
Technology
Collaboration
Programme
by iea
IEA EOR TCP
// STAVANGER 2022
ANNUAL EVENT
21 – 24 Nov
eor
Enhanced Oil Recovery

More Wells – More Oil?

A physics based analysis of the Norwegian DISKOS database

Aksel Hiorth
Professor, University of Stavanger, Department of Energy Resources
CSSR - Centre for Sustainable Subsurface Resources
(NCS2030)

Ref:
Hiorth, A., Jettestuen, E., Osmundsen, P. "A physics based reservoir model for analysing large amount of reservoir production data", *submitted 2022*
Hiorth, A. & Osmundsen, P. «Petroleum taxation. The effect on recovery rates». *Energy Economics*» **87** (2020). https://doi.org:http://dx.doi.org10.1016/j.eneco.2020.104720

Enhanced Oil Recovery

IEA EOR TCP

Drilling and Production Practice 1950

More Wells - More Oil?

H. H. KAVELER*

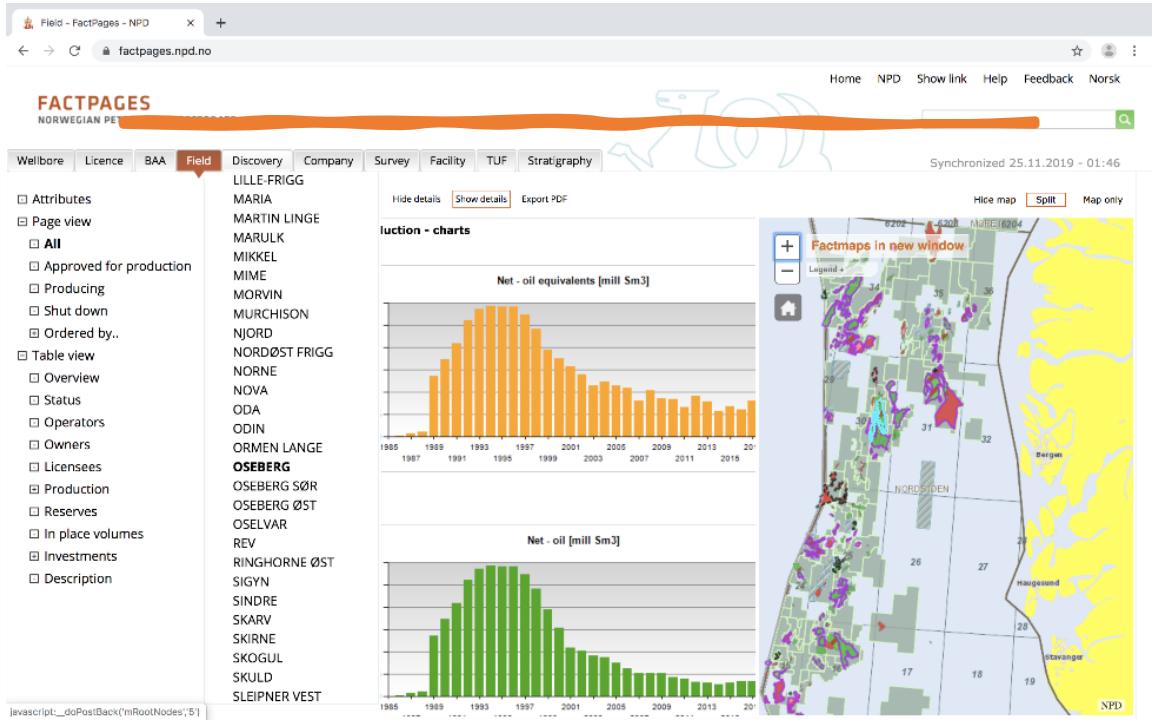
ABSTRACT

The paper presents conclusions regarding the effect of well spacing on ultimate recovery, based upon a study of more than 50 pools. Production statistics and related facts on 6 pools are presented in substantiation of a general recommendation for wide spacing.

- Do more wells produce more oil?
- Are oil reserves lost because only 1 well is often drilled to each 40 acres rather than 2 or 4 wells to 40 acres? (40 acres = 0.16 km2)

One important point from Kavelers paper is that we need to investigate the data and not trust the “expert”

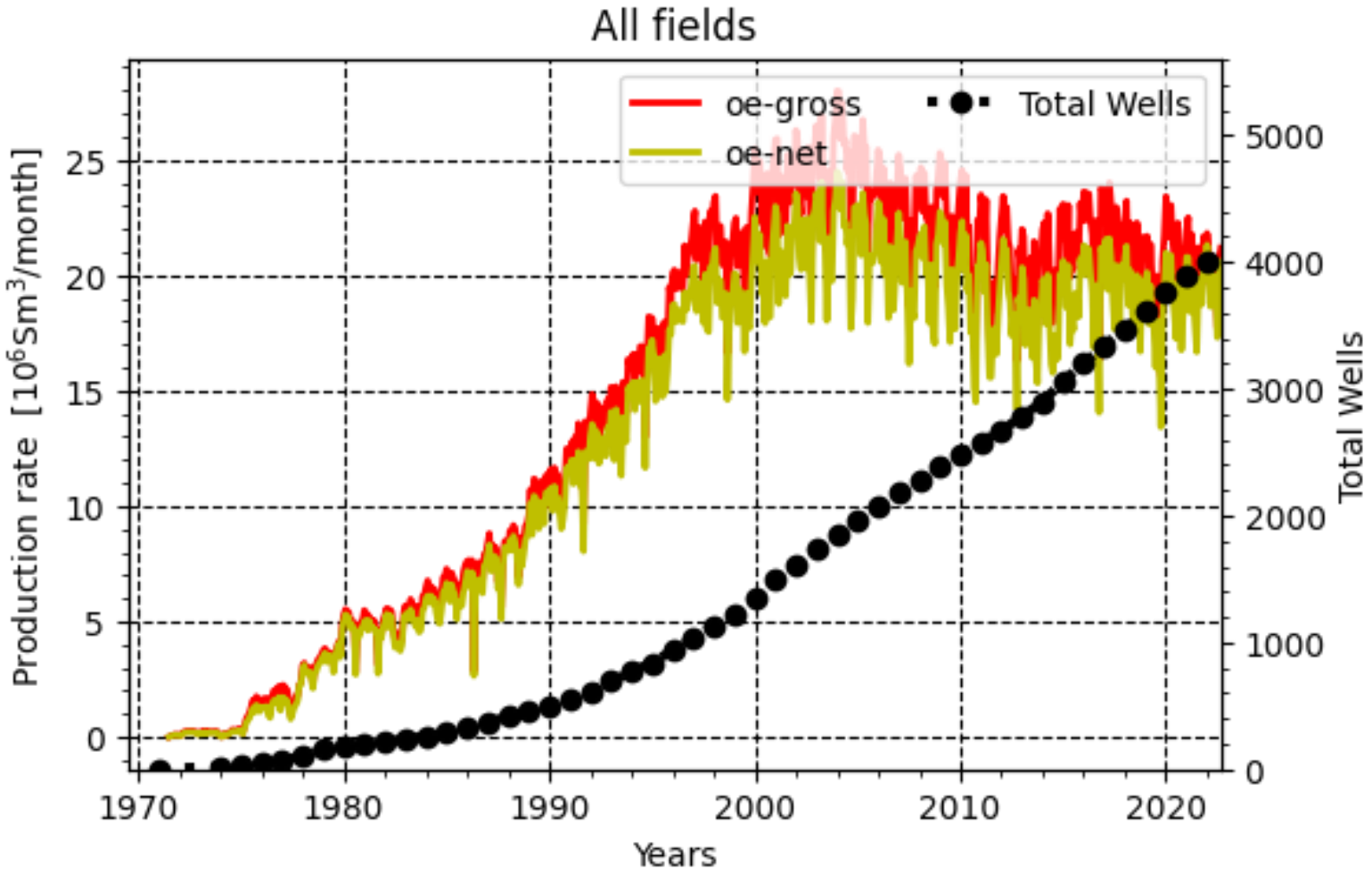
What does data tell? (and do we have data?)



Parameters	DISKOS	FactPages
Field Fluid injection	Yes	No
Field Fluid production	Yes	Yes
Complete production history	No	Yes
Complete injection history	No	No
Individual well production/injection	Yes	No
Well schedules	Yes	Yes

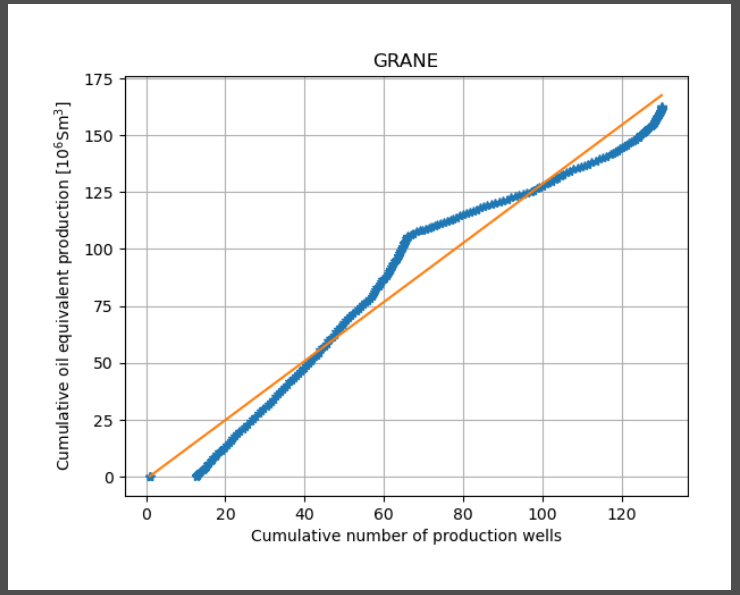
	prfInformationCarrier	prfYear	prfMonth	prfPrdOilGrossMillSm3	prfPrdGasGrossBillSm3	prfPrdCondensateGrossMillSm3	prfPrdOeGrossMillSm3	prfPrdProducedWaterInFieldMillSm3	prfNpdidInformationCarrier
0	16/1-12 (Rolvsnes)	2021	8	0.00651	0.00114	0.0	0.00765	0.00291	17196400
1	16/1-12 (Rolvsnes)	2021	9	0.01042	0.00250	0.0	0.01292	0.00719	17196400
2	16/1-12 (Rolvsnes)	2021	10	0.01204	0.00220	0.0	0.01425	0.00912	17196400
3	16/1-12 (Rolvsnes)	2021	11	0.01384	0.00249	0.0	0.01634	0.01186	17196400
4	16/1-12 (Rolvsnes)	2021	12	0.00471	0.00080	0.0	0.00551	0.00418	17196400

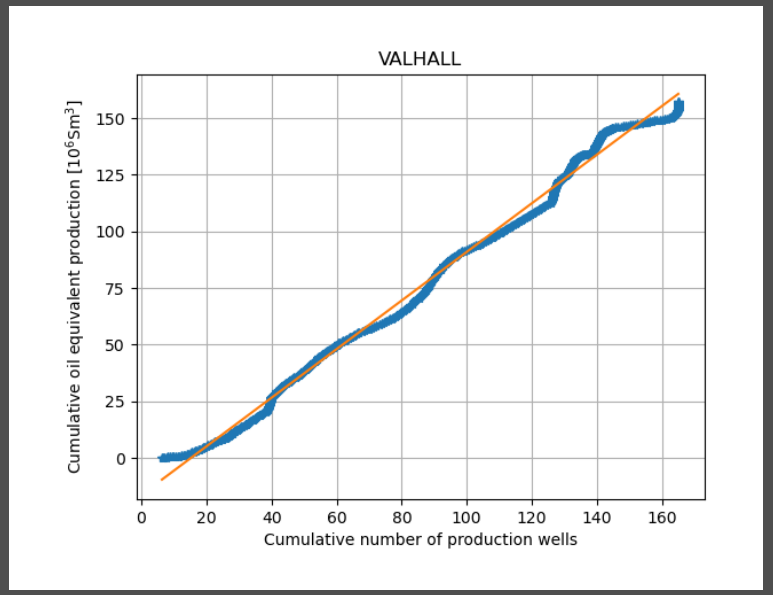
Wells and oil equivalent recovery

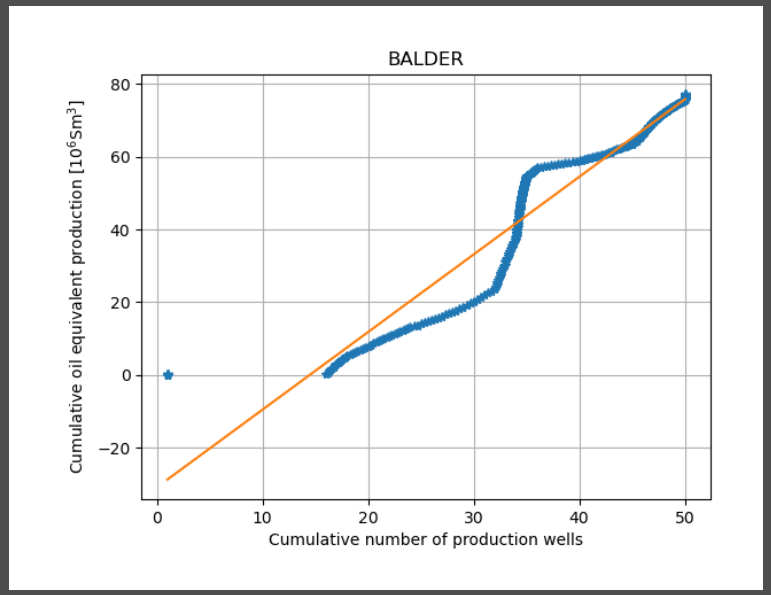


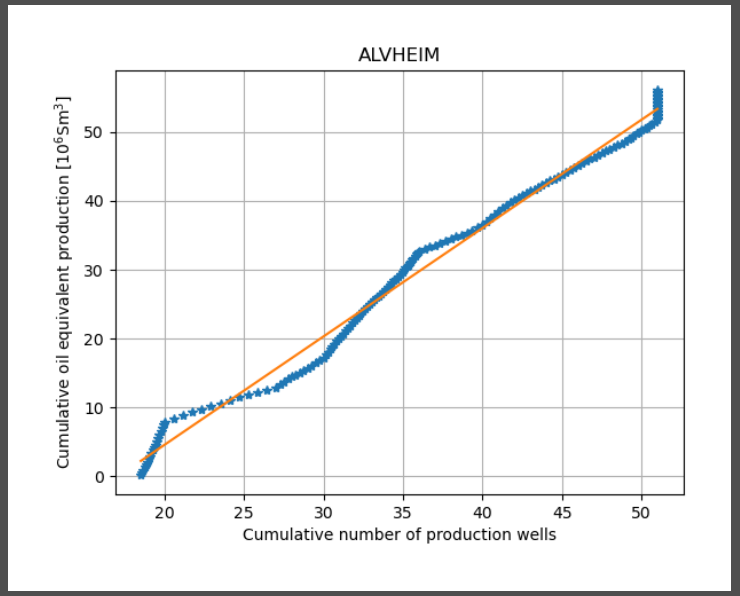
Python code:

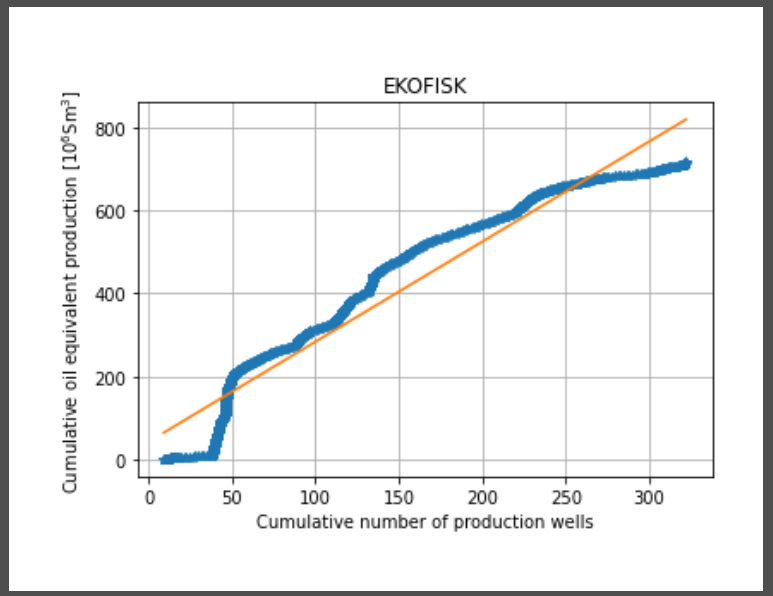
```
df=pd.read_csv('field_production_gross_monthly.csv',sep=',')
df=df.groupby('prfYear').sum()
df.plot(y='prfPrdOeGrossMillSm3',grid=True)
```

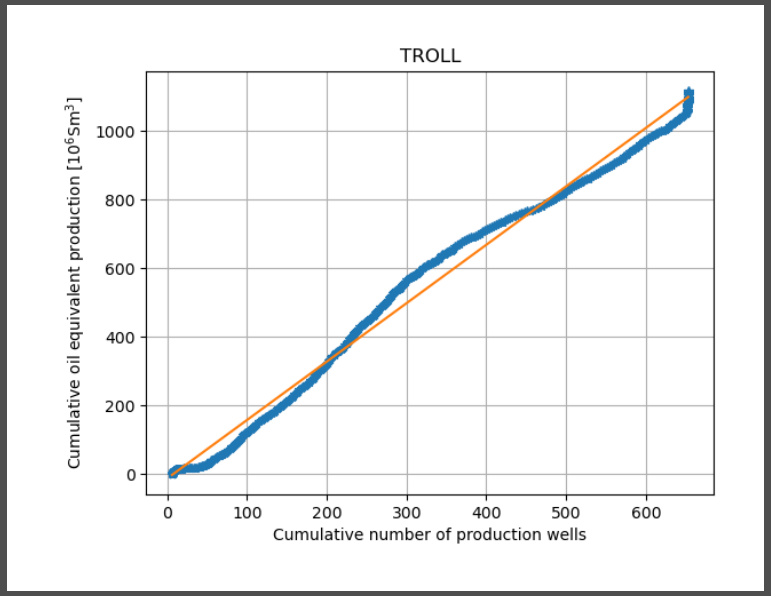

GRANE
Cumulative oil equivalent production [10⁶Sm³]
Cumulative number of production wells


VALHALL
Cumulative oil equivalent production [10⁶Sm³]
Cumulative number of production wells


BALDER
Cumulative oil equivalent production [10⁶Sm³]
Cumulative number of production wells


ALVHEIM
Cumulative oil equivalent production [10⁶Sm³]
Cumulative number of production wells

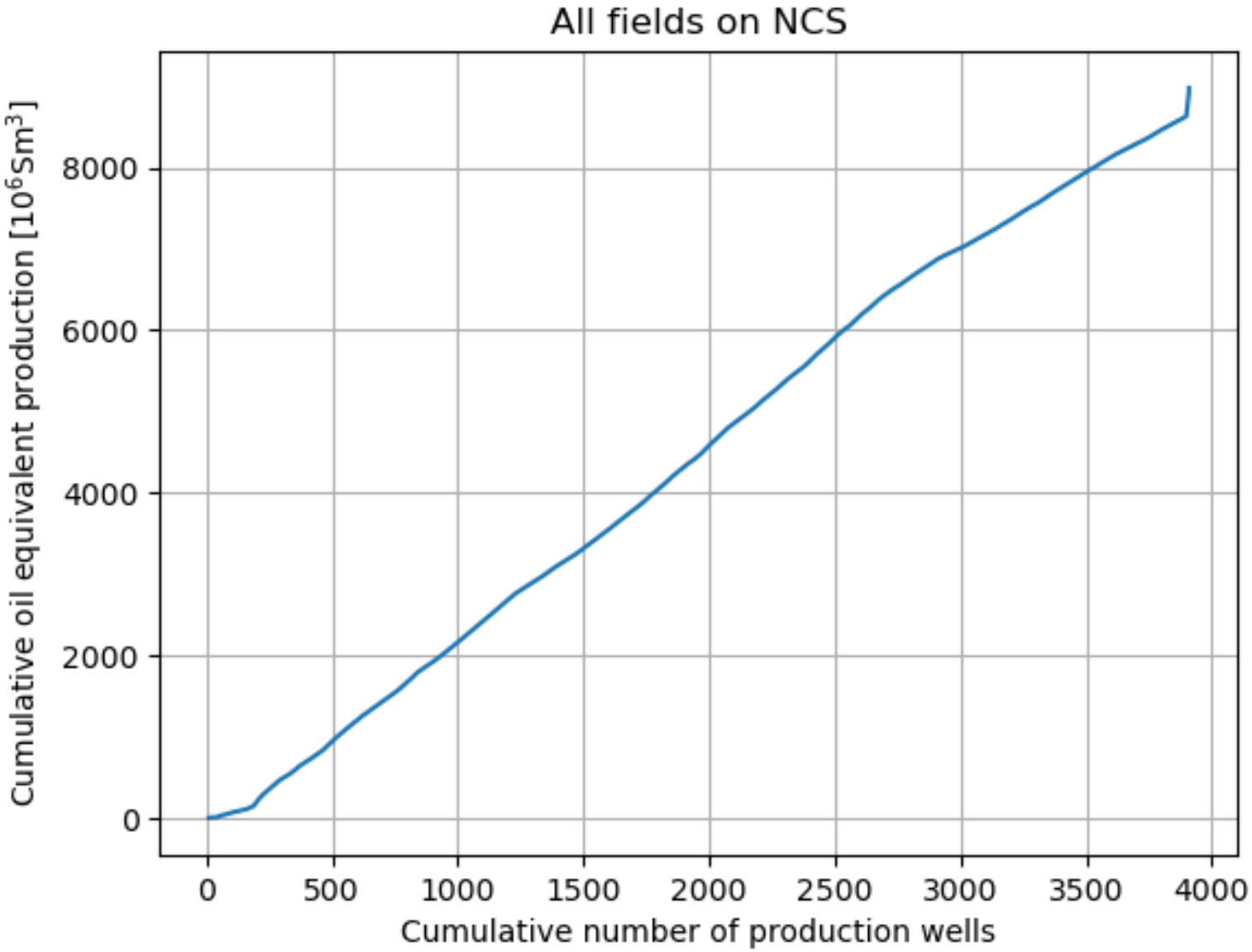

EKOFISK
Cumulative oil equivalent production [10⁶Sm³]
Cumulative number of production wells


TROLL
Cumulative oil equivalent production [10⁶Sm³]
Cumulative number of production wells

A clear correlation between wells and oil equivalent recovery

Is this the answer? Just add more wells, and more oil is produced?

Correlation does not imply causation!

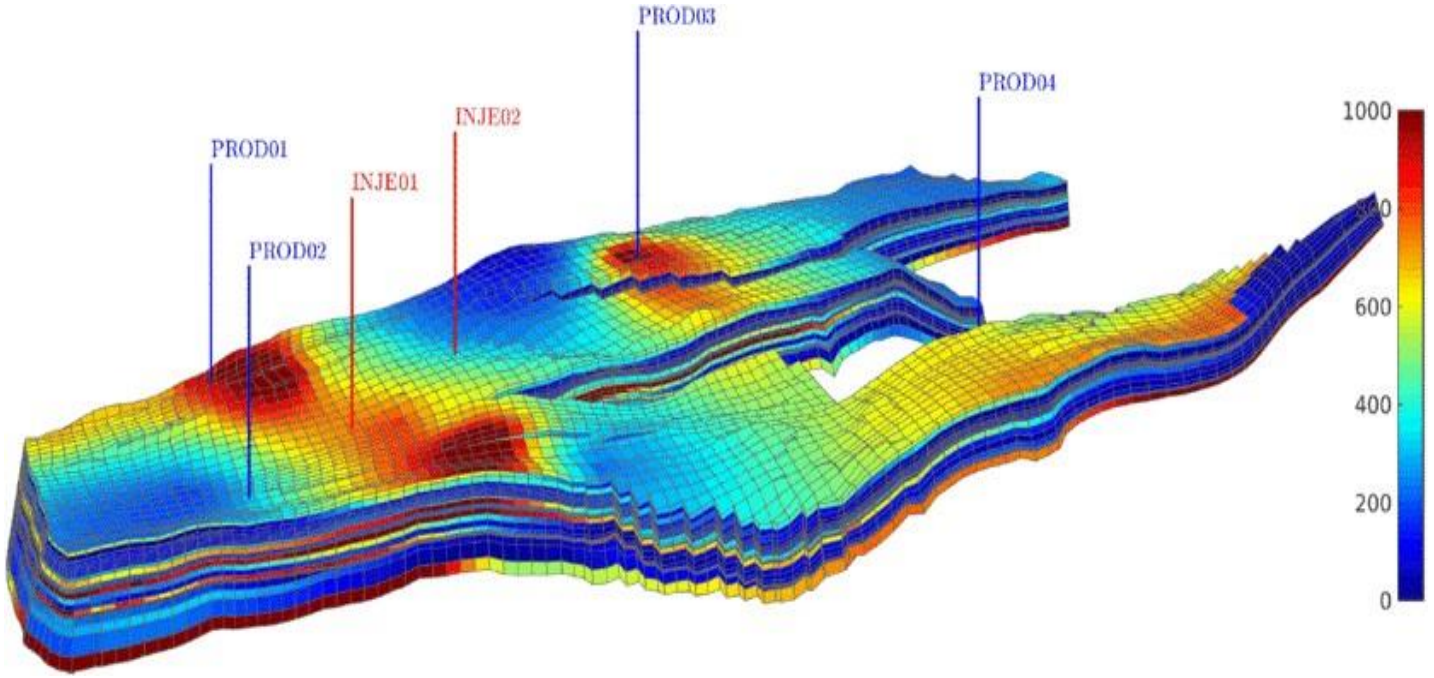


Data has no value in itself - to interpret data we need a model

A model is a *sufficient* simplification of a real-world problem

The “gold standard”
Reservoir simulators:

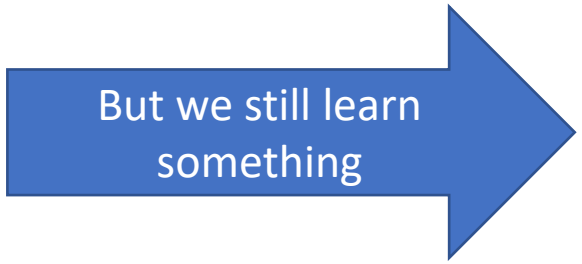
- Needs lot of data
- Good for field specific studies



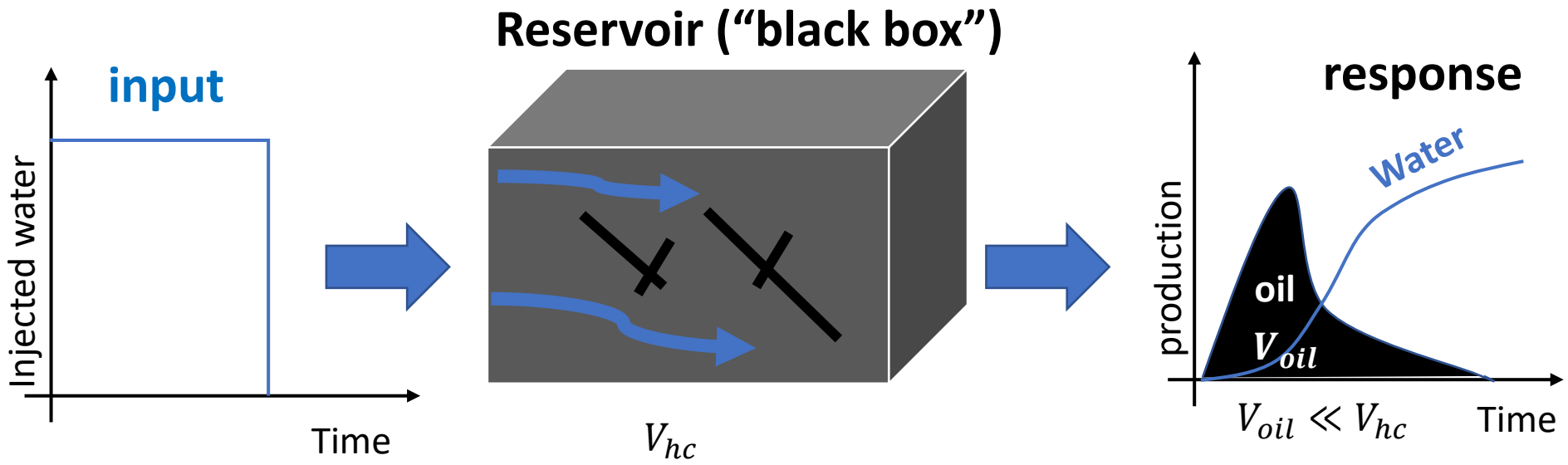
…public data does not include data for grid-based models

Why use simple models?

- Strength
  - Less input parameters
  - If it works we know that assumptions could be right
  - If it does not work we know that assumptions are wrong
  - If the model is based on physics:
    - Can predict outside data range
- Weakness
  - Mechanisms are masked
  - Detailed planning needs detailed models



Borrow ideas from chemical engineering

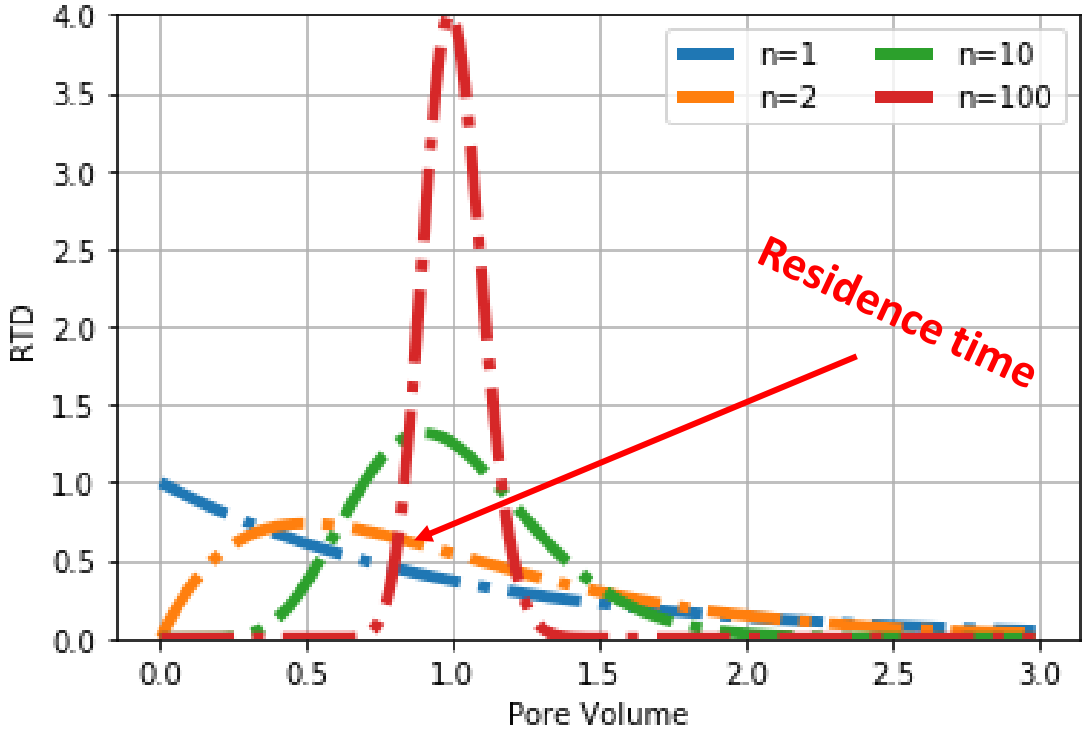


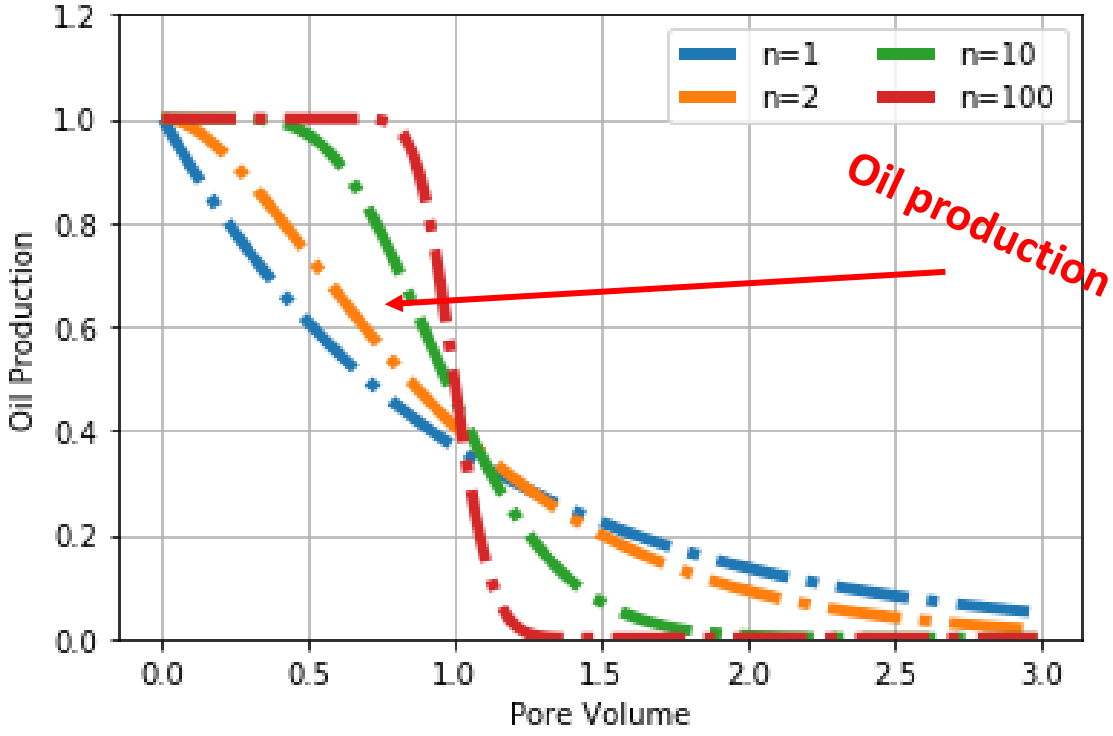
$$c_{in}(t) = \frac{V_w(t)}{V_w(t) + V_{hc}(t)} = 1$$

$$c_{out}(t) = \frac{V_w(t)}{V_w(t) + V_{hc}(t)} = \int_0^t c_{in}(t - t')E(t')dt'$$

Residence Time Distribution
or Exit age distribution

Residence time and oil production

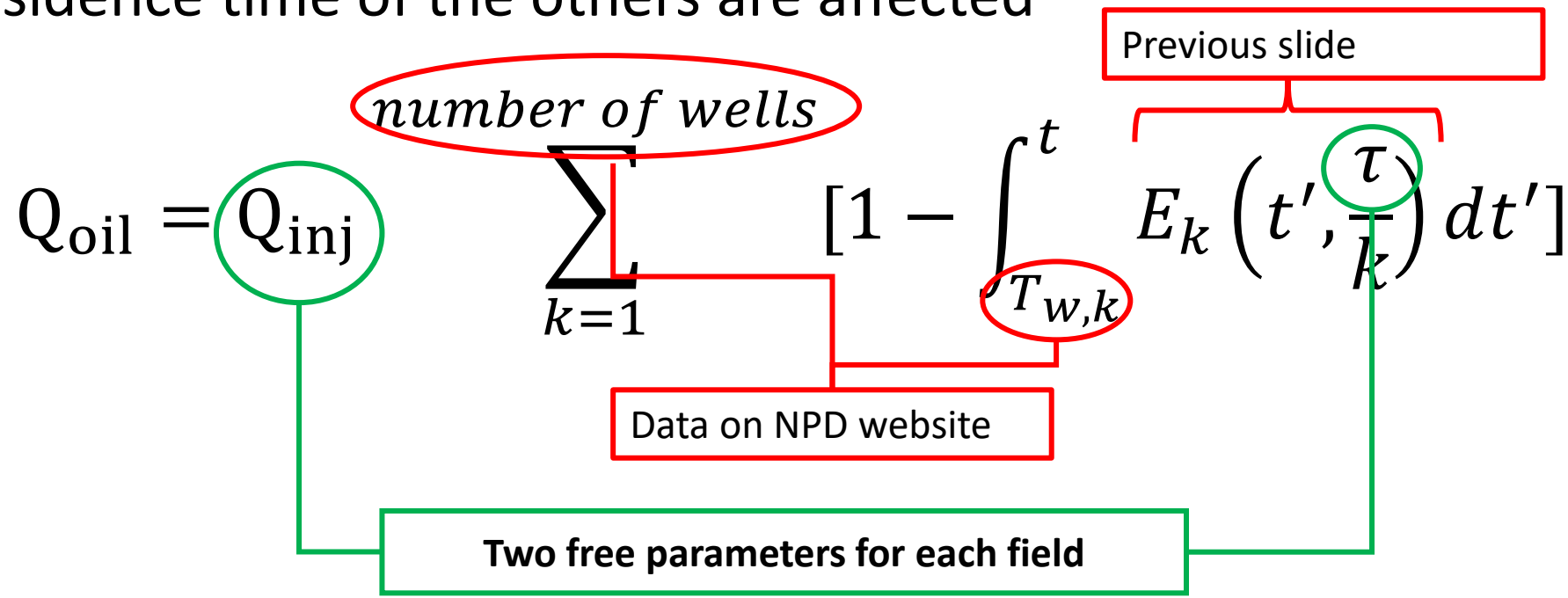




$''n''$ represents a heterogeneity factor $n \to \infty \Rightarrow$ piston displacement (homogeneous)

A full field oil production model

- Assume that each well can be modelled using the same residence time distribution
- Well interference: whenever a new well is put online the mean residence time of the others are affected



What are the assumptions?

- Different parts of the reservoir are connected
  - A well drilled in one part of the reservoir affects the other wells immediately
- A new well produce with the same initial rate
- Reservoirs behaves as continuous flow systems
  - Similar volume of fluids are injected that are produced
  - Note: hard to quantify as reservoirs can have active aquifers

Note: all the above assumptions can be relaxed, but with the cost of introducing more parameters

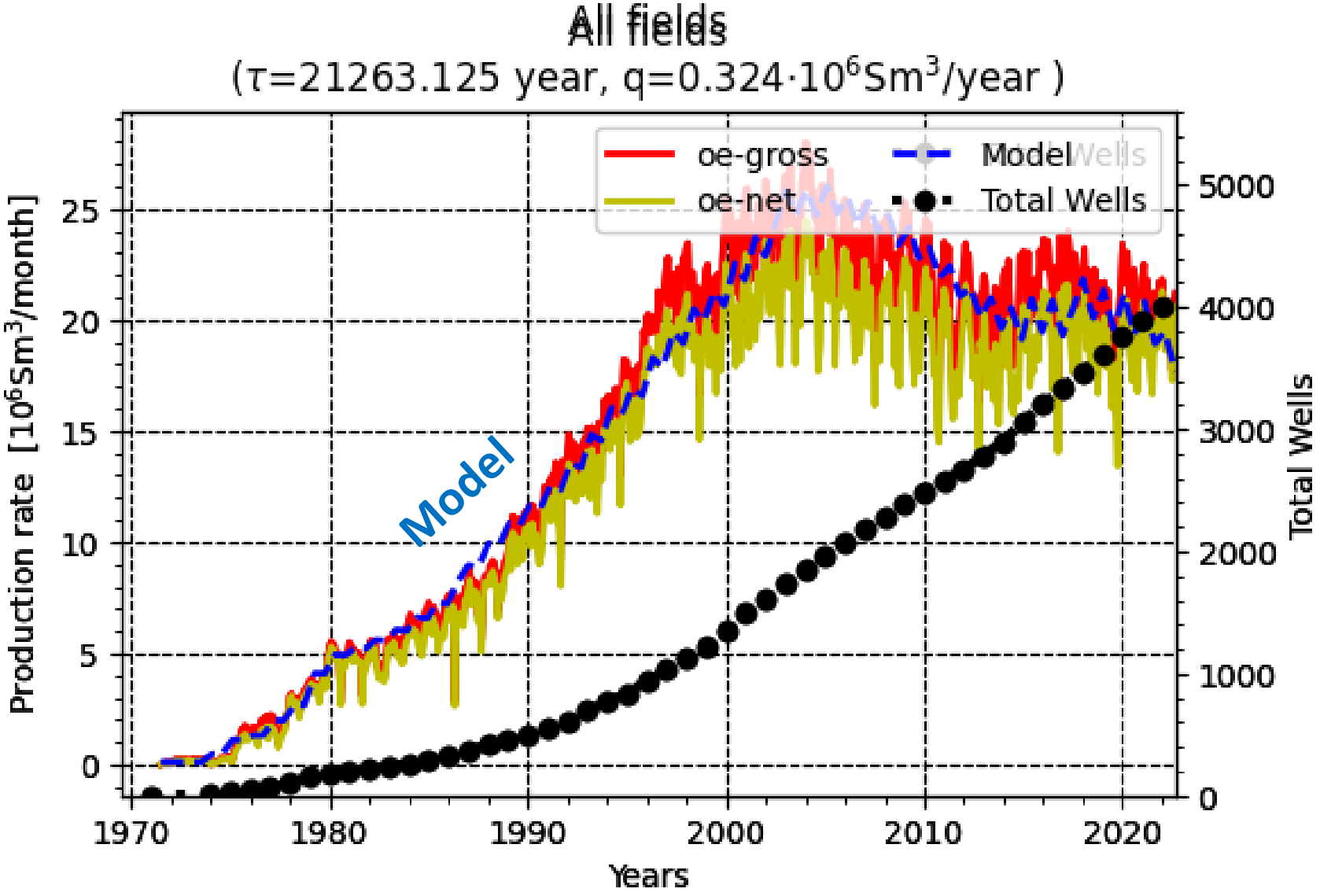
Test model on all field data

Model does not need spatial information
Only when wells are drilled

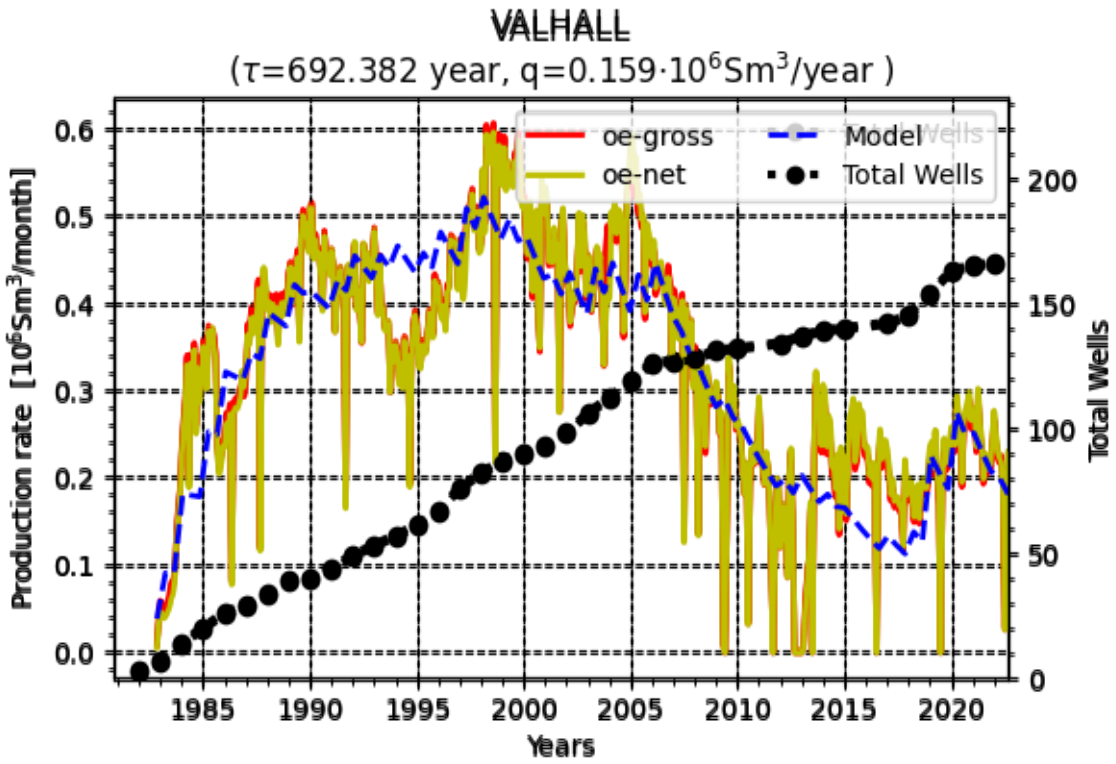
$$\tau \cdot q = 6.9\ 10^9 Sm^3$$

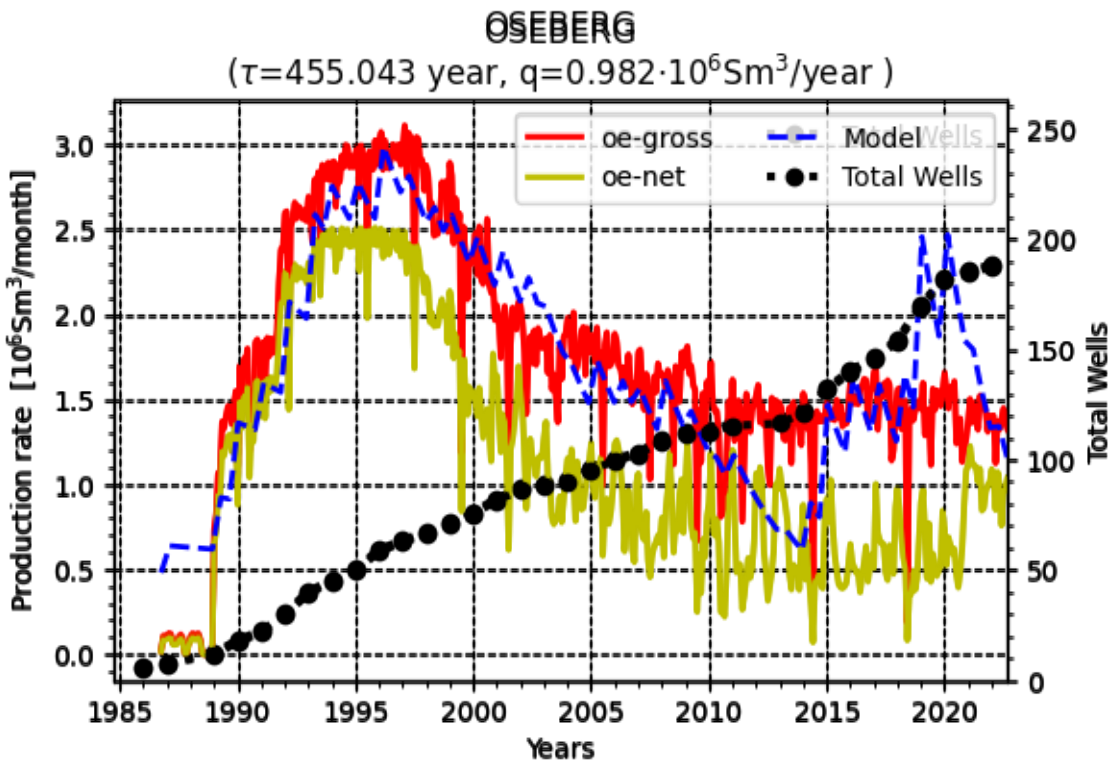
$$V_{hc} = 10.6 \cdot 10^9 Sm^3$$

$$\frac{\tau \cdot q}{V_{hc}} = 0.65$$

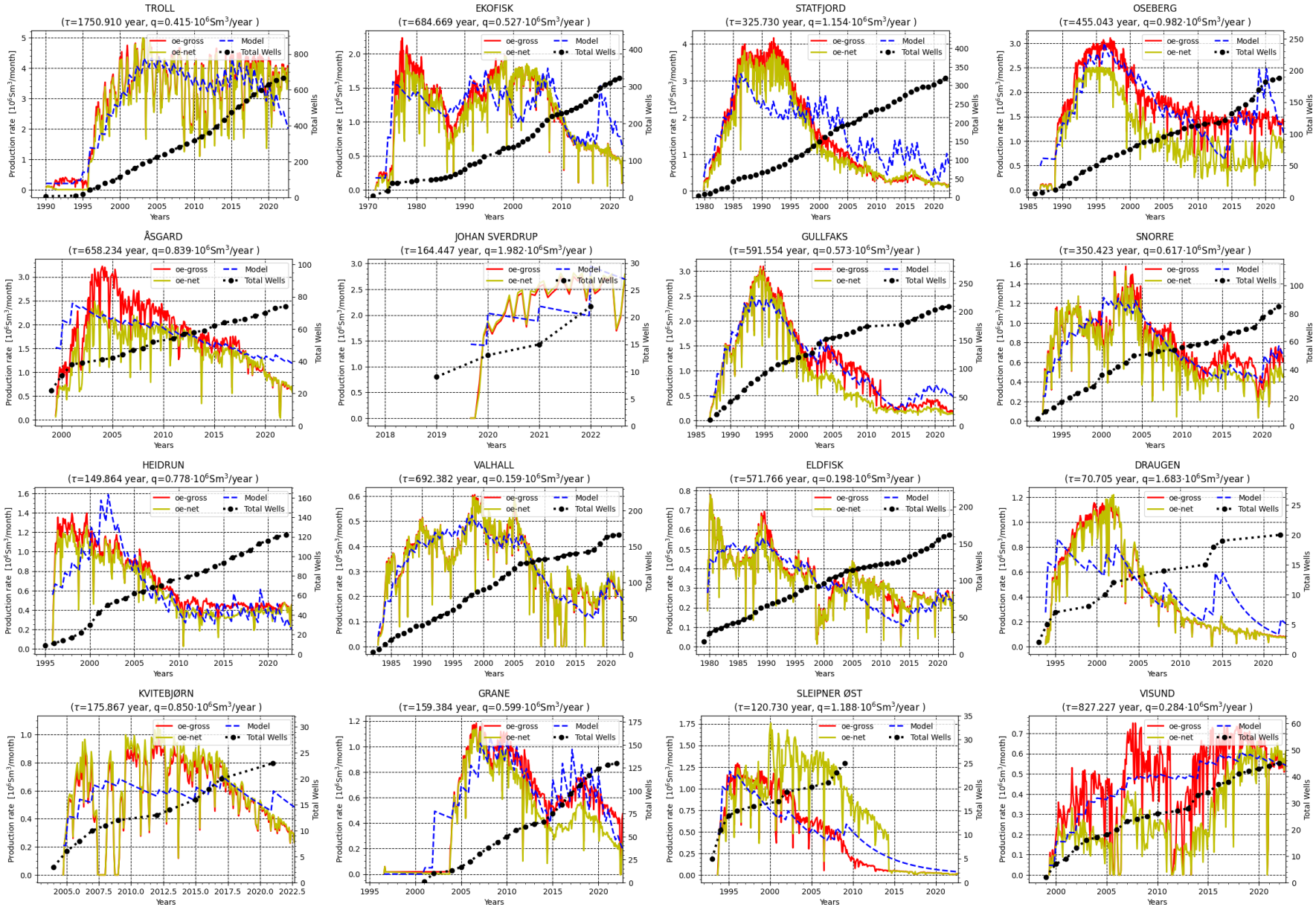


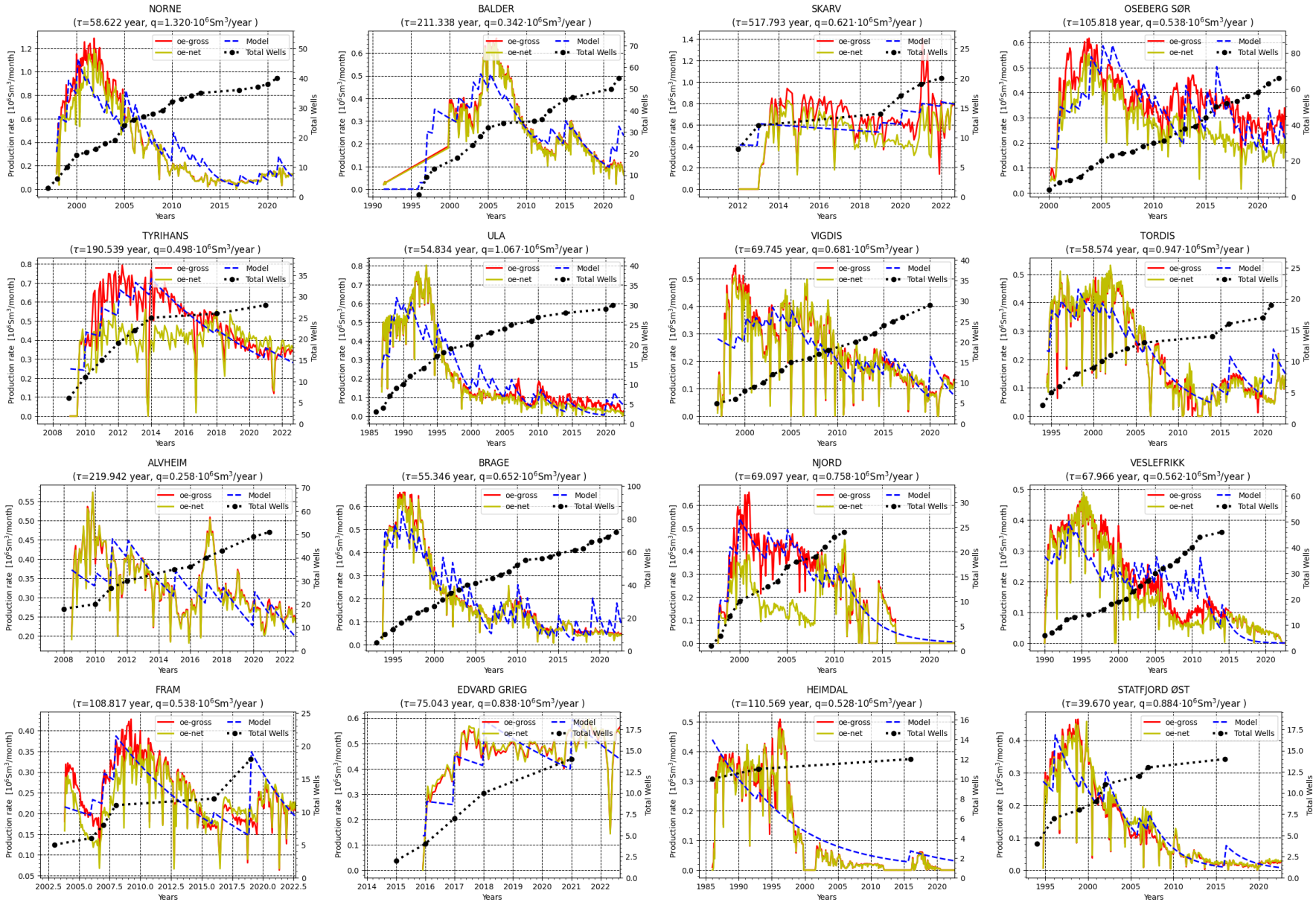
Some more examples



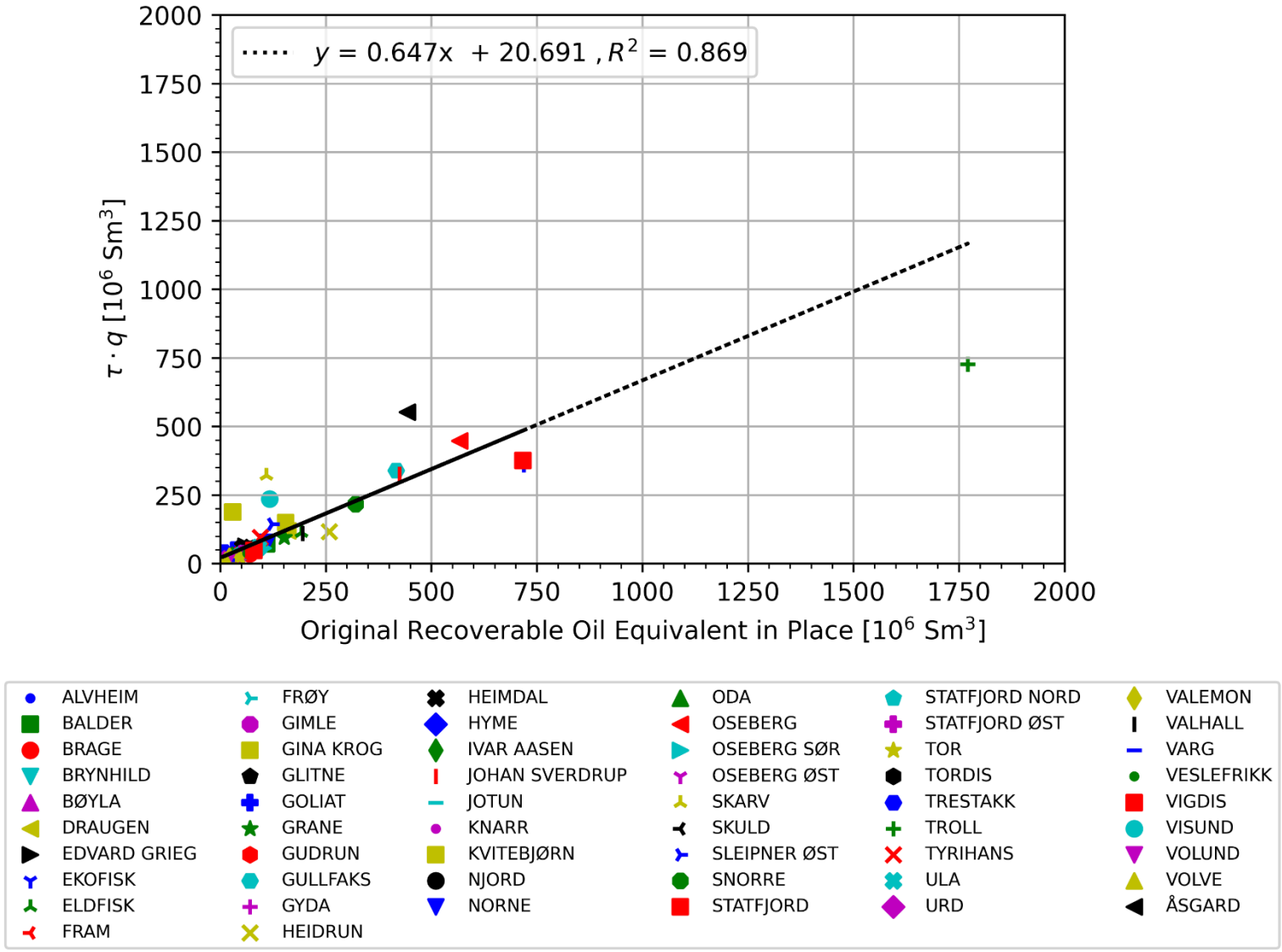


… and some more



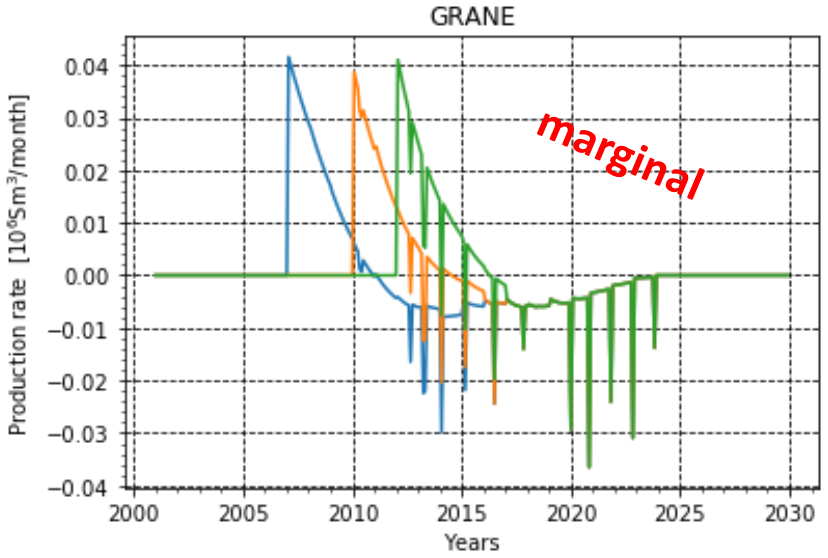

NORNE
(τ=58.622 year, q=1.320·10⁶Sm³/year)
BALDER
(τ=211.338 year, q=0.342·10⁶Sm³/year)
SKARV
(τ=517.793 year, q=0.621·10⁶Sm³/year)
OSEBERG SØR
(τ=105.818 year, q=0.538·10⁶Sm³/year)
TYRIHANS
(τ=190.539 year, q=0.498·10⁶Sm³/year)
ULA
(τ=54.834 year, q=1.067·10⁶Sm³/year)
VIGDIS
(τ=69.745 year, q=0.681·10⁶Sm³/year)
TORDIS
(τ=58.574 year, q=0.947·10⁶Sm³/year)
ALVHEIM
(τ=219.942 year, q=0.258·10⁶Sm³/year)
BRAGE
(τ=55.346 year, q=0.652·10⁶Sm³/year)
NJORD
(τ=69.097 year, q=0.758·10⁶Sm³/year)
VESLEFRIKK
(τ=67.966 year, q=0.562·10⁶Sm³/year)
FRAM
(τ=108.817 year, q=0.538·10⁶Sm³/year)
EDVARD GRIEG
(τ=75.043 year, q=0.838·10⁶Sm³/year)
HEIMDAL
(τ=110.569 year, q=0.528·10⁶Sm³/year)
STATFJORD ØST
(τ=39.670 year, q=0.884·10⁶Sm³/year)
oe-gross
oe-net
Model
Total Wells
Production rate [10⁶Sm³/month]
Total Wells
Years

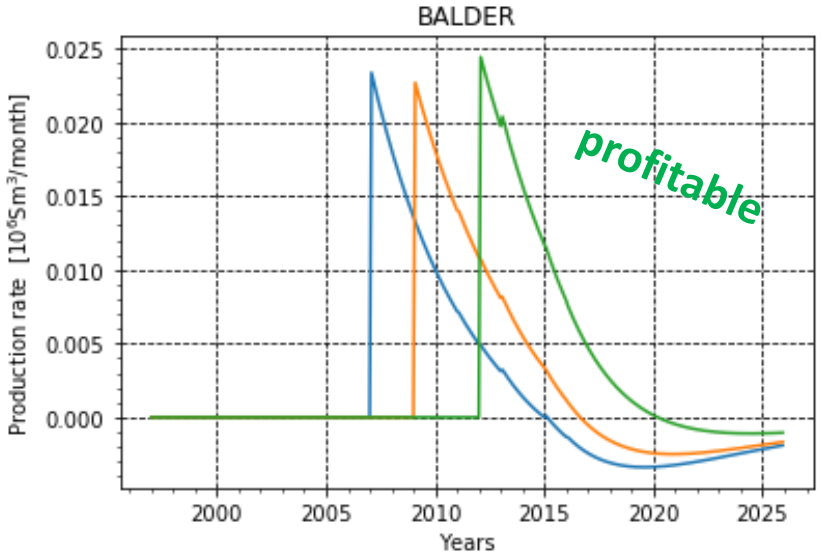
Model parameters vs original oil equivalents in place



Effect of adding one more well

- We run the model once with τ and q determined from data
- At a certain time we add a well
- The difference in field recovery gives additional oil recovery





Preliminary conclusions

- The model seems to work
  - Which indicates that reservoirs are connected
  - Wells drain from the same pool of oil
- More wells – More oil ?
  - Sometimes, but it requires detailed analysis based on a reservoir technical understanding
  - Just adding more wells does not imply higher recovery
  - *"Wells only provide the means for utilizing the energy of production by creating pressure sinks to drain reservoir energy and to establish the process by which the expulsion of oil from rock is brought about" H. H. Kaveler*
- Our modeling shows that we can model reservoirs with injection as continuous flow systems
  - Most fields behaves (surprisingly) similar
- Why? Maybe it is NPDs unique role and the petroleum act
  - "The extraction must take place in accordance with sound technical and sound economic principles and in such a way that the loss of petroleum or reservoir energy is avoided"

Tusen takk!

aksel.hiorth@uis.no
cssr.no

Centre for Sustainable Subsurface Resources

CSSR is a collaboration between NORCE and the University of Bergen and receives funding from the Research Council of Norway (nr: 331841) and industry stakeholders.


¡THANKS!
// STAVANGER 2022
ANNUAL EVENT
eor
Enhanced Oil Recovery
Technology Collaboration Programme
by iea