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Enhancing Field Management Strategy Through Precise Modeling of Superheated Steam

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BACKGROUND AND MOTIVATION

- Largest geothermal field in the world with 600+ wells and 725 MW net (2025) after peaking nearly 2,000 MW (1987): dry steam production with augmented wastewater injection.
- **Thermodynamics complexity:** Increasing superheat conditions at sections of mature geothermal fields and overarching impact of cold water injection.
- **Technical deficiency:** lack of capable modelling approach to characterize localized superheat, quantify injection-derived steam, and perform reliable production forecast.
- **Operational optimality**: refine injection strategy, enhance steam productivity, maintain reservoir pressure support, and mitigate production decline.

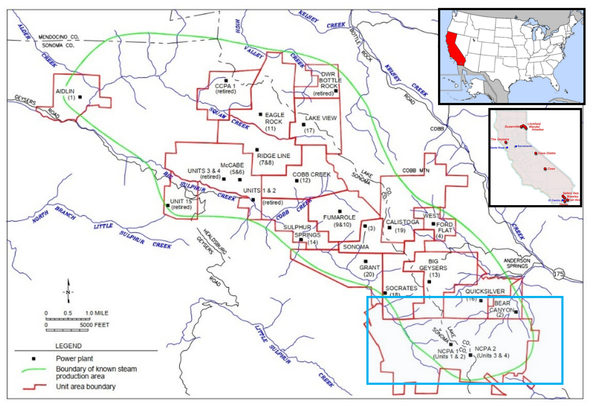


Figure 1. Location of NCPA's steam field within The Geysers geothermal field in the southeastern corner (blue rectangle).

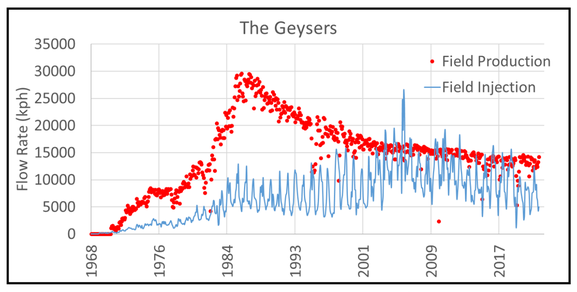


Figure 2. Geysers historic field production and injection.

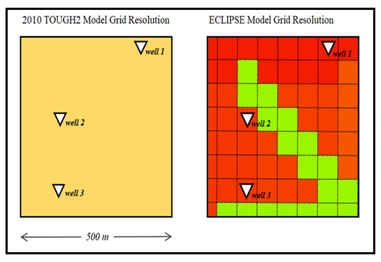


Figure 3. Compared to ECLIPSE, single-processor simulators do not have sufficient resolution to model observed field behavior in densely packed wellfield.

APPROACH

- A dual-permeability multi-physics model with 400,000+ grid cells in ECLIPSE.
- Calibrated against: historical dynamics (production/injection), reservoir pressure, and superheat thermodynamics (pressure/temperature).
- Calibration parameters: porosity and permeability of matrix and fracture, initial steam saturation, matrix-fracture flow and thermal coupling, relative permeability

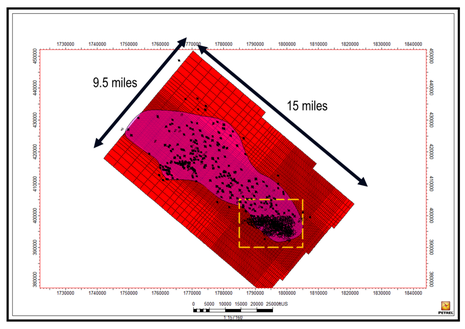


Figure 4. Bird-eye view showing productive area boundary and refinement in NCPA lease.

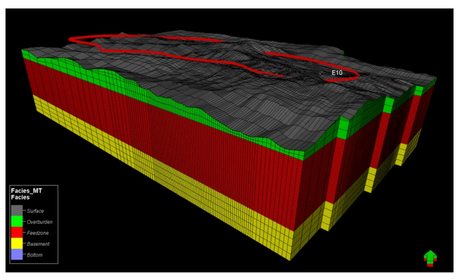


Figure 5. Side view showing overburden, feedzone, and basement layering.

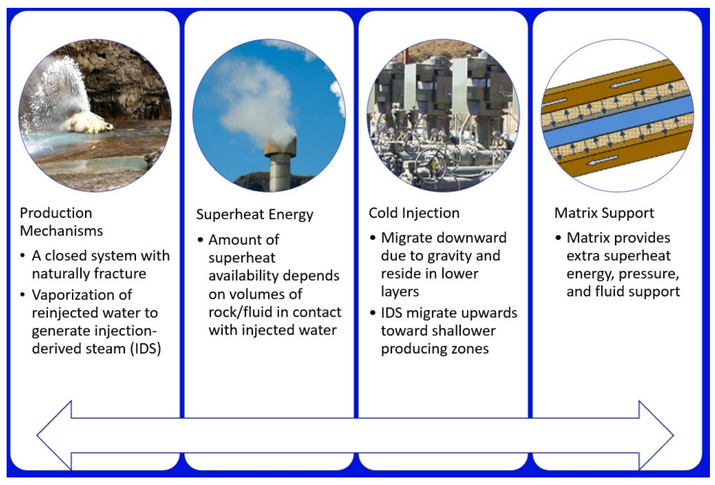


Figure 6. High model resolution allows complex physics to be modeled properly, facilitating more reliable forecast of steam production.

RESULTS

- The calibrated model effectively replicated reservoir pressure trends, superheat heterogeneity, and production decline rates across wells.
- Parameters (such as fracture permeability, fracture porosity, initial steam saturation, fracture density) are iteratively adjusted to match observed pressure, temperature, and superheat data.
- The primary objective of production forecasts is to predict how the reservoir will respond to different injection strategies in terms of varying amount of voidage replacement.

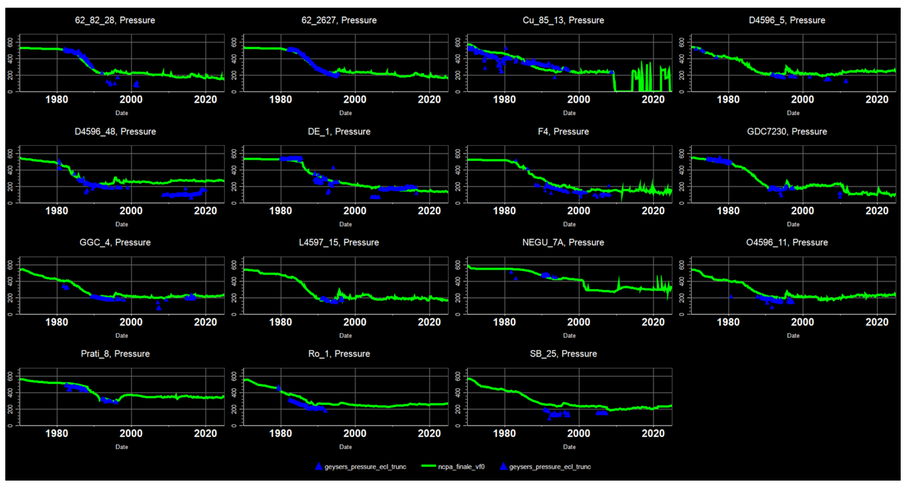


Figure 7. Observed and calculated reservoir pressures for all observational wells.

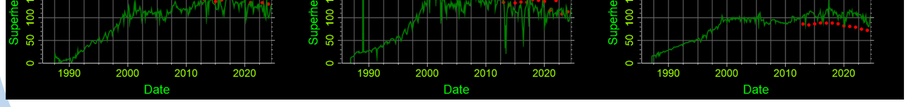


Figure 8. Observed and calculated downhole degree of superheat (°F) for various production wells in NCPA leases.

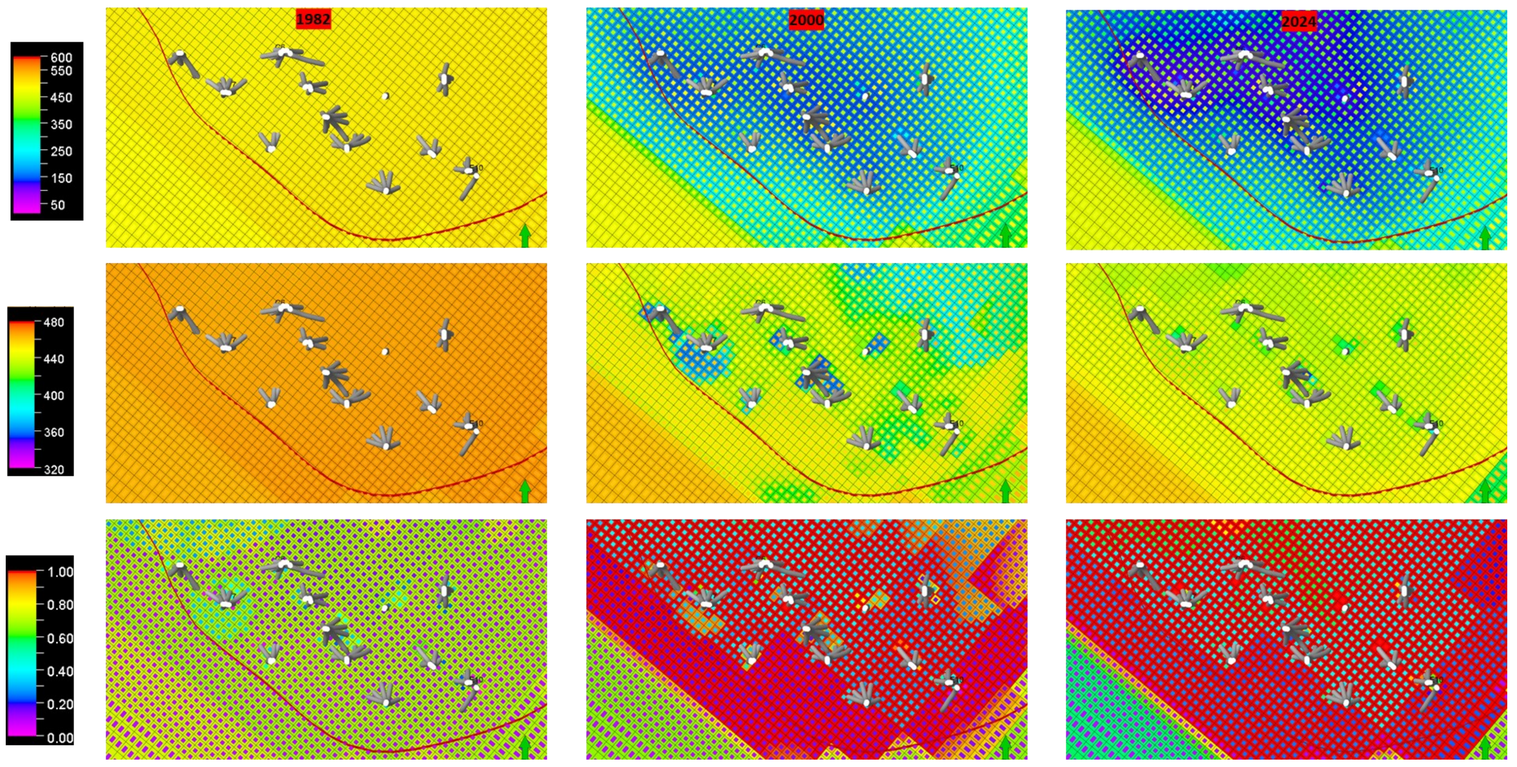


Figure 9. Evolution of the thermodynamic state of reservoir during history matching period (1980-2024). 3 columns represent three time markers (from left to right: Year 1982, 2000, and 2024). 3 rows show different properties from top to bottom: pressure, temperature, and steam saturation.

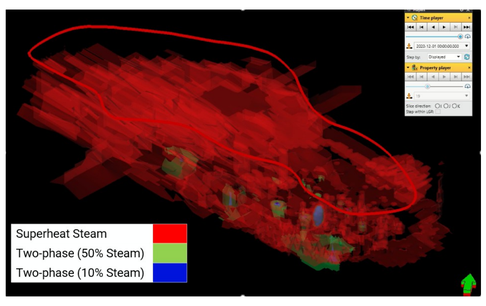


Figure 10. Steam saturation distribution in Year 2024.

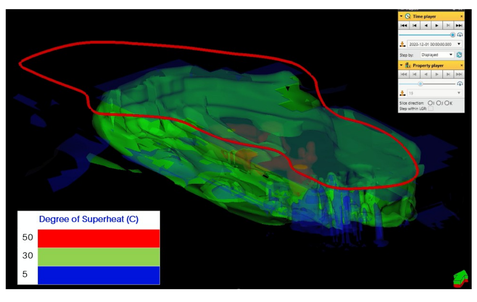


Figure 11. Degree of downhole superheat distribution in Year 2024.

CONCLUSION

- Parallel computing facilitates unprecedented high-resolution model to resolve complex physics in superheat geothermal fields. Proper modeling of superheat allows effective injection strategy to take advantage of superheat energy. It also highlights the significant impact of boiling accumulated water in the deeper parts of the reservoir on the long-term performance of the field.
- Distributing injection in space: Injection rates are carefully calibrated to balance reservoir pressure while avoiding thermal shock to the geothermal system. Excessive injection rates can lead to rapid cooling and reduced steam production, while insufficient rates may fail to sustain reservoir pressure. The best approach is to distribute injection across as many wells as possible to provide widespread coverage of the whole field spanning multiple well pads.
- Ensuring reinjection occurs at optimal depths, preferably trickled injection near the top of feed zones: Fluids are injected at depths that allow sufficient reheating as they migrate through the reser-

Acknowledgements

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