Receiver Operations and Solar Field Integration

Impactful R&D for Technology Adoption

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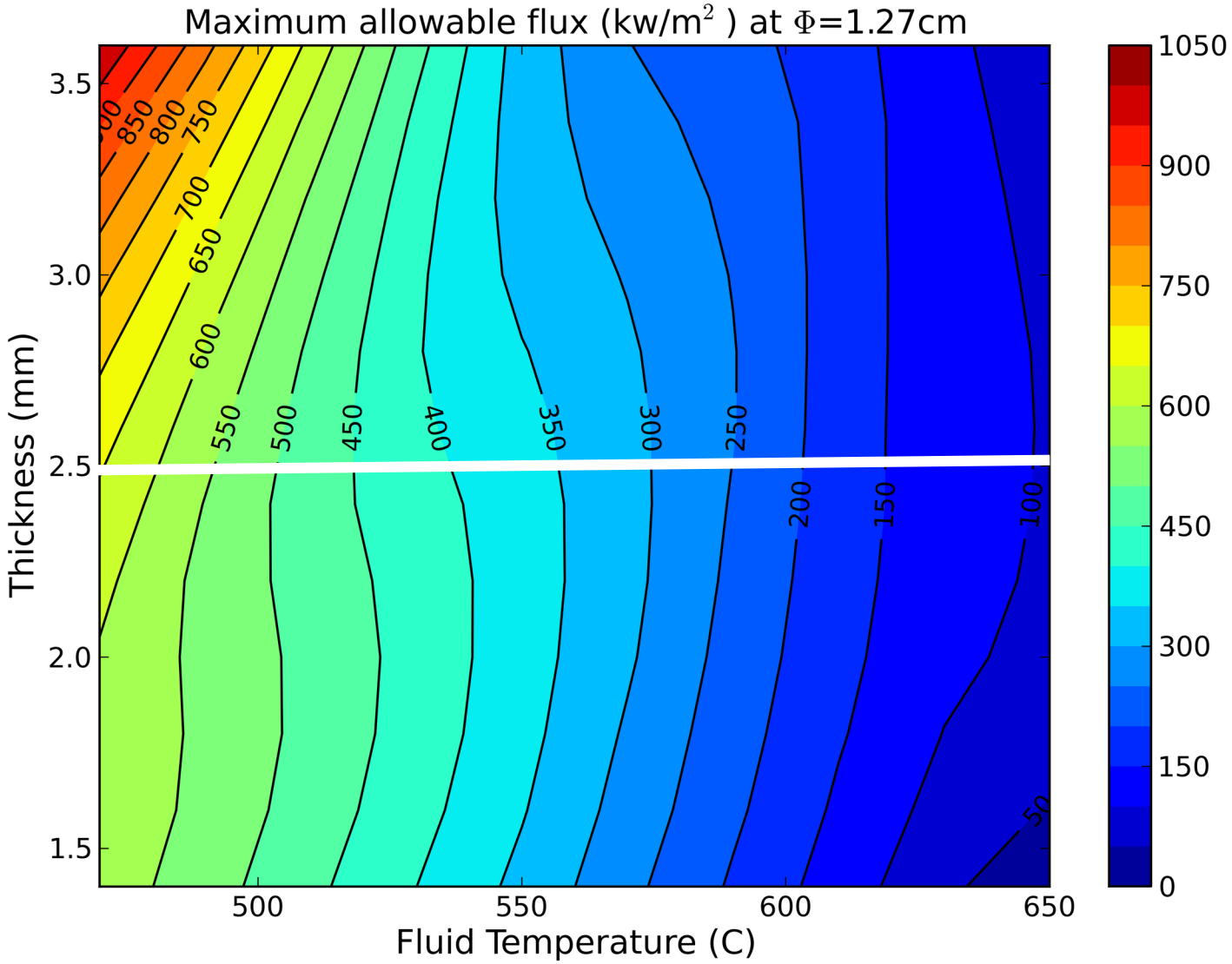
Topics

1. The role of allowable flux in receiver design
2. Heliostat optics and desired flux profiles
3. Influence of spillage loss on receiver design
4. Impact of non-ideal receiver flow control
5. Considering multiple receiver targets

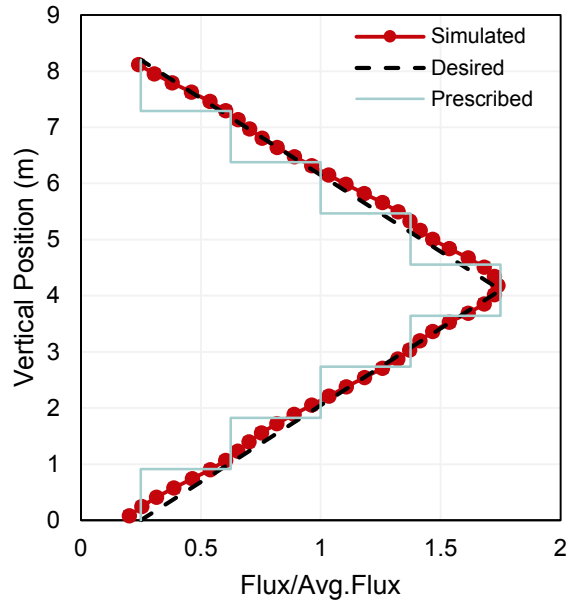
Allowable flux drives receiver design

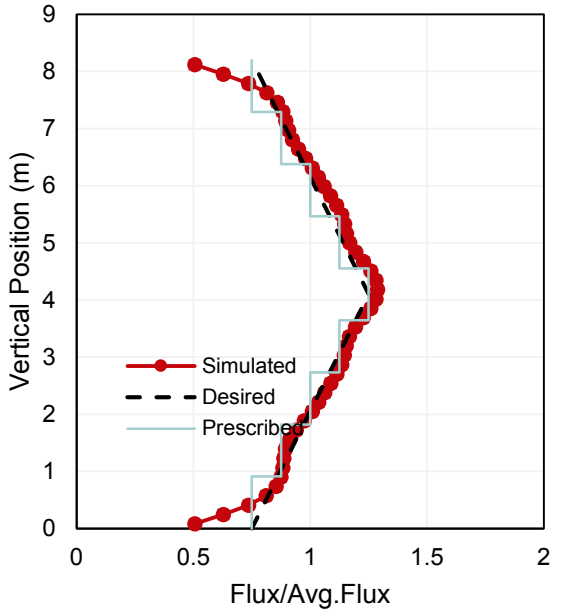
- Allowable flux in a fluid-based receiver (gas, liquid) depends on temperature & pressure
- Design decisions can include tube thickness, for example
- Allowable flux is generally higher for thick-walled tubes of a given diameter due to improved stress resistance, but sacrifices pressure drop
- Reproducing allowable flux limit profile *exactly* during operation maximizes thermal efficiency



Not all ideal flux profiles can be realized

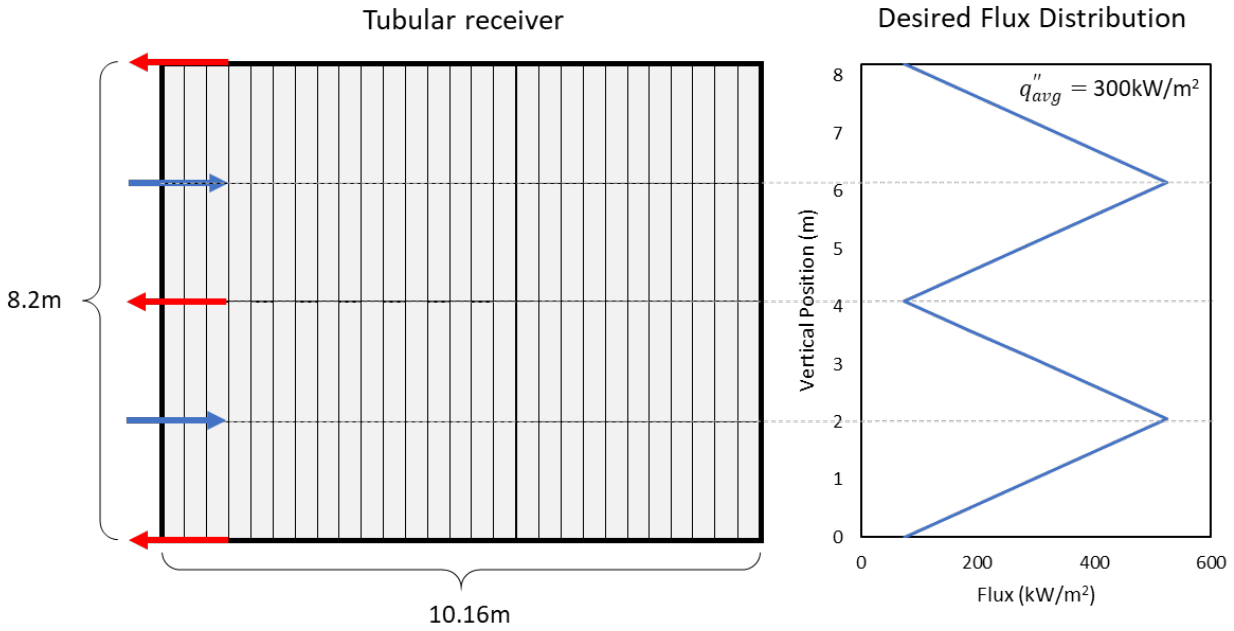
- Consider “triangular” ideal flux profile with max at receiver vertical centerline:
  - Spillage loss can be reduced by shifting heliostat images at edge toward the center
  - Ideal flux is not met near edge of receiver
  - Mass flow set to maintain max local material temperature
  - Temperature at outlet does not meet target!
- Receiver size can be increased to maintain desired profile shape
  - Less efficient / more expensive

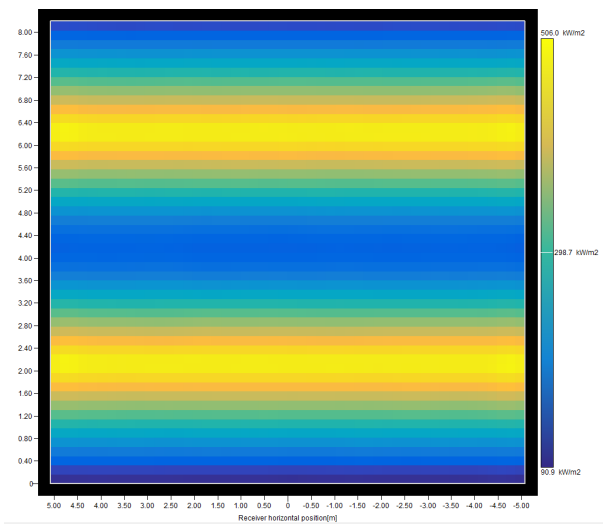


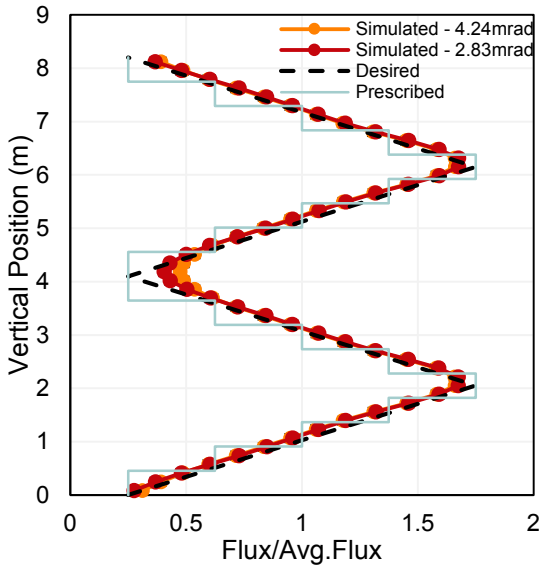


More complex profiles may violate local flux limit

- How does simulated flux profile vary with the *complexity* of the desired flux profile?
- Dependent on:
  - Heliostat characteristics
  - Field size vs size of geometry features

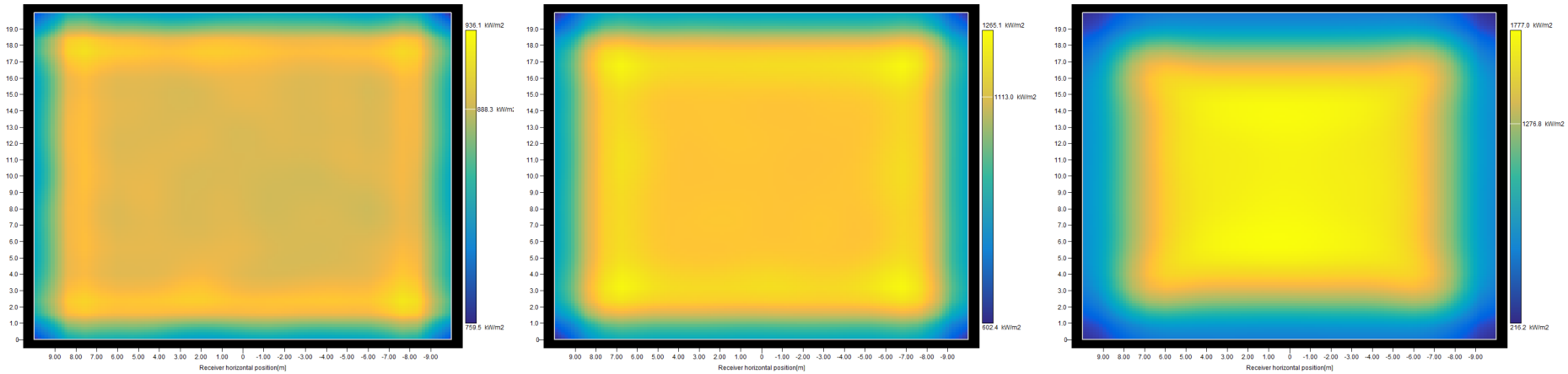


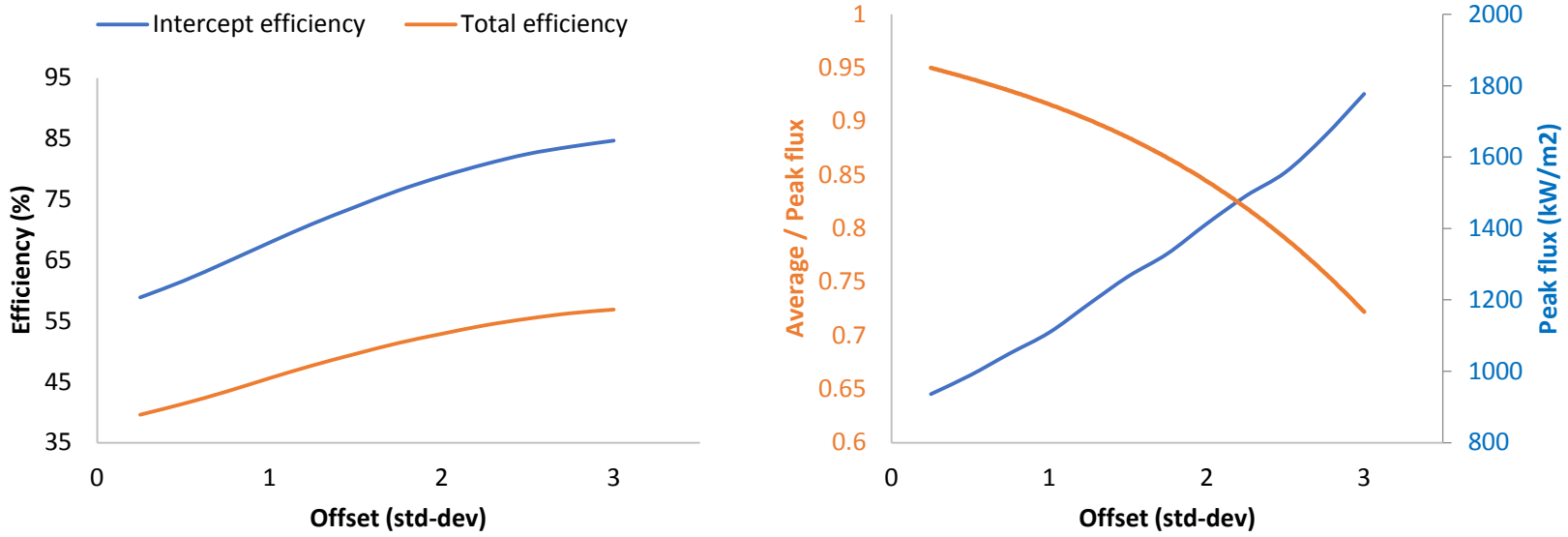




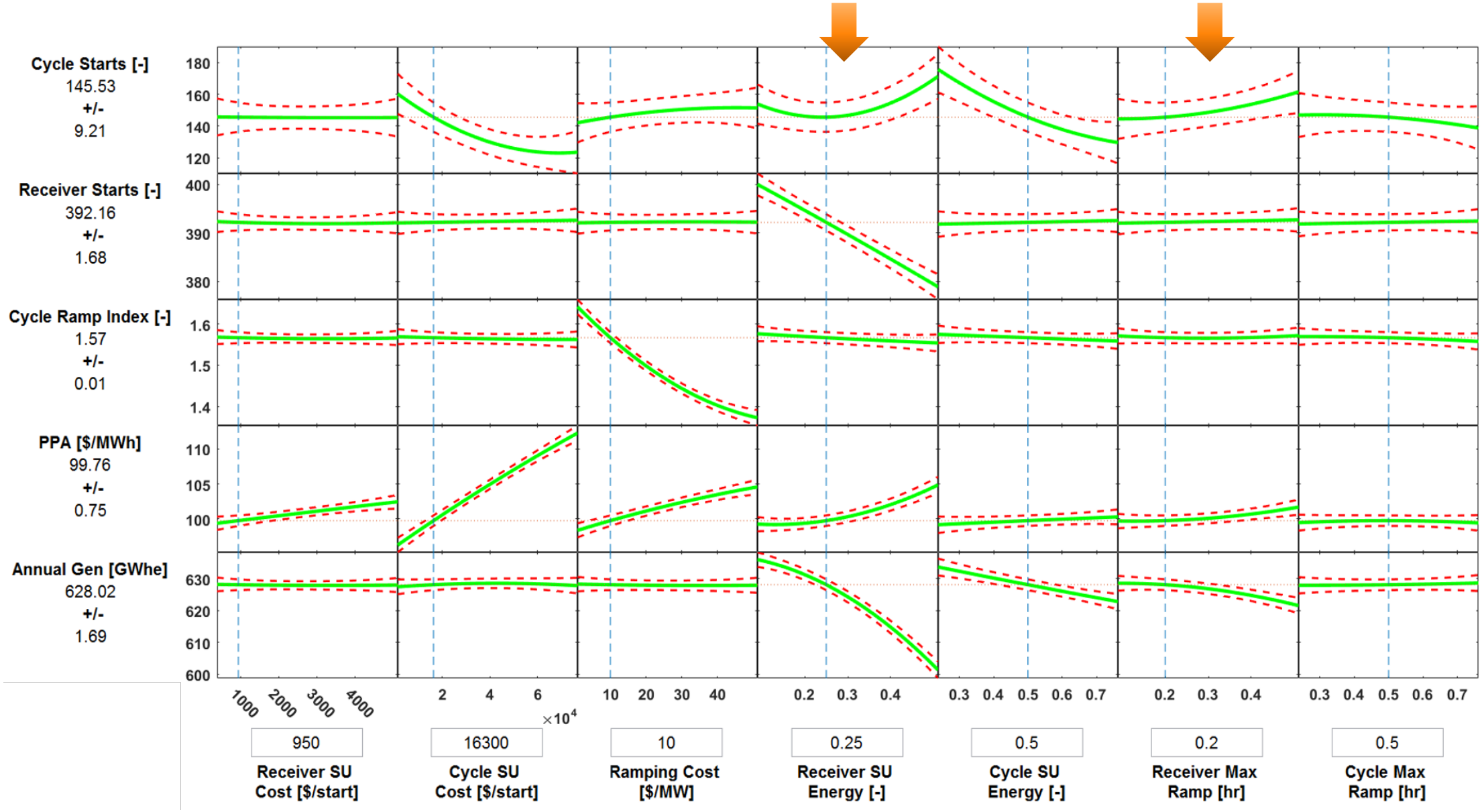
Field efficiency and flux “quality” compete

Increasing offset of images from receiver edge →





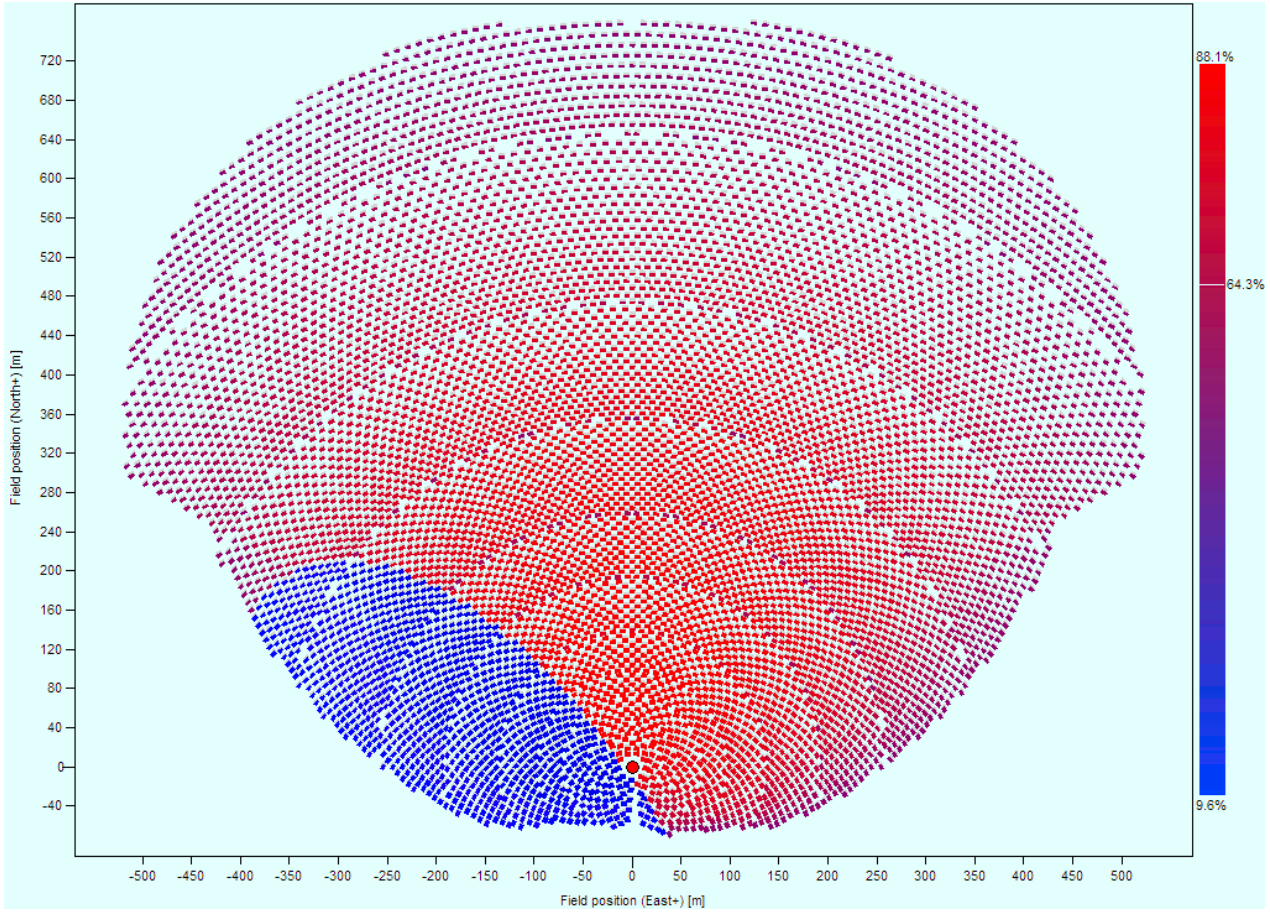
What is the impact of receiver startup?



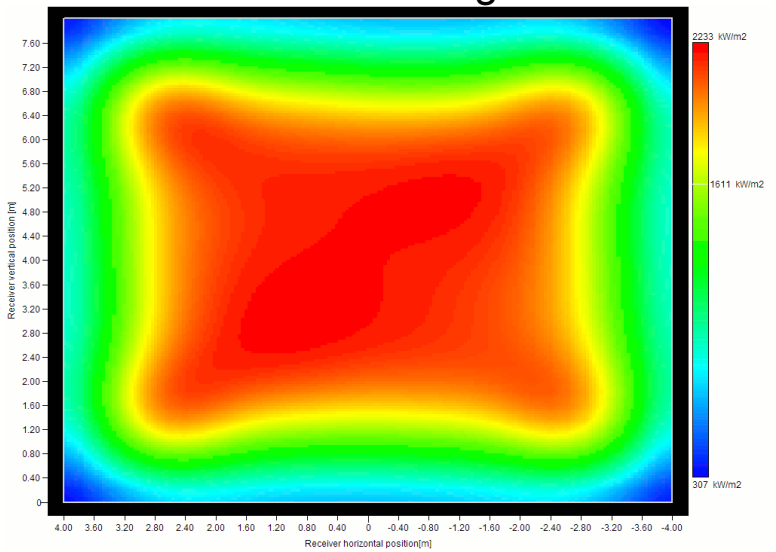
Consider possible operation during transients

- Do operational considerations impact receiver design?
- How quickly might conditions change during operation?
- Can the receiver operate through flux transients?

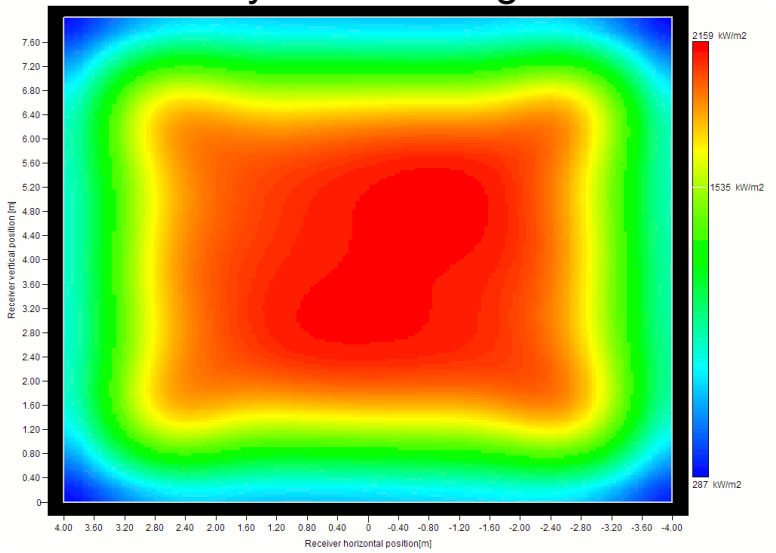
Receiver Transient Operation



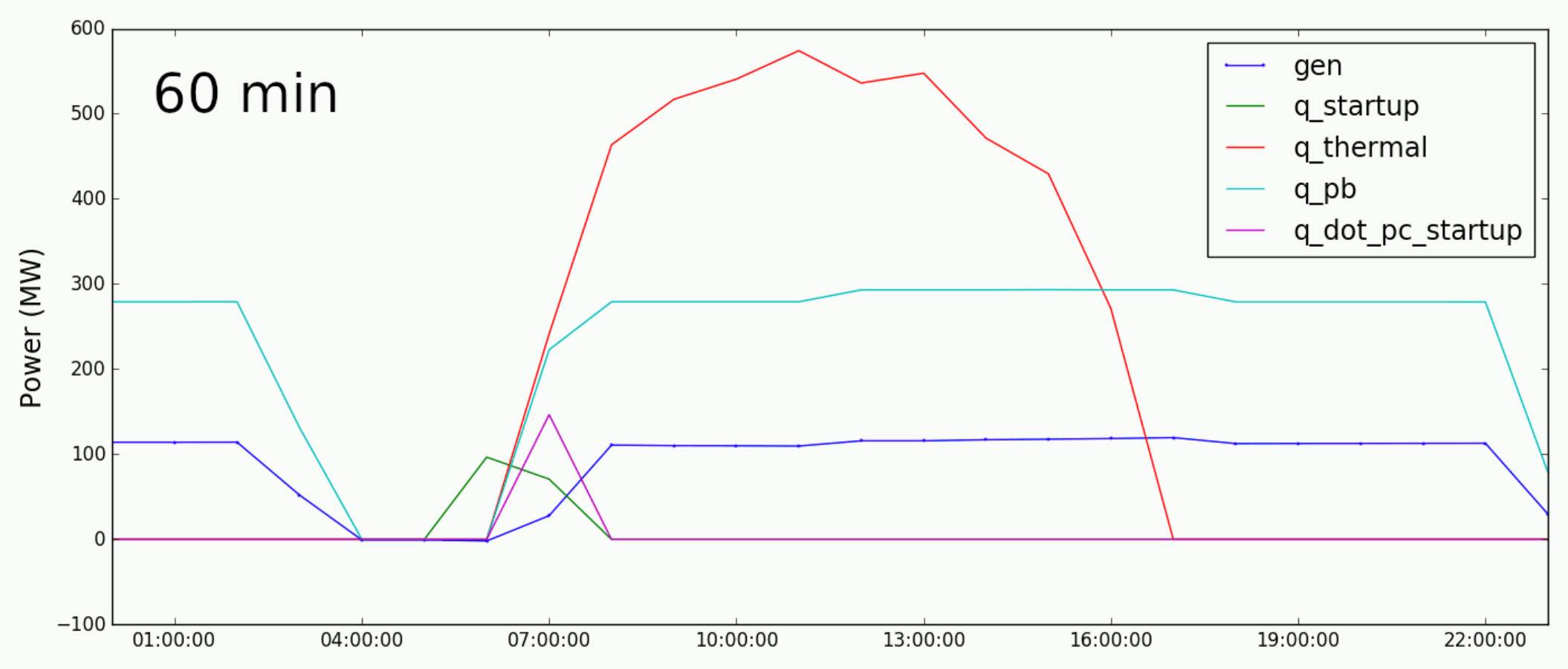
Static aiming



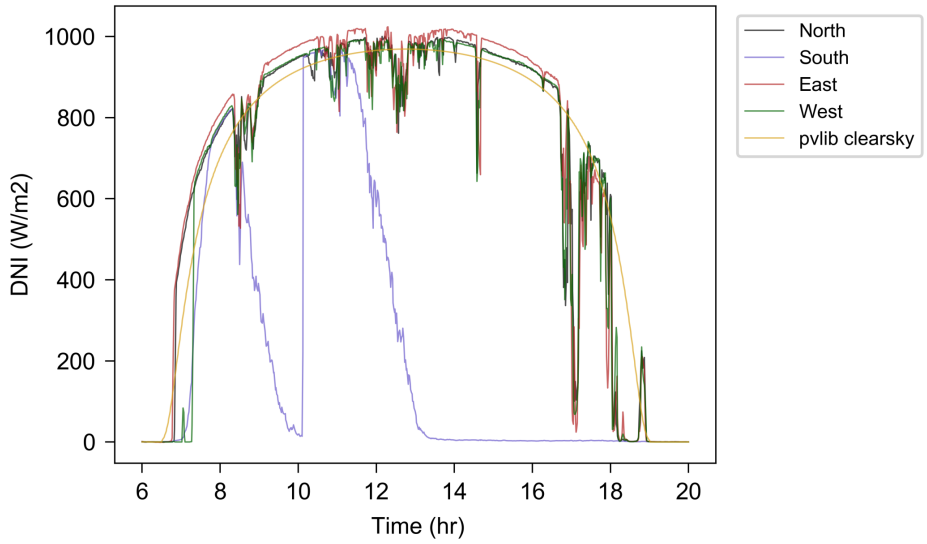
Dynamic aiming

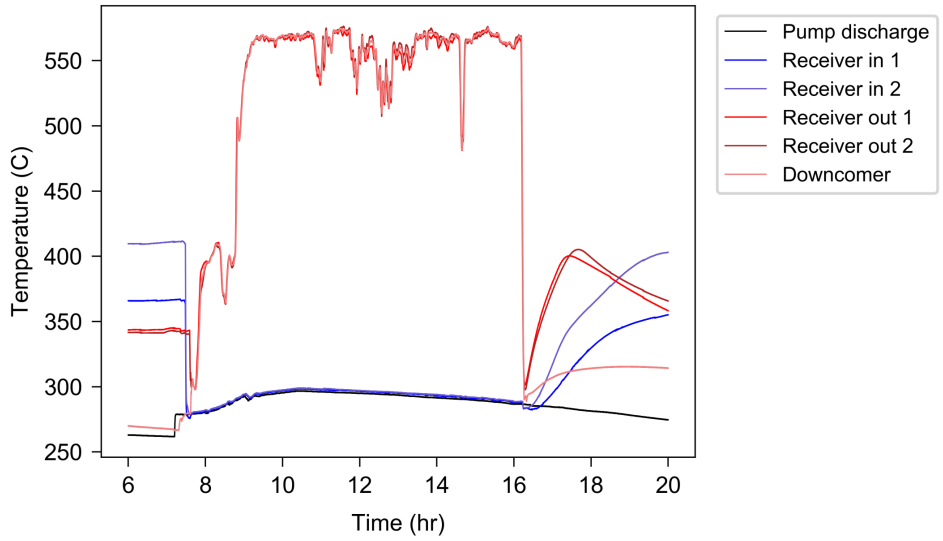


Data resolution is important to identifying possible operating scenarios

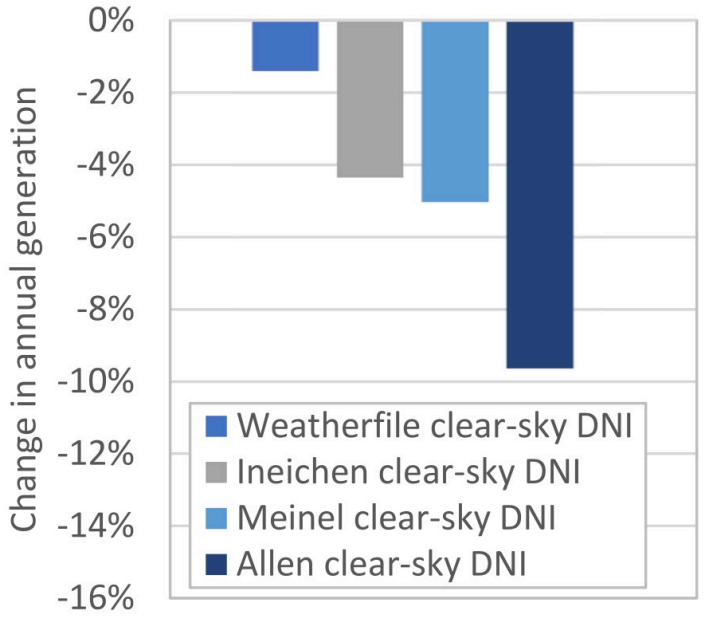


Ideal mass flow control risks receiver burnout



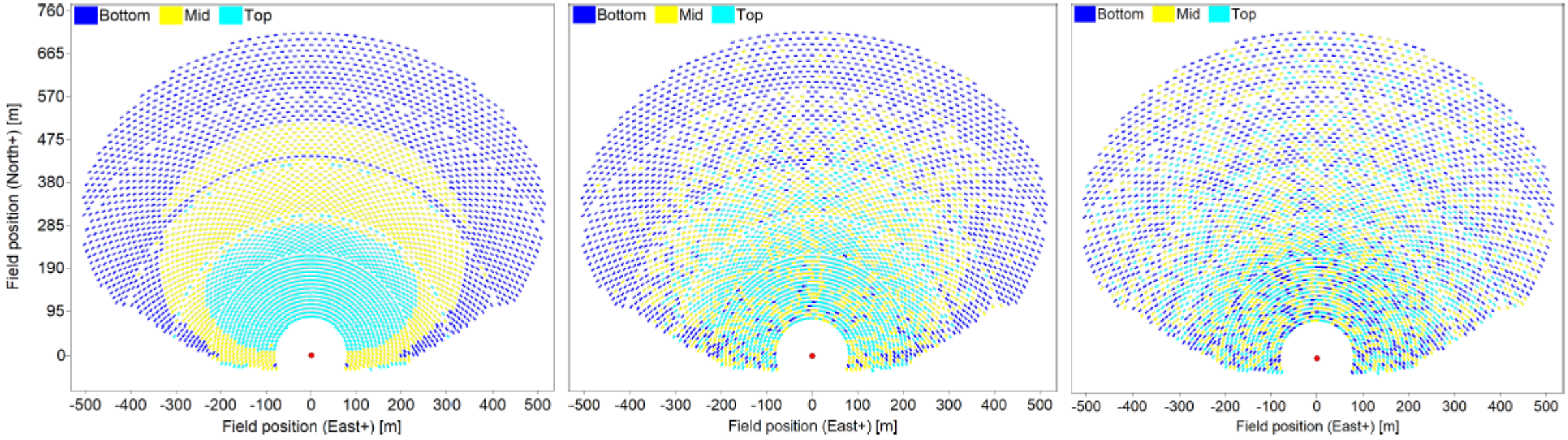


- Control based on clear sky DNI is safest
- Inaccurate models significantly reduce long-term performance
- More work on improved flow / temperature control is needed



Flux control for receivers with multiple targets

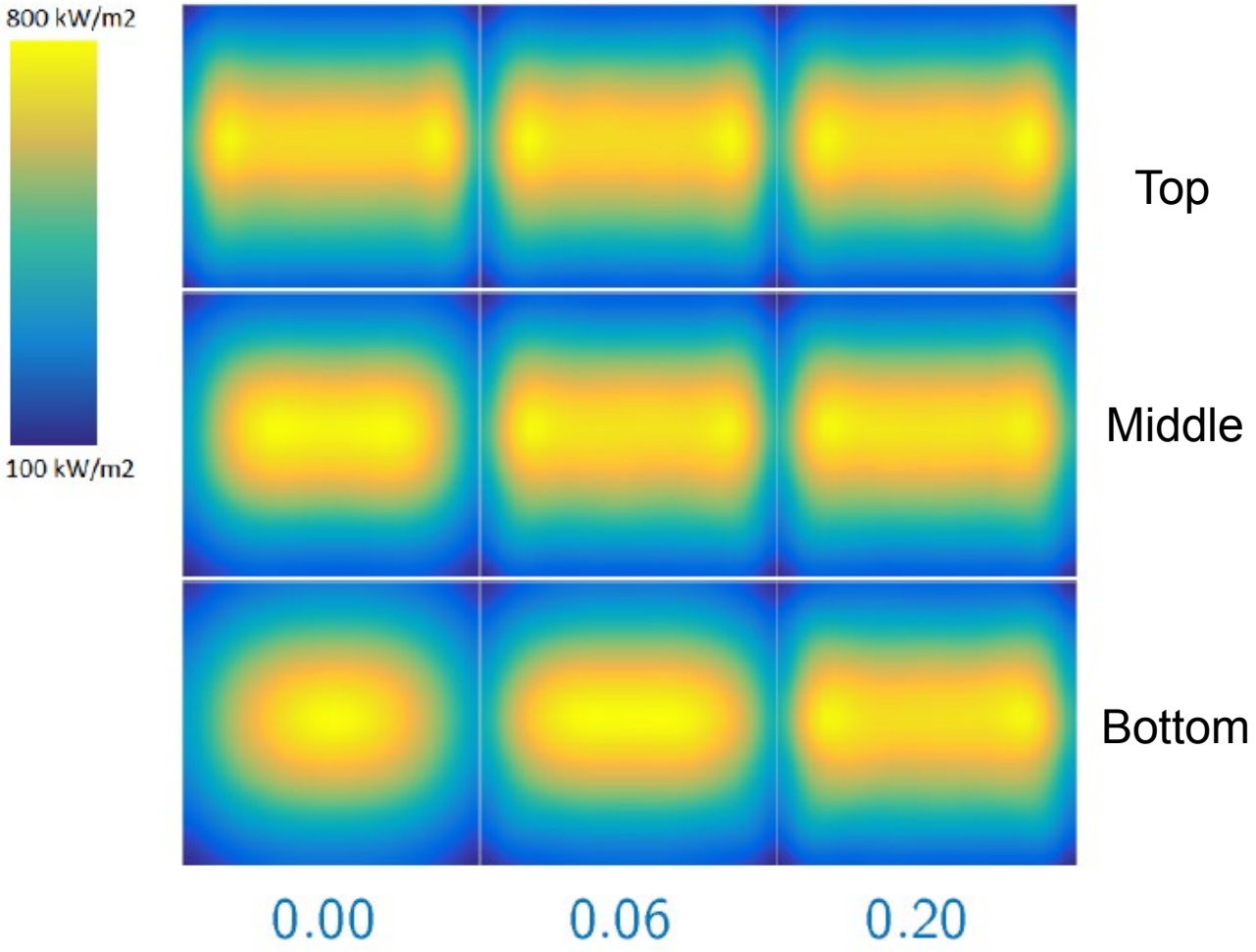
- Consider north-only field with top, middle, bottom targets of equal size
- Heliostats are optimally assigned based on optical performance
- We manually reassign optimal target using a randomized factor



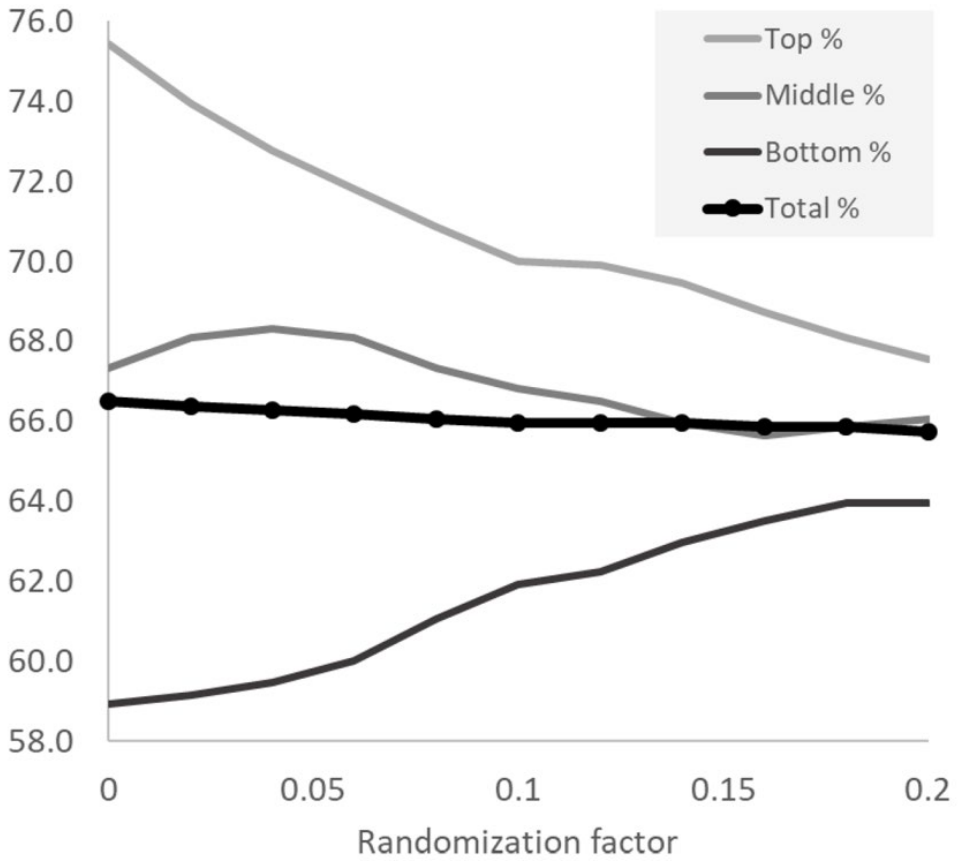
0.00 0.06 0.20

Multiple targets balance flux uniformity with overall field efficiency

Flux by receiver target for 3 randomization factors



Optical efficiency by target



Summary

- Allowable flux is local, depends on fluid conditions, and determines optical requirements from the field
- Heliostat field modeling can help determine ideal flux profile feasibility and should be considered in preliminary work
- The most optically efficient heliostat field may not produce a feasible flux profile
- There is a need for standardized optical characterization and acceptance of heliostats
- Receiver startup, shutdown, and ramping limits can have a large impact on productivity
- Design is not complete until off-design is considered
- Hourly irradiance data does not capture full receiver boundary condition variability
- Consider methods for and impact of controlling mass flow under variable irradiance

Thank you!

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