Multiphase RTA Consortium

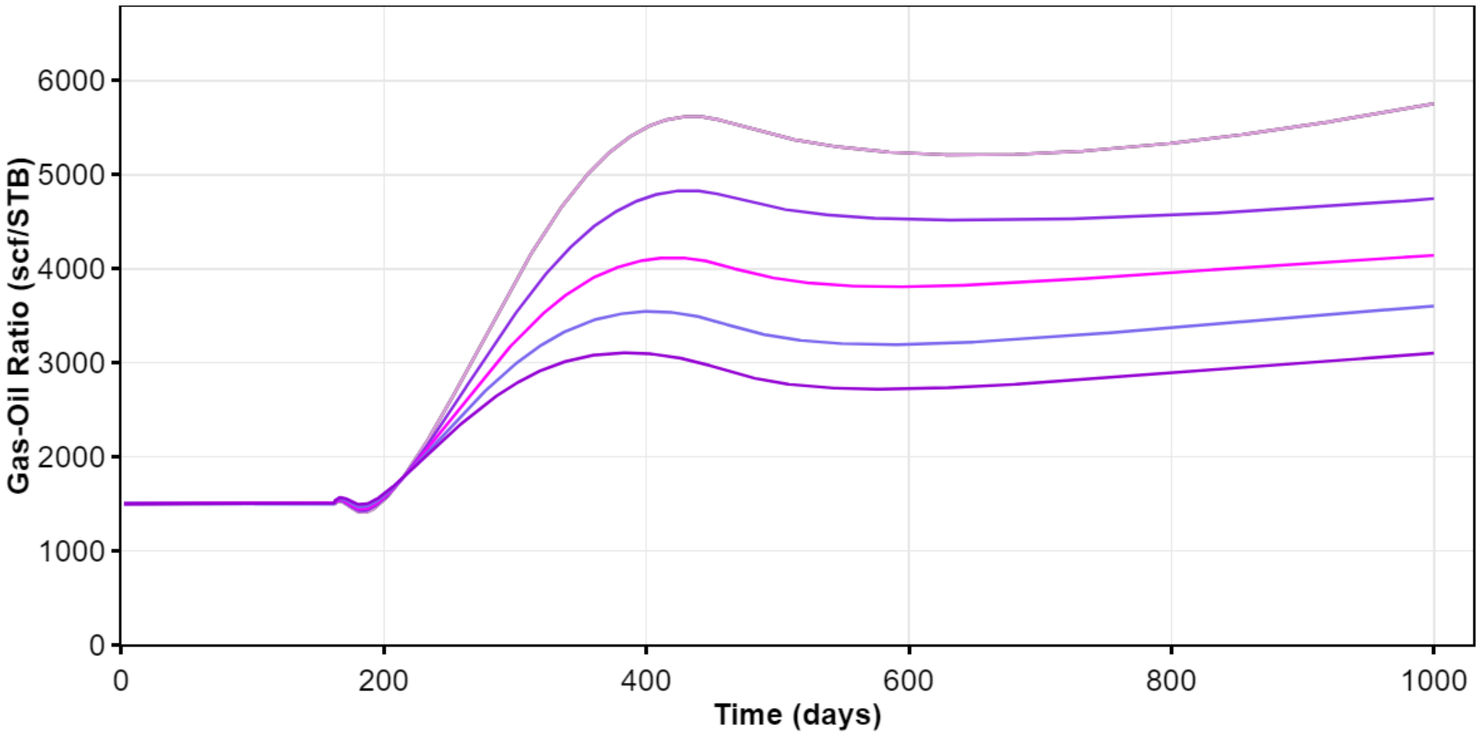
Which reservoir parameters change the producing GOR profile, and how?

2023

Intro

Problem Statement

We observe a wide-range of producing GOR profiles in tight unconventionals.



But which reservoir parameters change producing GOR when the bottomhole pressure is below the saturation pressure? And how?

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Summary:
Which parameters change producing GOR, and how?

Parameter	Relationship to producing GOR*
Fracture conductivity, F_{cd}	$GOR \propto F_{cd}$
Geomechanical effects, γ	$GOR \propto 1/\gamma_{matrix}$ | $GOR \propto 1/\gamma_{fracture}$
Volume beyond frac tips / height	$GOR \propto 1/x_e$ | $GOR \propto 1/h$
Relative Permeability Residuals	$GOR \propto S_{wc}$ | $GOR \propto S_{orw}$ | $GOR \propto S_{org}$ | $GOR \propto 1/S_{gc}$
Relative Permeability Exponents	$GOR \propto 1/n_w$ | $GOR \propto n_{ow}$ | $GOR \propto 1/n_g$ | $GOR \propto n_{og}$
Relative Permeability Endpoints[2]	$GOR \propto k_{rwro}$ | $GOR \propto 1/k_{rocw}$ | $GOR \propto k_{rgro}$

[1] Producing GOR when $p_{wf} < p_{sat}$

[2] k_{rwro}: Relative perm of water at $S_w = 1\text{-}S_{orw}$, $S_g = 0$

[2] k_{rocw}: Relative perm of oil at $S_w=S_{wc}$, $S_g=0$.

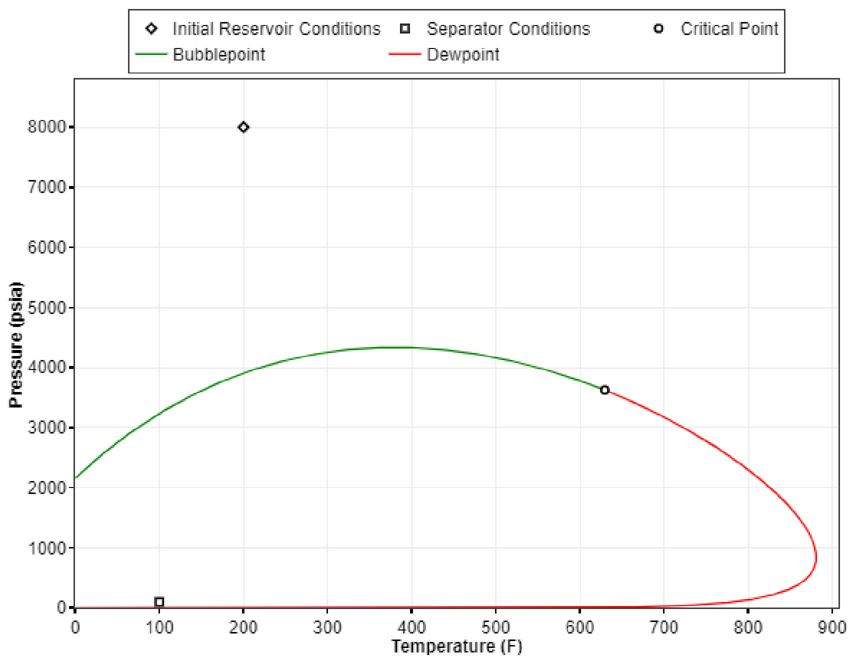
[2] k_{rgro}: Relative perm of gas at $S_w=S_{wc}$, $S_o=S_{org}$

Baker is used for three-phase relative perm.

Sensitivities

Base Case: Fluid System

Phase Envelope



- p_{Ri} = 8000 psia | T_{res} = 200 F
- Initially undersaturated
- Bubblepoint, p_{bi} = 3900 psia
- B_{oi} = 1.69 RB/STB
- R_{si} = 1500 scf/STB
- Volatile oil

Fluid Properties at Initial Reservoir Conditions

Reservoir Type	Total FVF - Bt	Total GOR - Rt	Bubblepoint - pb	Reservoir Classification
Undersaturated Oil	1.691 RB/STB	1500 scf/STB	3907.06 psia	Volatile Oil

Oil Saturation - So	Oil FVF - Bo	Solution GOR - Rs	Oil Viscosity - μo	Reservoir Oil Density - ρo
100%	1.691 RB/STB	1500 scf/STB	0.180 cp	40.046 lbm/ft3

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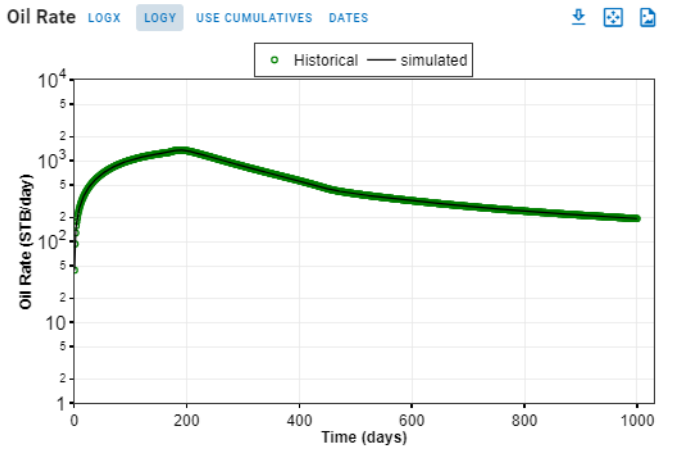
Base Case: Production Data

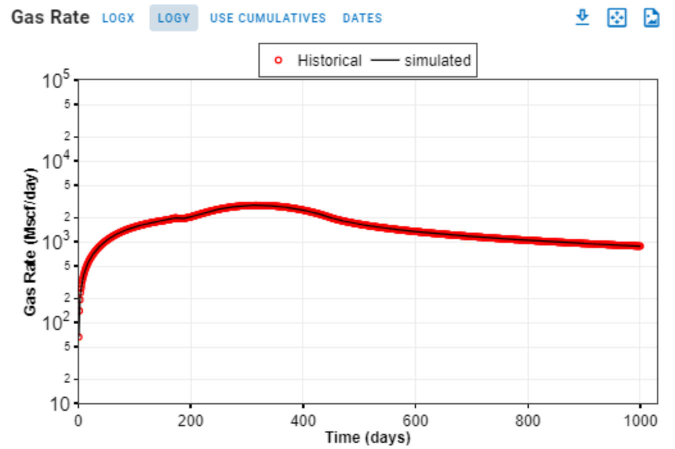
OOIP = 3130 STB | LFP = 320,000 $ft^2md^{1/2}$

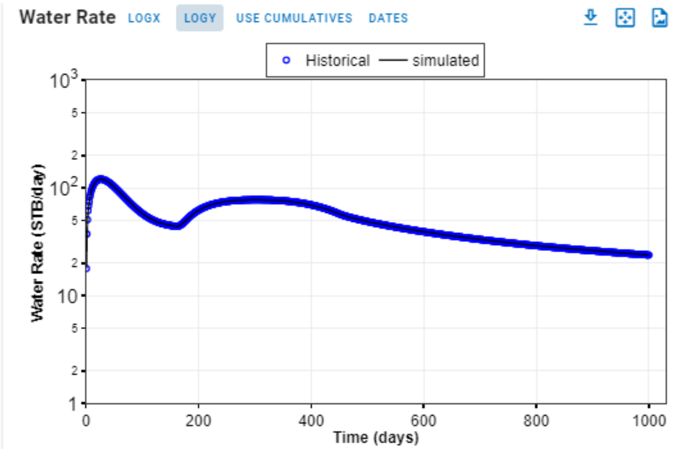
Oil		
OOIP	3126	MSTB

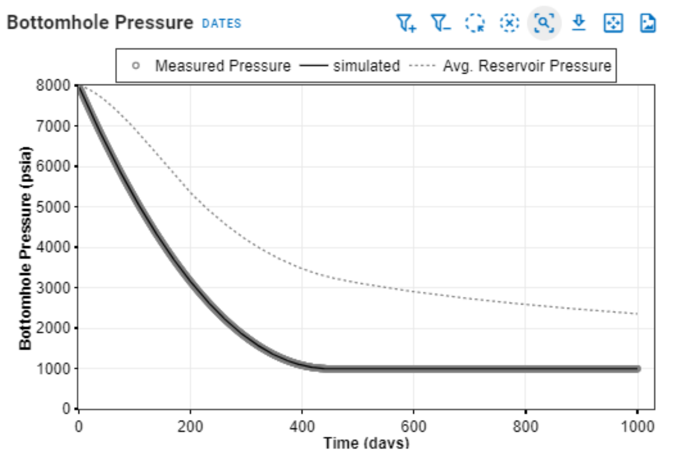
Gas		
OGIP	4690	MMscf

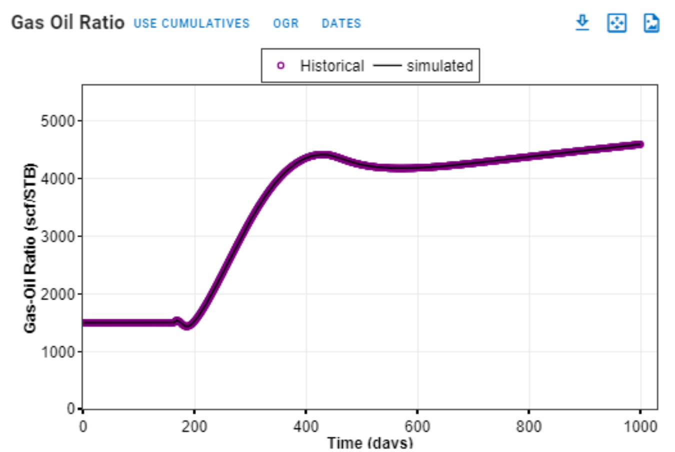
Water		
OWIP	2238	MSTB

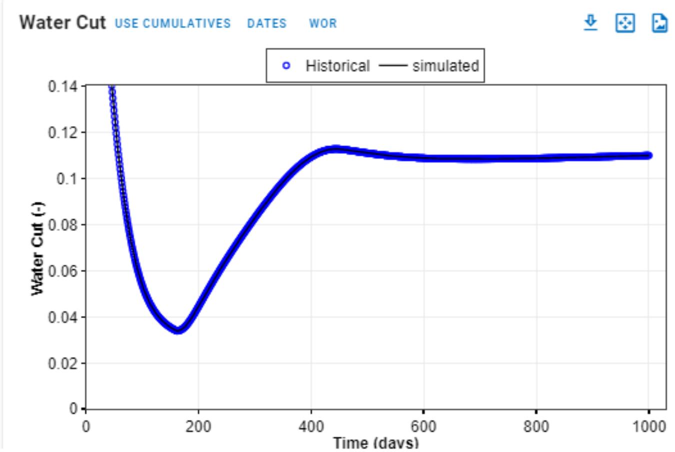






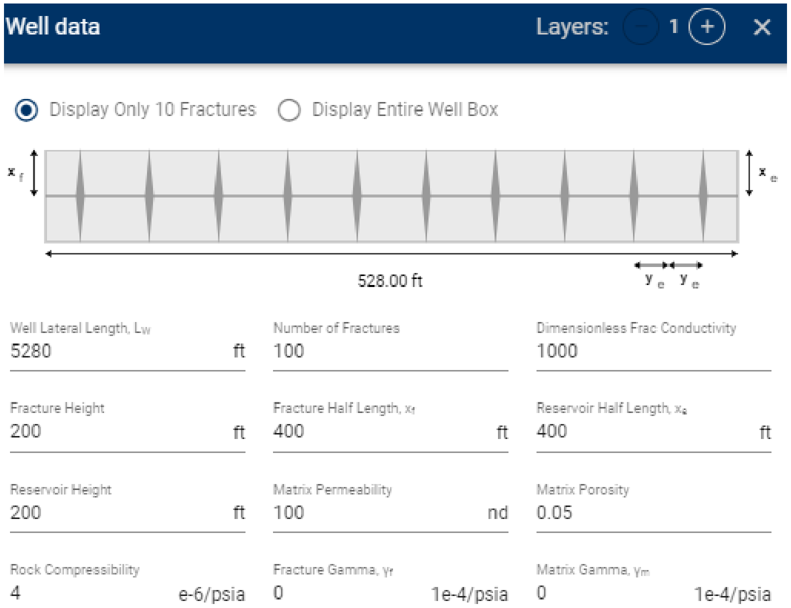


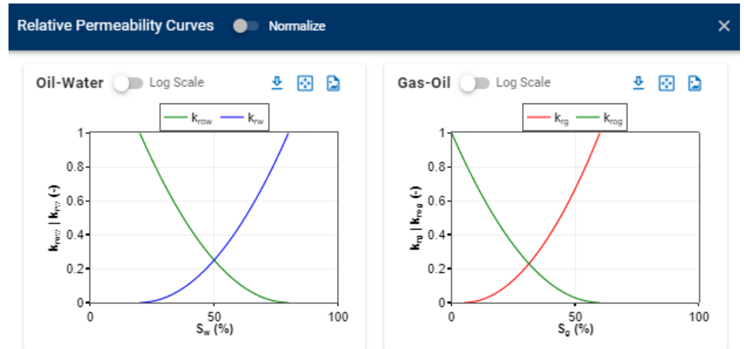


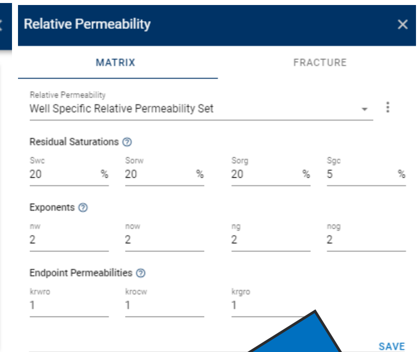


Base Case: Input

OOIP = 3130 STB | LFP = 320,000 $ft^2 md^{1/2}$

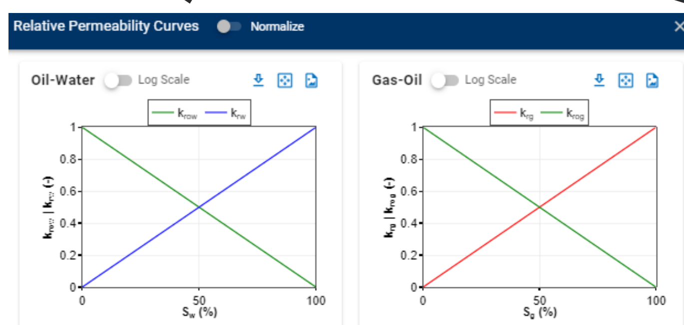






Matrix Rel. Perm: This is the default Corey relative permeability.

Fracture Rel. Perm: Straight line rel. permeabilities.



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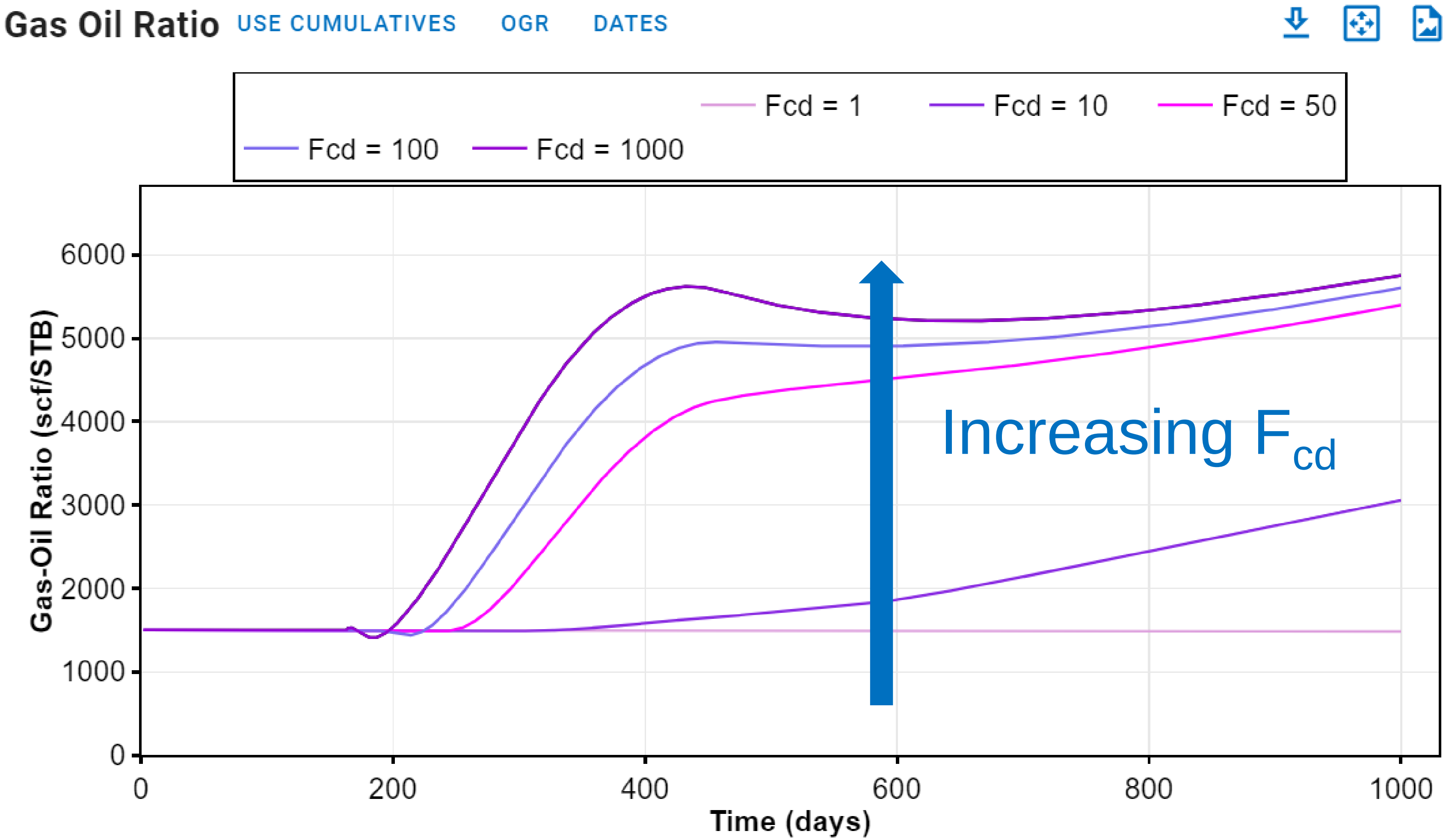
Fracture Conductivity: F_{cd}

GOR ∝ F_{cd}: When F_{cd} goes up, GOR goes up*



*The GOR does not go up more when F_{cd} starts to behave infinite conductive.

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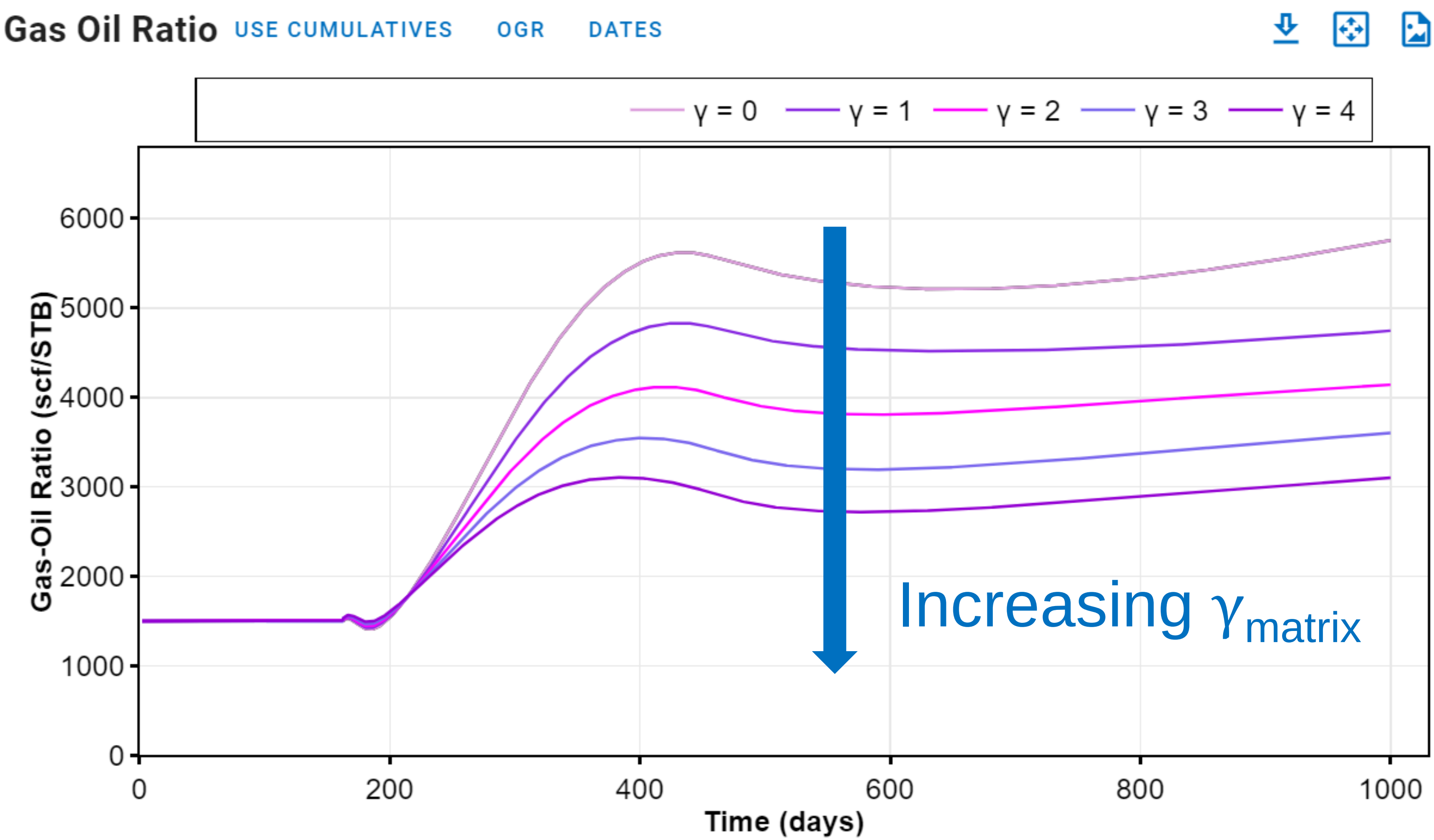
Geomechanical Effects: γ_{matrix}

GOR ∝ $1/\gamma_{matrix}$: When γ_{matrix} goes up, GOR goes down



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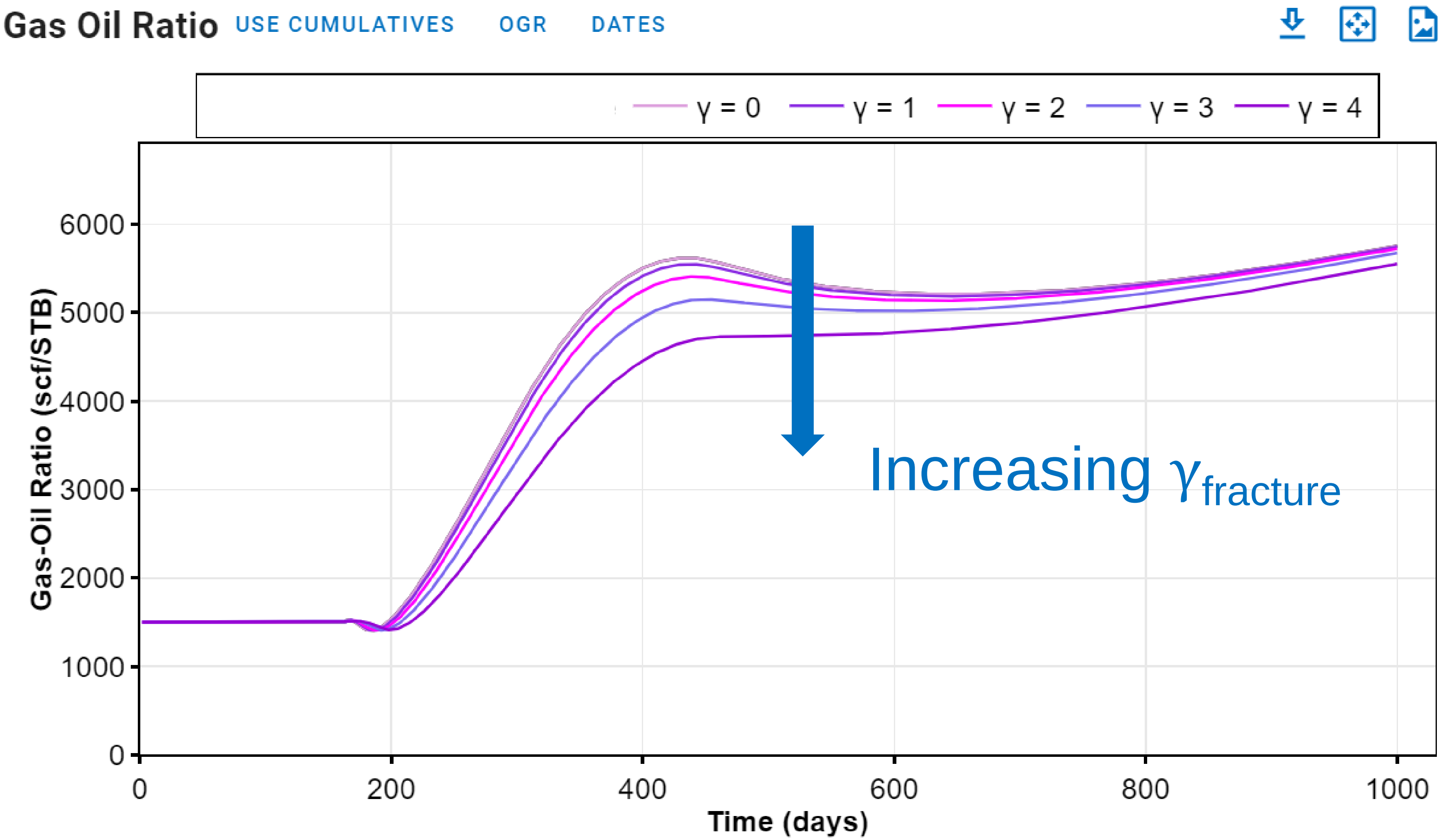
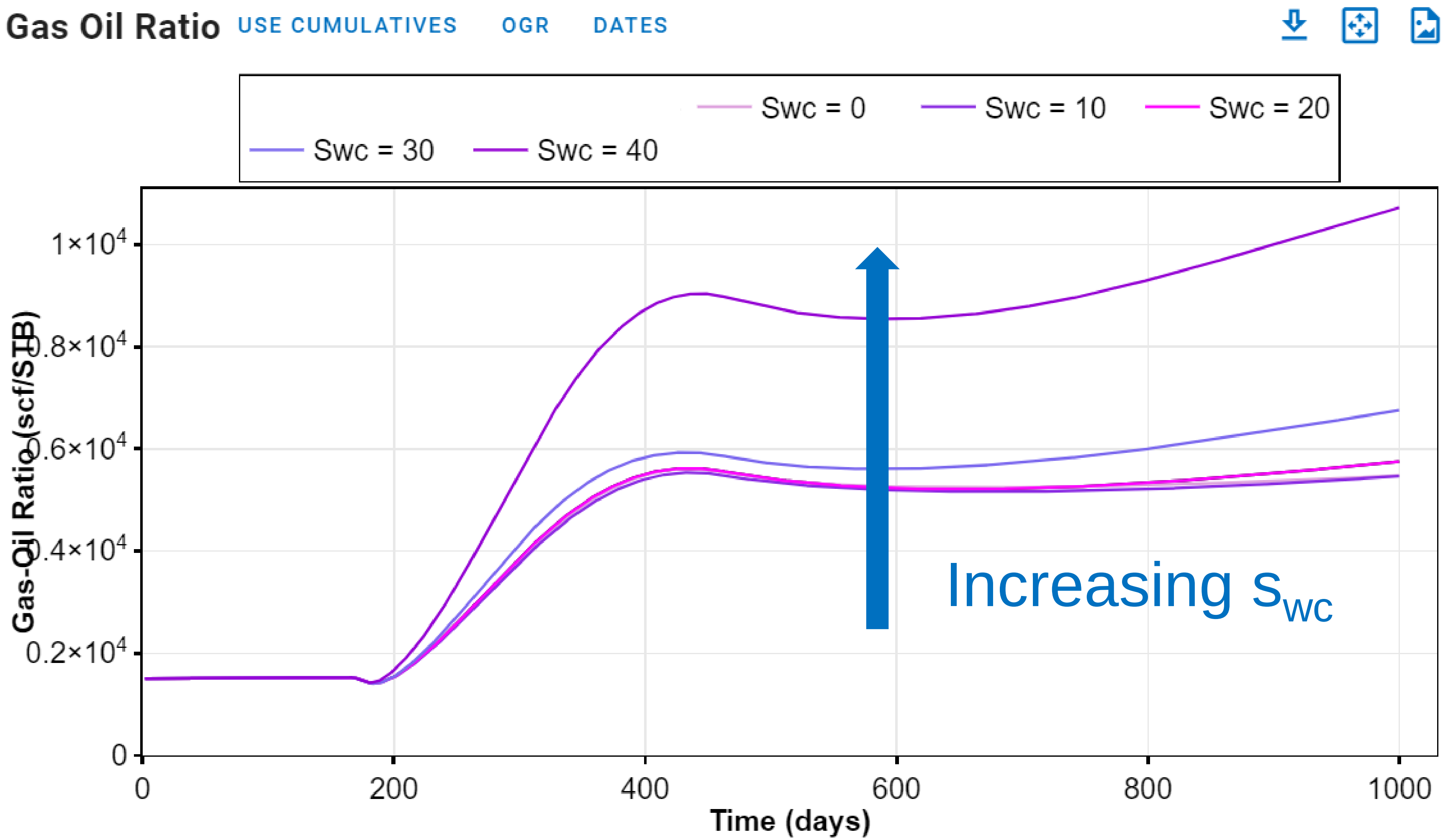
Geomechanical Effects: $\gamma_{fracture}$

$GOR \propto 1/\gamma_{fracture}$: When $\gamma_{fracture}$ goes up, GOR goes down



Relative Permeability: S_{wc}

GOR ∝ S_{wc}: When S_{wc} goes up, GOR goes up



*S_{wi} = 30% (if S_{wc} >= S_{wi}, no water flowing). Just a little water flow changes the GOR a lot (most likely a three-phase rel. perm model item).

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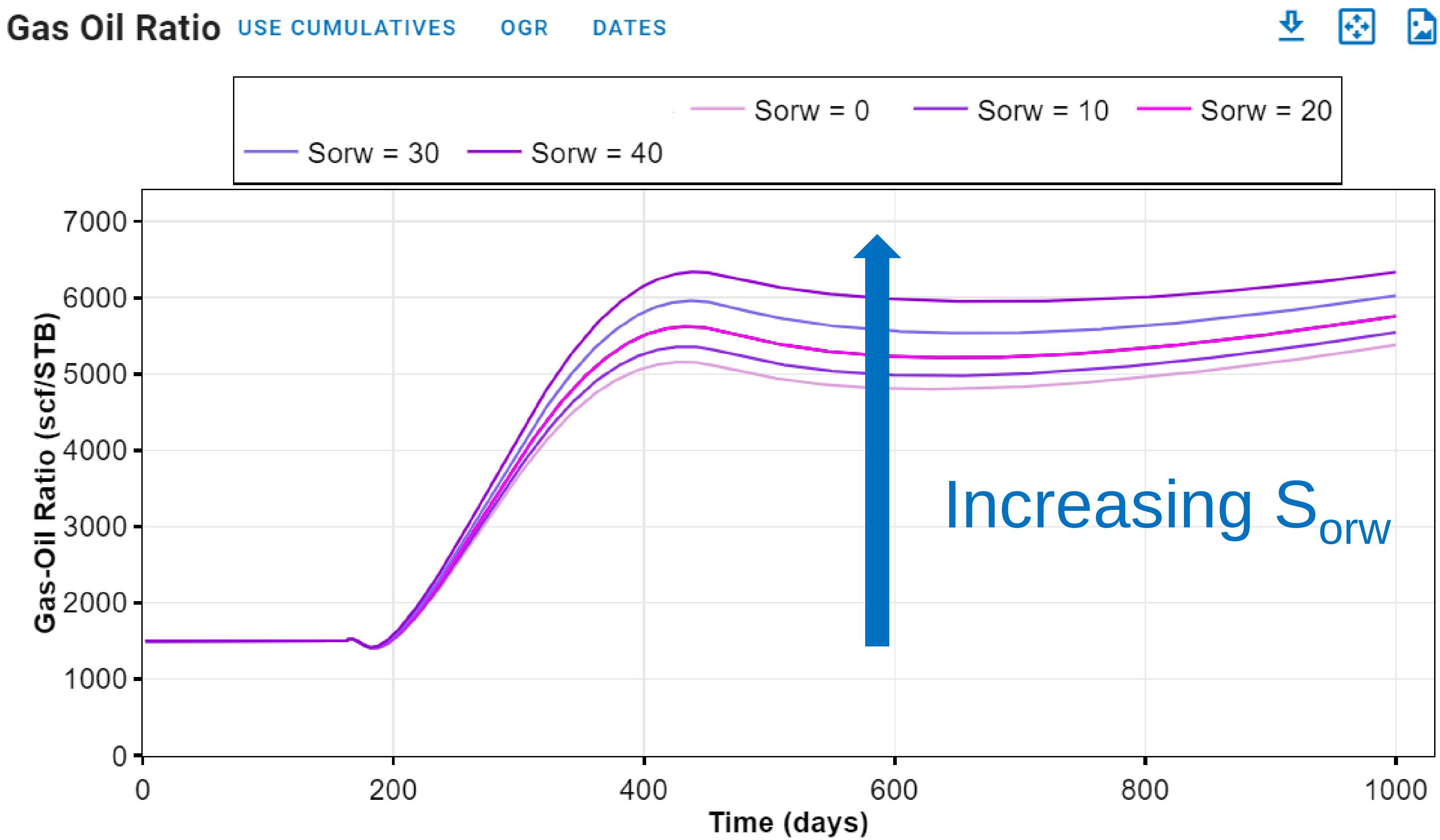
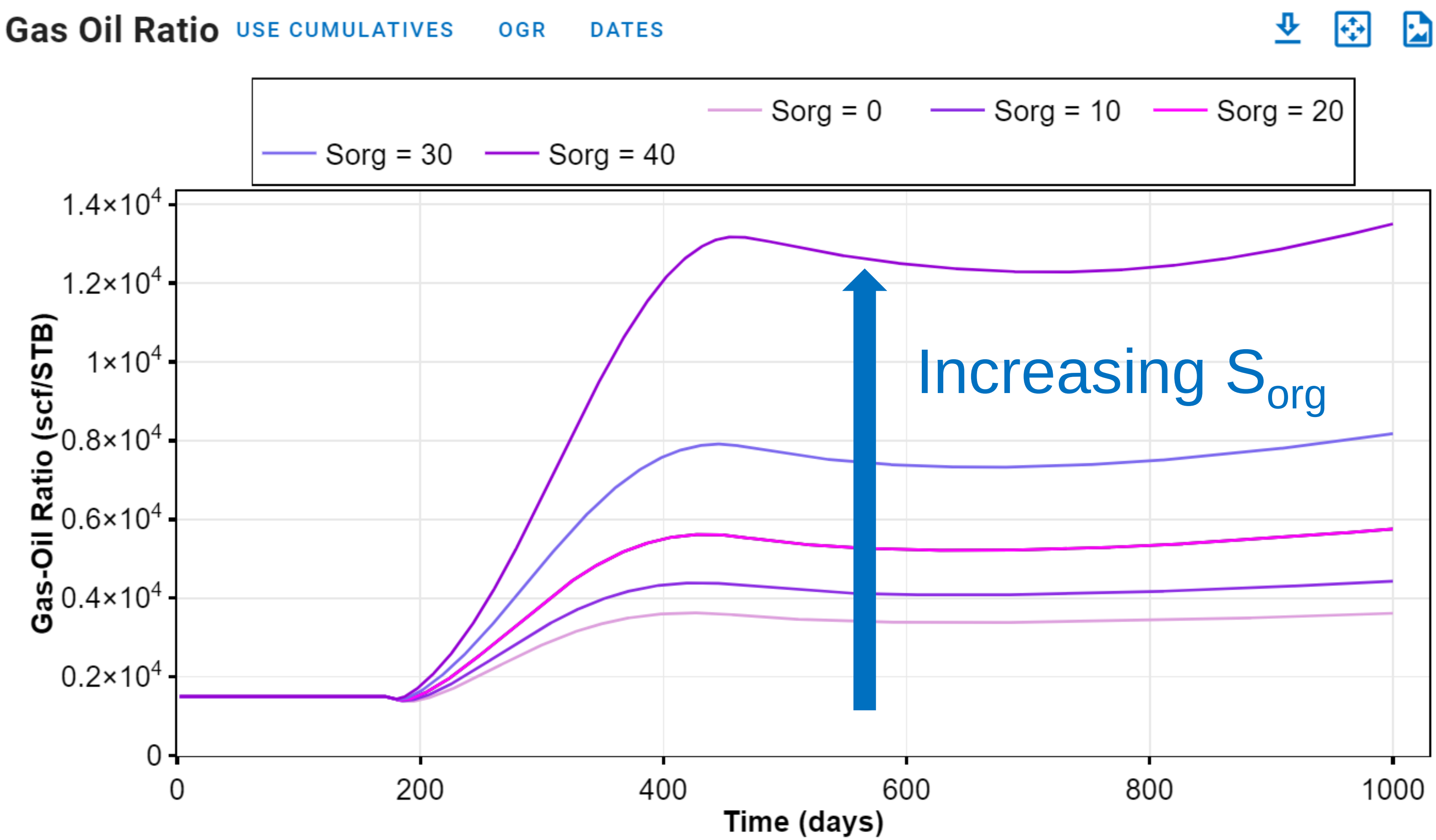
Relative Permeability: S_{orw}

GOR ∝ S_{orw}: When S_{orw} goes up, GOR goes up



Relative Permeability: S_{org}

$GOR \propto S_{org}$: When S_{org} goes up, GOR goes up



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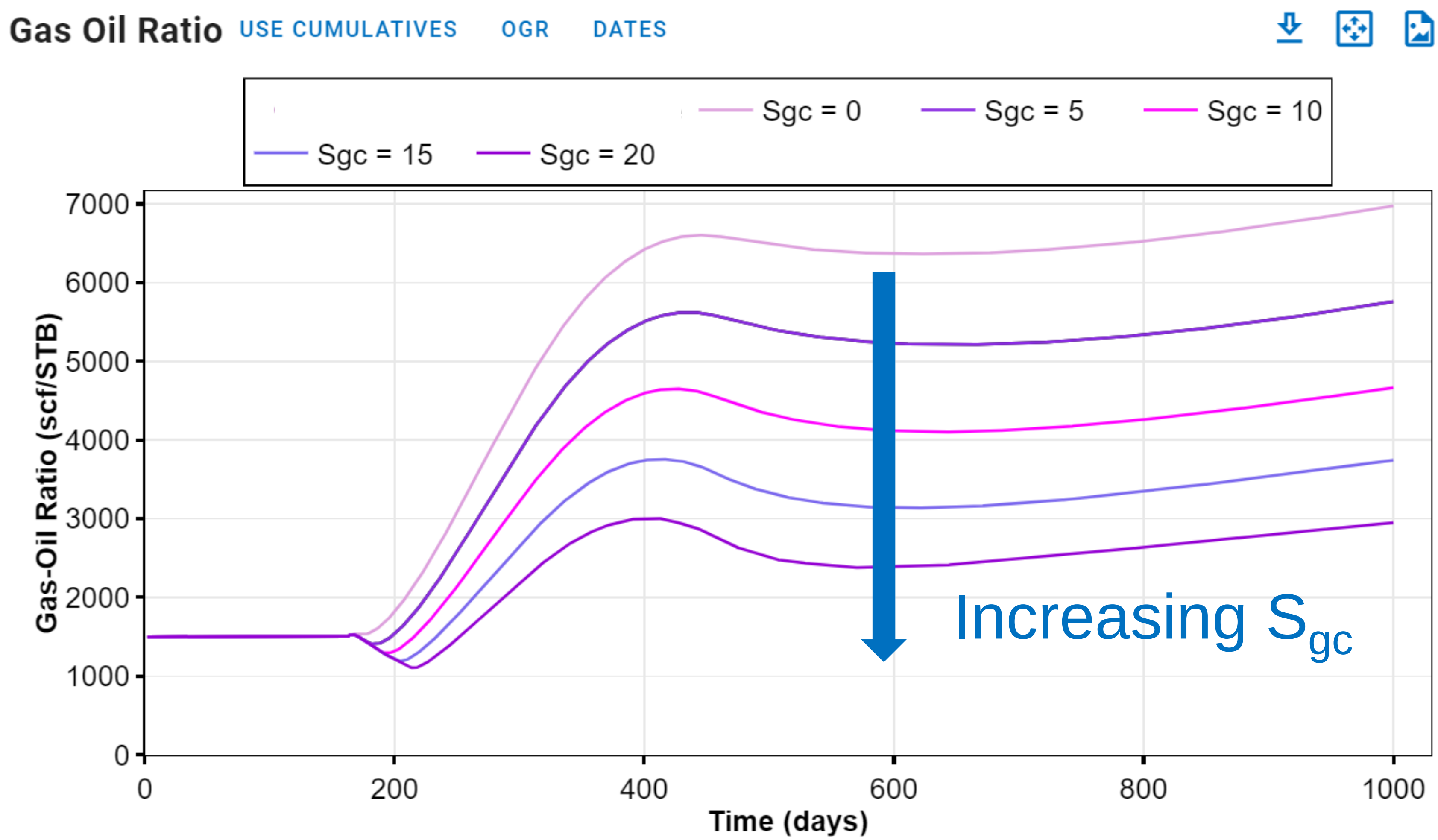
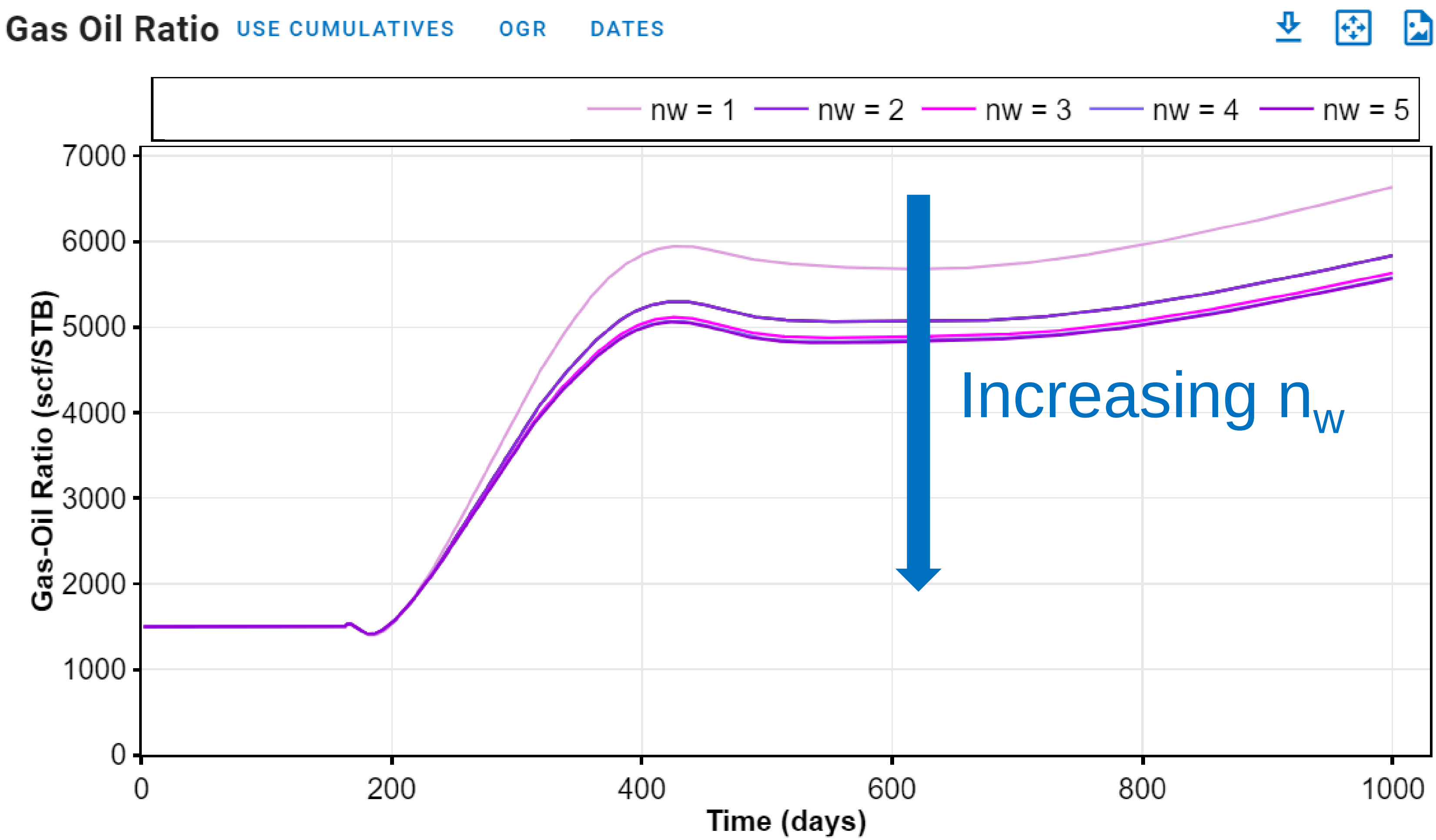
Relative Permeability: S_{gc}

$GOR \propto 1/S_{gc}$: When S_{gc} goes up, GOR goes down



Relative Permeability: n_w

$GOR \propto 1/n_w$: When n_w goes up, GOR goes down



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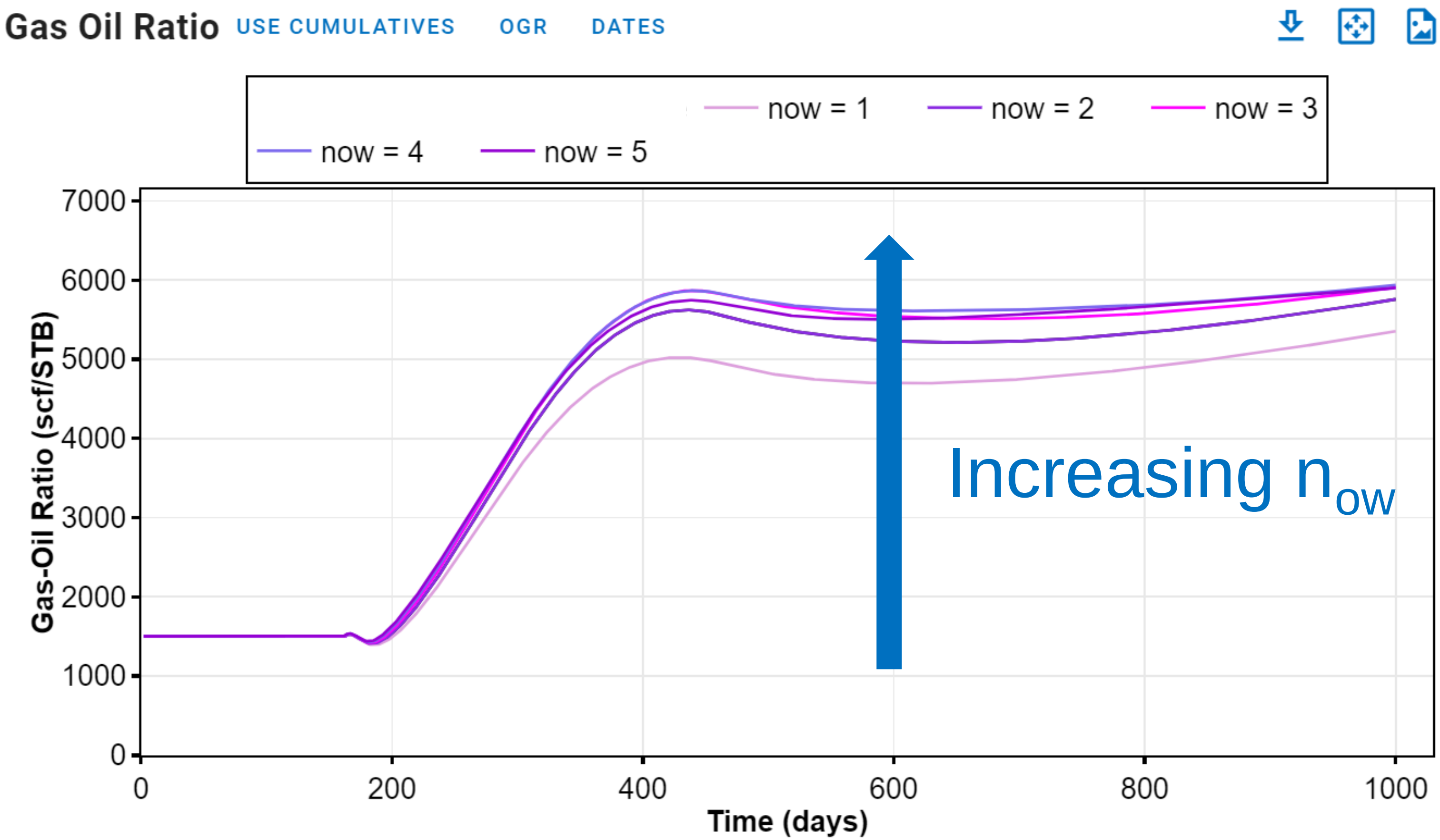
Relative Permeability: n_{ow}

$GOR \propto n_{ow}$: When n_{ow} goes up, GOR goes up



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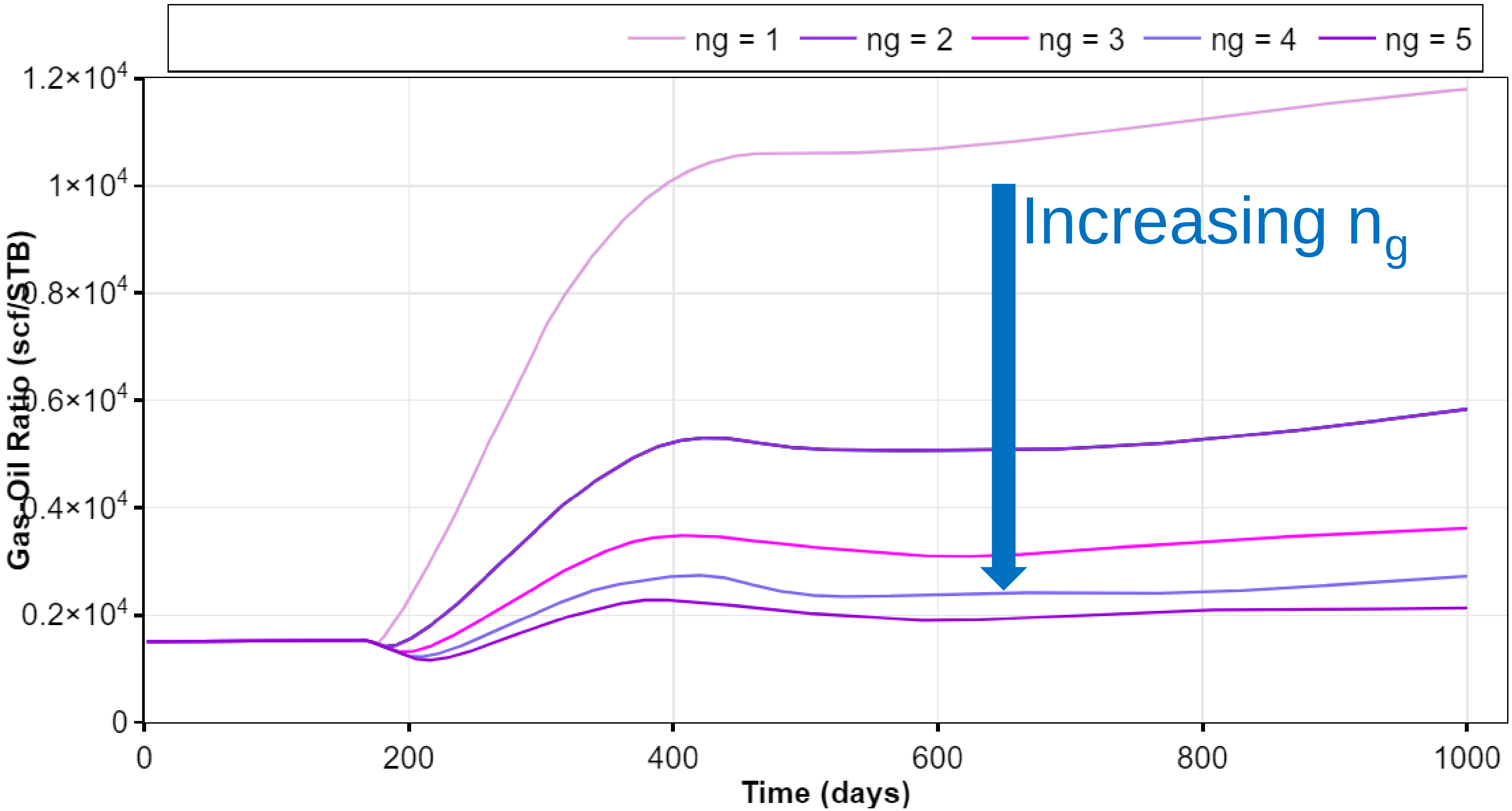
Relative Permeability: n_g

GOR ∝ $1/n_g$: When n_g goes up, GOR goes down



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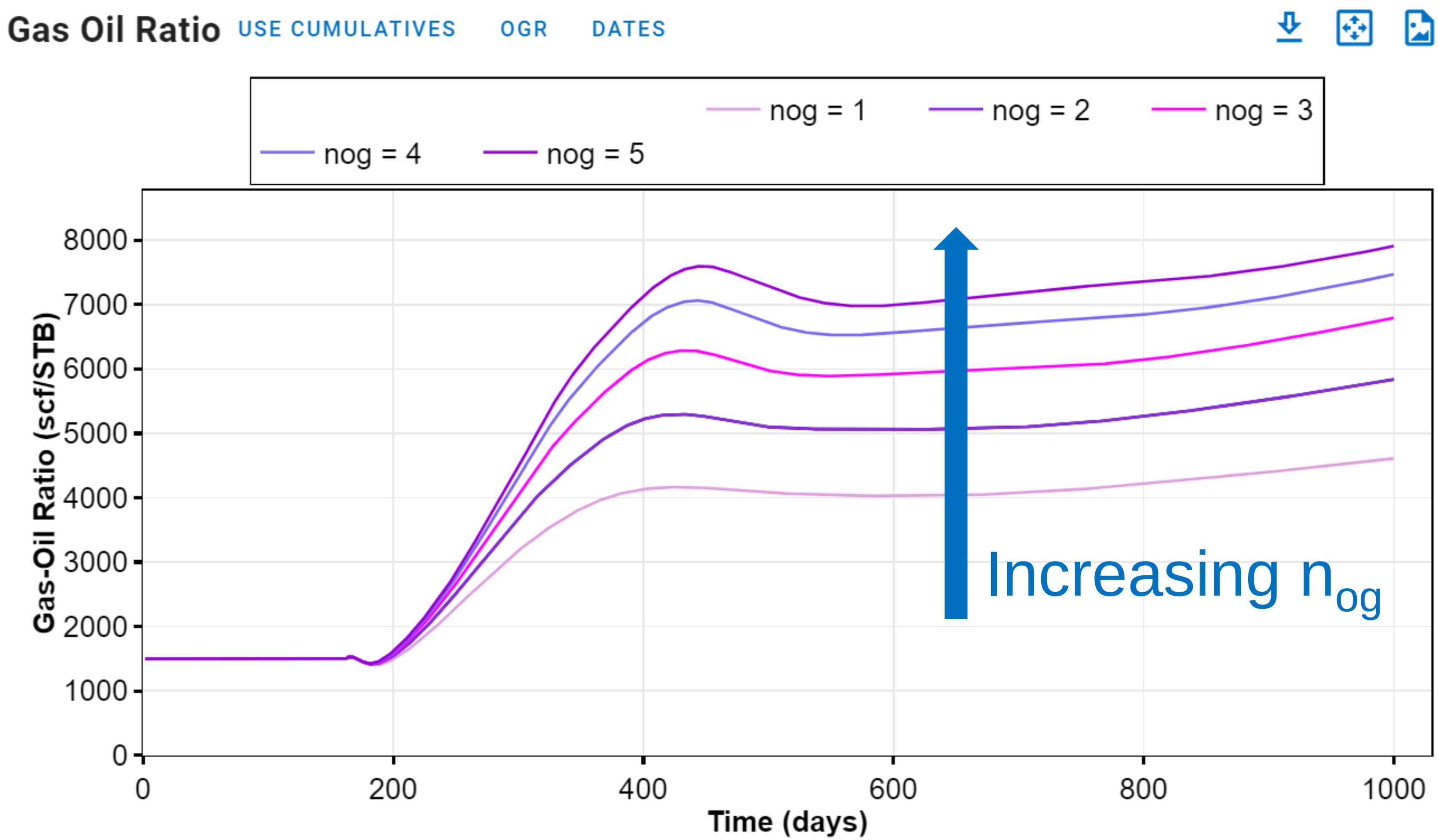
Relative Permeability: n_{og}

GOR ∝ n_{og}: When n_{og} goes up, GOR goes up



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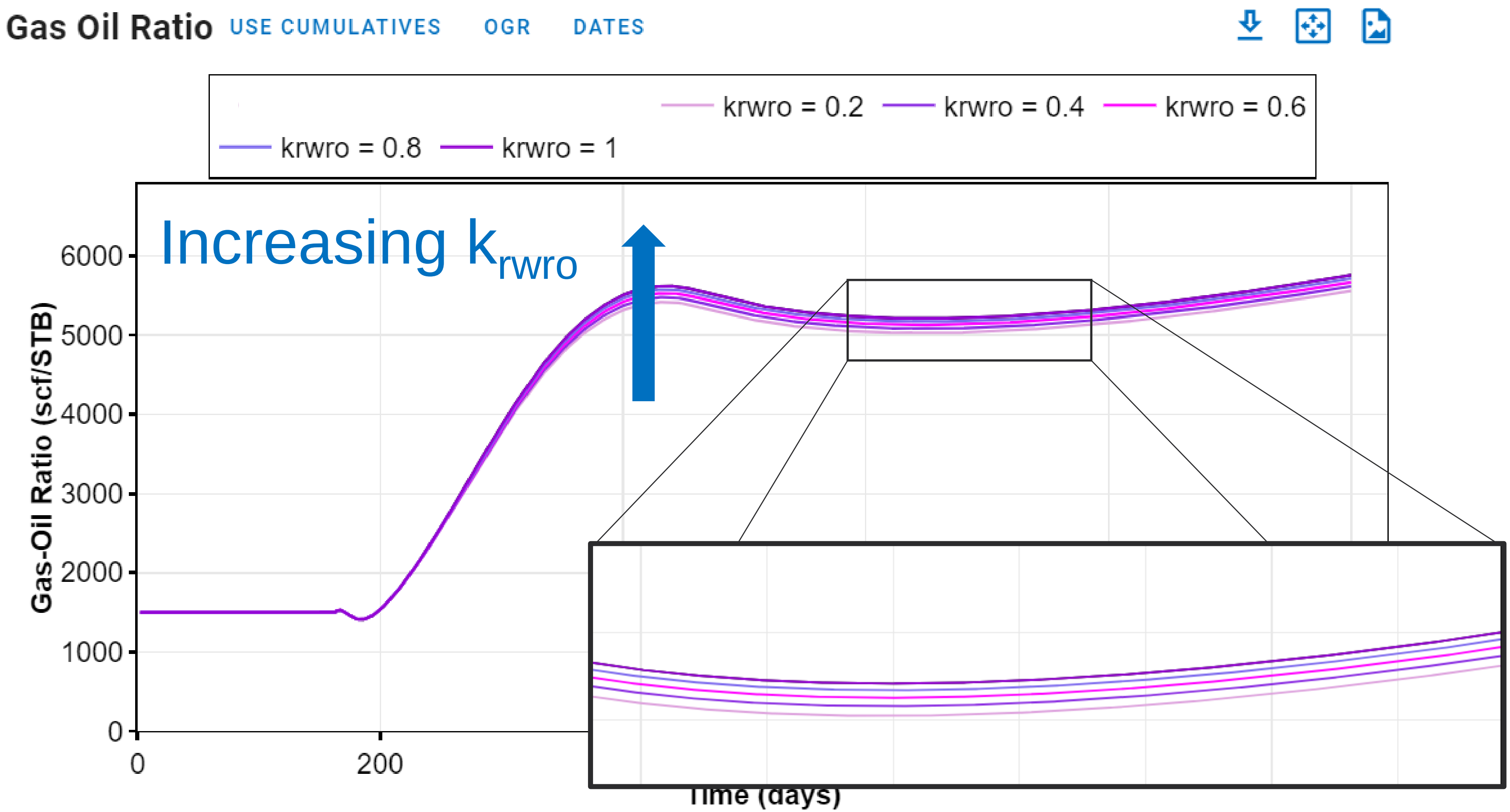
Relative Permeability: k_{rwro}

$GOR \propto k_{rwro}$: When k_{rwro} goes up, GOR goes up



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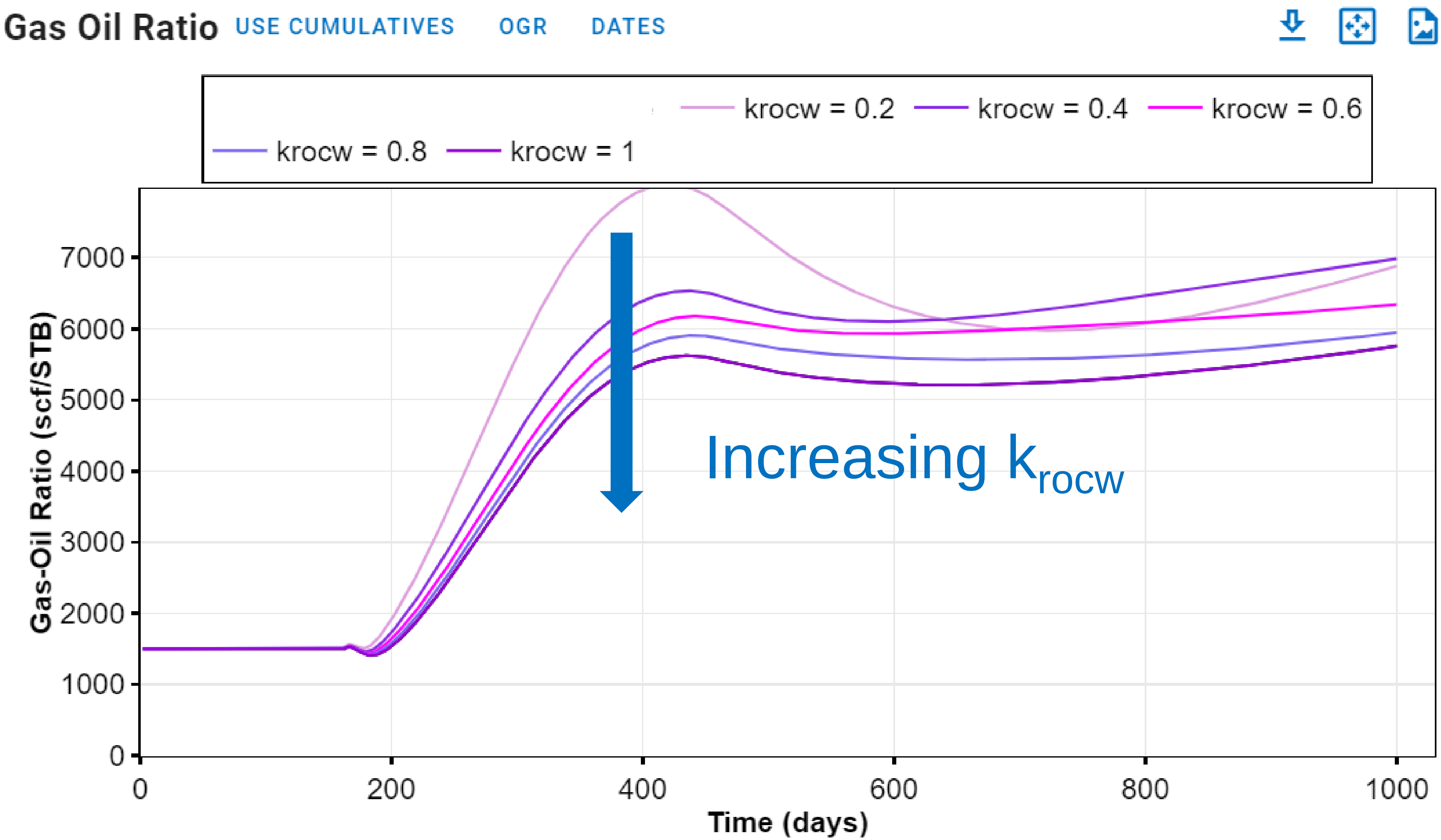
Relative Permeability: k_{rocw}

GOR $\propto 1/k_{rocw}$: When k_{rocw} goes up, GOR goes down



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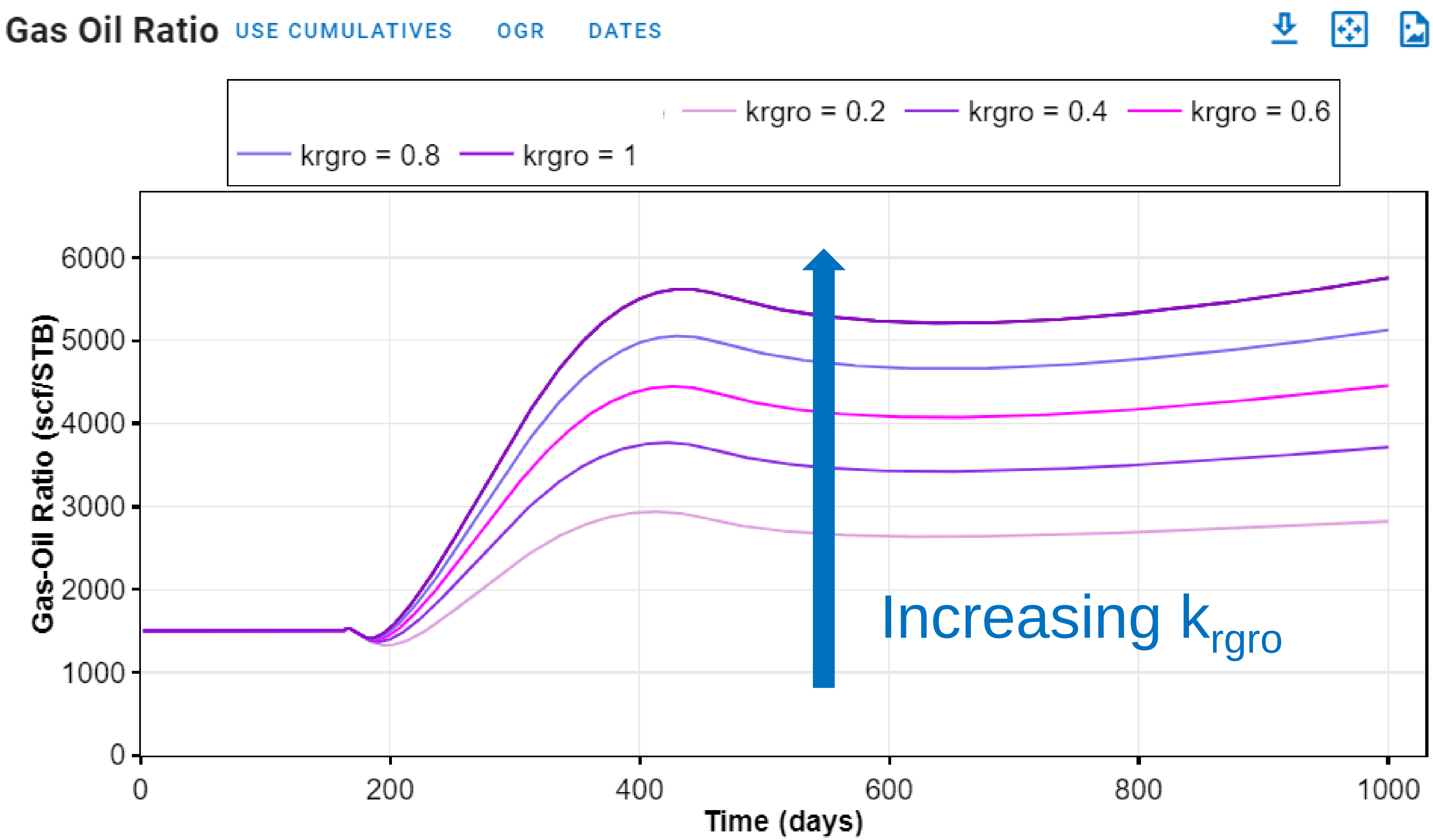
Relative Permeability: k_{rgro}

GOR ∝ k_{rgro} : When k_{rgro} goes up, GOR goes up



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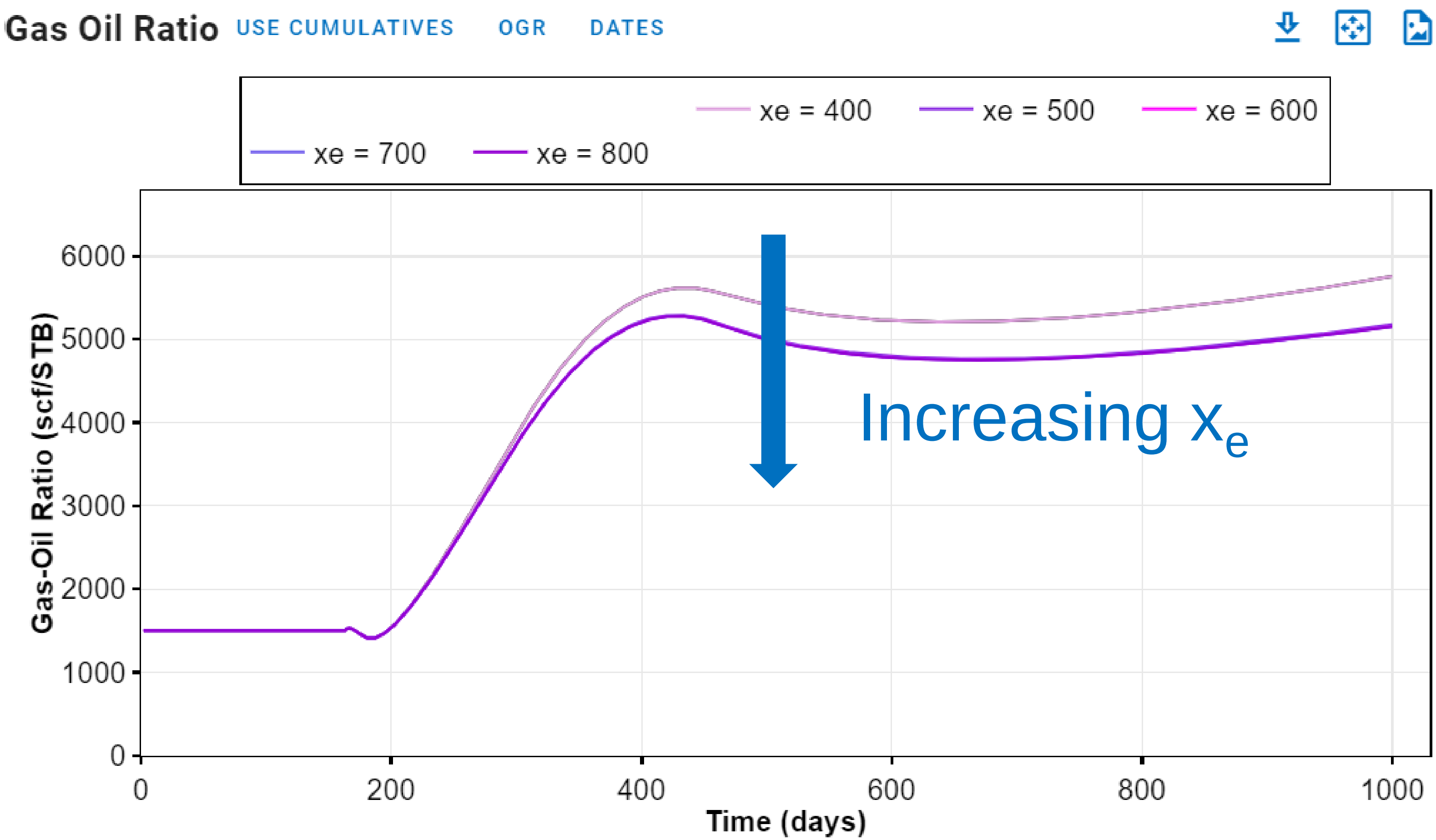
Reservoir extent > Frac length (k = 100 nd)

GOR ∝ $1/x_e$: When x_e goes up, GOR goes down*



*This is a strong function of permeability.

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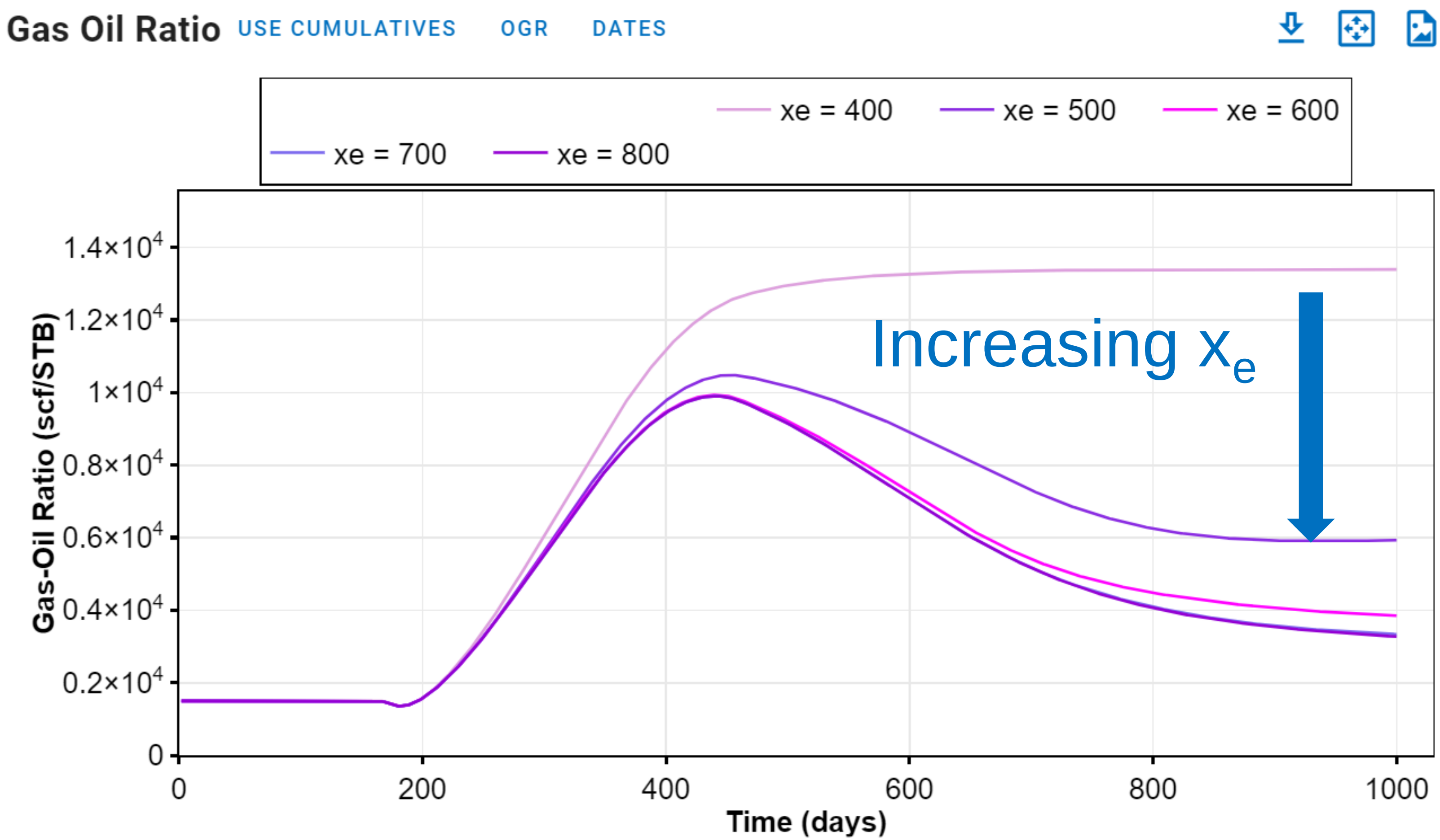
Reservoir extent > Frac length (k = 1000 nd)

GOR ∝ $1/x_e$: When x_e goes up, GOR goes down*



*This is a strong function of permeability.

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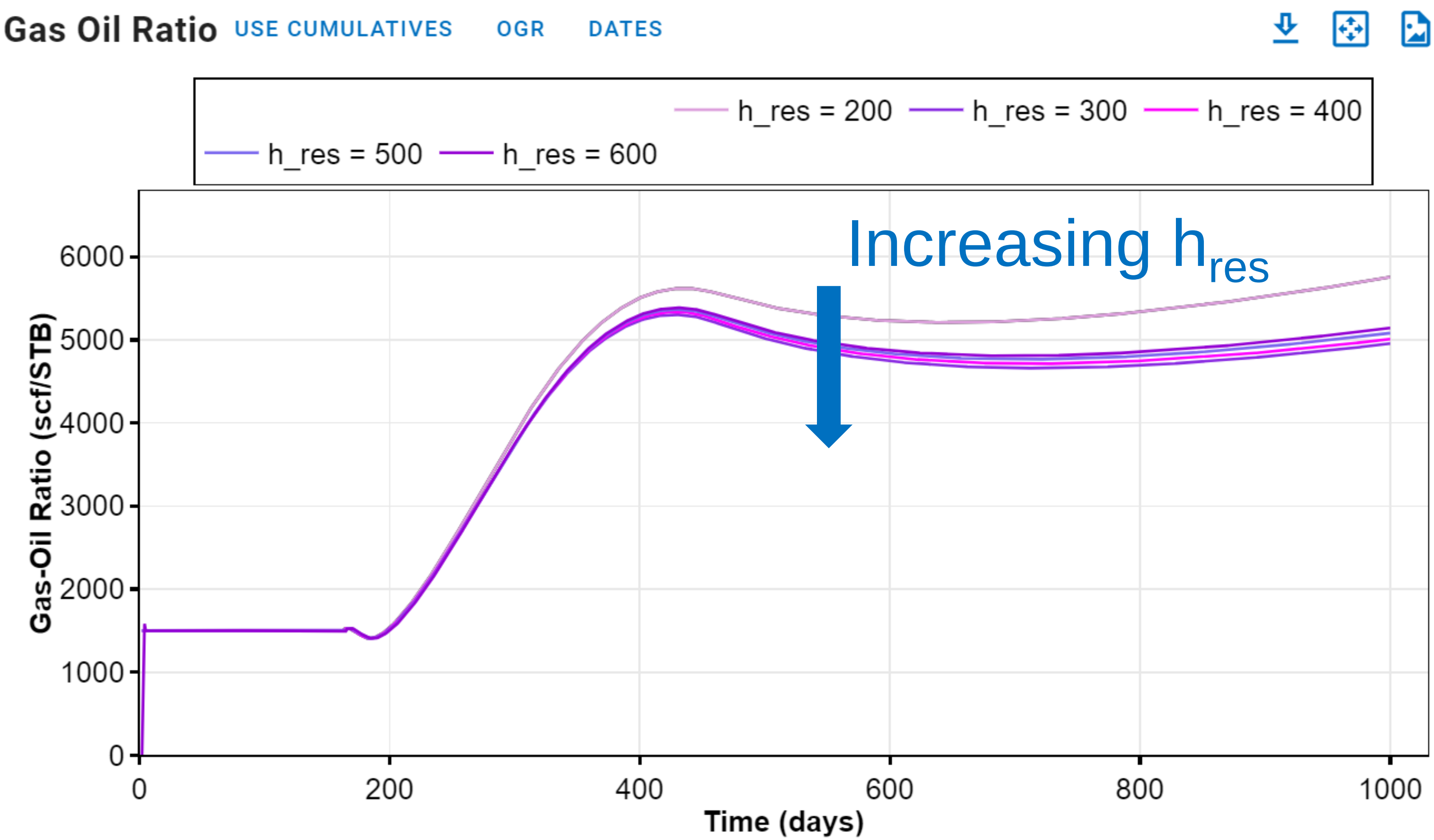
Reservoir height > Frac height (k = 100 nd)

GOR ∝ $1/h_{res}$: When h_{res} goes up, GOR goes down*



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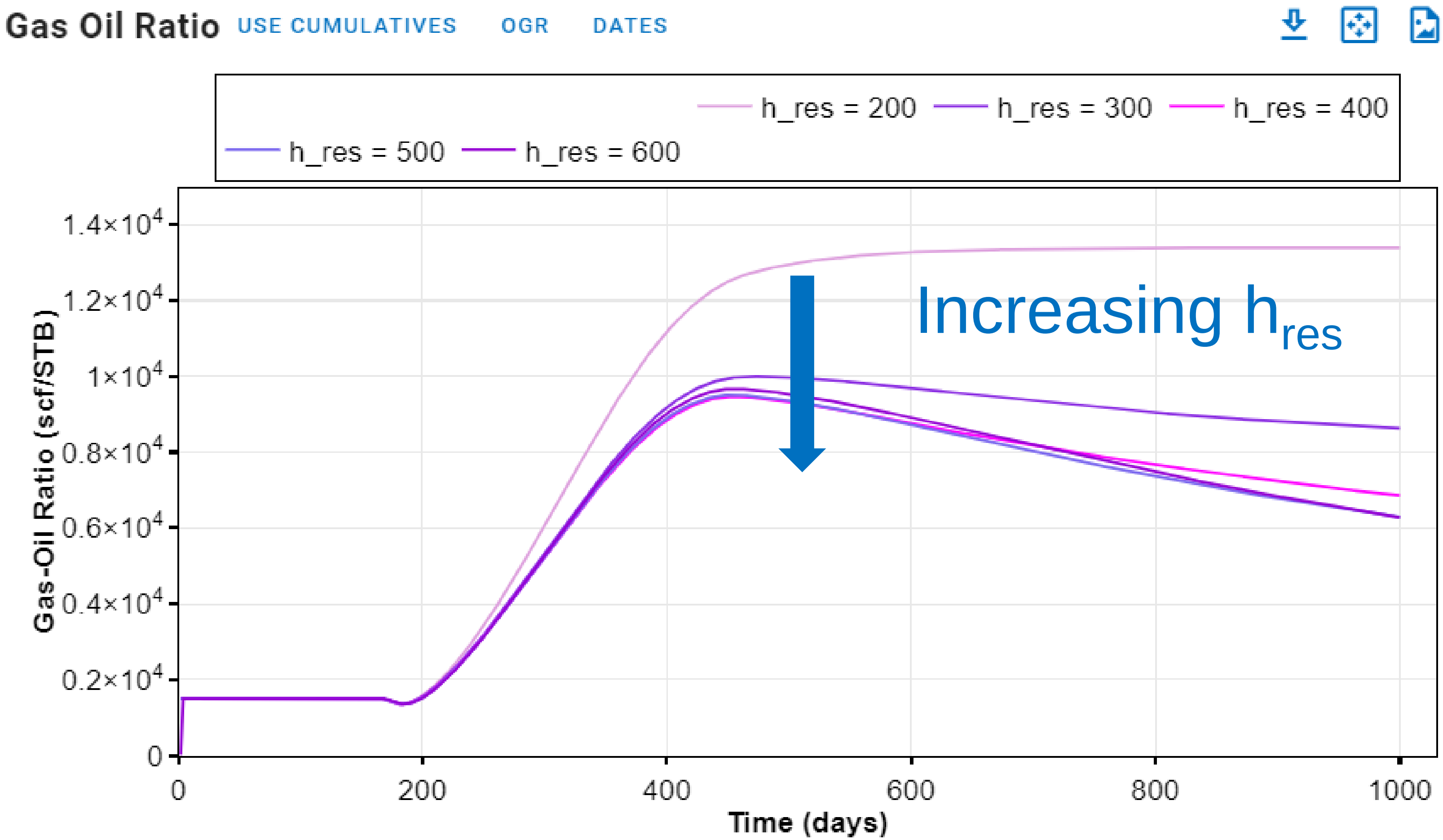
Reservoir height > Frac height (k = 1000 nd)

GOR $\propto 1/h_{res}$: When h_{res} goes up, GOR goes down*



*This is a strong function of permeability.

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Appendix