Fast and accurate Computation of Flux Density formed by Solar Concentrators and Heliostats

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Summary

- Computing the flux densities formed by solar concentrators is a fundamental tool for optimizing the parameters of a Concentrated solar power (CSP) facility
- This poster deals with the concentrating power of focusing heliostats implemented into the field of a solar tower power plant
- Such numerical computations can be performed in two different ways by use of:
  - **Ray-tracing models** based on grid ray-tracing (GRT), starting from the solar disk, impinging the surface of the solar concentrator, and finally reaching the focal plane of the installation → It is reliable and accurate, but requires extensive computing time
  - **Convolution algorithms** → Much shorter computing time, but less accurate under high incidence angles of the sunrays
- We describe an improved convolution algorithm based on Fast Fourier transforms (FFT) of flux densities
- The achieved accuracy is comparable to those of GRT models

Case study

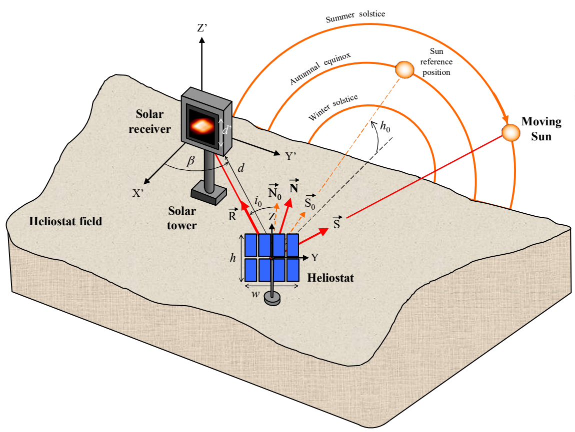
(A) Spherical heliostat, Day time from 09h00 to 15h00 GMT

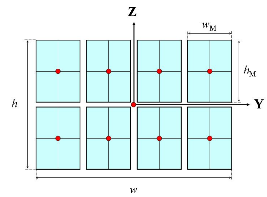
(B) Spherical heliostat, Focusing error from -20 to +20 m

(C) Spherical / Off-axis heliostat comparison, Day time from 09h00 to 15h00 GMT

→ The off-axis heliostat is optimized for a reference Sun vector $\mathbf{S_0}$

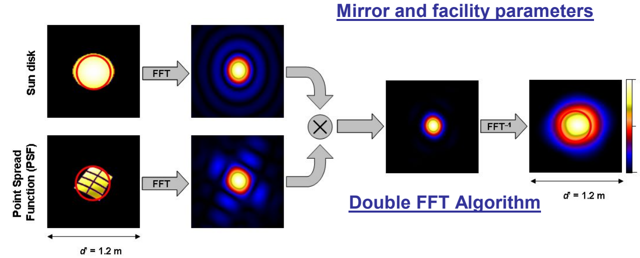
→ Cases of a single heliostat and a couple of symmetric heliostats





Parameter	Symbol	Value	Unit
Target vector from heliostat to receiver	**R**	(86.6, 50., 0.)	m
Distance from heliostat to receiver	*d*	100	m
Incidence angle on solar receiver	*b*	30	degrees
Heliostat width along Y-axis	*w*	3.4	m
Heliostat height along Z-axis	*h*	3.	m
Number of heliostat modules	*m* x *n*	4 x 2	–
Module width along Y-axis	w_M	0.7	m
Module height along Z-axis	h_M	1.4	m
Module focal length	*f*	80 £ *f* £ 120	m
Solar receiver diameter	*d'*	1.2	m

Mirror and facility parameters



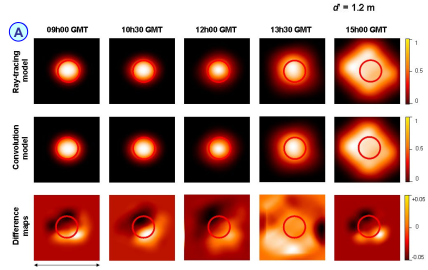
Double FFT Algorithm

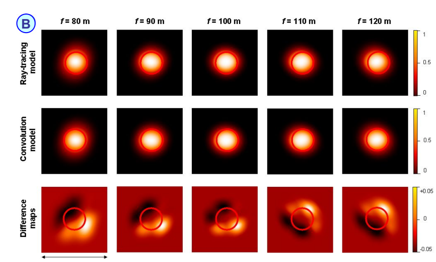
Results

GRT / Convolution models difference

(A) Spherical heliostat	09-23-2022, Day time GMT				
	T = 09h00	T = 10h30	T = 12h00	T = 13h30	T = 15h00
PTV difference (%)	7,2	6,6	6,4	6,8	7,3
RMS difference (%)	0,8	0,9	0,9	1,0	0,8

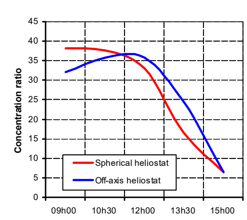
(B) Spherical heliostat	Heliostat modules focal length				
	f = 80 m	*f* = 90 m	*f* = 100 m	*f* = 110 m	*f* = 120 m
PTV difference (%)	5,0	6,3	7,3	6,7	5,8
RMS difference (%)	0,8	0,8	0,8	0,8	0,8

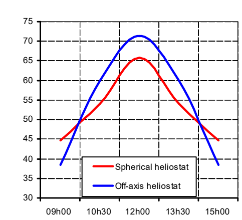


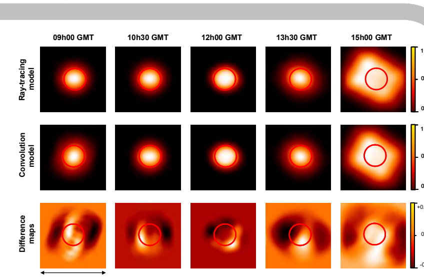


(C) Concentration ratio	09-23-2022, Day time GMT				
	T = 09h00	T = 10h30	T = 12h00	T = 13h30	T = 15h00
Spherical heliostat x 1	38,1	37,7	32,9	16,4	6,5
Spherical heliostat x 2	44,6	54,1	65,9	54,1	44,6
Off-axis heliostat x 1	32,0	35,7	35,7	24,3	6,5
Off-axis heliostat x 2	38,5	60,0	71,4	60,0	38,5

"Optimizing the concentration ratio of multi-faceted focusing heliostats," F. Hénault, G. Flamant, Cyril Caliot, submitted to *Solar Energy*







Conclusion and prospects

- Numerical simulations applied to the case of a Sun tracking focusing heliostat operating in a solar tower power plant demonstrate that the accuracy of the double FFT algorithm is comparable to those of Grid ray-tracing (GRT) models
- Error differences are about 1% RMS even when the sunrays are impinging the heliostat under high incidence angles
- The net gain factor in computing time with respect to GRT models is estimated around 250
- This gain can be further improved by under-sampling the Point spread function of the heliostat and developing analytical expressions of the Fourier transform of the Sun disk
- The double FFT algorithm may pave the way to fast and robust optimization of an entire heliostat field, and of its pointing strategy

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