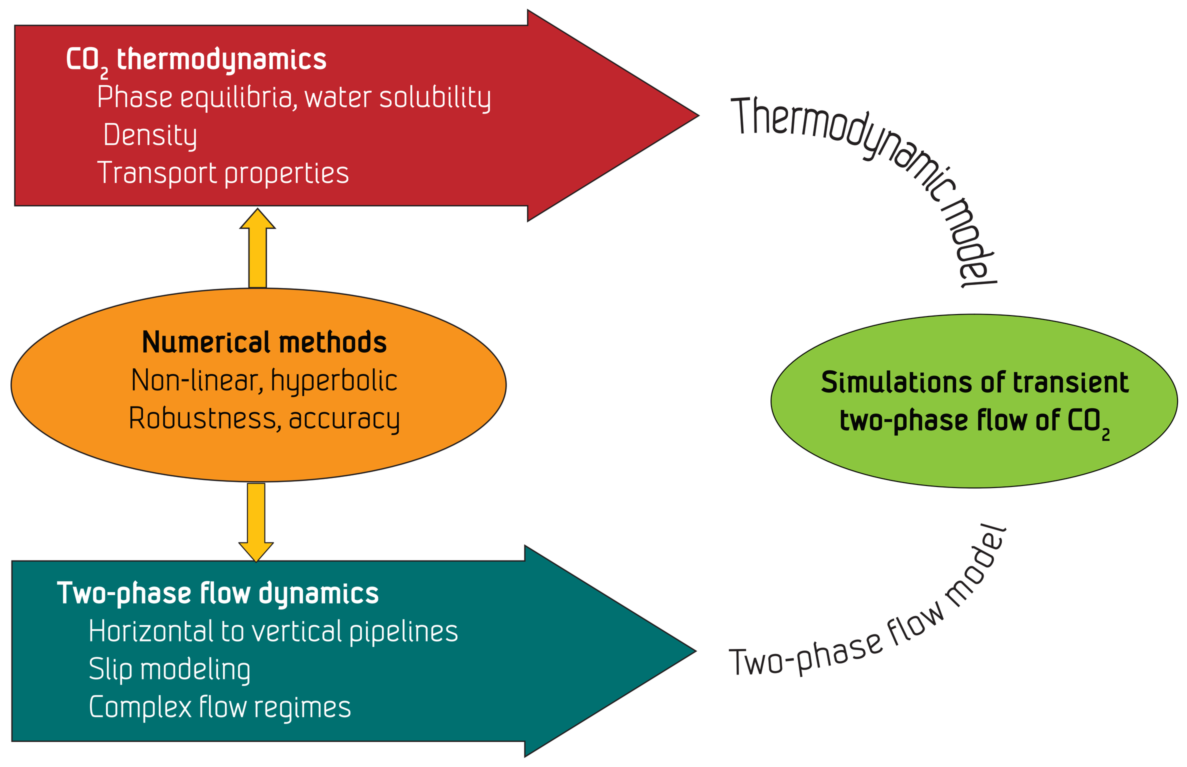
Thermo- and fluid-dynamical modeling of two-phase multi-component carbon dioxide mixtures

Motivation

Due to failure, or planned maintenance, the pipe for transport of CO_2 can be depressurized. This will lead to a strong cooling effect, which may cause the steel to become brittle. We establish a modeling framework to estimate the cooling of the pipe.



Drift-flux model for multicomponent mixture

Component-balances

$$\frac{\partial}{\partial t}(\rho_m z_i) + \frac{\partial}{\partial x}(\alpha_g \rho_g u_g z_{g,i} + \alpha_\ell \rho_\ell u_\ell z_{\ell,i}) = 0$$

Mass fractions:

$$z_i = \frac{\alpha_g \rho_g z_{g,i} + \alpha_\ell \rho_\ell z_{\ell,i}}{\alpha_g \rho_g + \alpha_\ell \rho_\ell}$$

Momentum

$$\frac{\partial}{\partial t}(\alpha_g \rho_g u_g + \alpha_\ell \rho_\ell u_\ell) + \frac{\partial}{\partial x}(\alpha_g \rho_g u_g^2 + \alpha_\ell \rho_\ell u_\ell^2 + p) = 0$$

Total energy

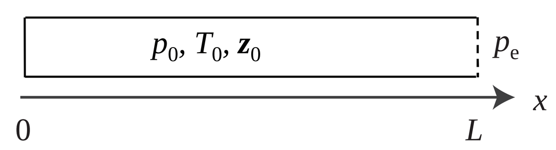
$$\frac{\partial}{\partial t}(\alpha_g \rho_g e_{t,g} + \alpha_\ell \rho_\ell e_{t,\ell}) + \frac{\partial}{\partial x}\left\{\alpha_g \rho_g u_g (h_g + 1/2 u_g^2) + \alpha_\ell \rho_\ell u_\ell (h_\ell + 1/2 u_\ell^2)\right\} = 0$$

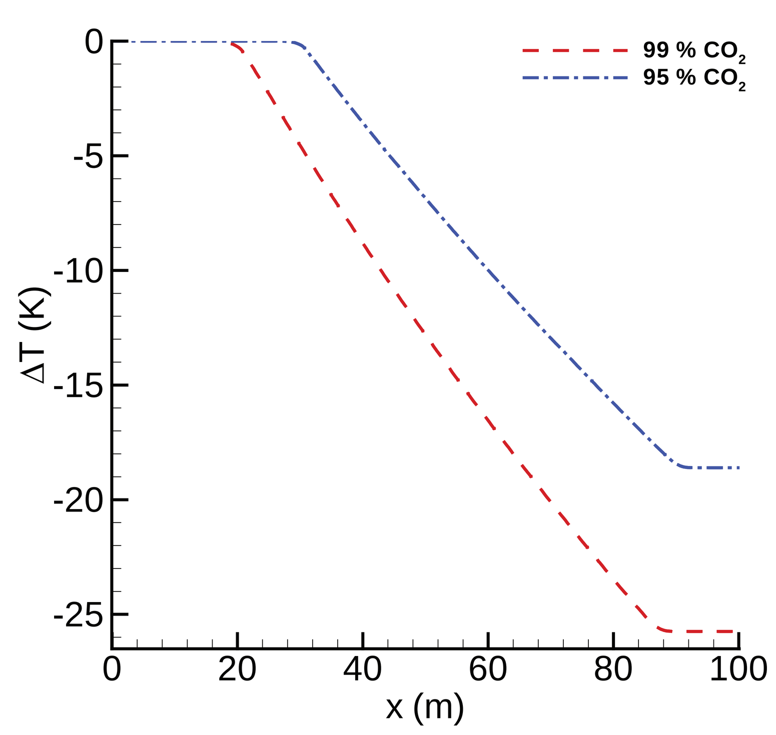
Slip relation $u_g - u_\ell = \Phi((\alpha\rho)_g, (\alpha\rho)_\ell, u_g)$ Here: Homogeneous flow, or no slip

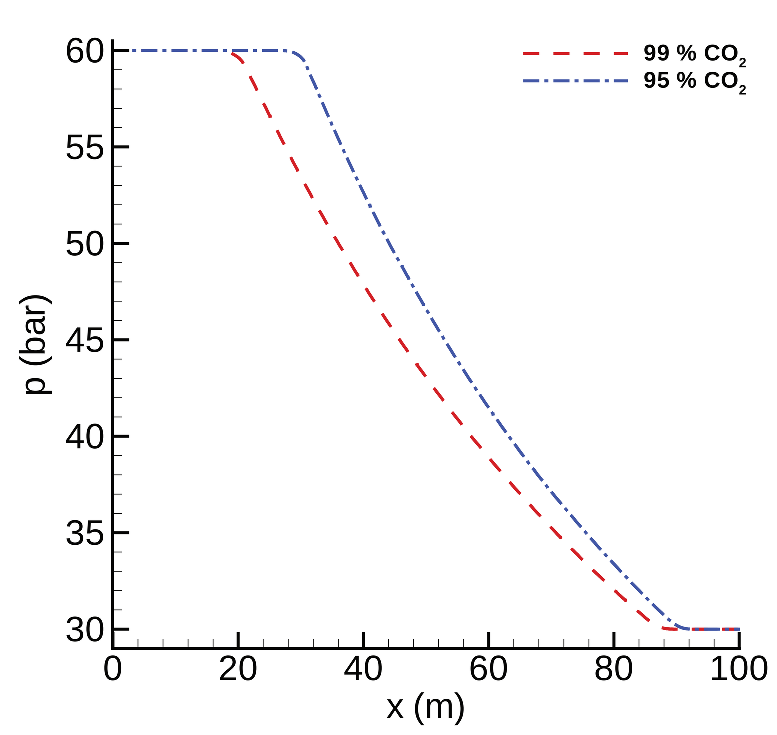
Numerical simulation

- Initial pressure: 60 bar
- External pressure: 30 bar
- Temp: 0.5 K above bubble point
- At t=0, a depressurization wave starts propagating from the left

Test-case setup





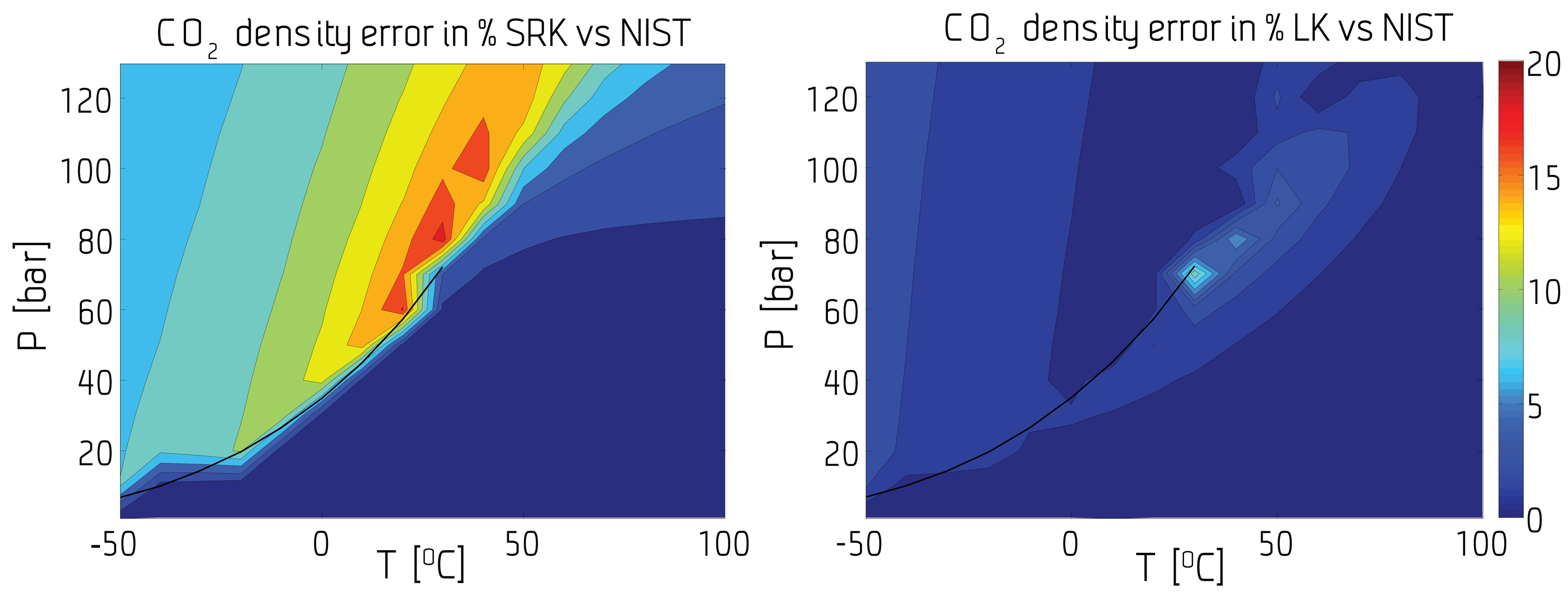


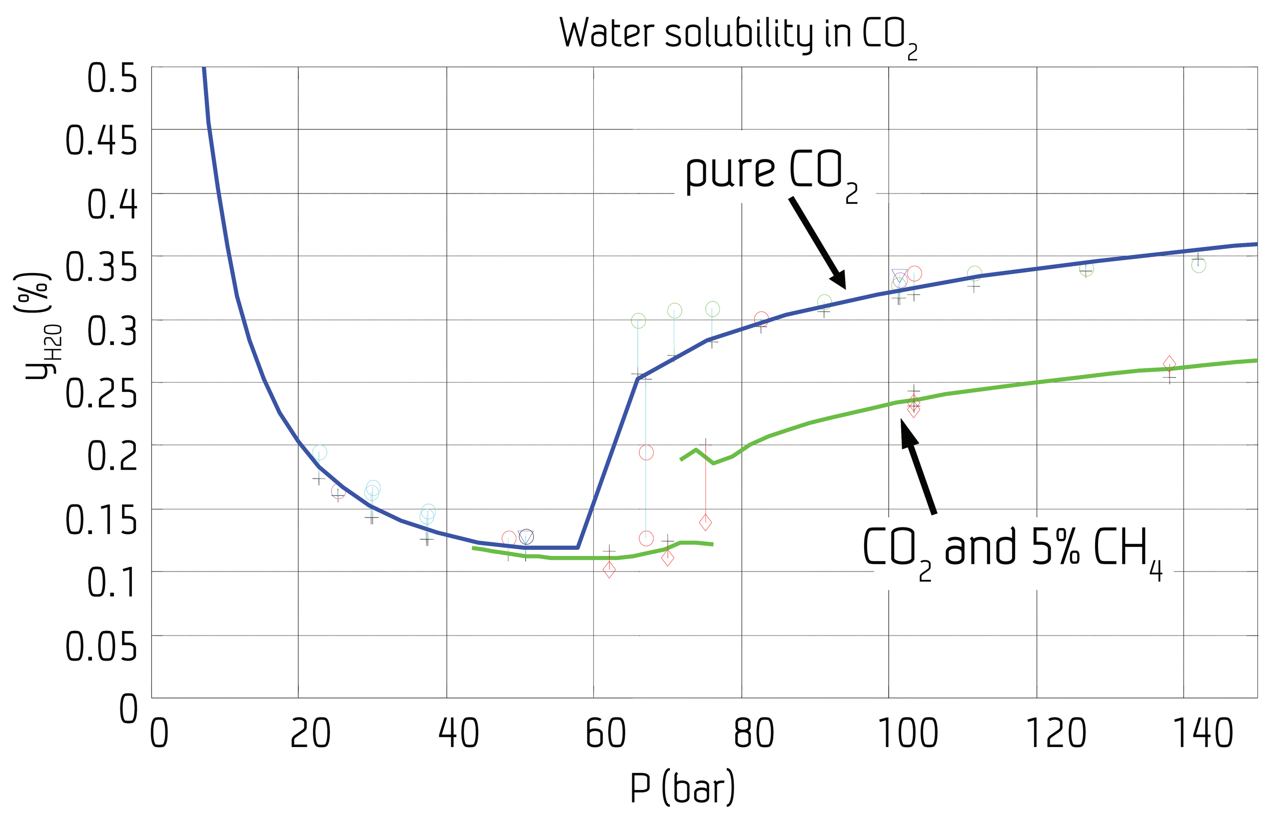
Conclusion

- A modeling framework for the calculation of CO_2 mixtures has been established.
- The mixture composition influences
  - The pressure-propagation speed
  - The cooling caused by the depressurization.

Thermodynamics

Models for thermodynamical and transport properties of CO_2 mixtures have been tested.





The impurities affect the thermodynamical properties of the CO_2 and thereby influence the compression, transport and injection process design and costs.

Contact:
Svend Tollak Munkejord
Jana P. Jakobsen
Anders Austegard
Mona J. Mølnvik

SINTEF Energy Research
www.sintef.no/energy

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