

Cirrus CCS reservoir simulator

FORCE open-source seminar
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Outline



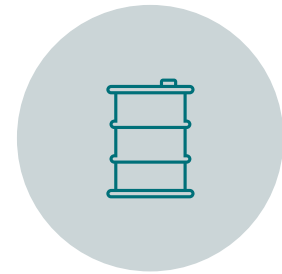
CIRRUS AND ITS
ORIGIN



WHY WE NEED A
SIMULATION TOOL FOR CCS



STORAGE IN SALINE
AQUIFERS



STORAGE IN DEPLETED
RESERVOIRS

Outline



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WHY WE NEED A
SIMULATION TOOL FOR CCS?

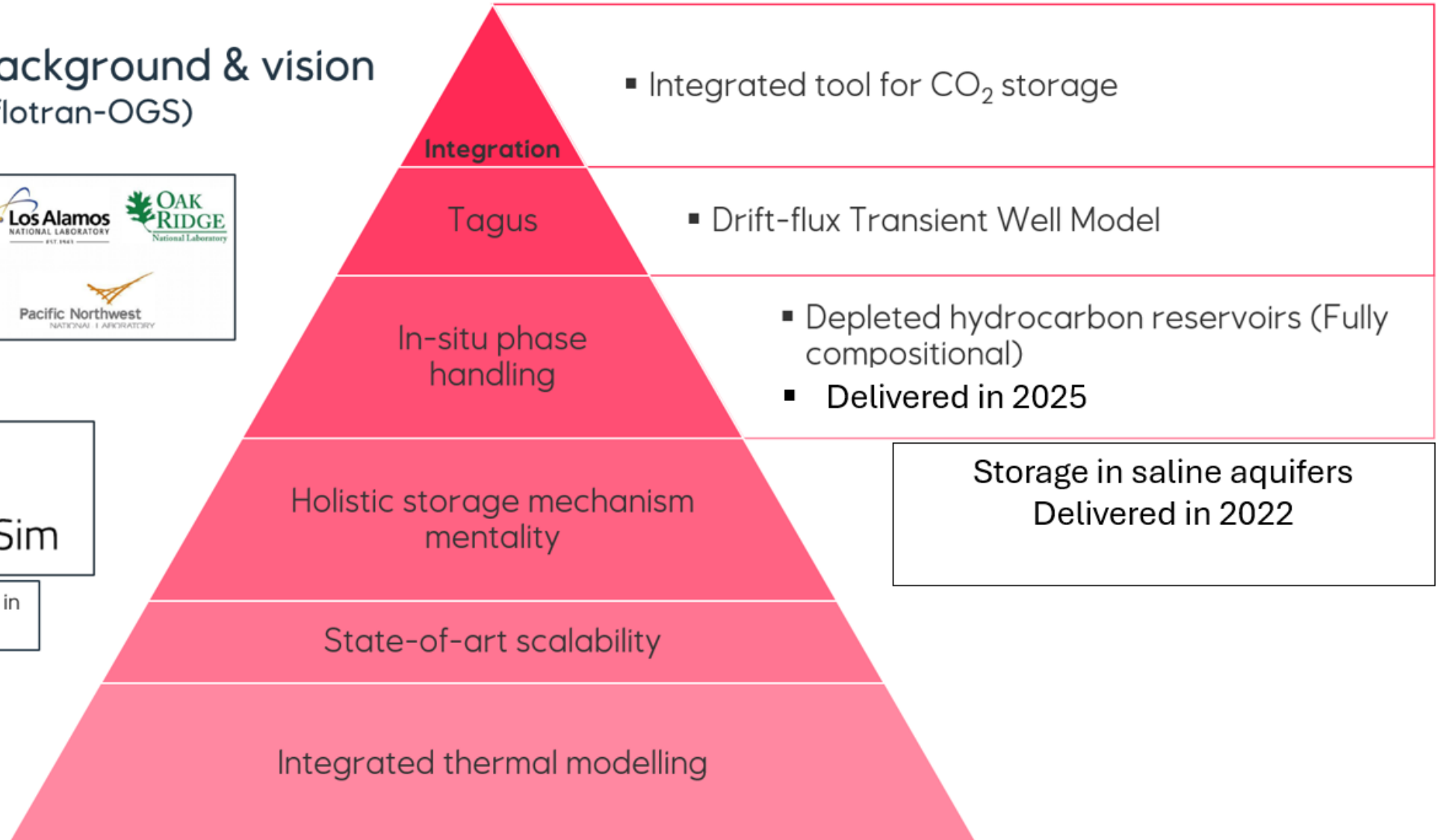


STORAGE IN SALINE
AQUIFERS



STORAGE IN DEPLETED
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Cirrus; background & vision (formerly Pflotran-OGS)



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Simulation of hydrocarbon production vs. CO₂ storage

Hydrocarbon production

CO₂ storage

★ • Model size:

- Original WOC and GOC + active aquifer
- Active cells < 2 millions

• Model size:

- Basin-scale models
- Active cells in the range of 2 – 20 millions

★ • Simulation time:

- ~ 50 years history + prediction (+ P&A)

• Simulation time:

- 500-1000 years (regulator + stable plume) (~ 5000 mineralization)

• Grid size:

- Geo-model resolution or lower for most applications

• Grid size:

- Lateral geo-model grid (50x50 m) for main storage mechanisms
- < 10 m for dissolution simulation

• Number of wells:

- several hundred

• Number of wells:

- ~ 10

• Reservoir management:

- Depletion or voidage replacement

• Reservoir management:

- Pressure buildup

• Thermal simulation:

- Assumption of isothermal operation is valid

• Thermal simulation:

- Phase property dependence

★ • Treatment of the water phase:

- Treated as a phase

• Treatment of the water phase:

- Salinity, dissolution and convective movement
- Modelling of solid content and precipitation

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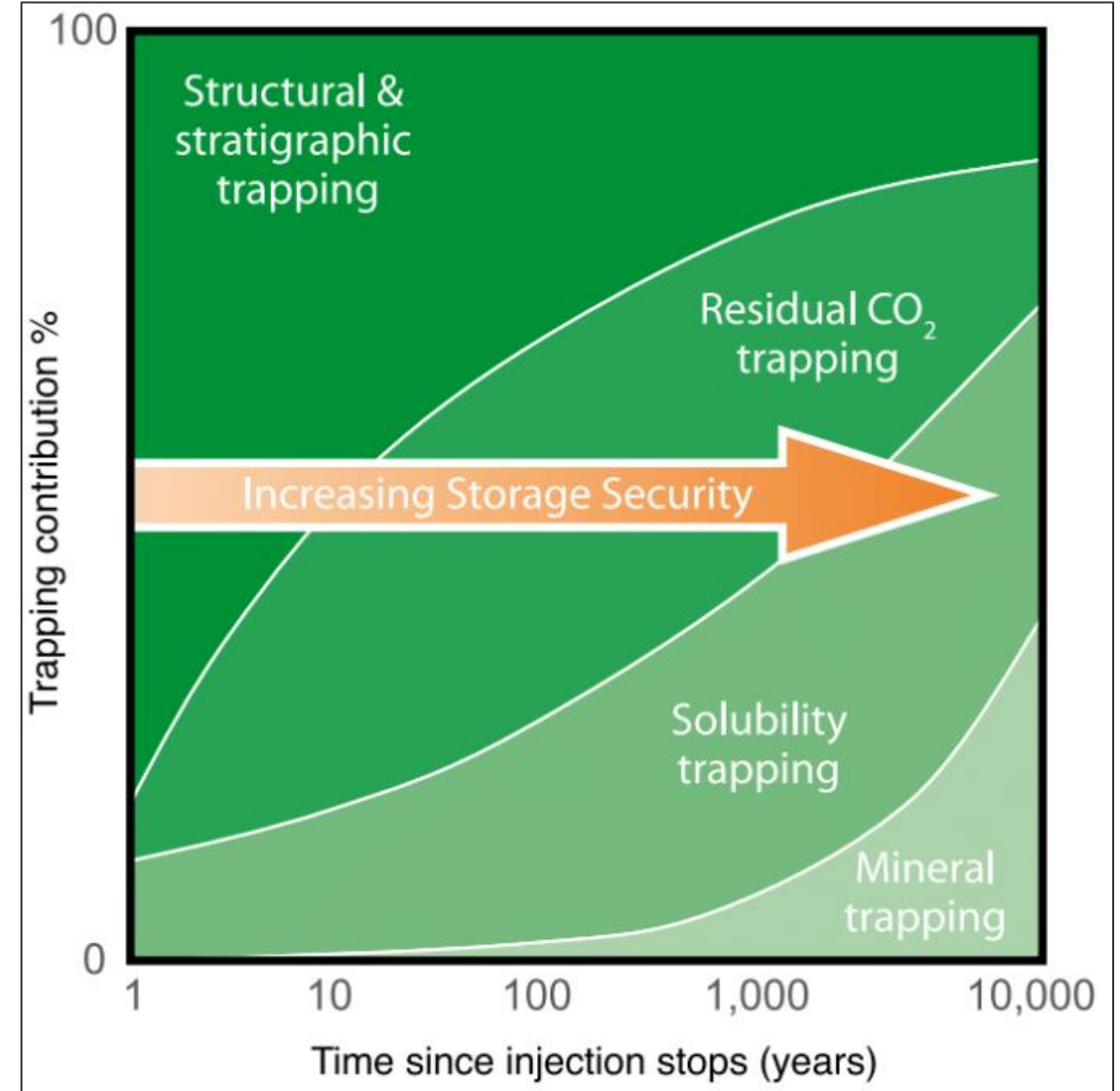


STORAGE IN DEPLETED
RESERVOIRS

Storage in saline aquifers

Options available in Cirrus

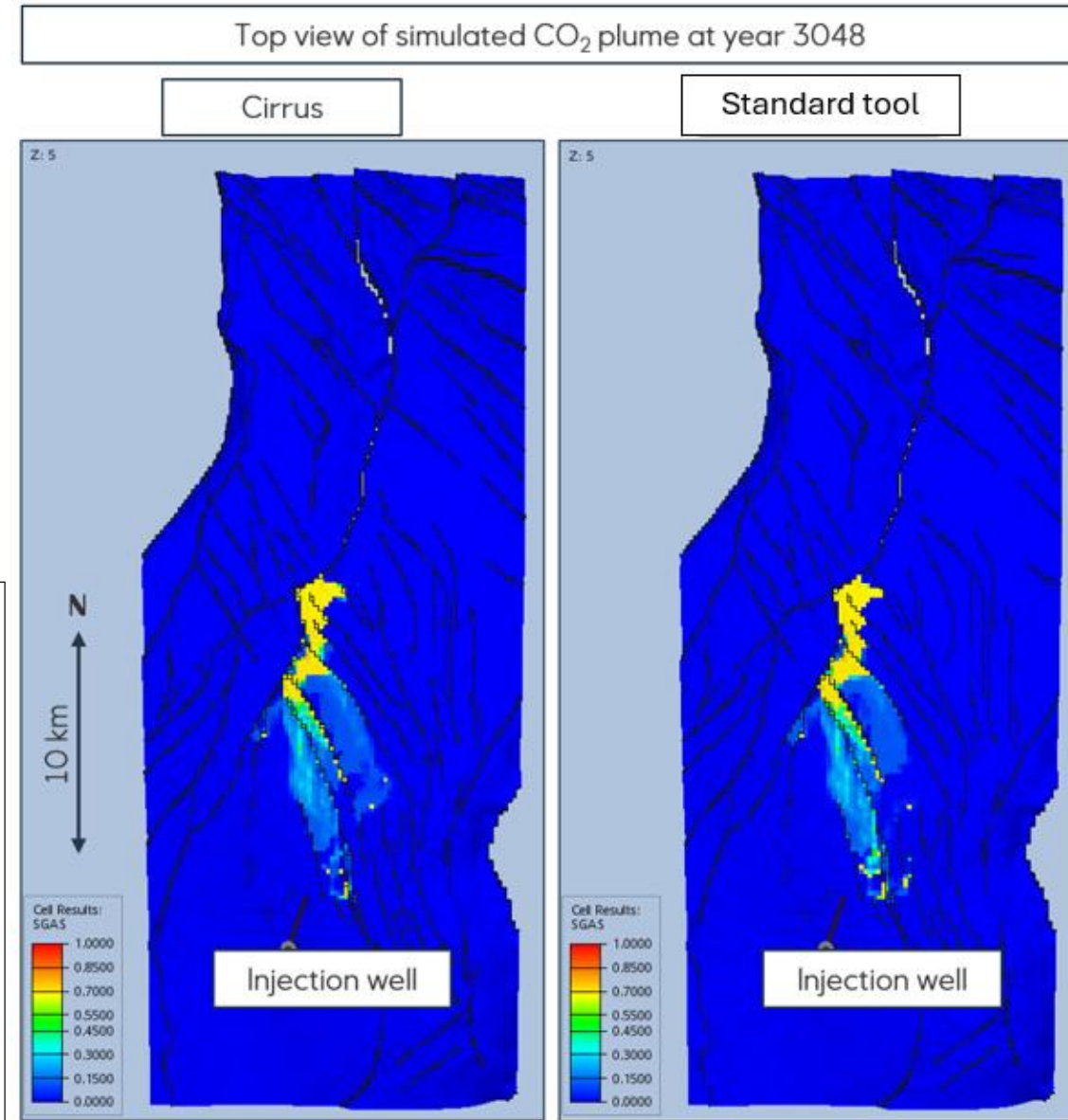
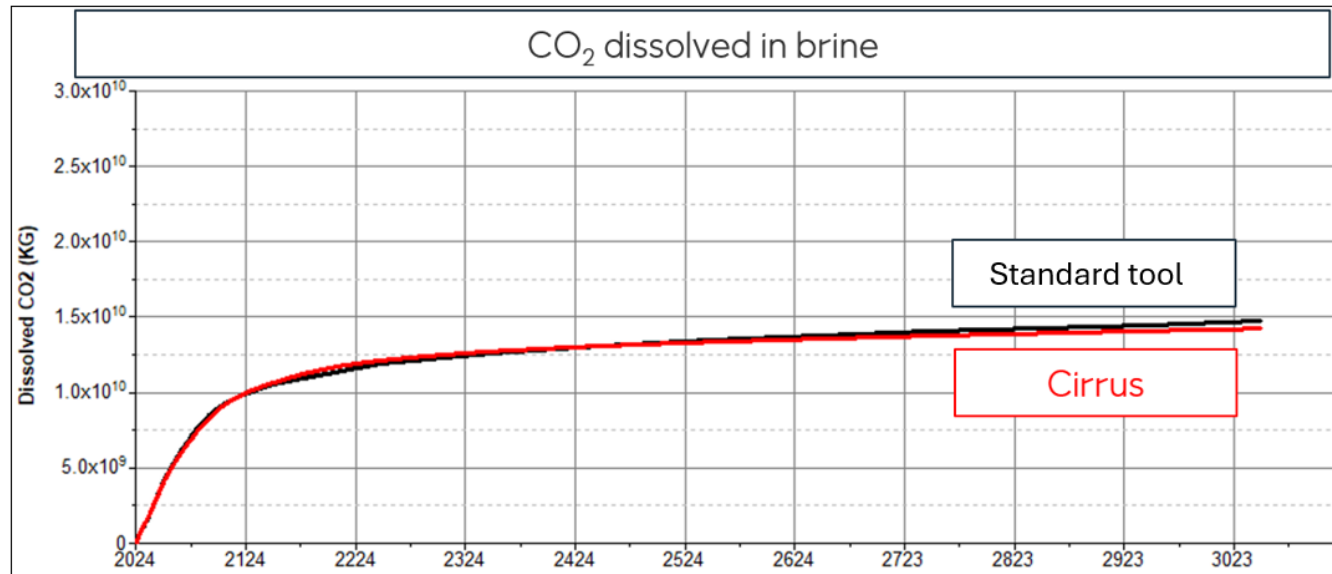
- **Gas_Water** module
- The aqueous phase may contain dissolved gas, and the gas phase may contain vaporized water
- Available in thermal modus
- Water salinity and variation with depth can be modeled



IPCC, 2005

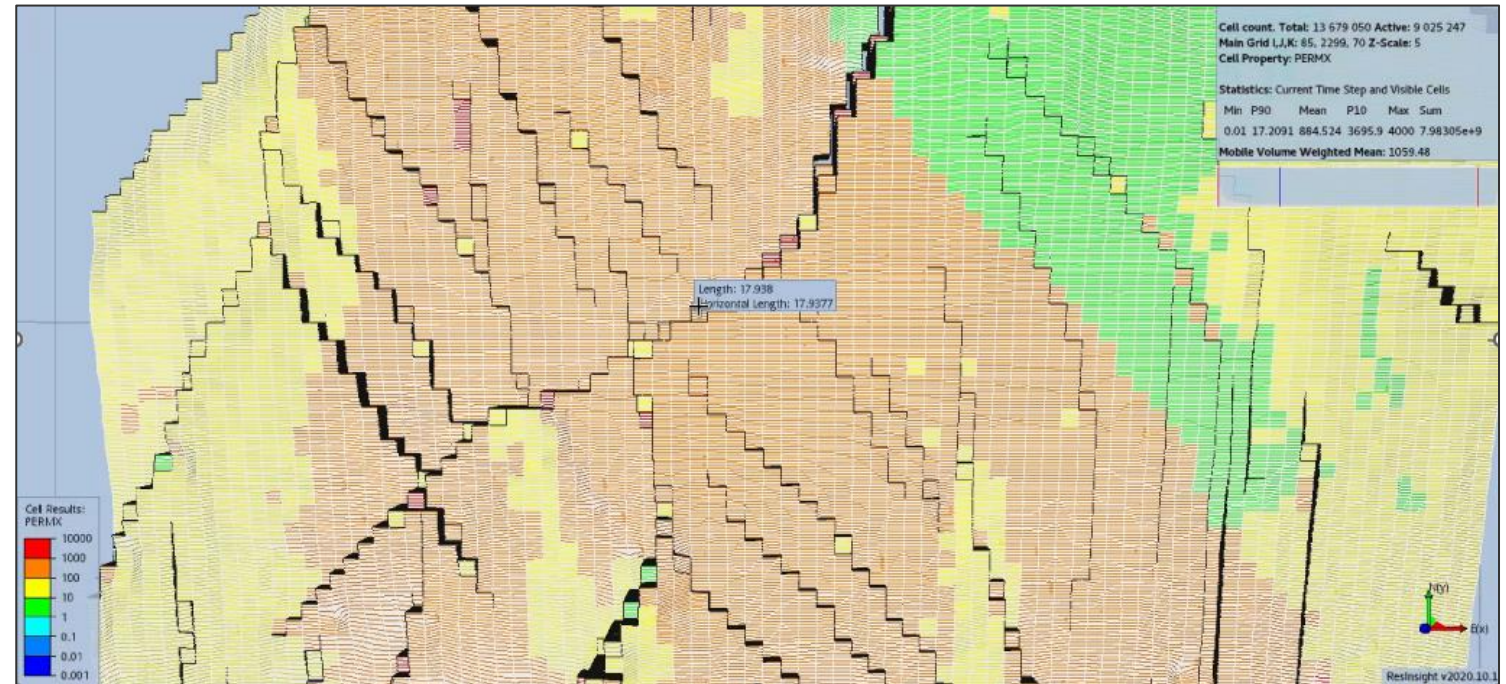
Benchmarking of the results

- Similar results are obtained from Cirrus when compared to standard tools.
- Dissolution modeling produces comparable results between Cirrus and standard tools.

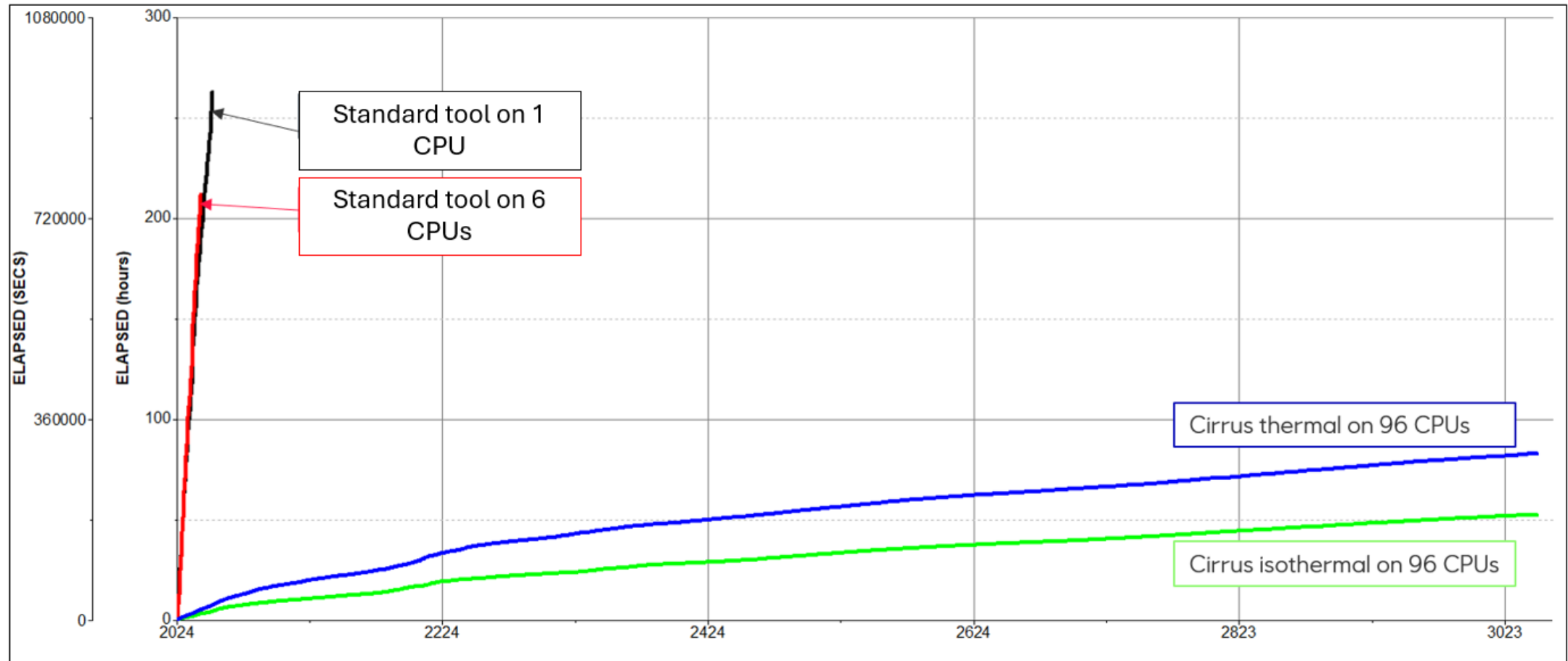


High-resolution test

- Simulation is repeated on high-resolution grid
- Grid size is decreased from ~200m to ~20m in the direction of the plume movement
- Number of active cells increased from **0.8 to 9 millions**



Performance on the high-resolution 9-million-cell model



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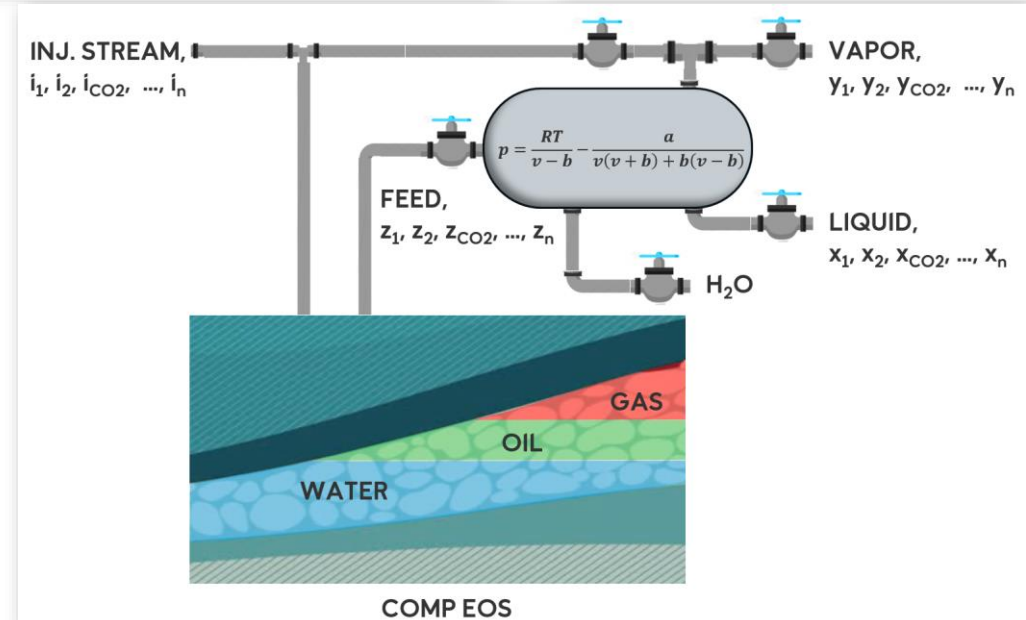
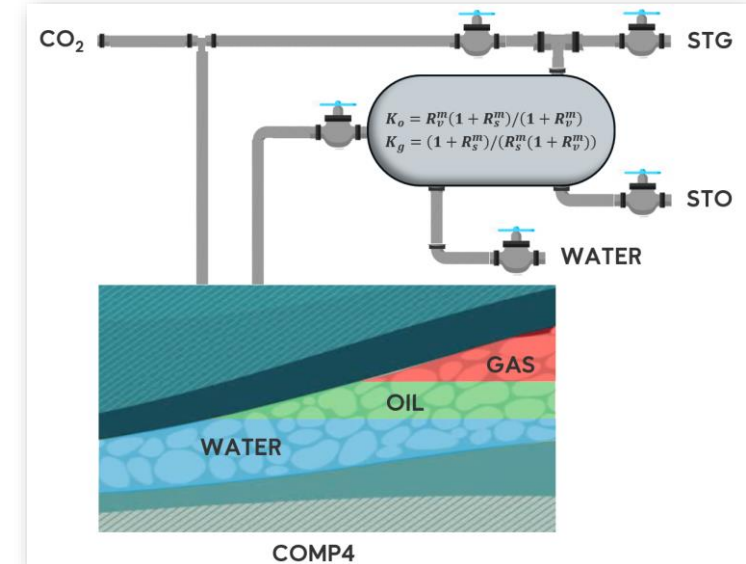
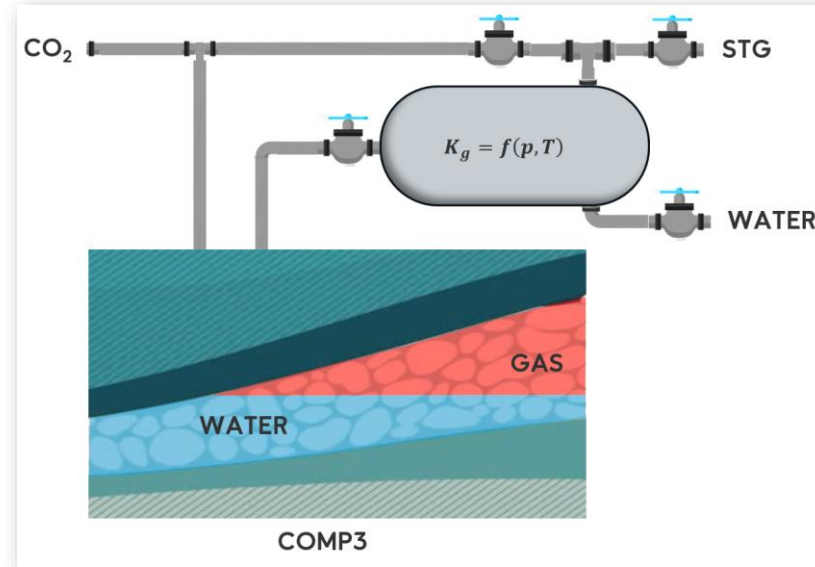
STORAGE IN DEPLETED
RESERVOIRS

Storage in depleted reservoirs

Options available in Cirrus

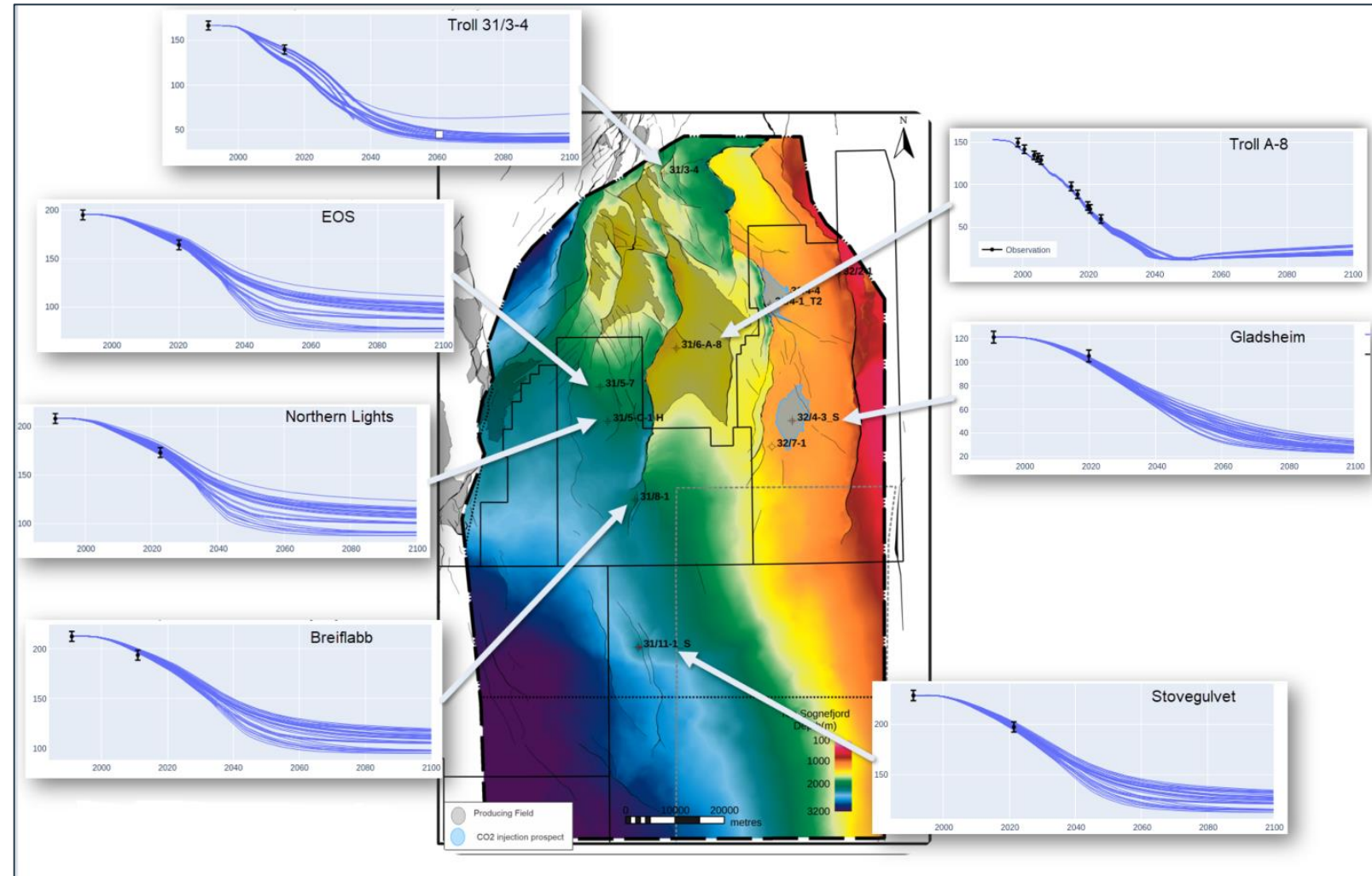
- **COMP3**: 2 phases + CO₂ as solvent*
- **COMP4**: 3 phases + CO₂ as solvent*
- **COMP EOS**: Fully compositional EoS-based formulation

* To differentiate CO₂ from the hydrocarbon gas



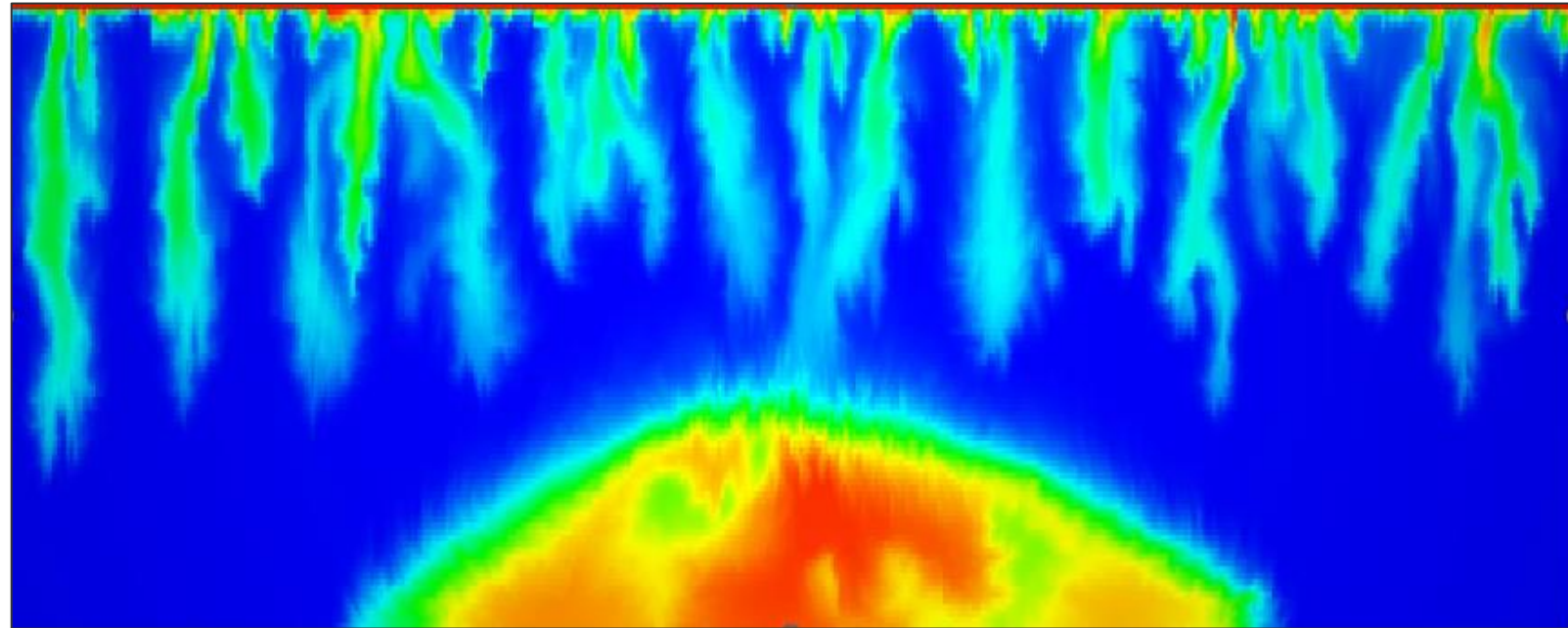
Simulation on regional models

- Cirrus COMP3 module is used to model the Horda Platform
- Model size is around 100 x 60 km
- Troll offtake is modelled from 1991 to 2051
- CO₂ injection into the Viking and Dunlin groups at multiple sites have been modelled
- Model run-time is around 2 to 4 hours



Availability

- No license limitations exist for the use of the software
- Cirrus is available for installation on both Windows and Linux machines
- Installation resources can be found here:
 - https://docs.opengosim.com/installing/ubuntu_install/
- Documentations are available through OpenGoSim wiki pages:
 - <https://docs.opengosim.com/tutorial/tutorials/>
- Tutorials are available here:
 - <https://docs.opengosim.com/tutorial/tutorials/>



High resolution Cirrus model simulating convective movement of dense phase aqueous CO₂

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Cirrus CCS simulator

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