Norsk Regnesentral
NORWEGIAN COMPUTING CENTER

Notat

SAND 2005

Notatnr SAND/01/06

Forfattere Petter Abrahamsen

Dato Februar 2006

Forfatterne

Petter Abrahamsen

Forskningssjef SAND

Norsk Regnesentral

Norsk Regnesentral (NR) er en privat, uavhengig stiftelse som utfører oppdragsforskning for bedrifter og det offentlige i det norske og internasjonale markedet. NR ble etablert i 1952 og har kontorer i Informatikkbygningen ved Universitetet i Oslo. NR er et av Europas største miljøer innen anvendt statistikk. Det jobbes med svært mange forskjellige problemstillinger slik som estimering av torskebestanden, finansiell risiko, beskrivelse av geologien i petroleums-reservoarer og overvåking av klimaendringer. NR er også ledende i Norge innen utvalgte deler av informasjons- og kommunikasjonsteknologi. Problemstillinger kan være overvåke inntrengning i datasystemer, e-læring i skole og næringsliv, bruk av datateknologi i markedsanalyser samt anvendelser av multimedia på forskjellige plattformer. NRs visjon er forskningsresultater som brukes og synes.

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Tittel	**SAND 2005**
Forfattere	**Petter Abrahamsen**
Dato	Februar 2006
År	2006
Publikasjonsnummer	SAND/01/06

Sammendrag

Referat fra SAND samling.

Emneord	
Målgruppe	Intern
Tilgjengelighet	Konfidensiell
Prosjektnummer	
Satsningsfelt	
Antall sider	
	Norsk Regnesentral

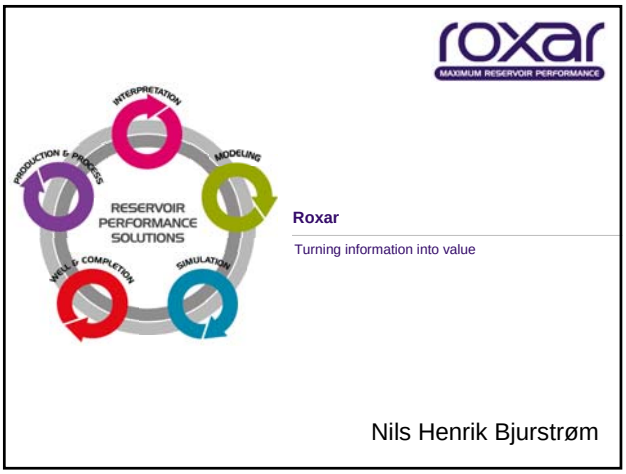
SAND torsdag 2. februar 2006

Radisson SAS Scandinavia Hotel, Holbergsgate 30

Agenda		Ansvarlig	Referent
09.00 – 10.00:	Evaluering av 2005 prosjekter	Arne	Petter
10.00 – 10.45	Nils Henrik, Roxar		
10.45 – 11.00	Kaffepause		
11.00 – 11.25	Multipoint	Heidi	Harald
11.25 – 11.50	TuMod	Bjørn	Ragnar
11.50 – 12.15	COHIBA	Ariel	Pål
12.15 – 13.00	Lunch.		
13.00 – 13.25	FindHC	Odd	Ragnar
13.25 – 13.50	FaultFacies, utgikk	Anne Randi, syk	Per
13.50 – 14.20	Evaluering av 2005 mål	Arne	Petter
14.20 – 15.00	Gjennomgang av 2006 mål	Petter	Arne
15.00 – 15.15	Pause		
15.15 – 15.30	SAND historie	Petter	
15.30 – 16.30	SWOT	Petter	Arne
16.30 – 17.00	SAND NIRVANA hva er det?	Alle	Petter
17.00 – 18.00	På(fyll) i **Summit 21** (Toppetasjen på hotellet)		
18.30 –	Middag på **Brasserie Blanche**, Josefines gate 23		

Evaluering av 2005 prosjekter

SAND										**2005**		
Markedsoversikter 2005									Markedsmål	9 200	Prognose	12 200
Status per	**15.02.06**								Oppnådd	143,0 %	Oppnådd	107,8 %
Oppdatert:	23.11.2005								Inkl 90%	152,9 %	Inkl 90%	115,3 %
Oppdrags-giver	**Prosjekter**	**Pr. nr.**	**Finans av**	**Fag-område**	**Pr. leder**	**Påløpt per 1.8.04**	**Kontrakts-festet**	**90% Sanns.**	**Kommentar**	**Karakter**		
Statoil	HAVANA lisens 25%	914002	O	St	Harald	105	135	0	bugfix	B		
	HAVANA utvikling	807014	O	St	Harald	0						
	SUMFS	807015	O	St	Harald	284	216		Mange skjær i sjøen	C		
	Snorre case study		O	R	Arne	0	0	0				
	Geostat kurs	677003	O	B	Knut	0	0	0				
	Smørbukk	581019	O	Se	Ragnar	1 310	1 426	0		A		
	Find HC	581015	O	Se	Odd	1 420	2 000	0		A		
	COHIBA	388676	O	St	Arne	338	1 000	0	Endelig… Treg oppstart	B		
Hydro	HAVANA lisens 25%	914002	O	St	Harald	105	135	0				
	HAVANA utvikling	807014	O	St	Harald	0	0					
	4DNJORD	298002	O	Se	Arne	39	25	0				
	Usikk. Oseberg Sør	298003	O	B	Knut	93	250	0		A		
	TROLLBOR	298004	O	B	Knut	41	0	60				
	Bore NR (Harald)	298006	O	B	Knut	92	250		Vanskelig å sette ut	C		
	Bore BG	298007	O	B	Knut	1 486	1 475	150	Variert	B-C		
	Bore NR2 (Knut)	298008	O	B	Knut	601	620	0				
	Bore Reise	298009	O	B	Knut	98	68	37		A		
	Rankseis	298010	O	Se	Anne R	338	420	0	Vanskelig	C		
	FS kube	298011	O	R	Anne R	102	250	0		B		
	IDEA	677002	O	B	Harald	226	172	50	Fort og gæli, Dårlig spekka, Manglende finansiering	C		
	Geostat kurs	677003	O	B	Knut	0	0					
	HTP risk	689005	O	B	Knut		0	100				
Roxar	XUTV	675010	O	R	Petter	34	34	10		B		
	Karbonater	643020	O	R	Anne	0	0					
	IKSIM05	643018	O	R	Harald	216	240	0	Fornøyd kunde, raskt	A		
	SedSeis	643019	O	R	Ragnar	193	188	0	Rykkete finansiering	B		
	Rammeavtale		O	R	Petter	0	0	0		A		
	Vario	643024	O	R	Ragnar	51	400	0		B-C		
	FieldWatch	643020	O	H	Arne	39	0	100	Treg oppstart	C		
OD	Utbygging	320002	S	B	Anne	134	200	0	Kontaktperson sluttet	C		
	Profiler	320001	S	B	Knut	8	0	34	Vet ikke hva det dreier seg om!	E		
ENI	Seismisk inversjon		UO	Se	Odd	0	50	0	Kun oppstart	A		
Lundin oil	Regneark	346001	UO	B	Knut	88	300		Skjer lite	C		
DNO	DNO Decision sup.	255002	O	B	Knut	56	56	0	Pssssss….	D		
BP	Geostat kurs		UO	B	Bjørn							
British Gas	HAVANA lisens, 25%	914002	UO	St	Harald	75	0	75				
Shell	HAVANA lisens, 25%	914002	UO	St	Harald	0	0		Mistet	E		
Total	HAVANA salg		UO	St	Harald							
Genkey	FPRINT	345001	O	B	Odd	30	30		Jørn Lyseggen!!!	A		
Scandpower	Konsulent		UO	B	Petter							
NFR	IRM-SIP	808003	N	R	Petter	460	583		Litt foredrag/poster!	B		
	Multipoint	808002	BN	N	Petter	530	350	300	Spennende/ dårlig organisering	B		
	TuMod - turbiditter	808004	BN	R	Petter	1 650	1 290		forventet	C		
	Fault facies	808005	BN	St	Anne	826	990	0		A		
NR	4D Seismikk	1041	N	Se	Anne	107			Artig, publisert	A-B		
	GB publ	1042	N		Petter	149						
	SAIGUP Publ	1043	F		Arne	84				C		
	SIP Star		N		Knut	50			Publisering!!	A		


roxar
MAXIMUM RESERVOIR PERFORMANCE
INTERPRETATION
MODELING
SIMULATION
WELL & COMPLETION
PRODUCTION & PROCESS
RESERVOIR PERFORMANCE SOLUTIONS
Roxar
Turning information into value
Nils Henrik Bjurstrøm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MAXIMUM RESERVOIR PERFORMANCE
Professional & Committed Partner
•Strong Value Proposition
•Global reach
•World class products
•Leading market shares
We help you know your reservoir
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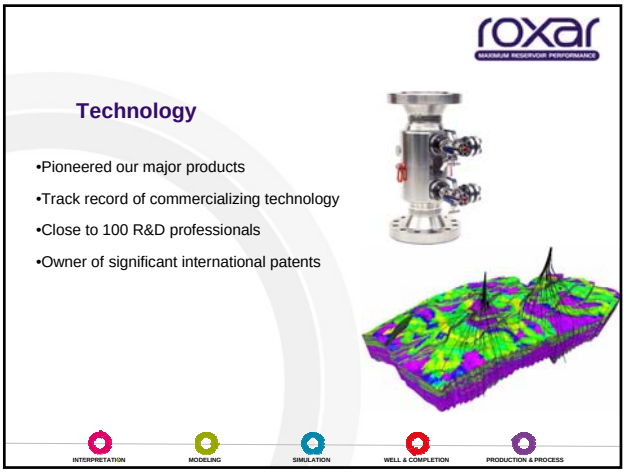
MODELING
SIMULATION
WELL & COMPLETION
PRODUCTION & PROCESS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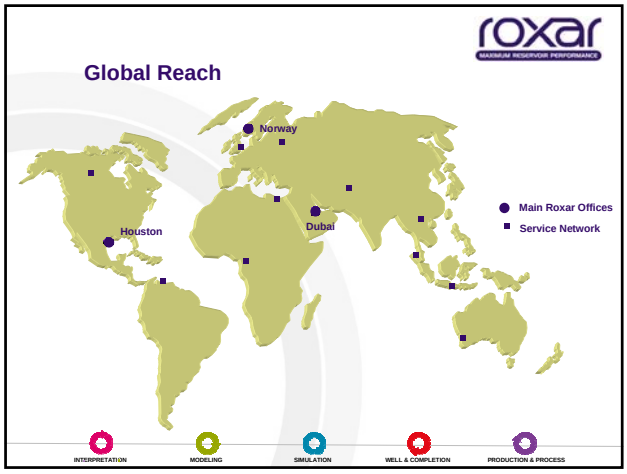
MAXIMUM RESERVOIR PERFORMANCE
Technology
•Pioneered our major products
•Track record of commercializing technology
•Close to 100 R&D professionals
•Owner of significant international patents
INTERPRETATION
MODELING
SIMULATION
WELL & COMPLETION
PRODUCTION & PROCESS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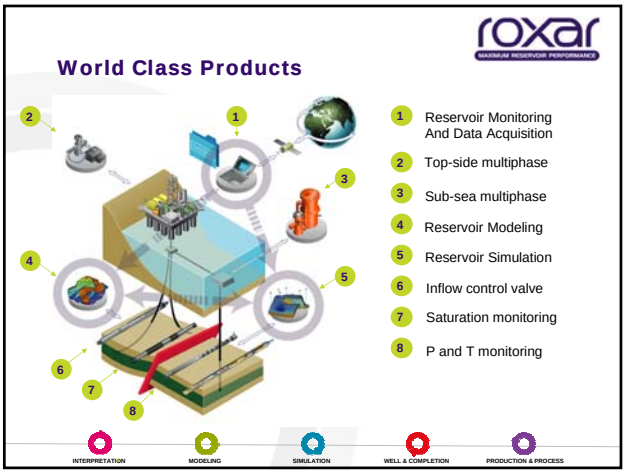
Global Reach
Norway
Houston
Dubai
Main Roxar Offices
Service Network
INTERPRETATION
MODELING
SIMULATION
WELL & COMPLETION
PRODUCTION & PROCESS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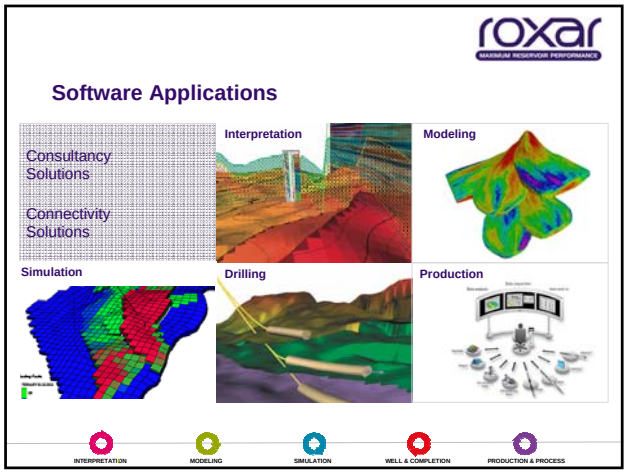
MAXIMUM RESERVOIR PERFORMANCE
World Class Products
1 Reservoir Monitoring And Data Acquisition
2 Top-side multiphase
3 Sub-sea multiphase
4 Reservoir Modeling
5 Reservoir Simulation
6 Inflow control valve
7 Saturation monitoring
8 P and T monitoring
INTERPRETATION
MODELING
SIMULATION
WELL & COMPLETION
PRODUCTION & PROCESS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Software Applications
Consultancy Solutions
Connectivity Solutions
Interpretation
Modeling
Simulation
Drilling
Production
INTERPRETATION
MODELING
SIMULATION
WELL & COMPLETION
PRODUCTION & PROCESS

Metering Products

Topside	Subsea	Downhole
•Multiphase meter, gamma or non-gamma •Flare gas meter •Wet gas meter •Water cut meter •Pig detection •Sand monitoring	•Multiphase meter gamma or non-gamma •Wet gas meter •Pig detection •Sand monitoring	•Permanent P&T gauge •Gauge Carrier •Downhole cable •Electrical connectors •Wellhead pressure barriers

WetGas Meter

Subsea Sand Detector

Permanent P&T gauge

INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

Global Customer base

ADCO
ADGAS
ADMA
ADNOC
AEC Ecuador
APPC
Agip /Eni
Aker Offshore
Alberta Energy
Alderly Systems
Amerada Hess
Anadarko
Apache
Ballard
Bashneft
Beach Petroleum
Belkamneft
British Gas
BHP
BP
Burlington Resources
Cairn Energy
Cameron
CGE
Chaparral Energy
ChevronTexaco
Clough Engineering
CNOOC
CNSPC
ConocoPhillips
Coogee Resources
Corelab
CTOC
DeGolyer & MacNaughton
Devon Energy
Dominion
Dong
Dove Energy
DPC
Dragon Oil
Ecopetrol
Emerson
Encana
EOG
Expro
ExxonMobil
Flare industries
FMC
Gaffney Cline
Geisum
GeoServices
Giprovostokneft
Halliburton
Helix RDS
Henan
Husky
Idemitsu
INPEX
Jiangsu
JVPC
Karachaganack
KBR
Kerr McGee
Kinder Morgan
KOC
Kvaerner
LLOG
Lukoil
Maersk
Marathon
Mariner Energy
Maxus
MOL
Murphy
Nexen
NIPC
Nippon
Novus
Norsk Hydro
NPD
NVNIIGG
OMV
ONGC
Occidental
PDO
PDVSA
Pemex
PermNIPIneft
Petrobras
PetroCanada
PetroChina
Petronas
PetroVietnam
Pertamina
PGDC
PGS
Pioneer Natural Res
Premier
PTTEP
QP
Rashpetco
Repsol/YPF
RIPED
RML
RWE-DEA
Santa Fe
Santos
Saudi Aramco
Scott Pickford
Soekor
Shell
Shanghai Petroleum
Shengli Petroleum
Sibneft
SINCOR
Snamprogetti
Sonatrach
Statoil
Suco
Talisman
Tap Oil
Technip
Tengiz
Total
UfaNIPIneft
Unocal
Veba
Venture production
Vetco Gray
Vietsovpetro
Wanzhuang
Weatherford
Wintershall
Wood Group
Woodside
Yukos
Zadco
Zarubezhneft

More than 150 customers worldwide…

INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

Global Market Share

- Every 2nd 3D modeling software application is likely to be **a Roxar product**
- Every 2nd multiphase meter purchased is likely to be **a Roxar product**
- Every 4th quartz downhole permanent P&T gauge installed is likely to be **a Roxar product**

INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

Business Drivers

Mature, complex fields

Uncertain oil price

Increasing demand for hydrocarbons

Shortage of experienced and educated staff

Risk management, portfolio optimisation

INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

The Irap RMS Interface

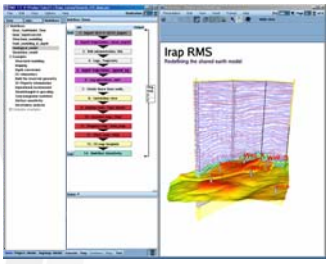
Easy to use interface

Data explorer layout

Tabs selector

•data, jobs & workflow

Common GUI



INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

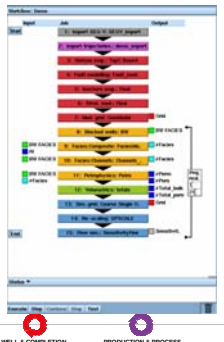
Workflow Management

A productivity tool which allows the repetition and automation of complete workflows

Visual macros for the 21st century

Frees up the users time allowing them to do other work

Provides a clear and repeatable audit trail of the workflow



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Well Correlation in RMS

Powerful & integrated well correlation tool

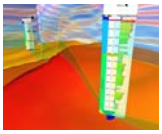
- Interactive correlation in 2D and 3D

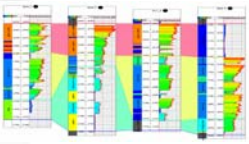
Well picks calculator:

- Calculate TST; MD
- Log averages

Tight integration with mapping

- Faster workflows
- Quick model updates





INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

Mapping in RMS

Flexible and powerful mapping

- Scalable and data adaptive gridding methods

Easy to use

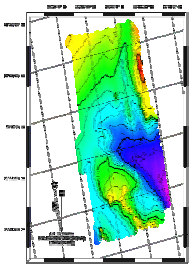
- For everyday and casual users

Complete structural framework

- Horizons, thickness maps, fault model

Produce better maps quicker

- Plot templates & multi-plot option



INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

Fault Modelling

A complete range of fault styles can be modelled

Vertical

Inclined
Normal & reverse

Listric

Branching

Crossing

Y fault

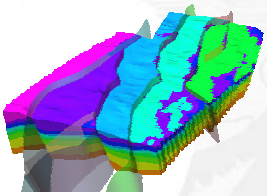
INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

Faulted 3D grids

Flexible 3D grid building

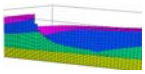
Geological & Simulation grid building

Robust incorporation of faults

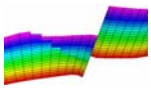


Normal & Reverse faults

Stair stepped listric fault



Stair stepped Y fault



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Modeling

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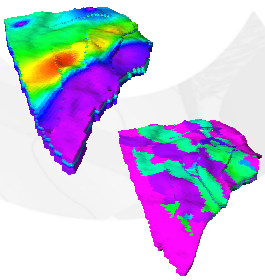
Deterministic Petrophysical Modelling



Quick and easy

First pass and simple models

Choice of methods

- 3D interpolation
- 3D kriging

Include geological trends

Facies model conditioning

INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

FaciesIndicators

Sequential indicator simulation (SIS)

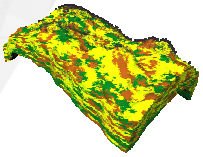
Fast, flexible and easy to use

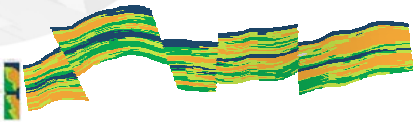
Millions of cells and thousands of wells

The perfect solution for large, mature fields

Easily incorporate geological trends

Vertical proportion curves & trend maps





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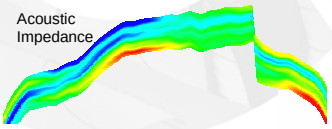
FaciesIndicators

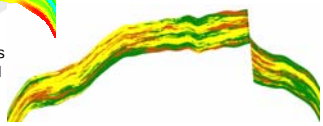
Easily conditioning to seismic attributes

Co-simulation and conditional probabilities

Acoustic Impedance



Facies Model



INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

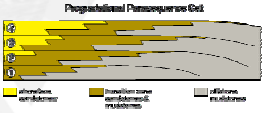
FaciesBelts

Designed for modelling transitional environments

Pixel based, Truncated gaussian simulation

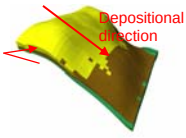
Geologically intuitive interface

Define stacking pattern, angle and depositional direction



Stacking angle

Depositional direction

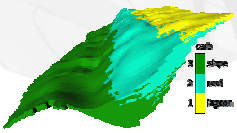


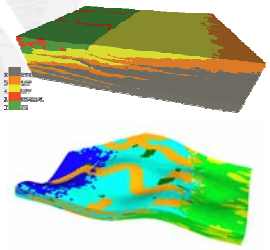
INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

FaciesBelts

Model a complete range of geological environments

- Carbonate
- Shoreface
- Delta front





INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

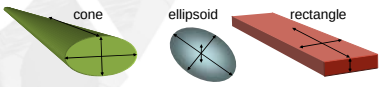
FaciesComposite

Flexible modelling tool for isolated bodies

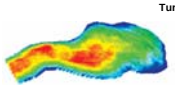
Wide selection of shapes

User defined shapes

Complex body shapes



cone ellipsoid rectangle



Turbidite lobe

INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

FaciesComposite

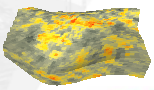
Condition to geological trends and seismic attributes

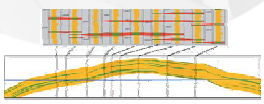
Comprehensive data analysis support

Accurate well conditioning

Multi well conditioning

Well to well correlations





INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

FaciesChannels

Unique tool for object based channel modelling

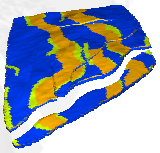
Model all types of channelised environments

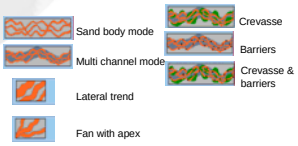
Flexible channel options

Range of channels facies types

Choice of sand body or multi channel systems

Choice of geological trends





INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

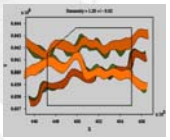
FaciesChannels

Condition to multiple data

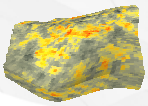
Wells

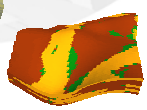
Seismic attributes

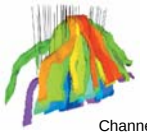
Geological trends



Interactive previewer







Channel fan with Multi- well conditioning

INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

Stochastic Petrophysical Modelling

Stochastic modelling of continuous properties

Porosity

Permeability

Fast and scalable solution

Millions of cells thousands of wells

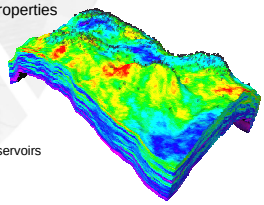
Small to large models; simple to complex reservoirs

Easy to use

First pass, simple and advanced user modes

Automated, guided or manual parameter set-up

Interactive variogram pre-viewer



25 million cells
1000 wells
16 minutes on a PC

INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

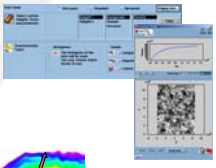
Stochastic Petrophysical Modelling

Easy to use

First pass, simple and advanced user modes

Automated, guided or manual parameter set-up

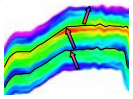
Interactive variogram pre-viewer

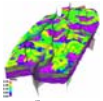


Kriging algorithm chosen automatically

Choice based on input data and modelling options

Simple kriging, ordinary kriging, universal kriging, Bayesian kriging, co-located cokriging





INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

Fault Seal Analysis

Geological model is used to calculate fault zone properties

Calculate fault permeabilities using:

- Manzocchi, Sperrevik or SGR curve methods

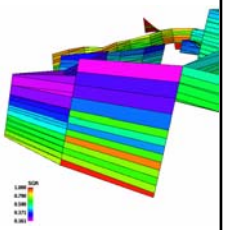
Additional calculations options:

- Clay Smear Potential
- Shale Smear Factor

Results are used to calculate fault transmissibilities for use in simulation

Better estimates of flow across faults = better simulation & history matching

Cooperating with Rock Deformation Research Ltd at Leeds University



INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

Volumetrics

Flexible full field volumetrics

By fault block, zone, license boundary or facies

Comprehensive reporting

Table, ASCII or Microsoft Excel

User defined units & report structure

Connected volumes

Geometric facies connection to well

Distance, well & contact constraints

INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

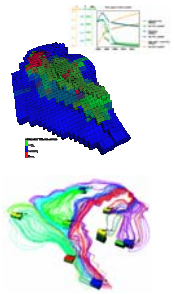
Reservoir Technology

A range of integrated reservoir technology tools

- Results import – Eclipse, VIP, Tempest
- Post processing - 3D recurrent data, 2D profile data

Integrated simulation

- Black oil
- Easy to use GUI
- Ranking & screening
- Streamlines analysis
- Single phase
- Large model handling
- Ranking & QC



INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

Well planning

Interactive target design in 3D

Use all available reservoir data

Automated alarms for dog leg severity

Automated well trajectory design

Links slot location to targets -> drillable trajectory

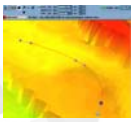
Constrained based on geometrical & drilling constraints

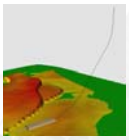
Complex & designer wells

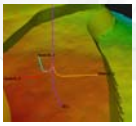
Multi laterals & sequential targets

User defined kick off points

Build rates and straight sections







INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

Uncertainty Management

Manage and understand reservoir uncertainty

Scenario & uncertainty management

Structural & geological uncertainty

Analysis and ranking of results

Utilises Irap RMS job concept and WFM

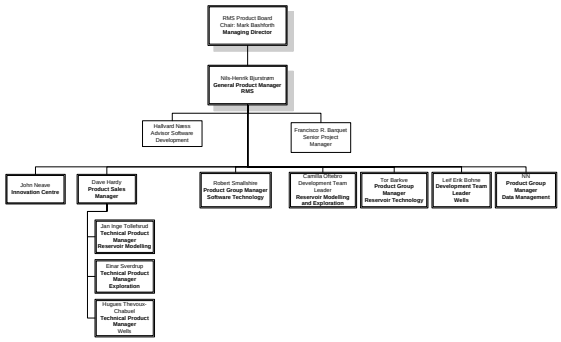
Realizations & scenarios easily managed within project data store

Workflow manager allows looping through jobs

Jobs can be updated to reflect different scenarios

INTERPRETATION MODELING SIMULATION WELL & COMPLETION PRODUCTION & PROCESS

PG RMS Management org. chart



Multipoint prosjektet

- en uformell oversikt og statusrapport til SAND, februar 2006

Heidi,

m/innspill fra Harald, Odd og låning av figurer fra diverse presentasjoner

Objective

- "Develop new and improved methods for modeling geological facies by combining the efficiency of multipoint methods with the robustness and consistency of Markov random field methods. Develop software tools and test new methods on real cases and data."

Multipoint methods (*snesim, simpat, filtersim)*
-fast
-problems with statistical foundation
-Stanford based

Markov random fields
-slow
-robust statistical foundation
-NTNU has great expertice

Project work

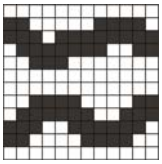
Merged methods by the end of 2008
-fast
- robust statistical foundation

And the more dreary details:
•Participants: NR, NTNU, Stanford
•Sponsors: NFR, Hydro, Statoil, ENI
•Money: 8 mill. (total)
•Time: 3 years (through 2008)

More details, sub goals

- Investigate advantages and limitations of the existing pixel based methods for modeling geological facies including multipoint methods (snesim, simpat, filtersim) and Markov random field methods.
- Establish objective criteria to compare different methods beyond visual inspection. Connectivity and the prediction of fluid flow will be considered for this purpose.
- Get a deeper understanding of how multipoint methods work.
- Reduce artifacts in multipoint methods.
- Develop better ways of calibrating the methods to training images or other data.
- Develop practical methods for generating training images that appeal to a geologist.
- Investigate differences and similarities between multipoint methods and Markov random fields.
- Develop efficient software for pixel based facies models.
- Focus on efficient use of seismic data including time-lapse data (4D).
- Complete a Ph.D. thesis.

Multipoint methods in general

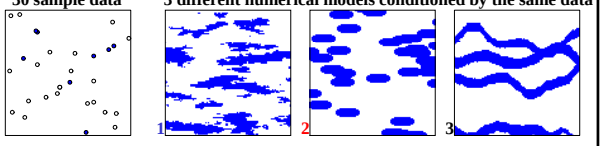


- Grid based – not objects
- Neighbourhood/template
- Beyond variogram based methods
- Several approaches
  - Markov Random Field (MRF)
  - *snesim* – using pattern frequencies
  - *simpat* – patching pattern pieces
  - *filtersim* – using scores for "filters"
- Training images required (3D, outcrop (2D),…)

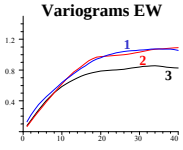
The importance of going beyond variogram based methods

30 sample data

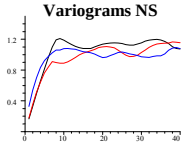
3 different numerical models conditioned by the same data



Variograms EW



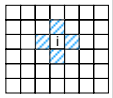
Variograms NS

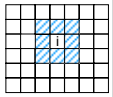


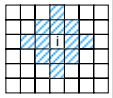
➡ **2-point correlation is not enough to characterize connectivity**
A prior geological interpretation is required

Markov Random Field –brief intro

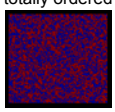
- Given a neighbourhood structure $\{\partial_i\}$ the Markov property says $p(z_i \mid \mathbf{z}_{-i}) = p(z_i \mid \{z_j: j \in \partial_i\})$
  - positivity condition: $p(\mathbf{z})>0$ for all configurations $\mathbf{z}$
  - neighbourhood are symmetric: $j \in \partial i \Leftrightarrow i \in \partial j$
  - NB: correlations may stretch much longer than the neighbourhood
- Example: 2D Ising model
  - nearest neighbourgs only
  - phase transition from totally disordered to totally ordered state







β = 0.20



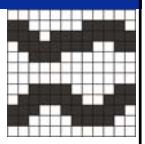
β = 3.00
(not fully converged)

MRF (cont'd)

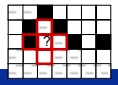
- General expression for an MRF exists*, but for practical usability further specification is necessary
  - too many free parameters
- MRFs are normally handled by doing MCMC simulations

* Hammersley Clifford theorem

Multipoint methods –brief intro (*snesim*)



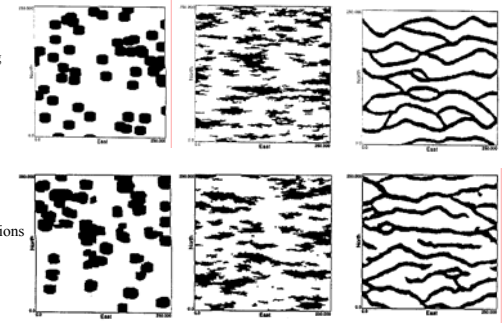
- Start out with a TI and a chosen data template
- Scan TI with template and estimate the frequences of the different template configurations. Data base of frequences now established
- Define a random path in the grid of the realisation
- Use the established frequences to assign a value for the next cell to visit, conditioned on the cells already visited



Examples from *snesim* (Strebelle, Caers)

Training images

Realizations



Initial limitations

- MPS
  - Lack of theoretical framework
  - Artefacts
  - Memory greedy algorithms
- MRF
  - Speed
  - Abstract model specification
  - Parameter estimation

- How to obtain representative training images?
- Do we capture the essence of the geological phenomenon?

Evaluation criteria for successfull merging of MRF and MPS

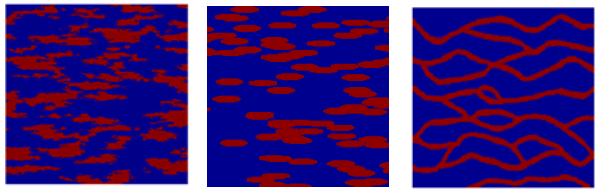
- Experimental criteria
  - ability to reproduce the *main features* of the TI, although with variations that mirror the inherent uncertainty/statistics (quantitative: Harald's work)
  - speed
- Theoretical criteria
  - model consistency: unconditional probabilities and probabilities conditioned on data should be consistent
  - increase control of approximations
    - the impact of parameter settings (neighbourhood structure, data template, TI size,…)
    - what to do when TI gives very little information

Initial plans set up at kick-off meeting

- Task 0: Agree upon a set of training images for testing.
- Task 1: Comparing unconditional realizations with training image.
  - Generate unconditional simulations (MPS & MRF) based on training image (TI).
  - Compare statistics from TI to statistics from realizations.
- Task 2: Test conditioning method in SNESIM
  - Generate conditional realizations.
  - Generate unconditional realizations and use rejections sampling
  - Compare statistics close to well data.
- Task 3: Repeat Experiment 1 and 2 in 3D.
- Task 4: Use SNESIM to make an initial realization for an MCMC for MRF
  - Compare efficiency.
- Task 5: Block updating.
  - Use SNESIM to propose a block update within a MCMC for MRF.

innocent looks may fool you! ☺

Training images, 2D



Variogram based — Not variogram based

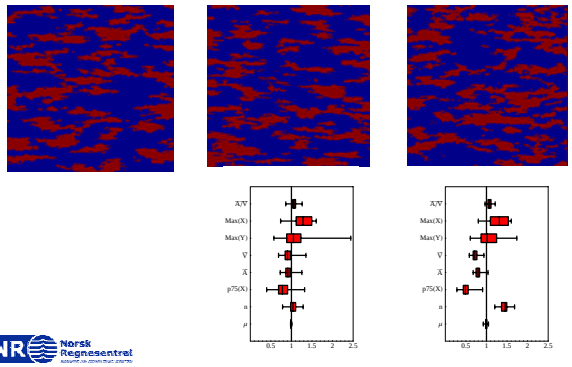
Common size: 250x250

Evaluation of facies realizations

- A facies body identifier has been implemented
- Statistics on training image and realizations
- Criteria
  - Greatest extension of bodies
  - Ratio of surface area to volume
  - Volumes
  - Number of bodies

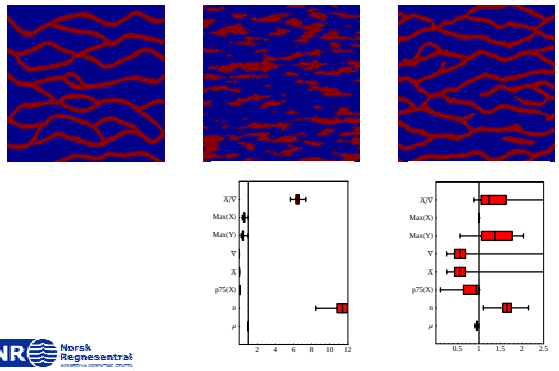
Variogram-based training image

Seq. indicator simulation — Multipoint



Channel-like objects

Seq. indicator simulation — Multipoint



Simulation from a pixel based model

Markov Random Field

Markov Chain Monte Carlo
- set up probability function p(z)
- create a Markov Chain in the space of grid configurations, transition probabilities determined by conditional probability function
- when converged: samples are independent realisations of the probability function p(**z**)
- requires many many visits of each grid cell, CPU!

- Sequential simulation
  - set up a set of conditional probabilities
  - run through the grid once, condition only on visited cells
  - resulting configuration is a realisation of the probability distribution

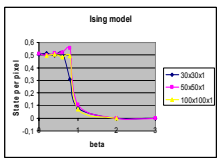
$$p(\mathbf{z}) = p(z_1)p(z_2|\,z_1)\,p(z_3|\,z_2, z_1)\ldots p(z_N|\,z_{N-1}, \ldots z_2, z_1)$$

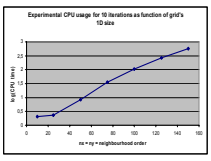
Multipoint algorithms

Random path sequential simulation
- same as sequential simulation, but visit the cells in random order
- resulting probability distribution depends on the path

Implemented simulation methods

- **MCMC simulation with Gibbs update**
  - rotational symmetric neighbourhood, general 2-particle interactions

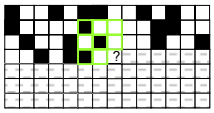




Implementation works and is OK for small neighbourhoods. Horrible CPU usage for large neighbourhoods

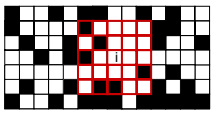
- **Sequential simulations**
  - random path/sequential path
  - optional restrictions on sequential neighbourhood: sphere, box

MPS as an MRF



Sequential simulation

η_i = "sequential neighbourhood"
$p(z_i | z_{j<i}) = p(z_i | z_j : j \in \eta_i)$



The resulting configuration is a realisation of an MRF, with known probability distribution

δ_i = MRF neighbourhood, can be expressed in terms of sequential neighbourhoods

- Random paths and data conditioning
  - Still an MRF realisation, path dependent
  - Randomizing over paths hence is directly related to randomizing over MRFs
- What are the consequences of this view?
- Relevant for the merging of MPS and MRF, from a theoretical point of view, and may be helpful for gaining insight to how MPS methods can be further improved

Parameter estimation for a model

- Stanford approach: frequencies from TI
  - scan the TI and count frequencies for certain predefined configurations
- Common method: maximum likelihood (pseudo)
  - method for estimating the parameters of a predefined model
  - requires a parametrized model to be set up
  - normalisation constant often a problem

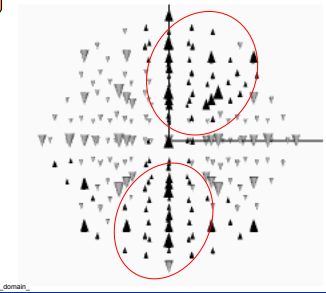
MRF –the need for model simplification

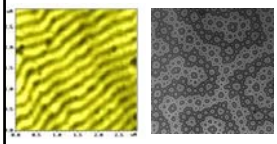
- Hammersley-Clifford theorem gives most general form of an MRF
  - one independent parameter for each configuration of every set of pixels where all are neighbourgs
  - hugh number!
  - simplification of model necessary
- Guidelines:
  - model simplicity
  - must be able to generate patterns like those in the TIs
    - lumps of facies, lump shapes different for the various TIs

Examples from physics – magnetic systems

Magnetic moment ↔ Facies

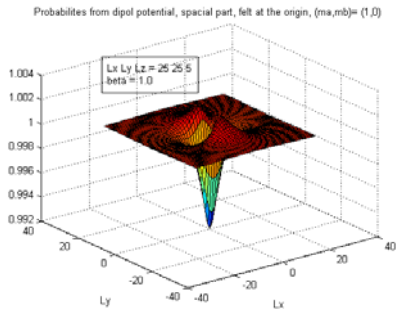
Magnetic domains. Crystalic sphere, dipole interactions. Simulation (Heidi, 2001)





http://www.ntmdt.ru/Application-Notes/Science_Technology_Applications/Magnetic_measurements/Investigations_of_the_domain_structures_of_the_magnetic_materials/text21.htm

Magnetic dipole interactions



not normalized

MRF –initial choice of model

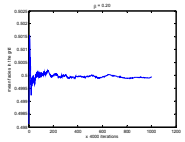
- Two-particle interactions
  - $p(\mathbf{z}) = Z^{-1} \exp\{ -\Sigma_{1 \le i < j \le N} G_{ij}(z_i, z_j) \}$
  - Potential "energy": $G_{ij}(z_i, z_j) = G_{ij}(z_i, z_j, \mathbf{r}_i - \mathbf{r}_j)$
- Generally not identical to a restriction to variogram based methods
  - MPS ideas go beyond variogram methods, important to keep that aspect
- Important with large neighbourhoods

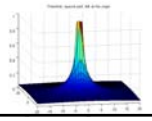
Initial results from MCMC simulations, 1D

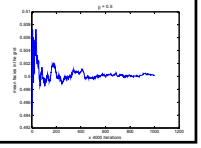
- **1D**: $G_{\beta}(z_i, z_j) = -\beta\, I(z_i, z_j)\, 1/|\mathbf{r}_i - \mathbf{r}_j|$
- Higher β gives stronger coupling between facies of the same kind, hence expect larger bodies

β = 0.20:

β = 0.50:







Initial results from MCMC simulations, 2D

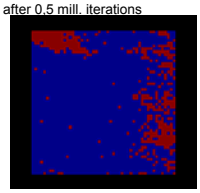
2D:

$G_{\beta}(z_i, z_j) = -\beta\, I(z_i, z_j)\, 1/|\mathbf{r}_i - \mathbf{r}_j|^3$

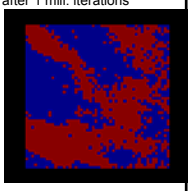
Grid: 50x50

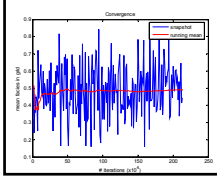
Neighbourhood cut off at r = 20 pixels

after 0.5 mill. iterations

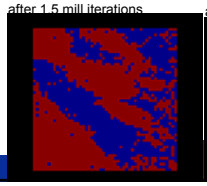


after 1 mill. iterations

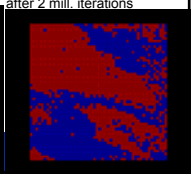




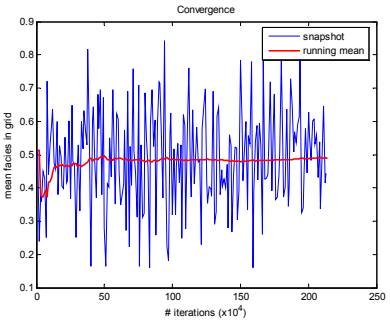
after 1.5 mill iterations



after 2 mill. iterations



Convergence for 2D

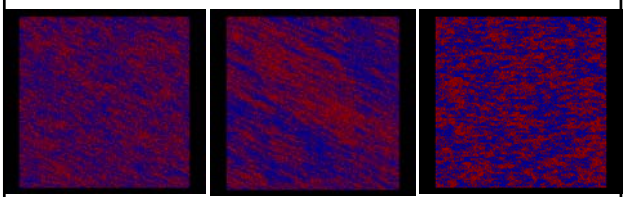


Initial results from MCMC simulations

- **2D**: Immediate phase transition observed for a number of tests, while others give seemingly random results
  - approximation of the MRF based on frequency estimation from TIs
  - $1/r$ and $1/r^2$ potensials
  - trade off between interaction strength at a distance and the number of interacting particles

Initial results from sequential simulations

Common: •grid = 250x250
•Gij(zi, zj) = -β I(zi, zj) 1/|**ri** - **rj** |3
•dependence on all previously visited cells



Sequential path, β=0.5 | Sequential path, β=0.7 | Random path, β=0.7

To do in immediate future

- Establish parametrized model
- Implement parameter estimation (likelihood)
- Cluster algorithms for better performance of MCMC
- Set up plan for tests

www.nr.no

Tumod – an overview

Sand-session.February 2006 - Oslo

Modeling of submarine sediment gravity flows

Petter, Bjørn, Ragnar

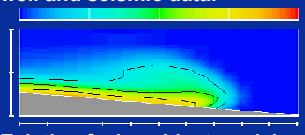
What is a turbidite?

A sedimentary deposit formed by a turbidity current.

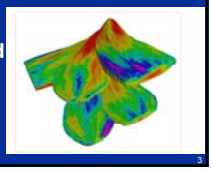
- **Turbidity current?**
  - "An influx of rapidly moving, sediment-laden water down a slope into a larger body of water; also called a density current because the suspended sediment results in the current having a higher density than the clearer water into which it flows."
  - Such currents can occur in lakes and oceans.

Why new approach?

- **Process models have a hard time honouring well and seismic data.**

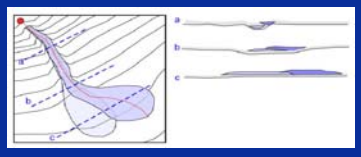


- **Existing facies object models have too simplistic geometry and incorrect interaction between flow events.**



Basic idea

- **Use simplified physical flow process to generate channel/lobe shapes fast.**

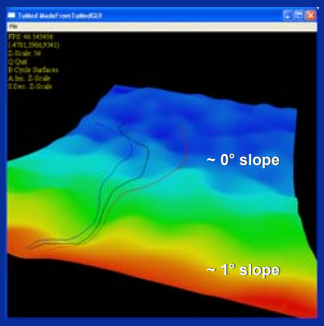


- **Multiple events (10-1000?) flows generated chronological.**
- **Minor stochastic element added to the physical process.**
- **Allows us to honor data by intelligent trial and error.**

Main forces on a fluid particle

- **Gravity**
  - **Force the particle downhill.**
- **Friction**
  - **Surface friction, currently set to zero.**
  - **Fluid friction.**
- **Normal**
  - **Force normal to underlying surface.**

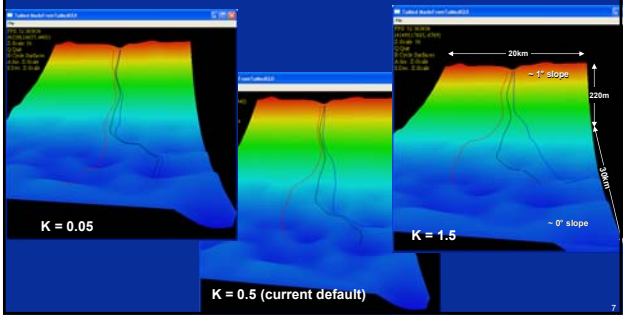
We use three lines: centreline, left and right



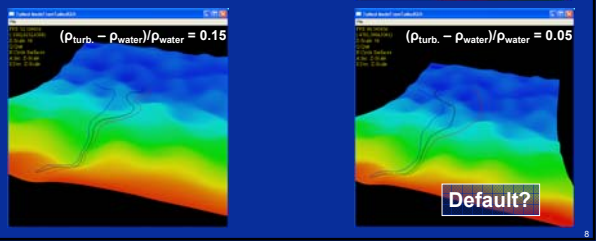
- **More lines:**
  - **Too much CPU.**
  - **Too much crossing.**
- **Repulsion:**
  ~ 1/(Distance to centreline)

Repulsion

- Force = K / (Distance to centreline)



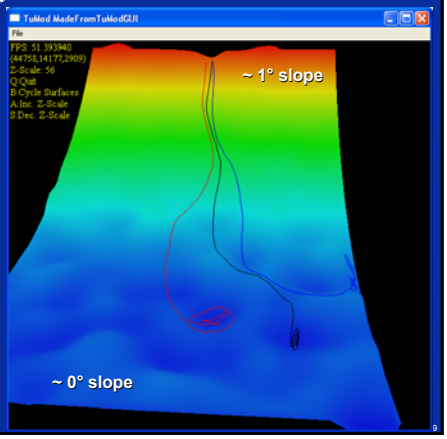
Density and velocity determines sensitivity to topography.



Turbidite trapped

Unable to pass small hills unless very low density.

We are unable to make a turbidite from this. ⊗



Deposition and erosion

- Early deposition and erosion model failed.
  - Deposition rate did go as: K_1 *(Current mass).
  - Erosion rate did go as: K_2*(v – v_{limit}).
- A new approach to solve problem needed.
  - Currently testing method formulated by Leo C. Van Rijn.

Rijn's method for a 1D-case

- Assumptions (some!)
  - Turbidity current schematized into two layers:
    - Upper layer with low concentration of sediment.
    - Lower layer with high concentration.
  - Steady flow.
  - Velocity and sediment concentration negligibly small in upper layer.
  - Flow in lower layer is fully turbulent.
  - Pressure is hydrostatic.

Two-layer schematization method

- Equations give for lower layer:
  - Velocity
  - Concentration
  - Thickness
- Complicated:
  - 15-20 input values.
- Only one dimension.
- Handle large space-steps badly.
- Fast.

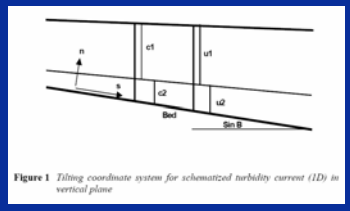


Figure 1 *Tilting coordinate system for schematized turbidity current (1D) in vertical plane*

Equations (some)

- Thickness gradient

$$\frac{\partial h_2}{\partial s} = \frac{[1/(\gamma_2(1-c_2))][\gamma_1(1-c_1)\cdot(1-c_2)(\tau_1+\tau_b) - \Delta\rho_{21} g h_2 (W_1+W_b) - \gamma_2 c_2 \frac{\partial \tau_1}{\partial s}]}{}$$

with:

$\gamma_1 = (\rho_1-\rho_w)h_1 c_1 g \sin\beta$

$\gamma_2 = (\rho_2-\rho_w)h_2 c_2 g \cos\beta \cdot \rho_2 (u_2)^2 = (\rho_2-\rho_w)h_2 c_2 g \cos\beta\,[1-(h_{2cr}/h_2)^3]$

$\gamma_2 = 2\rho_2 h_2 (u_2)^2 + (\rho_2-\rho_w)(1-c_2)h_2 (u_2)^2 + 0.5(\rho_2-\rho_w)(1-c_2)(h_2)^2\, g \cos\beta$

mass balance for fluid in lower layer 2

$\partial(u_2 h_2(1-c_2))/\partial s - W_1 - W_b = 0$

mass balance for sediment in lower layer 2

$\partial(u_2 c_2 h_2)/\partial s - S_1 - S_b = 0$

with :

h_1, h_2 = thickness of upper and lower layer ($h_1+h_2=h$=flow depth),

c_1, c_2 = depth-averaged volumetric suspended sediment concentration in upper layer 1and lower layer 2,

$u_1=q_1/h_1$, $u_2=q_2/h_2$ = velocity in upper layer 1 and lower layer 2,

W_1= exchange of fluid at the interface,

W_b = exchange of fluid at the bed,

S_1 = exchange of sediment at the interface,

S_b = exchange of sediment at the bed,

ρ_2 = mixture density of lower layer,

ρ_w = fluid density (clear water in upper layer 1),

ρ_s = sediment density,

τ_1 = shear stress at interface (= $\rho\, C_{fi}\, u_2^2$),

τ_b = bed shear stress (= $\rho\, C_b\, u_2^2$),

C_b = bottom friction coefficient (= g/C^2), C = Chézy coefficient,

C_{fi} = interface friction coefficient,

β = angle of bed slope in s-direction,

s = coordinate along bed slope.

Zaire canyon

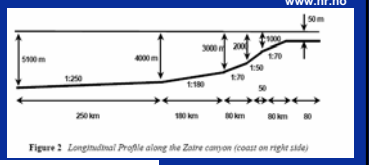
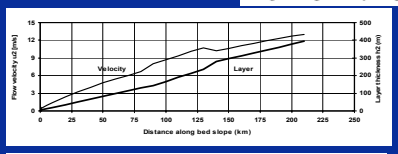
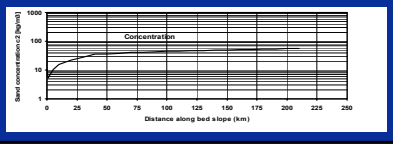


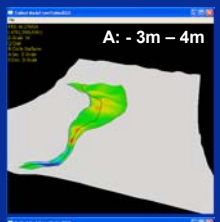
Figure 2 *Longitudinal Profile along the Zaire canyon (coast on right side)*

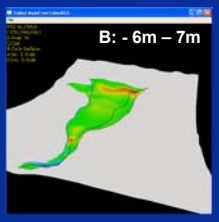


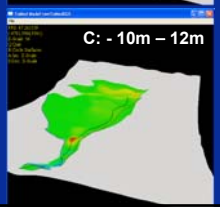


Leo C. Van Rijn's results.

Stacking turbidites

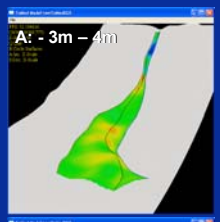


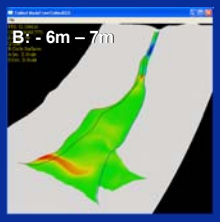


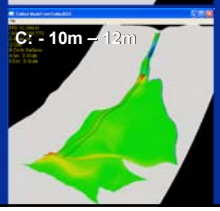


Old deposition and erosion method.

Seen from below



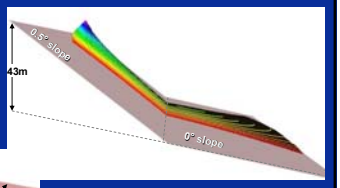


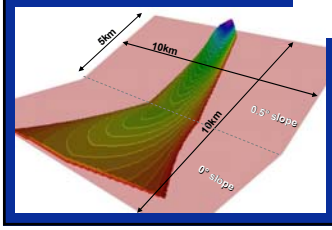


Current status

- Centreline physics.
  - Kinematics OK.
    - Gravity driven.
    - Centripetal forces, ocean currents, coriolis…
    - Speed?
  - Friction OK.
  - Density?
- Width of turbidite?
- Mass deposition?
- Erosion?
- Stopping criteria – mass exhaustion and or speed?

Deposition



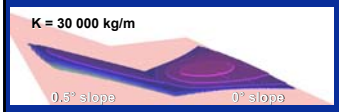


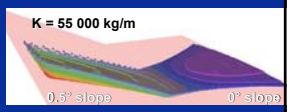
Erosion

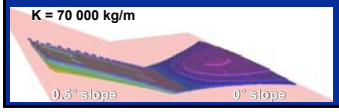
- Adds mass to turbidite.
- Mass rate goes as:

$$K\,(v - v_{limit})$$

- Slows down turbidite.
  - Friction? (None presently)
  - Added mass reduce speed.

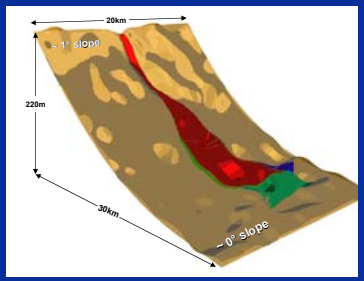




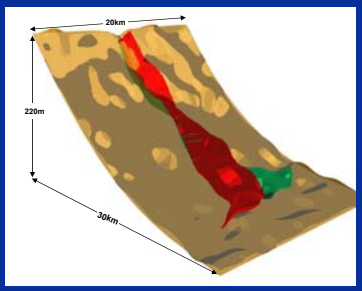


6 small turbidites

Stacked because they are small and extremely flat.

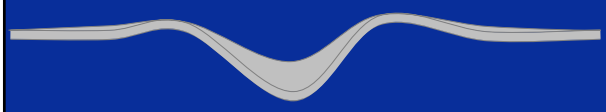


2 large turbidites



Deposition between turbidite events

- Hemipelagic
  - Constant thickness
- Infill from numerous small flows
  - Fills up accommodation space



We observe

- Little repulsion.
- Unstable behaviour:
  - Erode at the same place: Deep ditches.
  - Deposit at the same place: Big piles.
- Every new turbidite usually becomes wider.

Important problems

- What is the turbidite profile?
  - Shape and width?
- What are reasonable speeds?
- What are reasonable volumes (masses)?
- What is the density of the flow?
  - Should it decrease?

- Many parameters to tune.

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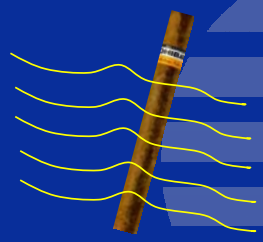
COHIBA



A program for efficient modeling of multiple subsurfaces

Keywords

- Gaussian fields
- seismic depth conversion
- multi-layer models
- ambiguous models
- inequality constraints

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Limitations in current storm-horizon:

- Cannot satisfactorily handle horizontal wells
- Slow on large problems:

  Troll study showed significant speed limitations
  - 93 wells, 24 surfaces, 50 x 50 cells
  - 191 x 351 grid points

  CPU time: 10h .

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Goals of COHIBA

1. Use available information from horizontal well paths
2. Increased efficiency – can handle large studies like Troll
3. Robustness
   - Accept any input data
   - Report inconsistent or erroneous data

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Robustness

- Current storm-horizon and old horizon_dc:
  - Require perfect data
  - No feedback on possible errors in data
- COHIBA will:
  - accept any data without aborting
  - automatically repair inconsistent data (problem in Troll study)
  - detect possible errors in data and report them in an understandable way

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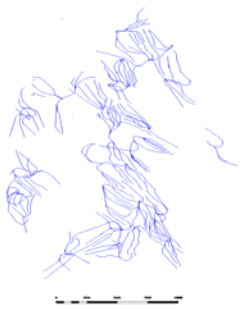
Storm-horizon tests on Troll

thanks to Pål...

Well trajectories in Troll west



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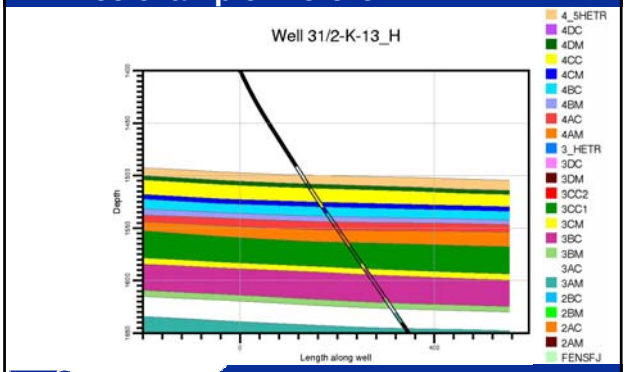
Nice example: Before



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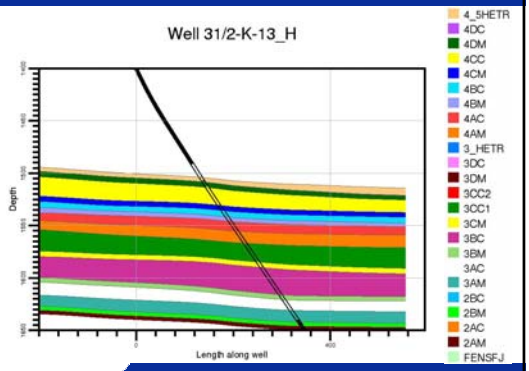
After Horizon:



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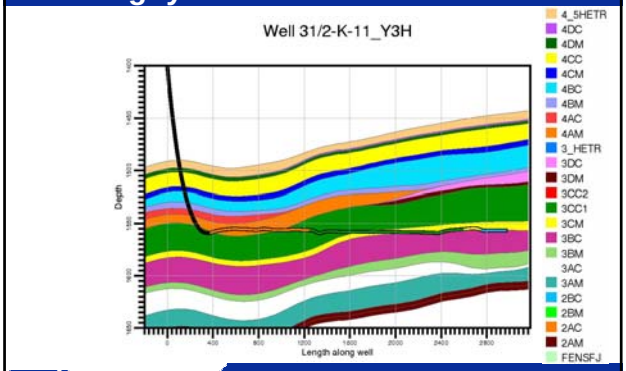
Bad guy: Before



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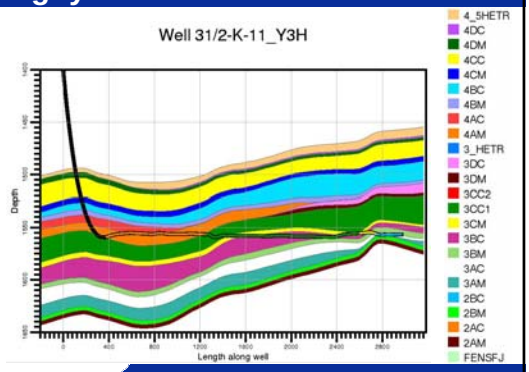
Bad guy: After



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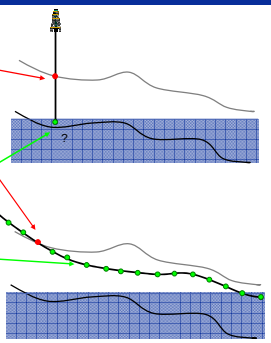
Remedies to deal with ….

Horizontal wells

Horizontal wells – conditioning on inequalities

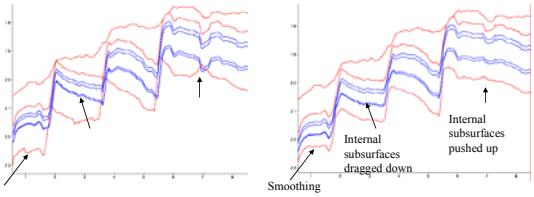
- Old versions can only use well intersections
- COHIBA should be able to use the whole well path



Kriging
Multiple models…

Predicted cross section of Fram

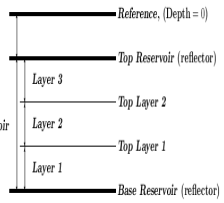
- "Straight forward"
- Combining models



Multi-layer models

- Two basic assumptions:
  - Thickness/Velocities of each interval modelled independently
  - Depth given by sum of intervals above

→ Use relation: $\Delta Z = V \Delta T$ *Reservoir*



- Errors are model by Gaussian fields:

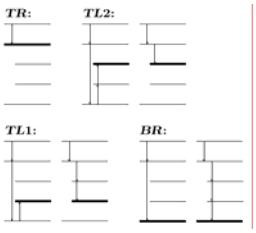
$$V = \tilde{V} + R_v$$

$$\Delta T = \Delta t + \Delta R_t$$

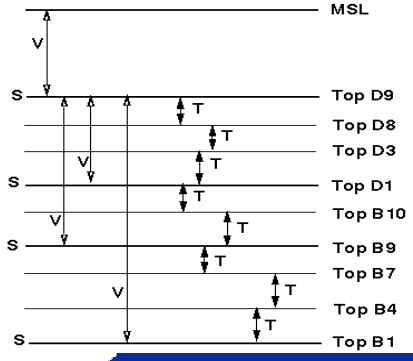
Ambiguous description of surfaces?

- At most two alternatives for each layer:

→ Do a clever weighting of models.



Lasagne from the North Sea



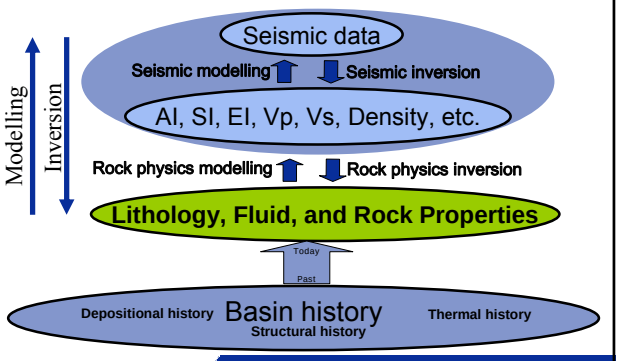
FIND 2004 – 2005

Odd Kolbjørnsen
Ragnar Hauge
Heidi Kjønsberg
Pål Dahle
Per Røe
Petter Abrahamsen

Summary

- Work scope
  - 6 people
  - kNOK 3500
  - Planned 2006:
    - kNOK 2000
- Work area
  - Rock physics simulations
  - Seismic inversion
  - Methodology testing
  - Case studies
- Products:
  - Scenario
  - P-map
  - LFP - Risk
  - PCUBE
    - LFP
    - Property prediction
    - Volume
  - 1D Object model inversion

Geology - Seismic data graph



Lithology and Fluid Prediction = LFP

Forward model:

LF class → rock physics → Elastic parameters → convolution → Seismic

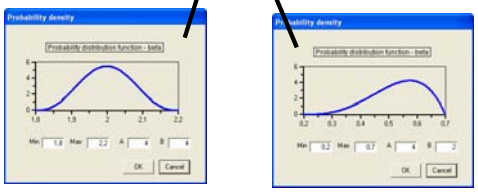
Bayesian LFP:

$$p(\mathrm{LF}\,|\,\mathrm{Seismic}) = \iiint_{\mathbf{m}} p(\mathrm{LF}\,|\,\mathbf{m})\,p(\mathbf{m}\,|\,\mathrm{Seismic})\,d\mathbf{m}$$

PCUBE — Rock physics inversion — AVO inversion

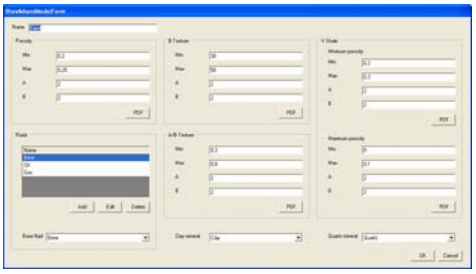
Rock physics - Shale

$$[V_P \quad V_S \quad \rho] = h_{\mathrm{Shale}}\left(\frac{V_P}{V_S}, W \,|\, \text{fixed parameters}\right)$$

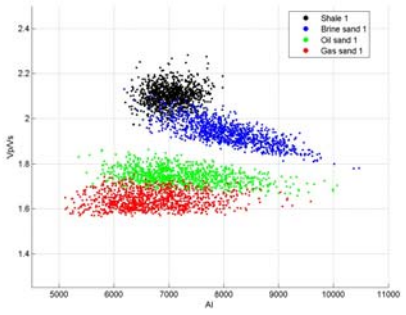


Rock physics - Sand

$$[V_P \quad V_S \quad \rho] = h_{\mathrm{Sand}}\left(\mathrm{Fluid}, \varphi, V_{sh}, \alpha, \beta | \text{fixed parameters}\right)$$



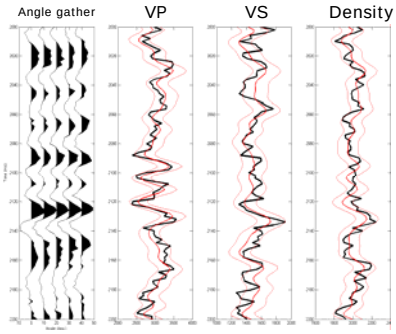
Rock physics simulations



PCUBE: Seismic AVO/AVA inversion

- Simultaneous inversion
- Angle dep. Wavelets
- Aki & Richards
- Convolutional model
- Parameter correlation
- Fast

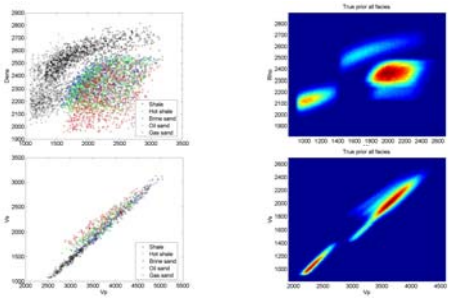
Buland & Omre, 2003,
Geophysics, **68**, 185-198.



Distribution of elastic parameters

p(m|LF)

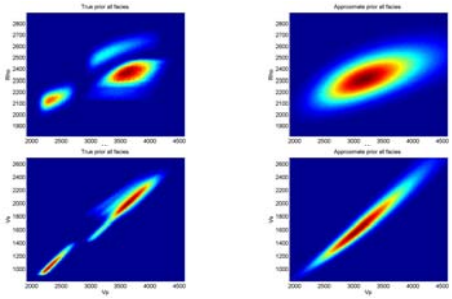
p(m) = ∑ P(LF) p(m|LF)



Approximate distribution of elastic parameters

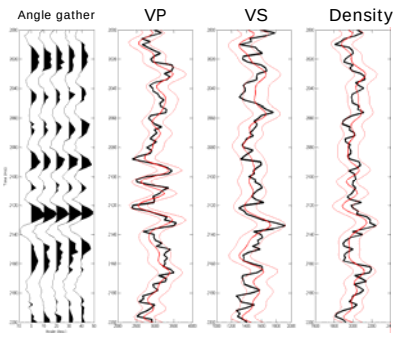
p(m)

p*(m)



PCUBE: Seismic AVO/AVA inversion

- Simultaneous inversion
- Bayesian method
  - Includes uncertainty



PCUBE - sketch

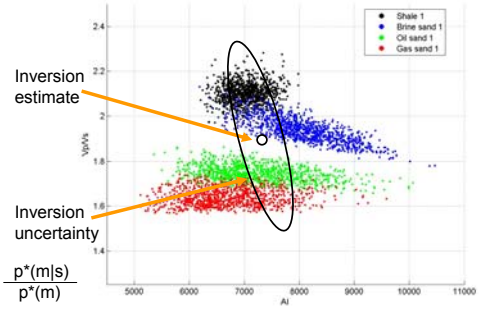
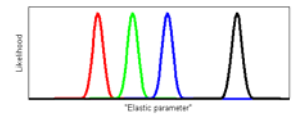


Illustration along one elastic parameter

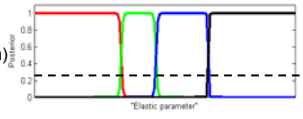
Rock physics distributions

Prior:
P(Gas) = 0,25
P(Oil) = 0,25
P(Brine)= 0,25
P(Shale)= 0,25

p(m|LF)



P(LF|m)



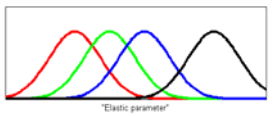
Prior=0,25

Illustration along one elastic parameter

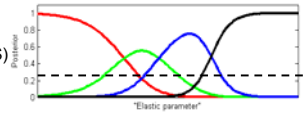
Rock physics distributions blurred with seismic uncertainty

Prior:
P(Gas) = 0,25
P(Oil) = 0,25
P(Brine)= 0,25
P(Shale)= 0,25

p(s|LF)



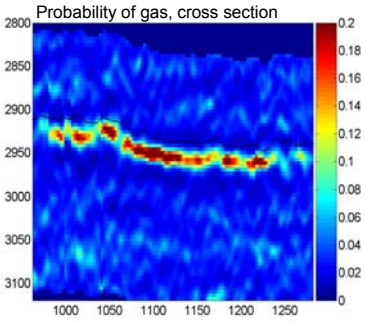
P(LF|S)



Prior=0,25

PCUBE – Output

- Marginal probabilities of LF classes
- Challenge: Combine marginal probabilities to volume probabilities
- Filling principle



Filling principle

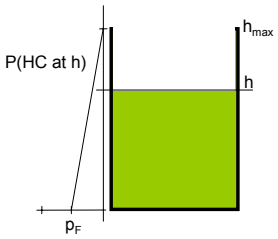
Given the marginal probabilities, p(x), for hydrocarbons at all locations in a cube, $x \in C$

If there are hydrocarbons at a location x_0 with marginal probability $p(x_0) = p_0$ then there are hydrocarbons at all positions with marginal probabilities larger than p_0, i.e. $\{x: p(x) > p_0\}$

Filling principle, Example

- How much HC in the bucket?
- $P(H > 0) = p_F$
- $P(H > h) = p_F \cdot (1 - h / h_{max})$

Any volume equally likely.



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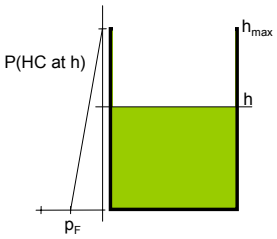

Filling principle, Example

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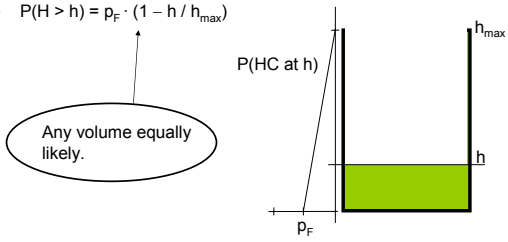

Filling principle, Example

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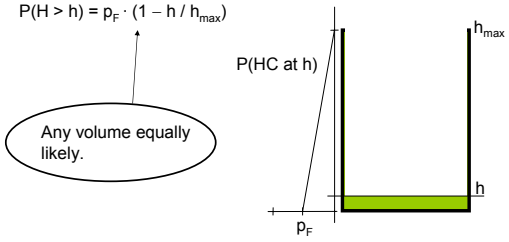
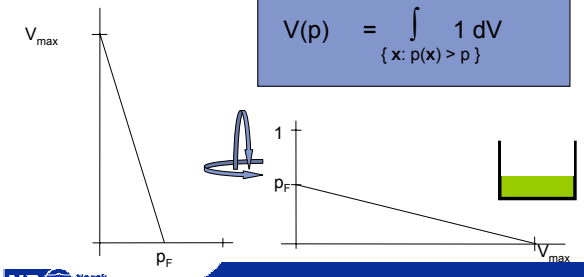


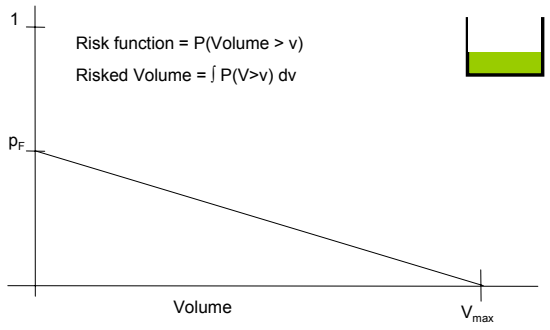
Volume-probability curve

- Count cells with probability larger than or equal to a given probability.

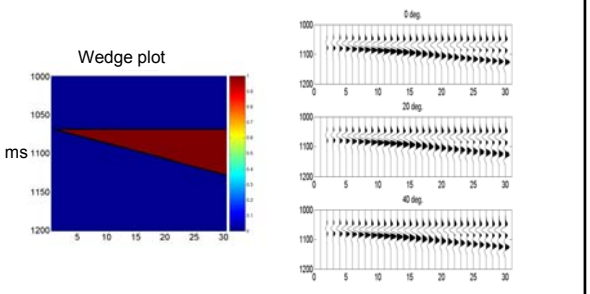
$$V(p) = \int_{\{x:\, p(x) > p\}} 1 \, dV$$



Volume-probability curve (bucket)

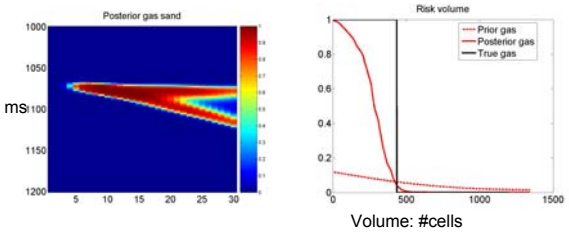


Wedge example



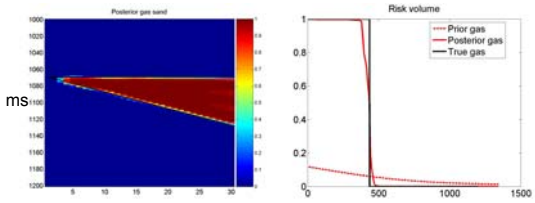
Wedge probabilities

Case: medium seismic quality



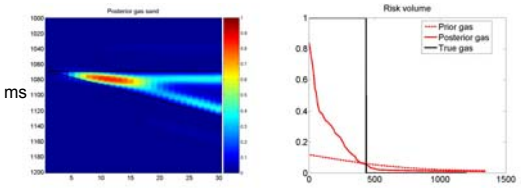
Wedge volume

Case: good seismic quality

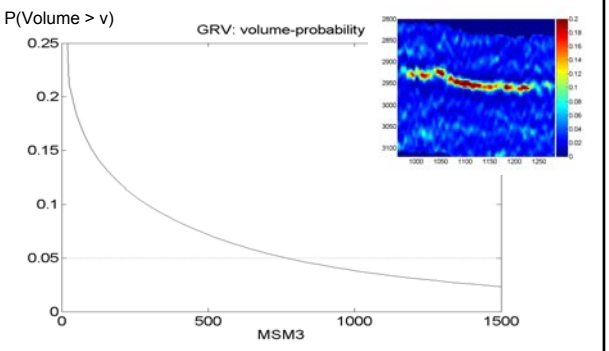


Wedge volume

Case: poor seismic quality



Volume-probability curve; GRV



Property prediction given LF-class

- Identical rocks filled with gas and brine will give different seismic response.
- Identical seismic response can come from gas and brine filled rocks, but only if the rocks are different.

Expected properties given seismic depends on Lithology-Fluid class

Property prediction - formula

$$E(\varphi \mid \mathrm{LF}, \mathrm{Seismic}) = \iiint_{\mathbf{m}} \underbrace{E(\varphi \mid \mathrm{LF}, \mathbf{m})}_{\text{Rock model}} \underbrace{p(\mathbf{m} \mid \mathrm{LF}, \mathrm{Seismic})}_{\text{PCUBE}} d\mathbf{m}$$

- Extension of PCUBE
  - Rock modelling
  - Seismic AVO inversion
- Marginal estimates of properties, e.g. expected porosity

How to solve it

p(**m** | LF, Seismic)

= p(**m**,LF | Seismic) / p(LF|Seismic)

= p(**m**|Seismic) p(LF| **m**, Seismic) / p(LF|Seismic)

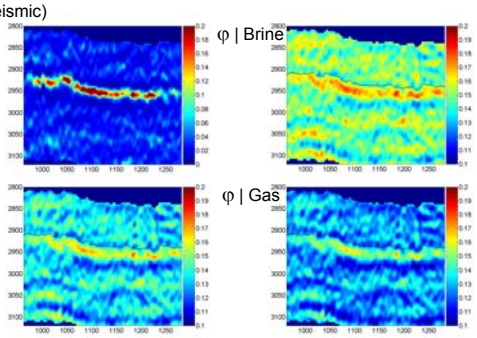
New term — Almost PCUBE

$$E(\varphi \mid \mathrm{LF}, \mathrm{Seismic}) = \frac{\iiint_{\mathbf{m}} E(\varphi \mid \mathrm{LF}, \mathbf{m})\, p(\mathrm{LF} \mid \mathbf{m})\, p(\mathbf{m} \mid \mathrm{Seismic})\, d\mathbf{m}}{p(\mathrm{LF} \mid \mathrm{Seismic})}$$

PCUBE

Expected porosity sand facies

P(gas|seismic)



φ | Brine

φ | Oil

φ | Gas

HC volume prediction

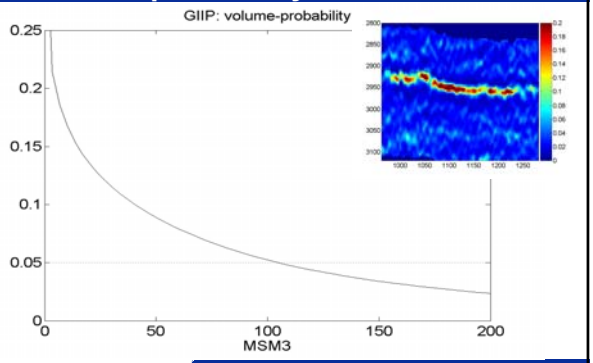
- Add expected property values in cells with probability larger than or equal to a given probability.

Property prediction

$$V_{HC}(p) = \int_{\{\mathbf{x}:\, p(\mathbf{x}) > p\}} E\{\varphi\, s_{HC} V_p \,|\text{Seismic,HC}\}\, dV$$

PCUBE

Volume-probability curve; GIIP



Norsk Regnesentral
NORWEGIAN COMPUTING CENTER

Evaluering av SANDs mål i 2005

STRATEGISKE HOVEDOPPGAVER	1. tertial	2. tertial	Årsmål
Opprettholde den sentrale posisjonen internasjonalt i fagområdet gjennom utfordrende prosjekter.			
Øke volumet i oppdragsmarkedet		1 åv	1,5 åv A

MARKEDS- OG FAGMÅL Innsatsområder, forskningsinntekt (inkl. GB)	1. tertial	2. tertial	Årsmål
Utenlandske oljeselskap (03:0,3 mill, 04: 0,35, 05: 0,7)	0,5 mill	1 mill	2 mill, B
Usikkerhetsmodellering (03: 1.5 mill, 04: 2,4, 05: 3,4)			2 mill, A
Historietilpasning/dynamiske data (03: 0,04:0, 05:0,04)			0.5 mill, D
Forkastninger HAVANA (03: 1,5 mill, 04:1,3, 05:1,7)	0,4 mill	0,8 mill	1,5 mill, A
Nye reservoartyper (dypmarin) (05: 1,5mill)	0,3 mill	0,6 mill	1 mill, A
Nye reservoartyper (karbonat/MP) (05: 0,6mill)	0,3 mill	0,6 mill	1 mill, B
Etablere 90% og 100% sikre prosjekter for 2006 (12,6mill)	2 mill	2 mill	6mill, AA
Etablere nye fagområder/porteføljer på min. 1 mill (MP?)			1, D

SAMARBEID Strategiske kunder/partnere	1. tertial	2. tertial	Årsmål
UiB/CIPR på geologi (TuMod, Fault Facies)			B
Complex Flow Design i KMB			C
Sentrale kunder			
Roxar, prosjektvolum (03: 1,5 mill, 04: 0,8 mill, 05: 0,9)	0,5 mill	1 mill	1,5 mill, B
Statoil, prosjektvolum (03: 1,3 mill, 04: 2,5 mill, 05: 4)	0,5 mill	2 mill	3 mill, A
Norsk Hydro, prosjektvolum (03: 3 mill, 04: 3, 05: 4,5)	0,5 mill	2 mill	3 mill, A

PROFILERING Publisering/konferanser	1. tertial	2. tertial	Årsmål
Int. tidskriftart. (innsendt). (01: 4, 02:2, 03:2, 04:0, 05:2)			4, C
Int. tidskriftart. (publ.). (99:5, 00:5, 01:4, 02:1, 03:3, 04: 0, 05:5)			3, A
Konferanseart. med ref. (99:7, 00:11, 01:1, 02:1, 03:5, 04: 2, 05:10)			5, A
Notater og rapporter (99:15, 00: 14, 01: 8, 02: 7, 03: 7, 04: 15, 05: 16)			10, A
Øvrige foredrag og innlegg (99:5, 00: 9, 01:5, 02:0, 03:8, 04: 11)			8, A
Diplomstudenter/sommerjobb		2	F

MEDIEOPPSLAG (data innhentet av CyberWatcher)	1. tertial	2. tertial	Årsmål
Totalt antall medieoppslag [fra CyberWatcher] (99: 0, 00: 0, 01: 0, 02: 0, 03:0, 04: 0, 05:1)			2, C
Artikler/saker som er skrevet av SAND-ansatte eller SAND-ansatte har blitt intervjuet (antall saker/antall oppslag)			1, F
Saker som omtaler NR eller SAND-ansatte (antall saker/antall oppslag)			1, F

PERSONAL	1. tertial	2. tertial	Årsmål
Nyansettelser (99: 1, 00: 3, 01:2, 02: 3, 03:0; 04: 0, 05:3)	1	1	2, A
Årsverksekvivalenter (01: 12,9, 02: 12,5, 03: 10,4, 04: 10, 05: 10)			11, A

ØKONOMI	1. tertial	2. tertial	Årsmål
Finansielt resultat (99:-0,9, 00:0, 01: 0,7, 02:0, 03: 0,9, 04:1,4, 05:?)	0,5 mill	1 mill	1,5 mill, A

SAND RESULTAT 2005

	DENNE MÅNED:		12	AKKUMULERT etter		DESEMBER		
	Resultat	Budsjett	Avvik	Resultat	Budsjett	Avvik	Budsjett 2005	Prognose 2005
INNTEKTER								
Forskningsprosjekter	1 090 000	746 270	343 730	13 821 000	8 716 000	5 105 000	8 716 000	12 653 977
Instituttprosjekter	183 000	65 842	117 158	769 000	769 000	0	769 000	769 000
Utviklingsfond	0	0	0	0	0	0	0	
Sum prosjektinntekter	1 273 000	812 113	460 887	14 590 000	9 485 000	5 105 000	9 485 000	13 422 977
Internhandel								
Salg av timer	0	0	0	598 000	0	598 000	0	584 000
Kjøp av timer	98 000	0	98 000	1 261 000	0	1 261 000	0	1 051 000
Sum internhandel	-98 000	0	-98 000	-663 000	0	-663 000	0	-467 000
Direkte utlegg	84 000	29 167	54 833	1 469 000	350 000	1 119 000	350 000	830 000
FORSKNINGSINNTEKTER	**1 091 000**	**782 946**	**308 054**	**12 458 000**	**9 135 000**	**3 323 000**	**9 135 000**	**12 125 977**
UTGIFTER								
Direkte belastet gruppen								
Lønn og sosiale utgifter	1 035 786	515 727	520 059	7 114 265	6 033 678	1 080 587	6 033 678	6 726 000
Dr. grad støtte	0	0	0	0	0	0	0	0
Diverse lønnskostnader	0	0	0	0	0	0	0	0
Kompetanseutvikling	2 010	14 543	-12 533	381 242	174 512	206 730	174 512	330 000
Bøker/tidsskrifter	3 656	4 252	-596	54 548	51 022	3 526	51 022	51 022
Medlemsskap	401	1 546	-1 145	16 606	18 553	-1 947	18 553	18 553
Markedsføring	5 097	5 798	-701	97 699	69 575	28 124	69 575	80 000
Sosialt på gruppen	3 970	2 319	1 651	11 720	27 830	-16 110	27 830	27 830
Diverse utgifter	23 095	2 396	20 699	106 321	28 758	77 563	28 758	119 000
Sum belastet gruppen	1 074 015	546 581	527 434	7 782 401	6 403 927	1 378 474	6 403 927	7 352 405
Dekningsbidrag I	**16 985**	**236 365**	**-219 380**	**4 675 599**	**2 731 073**	**1 944 526**	**2 731 073**	**4 773 572**
Andel Fellesutgifter	189 466	192 959	-3 493	2 273 570	2 315 510	-41 940	2 315 510	2 273 572
Resultat	**-172 481**	**43 406**	**-215 887**	**2 402 029**	**415 563**	**1 986 466**	**415 563**	**2 500 000**

ÅRSPLAN 2006 - SAND

HOVEDMÅL FOR SAND I 2006

Ha et høyt faglig nivå i gruppen ved hjelp av faglig utfordrende prosjekter.
Forbedret synliggjøring av vår internasjonale ekspertise på matematisk/stokastisk modellering av geologi.
Øke volumet til 14 årsverk.

Status

SAND har konsentrert sitt arbeid i en nisje innen petroleumsbransjen. Innen denne nisjen er vi blant de internasjonalt ledende miljøene. Gruppen har en blanding av ansatte med statistikk-, matematikk- og fysikkbakgrunn. De fleste er erfarne i arbeid mot petroleumsbransjen.

Etablerte aktiviteter

Det mangeårig gode samarbeidet med softwareleverandøren Roxar ønskes opprettholdt. Vi er samarbeidspartner i et prosjekt finansiert av NFR og Statoil der vi får oppdrag for 2 mill i 2006. I tillegg vil vi undertegne en rammeavtale med Roxar der vi får garantert et årlig minimumsbeløp i størrelsesorden 2-3 mill i 3 år fremover. Motytelsen er at vi avstår fra å utføre oppdrag for deres konkurrenter. Resultatet er at vi ser for oss et betydelig øket oppdragsvolum fra Roxar i årene fremover i forhold til volumet i 2005.

Det er nå to store norske oljeselskaper med operatøransvar: Hydro og Statoil. Det vil være viktig å opprettholde samarbeid med disse og målet er å øke oppdragsmengden fra disse.

I 2005 hadde vi ca. 3 mill fra NFR. Prosjektvolumet mot NFR vil antagelig ligge på 4 mill i 2006. Veksten kommer fra en KMB (PETROMAKS) som vi har i samarbeid med NTNU og Stanford University. Finansieringen vil vare i 3 år og er en fantastisk god mulighet til spennende vitenskapelig arbeid med trygg finansiering.

De senere år har SAND hatt en betydelig aktivitet innen modellering av forkastninger, primært gjennom utviklingen av softwaremodulen Havana. For 2006 ser det ut som om denne aktiviteten blir redusert. Som en kompensasjon kommer nå Havana til nytte i et samarbeidsprosjekt vi har med UiB/CIPR.

Usikkerhetsmodellering og beslutningsstøtte er blitt en betydelig aktivitet som i 2005 vil ha et omfang på nesten 3 mill. Våre kunder er hovedsakelig Hydro, Lundin og OD, men håpet er å få Statoil på kundelisten. For 2006 er prognosene relativt lave på dette området, men erfaringsmessig kan dette ta seg kraftig opp.

Seismisk inversjon har de senere år vært en aktivitet i voldsom vekst. I 2005 vil vi utføre oppdrag for bortimot 4 mill på dette området. Hvis vi greier å opprettholde dette volumet skal vi være meget godt fornøyd. En hyggelig nyhet er at vi har fått en kontrakt med ENI (Agip) på 0,5 mill innen dette området og vi håper på en betydelig utvidelse.

Satsingsområder

1. *Reservoarbeskrivelse*. 3D modellering av geologiske sedimentære avsetninger og petrofysiske egenskaper i disse.
2. *Strukturmodellering*: Beskrivelse av flater, forkastninger og sprekker.
3. *Beslutningstøtte*: Kvantitativ beskrivelse av usikkerhet og risiko i forbindelse med boring og feltutbygging.
4. *Seismiske data*: Bruk av seismiske data i reservoarbeskrivelse og leting.
5. *Dynamiske data*: Bruk av dynamiske data som produksjonshistorie og trykktester i reservoarbeskrivelse.

Internasjonalisering

Våre aktiviteter har i alle år vært farget av at våre kunder er norske og primært har operert på norsk sokkel. Som følge av styrets ønske om å se på muligheter internasjonalt prøver vi derfor aktivt å trekke utenlandske oljeselskaper inn i noen prosjekter. I løpet av de siste årene har vi fått kontrakter med ConocoPhillips og ENI.

Vi ønsker i tillegg å etablere bedre kontakt med flere internasjonale fagmiljøer. Dette gir faglig påfyll og øker sjansen for å få tilsagn på NFR prosjekter.

Viktige og nye aktiviteter i 2006

1. *Modellering av dypmarine avsetninger.* Vi har i samarbeid med UiB et prosjekt som løper over tre år. Dette prosjektet finansieres av NFR, ConocoPhillips og Norsk Hydro.
2. *Usikkerhetsmodellering og risikohåndtering*. Utvikling av verktøy og metodikk for beslutningsstøtte. Dette er per i dag en stor aktivitet og vi ser et betydelig vekstpotensial. Viktigste kunder er Hydro, Lundin og OD. Vi håper å få Statoil som en stor ny kunde innen dette området. Her er det også mulig å selge tjenester internasjonalt.
3. *Inversjon av seismikk.* Vi har i samarbeid med Statoil utviklet en prototyp for seismisk inversjon som kalles CRAVA. Om og hvordan CRAVA skal kommersialiseres bør avklares i 2006. Vi har fått en kontrakt med ENI på 0,5 mill for bruk av CRAVA i 2006. Vi anser sjansene for en utvidelse som store. Vi har i tillegg en stor aktivitet for Statoil innefor leting der seismisk inversjon er en viktig faktor. Denne aktiviteten vil fortsette inn i 2006.
4. *Modellering av forkastningssoner.* Vi har et samarbeid med CIPR som kalles FaultFacies. FaultFacies finansieres av NFR, Statoil og ConocoPhillips. Dette er en spennende og ny utvikling der bl.a. HAVANA har vist seg å være et nyttig verktøy.
5. *Dynamiske data.* Disse datatypene innbefatter historiske produksjonsdata og produksjonstester. I samarbeid med Roxar og Statoil har vi fått et stort prosjekt som kalles FieldWatch innenfor dette området. Prosjektet strekker seg fra 2005-2007. Vi har også tro på at Hydro vil interessere seg for lignende problemstillinger i 2006.
6. *Multipoint statistikk***.** Dette er en statistisk metode med stort potensial og det er store forventninger internasjonalt til metoden. NFR, Hydro og Statoil finansierer et treårig prosjekt innen dette området som vil pågå i 3 år. Prosjektet er et samarbeid mellom NR, NTNU og

Stanford University. ENI har uttalt interesse for dette prosjektet så vi håper på ekstra finansiering fra dem.

7. *COHIBA (kostbar cubansk cigar).* Nyutvikling av et verktøy for å beskrive flatene som avgrenser geologiske formasjoner og reservoarer. Stort prosjekt (3,7 mill i første omgang) som har både faglige og programmeringsmessige utfordringer. Prosjektet er finansiert av Hydro og Statoil. På sikt vil det være naturlig å kommersialisere dette gjennom Roxar men det er mange forretningsmessige føringer som gjør at et formelt samarbeid om dette foreløpig ikke er aktuelt.

Faglig utvikling

Det er et mål at SAND er synlig på de fleste relevante konferanser innen vår nisje. Bidrag der er viktig både faglig og for profileringen.

Med øket NFR finansiering burde det være mulig å øke publisering i vitenskapelige journaler.

Personell og rekruttering

Vi har ikke rekruttert i 2003 eller 2004 da vi ikke har greid å utvide markedet vårt. I 2005 har vi rekruttert to og fått en tilbake etter doktorgradspermisjon. For 2006 vil det være et mål å øke antallet årsverk med to da 2006 ser veldig bra ut. Det ønskes en jevnere kjønnsfordeling.

Det har ikke vært noen avgang fra gruppen de senere år. Dette medfører at langt de fleste i gruppen er svært rutinerte. Det er en av hovedårsakene til de særdeles gode økonomiske resultatene vi kan vise til de siste årene.

Gruppen er ganske sårbar med hensyn til avgang av noen nøkkelpersoner.

SANDs MÅL I 2006

STRATEGISKE HOVEDOPPGAVER	1. tertial	2. tertial	Årsmål
Opprettholde den sentrale posisjonen internasjonalt i fagområdet gjennom utfordrende prosjekter.			X
Etablere ny internasjonal akademisk kontakt			1
Forberede/sende inn ny PETROMAKS søknad			1
Øke volumet i oppdragsmarkedet			2 åv.

MARKEDS- OG FAGMÅL Innsatsområder, forskningsinntekt (inkl. GB)	1. tertial	2. tertial	Årsmål
Utenlandske oljeselskap (03:0,3 mill, 04: 0,35, 05: 0,7)	0,5 mill	1,0 mill	2,0 mill
Reservoarbeskrivelse (05: 2,5)	3,2 mill	3,2 mill	3,5 mill
Strukturmodellering (03: 1,5 mill, 04:1,3, 05:1,7)	3,3 mill	3,3 mill	3,5 mill
Beslutningsstøtte (03: 1.5 mill, 04: 2,4, 05:3,4)	1,2 mill	1,2 mill	2,0 mill
Seismiske data (0,5: 3,9)	2,4 mill	2,4 mill	3,0 mill
Dynamiske data (03: 0, 04:0, 05:0,04)	2,0 mill	2,0 mill	2,5 mill
Nye reservoartyper (karbonat?)	0,3 mill	0,6 mill	1,0 mill
Etablere 90% og 100% sikre prosjekter for 2007	7,0 mill	7,0 mill	9,0 mill
Etablere nye fagområder/porteføljer på min. 1 mill			1

SAMARBEID Strategiske kunder/partnere	1. tertial	2. tertial	Årsmål
UiB/CIPR på geologi (TuMod, Fault Facies)			X
Complex Flow Design i KMB			X
NTNU og Stanford I Multipoint prosjektet			X
Sentrale kunder			
Roxar, prosjektvolum (03: 1,5, 04: 0,8, 05: 0,9)	2,0 mill	2,0 mill	2,5 mill
Statoil, prosjektvolum (03: 1,3, 04: 2,5, 05: 4)	3,0 mill	3,5 mill	4,0 mill
Hydro, prosjektvolum (03: 3 mill, 04: 3, 05:4,5)	1,5 mill	3,0 mill	4,0 mill

PROFILERING Publisering/konferanser	1. tertial	2. tertial	Årsmål
Int. tidskriftart. (innsendt). (01: 4, 02: 2, 03: 2, 04: 0, 05:0)			4
Int. tidskriftart. (publ.). (99:5, 00:5, 01:4, 02:1, 03:3, 04: 0, 05:2)			2
Konferanseart. med ref. (99:7, 00:11, 01:1, 02:1, 03:5, 04: 2, 05:0)			3
Notater og rapporter (99:15, 00: 14, 01: 8, 02: 7, 03: 7, 04: 15, 05:16)			16
Øvrige foredrag og innlegg (99:5, 00: 9, 01:5, 02:0, 03:8, 04: 11)			8
Diplomstudenter/sommerjobb		2	

MEDIEOPPSLAG (data innhentet av CyberWatcher) (antall saker/antall oppslag)	1. tertial	2. tertial	Årsmål
Totalt antall medieoppslag [fra CyberWatcher] (99: 0, 00: 0, 01: 0, 02: 0, 03:0, 04: 0, 05:?)			2
Artikler/saker som er skrevet av SAND-ansatte eller SAND-ansatte har blitt intervjuet (05:1)			1
Henlagte saker som omtaler NR eller SAND-ansatte			2

PERSONAL	1. tertial	2. tertial	Årsmål
Nyansettelser (99: 1, 00: 3, 01:2, 02: 3, 03:0; 04: 0; 05: 2)		2	2
Årsverksekvival.(02:12,5, 03:10,4, 04:10, 05:11,9, 06:11,9)			14

ØKONOMI	1. tertial	2. tertial	Årsmål
Finansielt resultat (01:0,7,02:0,5, 03:0,9, 04:1,4, 05: 2,4)	0,5 mill	0,75 mill	0,95 mill

Norsk Regnesentral

www.nr.no

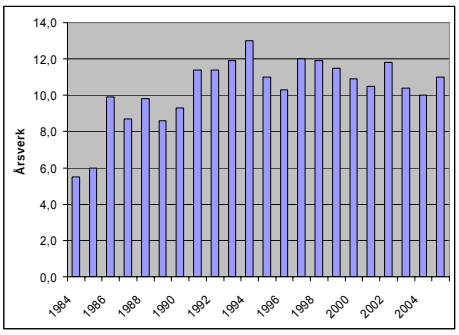
SAND historie

Petter Abrahamsen, 2006

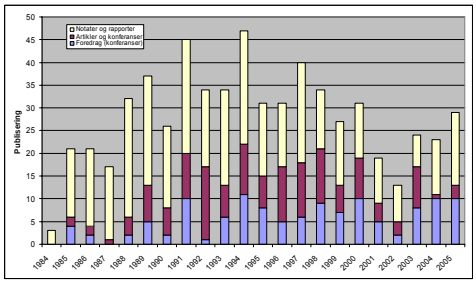
Tidslinje

	Faglige stikkord	Marked	Personell
1984			Henning starter SAND, Lars
1985			
1986	SISABOSA (Fluvial forgjenger), LITHOPRED		
1987	Miljøaktiviteten går til STAT, HORIZON 1		
1988	CLAPP		Petter, Håkon
1989	Rom-tid prosjektet (NTF) , Markov felt, EXPETR	Vinner Hydro anbud	
1990	MOHERES		Frode, Lars FS
1991	CONTSIM, HORIZON 4		
1992	HAVANA, FLUVIAL, GRUS, DepCon, STORM, C	Odin software & services	Arne, Henning går til NTNU
1993	DECISION, HORIZON/STORM, C++		Frode slutter
1994	SEQUENCE	Vinner Hydro anbud	
1995	TGSIM, Seismikk SIP (med IKU)	Odin og Geomatic blir til Smedvig	Ragnar
1996			Håkon går til NTNU
1997	GMPP, PUNQ (EU)		Harald, Jon (permisjon)
1998		Oljeprisen stuper	Anne Randi
1999		Smedvig T. blir Roxar, Saga konk	
2000	Petrosim		Ariel, Knut, Petter går til Roxar
2001	IKSIM, SAIGUP (EU)		Bjørn, Ariel stipend, Lars AD, Arne FS
2002			Per (GEM), Pål, Odd, Petter FS
2003	IRM-SIP (med NORSAR og IFE)	Kommersialisering HAVANA	
2004	CRAVA, TuMod (med CIPR) , FaultFacies (med CIPR)		
2005	COHIBA, Multipoint (med NTNU og Stanford), BoreRisk		Heidi, Ariel, Per til SAND

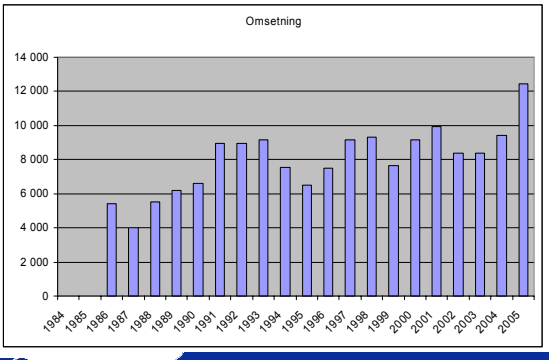
Antall årsverk



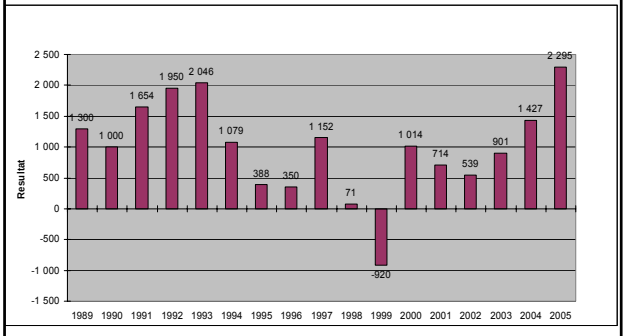
Antall artikler



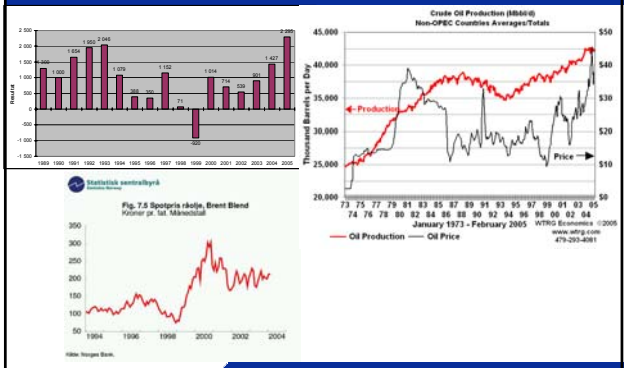
Omsetning



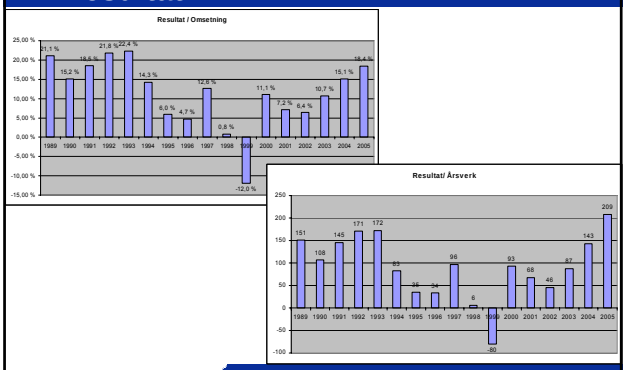
Resultat



Resultat



Resultat



Resultat siste 5 år

Årets SAND regnskap

	JUNI				DESEMBER			
	Resultat	Budsjett	Avvik	Resultat	Budsjett	Avvik	Budsjett 2005	Prognose 2005
INNTEKTER								
Forskningsprosjekter	1 090 000	746 270	343 730	13 821 000	8 716 000	5 105 000	8 716 000	12 653 977
Instituttprosjekter	183 000	65 842	117 158	769 000	769 000	0	769 000	769 000
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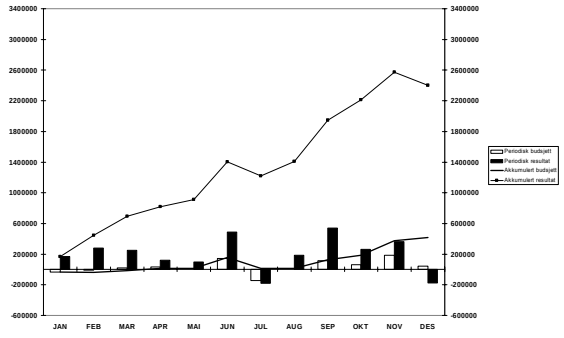
Andel Fellesutgifter	189 466	192 959	-3 493	2 273 570	2 315 510	-41 940	2 315 510	2 273 572
Resultat	**-172 481**	**43 406**	**-215 887**	**2 402 029**	**415 563**	**1 986 466**	**415 563**	**2 500 000**

Årets SAND regnskap



Oppsumering

- ►Vi går historisk godt
- ►… men det har vi gjort før også ☺

SAND: SWOT

- Sterke sider
- Svake sider
- Muligheter
- Trusler

Grupper:

1. Heidi, Per, Ariel
2. Knut, Anne Randi, Bjørn og Arne
3. Odd, Pål, Harald, og Ragnar

SAND: SWOT

- Sterke sider
  - Kompetente matematikere/statistikere
  - Gode programmerere
  - Godt marked
  - Bra samarbeid
  - .
- Svake sider
  - Tafatte, risiko averse
  - Lite kunnskap om kommersialisering
  - Manglende internasjonalt miljø
  - .
  - .
  - .
- Muligheter
  - Kommersialisering, spin-off
  - Faglig utvikling
  - Små oljeselskaper
  - .
  - .
- Trusler
  - Marked overtas av andre
  - patentering, lite kunnskap, manglende strategi
  - Avgang nøkkelpersoner
  - Fall i oljeprisen
  - Fusjoner

SAND (FASIT ☺)

- Sterke sider
  - Erfaring med marked
  - Veletablert faglig
  - Flinke og rutinerte medarbeidere
  - Unike (nisje)
- Svake sider
  - Sårbar personalsituasjon
  - Sterk kobling til ROXAR
  - "Forgubbing"
  - Immobile (tja)
  - Usynlige?
- Muligheter
  - Mange potensielle kunder i Norge
  - Mer kommersielle
  - Mer akademiske (NFR)
  - Internasjonalisering
  - Forvaltning
- Trusler
  - Få kunder
    - Fusjoner/oppkjøp
  - Personavhengige kontakter
  - Redusert aktivitet i Norsk oljeindustri på sikt

Arnes Nirvana

- Sand ca 25 personer.
- Jobber internasjonalt med forskning og konsulentarbeid mot en stadig mer spissfokuserende oljebransje.
- Er sammen med Samba og Sintef matematikk i et felles matematikk/statistikk-modelleringsmiljø (=bedrift).
- Fokus på anvendelser => både forskning og kommersielt fokus.
- Konkurrerer fremdeles om, og får, offenlige forskningmidler.
- Ikke lenger en stiftelse med styremedlemmer uten økonomiske motiver eller forankring i bedriften/bedriftskulturen.
- Privat eid, de ansatte har 50% av aksjene.