Uncertainty Assessment Using 3D Modeling*

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Abstract

Uncertainty exists at all levels of a reservoir study, starting with measurements of raw data and their interpretation. For instance, uncertainty in seismic interpretation and in velocity functions affects time-to-depth conversion and thus the position in depth of the reservoir's structural model. The geological model depends on a conceptual understanding of deposition. The petrophysical model exhibits uncertainty that is due to a very limited sampling of an often complex and heterogeneous subsurface. The parameters and equations controlling fluid flow also carry some uncertainty. The combination of these uncertainties affects one's ability to understand and predict reservoir behavior and to reliably forecast reservoir production, therefore impacting estimations of recoverable hydrocarbon resources.

In front of this overwhelming amount of uncertainty, it is important to follow a systematic methodology articulated along the following principles: (1) it is necessary to capture and integrate the complete spectrum of uncertainties, from time-to-depth conversion and structural modeling, to petrophysical property distribution and flow simulation; (2) one must then identify the critical sources of uncertainty; this is achieved by assessing their impact on specific reservoir management decisions; finally (3) these key uncertainties must be reduced to a level where a risk-acceptable decision can be made, either by refining the interpretation models or by gathering new data.

In view of the recently revised resources categorization, uncertainty quantified through 3D reservoir modeling can play a key role in the assessment of 1P, 2P, or 3P reserves (and 1C, 2C, and 3C contingent resources) values as they relate directly to P10, P50, and P90 reservoir models. However, it is important to understand that these are not merely the result of stochastic variations around a reference case or equiprobable realizations, but are the combination of alternative (possibly very different) scenarios and stochastic simulations describing all elements and parameters contributing to the construction of a realistic 3D representation of the subsurface.

This presentation illustrates the above concepts and the importance of 3D reservoir modeling in quantifying uncertainty for recoverable resources evaluation.

Uncertainty Assessment Using 3D Modeling

AAPG GTW

Geological Aspects of Estimating Petroleum Resources and Reserves

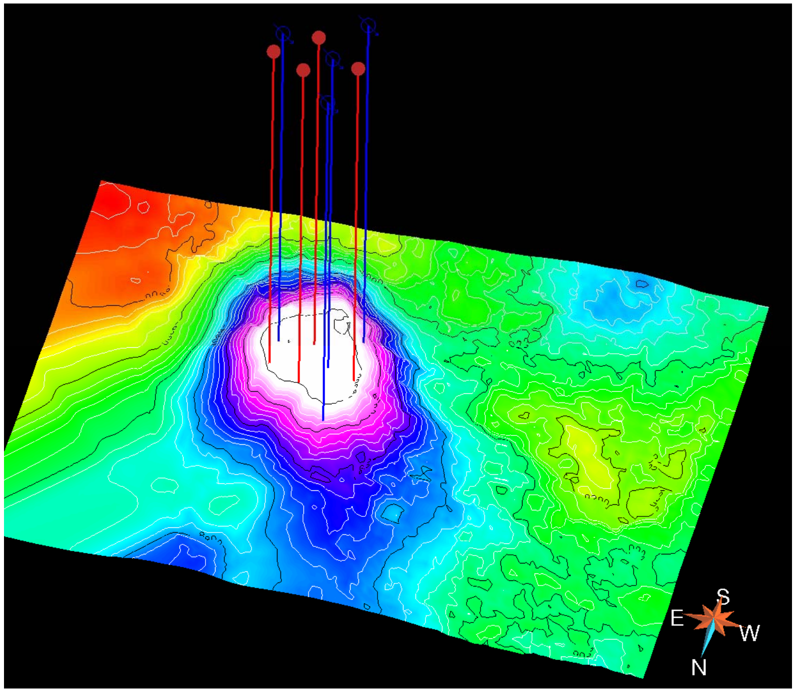
Houston, 9-11 September 2009

Dr. Emmanuel Gringarten

A short example

The problem:

to evaluate recoverable resources, we need a reliable estimate of Hydrocarbon Pore Volume, Water Saturation and Recovery Factor



“Resources” = GRV * NTG * Φ * (1- Sw) * RF / FVF

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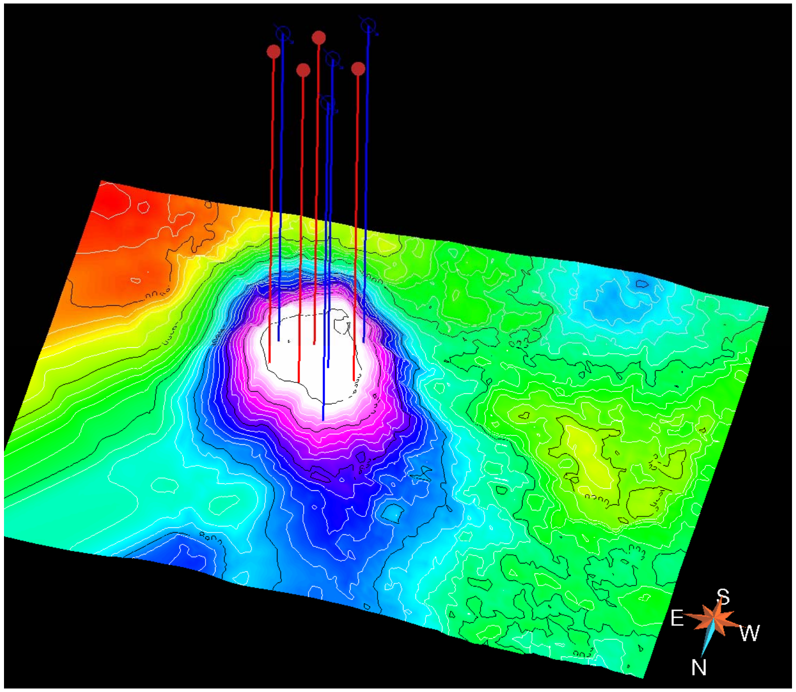
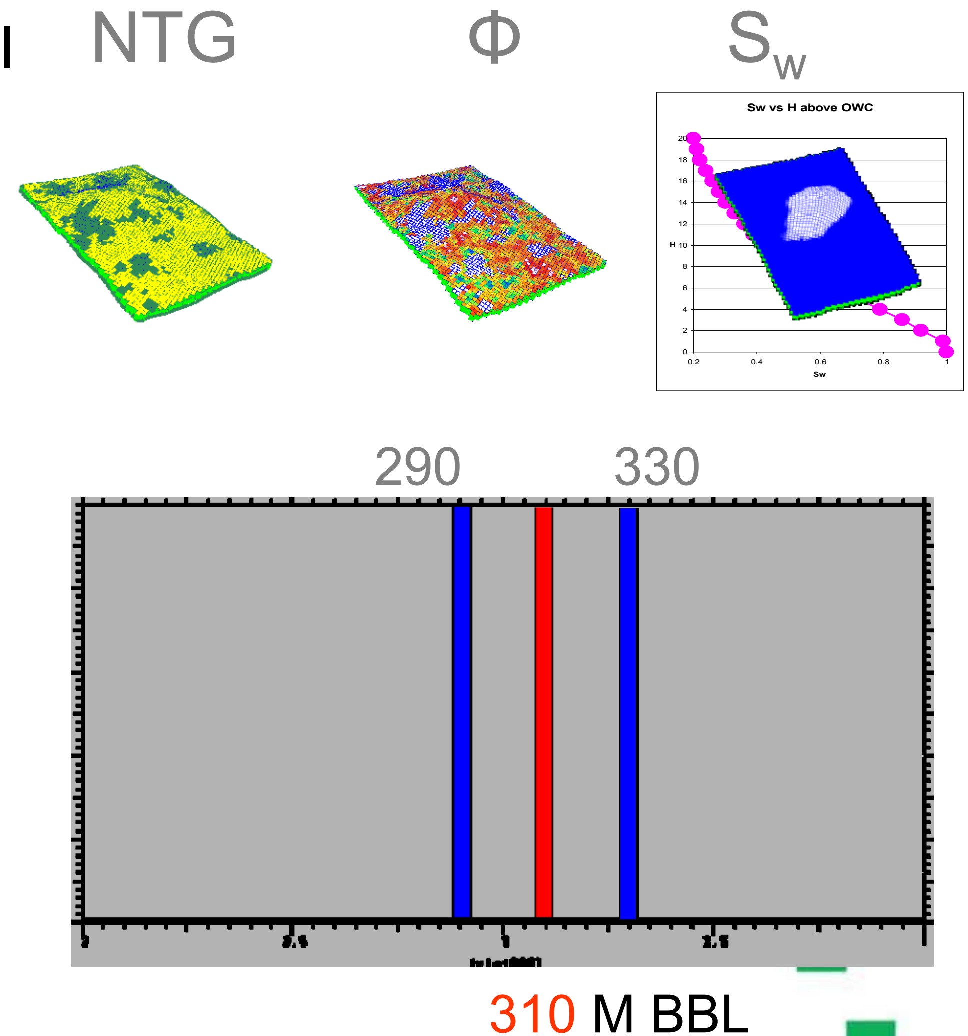


"Resources" = **GRV * NTG * Φ * (1- Sw)** * RF / FVF

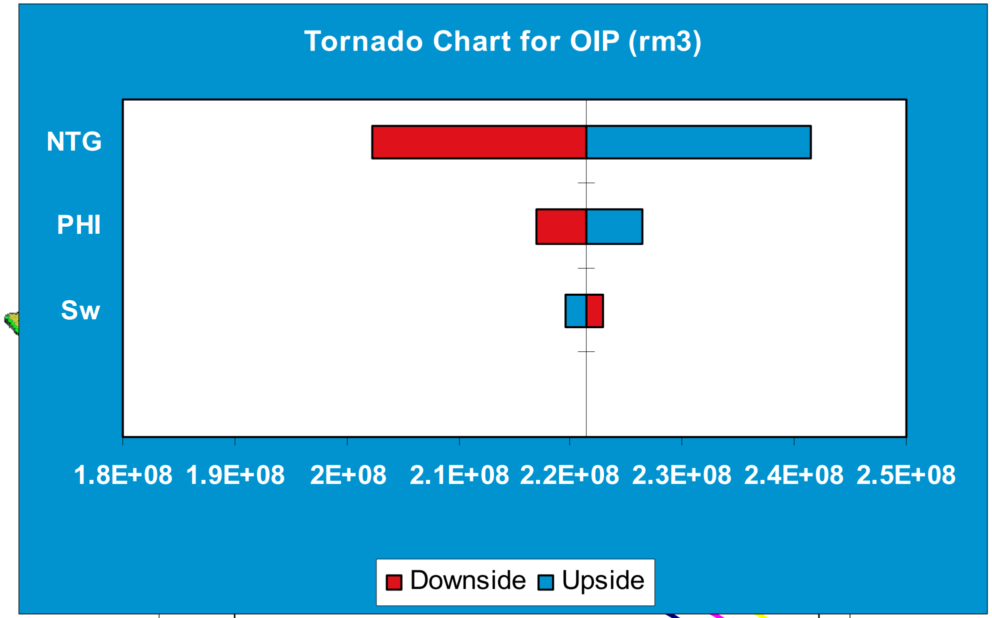
Typically…

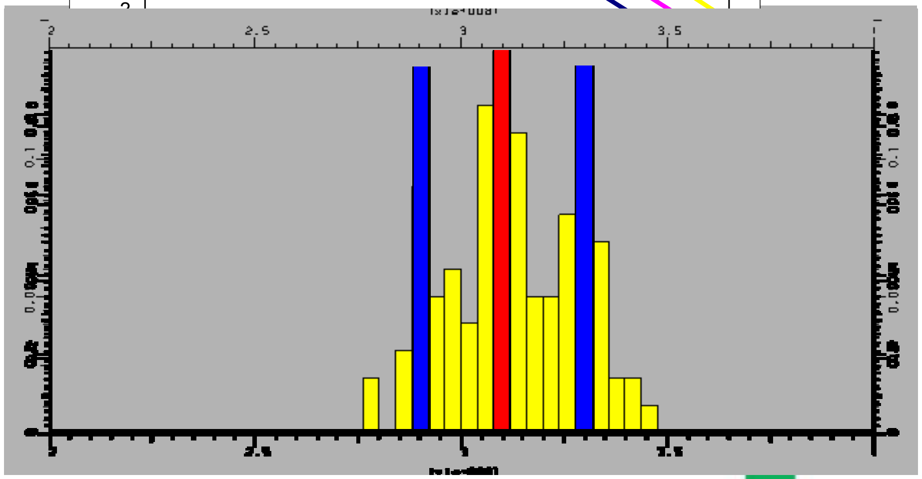
- Construct **One** 3D Reservoir Model
- Sometimes **Three**
  - Optimistic
  - Pessimistic
  - Somewhere in between…
- Very subjective assessment of uncertainty



Stochastic Simulation

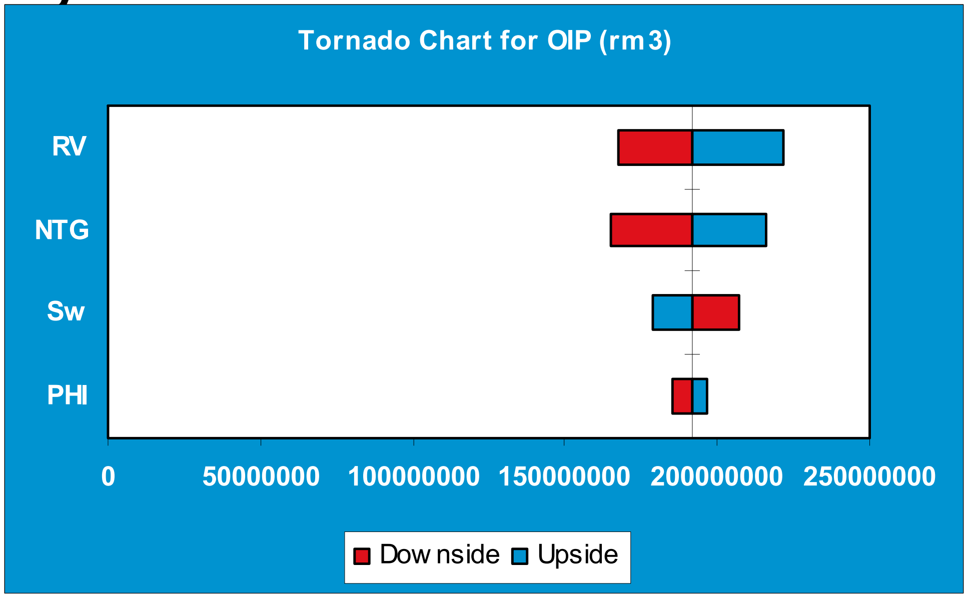
- With **efficient** use of stochastic simulation, one can generate **multiple** alternative models
- Typically focus only on facies and petrophysical properties (Φ, K, S_w)
- Yields comforting assessment of uncertainty
- **BUT** fluctuations are small

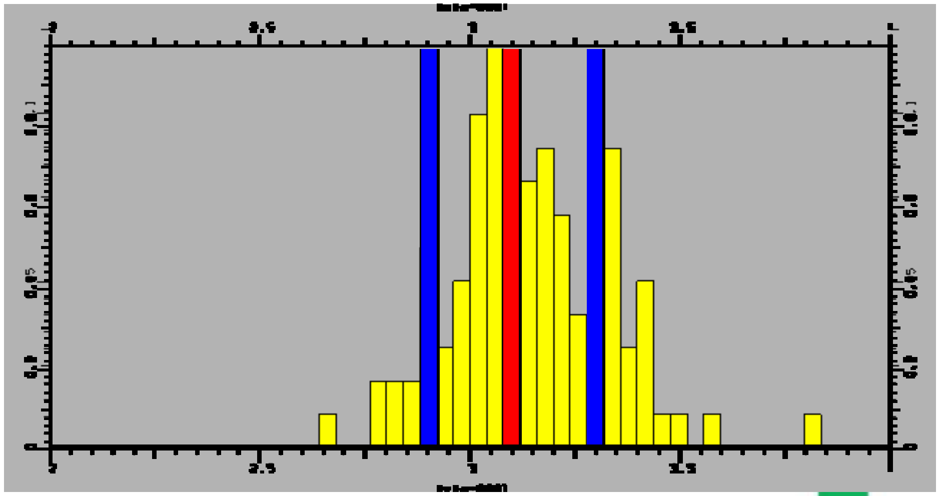




Beyond Facies and Porosity

- The “envelope”: first order elements may have first order impact
  - Reservoir structure
  - Fluid contacts
- Must account for them in stochastic simulation loop
- Yields larger, but more realistic assessment of uncertainty





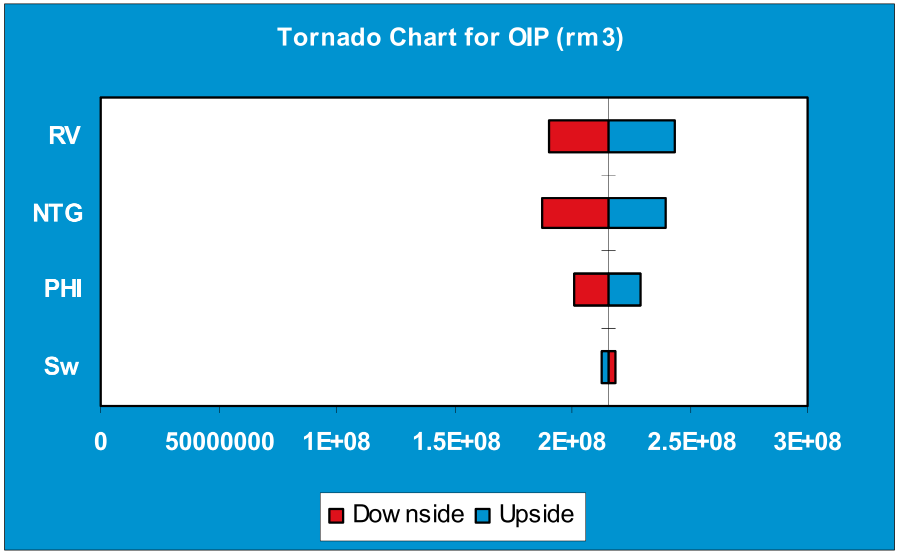
Anything else?

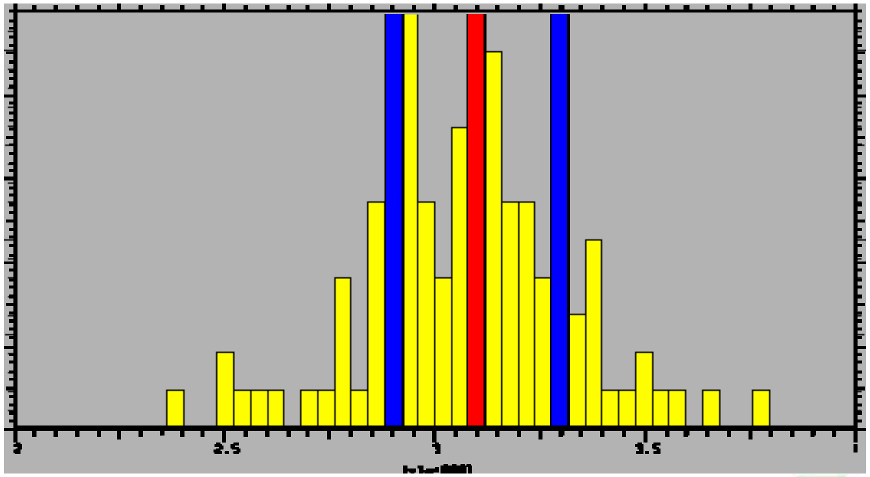
- The input ***parameters*** used by the algorithms?
- The input ***data***?
- The choice of ***algorithms?***

- They are unreliable and may be the largest source of uncertainty

- Stochastic simulation must account for parameter and data uncertainty as it may have the biggest impact

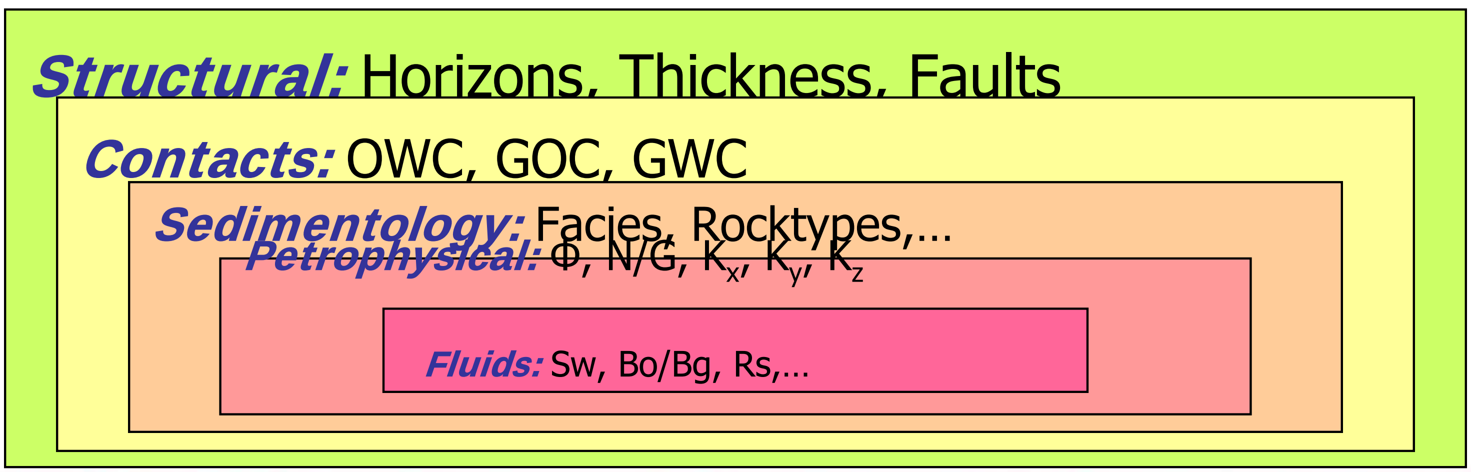
- Yields a **realistic** assessment of uncertainty





Assessing uncertainty through 3D modeling

- Constructing a 3D model is straight forward
- Generating multiple 3D models is easy
- Only way to understand ***cumulative impact*** of data/interpretation/modeling uncertainties on Reservoir Management decision



Reservoir modeling for resource evaluation

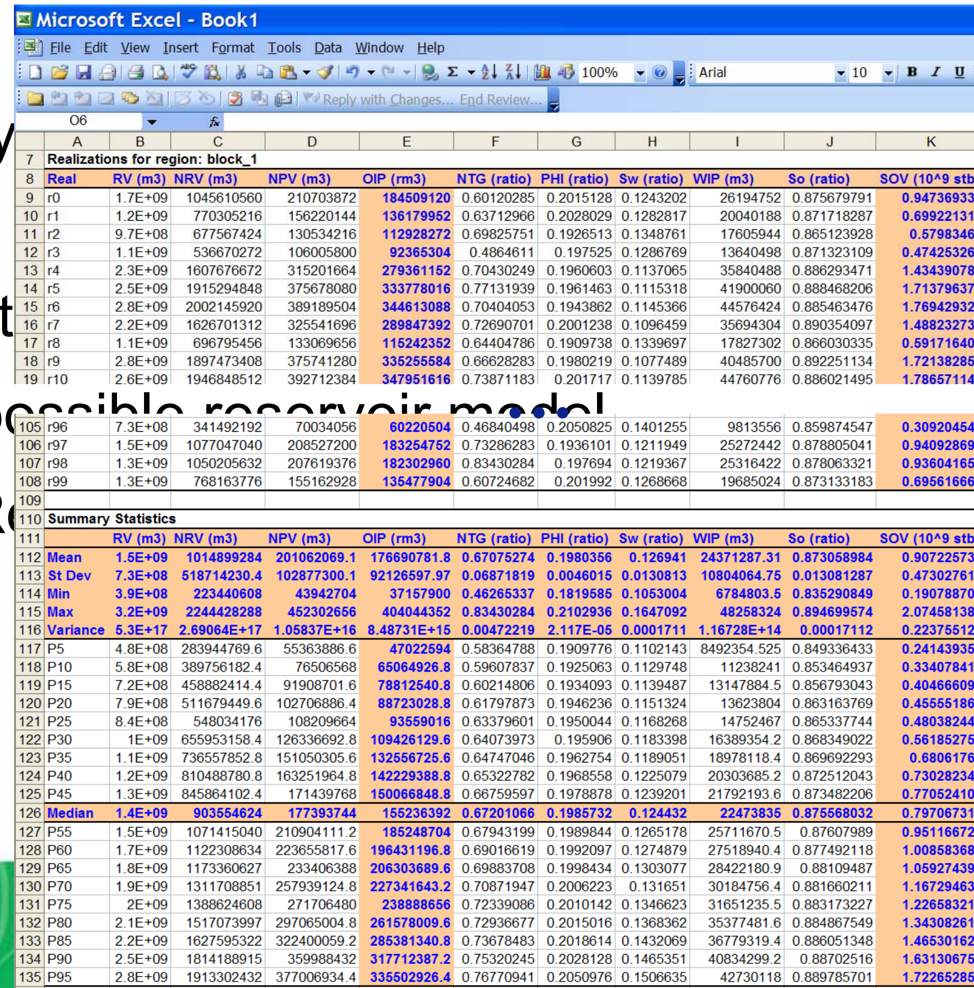
1) Infer reliable statistics for traditional **Monte Carlo / economic** spreadsheet analysis

2) **Rank** and retrieve representative models for low-mid-high volumes and flow simulation

3) Extracting information from **multiple** alternative realizations/scenarios

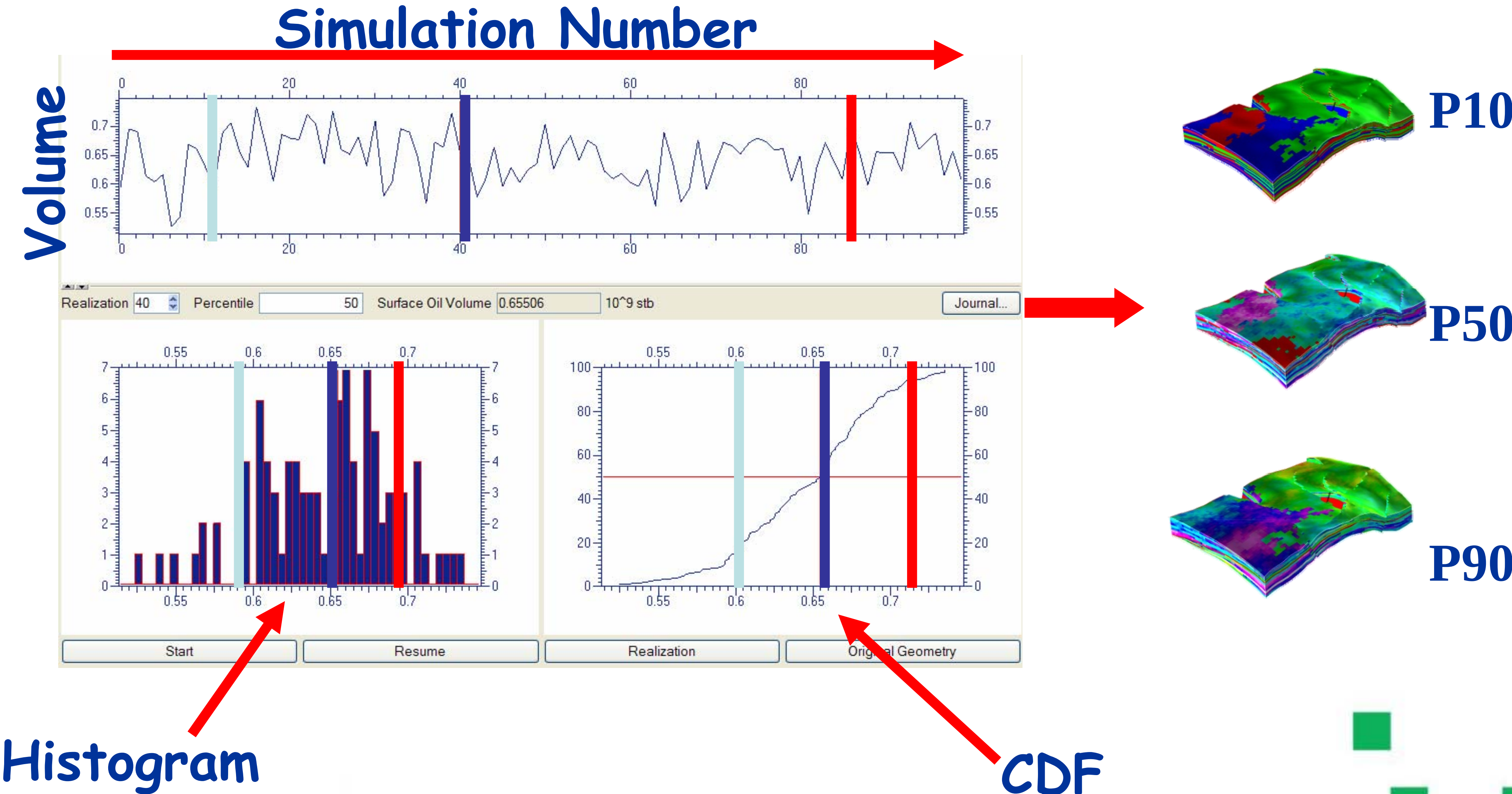
1 - 3D Reservoir Modeling
vs. Conventional Monte-Carlo Simulations

- Reservoir Modeling uses Monte-Carlo simulations
- It feeds reliable parameter distributions to Reserves / Economic MC estimations
- It captures 3D geological and phy
  between contributing elements
- Allows spatial estimates of uncert
- Each drawing corresponds to a possible reservoir model
- It is key to reliable estimates of Re

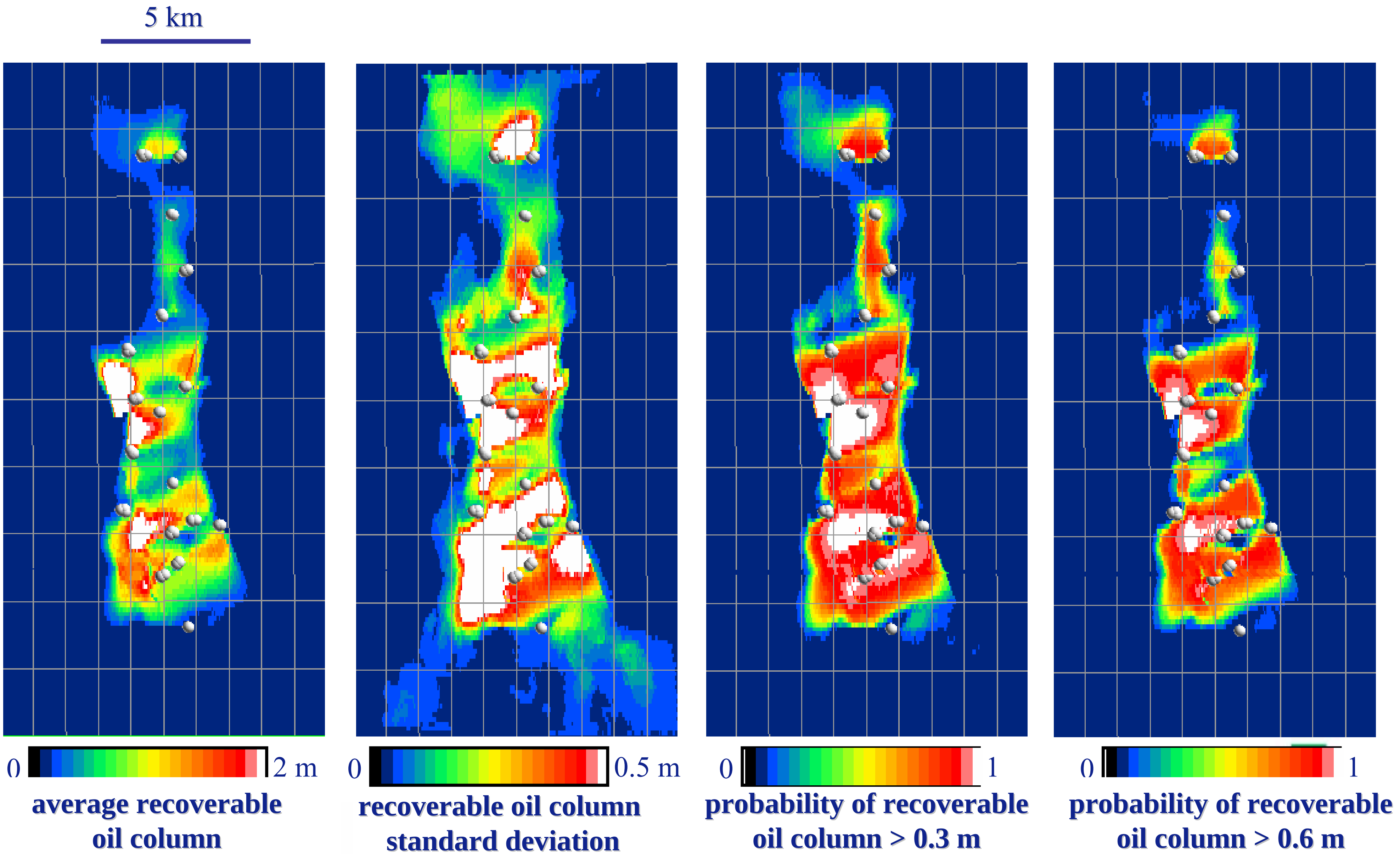


	A	B	C	D	E	F	G	H	I	J	K
7	Realizations for region: block_1										
8	Real	RV (m3)	NRV (m3)	NPV (m3)	OIP (rm3)	NTG (ratio)	PHI (ratio)	Sw (ratio)	WIP (m3)	So (ratio)	SOV (10^9 stb)
9	r0	1.7E+09	1045610560	210703872	184509120	0.60120285	0.2015128	0.1243202	26194752	0.875679791	0.947369337
10	r1	1.2E+09	770305216	156220144	136179952	0.63712966	0.2028029	0.1282817	20040188	0.871718287	0.699221313
11	r2	9.7E+08	677567424	130534216	112928272	0.69825751	0.1926513	0.1348761	17605944	0.865123928	0.57983464
12	r3	1.1E+09	536670272	106005800	92365304	0.4864611	0.197525	0.1286769	13640498	0.871323109	0.474253267
13	r4	2.3E+09	1607676672	315201664	279361152	0.70430249	0.1960603	0.1137065	35840488	0.886293471	1.434390783
14	r5	2.5E+09	1915294848	375678080	333778016	0.77131939	0.1961463	0.1115318	41900060	0.888468206	1.713796377
15	r6	2.8E+09	2002145920	389189504	344613088	0.70404053	0.1943862	0.1145366	44576424	0.885463476	1.769429326
16	r7	2.2E+09	1626701312	325541696	289847392	0.72690701	0.2001238	0.1096459	35694304	0.890354097	1.488232732
17	r8	1.1E+09	696795456	133069656	115242352	0.64404786	0.1909738	0.1339697	17827302	0.866030335	0.591716409
18	r9	2.8E+09	1897473408	375741280	335255584	0.66628283	0.1980219	0.1077489	40485700	0.892251134	1.721382856
19	r10	2.6E+09	1946848512	392712384	347951616	0.73871183	0.201717	0.1139785	44760776	0.886021495	1.786571145
105	r96	7.3E+08	341492192	70034056	60220504	0.46840498	0.2050825	0.1401255	9813556	0.859874547	0.309204549
106	r97	1.5E+09	1077047040	208527200	183254752	0.73286283	0.1936101	0.1211949	25272442	0.878805041	0.940928698
107	r98	1.3E+09	1050205632	207619376	182302960	0.83430284	0.197694	0.1219367	25316422	0.878063321	0.936041653
108	r99	1.3E+09	768163776	155162928	135477904	0.60724682	0.201992	0.1268668	19685024	0.873133183	0.695616663
109											
110	Summary Statistics										
111		RV (m3)	NRV (m3)	NPV (m3)	OIP (rm3)	NTG (ratio)	PHI (ratio)	Sw (ratio)	WIP (m3)	So (ratio)	SOV (10^9 stb)
112	Mean	1.5E+09	1014899284	201062069.1	176690781.8	0.67075274	0.1980356	0.126941	24371287.31	0.873058984	0.907225738
113	St Dev	7.3E+08	518714230.4	102877300.1	92126597.97	0.06871819	0.0046015	0.0130813	10804064.75	0.013081287	0.473027619
114	Min	3.9E+08	223440608	43942704	37157900	0.46265337	0.1819585	0.1053004	6784803.5	0.835290849	0.190788701
115	Max	3.2E+09	2244428288	452302656	404044352	0.83430284	0.2102936	0.1647092	48258324	0.894699574	2.074581385
116	Variance	5.3E+17	2.69064E+17	1.05837E+16	8.48731E+15	0.00472219	2.117E-05	0.0001711	1.16728E+14	0.00017112	0.223755128
117	P5	4.8E+08	283944769.6	55363886.6	47022594	0.58364788	0.1909776	0.1102143	8492354.525	0.849336433	0.241439353
118	P10	5.8E+08	389756182.4	76506568	65064926.8	0.59607837	0.1925063	0.1129748	11238241	0.853464937	0.334078416
119	P15	7.2E+08	458882414.4	91908701.6	78812540.8	0.60214806	0.1934093	0.1139487	13147884.5	0.856793043	0.404666093
120	P20	7.9E+08	511679449.6	102706886.4	88723028.8	0.61797873	0.1946236	0.1151324	13623804	0.863163769	0.455551863
121	P25	8.4E+08	548034176	108209664	93559016	0.63379601	0.1950044	0.1168268	14752467	0.865337744	0.480382442
122	P30	1E+09	655953158.4	126336692.8	109426129.6	0.64073973	0.195906	0.1183398	16389354.2	0.868349022	0.561852753
123	P35	1.1E+09	736557852.8	151050305.6	132556725.6	0.64747046	0.1962754	0.1189051	18978118.4	0.869692293	0.68061769
124	P40	1.2E+09	810488780.8	163251964.8	142229388.8	0.65322782	0.1968558	0.1225079	20303685.2	0.872512043	0.730282342
125	P45	1.3E+09	845864102.4	171439768	150066848.8	0.66759597	0.1978878	0.1239201	21792193.6	0.873482206	0.770524102
126	Median	1.4E+09	903554624	177393744	155236392	0.67201066	0.1985732	0.124432	22473835	0.875568032	0.797067314
127	P55	1.5E+09	1071415040	210904111.2	185248704	0.67943199	0.1989844	0.1265178	25711670.5	0.87607989	0.951166728
128	P60	1.7E+09	1122308634	223655817.6	196431196.8	0.69016619	0.1992097	0.1274879	27518940.4	0.877492118	1.008583689
129	P65	1.8E+09	1173360627	233406388	206303689.6	0.69883708	0.1998434	0.1303077	28422180.9	0.88109487	1.059274399
130	P70	1.9E+09	1311708851	257939124.8	227341643.2	0.70871947	0.2006223	0.131651	30184756.4	0.881660211	1.167294633
131	P75	2E+09	1388624608	271706480	238888656	0.72339086	0.2010142	0.1346623	31651235.5	0.883173227	1.226583213
132	P80	2.1E+09	1517073997	297065004.8	261578009.6	0.72936677	0.2015016	0.1368362	35377481.6	0.884867549	1.343082619
133	P85	2.2E+09	1627595322	322400059.2	285381340.8	0.73678483	0.2018614	0.1432069	36779319.4	0.886051348	1.465301627
134	P90	2.5E+09	1814188915	359988432	317712387.2	0.75320245	0.2028128	0.1465351	40834299.2	0.88702516	1.631306756
135	P95	2.8E+09	1913302432	377006934.4	335502926.4	0.76770941	0.2050976	0.1506635	42730118	0.889785701	1.722652853

2 - Model ranking

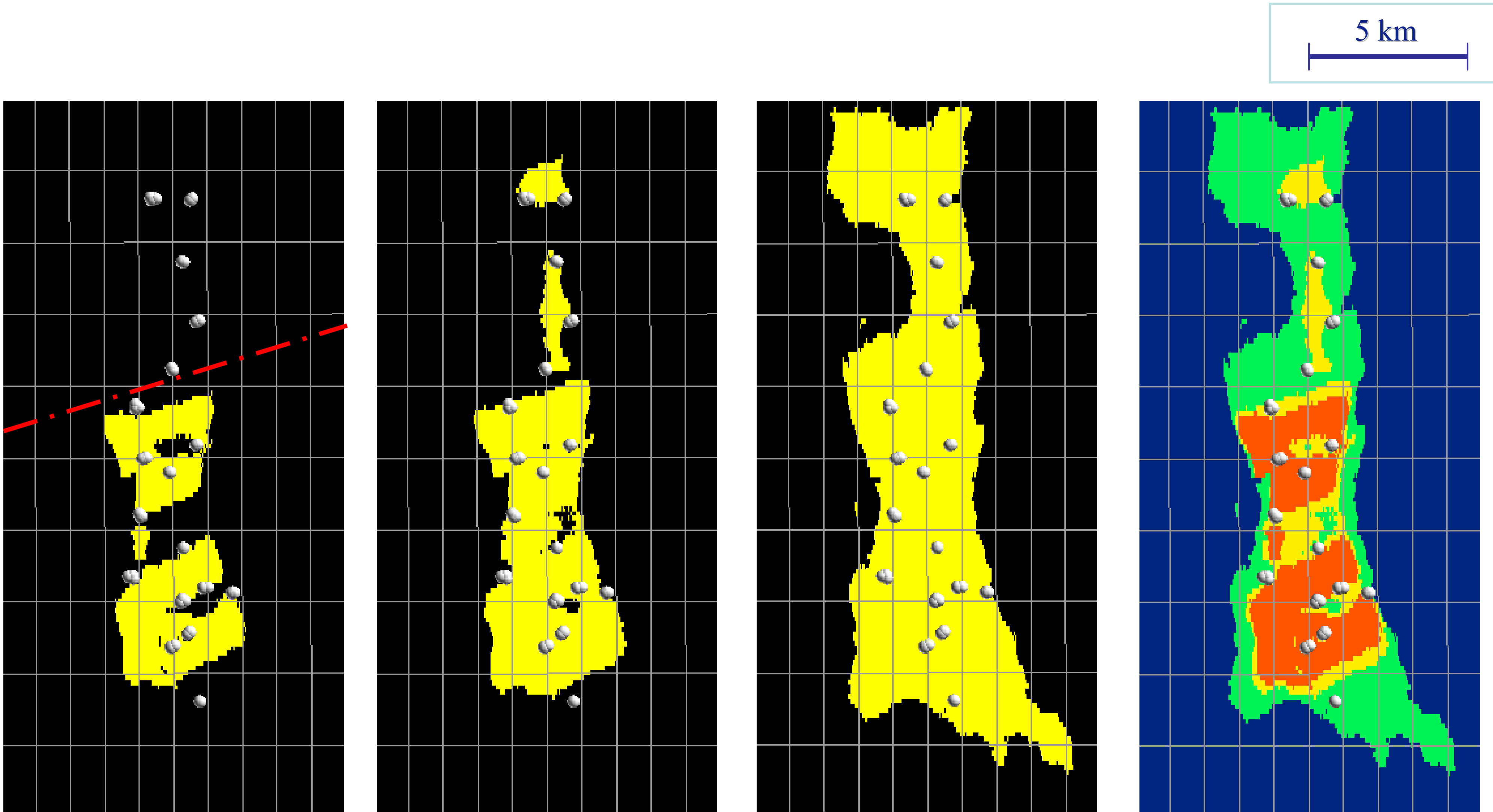


3a - Recoverable oil column



Courtesy of TOTAL

3b - Definition of segments for 1C,2C & 3C



probability of recoverable oil column > 0.6 m exceeds 50 % in the main pool

probability of recoverable oil column > 0.3 m exceeds 50 %

probability of recoverable oil column > 0.005 m exceeds 50 %

1C 17 km^2

2C 27 km^2

3C 62 km^2

Courtesy of TOTAL

Take away

- Uncertainty exists in all aspects of the subsurface
- All elements affecting quantification of resources must be considered
- Reconcile and integrate uncertainties through 3D reservoir modeling
- Do not stop at one or three scenarios, but consider as many as time allows, combined with stochastic simulations
- Incorporate 3D probabilistic reservoir modeling results in resource evaluation:
  - Infer representative distributions
  - Derive P10, P50, P90 volumes
  - Define segments
  - …