Polymer Simulator in OPM

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- Polymer flooding introduction
- Polymer simulation model
- Current polymer simulator status
- Examples
- The way forward

Motivation

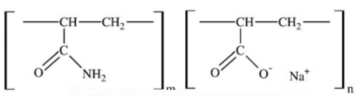
- Currently, Statoil uses Eclipse and CMG STARS.
- These simulators are proprietary.
- A platform for testing new algorithms and functionalities.
- Share the modern reservoir simulator infrastructure.

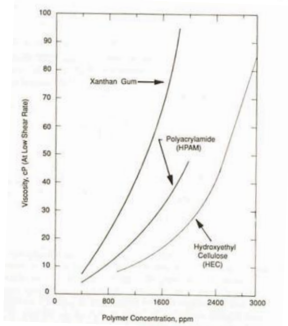
Polymer Flooding - Introduction

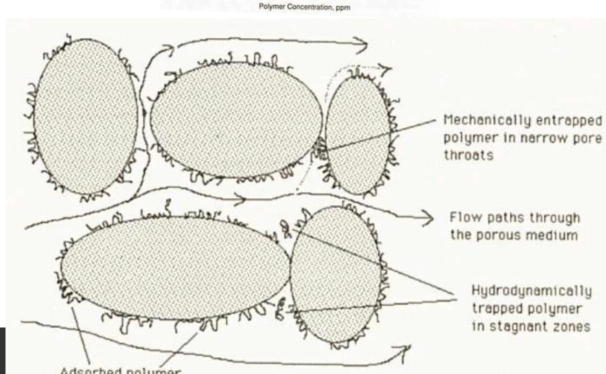
Large polymer molecules

Reduced water mobility

Improved sweep







$$\lambda_p = k_{rp} / \mu_p$$

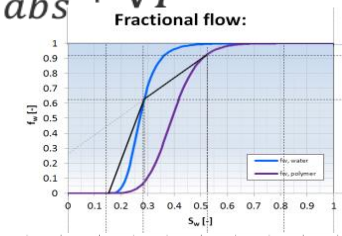
Increased water viscosity

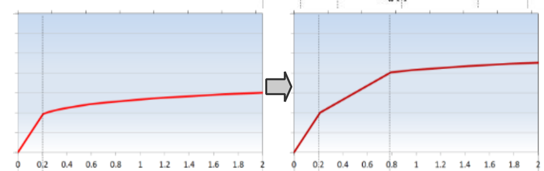
Retention effects (adsorption,entrapment)

Reduced water relative permeability

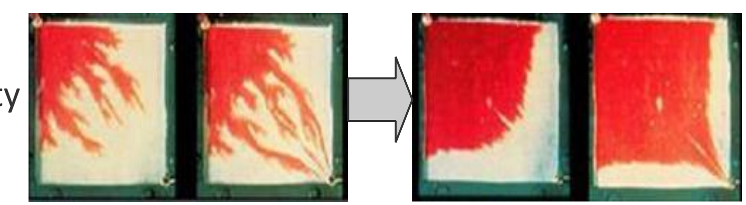
$$v_p = -\lambda_p * K_{abs} * \nabla P$$

Accelerated recovery

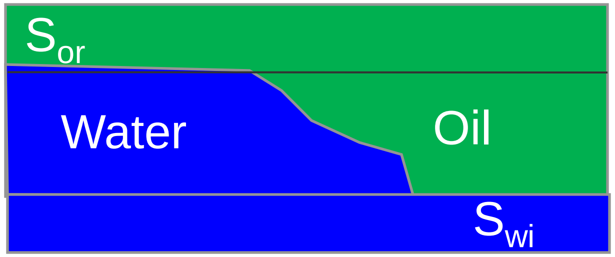




Macroscopic sweep improvement



EOR by Polymer Flood - Targets



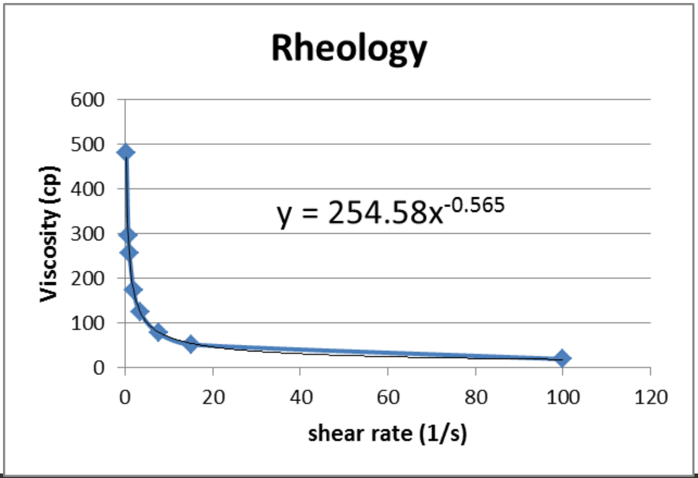
$$f_w(S_w) = \frac{1}{1 + \frac{1}{M}}$$

$$M = \frac{k_{rw}}{\mu_w} / \frac{k_{ro}}{\mu_o}$$

- Reduce SOR
  - Change wettability: **?**
  - Viscoelastic effects: **?**
- Reduce M
  - Reduce K_w : Yes
  - Increase μ_w : **Yes**
  - Increase K_o : No
  - Decrease μ_o : No

Polymer Flooding – Important parameters

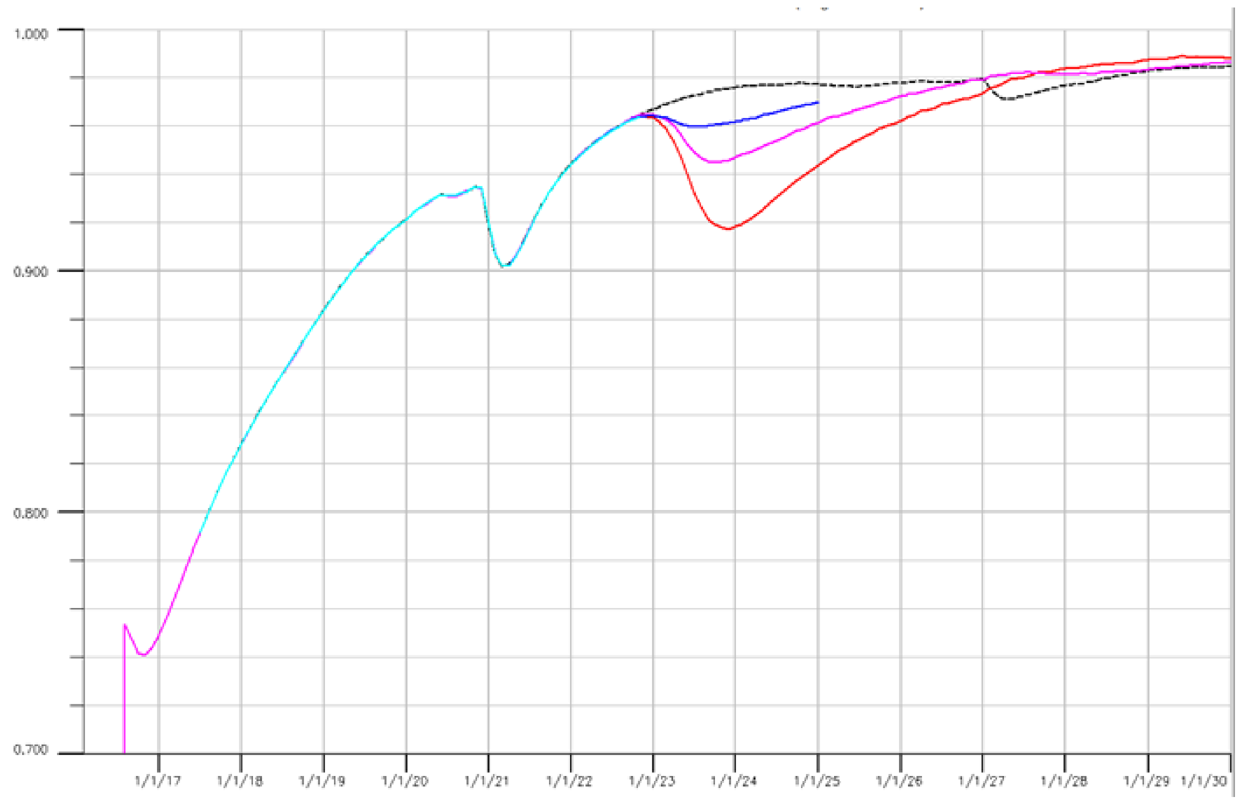
Viscosity	dependent on polymer concentration and shear rate. Rheology --- shear thinning or shear thickening
Adsorption	unit: µg/g rock
RRF	Residual resistance factor or residual permeability reduction factor
IPV	Inaccessible pore volume
Mixing	Water and polymer mixing, Todd-Long staff model



Non-Newtonian Behavior

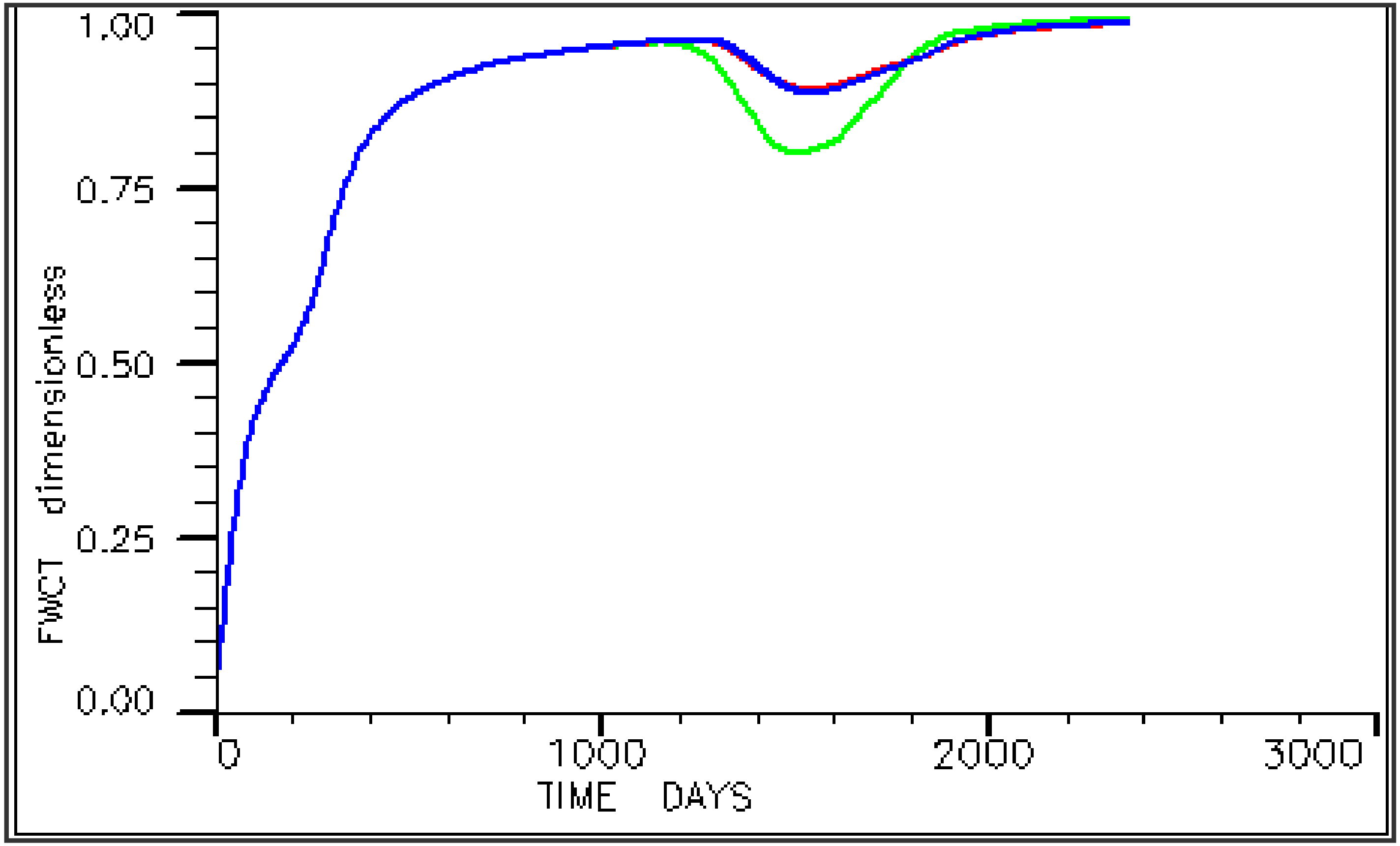
$$\mu = k \cdot \gamma^{n-1}$$

$$\mu_{sh} = \mu_{w,eff}\left[\frac{1 + (P-1)M}{P}\right]$$



Degradation effects

- Degratation effects for different injection rate and temperature



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Mathematical model

$$\frac{d}{dt}\left(\frac{V^* S_w C_p}{B_r B_w}\right) + \frac{d}{dt}\left(V \rho_r C_p^a \frac{1-\phi}{\phi}\right) = \sum\left[\frac{T k_{rw}}{B_w \mu_{p\,\mathrm{eff}} R_k}(\delta P_w - \rho_w g D_z)\right] C_p + Q_w C_p$$

$$V^* = V(1 - S_{\mathrm{dpv}})$$

$$\mu_{p,eff} = \mu_m(c)^{\omega} \mu_p^{1-\omega}$$

$$R_k(c^a) = 1 + \frac{\mathrm{RRF} - 1}{\mathrm{max\_ads}} c^a$$

$$\frac{1}{\mu_{w,eff}} = \frac{1 - c/c_{max}}{\mu_{w,e}} + \frac{c/c_{max}}{\mu_{p,eff}}$$

$$\mu_{w,e} = \mu_m(c)^{\omega} \mu_w^{1-\omega}$$

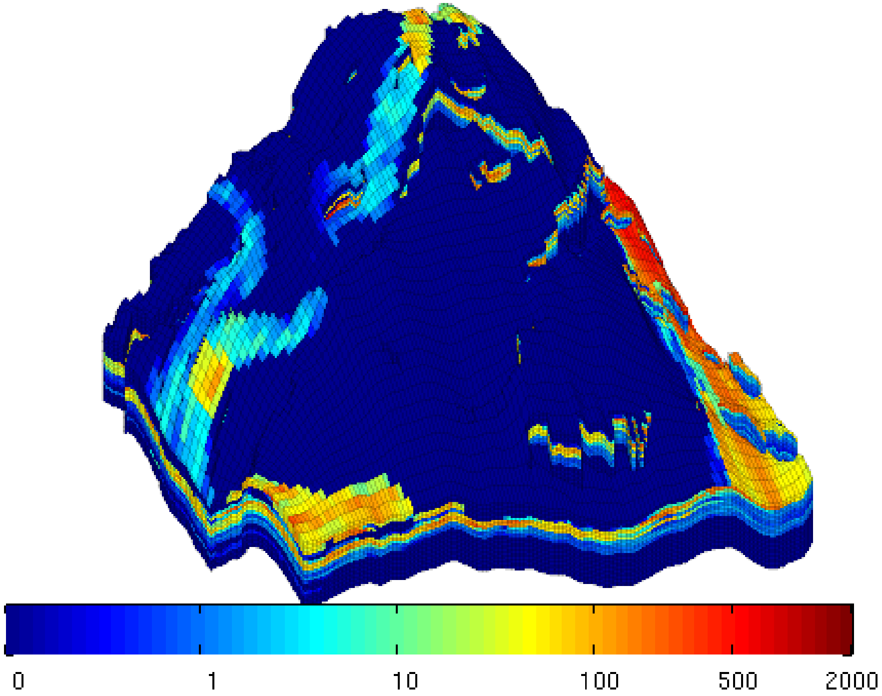
Current status

- Fully implicit blackoil (water-oil) + polymer simulators, flow_polymer, ready for use.
- Water-oil-polymer simulators based on operator splitting algorithm.

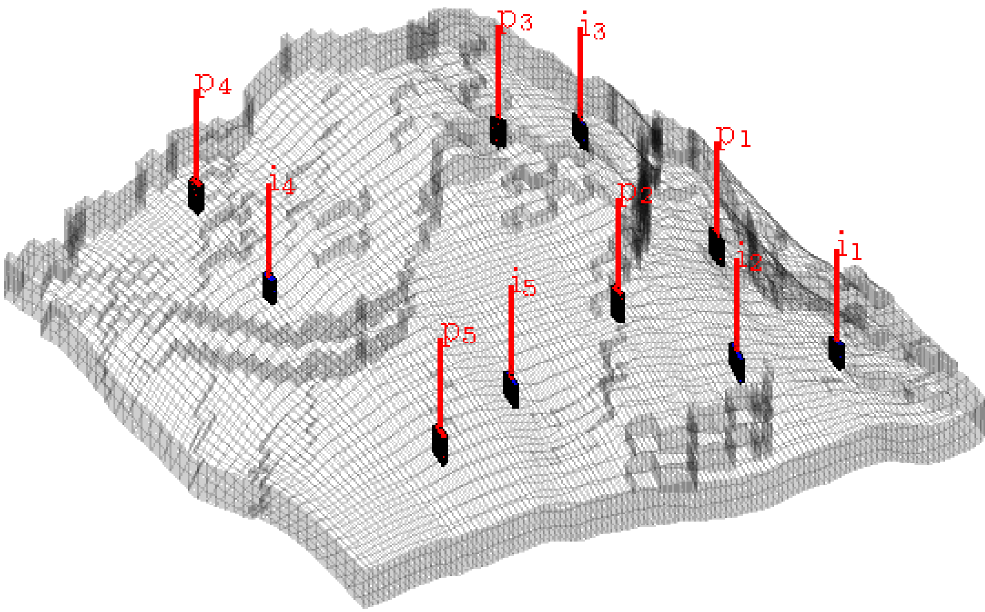
- Same functionalities with Eclipse except thermal degradation.
  - IPV
  - Adsorption
  - Permeability reduction
  - Mixing Parameter
  - Non-Newtonian behavior (by Kai Bao)

Example-SAIGUP study

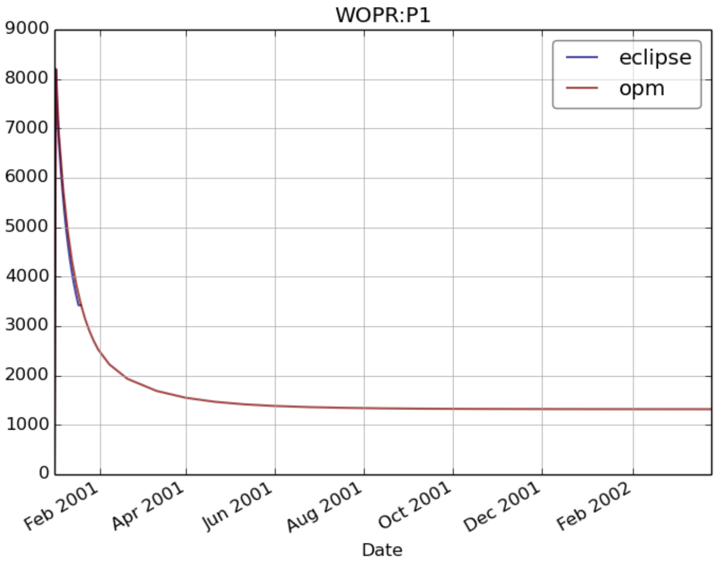
- 96000cells
- Permeability distribution

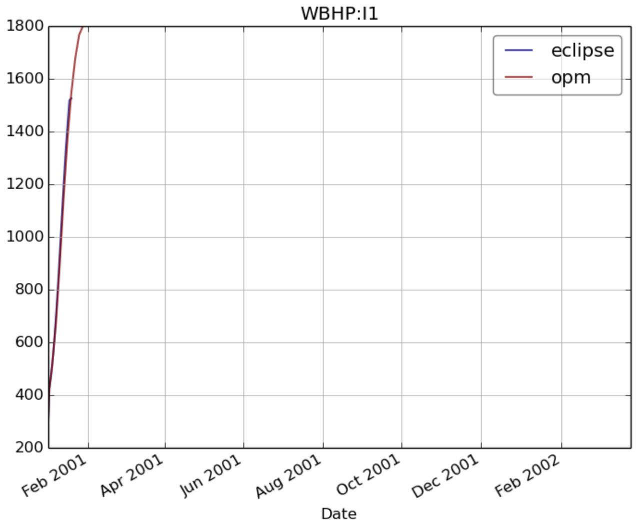


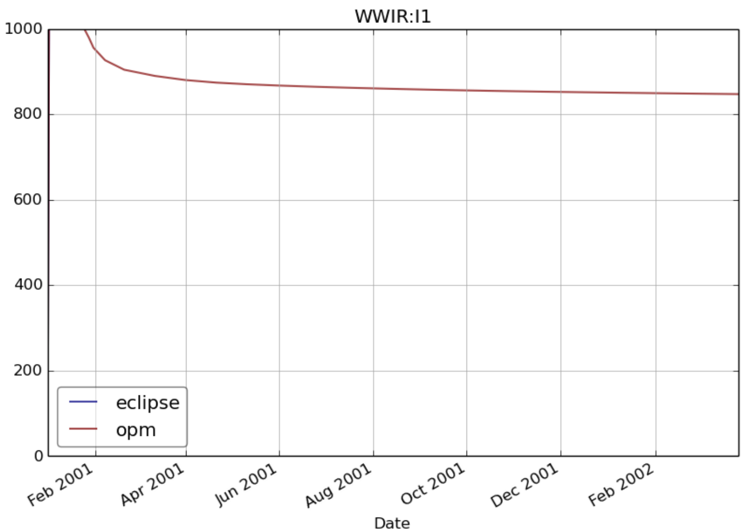
- 10 Wells



Well results







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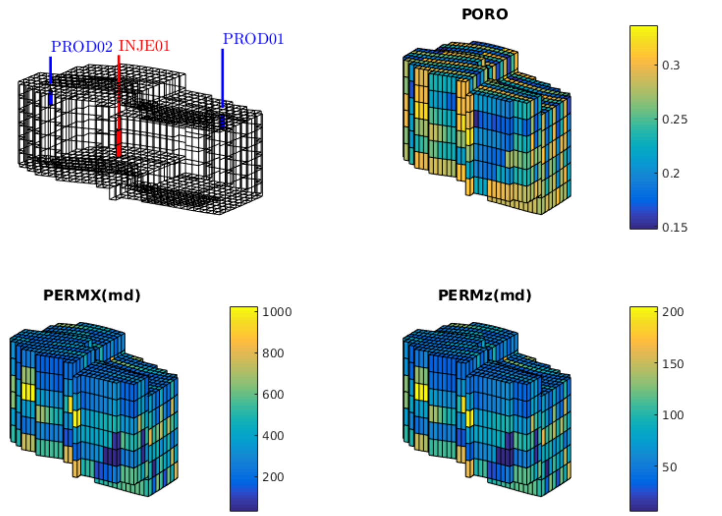
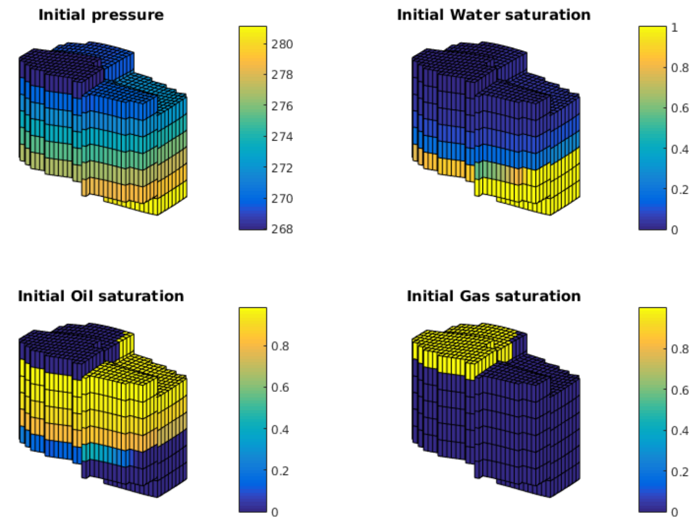
Example--3D with shear effects

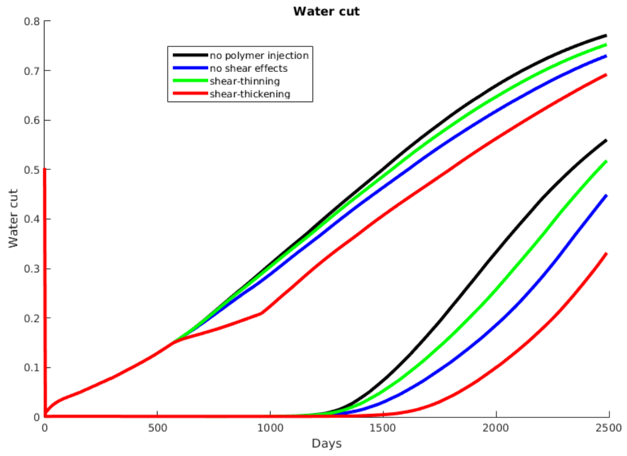
- Properties

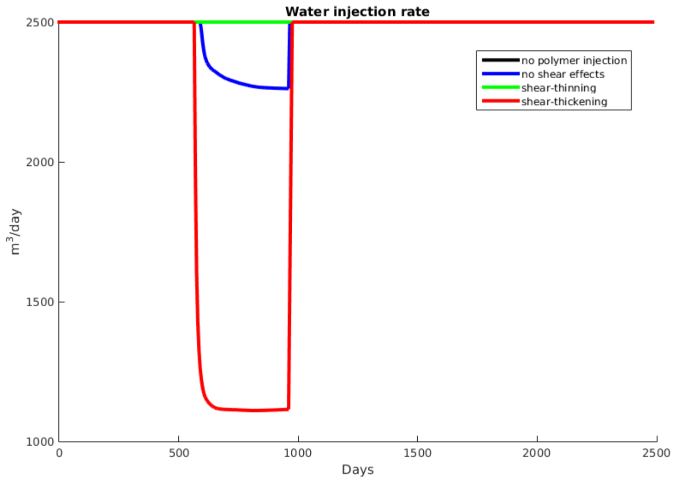


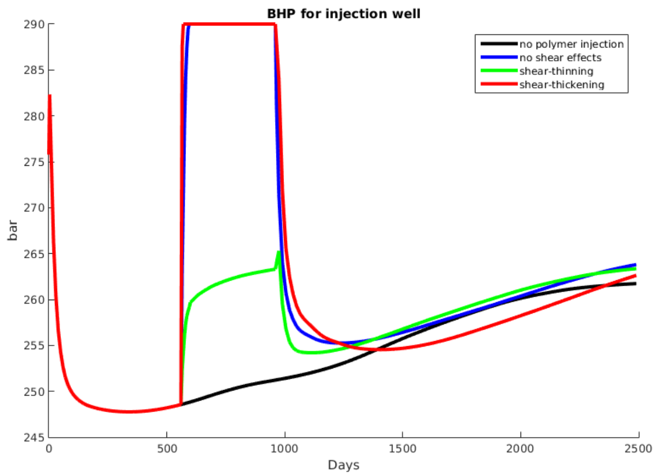
- Initial distribution



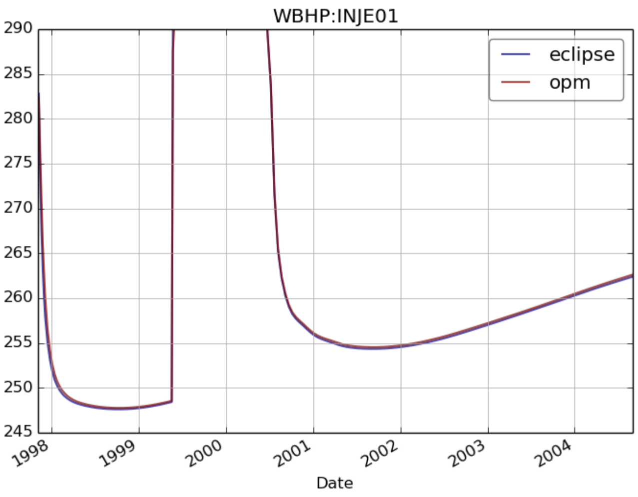
Shear effects

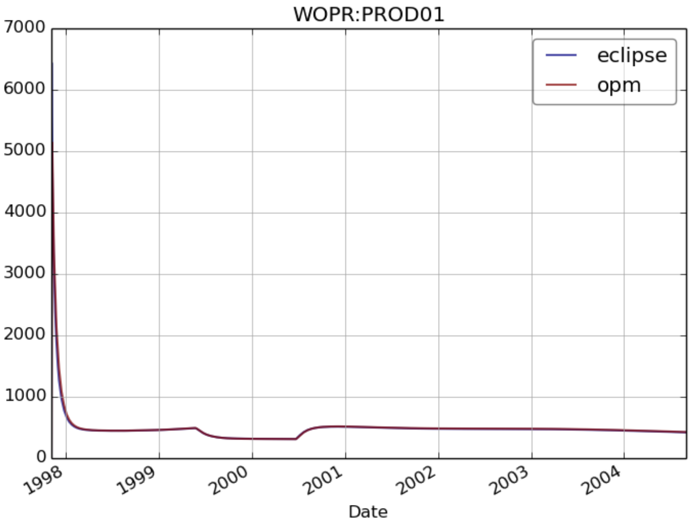


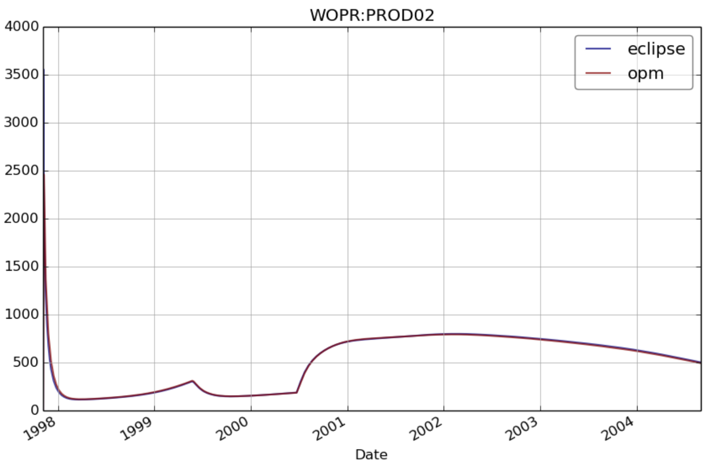




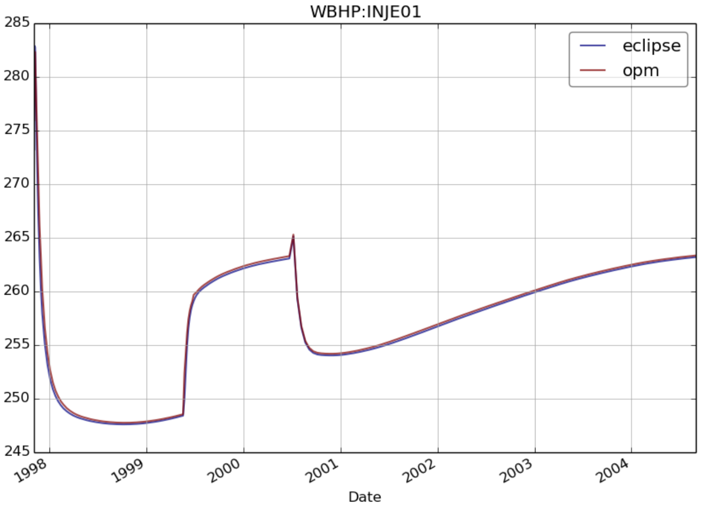
Shear-thickening

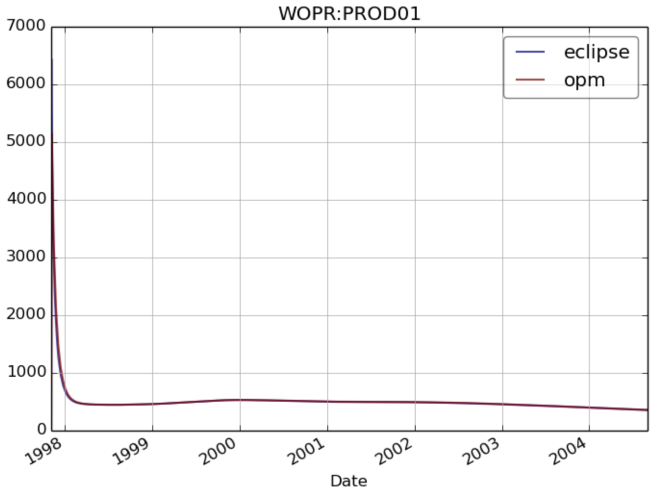


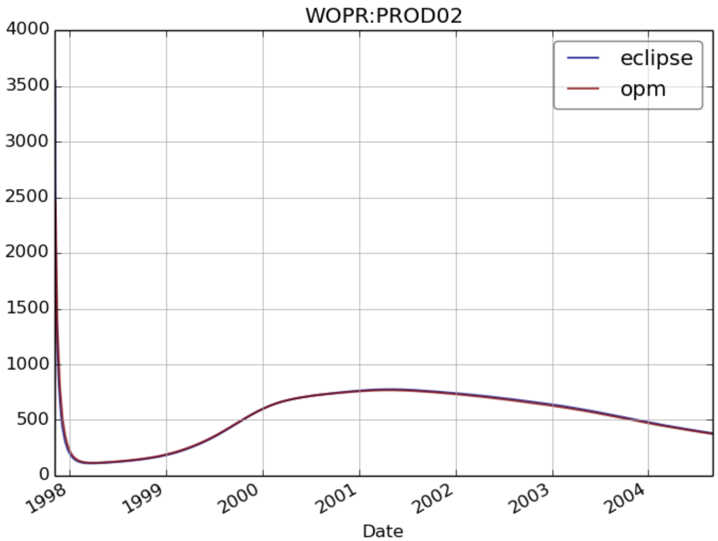




Shear-thinning







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The way forward

- Performance
- Degradation model
- Injectivity calculator
- Core-flooding?

Thank you!

There's never been a better time for good ideas

Presentation title

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