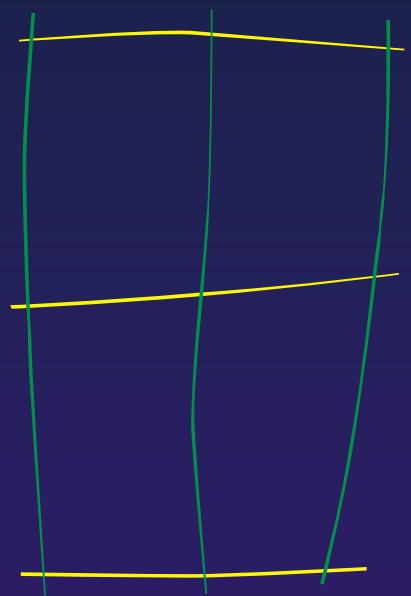
Top and base grids are implicitly treated as vertical,
- NOT the correct starting point for the construction procedure

Suggested Solutions:

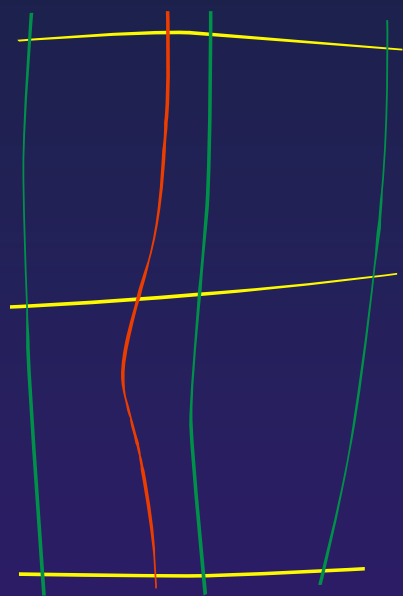
1. **Regularization algorithm (post-merge adjustment) (implemented in RESVIEW)**
2. **Introduce concept of split control lines**

Either way requires repeated sampling!

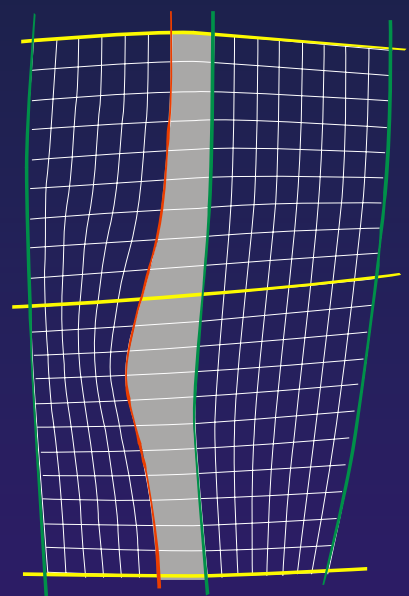
SLOPING GRID
SPLIT CONTROL LINES



1. Control lines (traditional)



2. Control line (auto)-split along fault



3. Revised grid, slope incorporated

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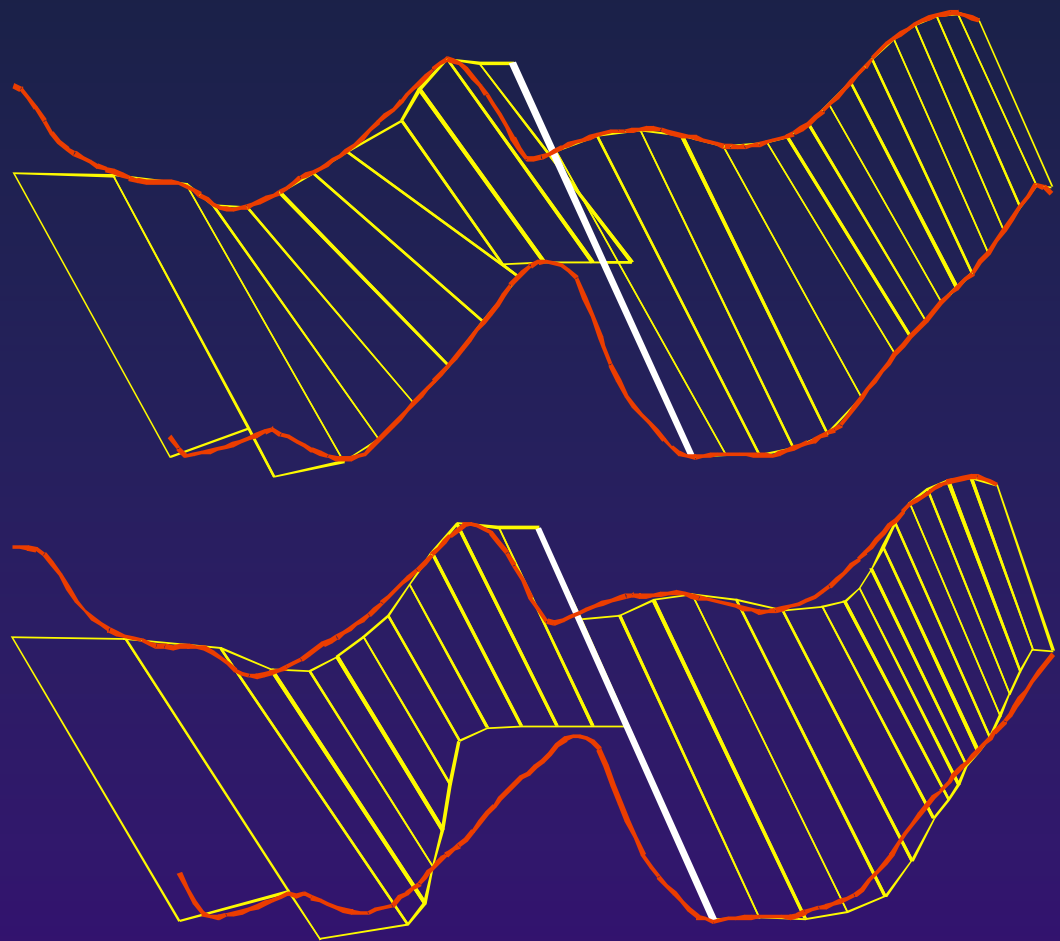
SLOPING GRIDS: REGULARISATION OF COORDINATE LINES

Before

After



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OUTLINE

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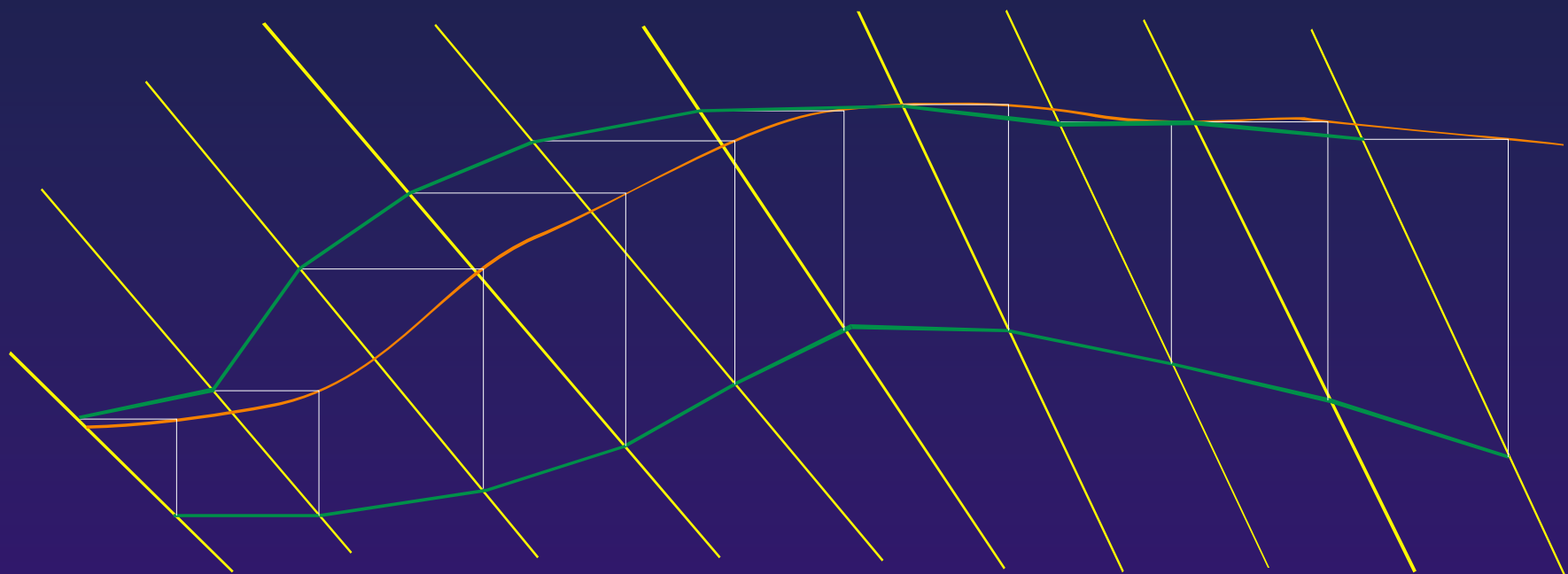
SLOPING GRIDS SAMPLING

Observations:

*** Depth Sampling algorithms not sufficiently complex**

*** Concept of Isochore (vertical thickness) has no meaning on a sloping grid**

SAMPLING INSUFFICIENT ALGORITHM



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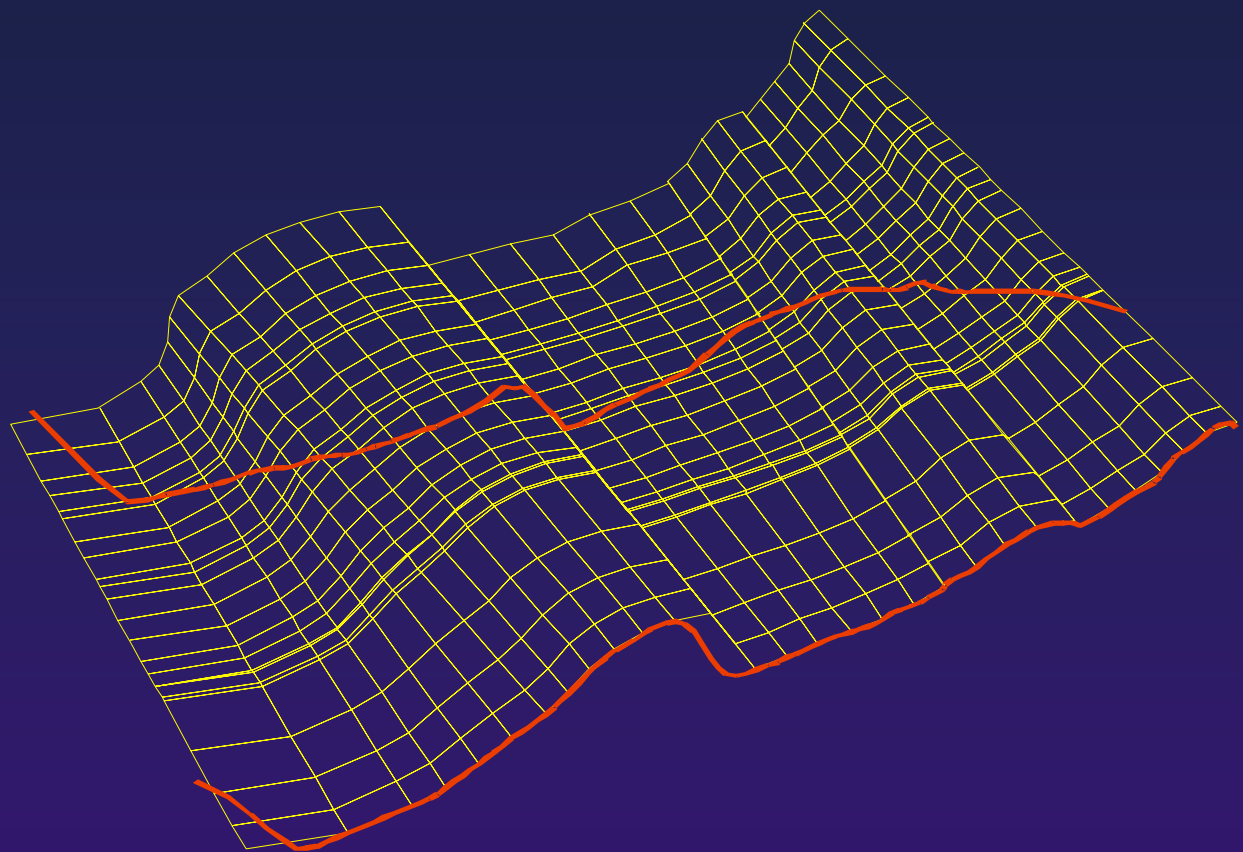
LAYER THICKNESS SAMPLING ERROR



STATOIL

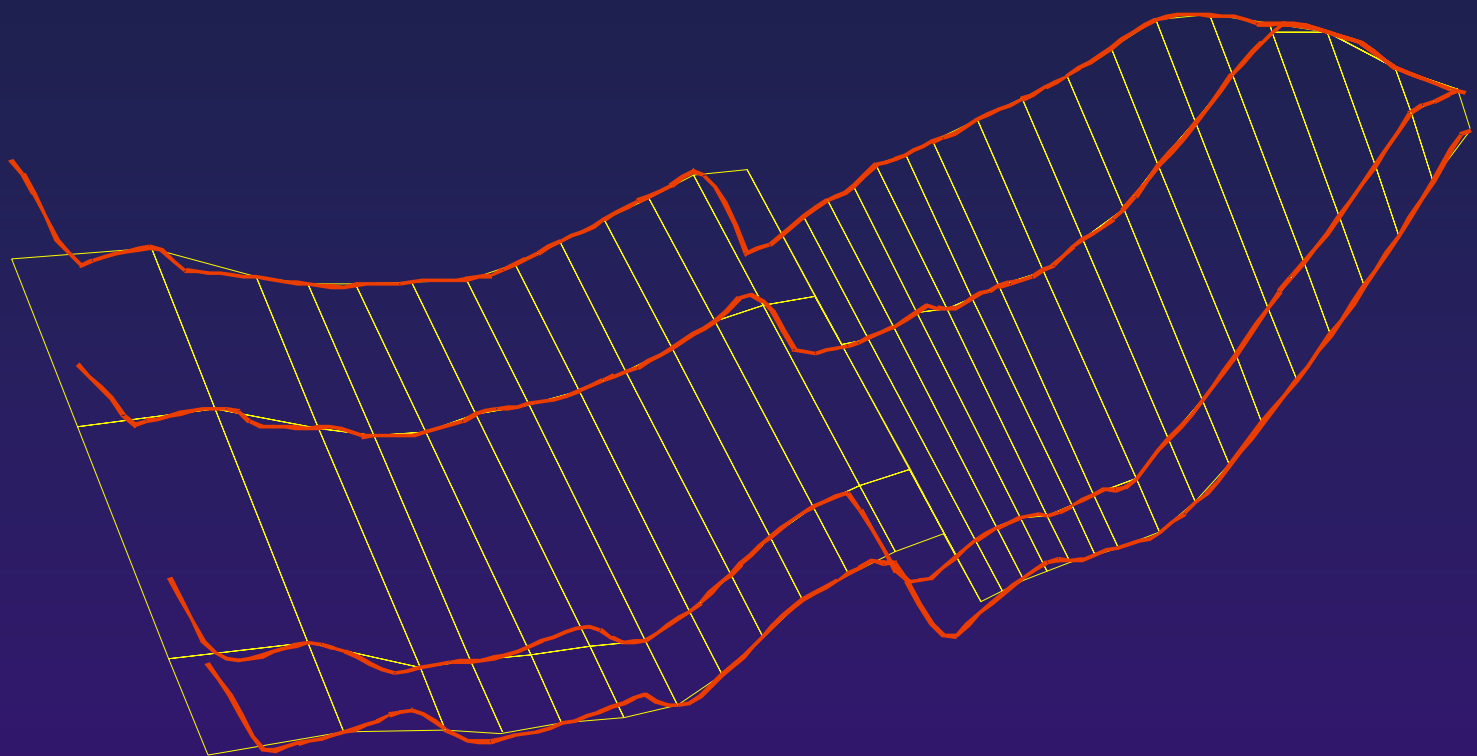
SAMPLING ERRORS
SUGGESTED SOLUTIONS

*** Improved depth sampling algorithm (RESVIEW)**

*** Isochores by Interpolation Surface**
(base intra-layer + isochore)
followed by depth sampling

*** QuickFix: Adjust (wrongly) sampled isochores to fit between interpreted surfaces**

LAYER THICKNESS CORRECTION: CALIBRATION GRID



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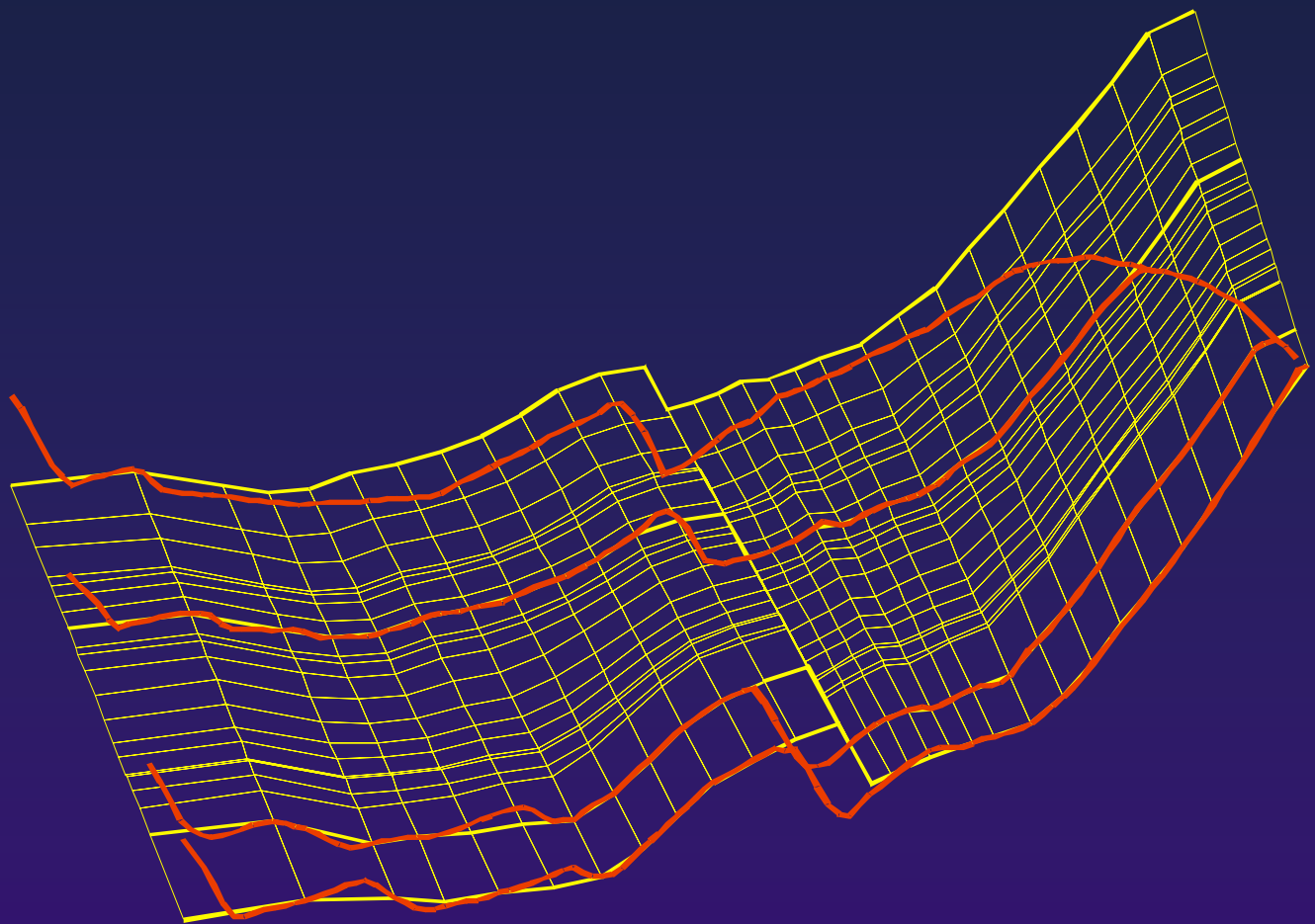
LAYER THICKNESS CORRECTION: MIDDLE UNIT ADJUSTED



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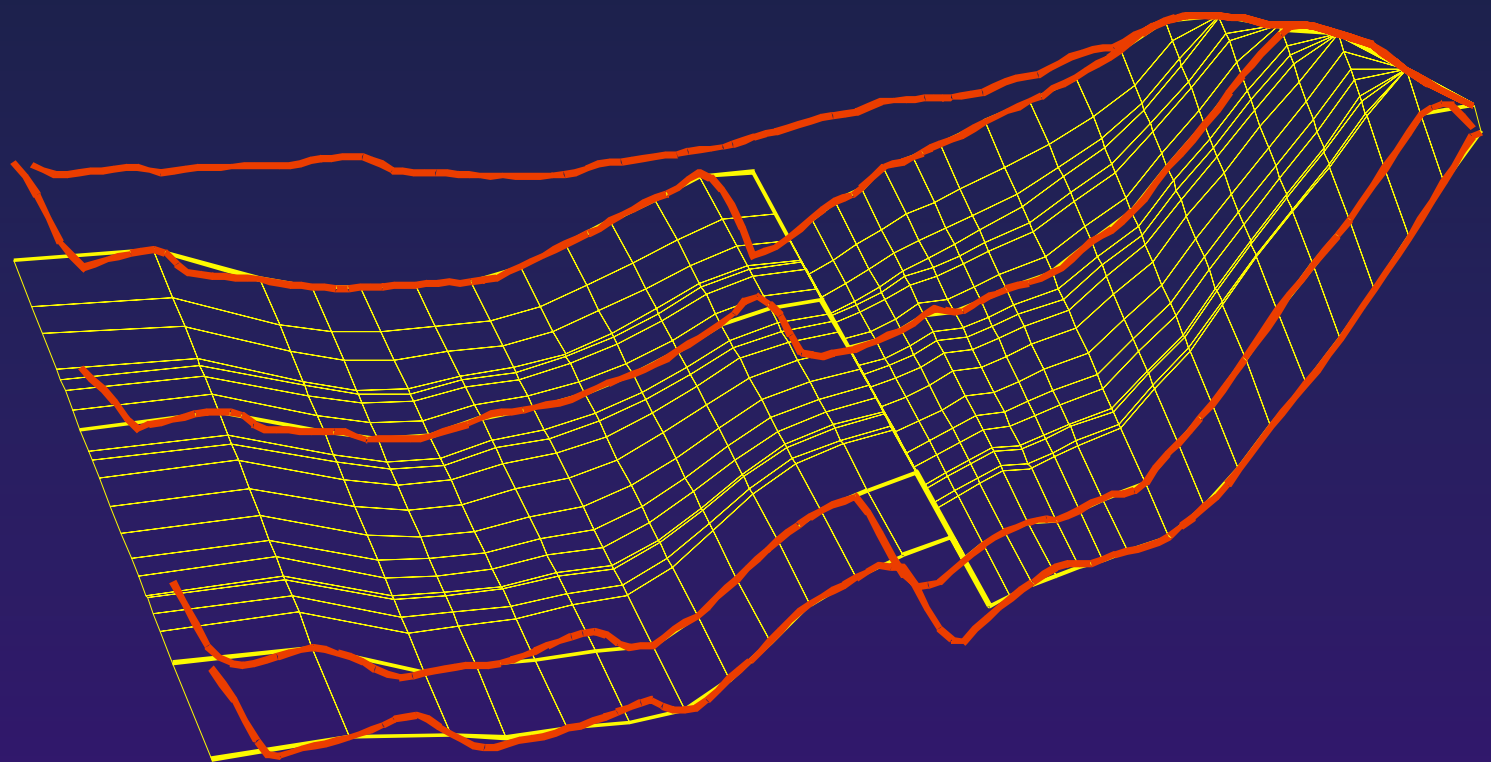
LAYER THICKNESS CORRECTION: FINAL RESULT



STATOIL

THE PRAGMATIC APPROACH

An Acceptable History Match is a Combination of

- **Correct Modelling of known Field Properties**
- **Incorrect Modelling of Insufficient Field Knowledge**
- **Grid Approximations**
- **Inaccuracies in the Simulator**
- **Simulator Characteristics**

A History Matched Model is not Transferable to another Simulator