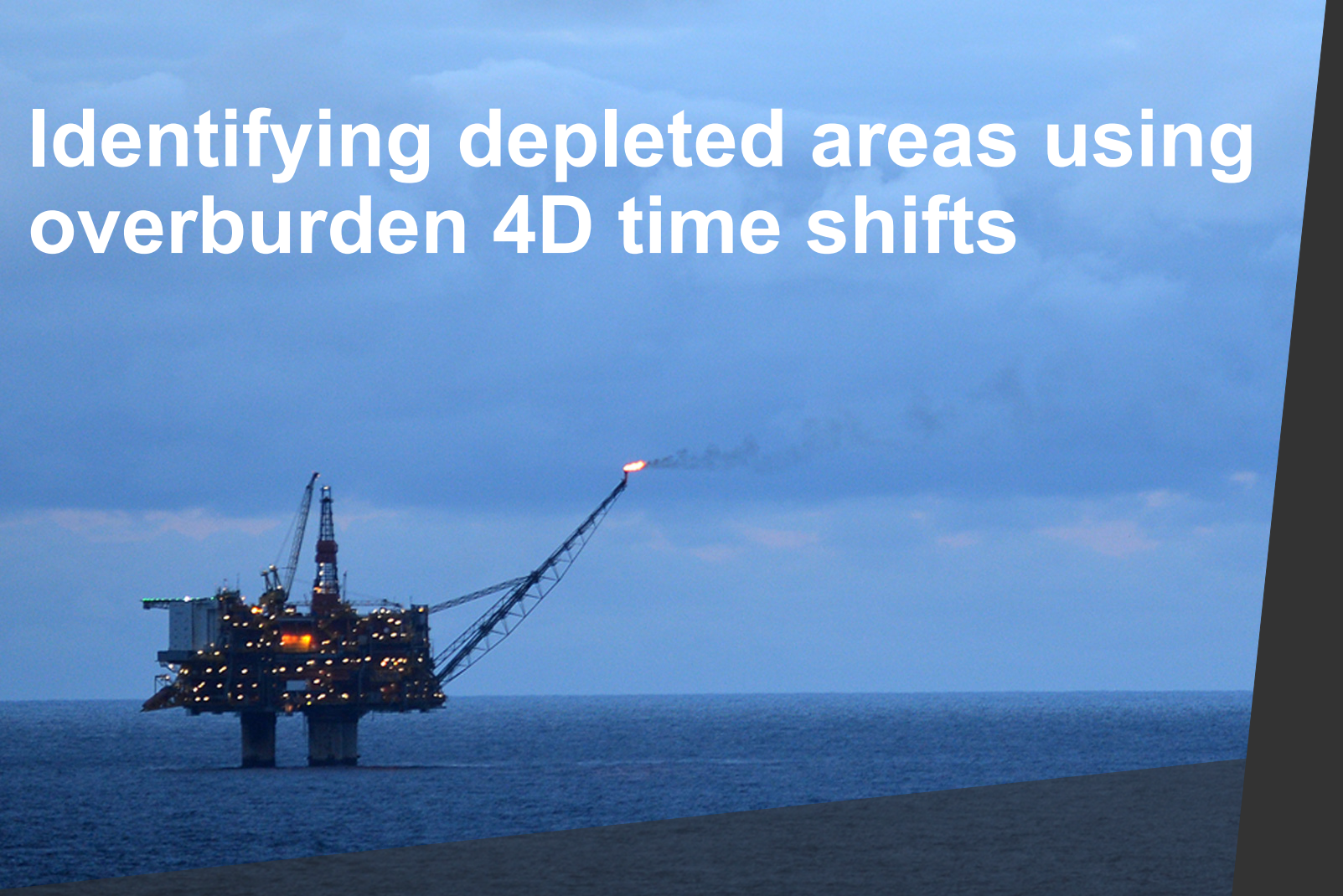
Identifying depleted areas using overburden 4D time shifts



Thomas Røste (Statoil)

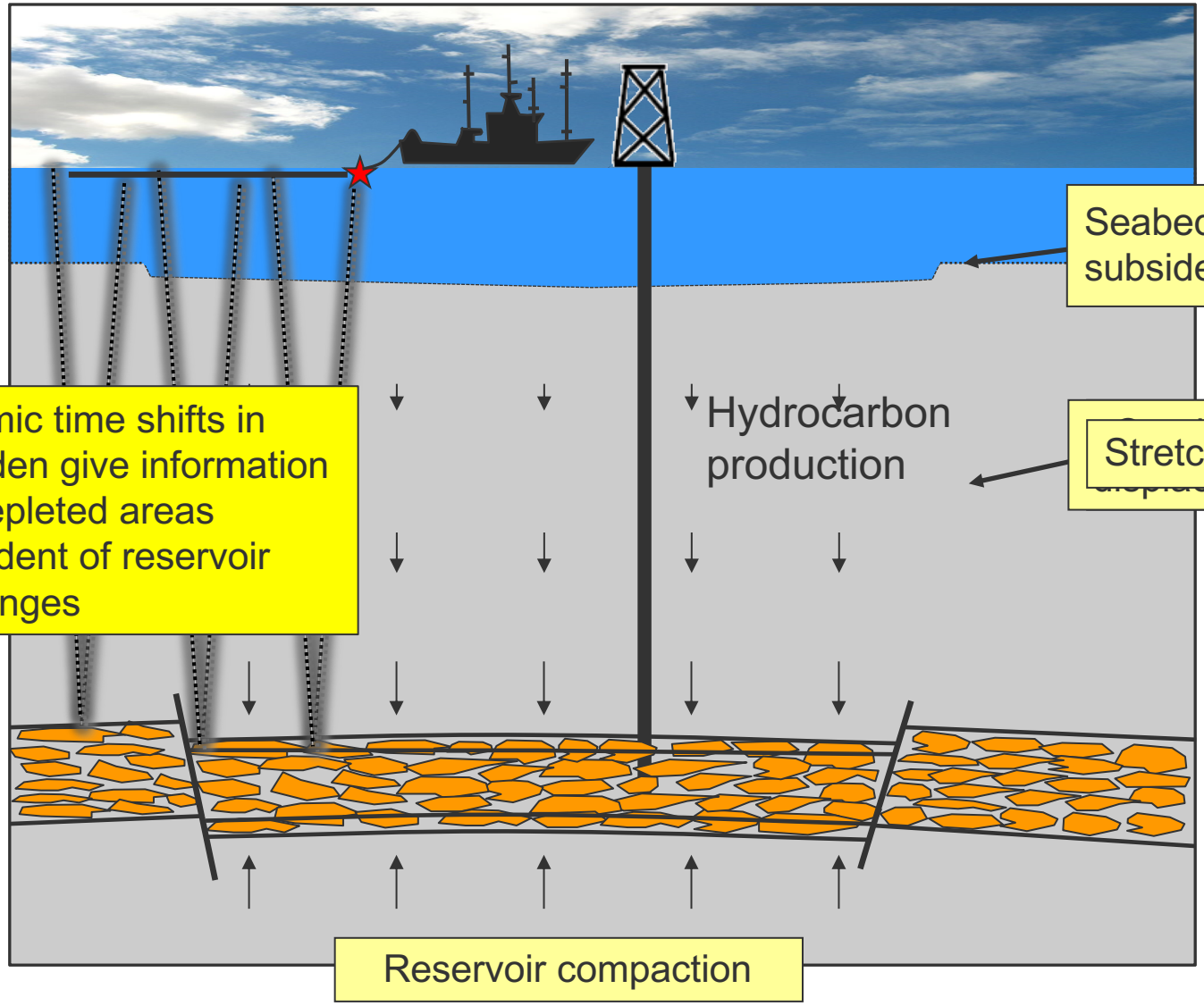
Statoil

ROSE meeting
23.-24. April 2018

Outline

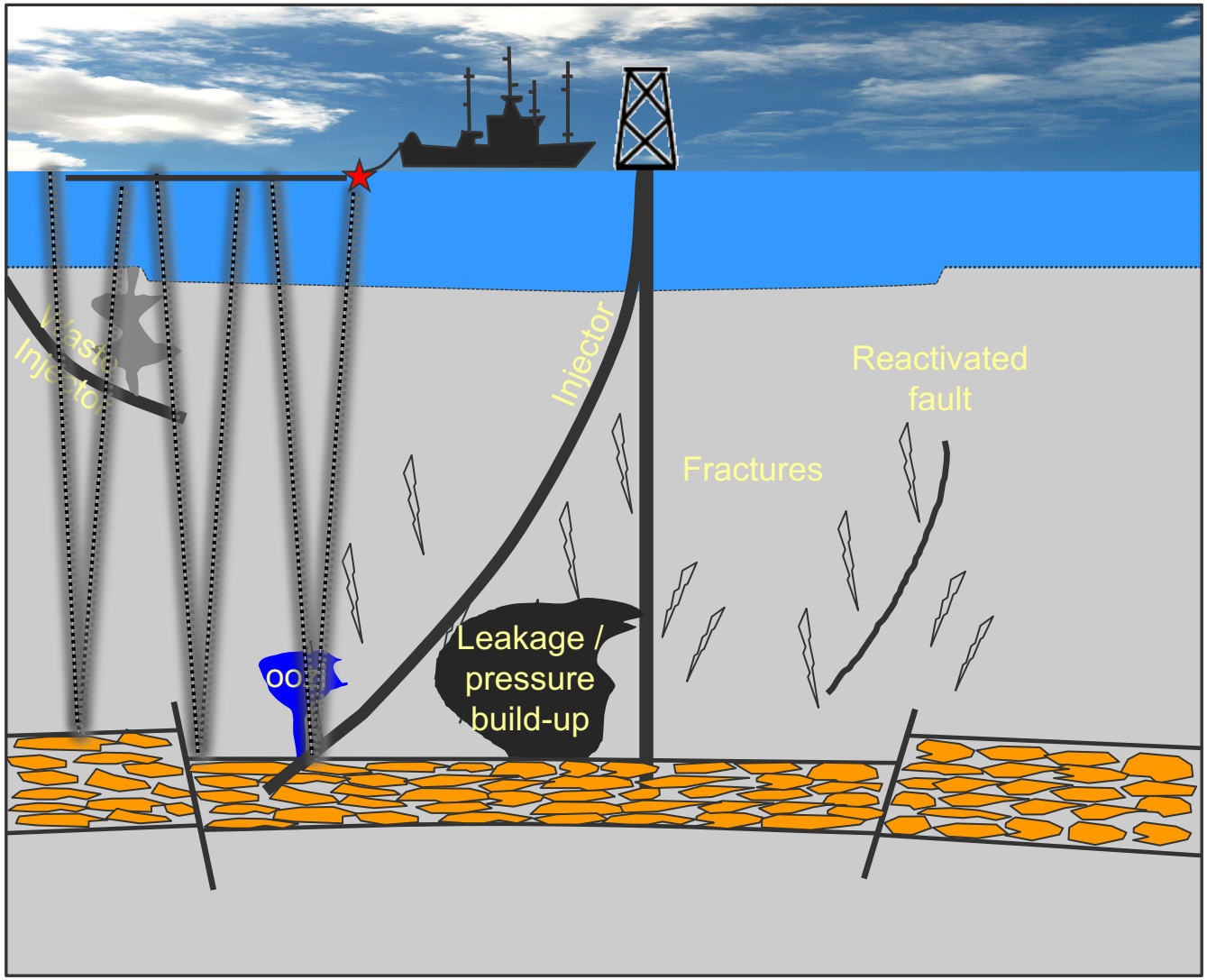
- Why monitor overburden?
- Time shifts and geomechanics
- Field examples
- Summary

Why monitor overburden



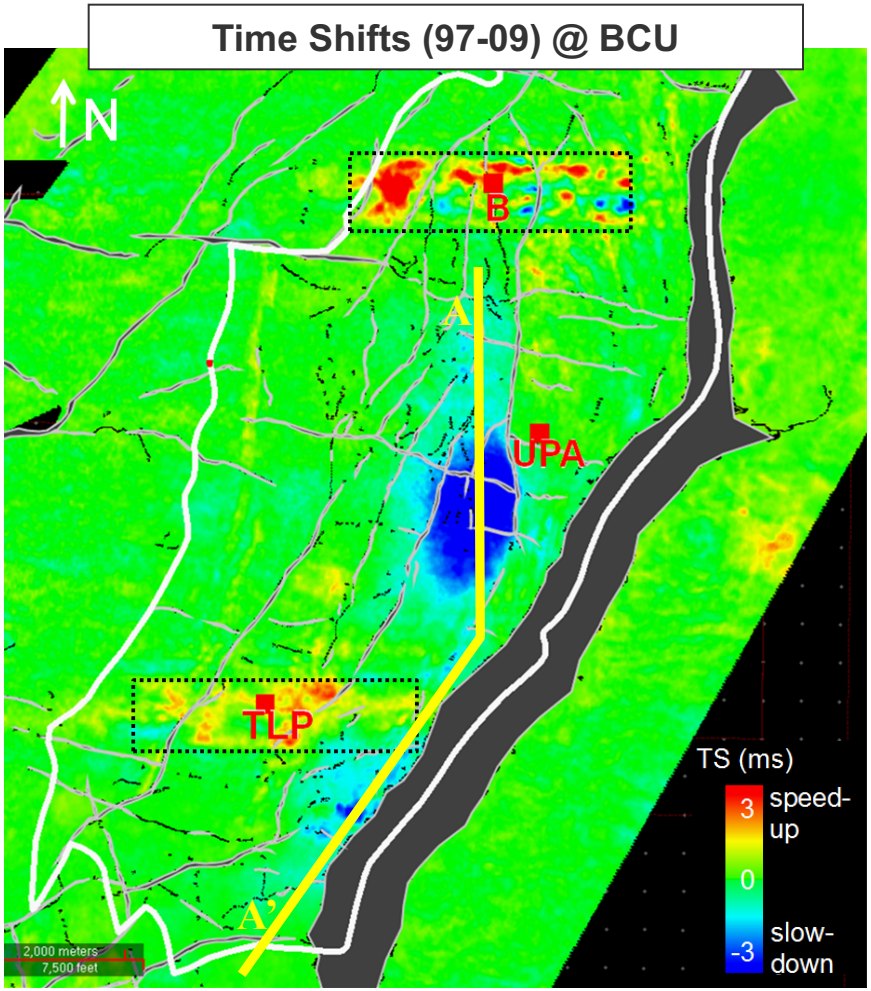
- 4D seismic time shifts in overburden give information about depleted areas
- Independent of reservoir fluid changes

Why monitor overburden



4D seismic might capture all effects inducing velocity changes

4D Seismic Time Shifts; Snorre



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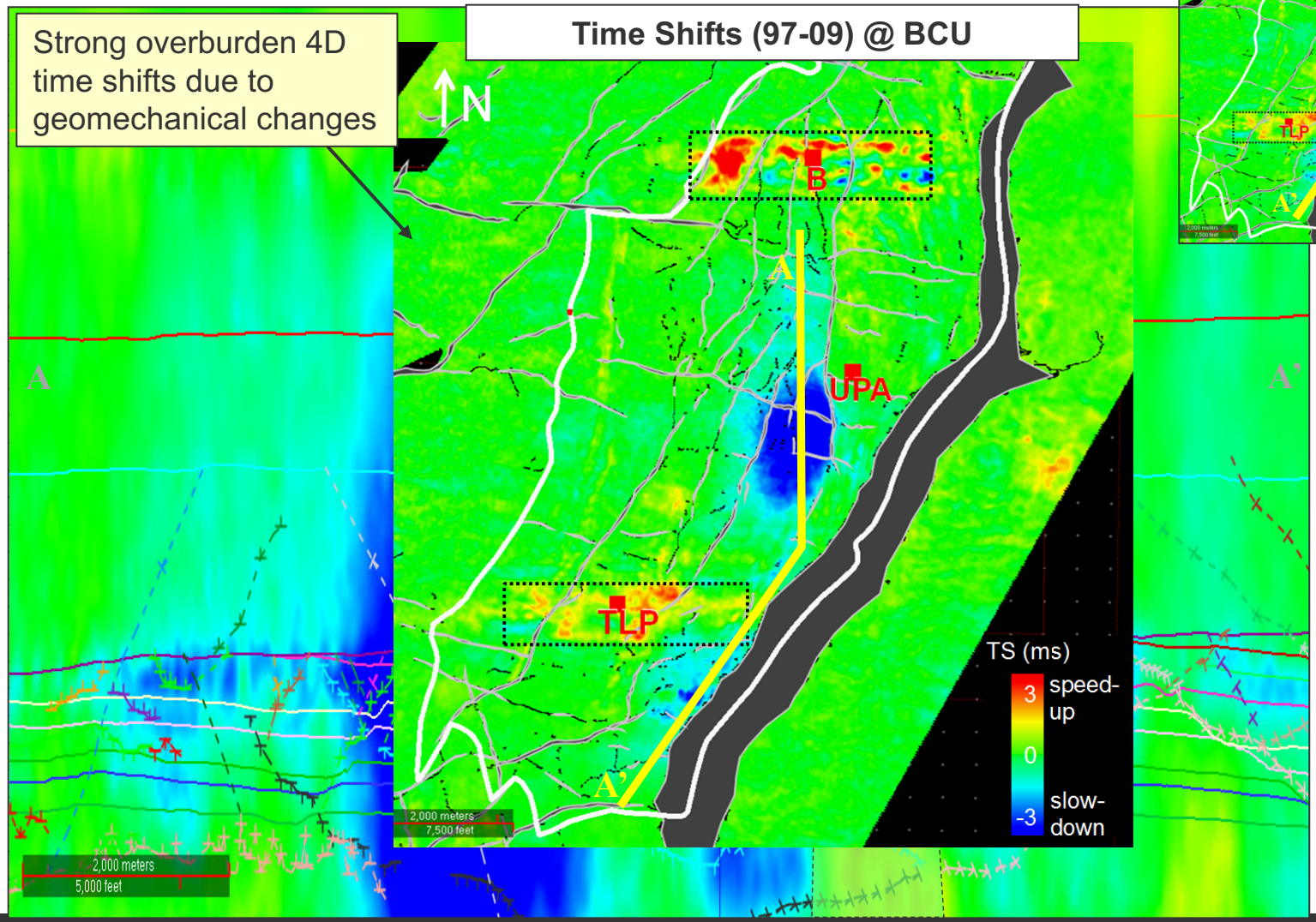
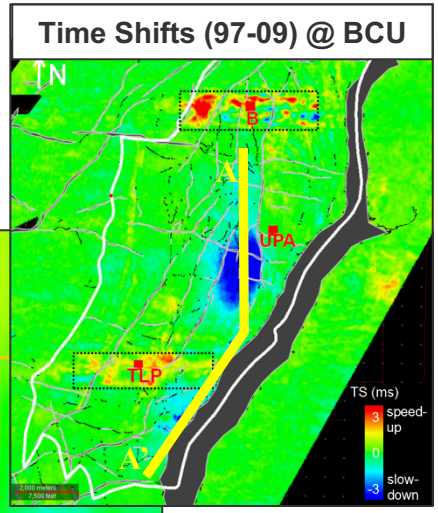
4D Seismic Time Shifts; Snorre

Strong overburden 4D time shifts due to geomechanical changes





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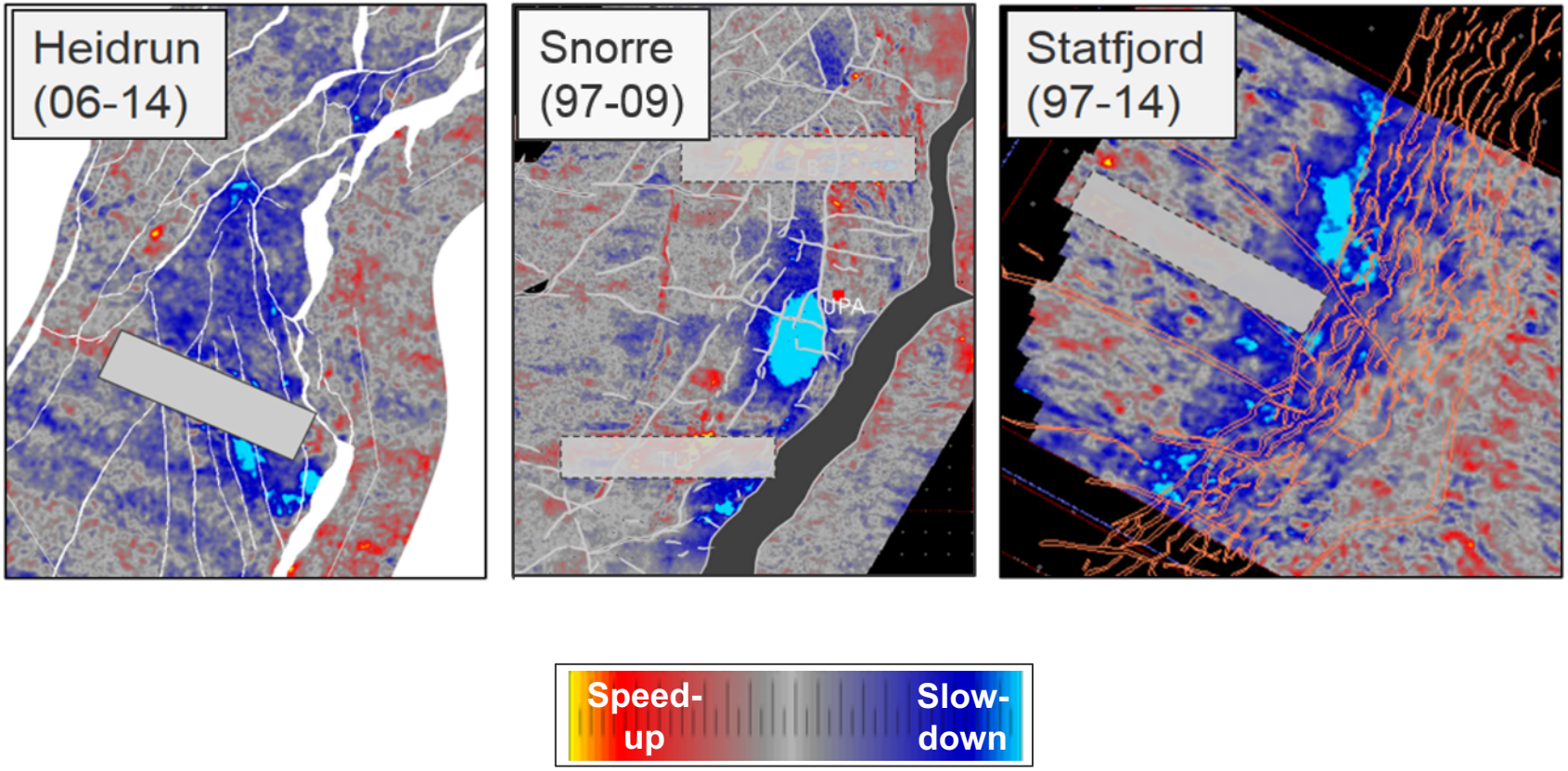
Examples of overburden time shifts



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Outline

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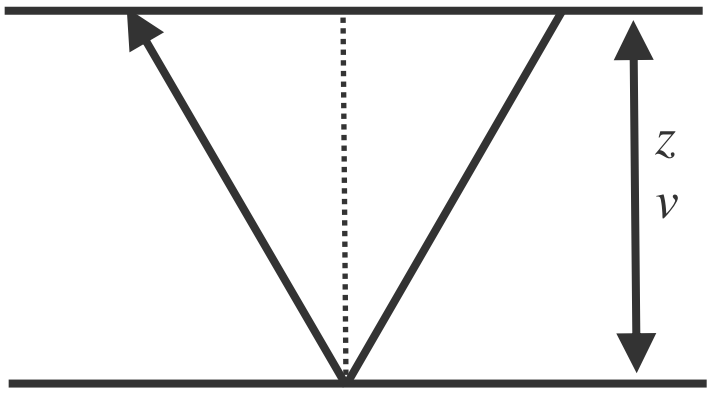
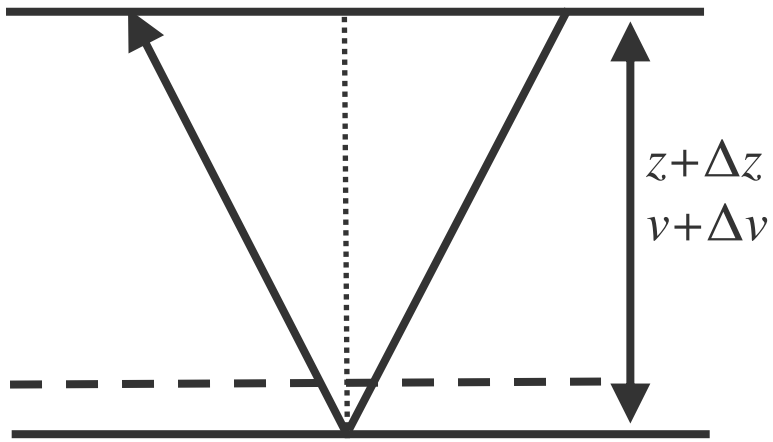
Time shifts and geomechanics

- 4D seismic time shifts capture changes in both thickness (z) and velocity (v)
- Røste et al. (2005) and Hatchell et al. (2005) independently assumed:

$$\frac{\Delta v}{v} \approx -R\epsilon_{zz} \qquad (1)\ *$$



Baseline



Monitor

* Note! The dilation factor R is sometimes referred to as α.
The relation is $R = -\alpha$

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Workflow for modelling time shifts

Statoil-workflow

- Input:
  - Reservoir pressures

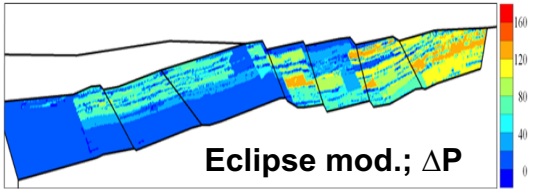
    (Eclipse model)

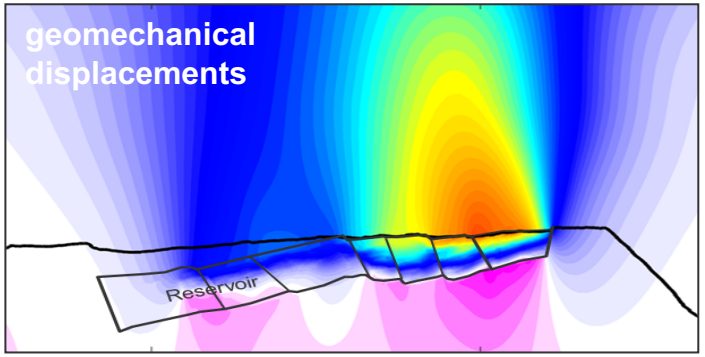
    ↓
- 4D geomechanical model:
  - Displacements
  - Stress changes
  - Strain (ϵ_{zz})

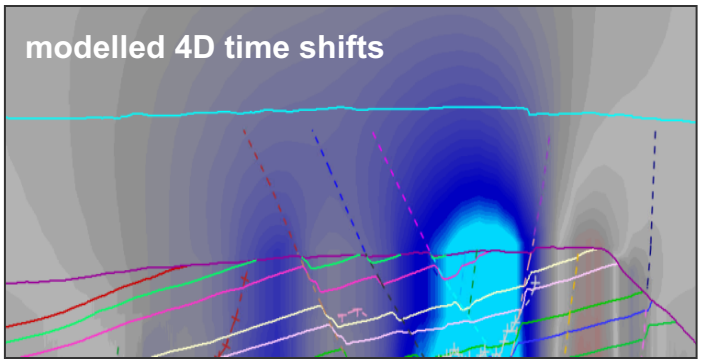
R-factor model:
$\Delta v/v \approx -R\epsilon_{zz}$

- Output:
  - Velocity changes (Δv)

    ↓
  - Time shifts







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Outline

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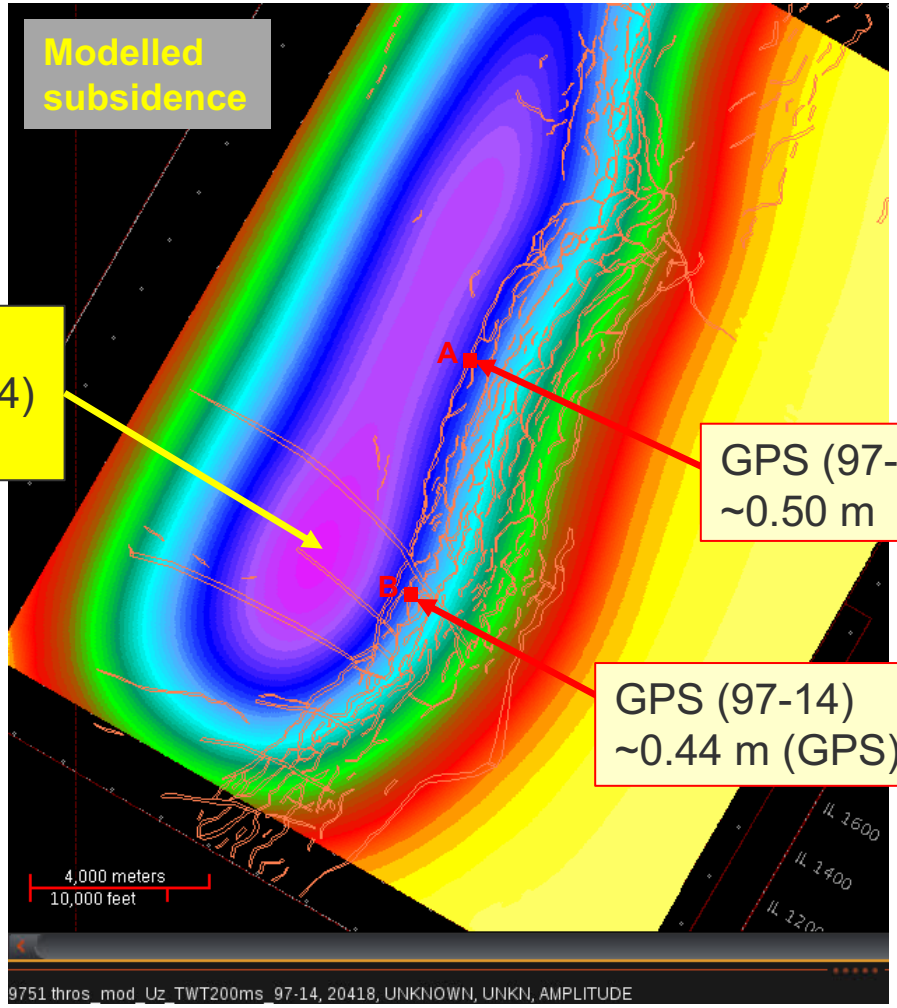
Geomechanical model (97-14)

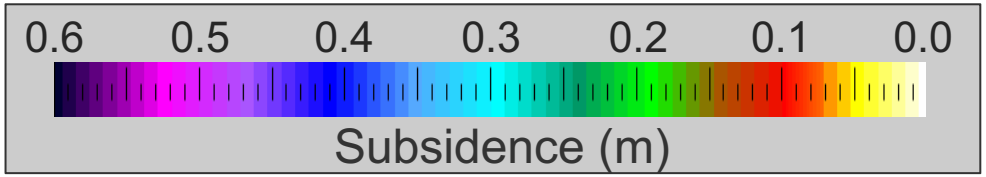
Statfjord



Max modelled subsidence (97-14) around 0.55 m

GPS (97-14) ~0.50 m

GPS (97-14) ~0.44 m (GPS)



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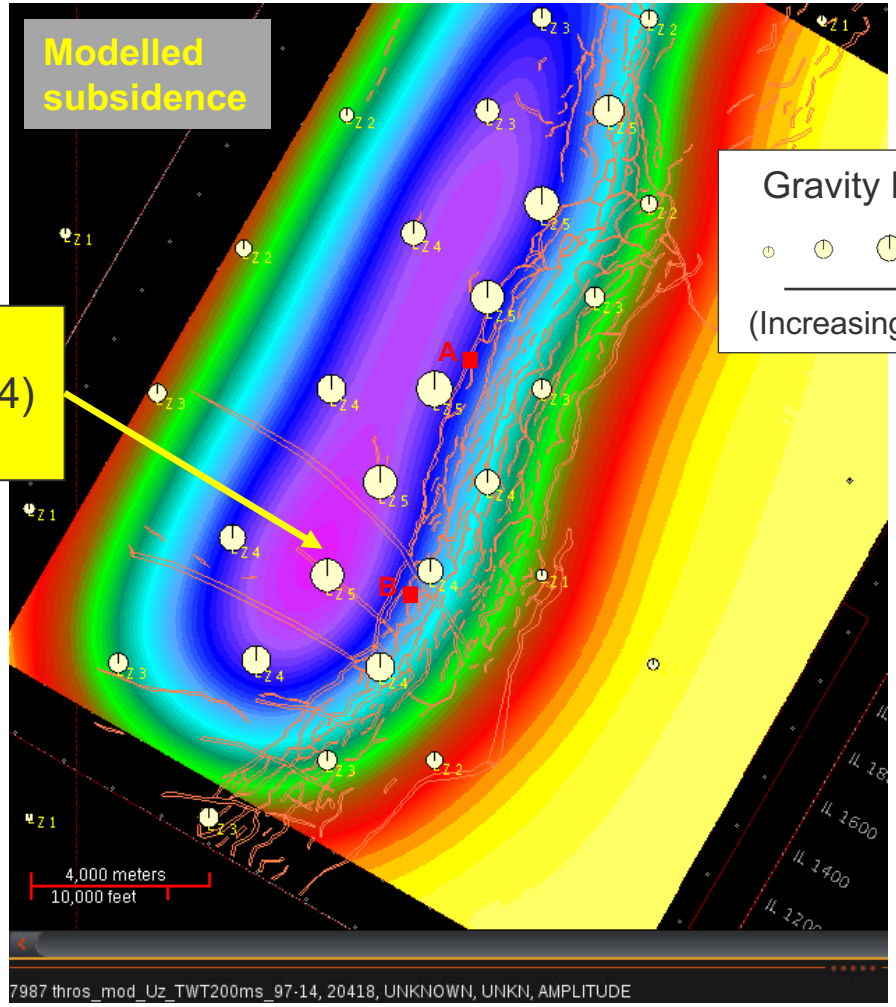
Geomechanical model (97-14)

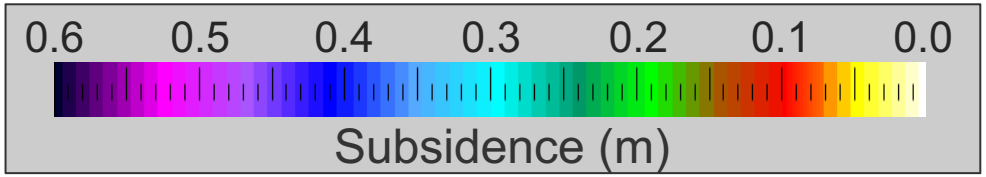
Statfjord



Max modelled subsidence (97-14) around 0.55 m

Gravity Monitoring

(Increasing subsidence)



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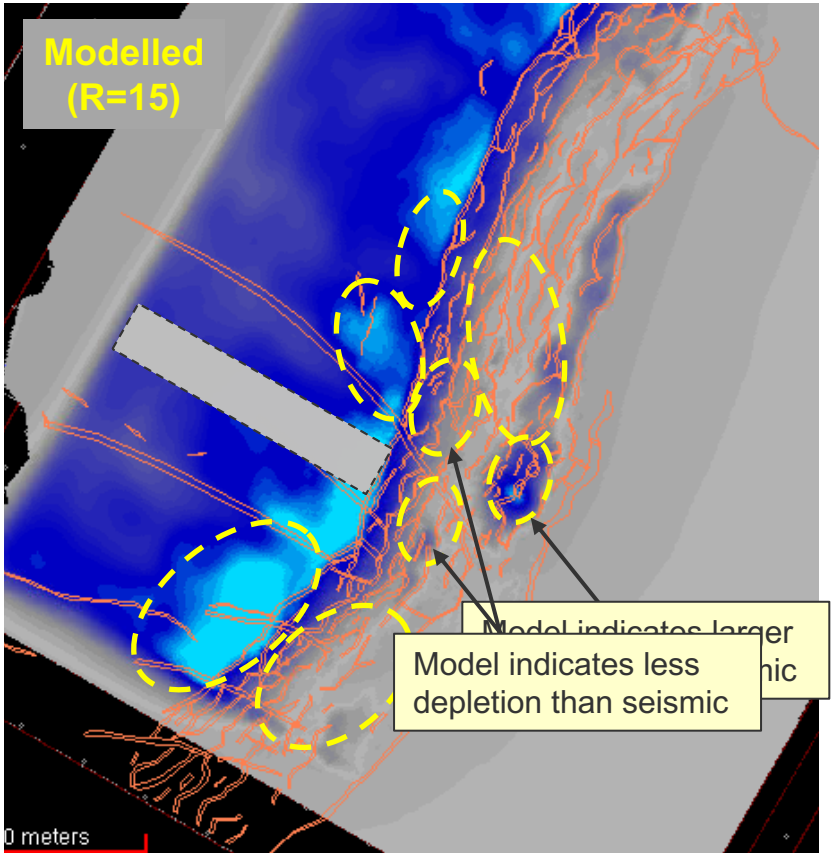
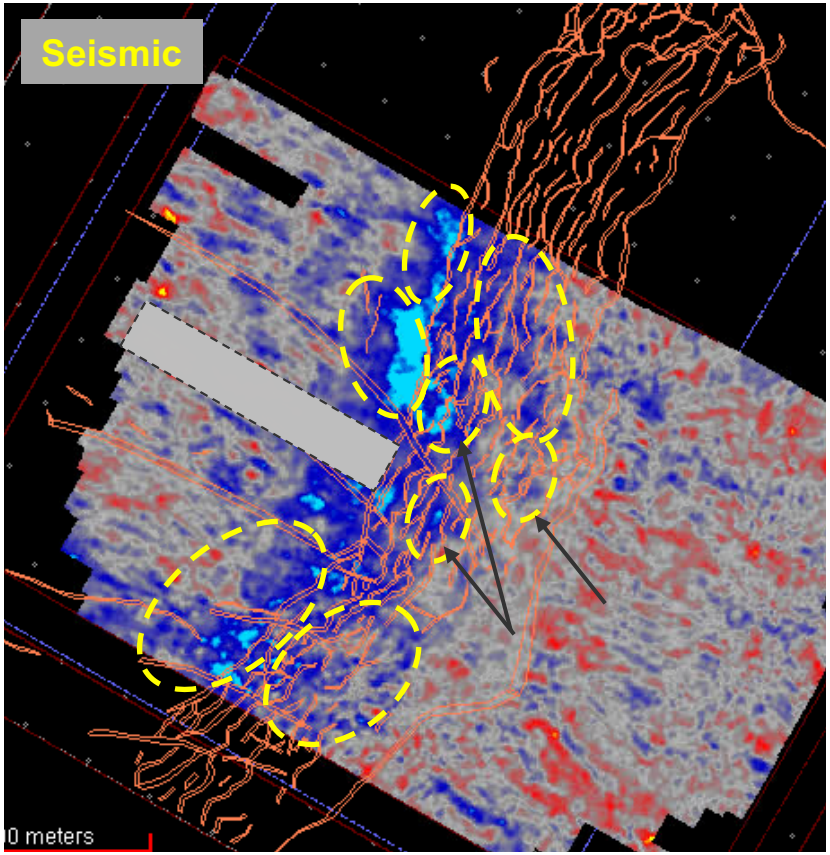
Time Shifts (97-14) @BCU

Statfjord





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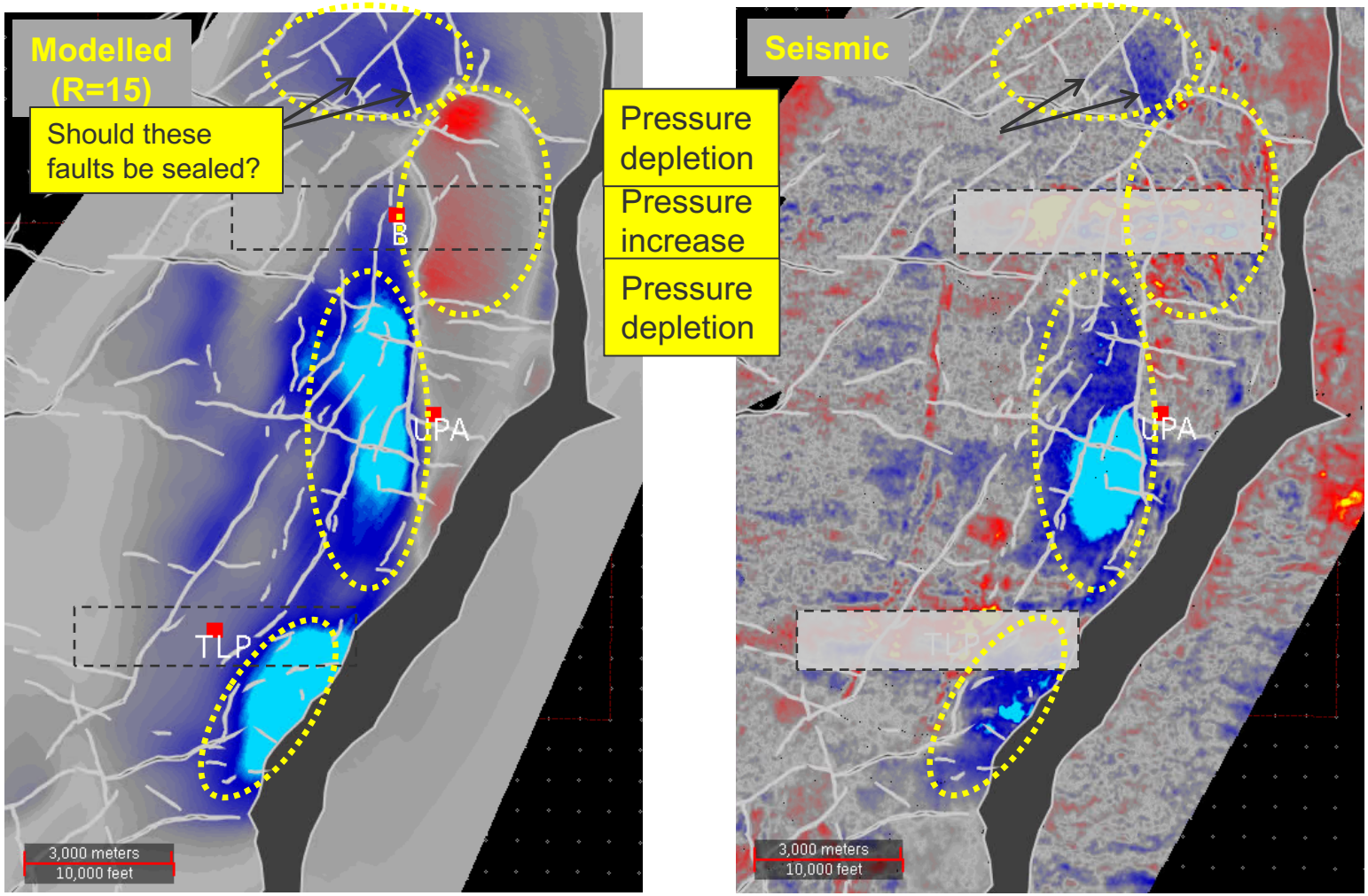
Time Shifts (97-09) @BCU

Snorre



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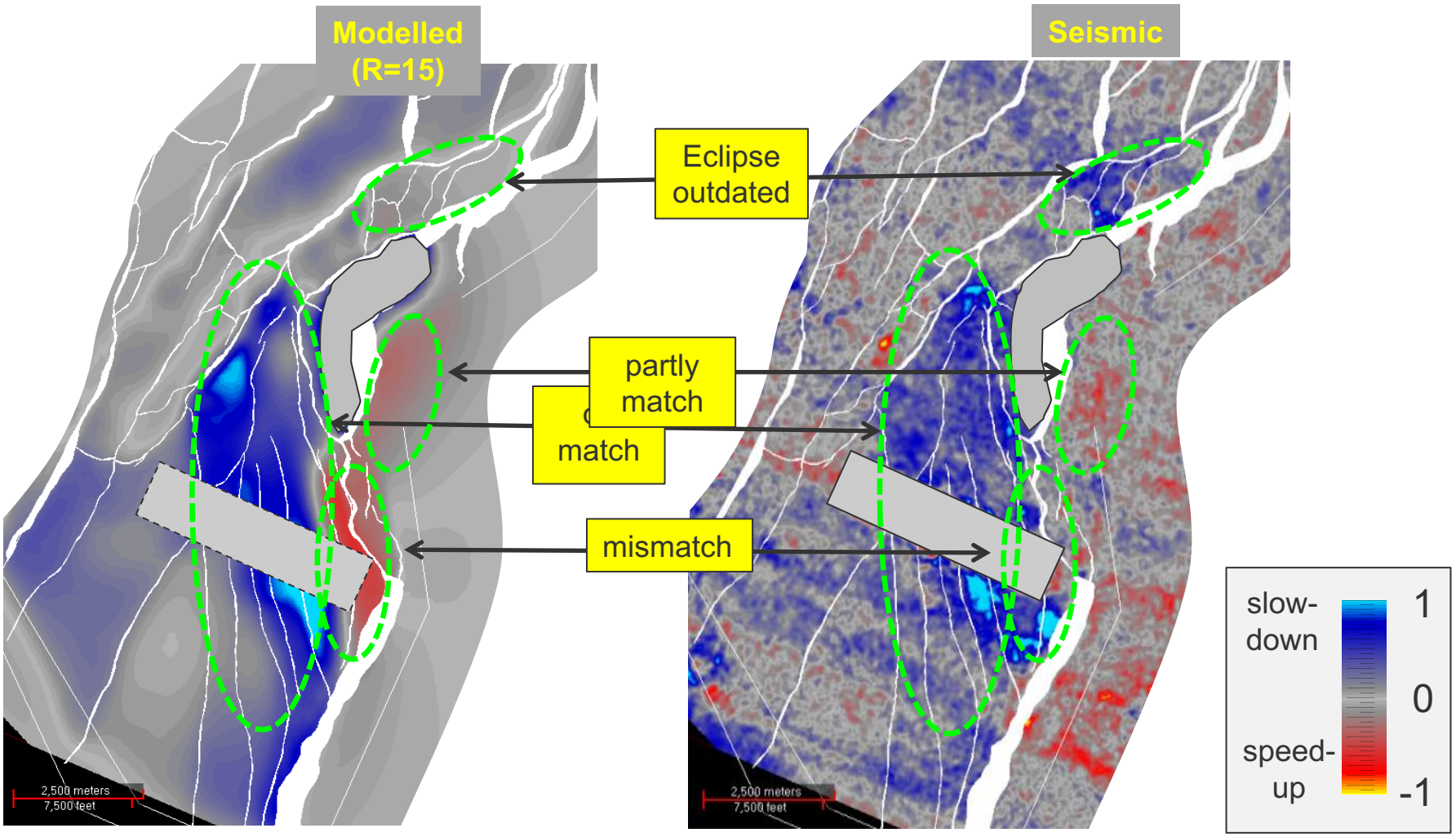
Time Shifts (06-14) @BCU

Heidrun



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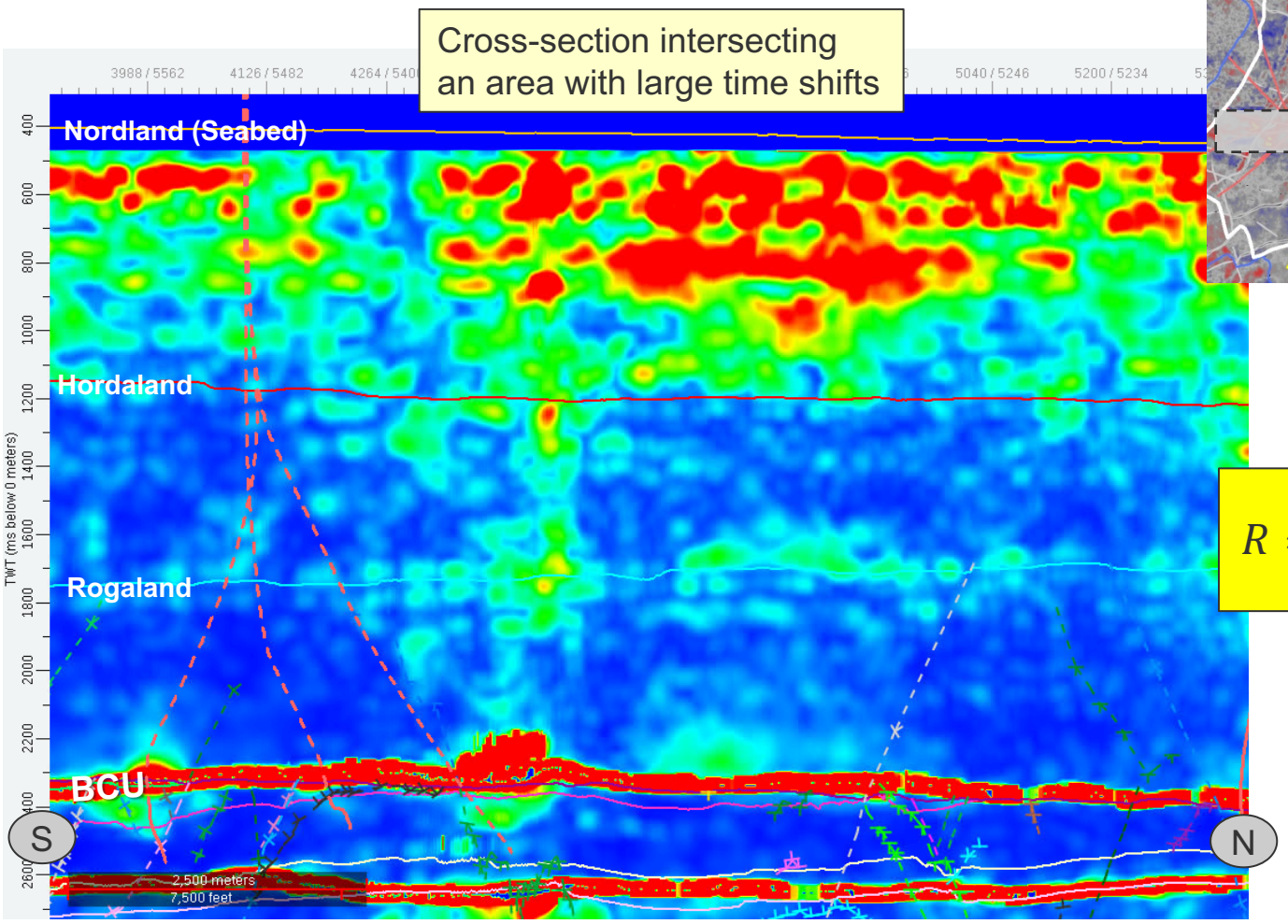
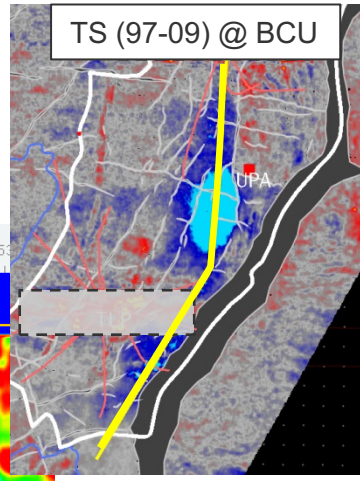
R inverted - Snorre

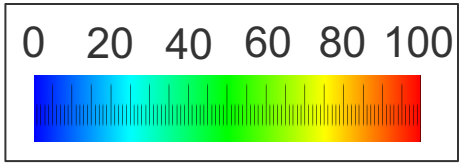




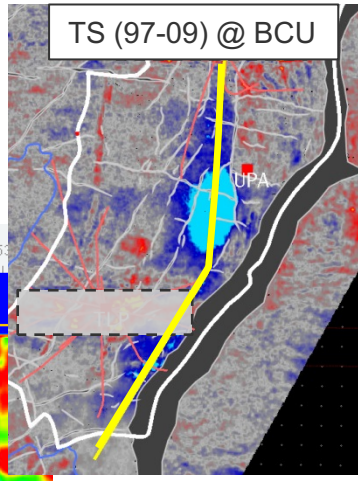
seismic time shifts

$$R \approx -\frac{\Delta v / v}{\epsilon_{zz}}$$

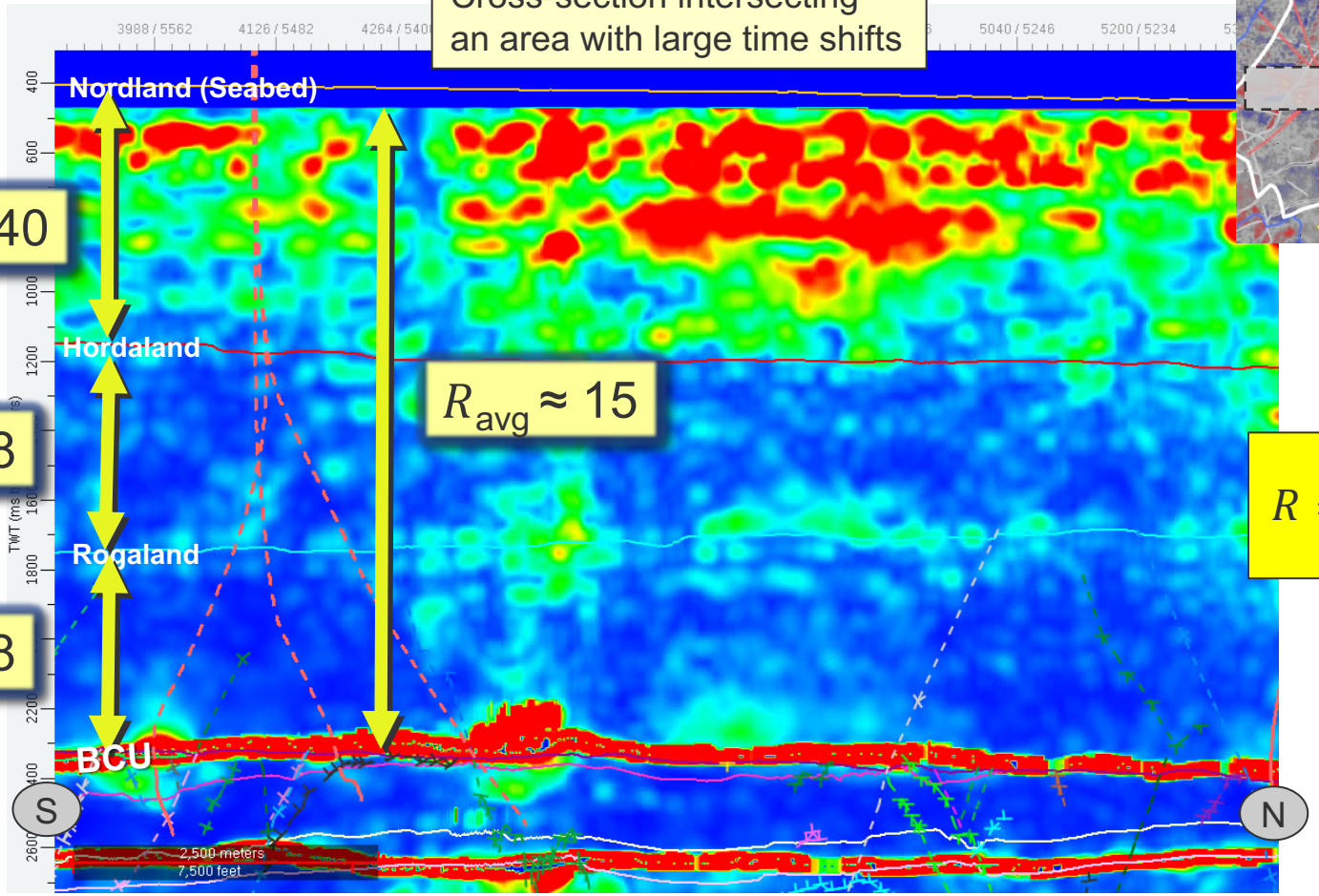
geomech. model



R inverted - Snorre



Cross-section intersecting an area with large time shifts



$R_{avg} \approx 40$

$R_{avg} \approx 8$

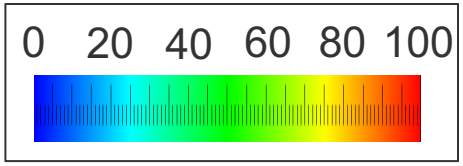
$R_{avg} \approx 8$

$R_{avg} \approx 15$

seismic time shifts

$$R \approx -\frac{\Delta v / v}{\epsilon_{zz}}$$

geomech. model



Outline

- Why monitor overburden?
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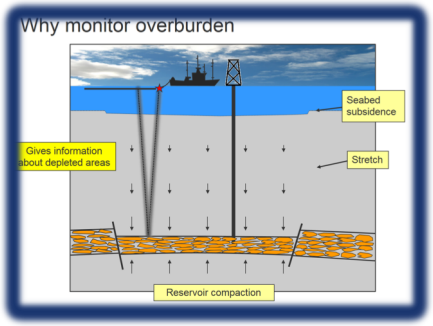
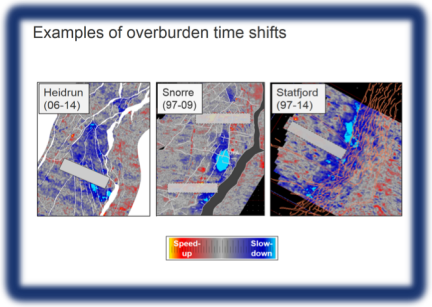
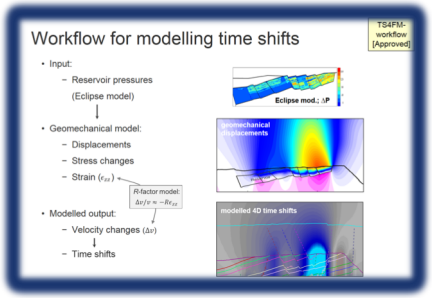
Summary

- Overburden geomechanical changes:
  - Occur for all fields
  - Detected as 4D seismic time shifts
- Time shift workflow:
  - Useful for updating reservoir model
  - Indicates $R_{avg} \approx 15$ for overburden







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- Ganpan Ke for fruitful discussions and input to geomechanical models
- Colleagues in Statoil and NTNU for discussions, especially:
  - Sascha Bussat, Lasse Renli, Martin Landrø, Kenneth Duffaut, Bård Bostrøm, Ola-Petter Munkvold, Øyvind Kvam, Ole K. Søreide, Svend Østmo, Odd Arve Solheim, Jon Lippard, Frank Aanvik, Torill Andersen, Marianne Houbiers, and Vibeke Haugen
- The Snorre, Statfjord, and Heidrun partnerships for permission to present this data

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