

3D mapping of groundwater salinity

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3D distribution of groundwater salinity as derived from airborne EM and a stochastic geological model

FRESHEM Zeeland project

Deltares
Enabling Delta Life

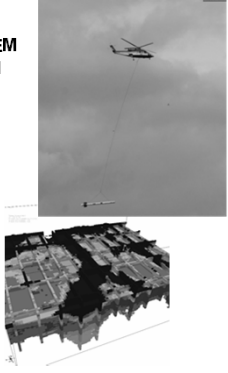
Esther van Baaren
Joost Deltman
Pieter Pauw
Marios Karaoulis
Tommer Vermaas
Huile Bootsma
Gualbert Oude Essink
Perry de Louw

BGR

Bernhard Siemon
Annika Steuer

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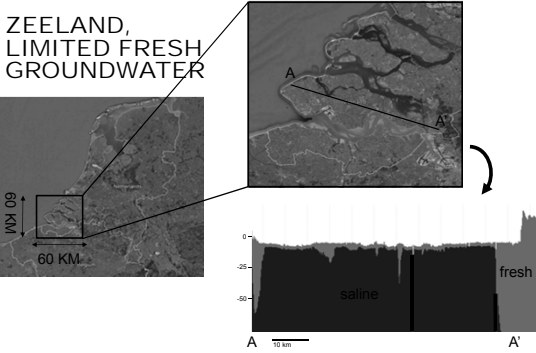
Willem Dabekaussen
Jan Gunnink
Amin Menkovic
Wim Dubelaar



FRESHEM 3D Workshop, Orleans, 23 February 2016

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ZEELAND, LIMITED FRESH GROUNDWATER



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MAN MADE LANDSCAPE

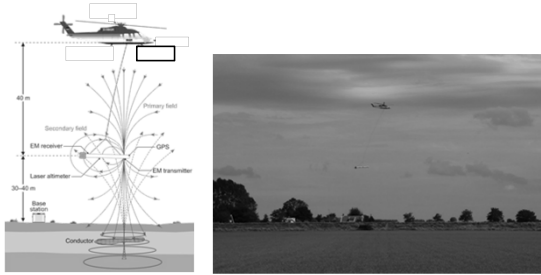


- › Tidal dominated system during most of Holocene
- › Formation of sandy channels and clayey flats

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HELICOPTER-BORNE EM




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FRESHEM SURVEY AREA

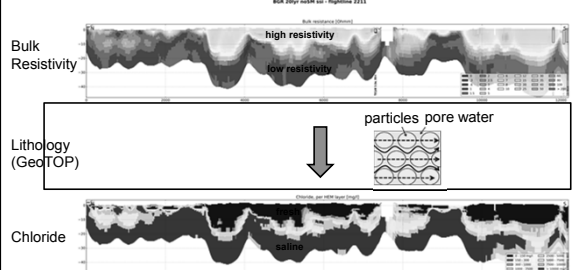
- › 6 weeks (summer 2015)
- › 8600 line kilometers
- › Area 1800 km²
- › Line spacing 100-300 m
- › Tie-lines every 1-2 km
- › 13 million data points
- › 7 high resolution areas



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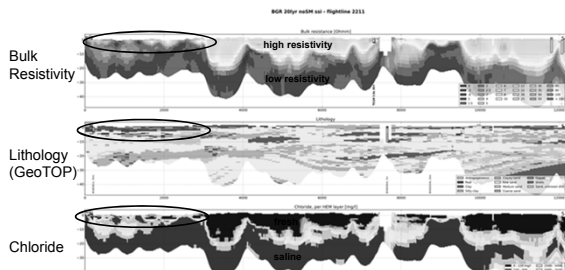
BULK RESISTIVITY TO CHLORIDE CONCENTRATION



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WHY THIS APPROACH?



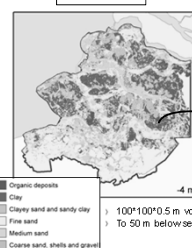
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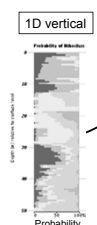
GEOLOGICAL MODEL GEOTOP

› stochastic: lithological probability per voxel from 100 simulations

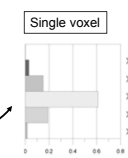
2D horizontal



1D vertical



Single voxel



- › clay
- › clayey sand
- › sand, fine
- › sand, medium
- › sand, coarse

› 100*100*0.5 m. voxels
› To 50 m. below sea level

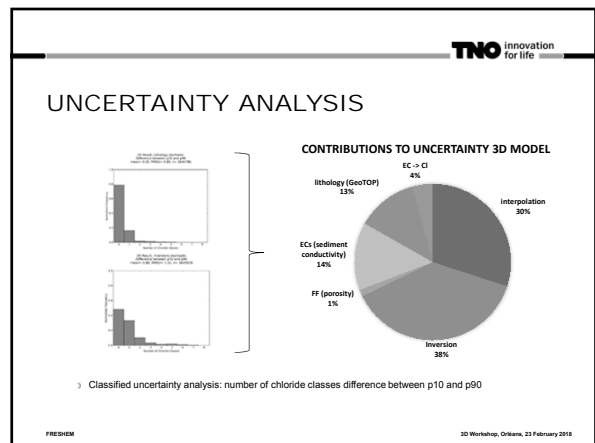
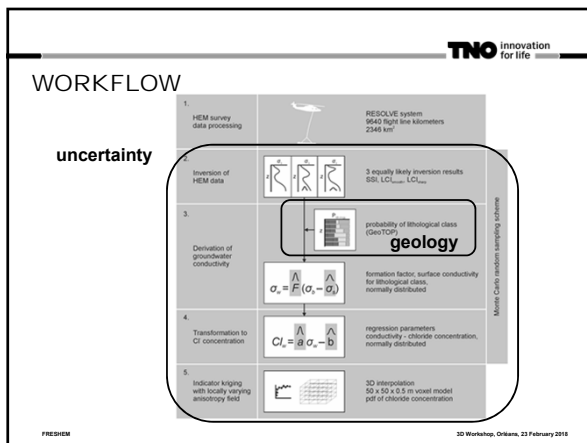
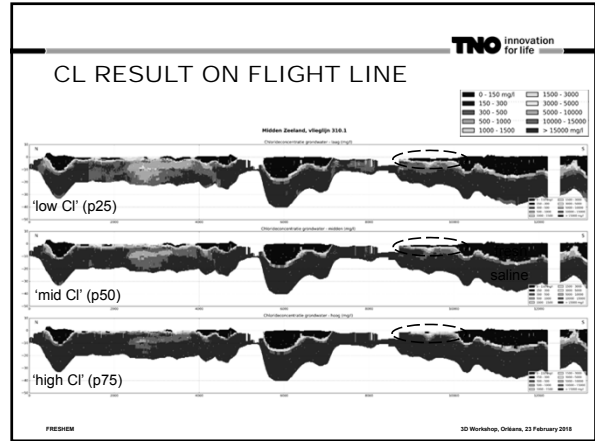
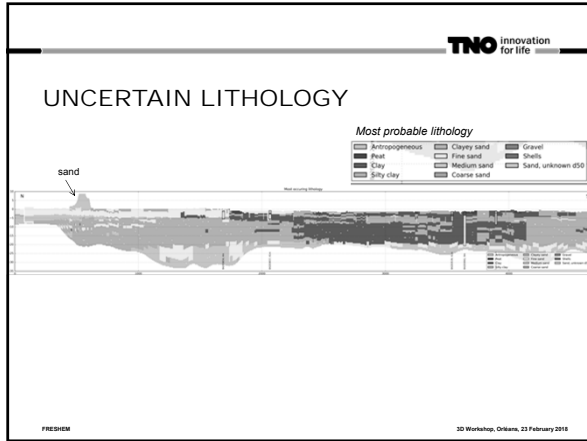
Legend:

- Organic deposits
- Clay
- Clayey sand and sandy clay
- Fine sand
- Medium sand
- Coarse sand, shells and gravel

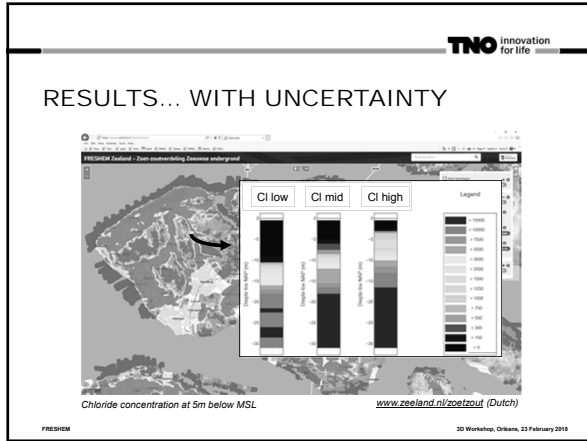
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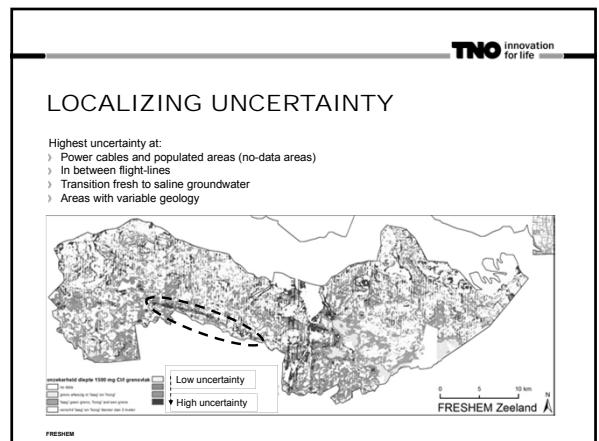
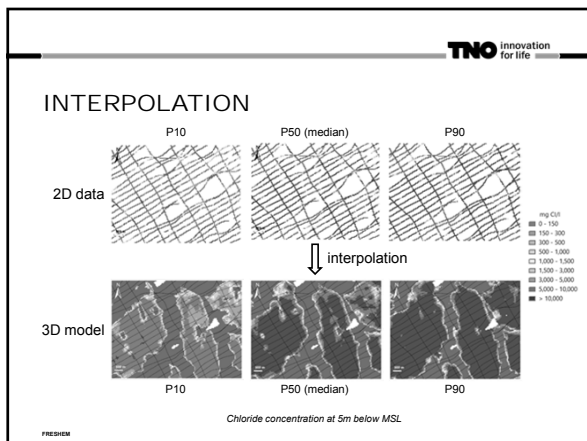
3D mapping of groundwater salinity



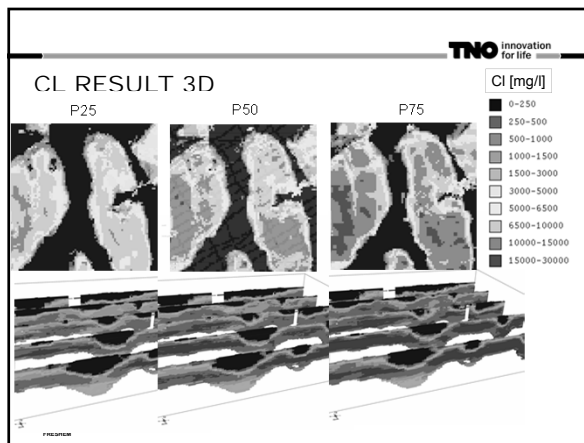
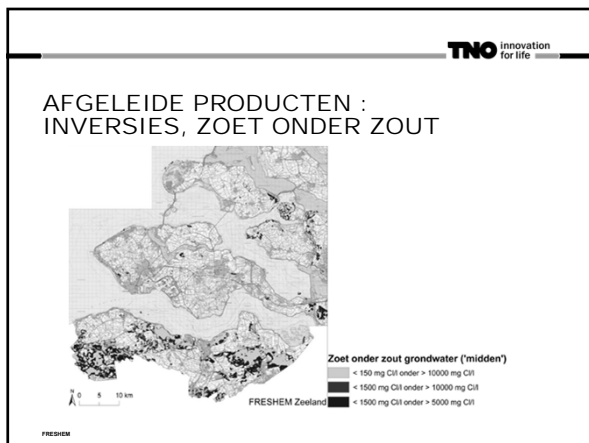
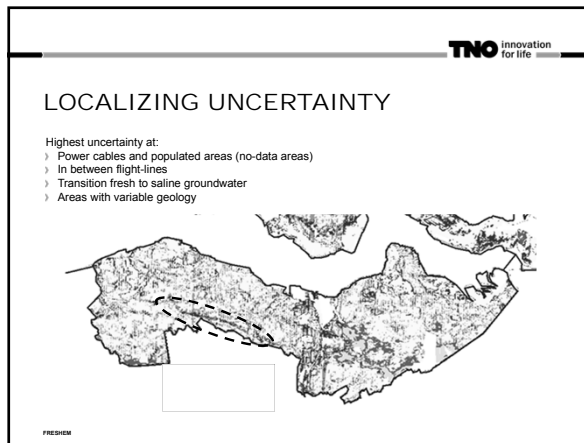
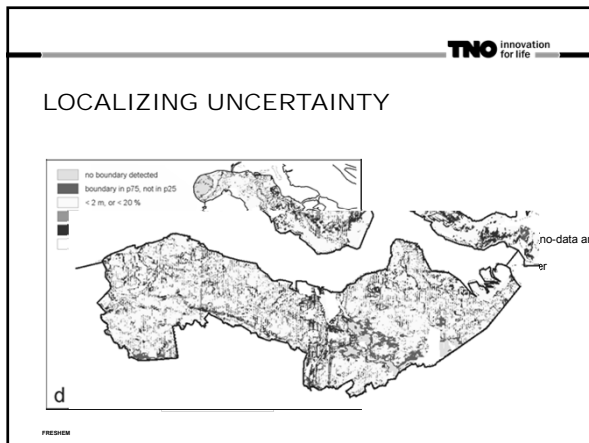
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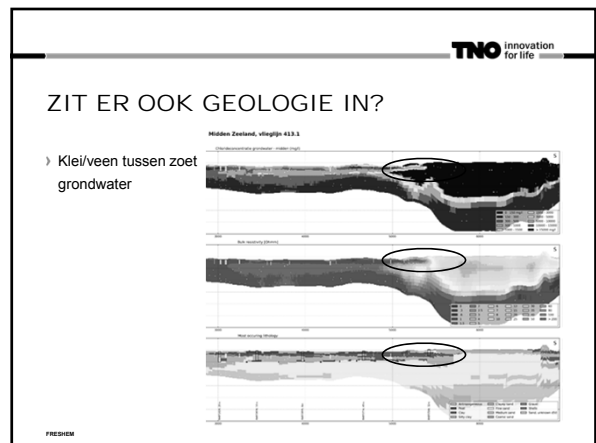
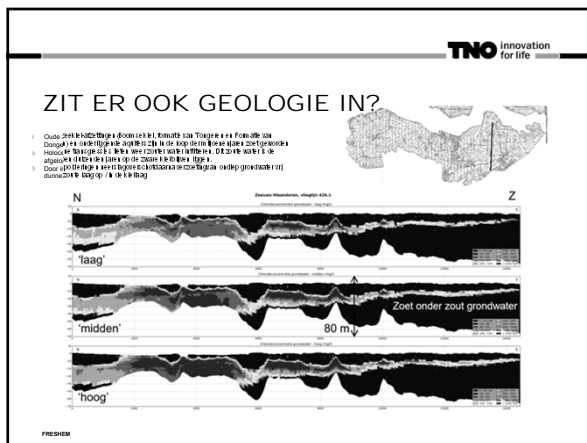
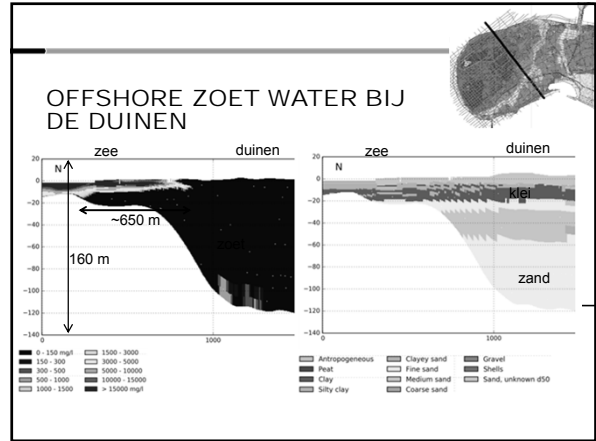
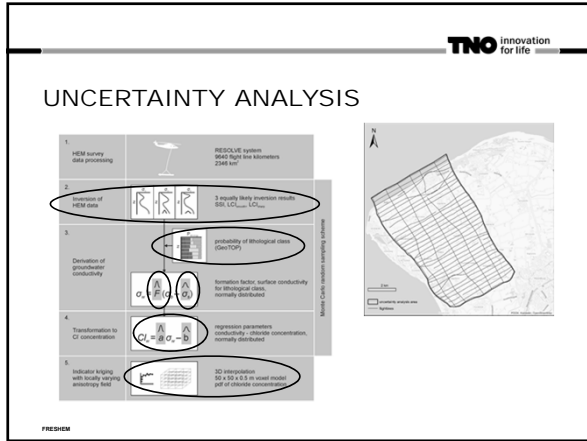
THANK YOU FOR YOUR ATTENTION



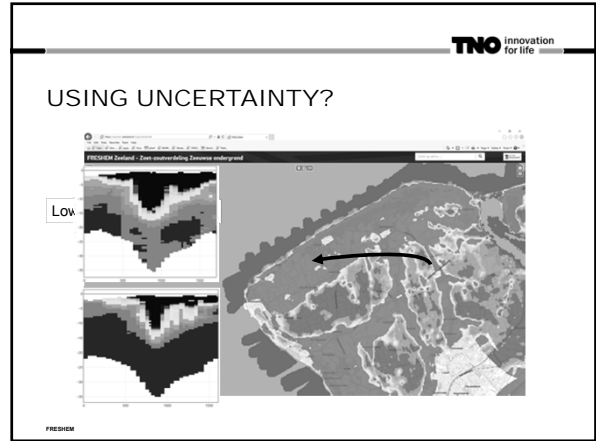
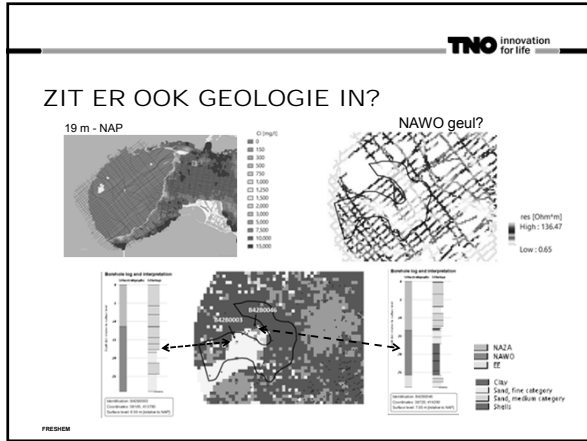
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3D mapping of groundwater salinity



HOE VERDER...

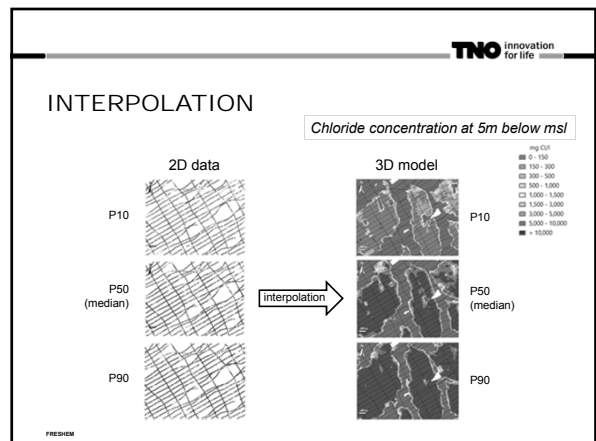
Met Deltares:

- > Deze methode gaat worden toegepast bij TopSOIL project in Vlaanderen
- > Freshem Nederland?

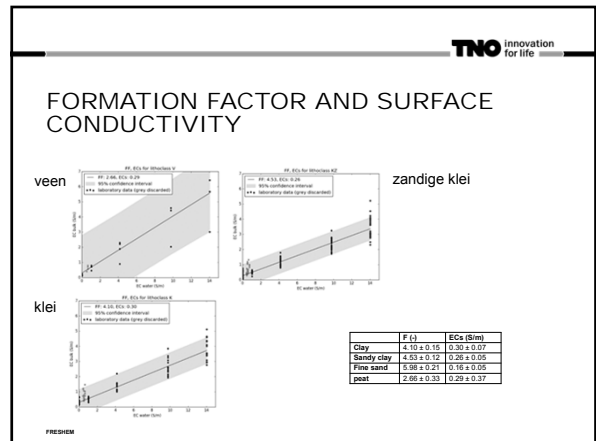
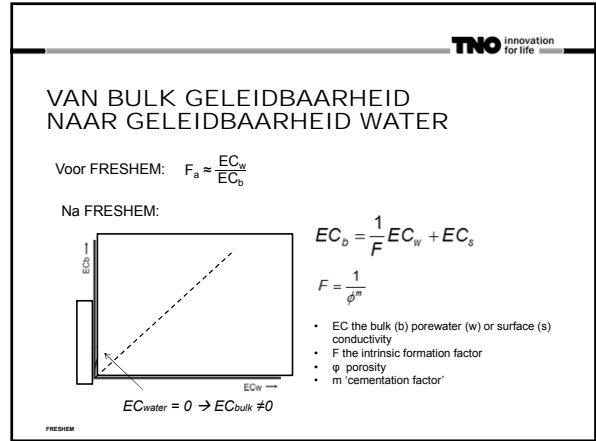
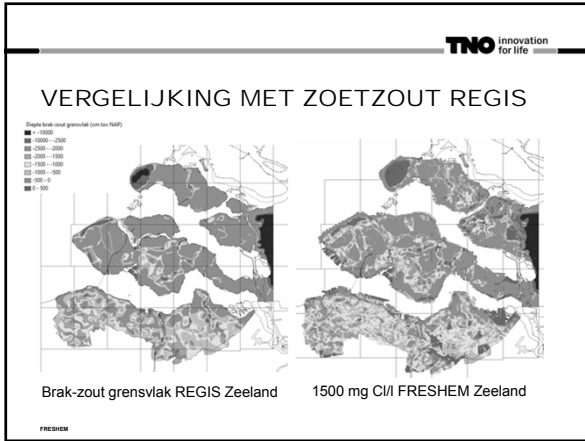
Mogelijke toepassingen in onze geologische modellen:

- > Cl grondwater aan GeoTOP toevoegen
- > Lithologische informatie voor onze modellen (o.a. Jan G./Armen)
- > Interpolatie met anisotropie voor fluviaatle afzettingen
- > Integrale aanpak onzekerheid/onzekerheidsanalyse

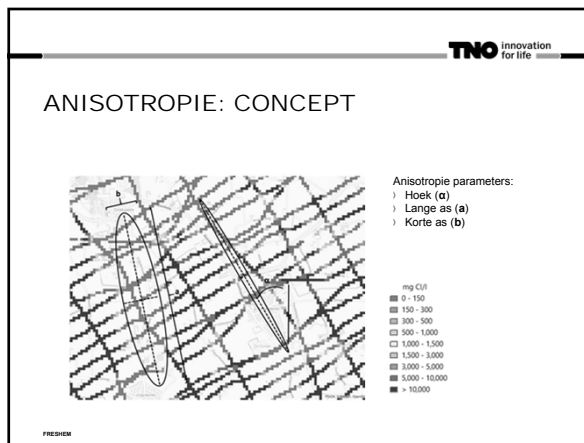
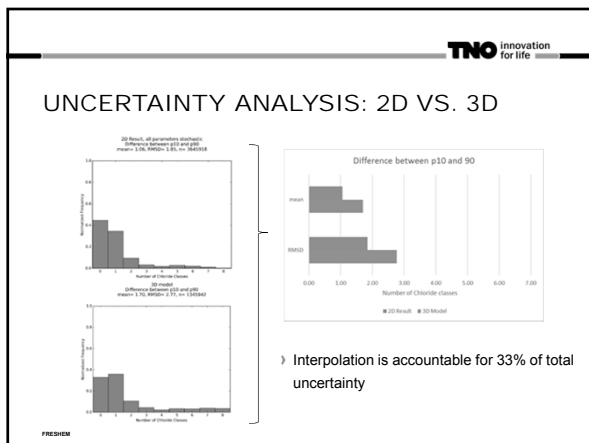
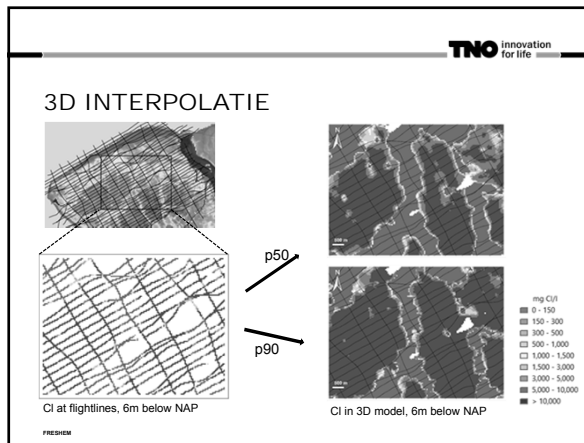
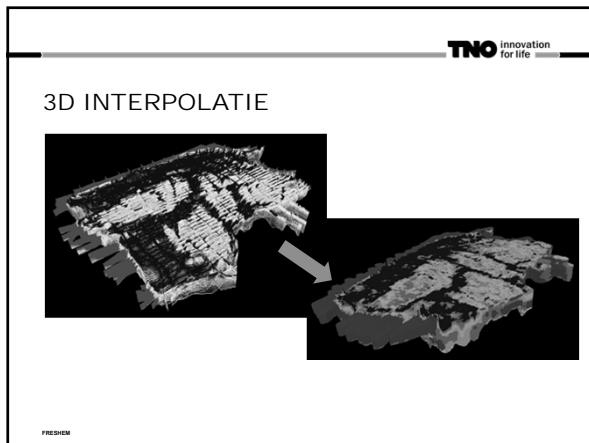
FRESHM



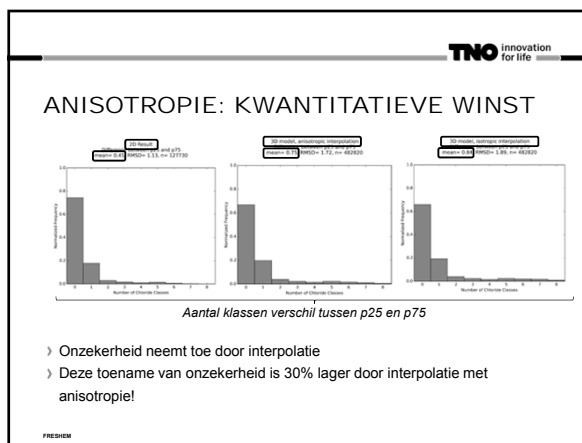
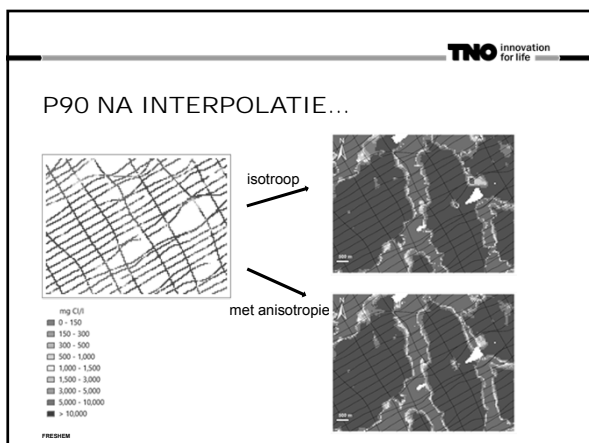
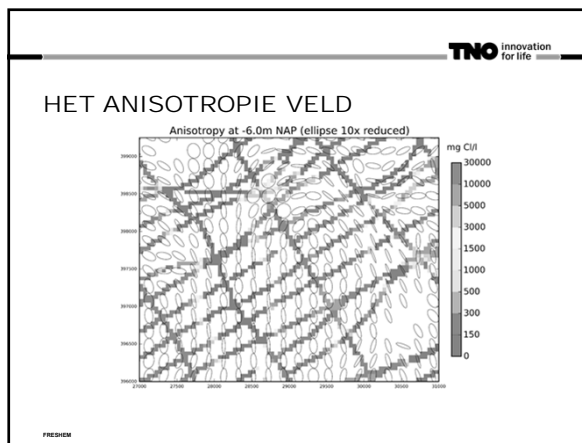
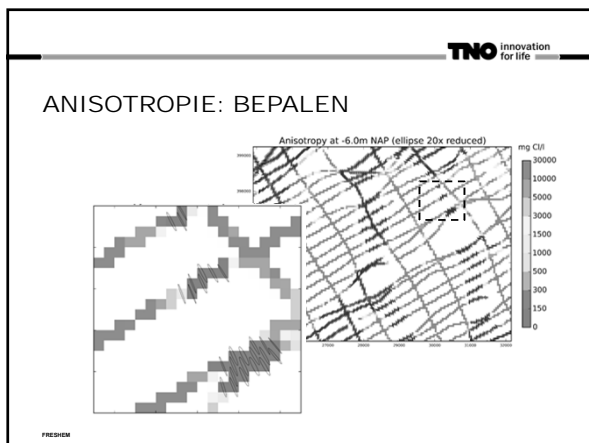
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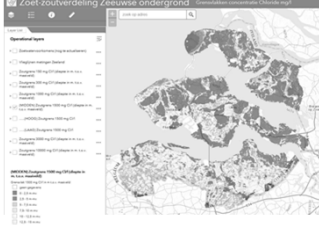
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RESULTATEN: GRENSVLAKKEN



Als download:

- 3D model (csv en asc)
- Plaatje per vlieglijn

Grensvlakkaarten via viewer:

- 150, 300, 1000, 1500, 3000 en 10000 mg Cl/l
- met 'laag', 'midden' en 'hoog'

Beschikbaar op <http://www.zeeland.nl/zoetzout>

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ONZEKERHEID

Visueel is weergegeven: 100*(grens_laag_mv - grens_hoog_mv)/grens_midden_mv voor de 1500 mg Cl/l grens

De grootste onzekerheid treedt op bij:

- › Hoogspanningskabel
- › Daar waar de helikopter hoog moest vliegen (rond de Kanaalzone)
- › Randen van het model (bij de no-data gebieden): grote afstand tot vlieglijn
- › Randen van zoetwaterlenzen
- › Tussen de vlieglijnen

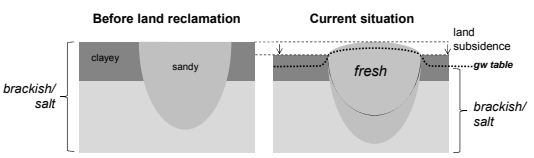


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ORIGIN OF CREEK RIDGES



Before land reclamation: clayey, sandy, brackish/salt

Current situation: fresh, land subsidence, gw table, brackish/salt

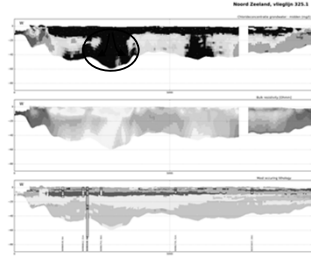
- › Compaction of clay-rich sediments
- › Tidal channels become highs
- › Fresh water lenses reaching to a depth of tens of meters

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ZIT ER OOK GEOLOGIE IN?

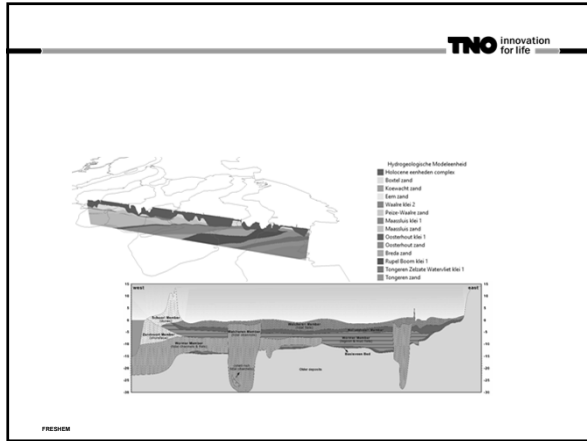
› Actieve verzoeting bij onderbroken kleilaag?



Noord-Zuid, vlieglijn 125.2

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INVERSIE

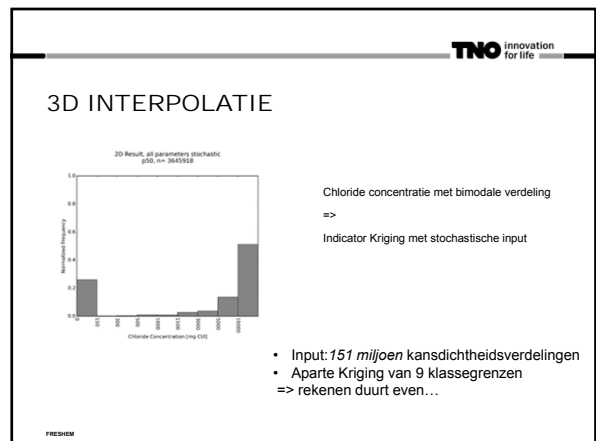
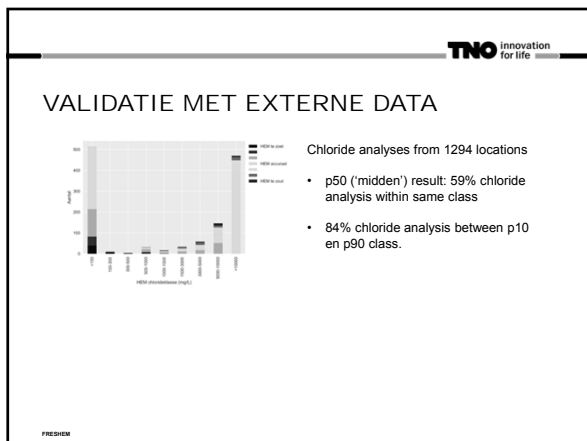
Van frequentie naar diepte:

Voor elke meetlocatie de geleidbaarheid als functie van de diepte vinden die het best bij de metingen past (inverse modellen)
) Verschillende modellen gebruikt

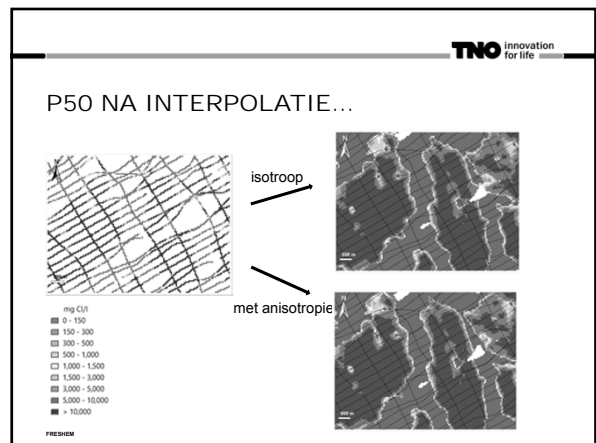
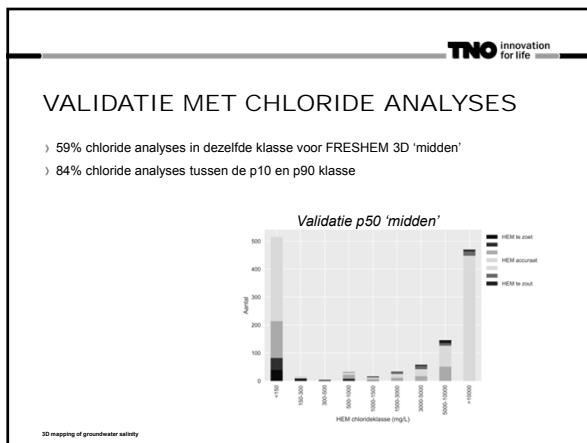
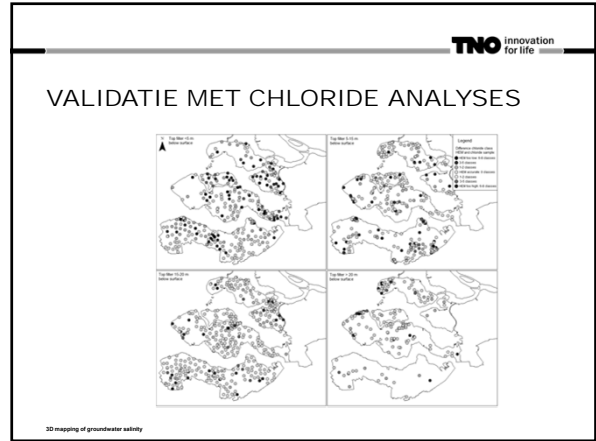
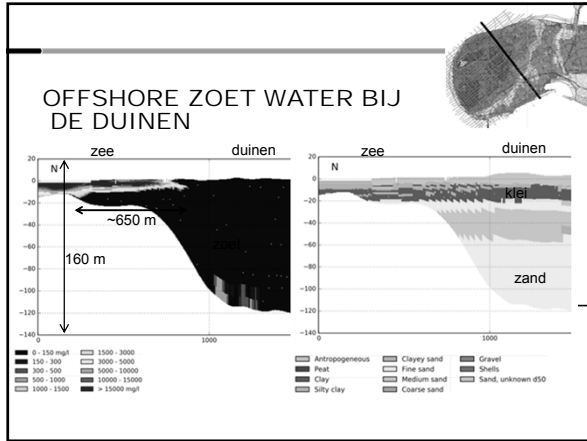
$$Z = \int_0^{\infty} R_1(f, \lambda, \rho, \mu, \epsilon) \frac{\lambda^3 e^{-2\alpha_0 h}}{\alpha_0} J_0(\lambda x) d\lambda$$

Diagram illustrating the inverse process: **Frequentie** (Frequency) on the left, **Diepte** (Depth) on the right, with a circular arrow indicating the iterative fitting process between ρ_{app} and ρ .

FRESHEN



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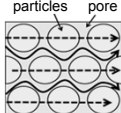
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VAN BULK GELEIDBAARHEID NAAR GELEIDBAARHEID WATER

- › Bulk elektrische geleidbaarheid is afhankelijk van:
 1. elektrische geleidbaarheid van het grondwater én
 2. elektrische geleidbaarheid van de bodemdeeltjes
- › Zout geleidt beter dan zoet
- › Klei geleidt beter dan zand
- › Zoet in klei = brak in zand

particles

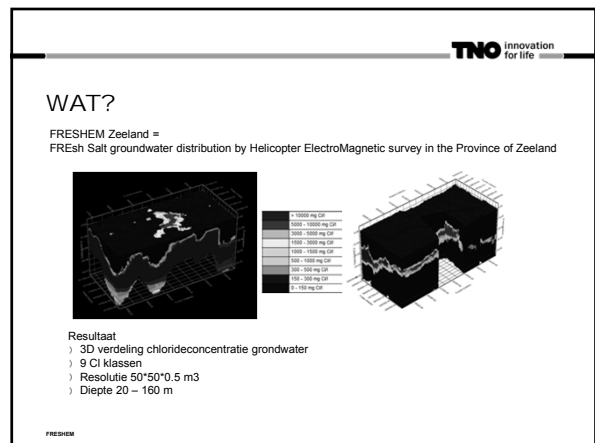
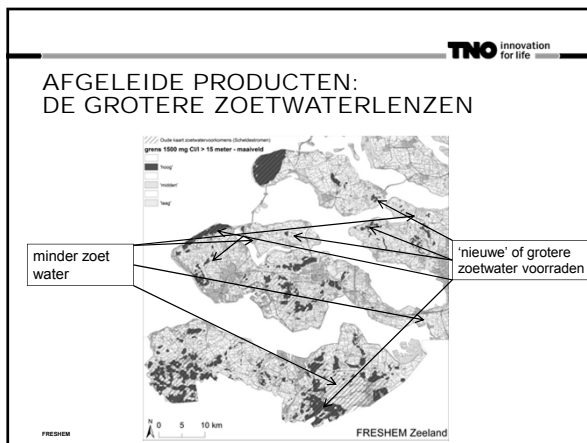


pore water

Contributions to conductivity

$$\text{Formation Factor} = \frac{EC_{\text{satiet}}}{EC_{\text{ouk}}}$$

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WIE?

Deltares
Exciting Delta Life

BGR

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Opdrachtgevers:

- Provincie Zeeland
- Rijkswaterstaat
- Het Rijk (Deltafonds)
- Evides
- Waterschap Scheldestromen
- ZLTO
- VNSC
- Zeeuwse gemeente

FRESH

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Nederlands Dagblad

Provincie Zeeland gaat strijd met zilte grond aan

Halo Nederland, NPO2

Boerderij.nl

Technisch Weekblad

Heli meet waar Zeeuws water zoeter kan

Nieuwe Oogst

Helikopter vliegt boven Zeeland voor zoet-zoutmetingen

Zout en zoet in Zeeland in kaart

PZC

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