Priority Project T^2RC^2:

Determination of governing parameters in the new radiation scheme

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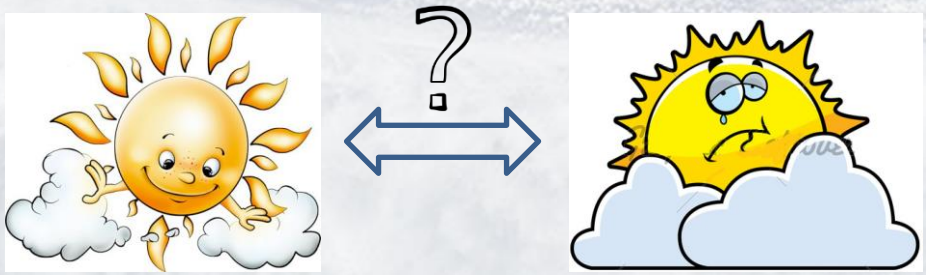

COSMO User Seminar, Offenbach, March 2016

Problem: New radiation scheme – 32 new parameters

(how microphysical properties influence radiation transfer)

Which of them are most important?

Difficult to answer… it depends on cloud type.

Solution:

1. Use ***idealized*** COSMO framework to create different cloud types
2. Decide which parameters are the most important for each cloud type

For example, we will find out that:

Cirrus	Warm Stratus	Mixed phase	Fair weather Cu	Anvil of CB
p1,p2,p3,p6,p7,p9,p10,p11,p14,p16,p23,p24,p25,p29,p30,p31,p32	p1,p2,p6,p8,p15,p17,p18,p19,p26,p27,p28,p32	p1,p2,p3,p6,p7,p8,p9,p10,p11,p14,p15,p16,p17,p18,p19,p23,p24,p25,p26,p27,p28,p29,p30,p31,p32	p2,p6,p7,p8,p15,p17,p18,p19,p32	p1,p2,p3,p6,p7,p9,p10,p11,p14,p16,p23,p24,p25,p29,p30,p31,p32

p8,p9,p15,p16,p32 – could be the new tuning namelist parameters in the future version

All the others – predefine in the code

1.	lrad_incl_qrqsqg	true / false switches
2.	iradpar_cloud	
3.	lrad_use_largesizeapprox	
4.	lrad_ice_smooth_surfaces	
5.	lrad_ice_fd_is_gsquared	
6.	itype_aerosol	
7.	icloud_num_type_rad	
8.	radqcfact	continuous parameters
9.	radqifact	
10.	rad_arearat_ls_i	
11.	rad_arearat_ls_s	
12.	rad_arearat_ls_g	
13.	rad_arearat_ls_h	
14.	rhobulk_ls_ini_i	
15.	reff_ini_c	
16.	reff_ini_i	
17.	cloud_num_rad	
18.	zref_cloud_num_rad	
19.	dz_oe_cloud_num_rad	
20.	tqc_thresh_rad	
21.	tqi_thresh_rad	
22.	tqs_thresh_rad	
23.	rhos_n0shigh_rad	
24.	rhos_n0slow_rad	
25.	n0s_low_rad	
26.	rhoc_nchigh_rad	
27.	rhoc_nclow_rad	
28.	ncfact_low_rad	
29.	rhoi_nihigh_rad	
30.	rhoi_nilow_rad	
31.	nifact_low_rad	
32.	qvsatfact_sgscl_rad	

Outline

1. Idealized COSMO model, examples of 5 types of clouds
2. True / False switches
3. Continuous parameters
    a. Method: How to define sensitivity to model parameters ?
    b. Sensitivity results: which parameters are most important ?
4. List of most important parameters
5. Summary

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1. Idealized COSMO model

Domain:
41X41X60 grid points
(around 30°E-30°N)

Resolution: 0.025°

Periodic B.C.

Removed the radiation heating term in the eqn. for temperature tendency

→

"Same" cloud for any radiation parameters

Set zenith angle to constant=30°

Predefine RH and T profiles
→ get desired cloud

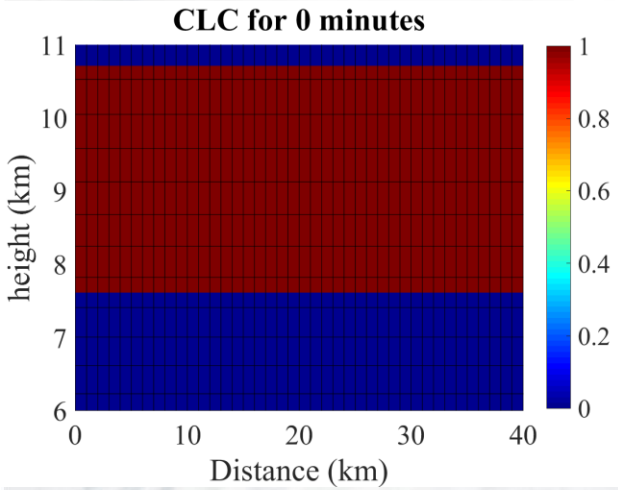
1. Idealized COSMO model

Idealized COSMO model was used for simulating 5 types of clouds:

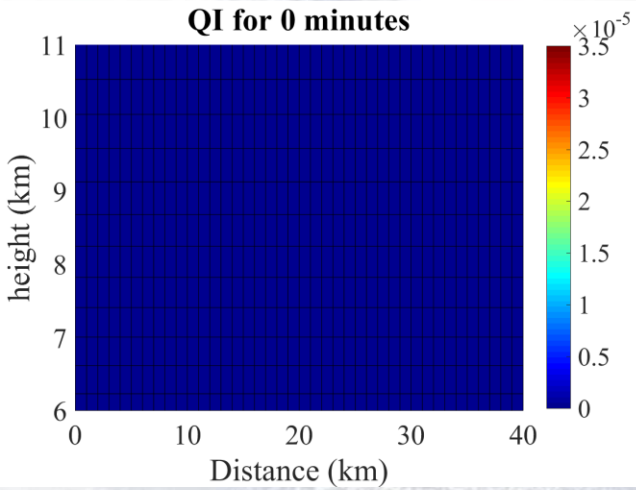
Cloud type	Altitude	RH over water	Temperature
Warm Stratus	stable layer 1.5-3km	101%	8.9 C till 2.9 C
Cirrus	stable layer 7.5-10.75km	80%	-23 C till -54 C
Mixed phase	stable layer 3.2-6km	101%	-2.8 C till -16.8 C
Fair weather Cu	stable layer 1.5-1.8km	95%	8.9 C till 7.7 C
Anvil of CB	Weisman-Klemp wind profile + T-bubble disturbance		

Cirrus (idealized simulation)

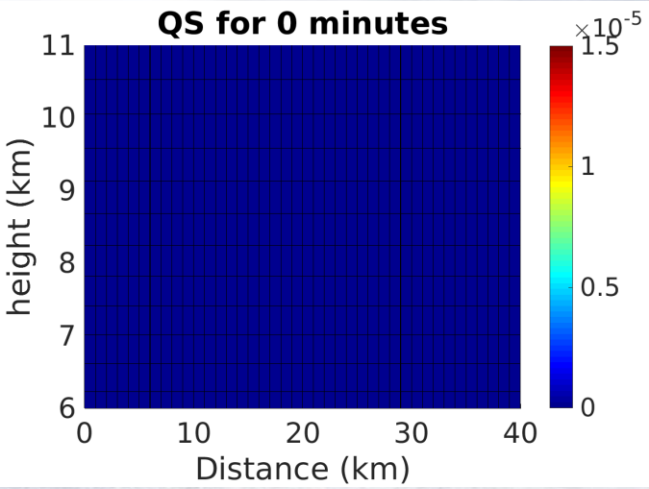
Cloud cover



Ice content (kg/kg)

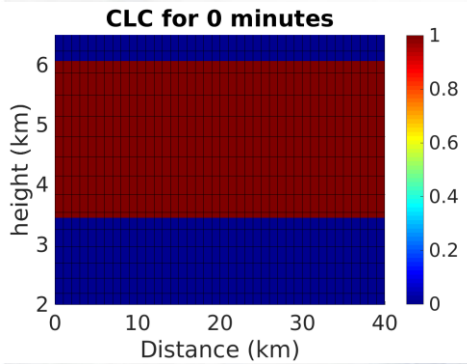


Snow content (kg/kg)

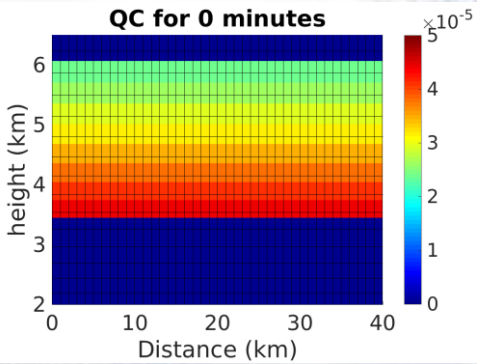


Mixed phase cloud (idealized simulation)

Cloud cover



Cloud droplets content (kg/kg)



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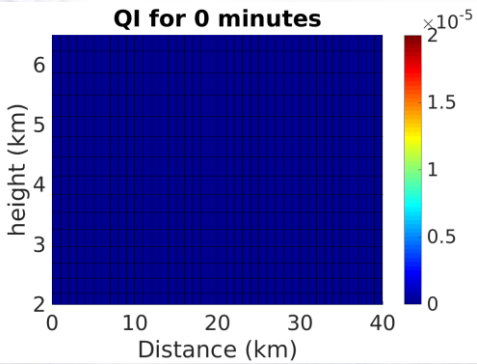

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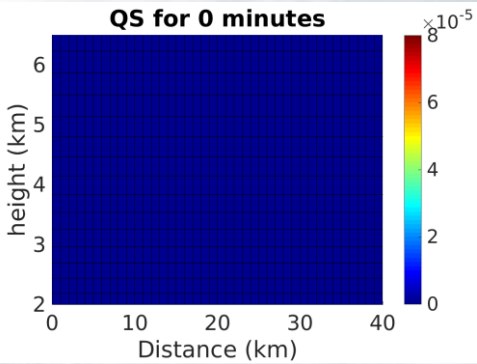
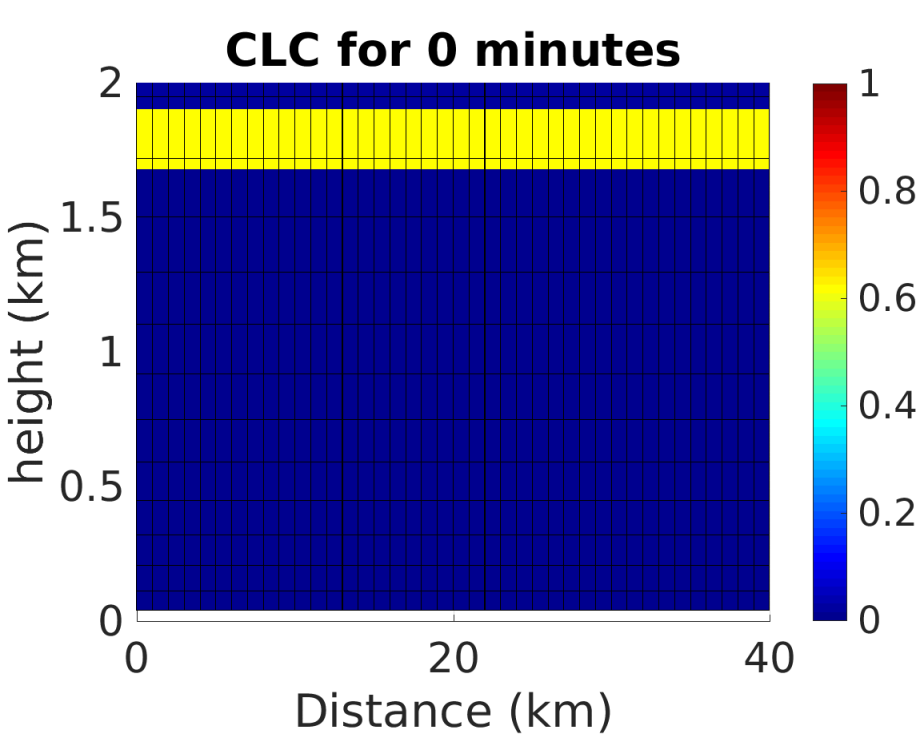
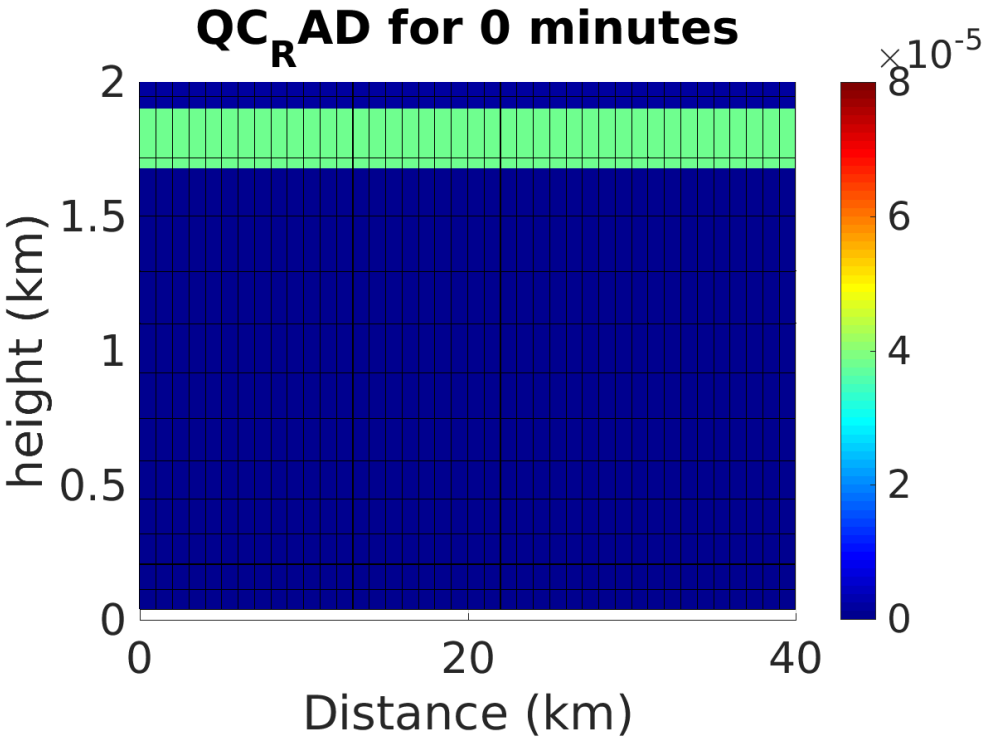


Fair weather Cu (idealized simulation)

Cloud cover

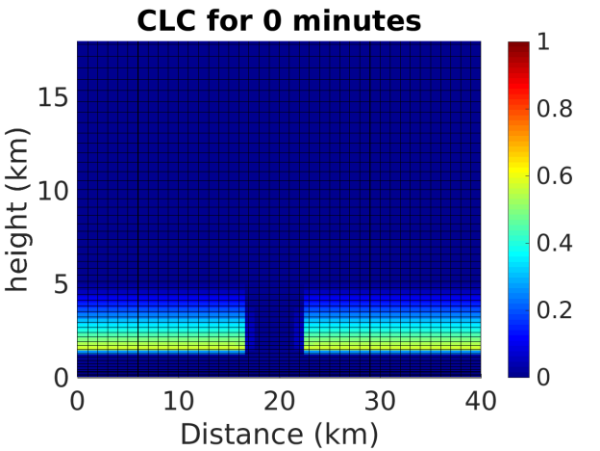


Subgrid cloud droplets content (kg/kg)



Anvil of CB (idealized simulation)

Cloud cover



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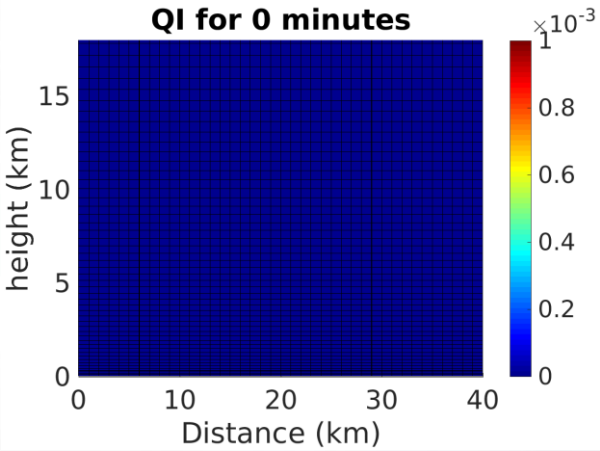
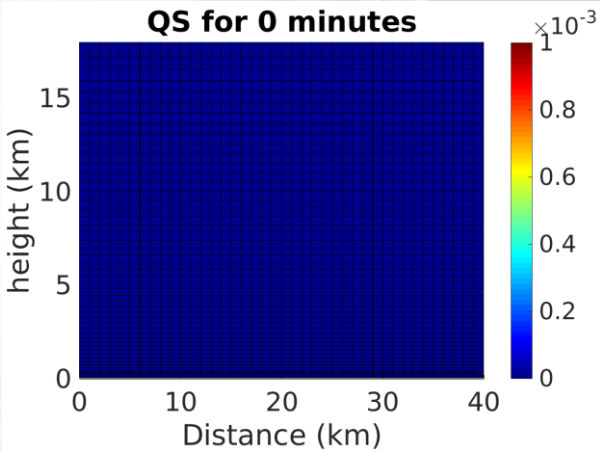
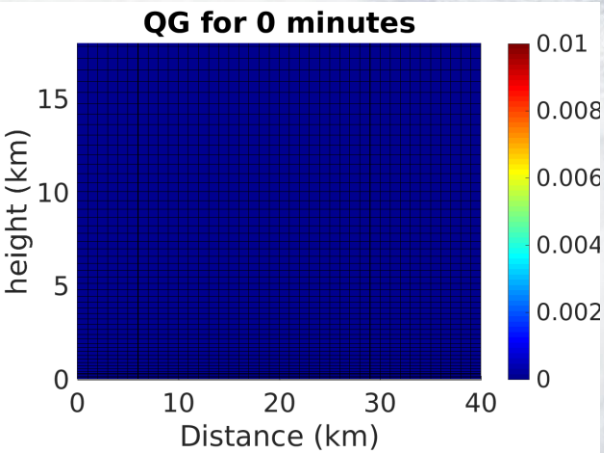


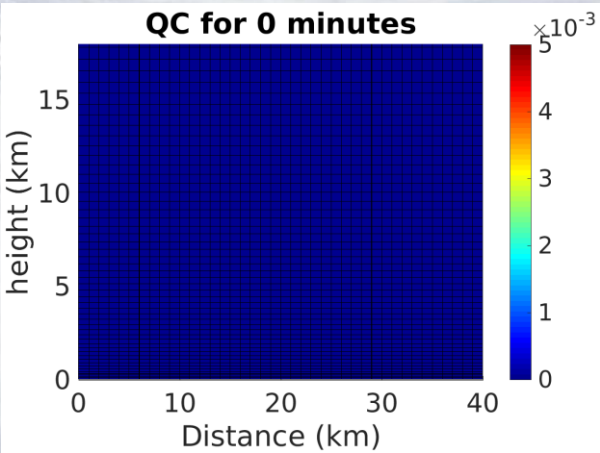
Snow content (kg/kg)



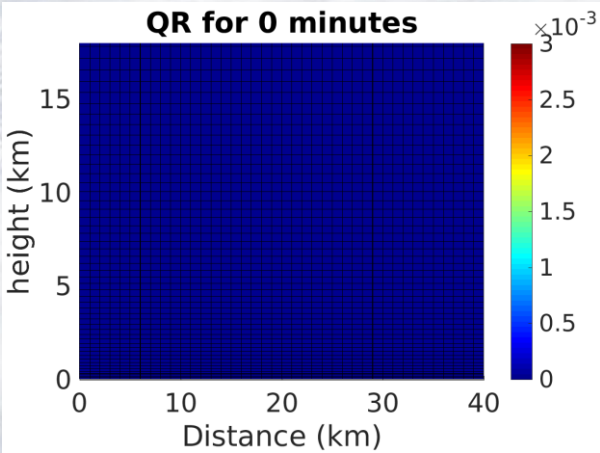
Graupel content (kg/kg)



Droplets content (kg/kg)

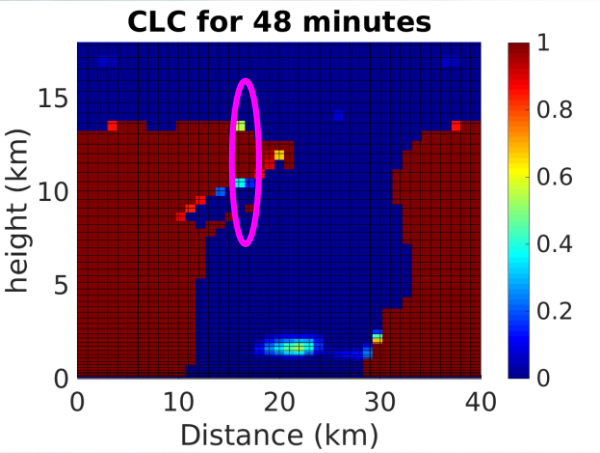


Rain content (kg/kg)

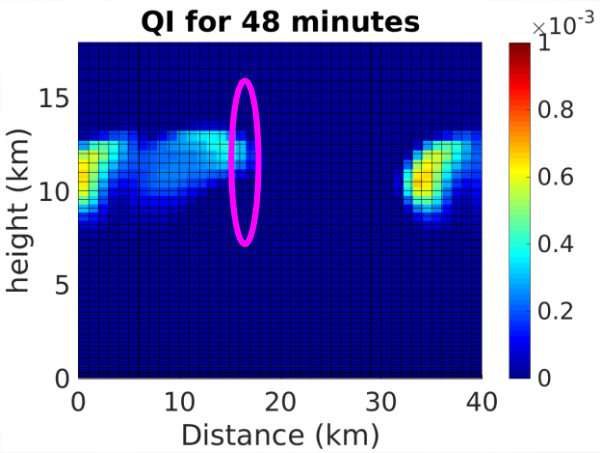


Anvil of CB (idealized simulation)

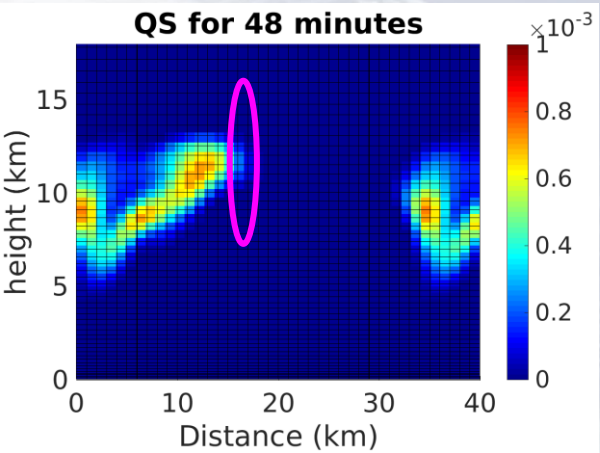
Cloud cover



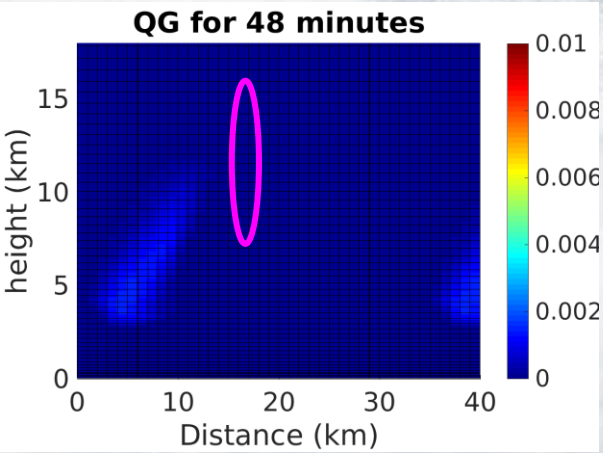
Ice content (kg/kg)



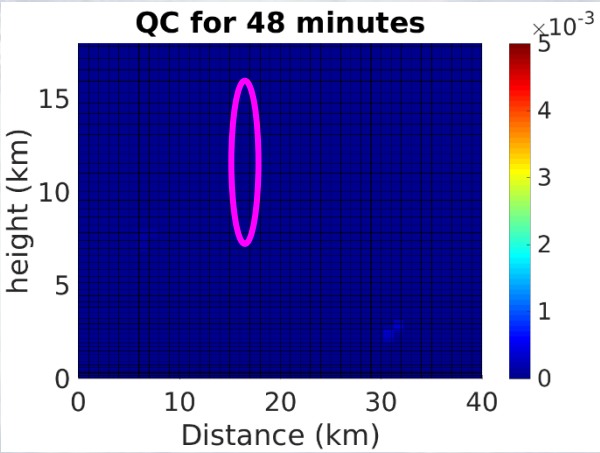
Snow content (kg/kg)



Graupel content (kg/kg)



Droplets content (kg/kg)



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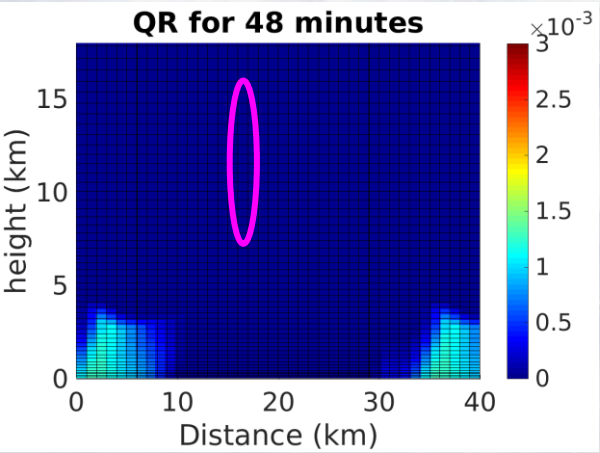
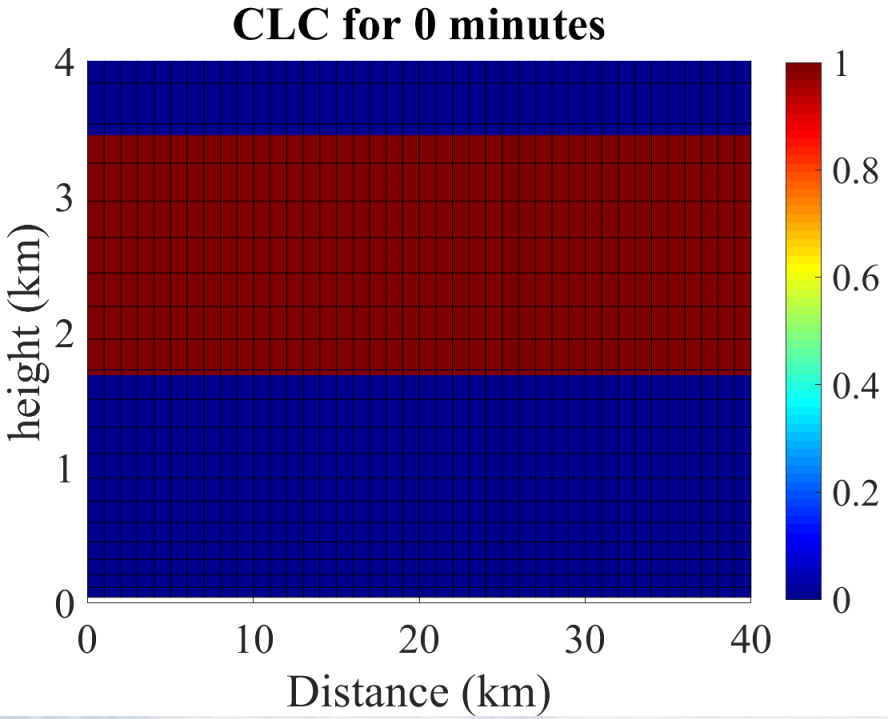
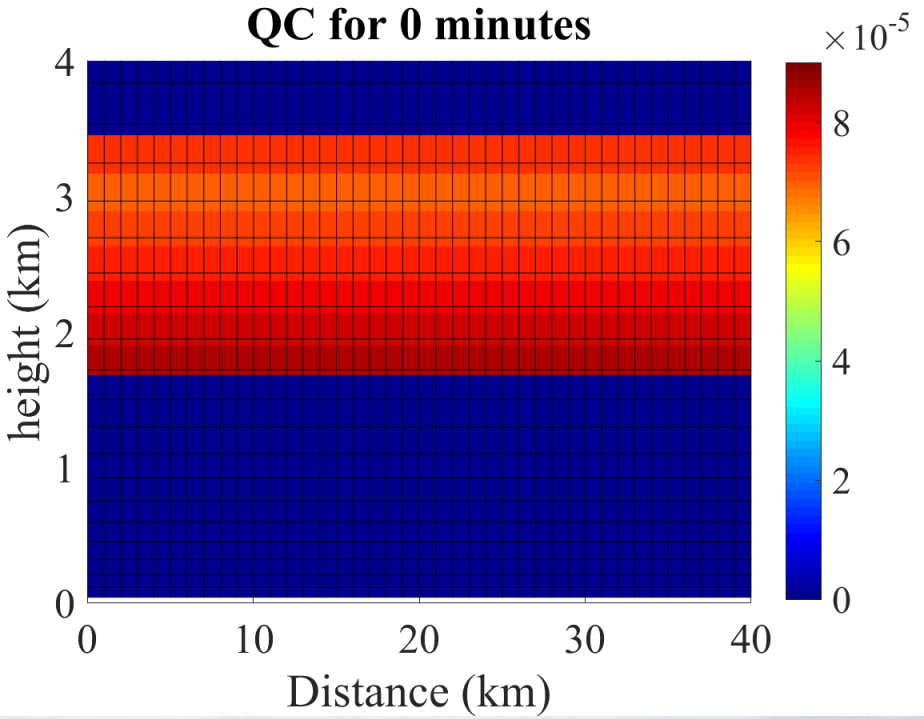


Warm Stratus (idealized simulation)

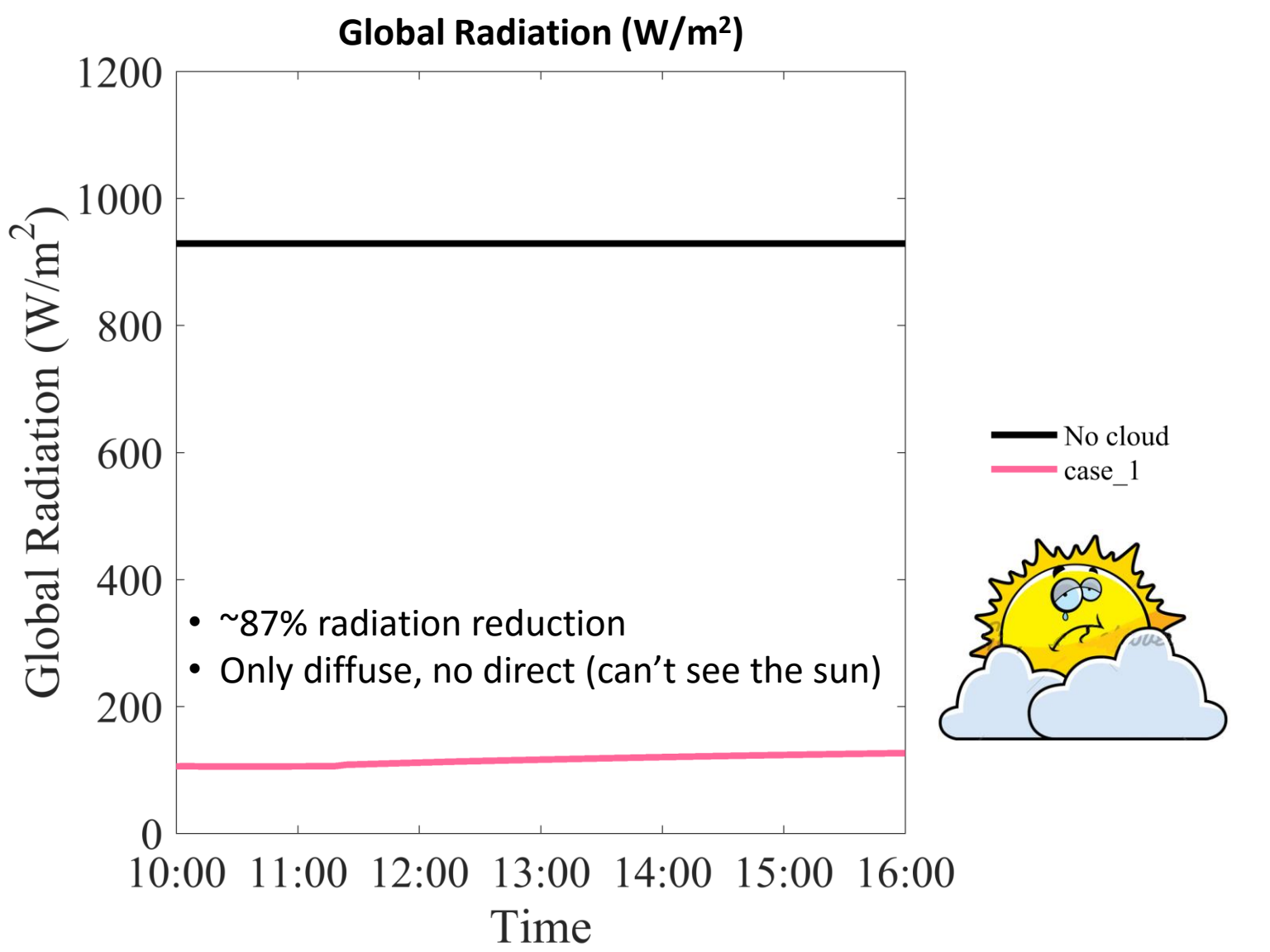
Cloud cover



Cloud droplets content (kg/kg)



Example: warm Stratus (idealized simulation)



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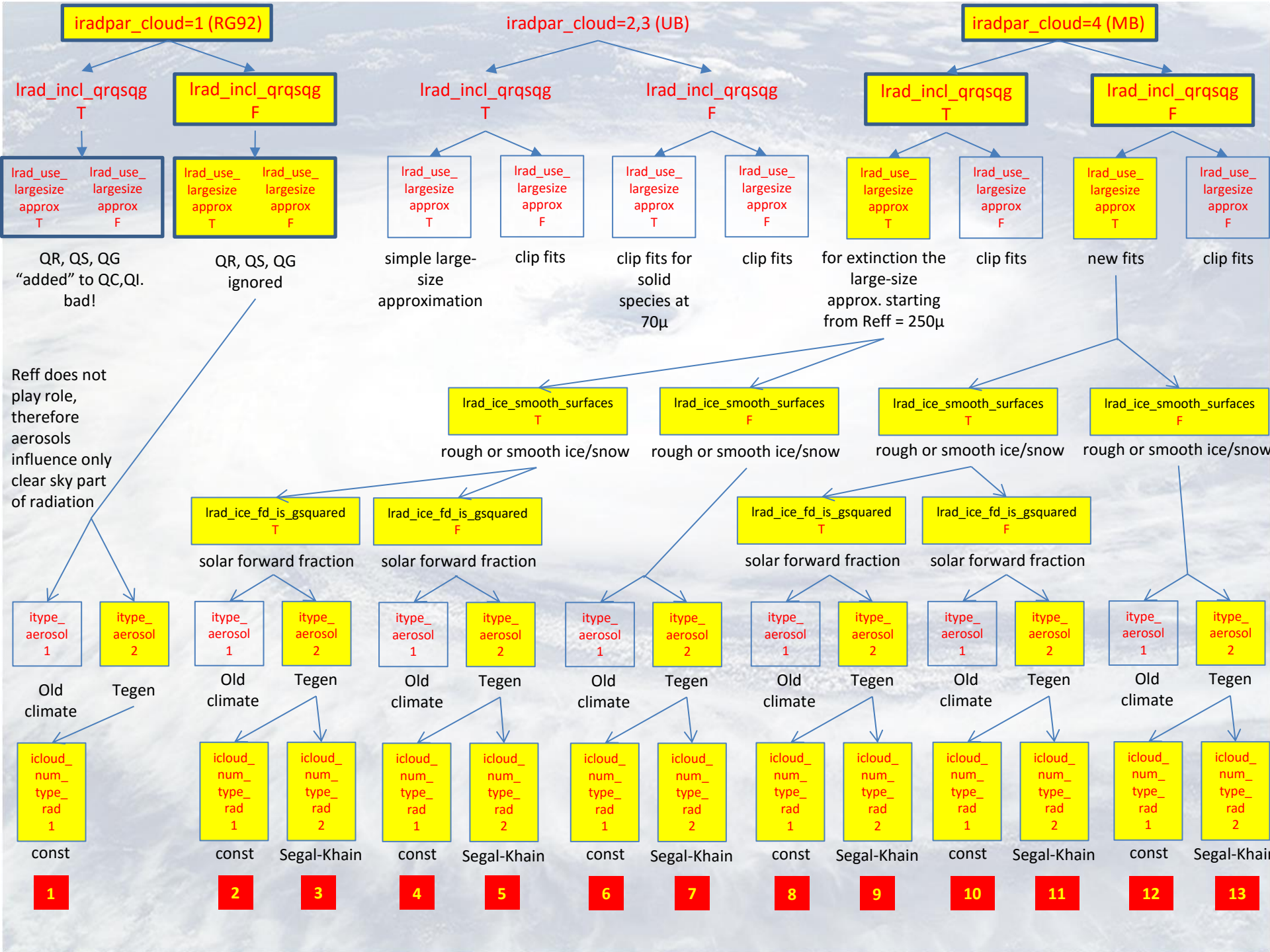
true / false switches

continuous parameters


iradpar_cloud=1 (RG92)
iradpar_cloud=2,3 (UB)
iradpar_cloud=4 (MB)
lrad_incl_qrqsqg T
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lrad_use_largesize approx T
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QR, QS, QG "added" to QC,QI. bad!
QR, QS, QG ignored
simple large-size approximation
clip fits
clip fits for solid species at 70µ
clip fits
for extinction the large-size approx. starting from Reff = 250µ
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new fits
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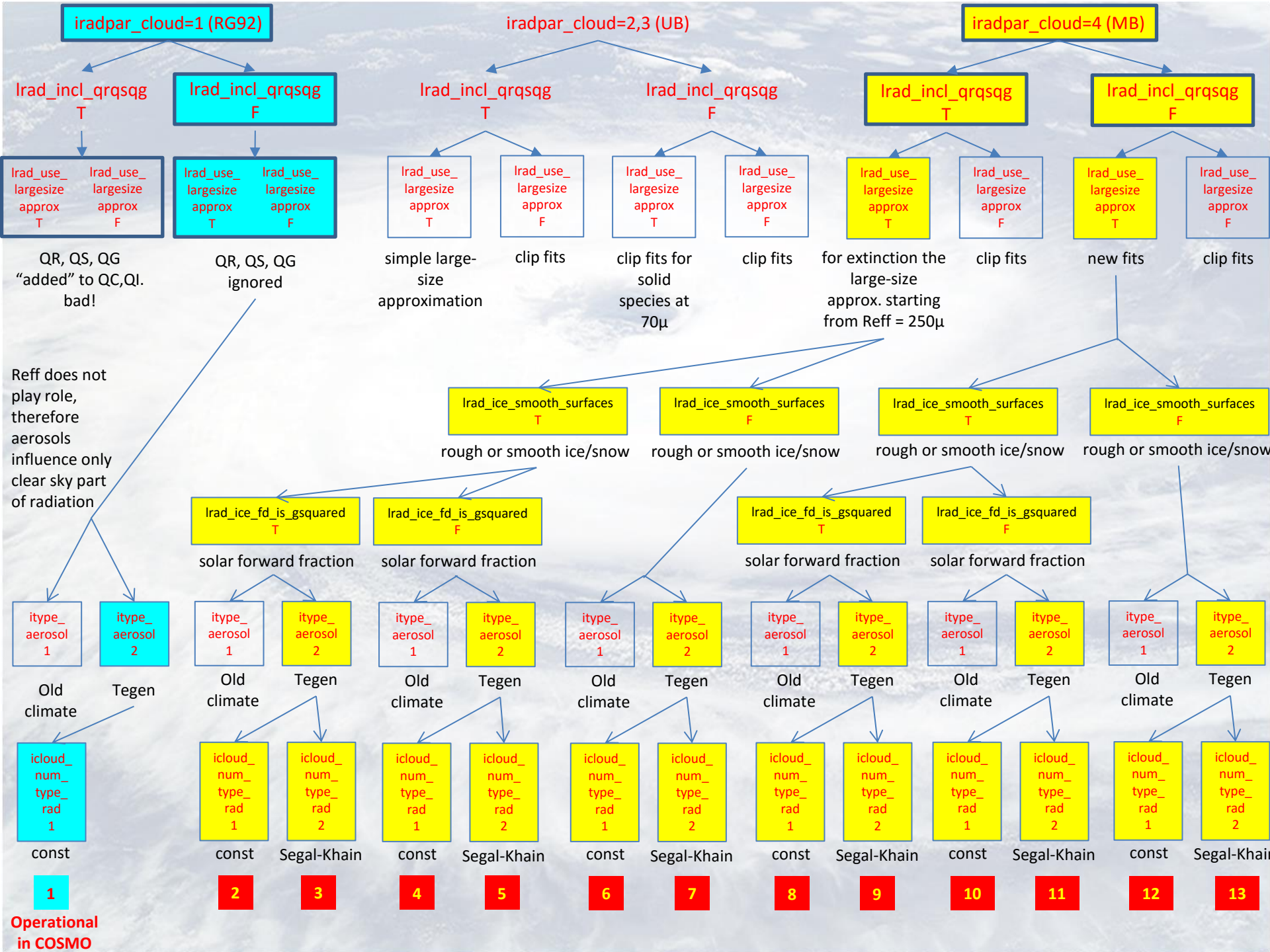
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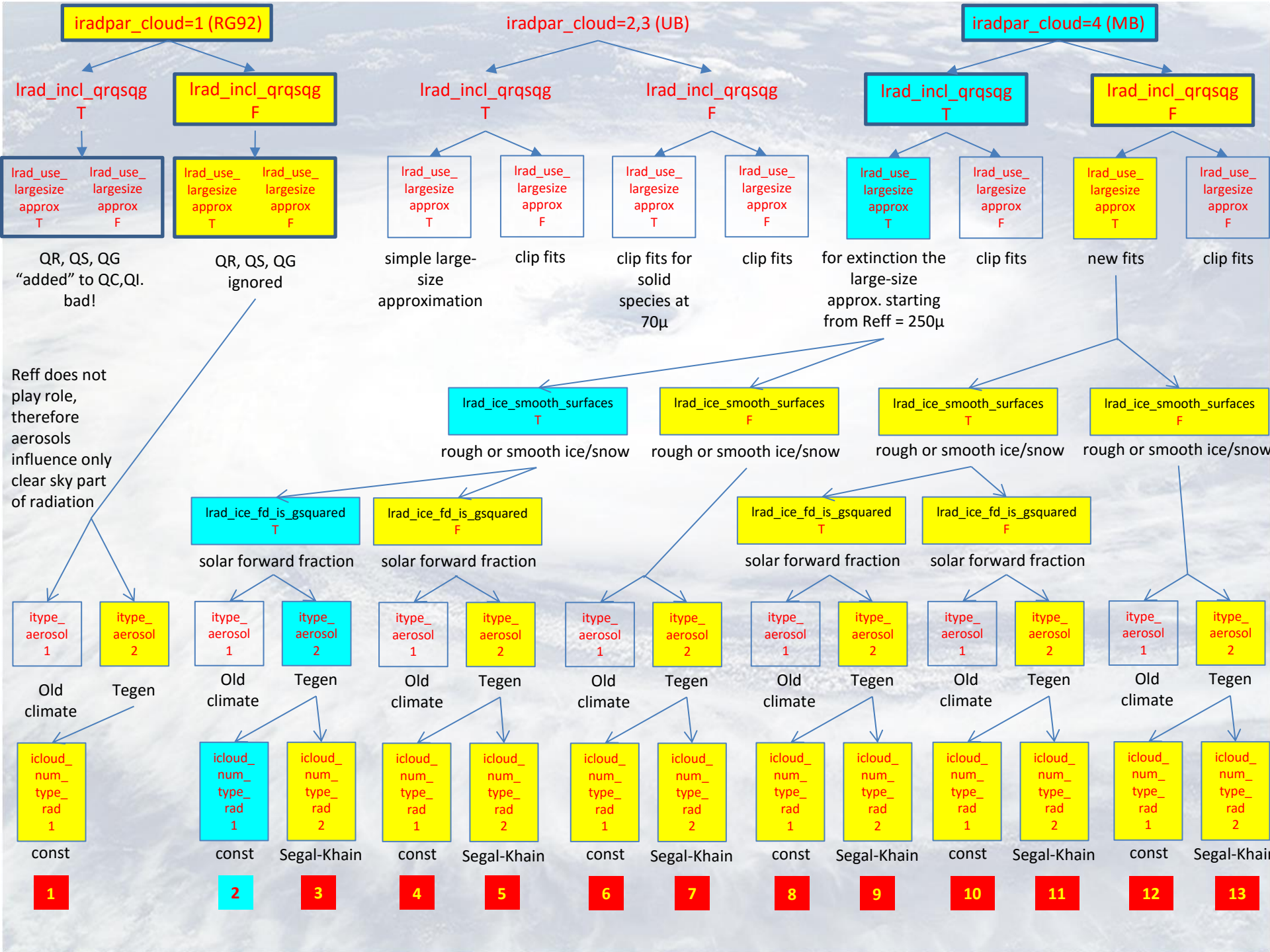
Operational in COSMO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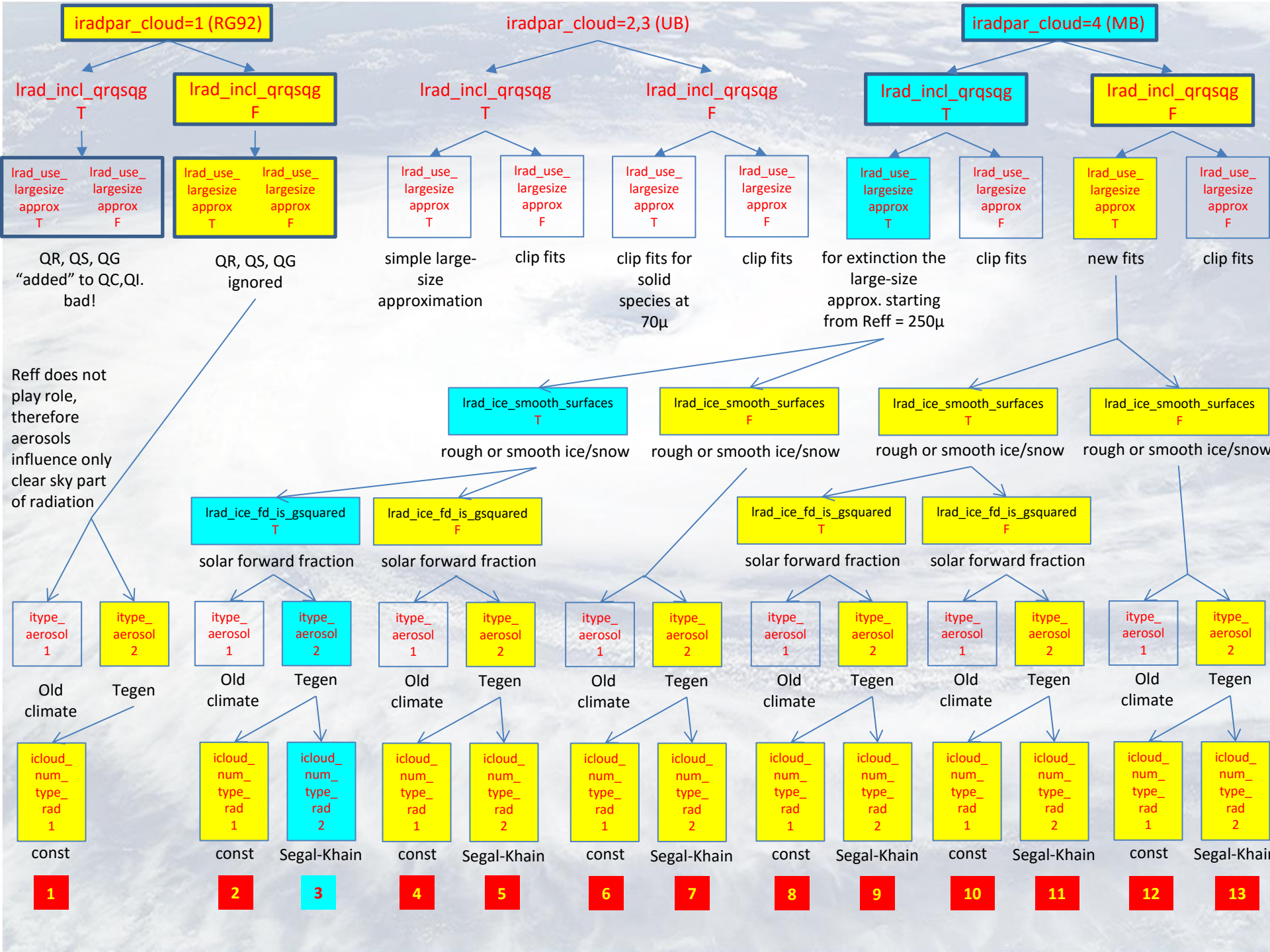
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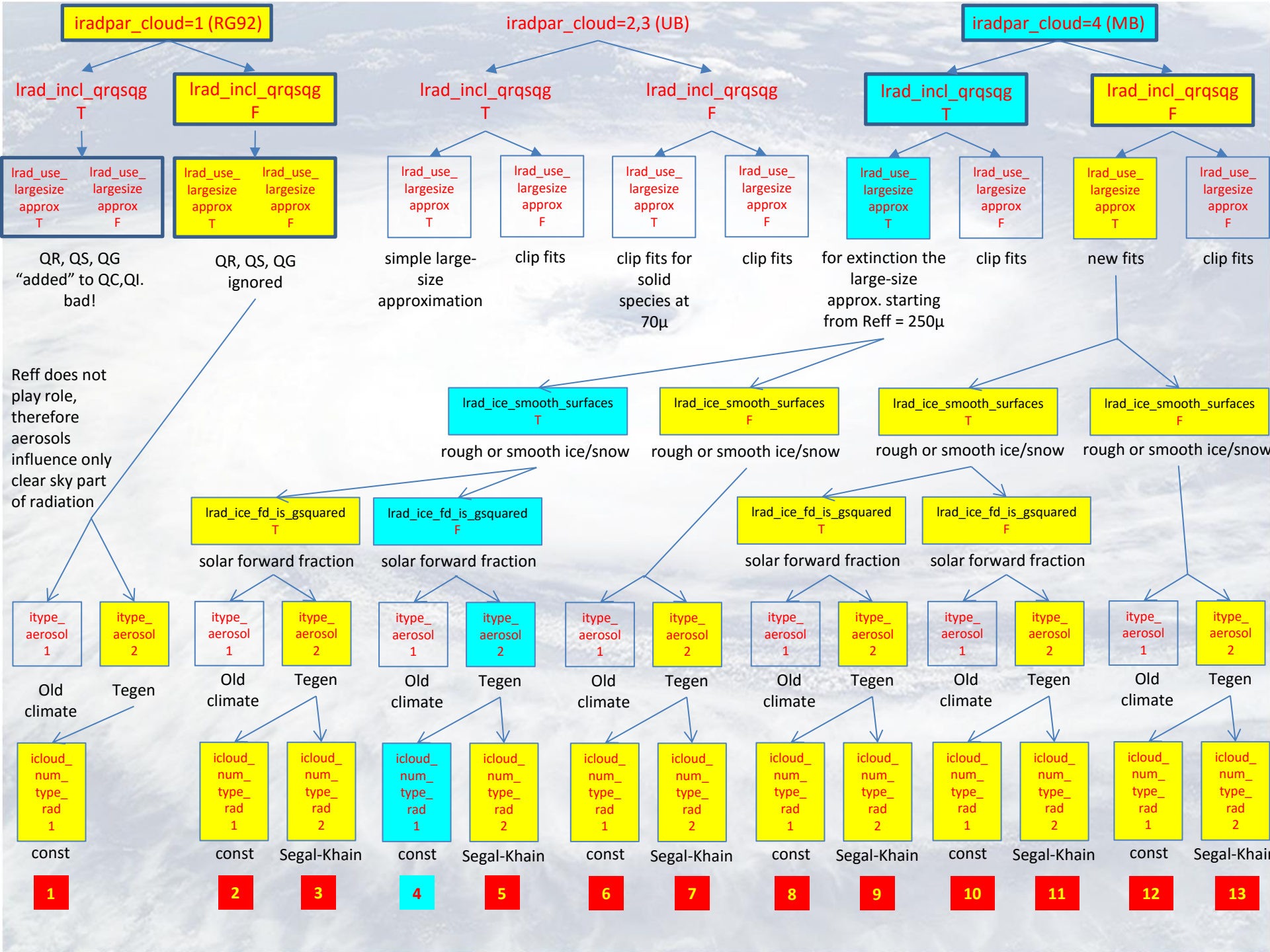
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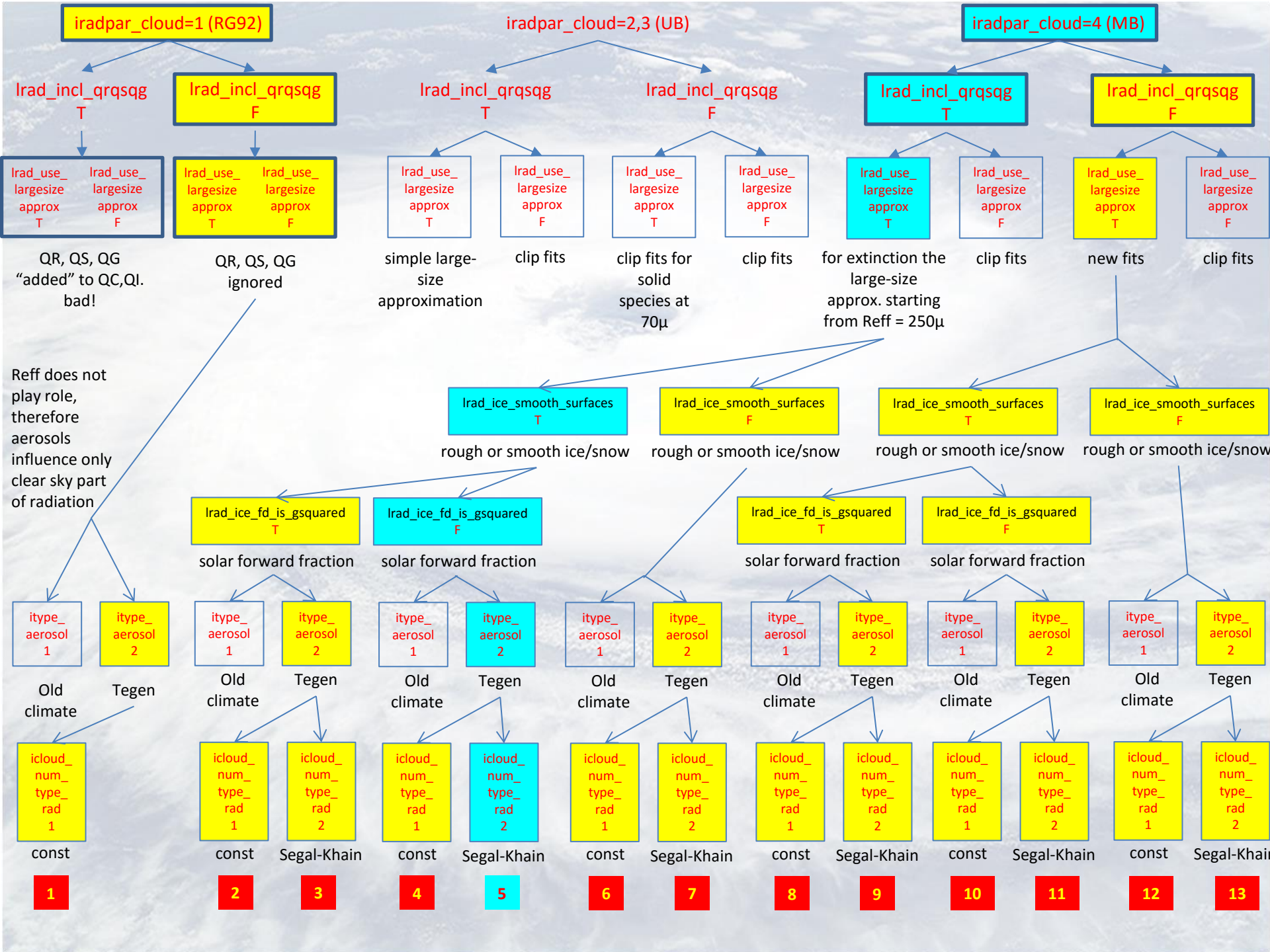
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lrad_ice_fd_is_gsquared T
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solar forward fraction
itype_aerosol 1
itype_aerosol 2
Old climate
Tegen
icloud_num_type_rad 1
icloud_num_type_rad 2
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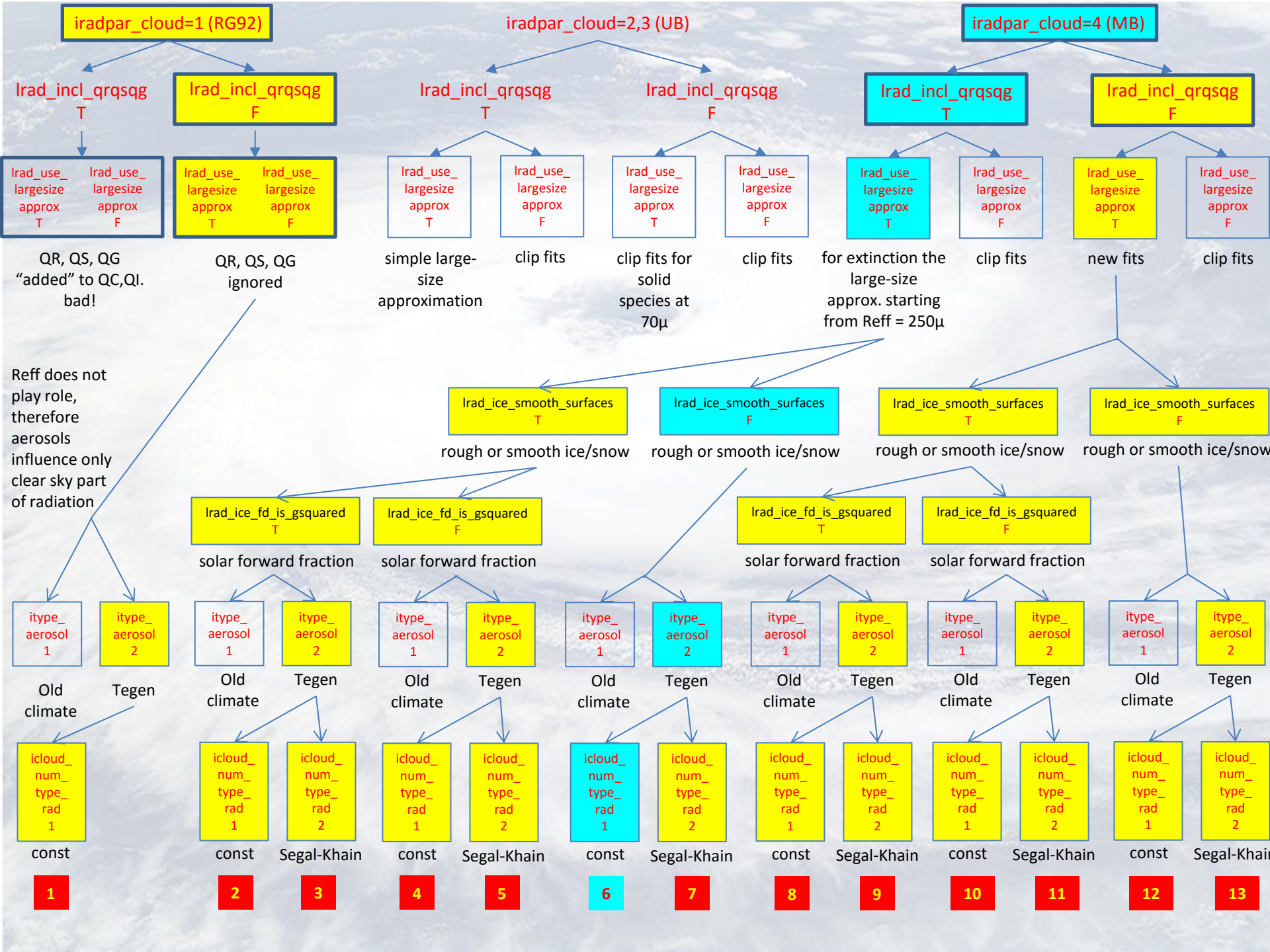
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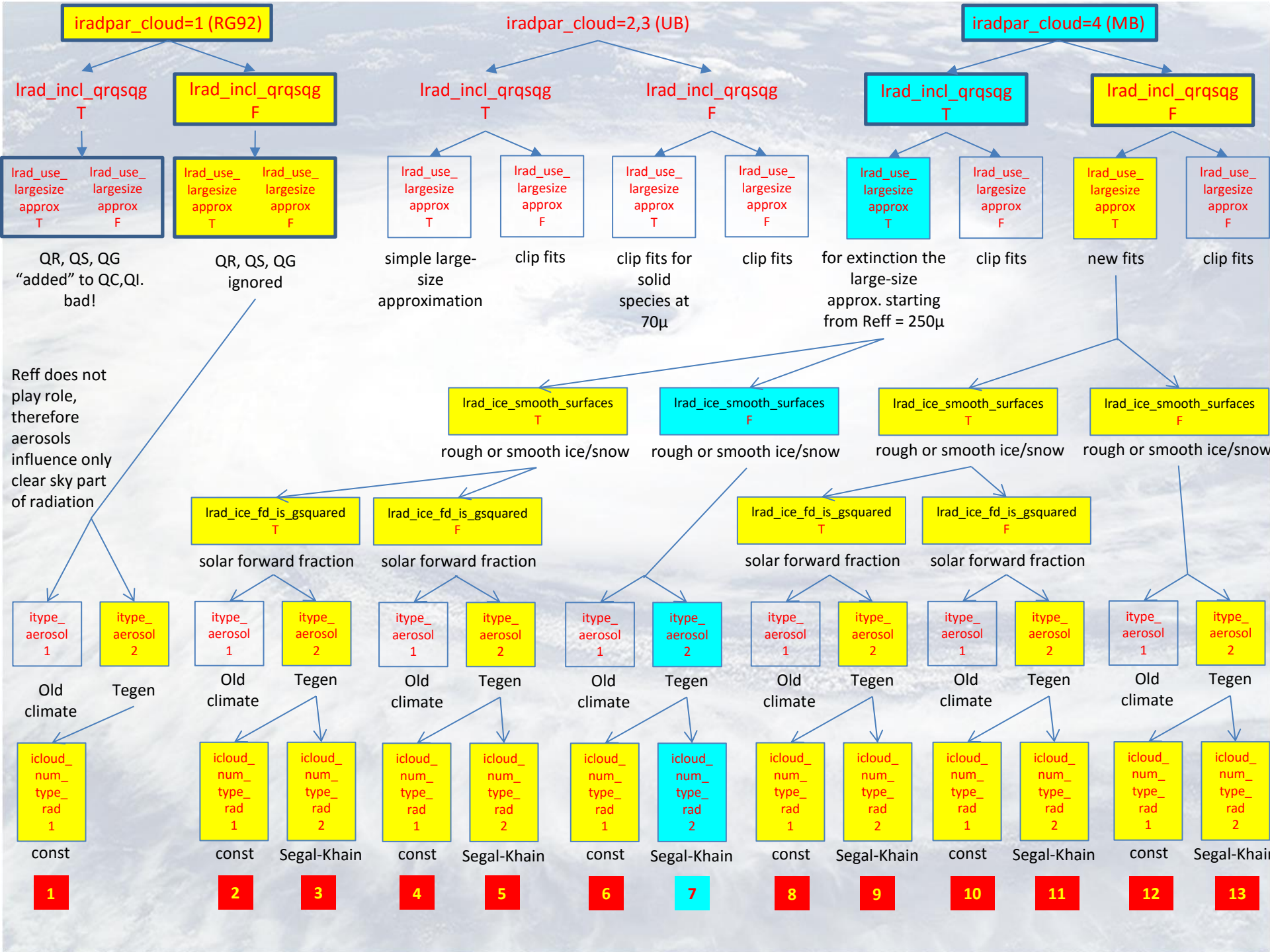
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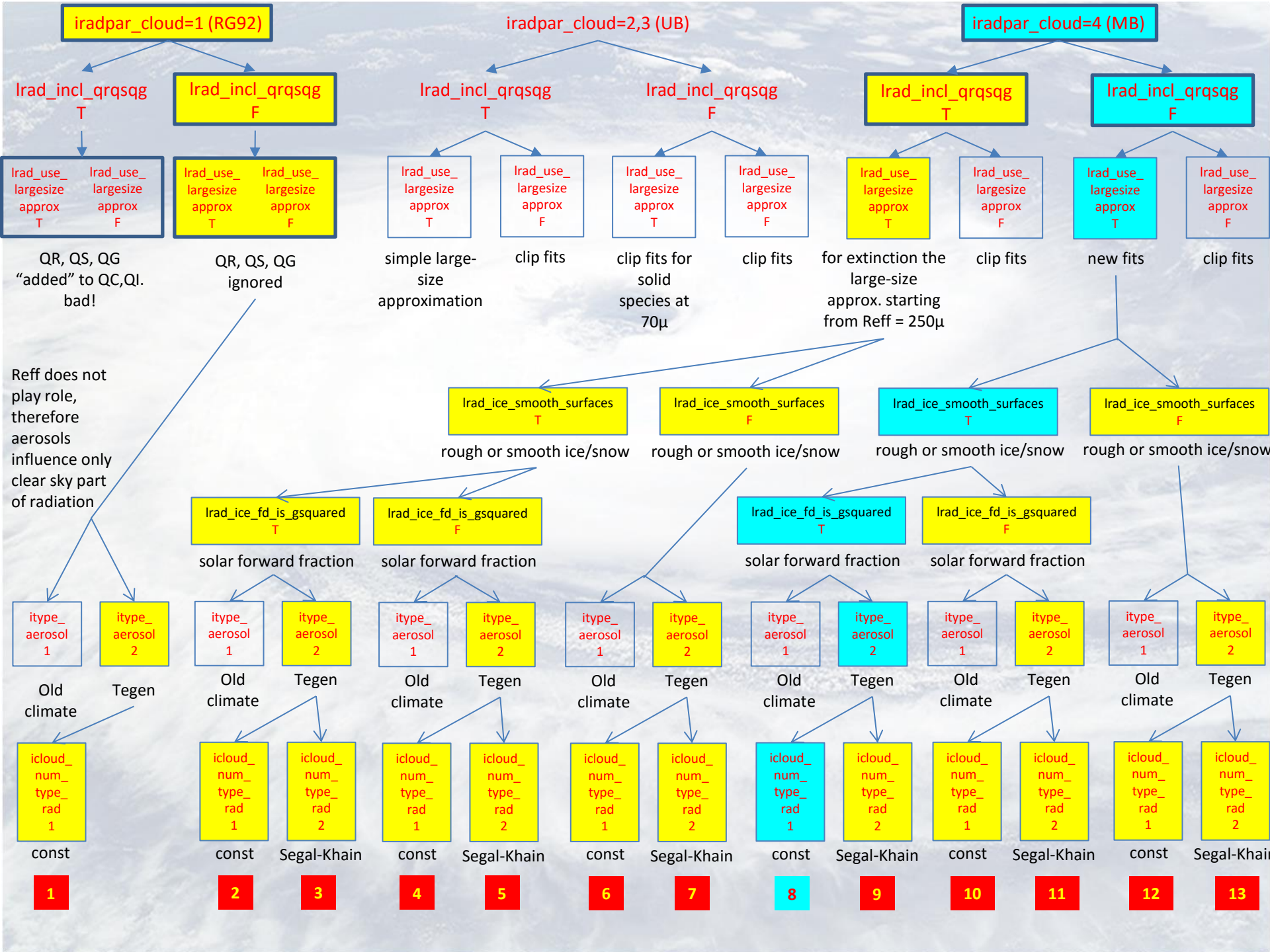
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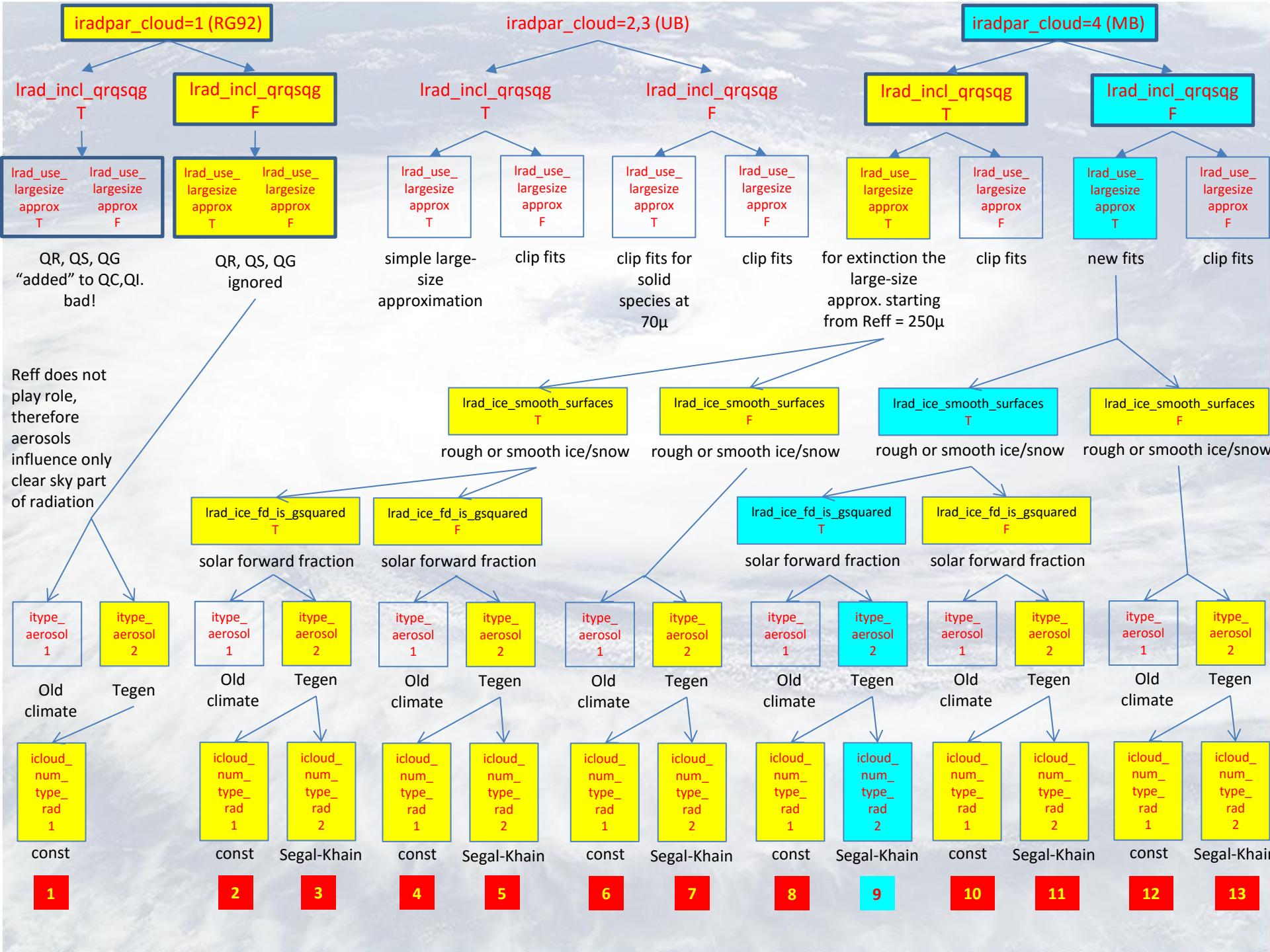
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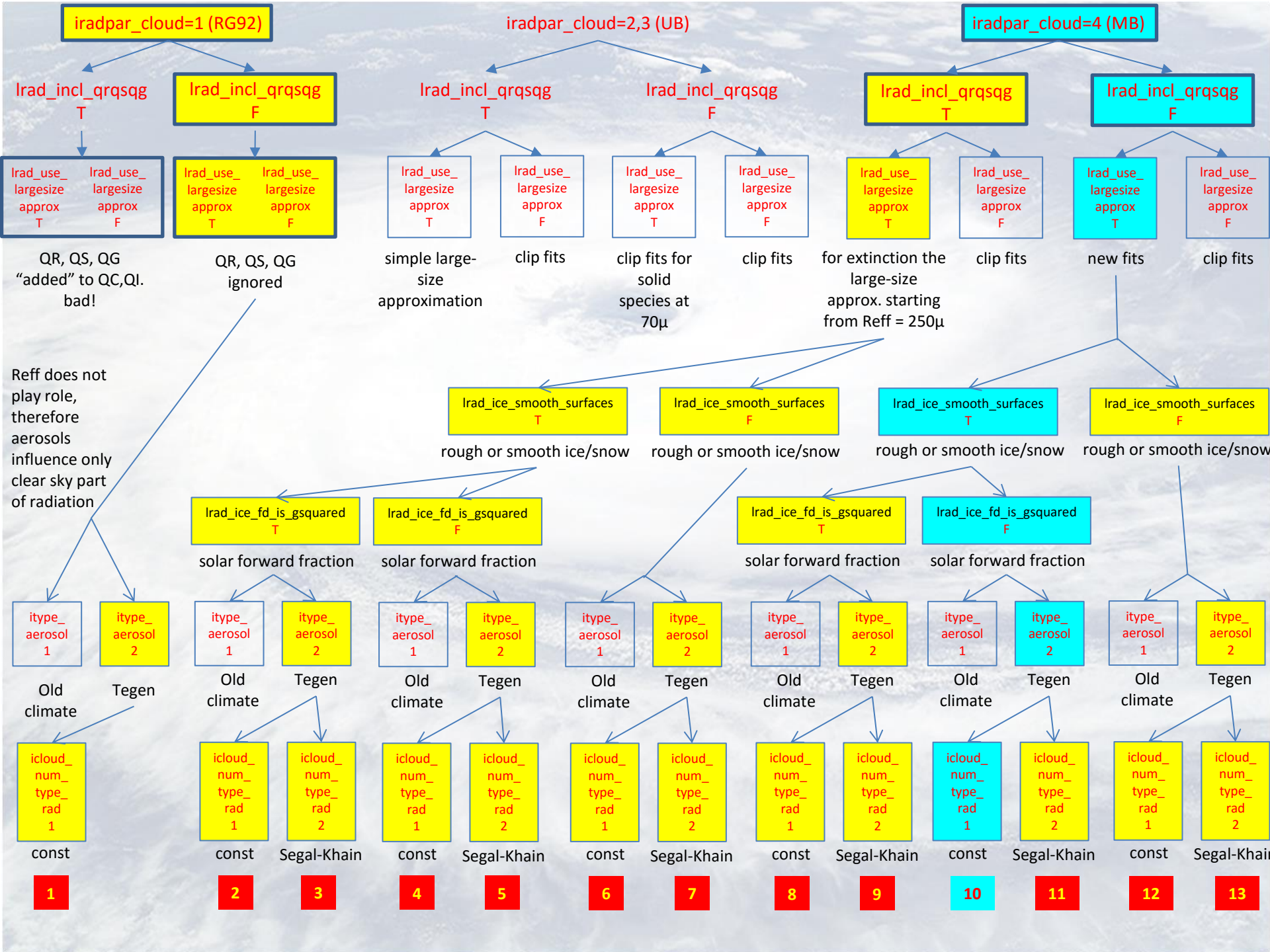
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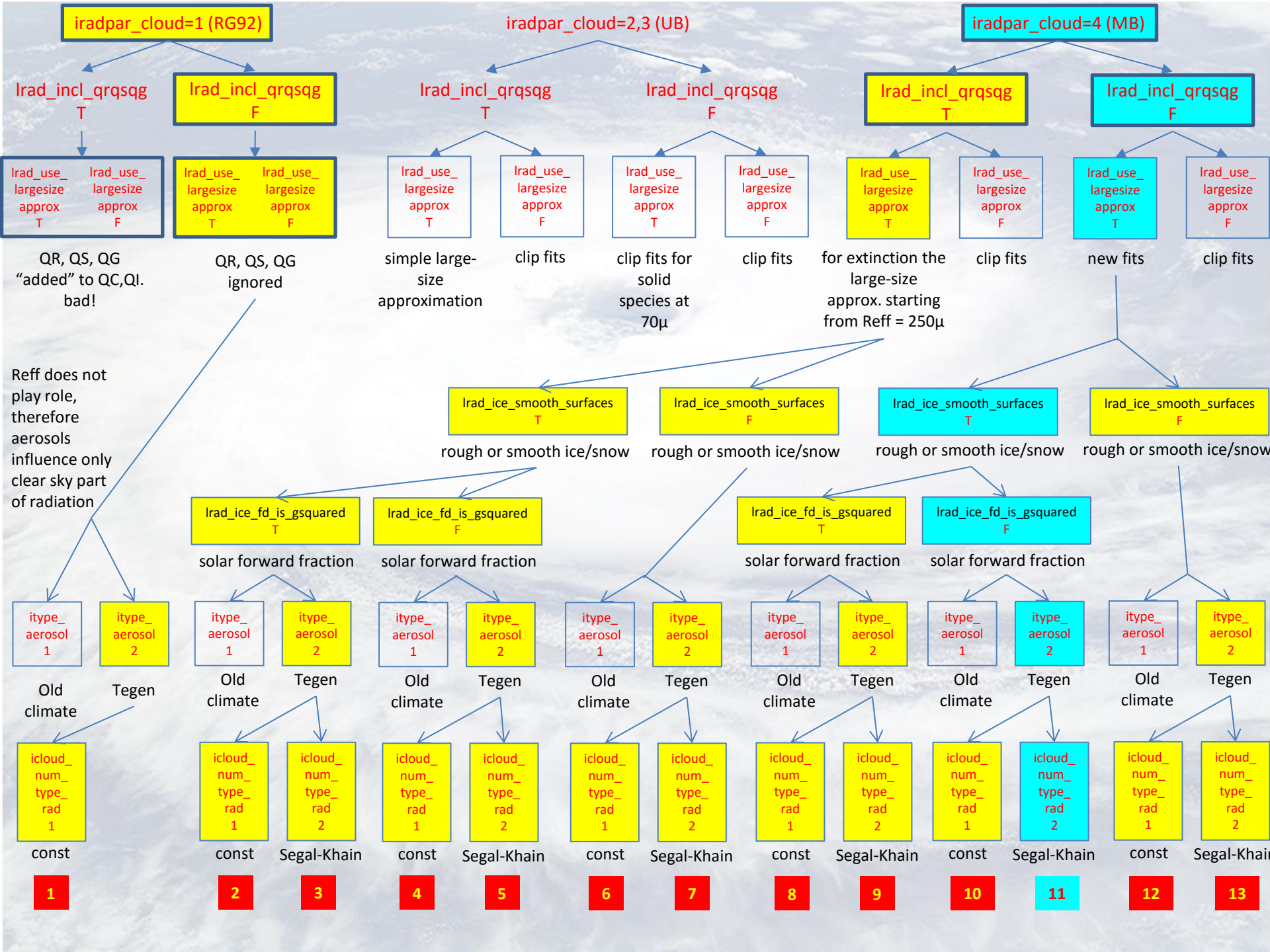
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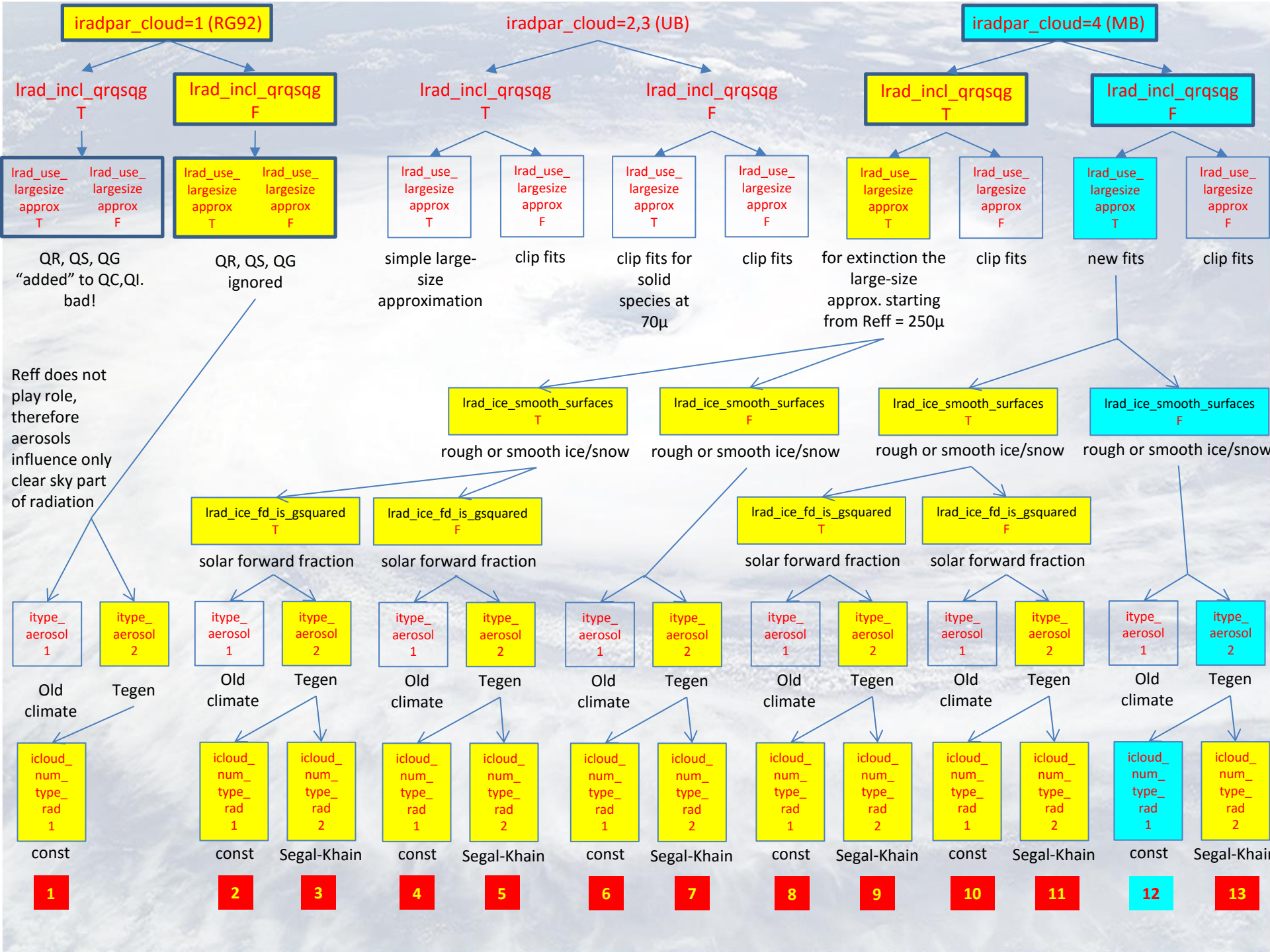
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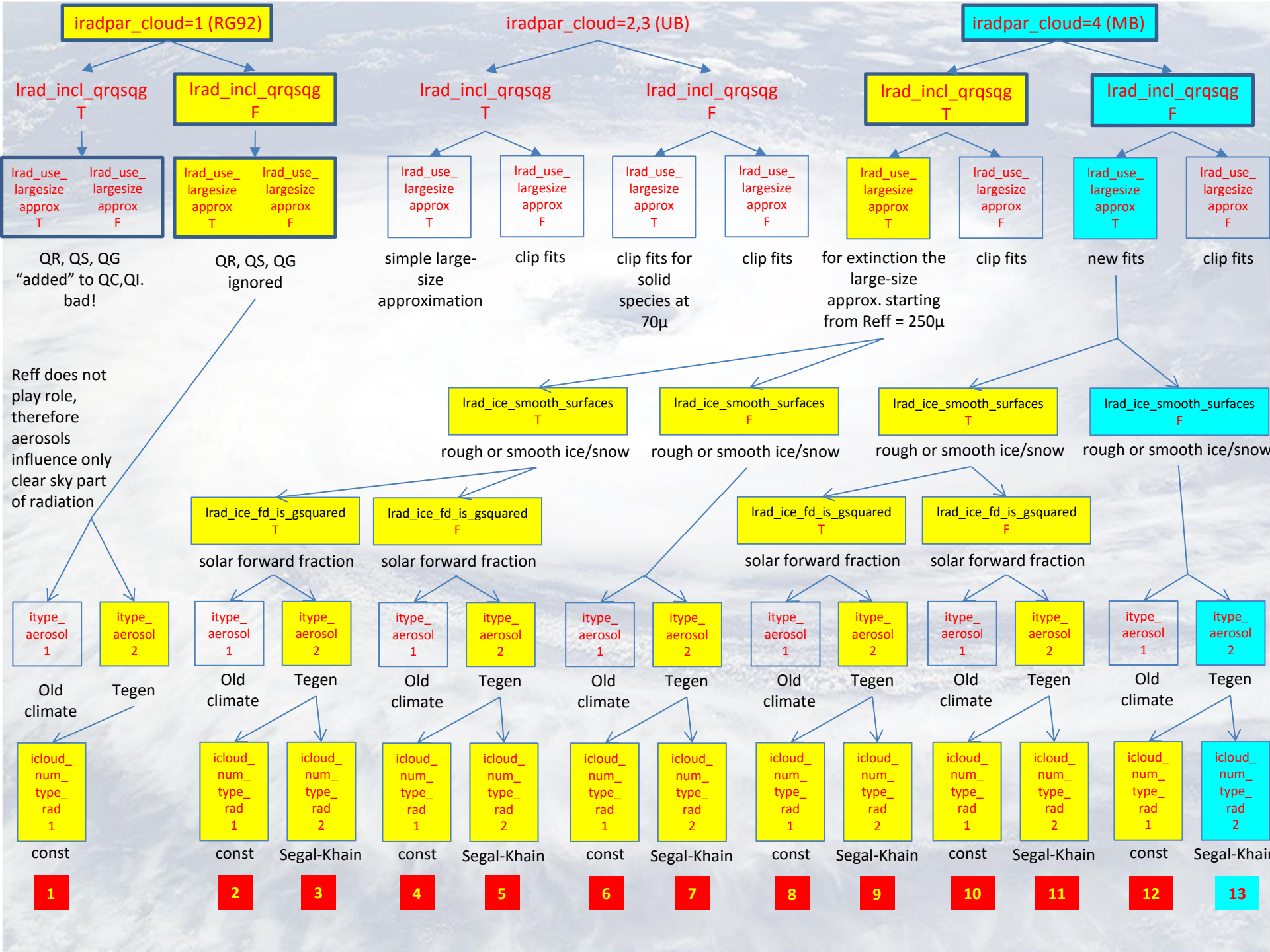
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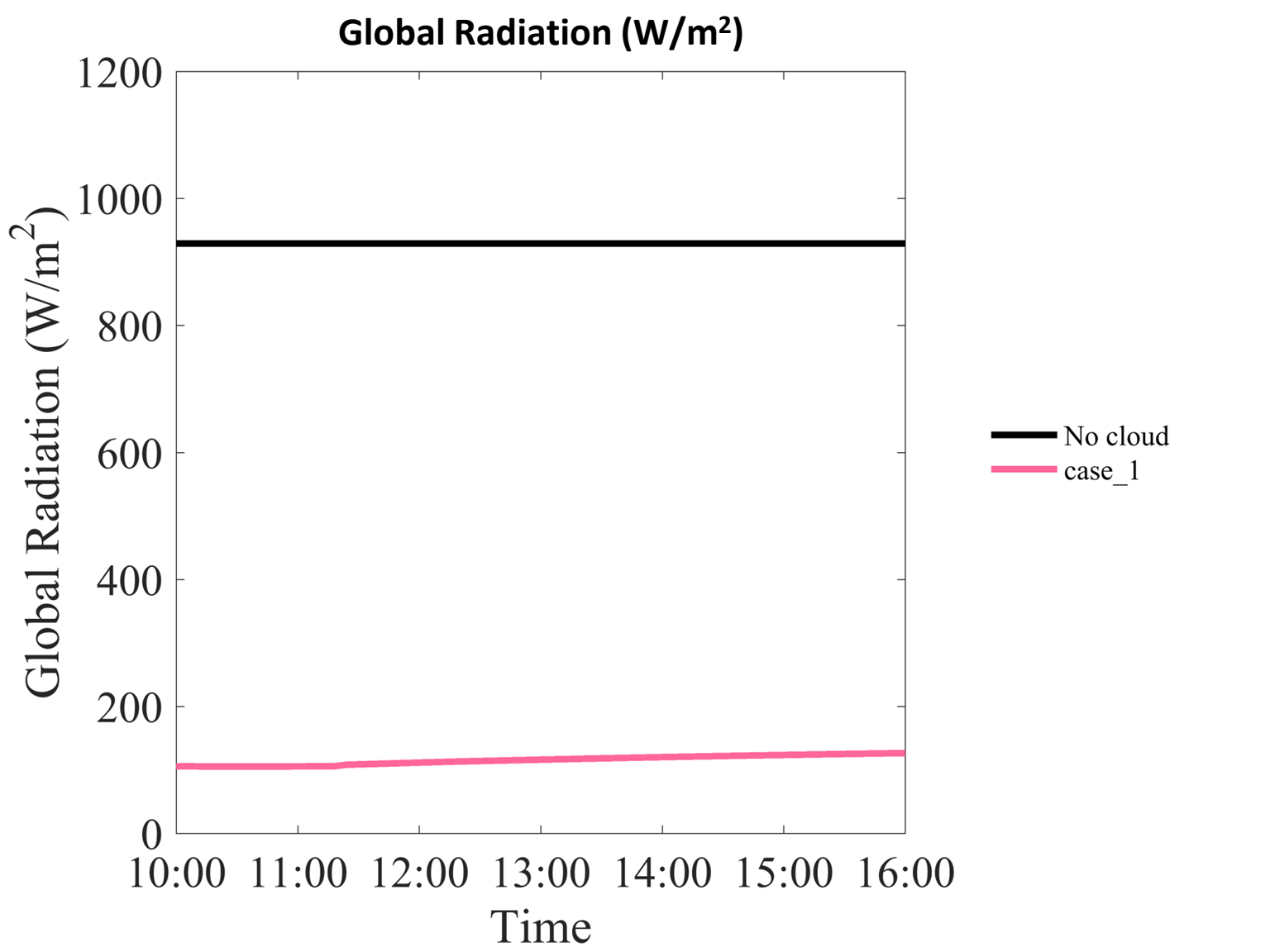
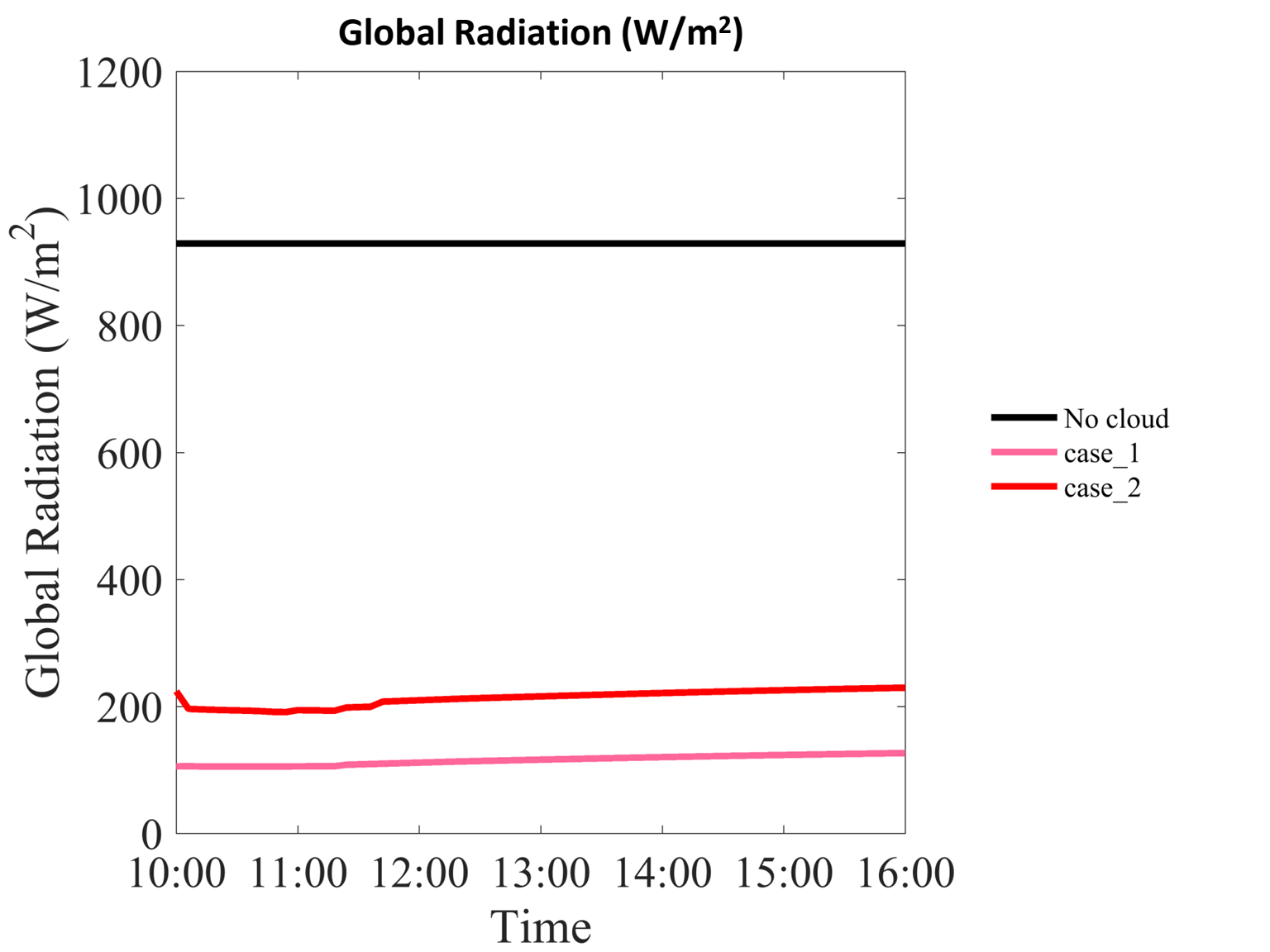
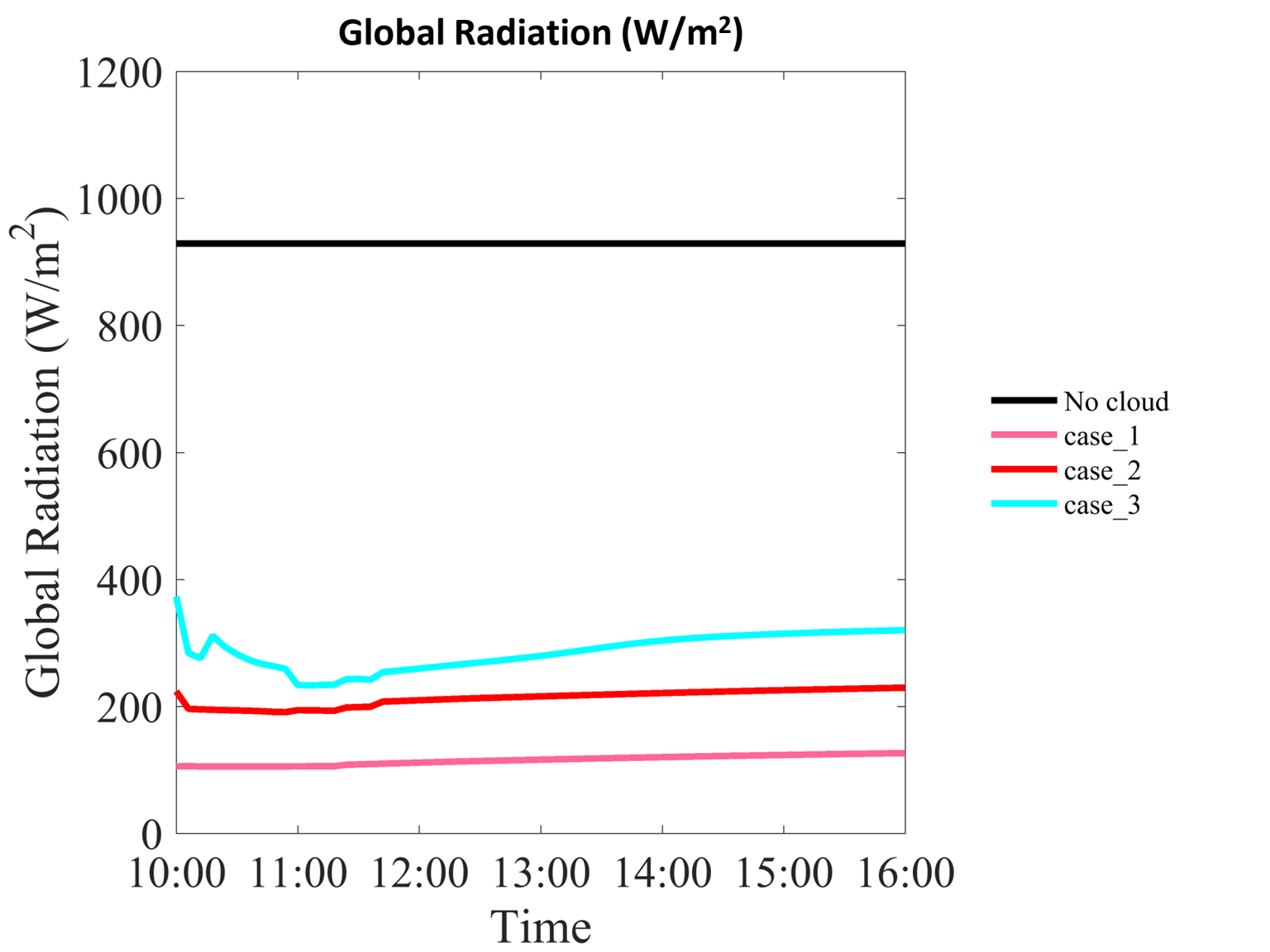
Warm Stratus: True / False switches



Warm Stratus: True / False switches



Warm Stratus: True / False switches



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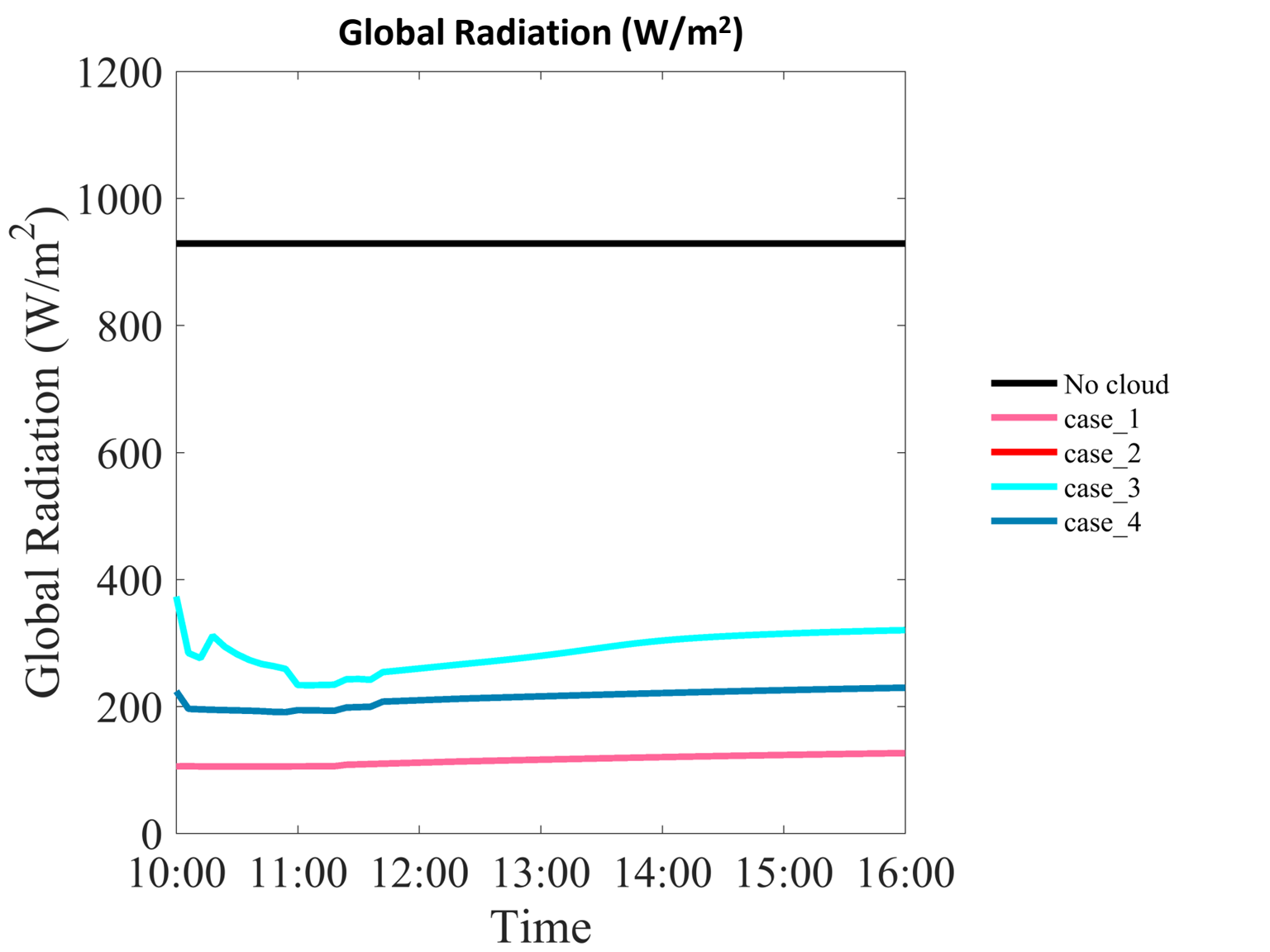

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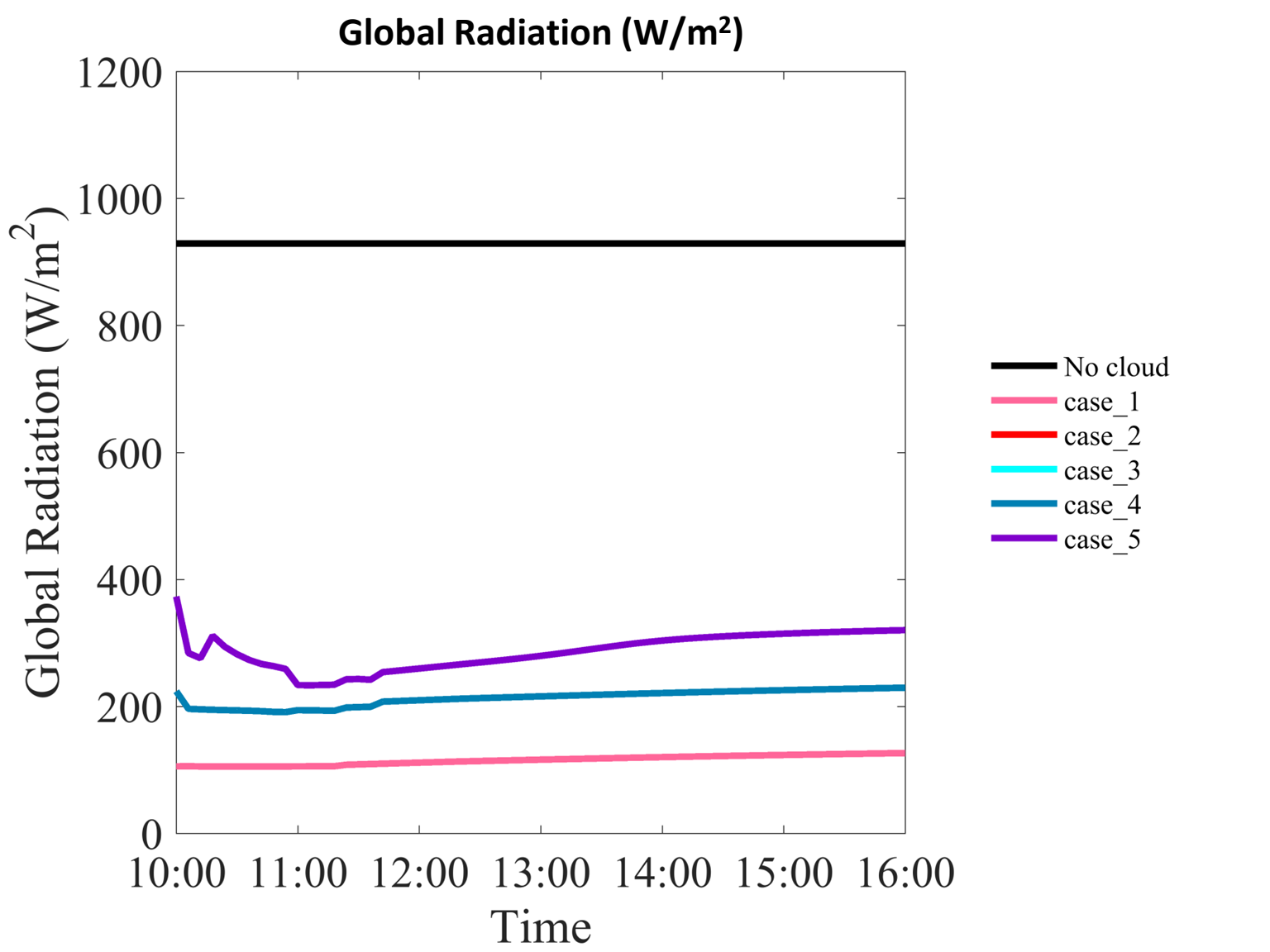

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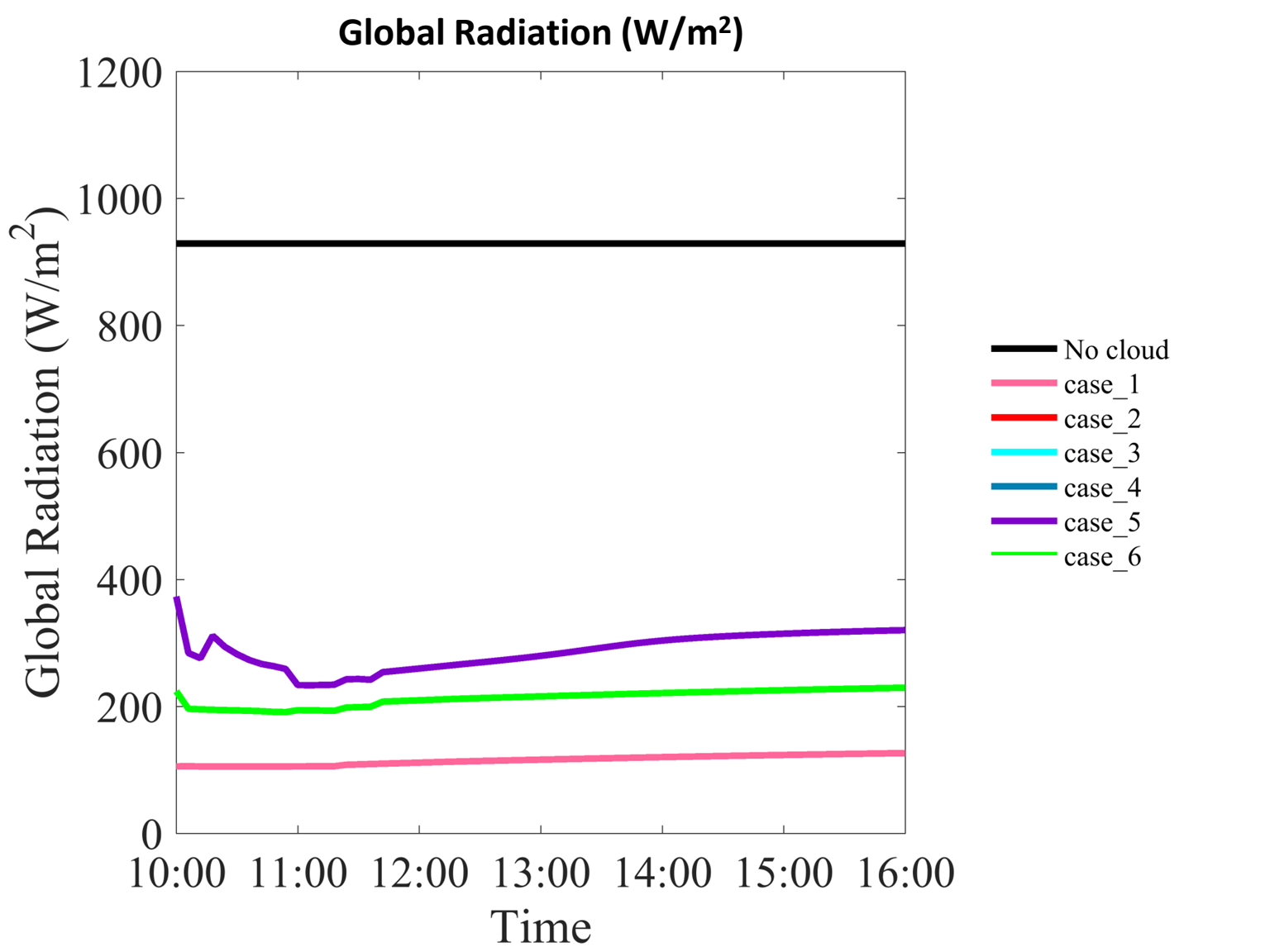

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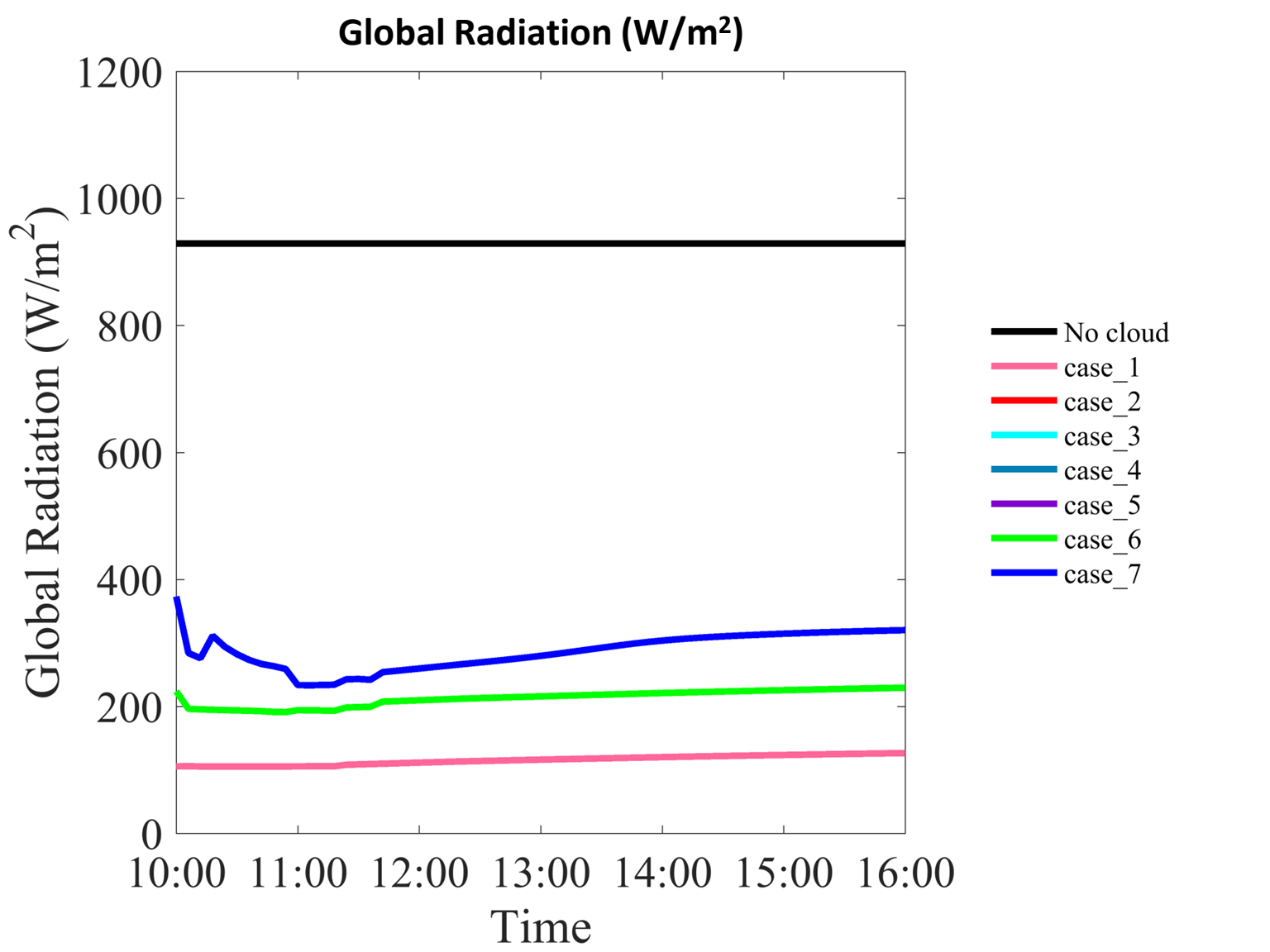

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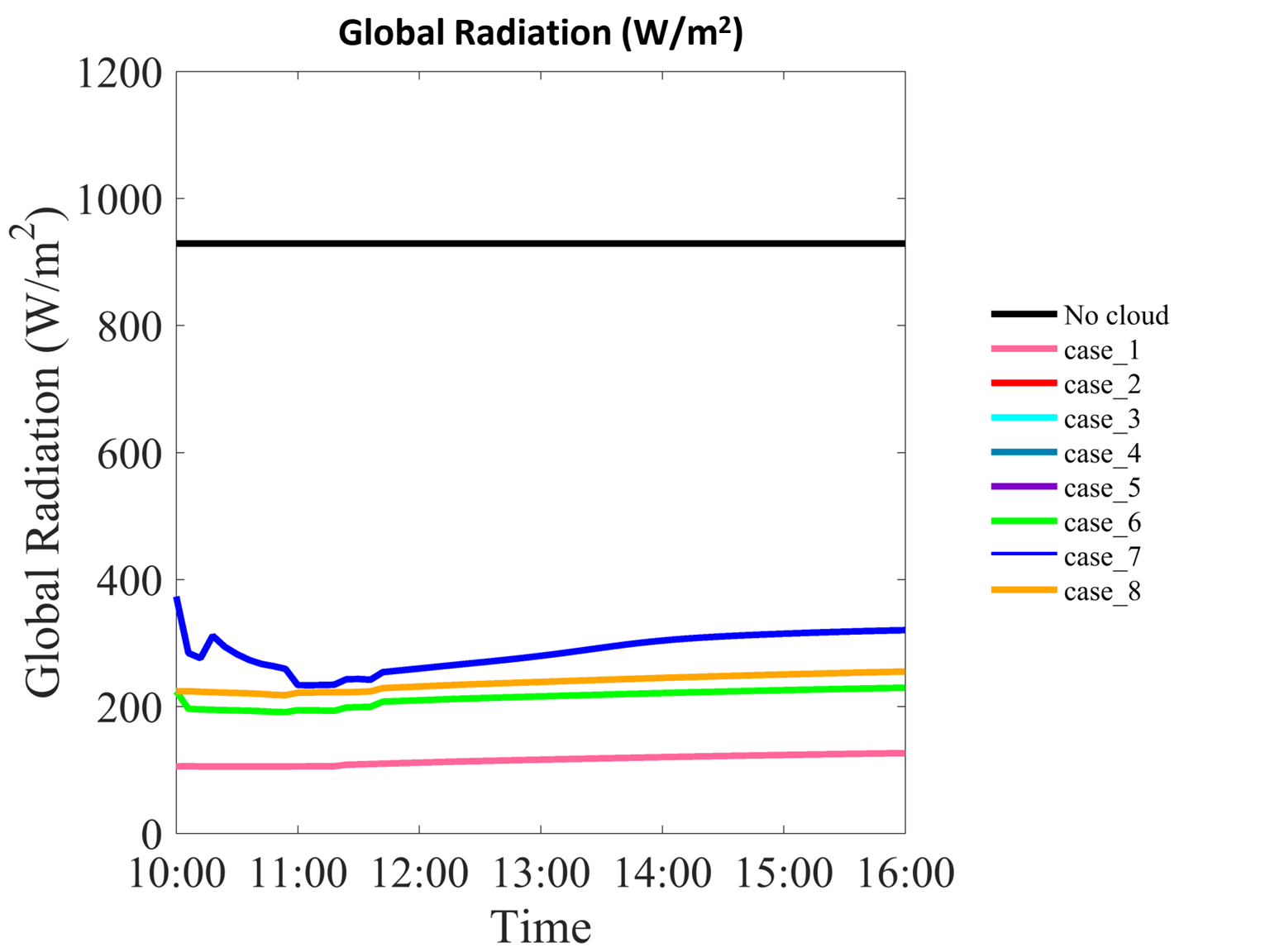

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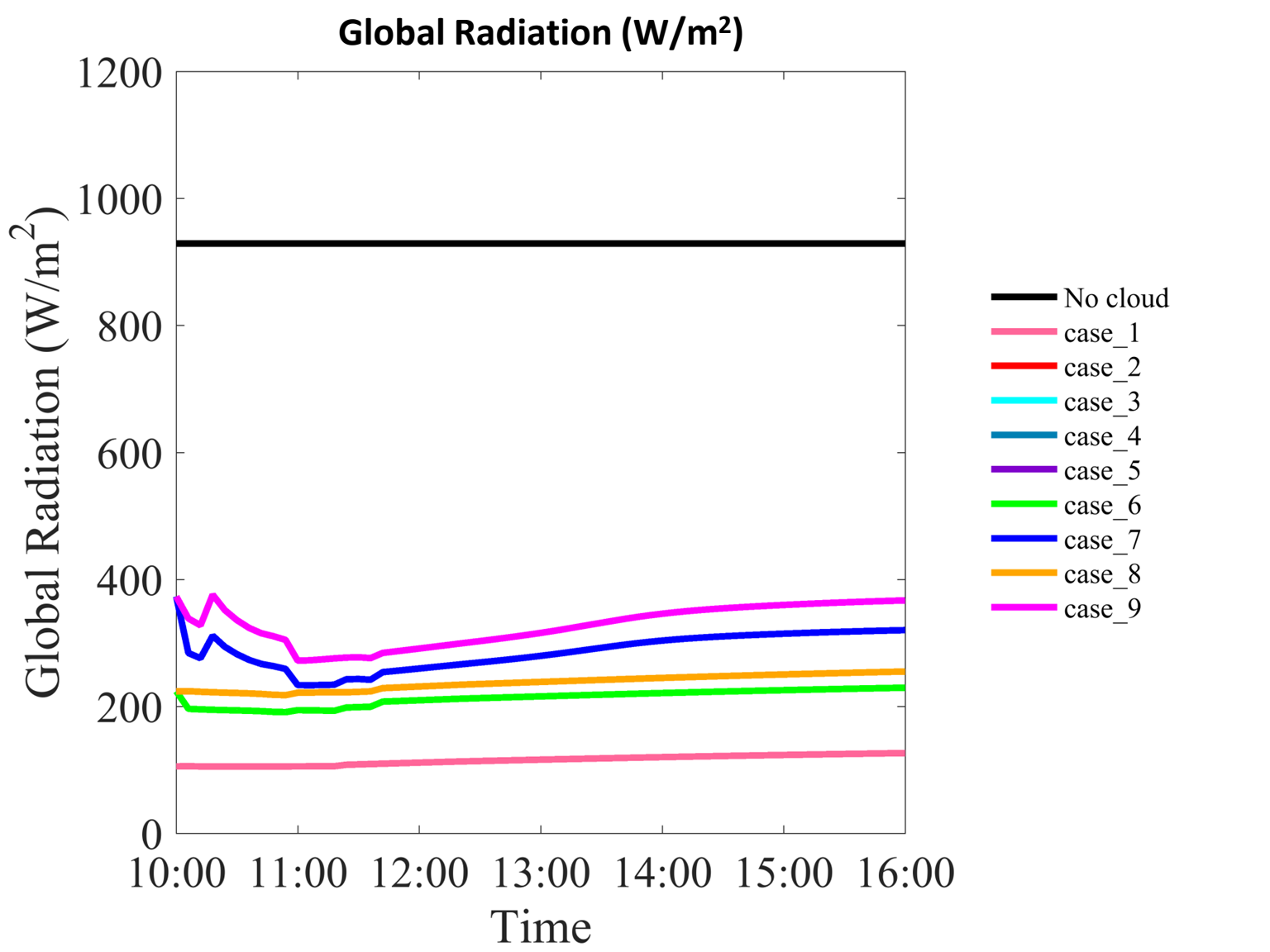

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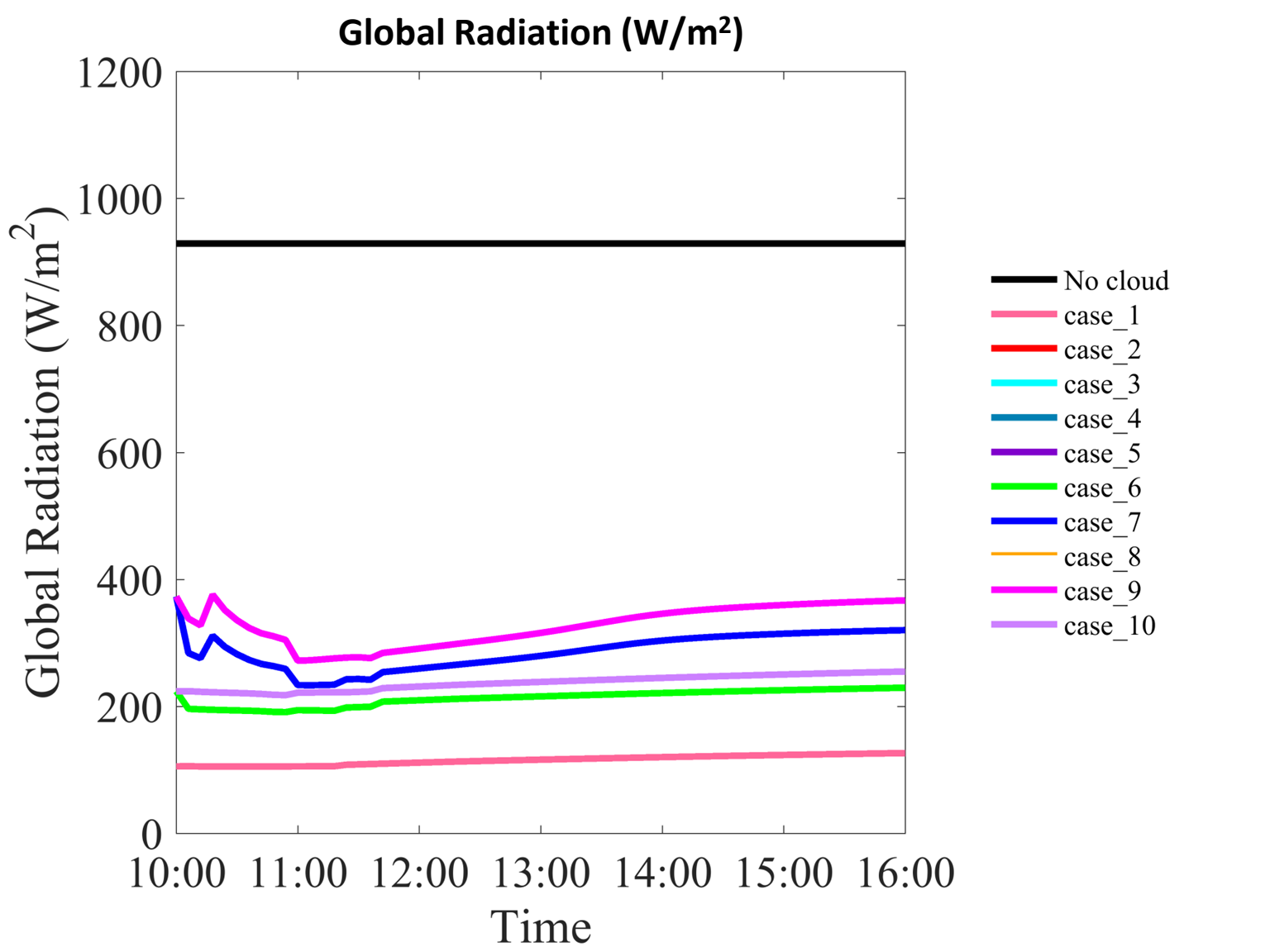

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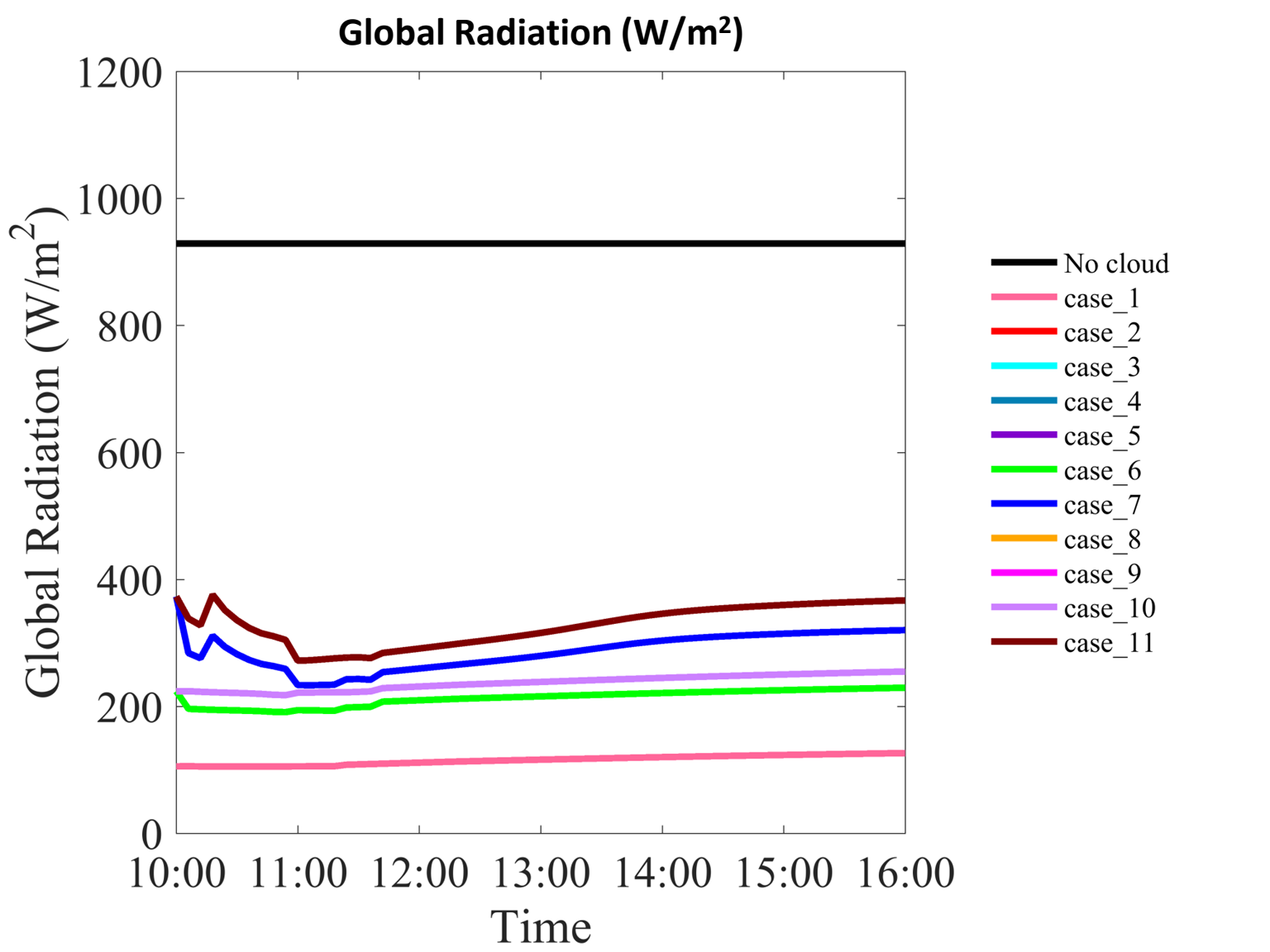

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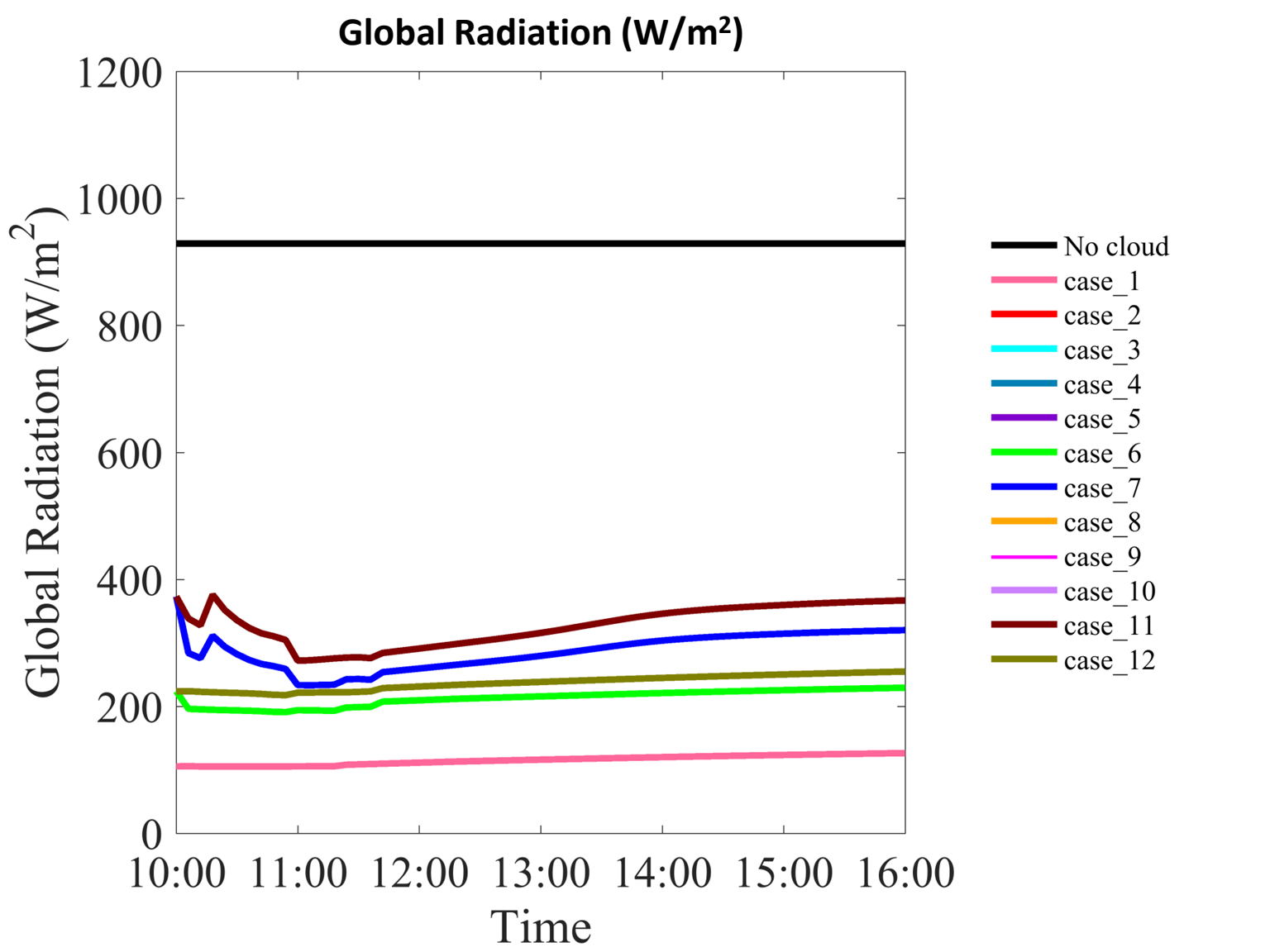

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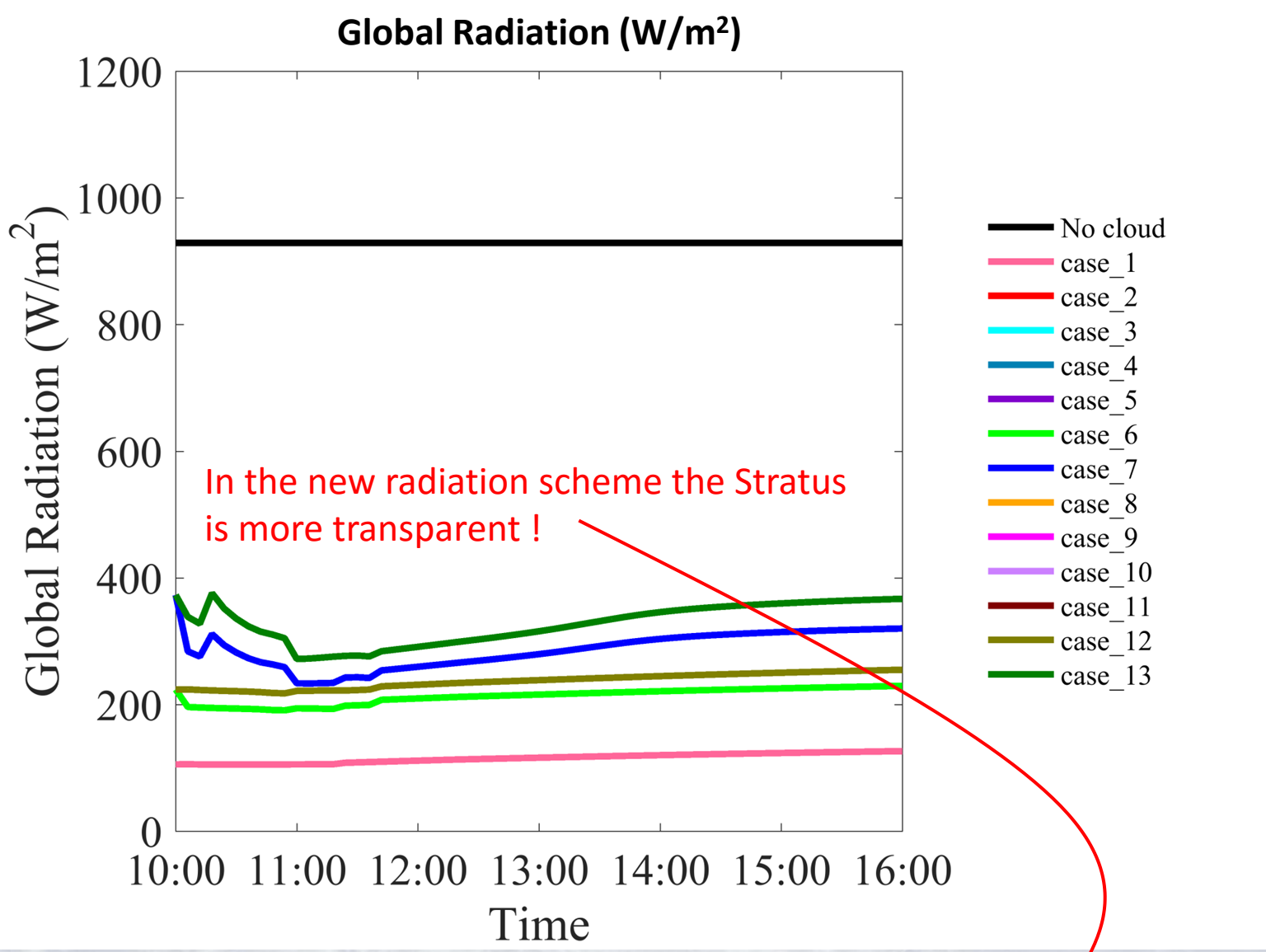
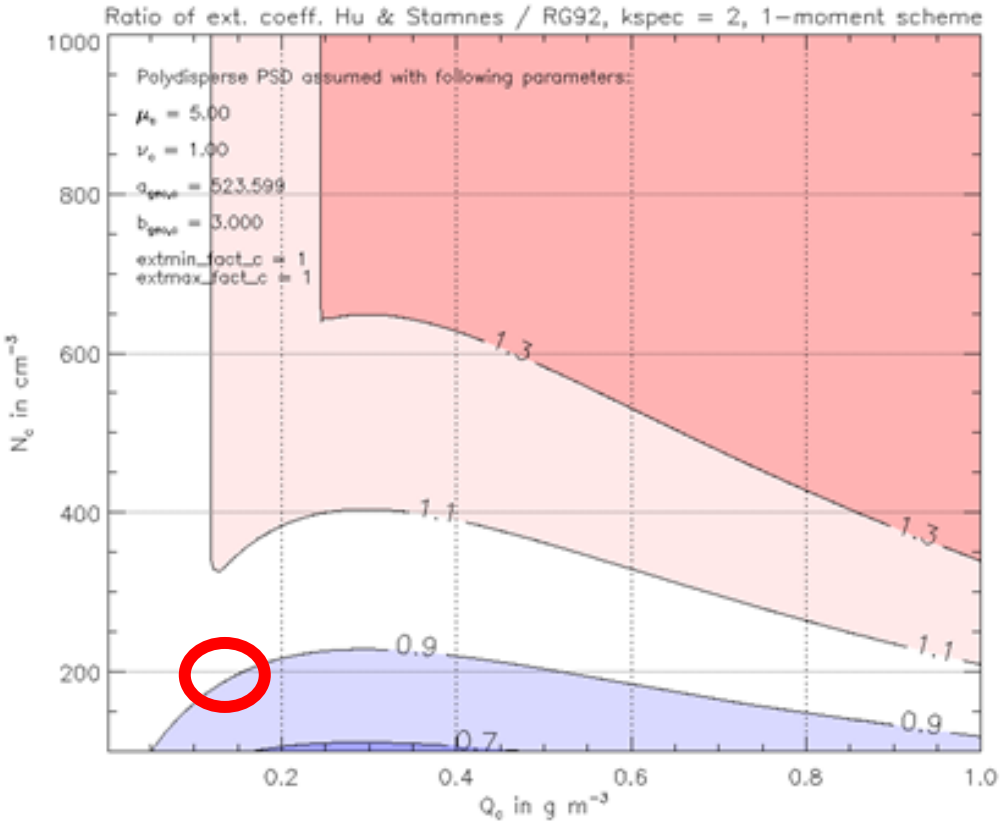


From Uli's Blahak presentation:

Cloud droplets comparison to RG92

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

➔If grid scale qc > 0: from cloud microphysics:



$$f(D) = N_0 D^{\mu} e^{-\lambda D}$$

$\mu = 5.0$

N_c = cloud_num

q_c prognostic

Spectral interval „2“ (visible range)

β_{ext} ratio HS / RG92

Warm Stratus: True / False switches - summary

Time averaged global radiation reduction (%)

case:	1	2	3	4	5	6	7	8	9	10	11	12	13
Warm Stratus	87	77	69	77	69	77	69	74	65	74	65	74	65

Global radiation sensitivity (%)

switch:	iradpar_cloud	lrad_incl_qrqsqg	lrad_ice_smooth_surfaces	lrad_ice_fd_is_gsquared	Icloud_num_type_rad
Warm Stratus	~22%	~4%	0	0	~9%
	Operational ⇕ New scheme	Neglect rain ⇕ Account for rain	Smooth ice ⇕ Rough ice	SW forward scattering formula 1 ⇕ SW forward scattering formula 2	Droplets concentration constant ⇕ Droplets concentration Segal-Khain

Warm Stratus: True / False switches - summary

Time averaged global radiation reduction (%)

case:	1	2	3	4	5	6	7	8	9	10	11	12	13
Warm Stratus	87	77	69	77	69	77	69	74	65	74	65	74	65

Global radiation sensitivity (%)

switch:	iradpar_ cloud	lrad_incl_ qrqsqg	lrad_ice_ smooth_surfaces	lrad_ice_ fd_is_gsquared	lcloud_num_ type_rad
Warm Stratus	~22%	~4%	0	0	~9%

All clouds : True / False switches - summary

Global radiation reduction (%)

case:	1	2	3	4	5	6	7	8	9	10	11	12	13
Warm Stratus	87	77	69	77	69	77	69	74	65	74	65	74	65
Cirrus	6.2	8	8	8	8	8	8	6.4	6.4	6.4	6.4	6.4	6.4
Mixed phase	80	64	60	64	60	64	60	57	52	57	52	57	52
Fair weather Cu	9	5	5	5	5	5	5	5	5	5	5	5	5
Anvil	50	76	76	76	76	76	76	61	61	61	61	61	61

Global radiation sensitivity (%)

switch:	iradpar_cloud	lrad_incl_qrqsqg	lrad_ice_smooth_surfaces	lrad_ice_fd_is_gsquared	Icloud_num_type_rad
Warm Stratus	~22%	~4%	0	0	~9%
Cirrus	~1.8%	~1.6%	0	0	0
Mixed phase	~28%	~8%	0	0	~5%
Fair weather Cu	~4%	0	0	0	0
Anvil	~26%	~15%	0	0	0

Outline

1. Idealized COSMO model, examples of 5 types of clouds
2. True / False switches
3. Continuous parameters
    a. Method: How to define sensitivity to model parameters ?
    b. Sensitivity results: which parameters are most important ?
4. List of most important parameters
5. Summary

Outline

1. Idealized COSMO model, examples of 5 types of clouds
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3. Continuous parameters
    a. Method: How to define sensitivity to model parameters ?
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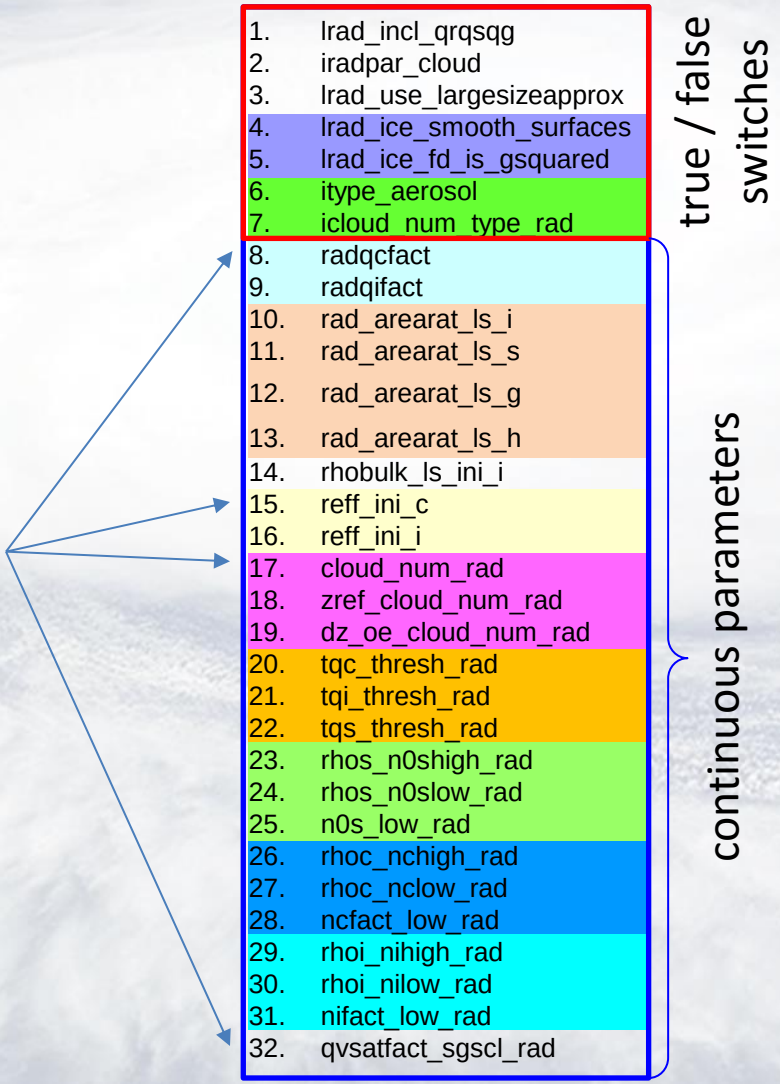
4. List of most important parameters
5. Summary

3. Continuous parameters (within the switches)



Can be important for Warm Stratus

Outline

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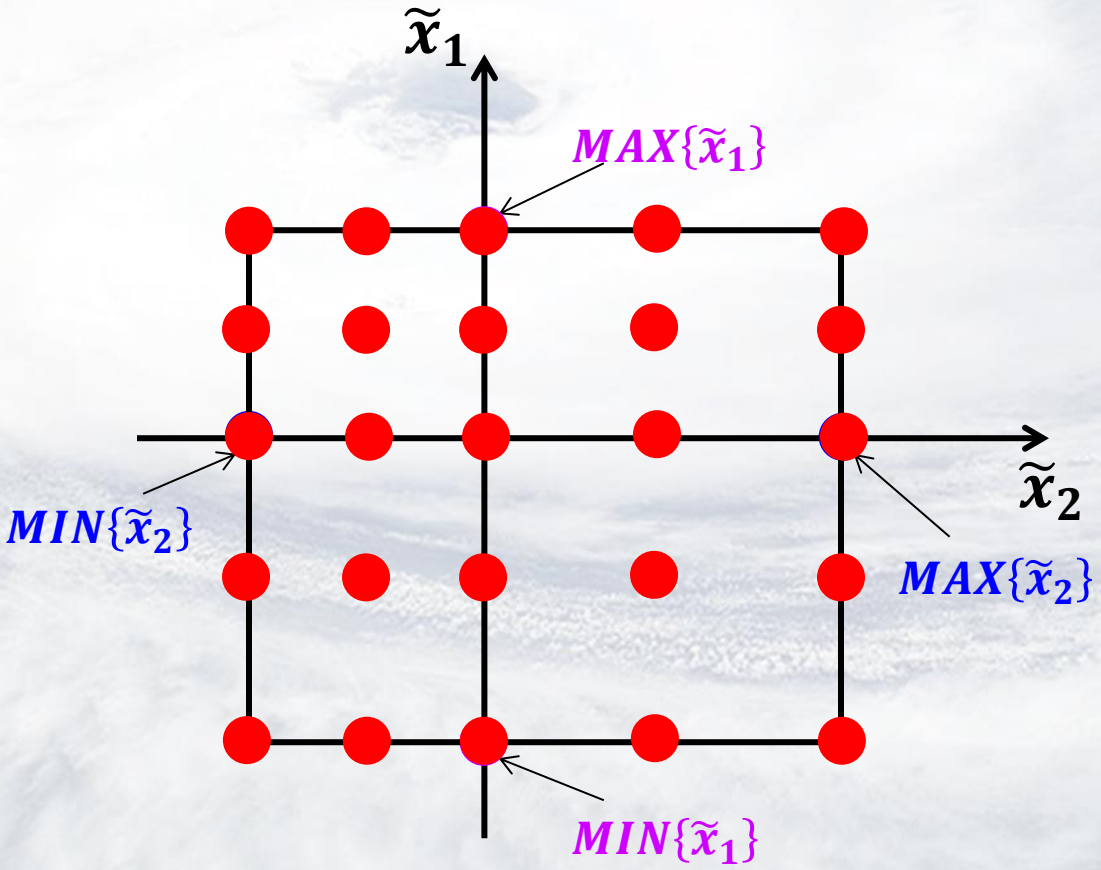
3a. Method: How to define sensitivity to model parameters ?

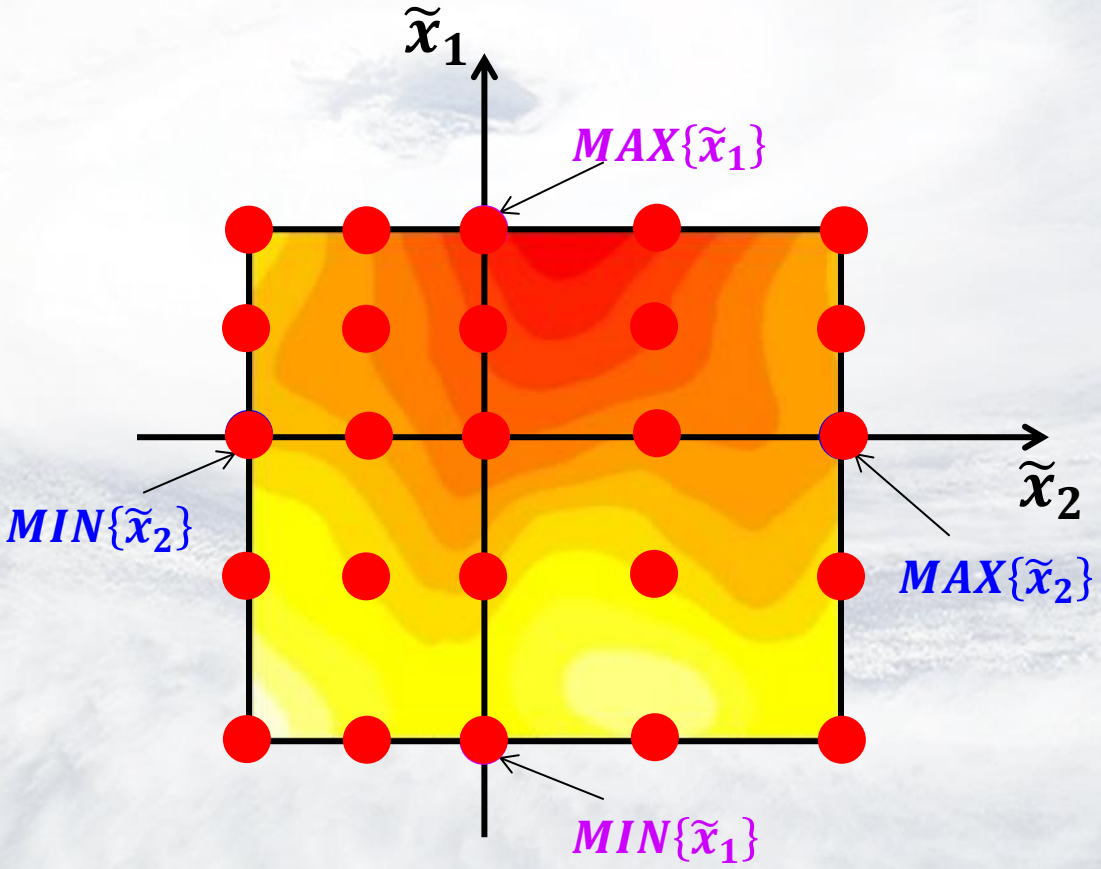
Example for 2 parameters :

STEP 1: Perform several idealized simulations to "fill the parameters space"
STEP 2: read the global radiation reduction at each point



3a. Method: How to define sensitivity to model parameters ?

STEP 3: Perform fit of the global radiation reduction in parameters space



3a. Method: How to define sensitivity to model parameters ?

For N=4 parameters, the approximation formula is:

(thanks to Harel Muskatel and Uli Blahak)

$$\tilde{R}(\tilde{x}_1,\tilde{x}_2,\tilde{x}_3,\tilde{x}_4) \cong \sum_{p=1}^{4} \frac{a_{p,1} + a_{p,2}\tilde{x}_p + a_{p,3}\tilde{x}_p{}^2}{a_{p,4} + a_{p,5}\tilde{x}_p + a_{p,6}\tilde{x}_p{}^2} + \frac{1}{2}\sum_{p=1}^{4}\sum_{i\neq p} b_{p,i}\tilde{x}_p\tilde{x}_i$$

Reduction of global radiation (%)

$$100 \text{ X } \frac{R_{no\ cloud} - R(\tilde{x}_1,\tilde{x}_2,\tilde{x}_3,\tilde{x}_4)}{R_{no\ cloud}}$$

normalized parameter

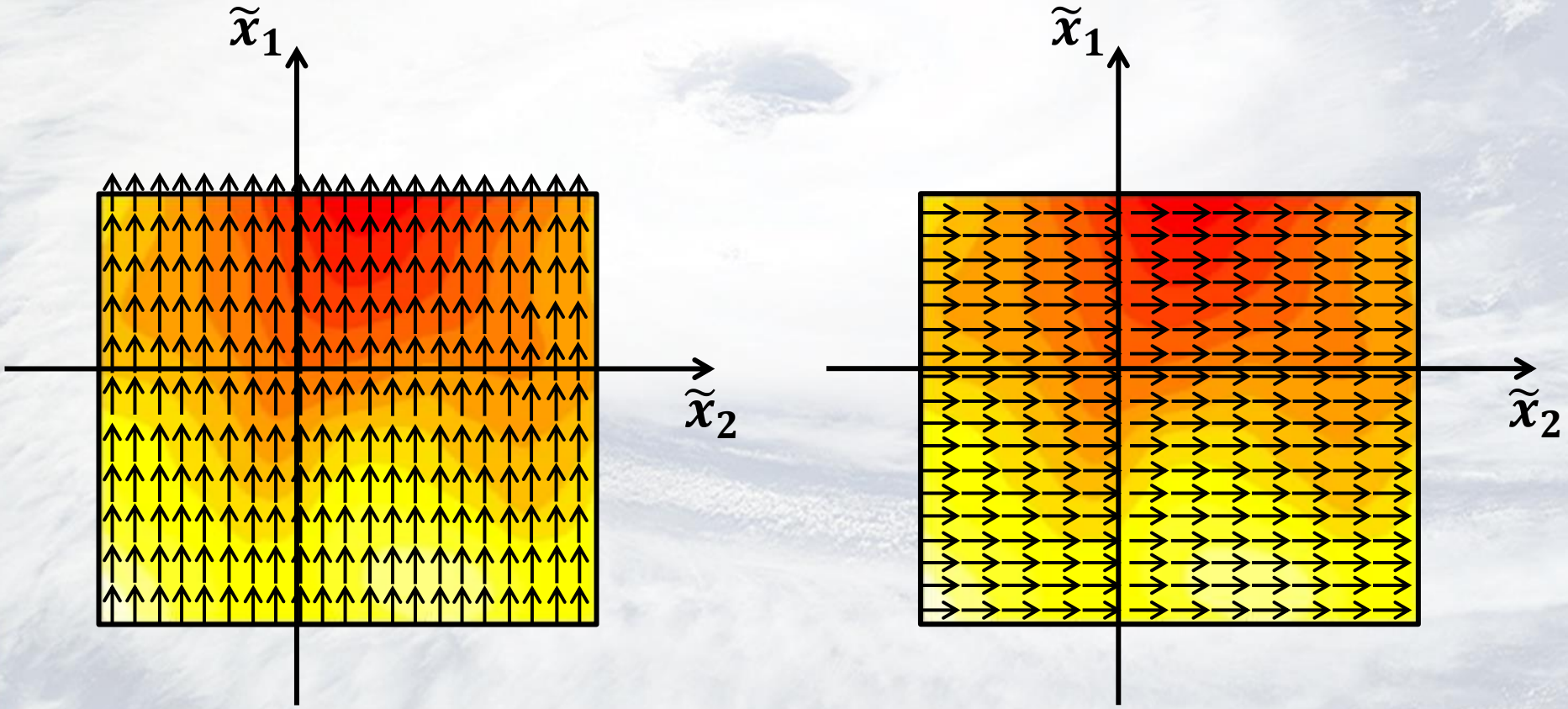
$$\frac{x_p - x_{p,def}}{MAX\{x_p\} - MIN\{x_p\}}$$

$x_1 \equiv radqcfact$
$x_2 \equiv qvsatfact\_sgscl\_rad$
$x_3 \equiv cloud\_num\_rad$
$x_4 \equiv reff\_ini\_c$

$$\frac{\partial \tilde{R}}{\partial \tilde{x}_p} = \text{Sensitivity to parameter } \tilde{x}_p$$

3a. Method: How to define sensitivity to model parameters ?

STEP 4: Calculate derivatives of the fit for global radiation reduction in different "parameters directions"



3a. Method: How to define sensitivity to model parameters ?

Now we have formulas for $\tilde{R}$ and $\frac{\partial \tilde{R}}{\partial \tilde{x}_p}$ for any point in parameters space

- Calculate $\frac{\partial \tilde{R}}{\partial \tilde{x}_1}, \frac{\partial \tilde{R}}{\partial \tilde{x}_2}, \frac{\partial \tilde{R}}{\partial \tilde{x}_3}, \frac{\partial \tilde{R}}{\partial \tilde{x}_4}$ for MANY points in parameters space
- Average over all points
- The most important parameters are those who have the highest $\overline{\left|\frac{\partial \tilde{R}}{\partial \tilde{x}_p}\right|}$

Outline

1. Idealized COSMO model, examples of 5 types of clouds
2. True / False switches
3. Continuous parameters
    a. Method: How to define sensitivity to model parameters ?
    b. Sensitivity results: which parameters are most important ?
4. List of most important parameters
5. Summary

Outline

1. Idealized COSMO model, examples of 5 types of clouds
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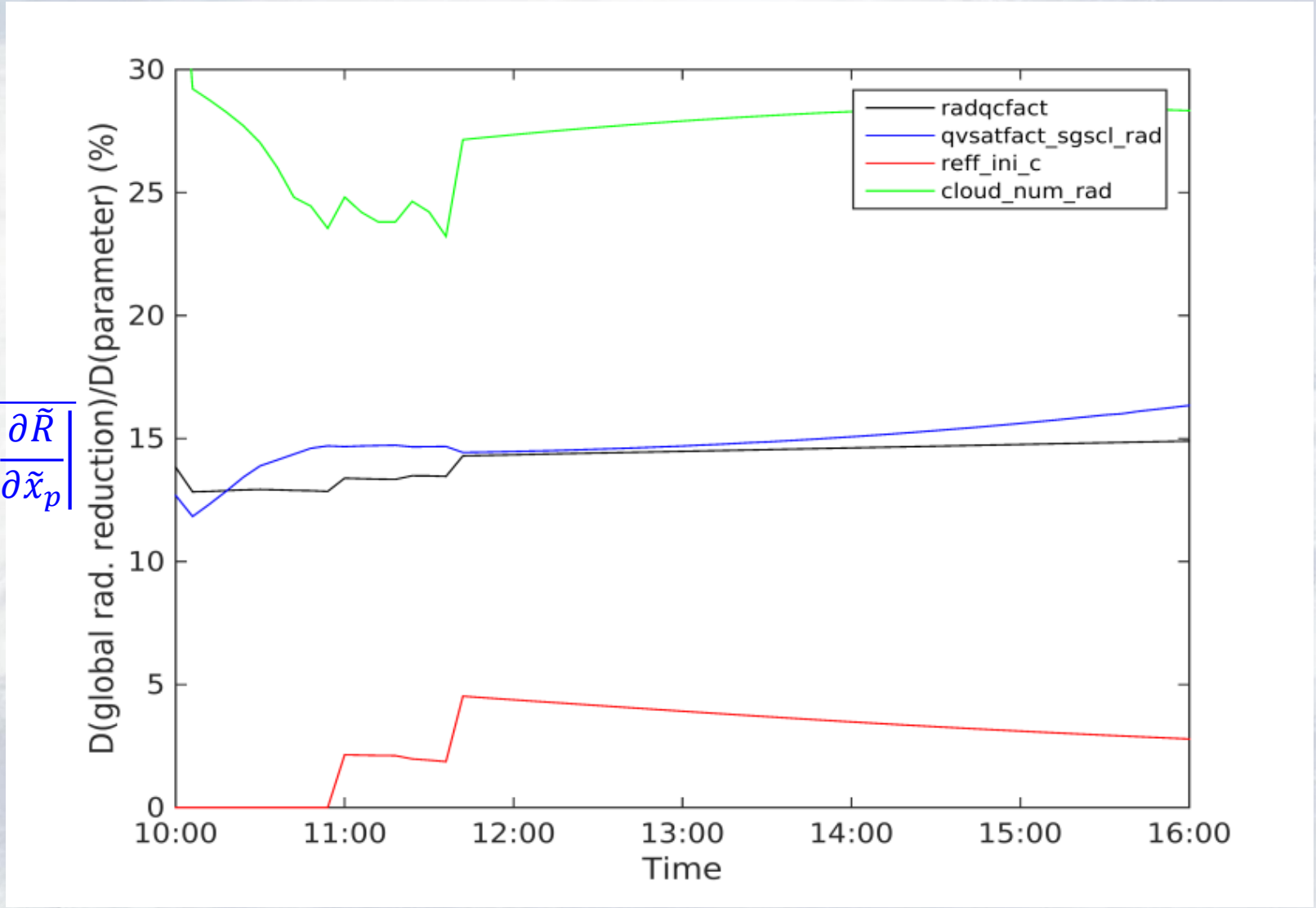
3b. Sensitivity results: which parameters are most important ?

Example: Case 4, warm Stratus

$$\left|\frac{\partial \tilde{R}}{\partial \tilde{x}_p}\right|$$



3b. Sensitivity results: which parameters are most important ?

Time averaged **D(global rad. reduction)/D(parameter) (%)** $\overline{\left|\frac{\partial \tilde{R}}{\partial \tilde{x}_p}\right|}$

case:	1	2	3	4	5	6	7	8	9	10	11	12	13
radqcfact				14									
qvsatfact_ sgscl_rad				15									
reff_ini_c				2.8									
cloud_num_rad				28									

3b. Sensitivity results: which parameters are most important ?

Time averaged D(global rad. reduction)/D(parameter) (%) $\overline{\left|\frac{\partial \tilde{R}}{\partial \tilde{x}_p}\right|}$

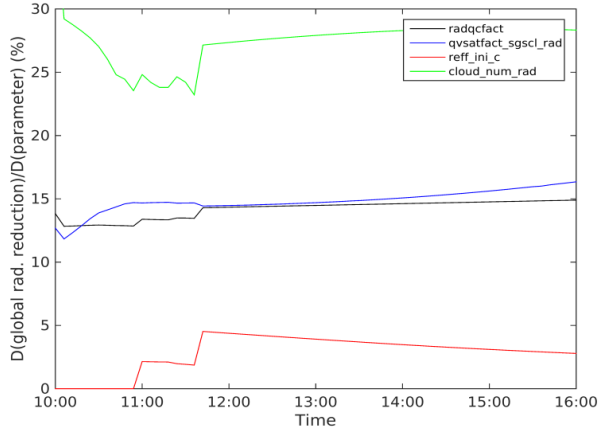
case:	1	2	3	4	5	6	7	8	9	10	11	12	13
radqcfact	8	14	17	14	17	14	17	15	18	15	18	15	18
qvsatfact_ sgscl_rad	9	15	19	15	19	15	19	16	20	16	20	16	20
reff_ini_c	0	2.8	4	2.8	4	2.8	4	3.4	5	3.4	5	3.4	5
cloud_num_rad	0	28	0	28	0	28	0	34	0	34	0	34	0

parameter:	radqcfact	qvsatfact_sgscl_rad	reff_ini_c	cloud_num_rad
Sensitivity (%)	**8-18%**	**9-20%**	**0-5%**	**0-34%**
	Subgrid-scale variability Link to explanation	Subgrid Cloud Water Content factor Link to explanation	Subgrid effective radius Link to explanation	Constant number concentration of cloud droplets (can see through *rain but not through fog…*)

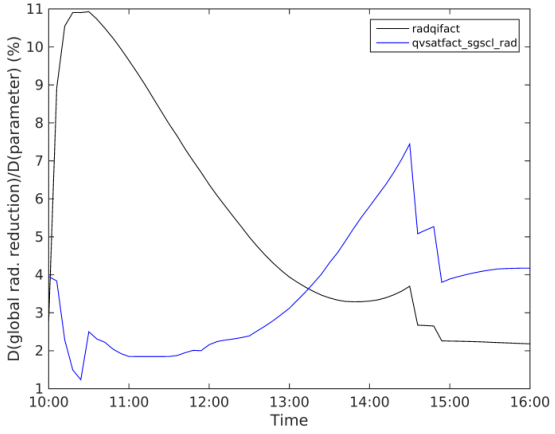
All clouds : continuous parameters - summary

Example: Case 4

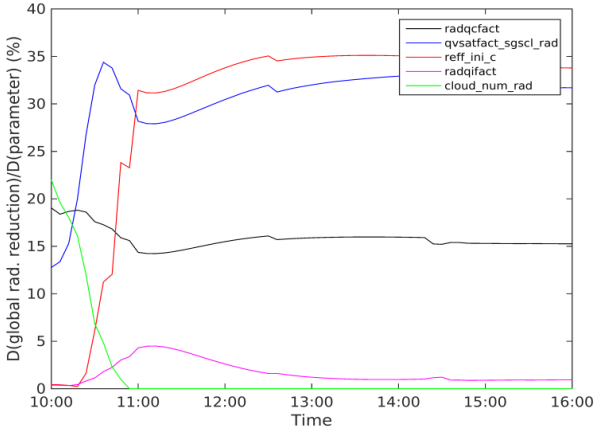
$\left|\frac{\partial \tilde{R}}{\partial \tilde{x}_p}\right|$ Warm Stratus



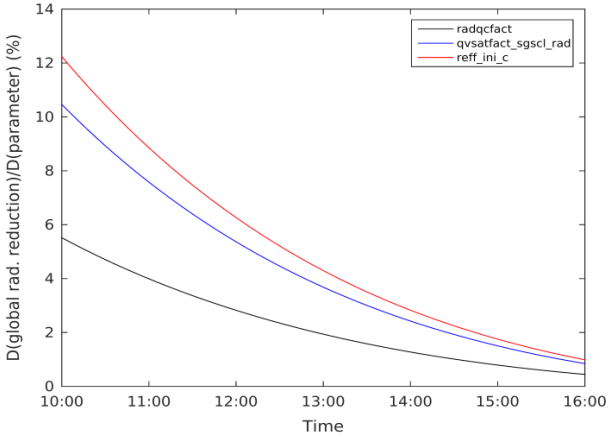
$\left|\frac{\partial \tilde{R}}{\partial \tilde{x}_p}\right|$ Cirrus



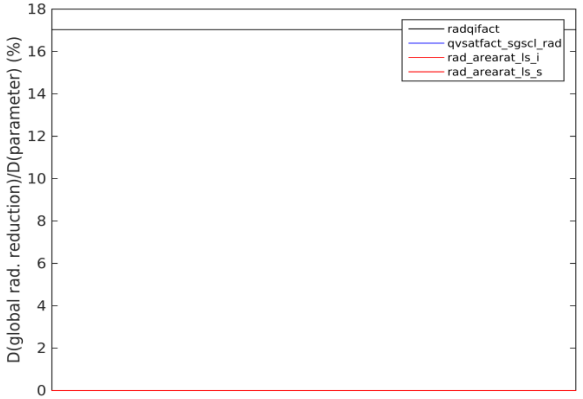
$\left|\frac{\partial \tilde{R}}{\partial \tilde{x}_p}\right|$ Mixed phase



$\left|\frac{\partial \tilde{R}}{\partial \tilde{x}_p}\right|$ Fair weather Cu



$\left|\frac{\partial \tilde{R}}{\partial \tilde{x}_p}\right|$ Anvil



All clouds : continuous parameters - summary

Time averaged D(global rad. reduction)/D(parameter) (%) $\overline{\left|\frac{\partial \tilde{R}}{\partial \tilde{x}_p}\right|}$

Warm Stratus:

case:	1	2	3	4	5	6	7	8	9	10	11	12	13
radqcfact				14									
qvsatfact_sgscl_rad				15									
reff_ini_c				2.8									
cloud_num_rad				28									

Cirrus:

case:	1	2	3	4	5	6	7	8	9	10	11	12	13
radqifact				5.2									
qvsatfact_sgscl_rad				3.5									

Mixed phase:

case:	1	2	3	4	5	6	7	8	9	10	11	12	13
radqcfact				16									
qvsatfact_sgscl_rad				30									
reff_ini_c				29									
reff_ini_i				1.6									
cloud_num_rad				2.2									

Fair weather Cu:

case:	1	2	3	4	5	6	7	8	9	10	11	12	13
radqcfact				2.3									
qvsatfact_sgscl_rad				4.4									
reff_ini_c				5.1									

Anvil:

case:	1	2	3	4	5	6	7	8	9	10	11	12	13
radqifact				17									
qvsatfact_sgscl_rad				0									
rad_arearat_ls_i				0									
rad_arearat_ls_s				0									

All clouds : continuous parameters - summary

Time averaged D(global rad. reduction)/D(parameter) (%) $\overline{\left|\frac{\partial \tilde{R}}{\partial \tilde{x}_p}\right|}$

Warm Stratus:

case:	1	2	3	4	5	6	7	8	9	10	11	12	13
radqcfact	8	14	17	14	17	14	17	15	18	15	18	15	18
qvsatfact_sgscl_rad	9	15	19	15	19	15	19	16	20	16	20	16	20
reff_ini_c	0	2.8	4	2.8	4	2.8	4	3.4	5	3.4	5	3.4	5
cloud_num_rad	0	28	0	28	0	28	0	34	0	34	0	34	0

Cirrus:

case:	1	2	3	4	5	6	7	8	9	10	11	12	13
radqifact	2.3	5.2	5.2	5.2	5.2	5.2	5.2	4.7	4.7	4.7	4.7	4.7	4.7
qvsatfact_sgscl_rad	1.9	3.5	3.5	3.5	3.5	3.5	3.5	3.2	3.2	3.2	3.2	3.2	3.2

Mixed phase:

case:	1	2	3	4	5	6	7	8	9	10	11	12	13
radqcfact	15	16	16	16	16	16	16	15	15	15	15	15	15
qvsatfact_sgscl_rad	31	30	30	30	30	30	30	29	29	29	29	29	29
reff_ini_c	0	29	29	29	29	29	29	28	28	28	28	28	28
reff_ini_i	0.4	1.6	1.6	1.6	1.6	1.6	1.6	0.7	0.7	0.7	0.7	0.7	0.7
cloud_num_rad	0	2.2	0	2.2	0	2.2	0	2.3	0	2.3	0	2.3	0

Fair weather Cu:

case:	1	2	3	4	5	6	7	8	9	10	11	12	13
radqcfact	3.8	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
qvsatfact_sgscl_rad	7.8	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
reff_ini_c	0	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1

Anvil:

case:	1	2	3	4	5	6	7	8	9	10	11	12	13
radqifact	13	17	17	17	17	17	17	19	19	19	19	19	19
qvsatfact_sgscl_rad	0.02	0	0	0	0	0	0	0.07	0.07	0.07	0.07	0.07	0.07
rad_arearat_ls_i	0	0	0	0	0	0	0	0	0	0	0	0	0
rad_arearat_ls_s	0	0	0	0	0	0	0	0	0	0	0	0	0

All clouds : continuous parameters - summary

Global radiation sensitivity (%)

parameter:	radqifact	radqcfact	qvsatfact_sgscl_rad	reff_ini_i	reff_ini_c	cloud_num_rad	rad_arearat_ls_i	rad_arearat_ls_s
Warm Stratus	not relev.	**8-18%**	**9-20%**	not relev.	**0-5%**	**0-34%**	not relev.	not relev.
Cirrus	**2.3-5.2%**	not relev.	**1.9-3.5%**	low sens.	not relev.	not relev.	low sens.	low sens.
Mixed phase	low sens.	**15-16%**	**29-31%**	**0.4-1.6%**	**0-29%**	**0-2.3%**	low sens.	low sens.
Fair weather Cu	not relev.	**2.3-3.8%**	**4.4-7.8%**	not relev.	**0-5.1%**	not relev.	not relev.	not relev.
Anvil	**13-19%**	not relev.	**0.02-0.07%**	low sens.	not relev.	not relev.	**0**	**0**

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4. List of most important parameters

Radiation reduction through clouds in the model is mainly governed by:

(2)	Operational / new scheme
(1)	Account (or not) for large particles (rain, snow, graupel)
(7,17)	Defining the number concentration of cloud droplets
(15,32)	Subgrid water clouds properties
(8,9)	Subgrid scale variability

1.	lrad_incl_qrqsqg	true / false switches
2.	iradpar_cloud	
3.	lrad_use_largesizeapprox	
4.	lrad_ice_smooth_surfaces	
5.	lrad_ice_fd_is_gsquared	
6.	itype_aerosol	
7.	icloud_num_type_rad	
8.	radqcfact	continuous parameters
9.	radqifact	
10.	rad_arearat_ls_i	
11.	rad_arearat_ls_s	
12.	rad_arearat_ls_g	
13.	rad_arearat_ls_h	
14.	rhobulk_ls_ini_i	
15.	reff_ini_c	
16.	reff_ini_i	
17.	cloud_num_rad	
18.	zref_cloud_num_rad	
19.	dz_oe_cloud_num_rad	
20.	tqc_thresh_rad	
21.	tqi_thresh_rad	
22.	tqs_thresh_rad	
23.	rhos_n0shigh_rad	
24.	rhos_n0slow_rad	
25.	n0s_low_rad	
26.	rhoc_nchigh_rad	
27.	rhoc_nclow_rad	
28.	ncfact_low_rad	
29.	rhoi_nihigh_rad	
30.	rhoi_nilow_rad	
31.	nifact_low_rad	
32.	qvsatfact_sgscl_rad	

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Problem: New radiation scheme – 32 new parameters. Which of them are most important?

Proposed method: How to define sensitivity to model parameters:

- Perform MANY idealized COSMO simulations
- Perform fit in parameters space
- Calculate derivatives (of the fit) with respect to parameters values. The highest – wins!

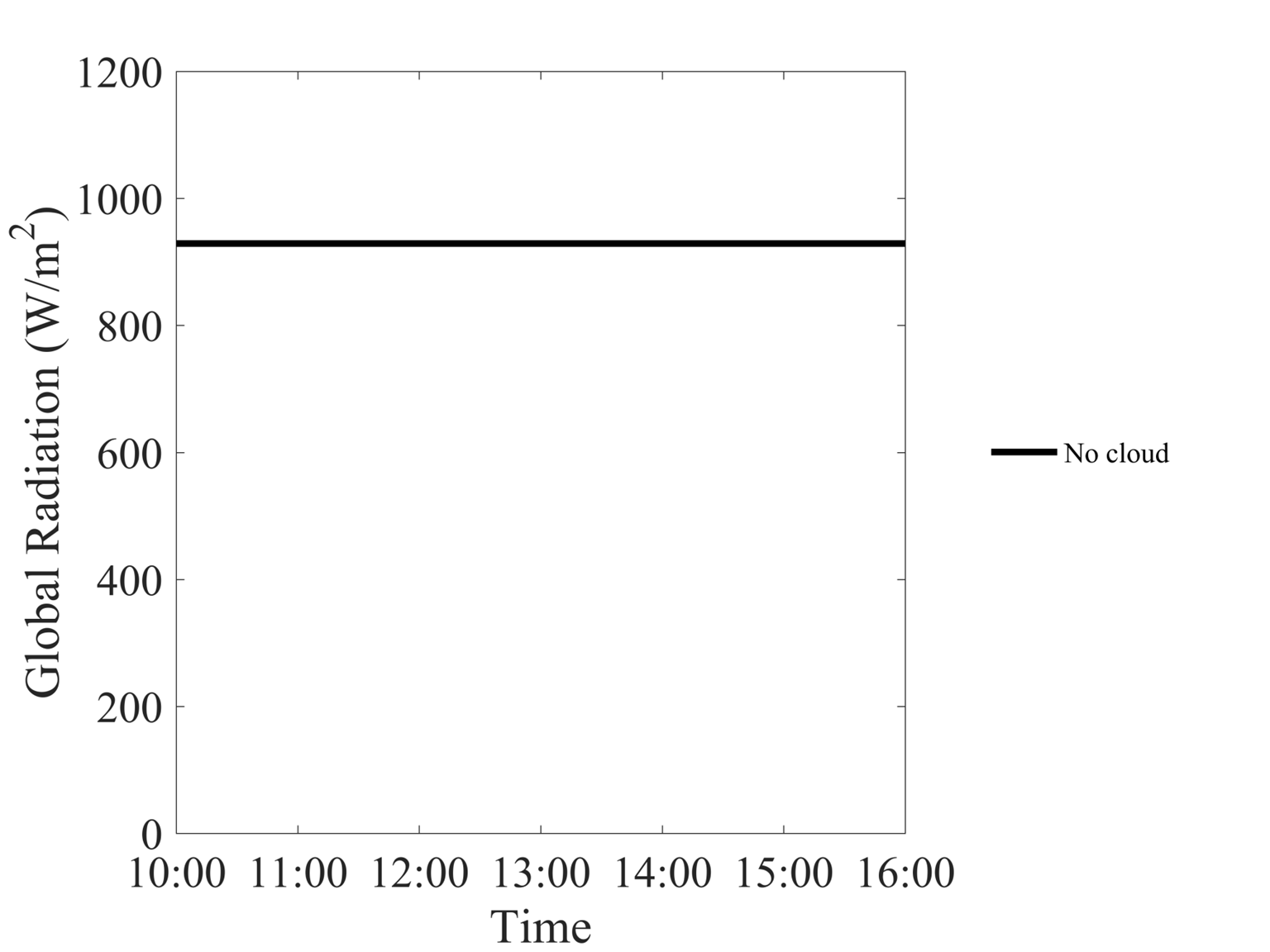
Sensitivity results:

- Most important: iradpar_cloud; lrad_incl_qrqsqg; icloud_num_type_rad; cloud_num_rad; qvsatfact_sgscl_rad; reff_ini_c; radqcfact; radqifact

Thank you !

Additional slides …

True / False switches on Cirrus:


1200
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Global Radiation (W/m2)
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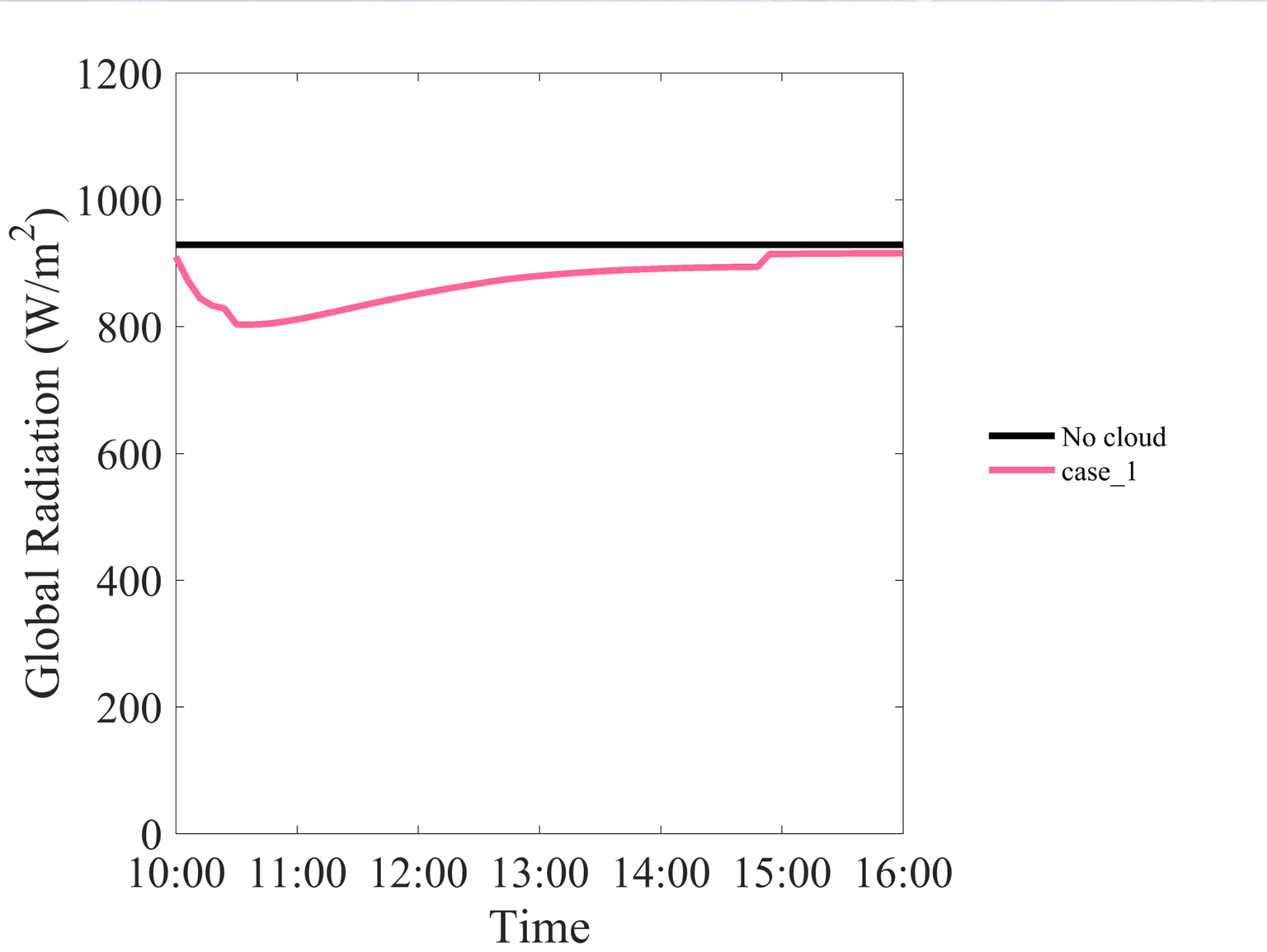
14:00
15:00
16:00
Time
No cloud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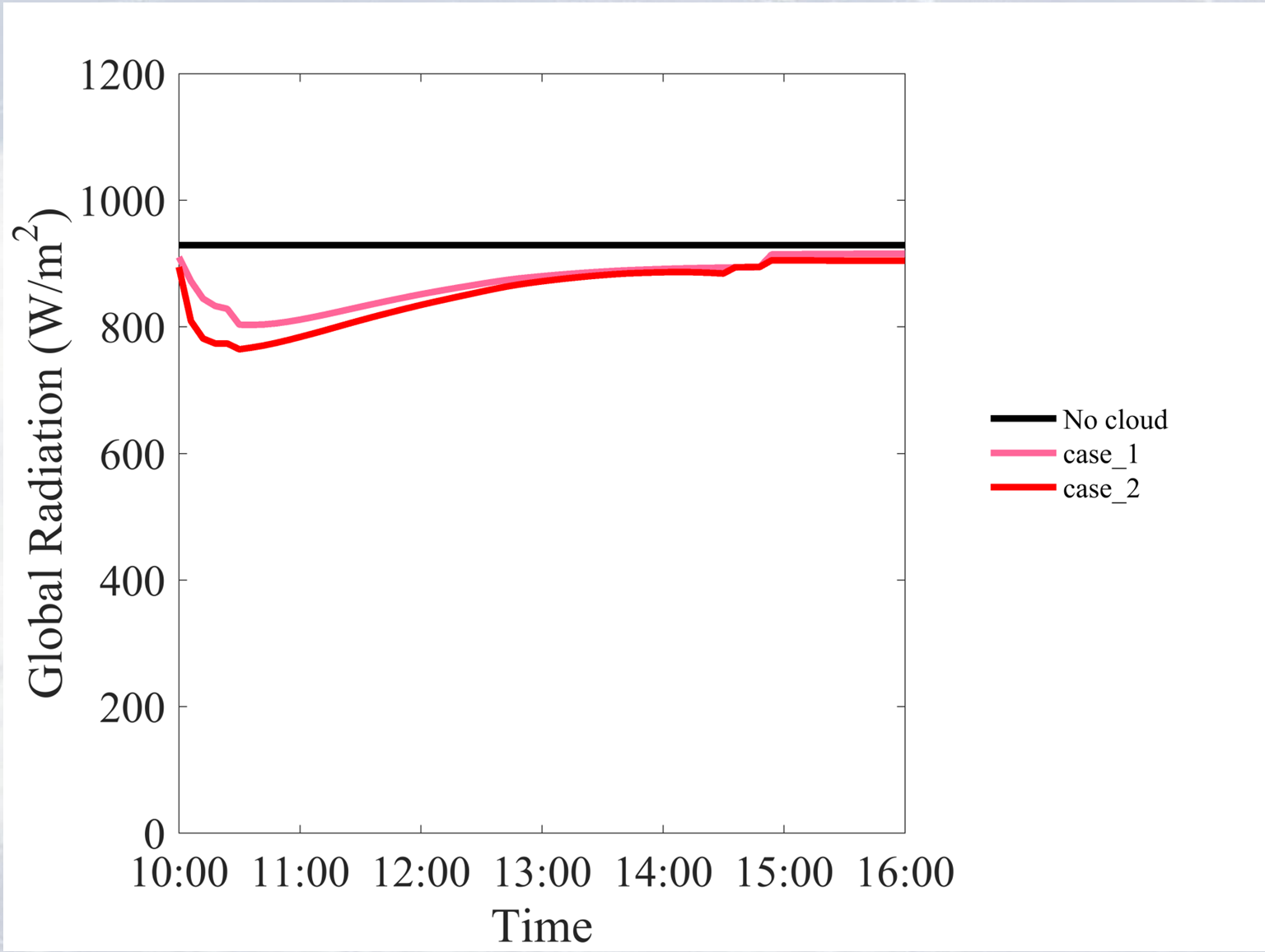
16:00
Time
No cloud
case_1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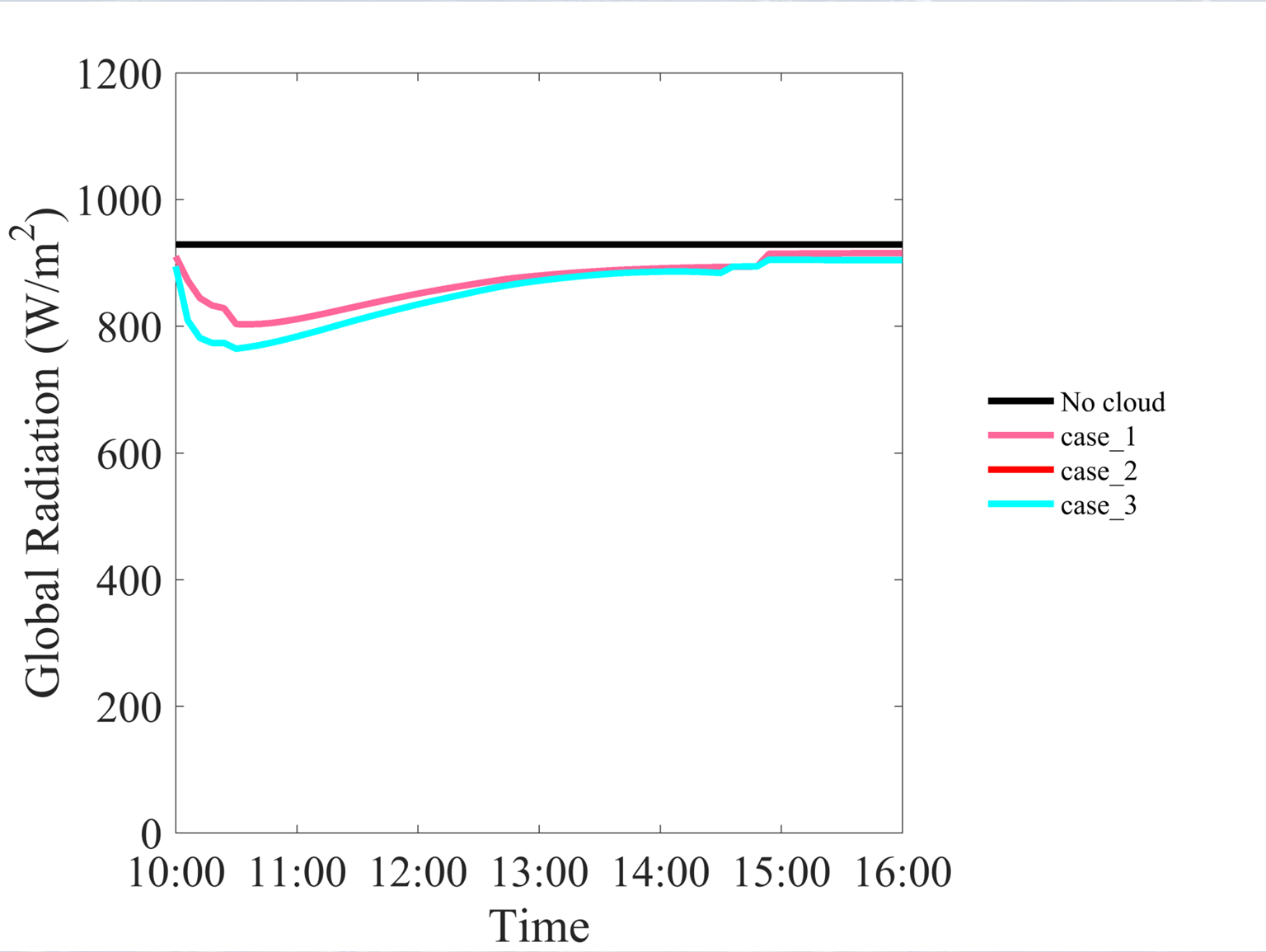
16:00
Time
No cloud
case_1
case_2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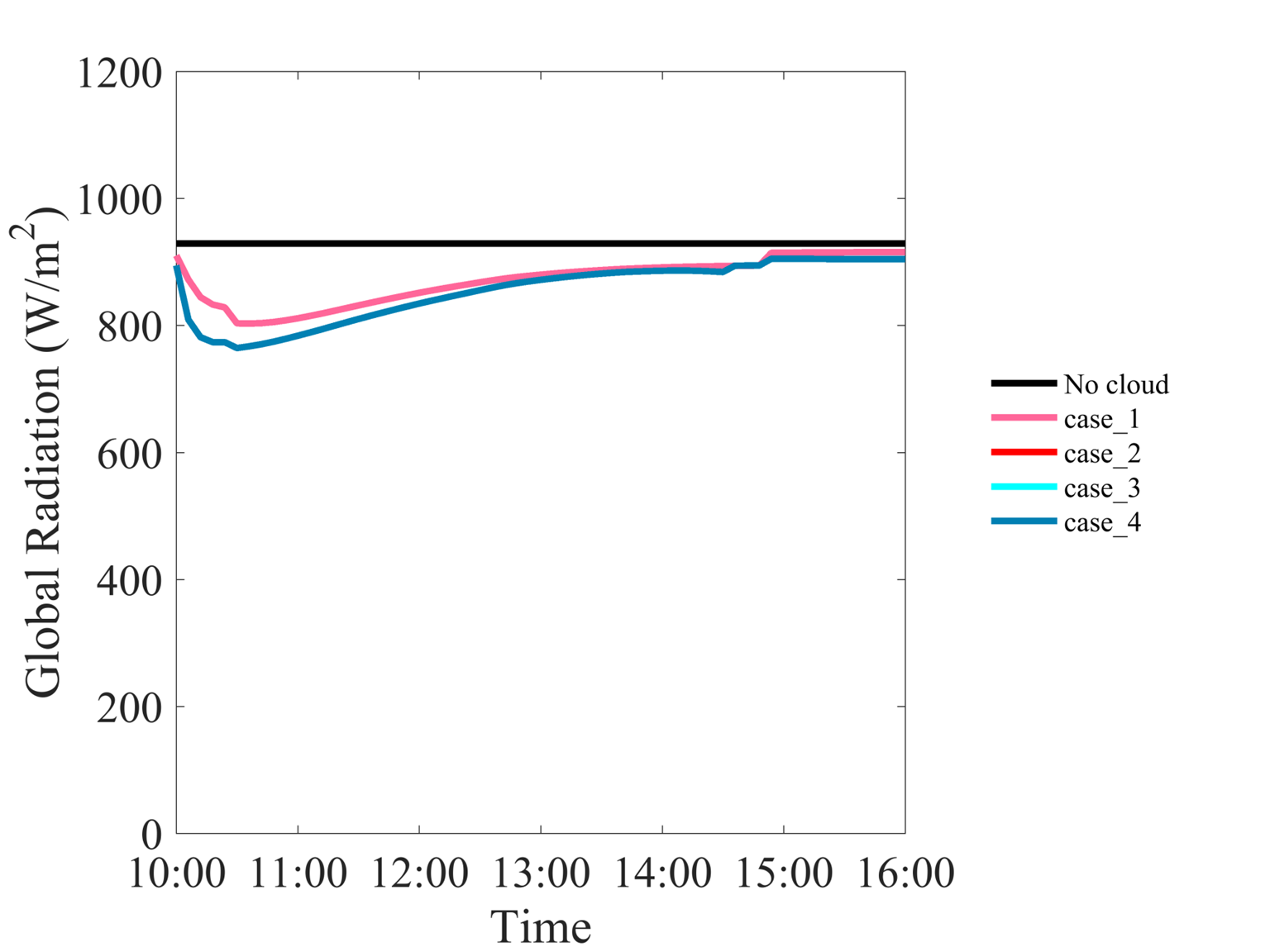
Time
No cloud
case_1
case_2
case_3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No cloud
case_1
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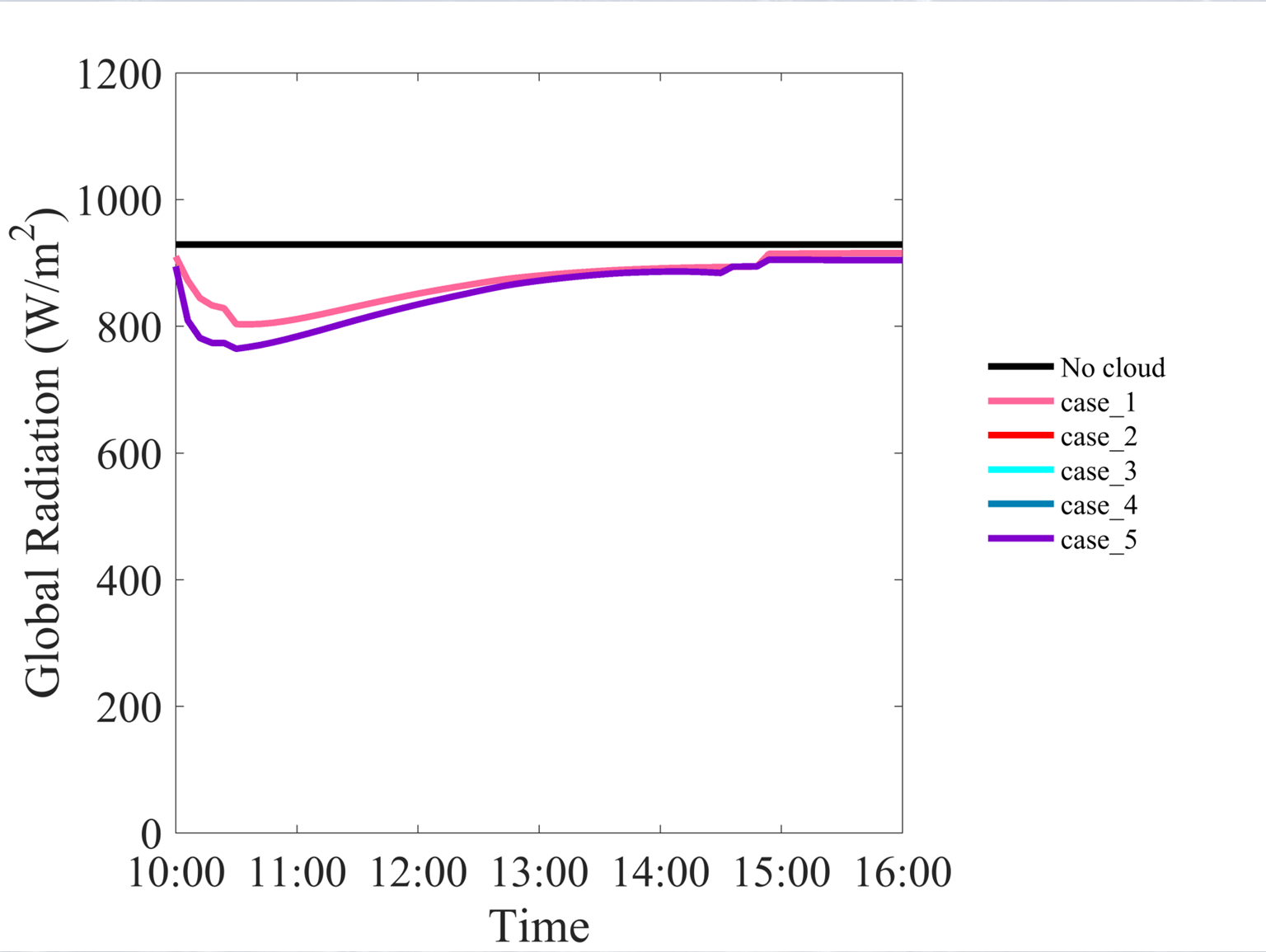
case_4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No cloud
case_1
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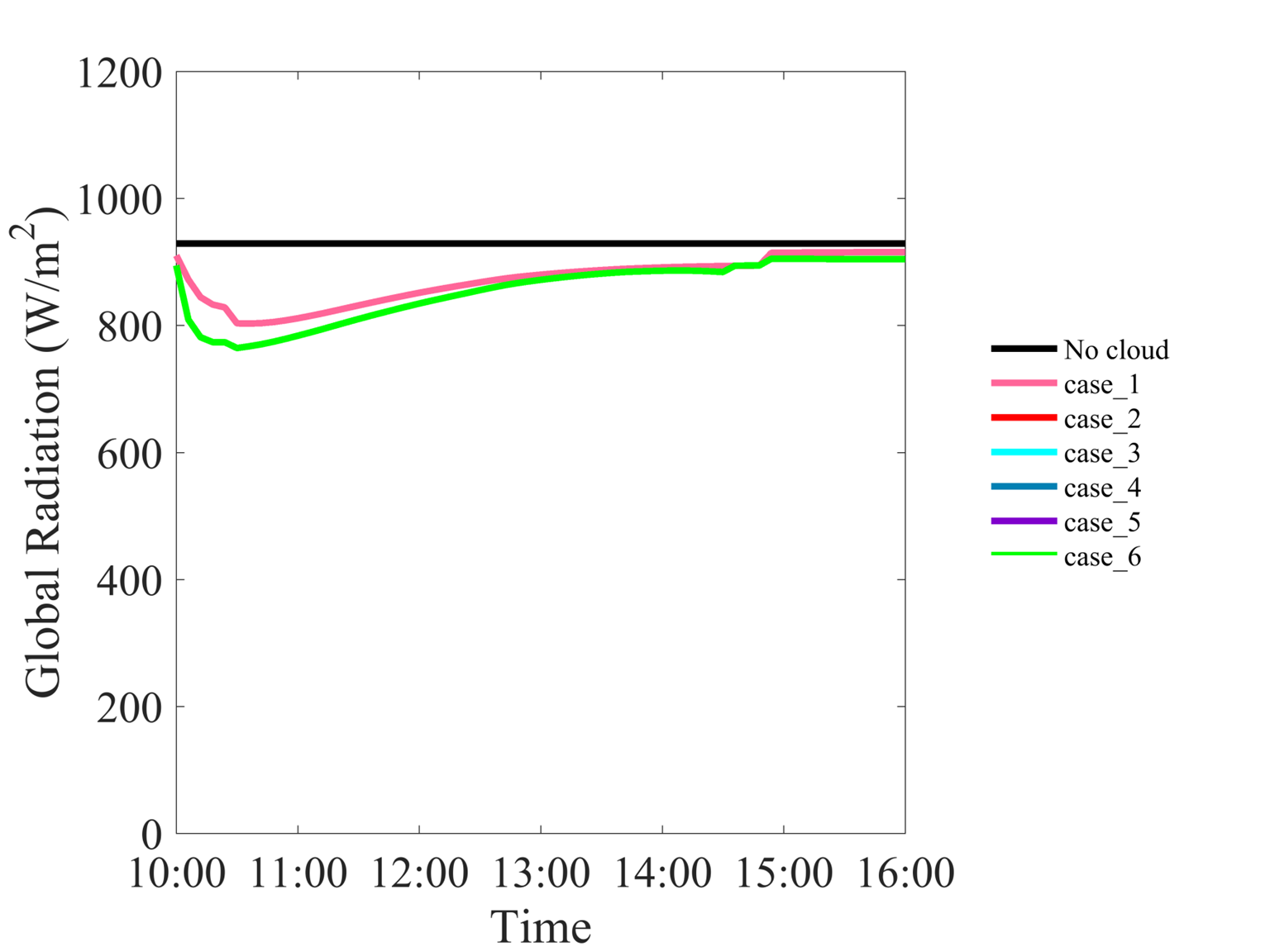
case_4
case_5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Time
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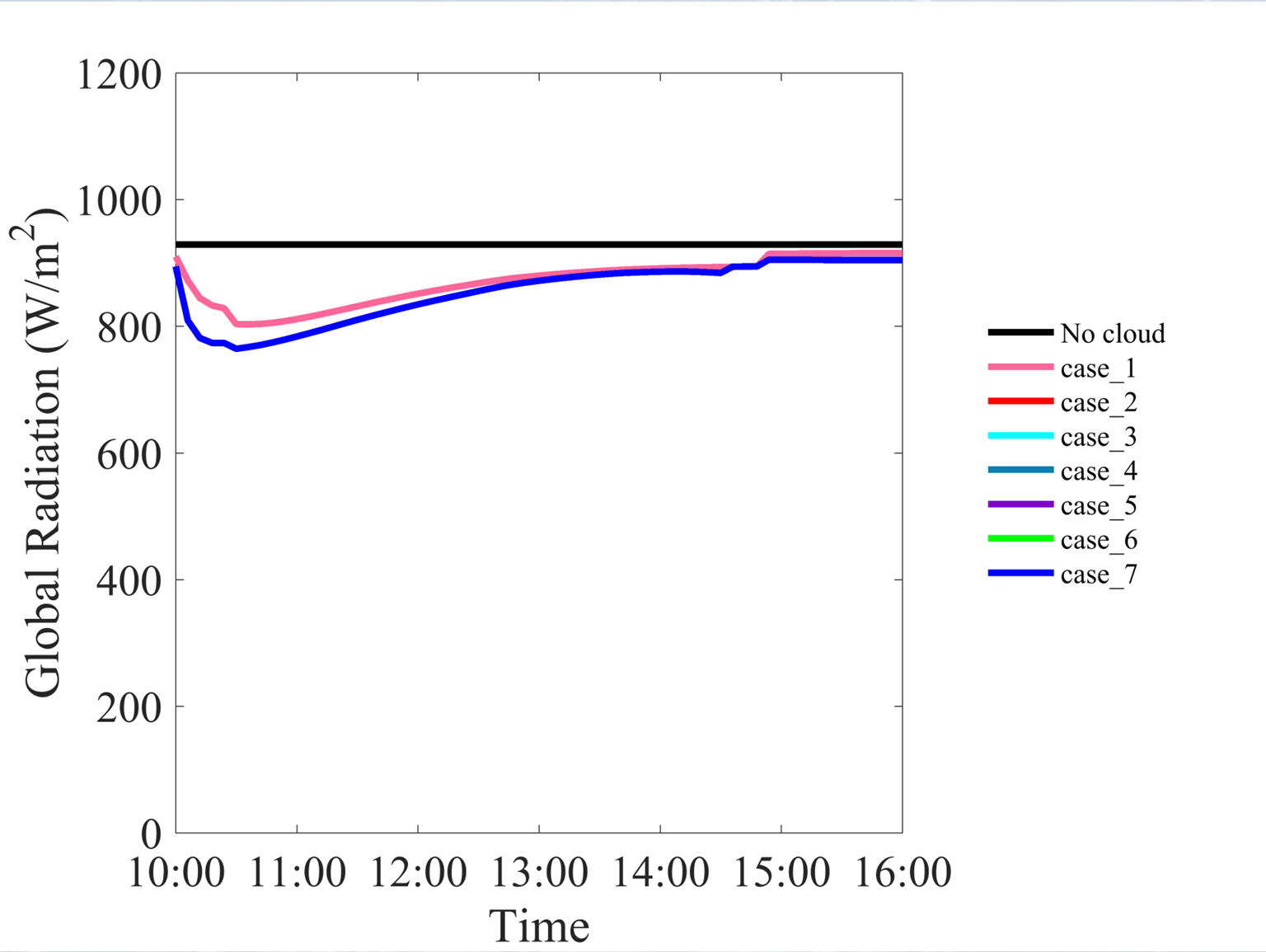
case_1
case_2
case_3
case_4
case_5
case_6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Time
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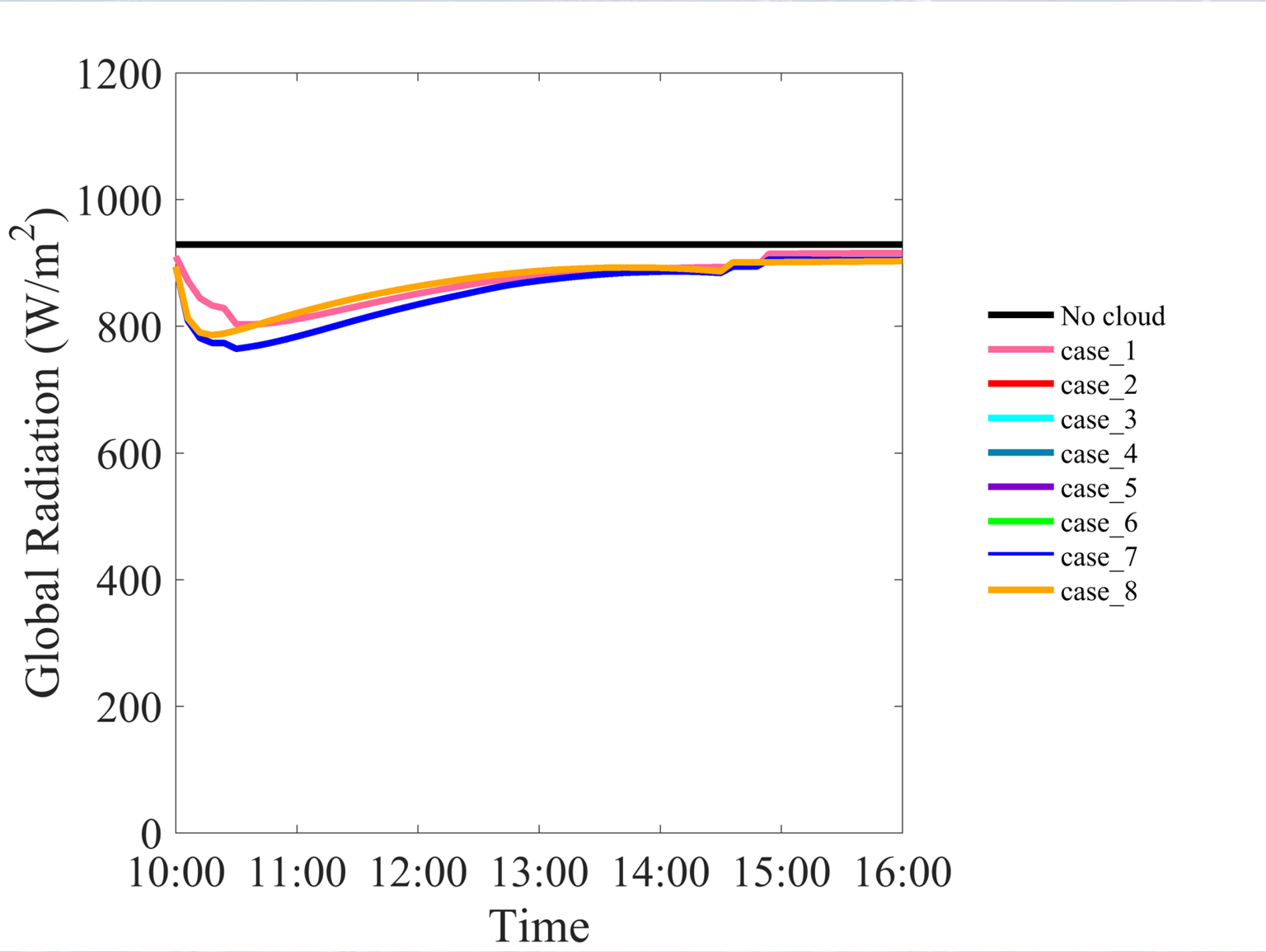
case_1
case_2
case_3
case_4
case_5
case_6
case_7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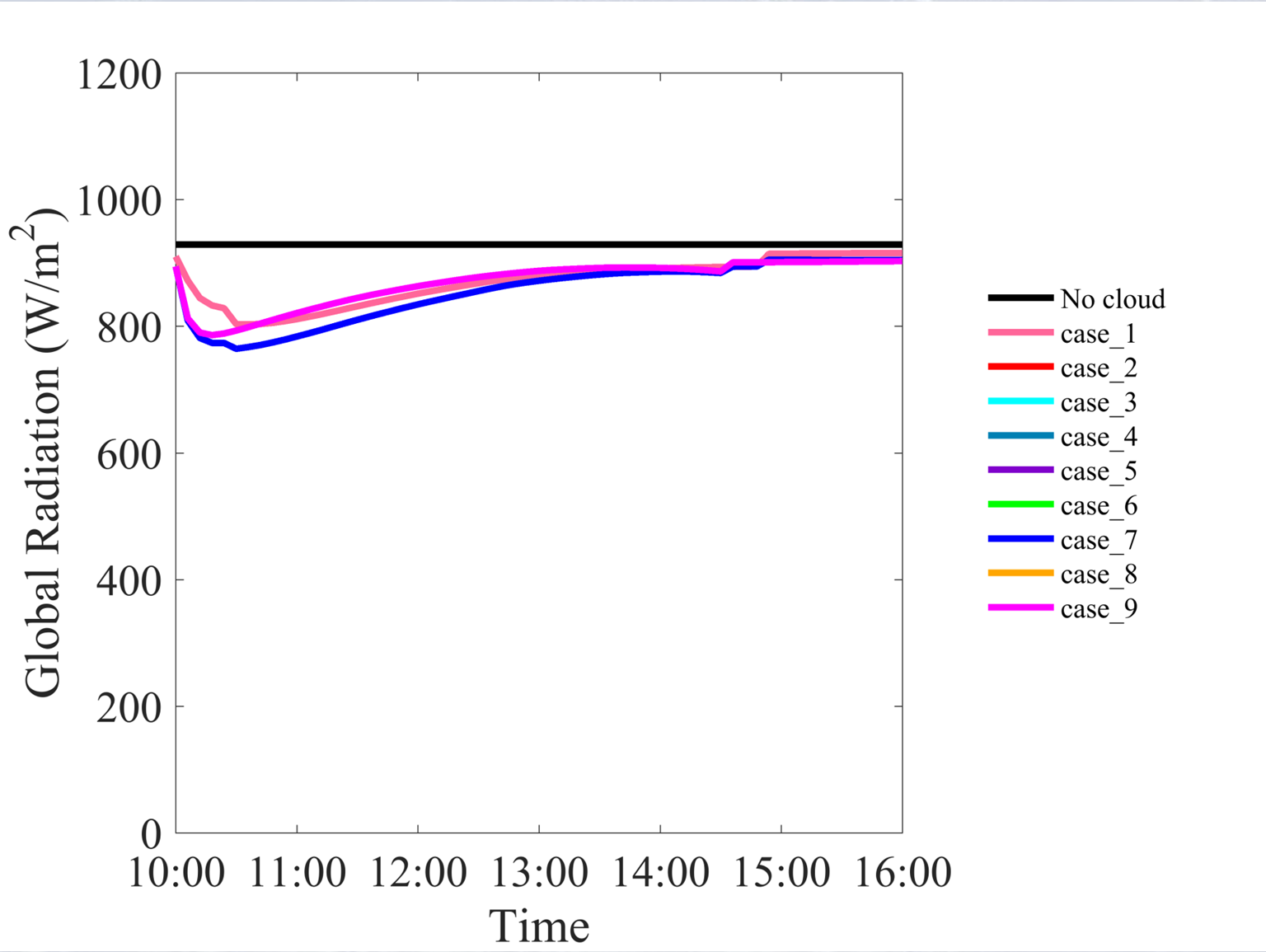
case_3
case_4
case_5
case_6
case_7
case_8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Time
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case_1
case_2
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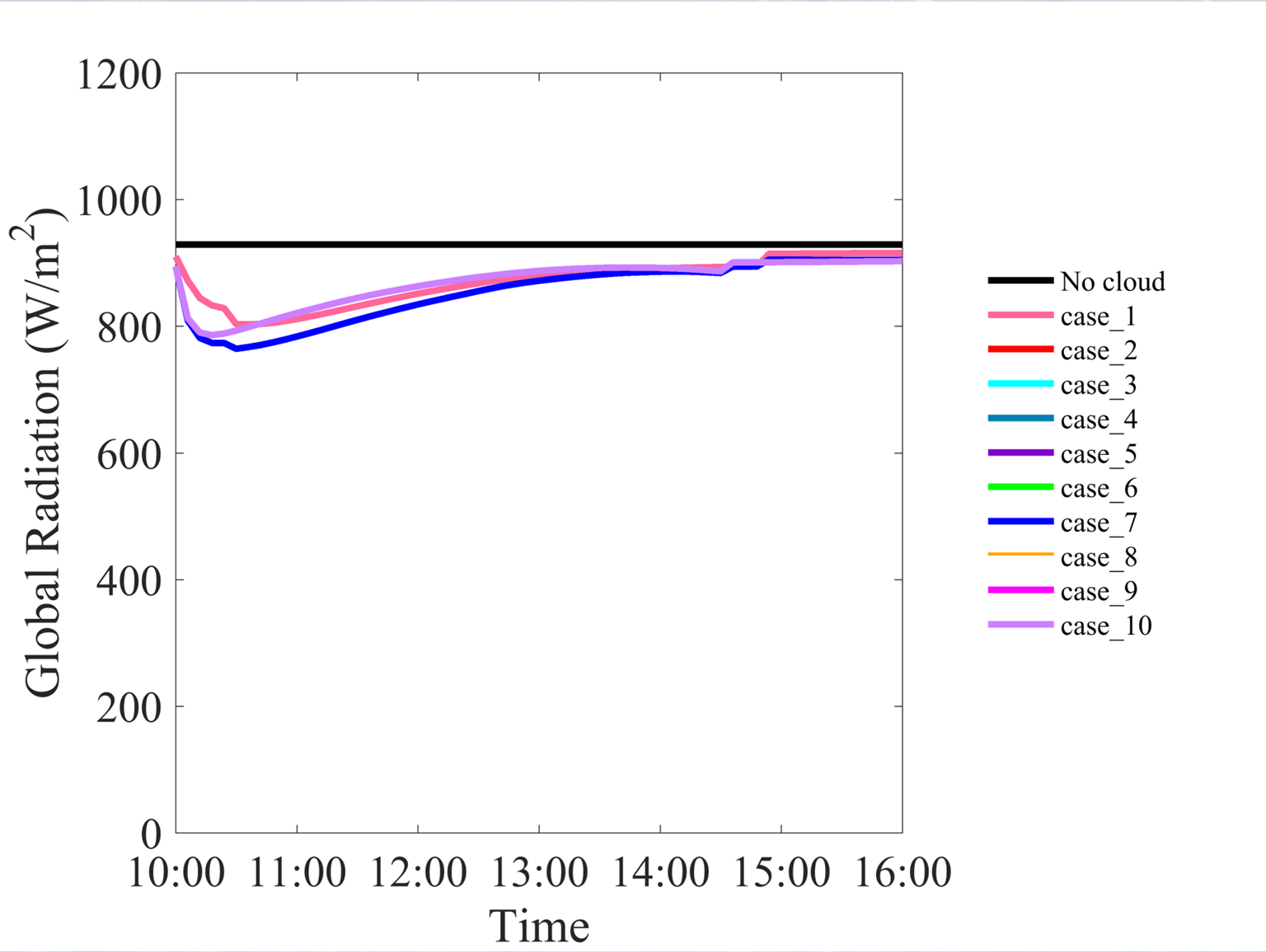
case_5
case_6
case_7
case_8
case_9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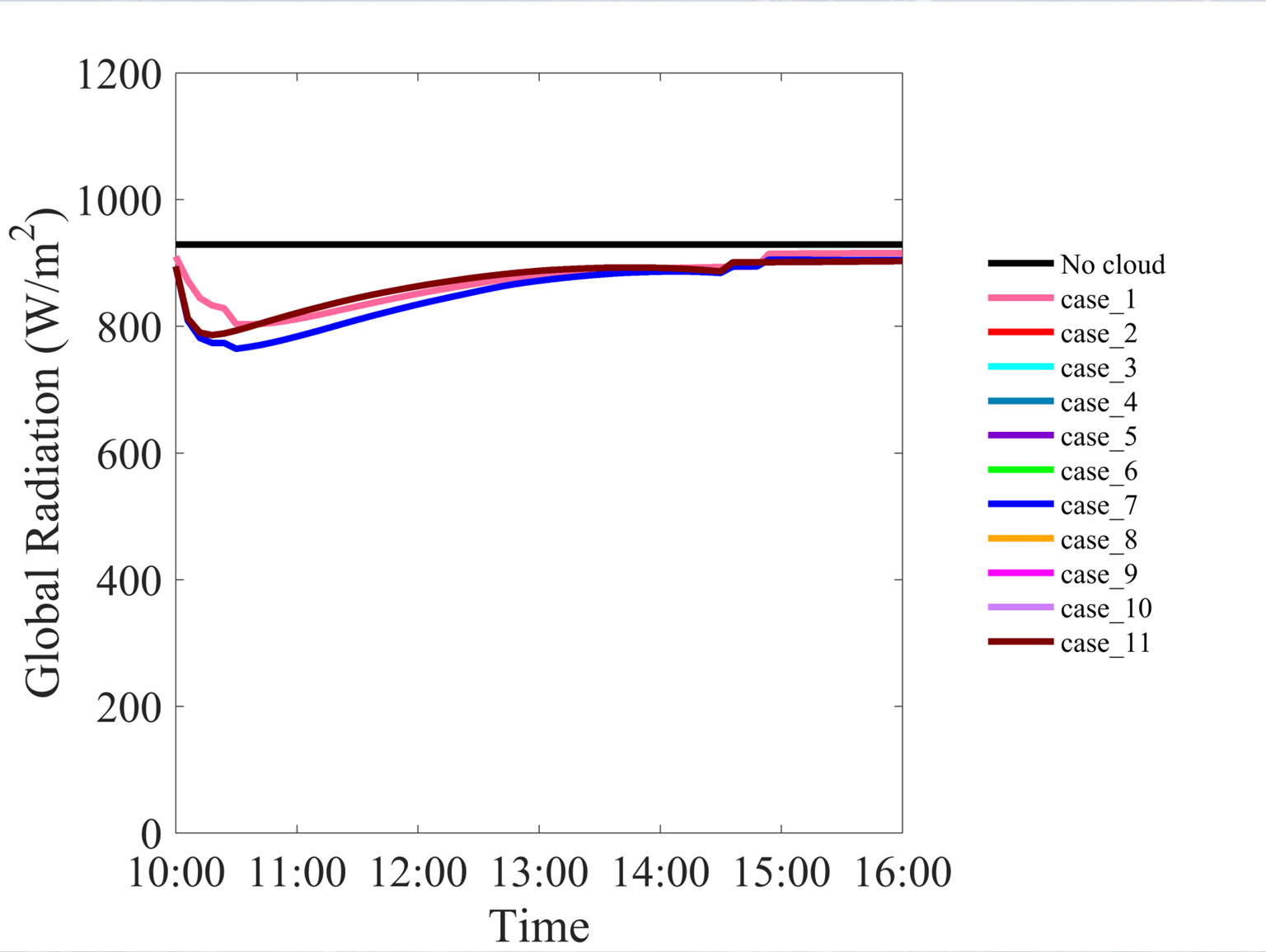
case_5
case_6
case_7
case_8
case_9
case_10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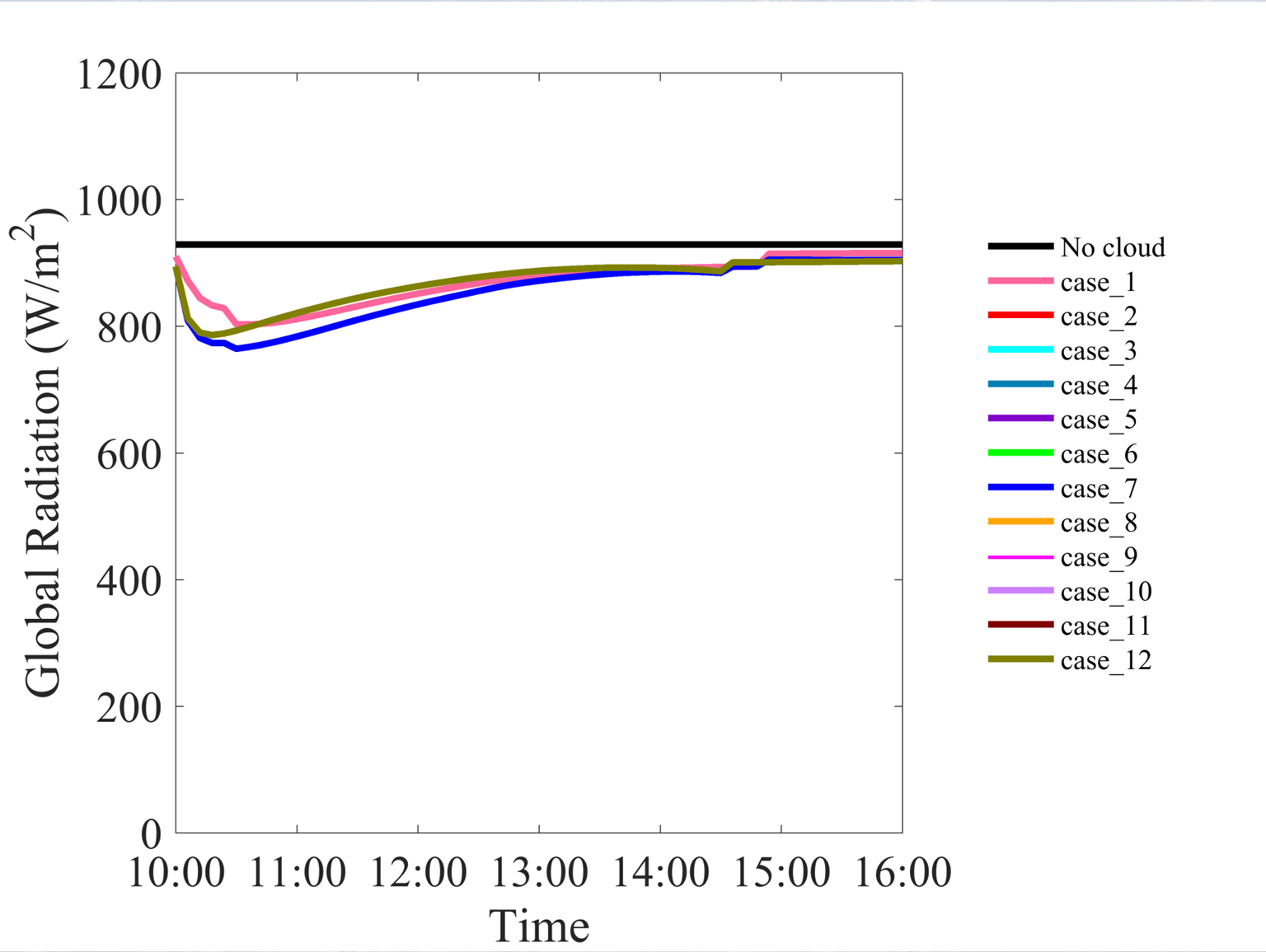
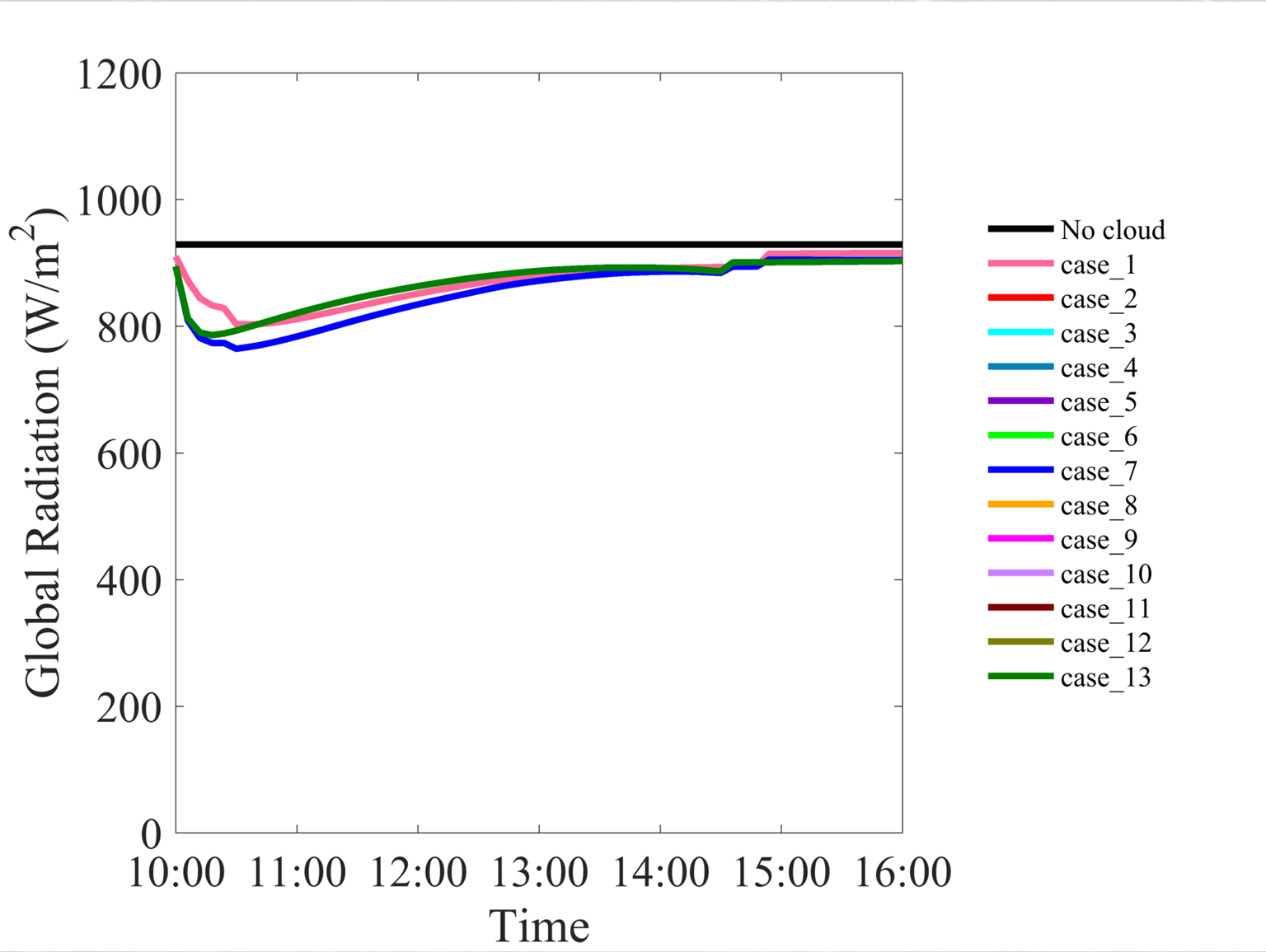
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1
case_2
case_3
case_4
case_5
case_6
case_7
case_8
case_9
case_10
case_11


1200
1000
800
600
400
200
0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1
case_2
case_3
case_4
case_5
case_6
case_7
case_8
case_9
case_10
case_11
case_12


1200
1000
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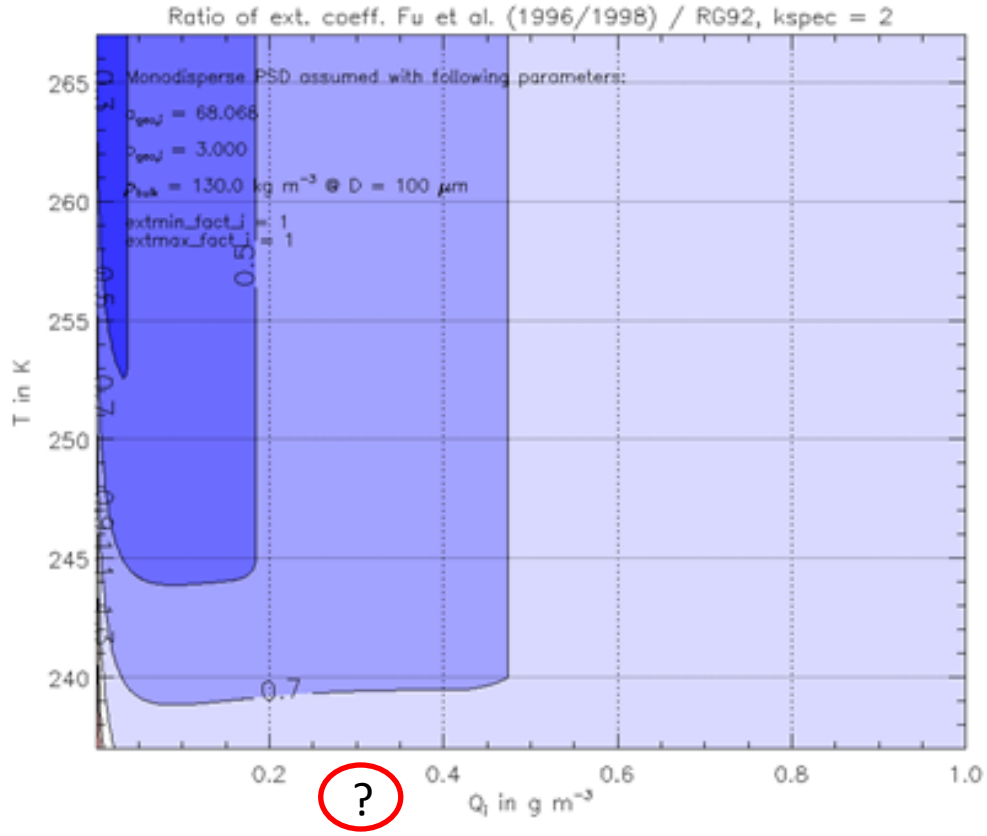
400
200
0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1
case_2
case_3
case_4
case_5
case_6
case_7
case_8
case_9
case_10
case_11
case_12
case_13

From Uli's Blahak presentation:

Cloud ice (visible; Fu et al.)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

➔If grid scale qi > 0: from cloud microphysics:



$f(D)$ = monodispers

$N_i(T) = a \exp(b(T_3 - T))$

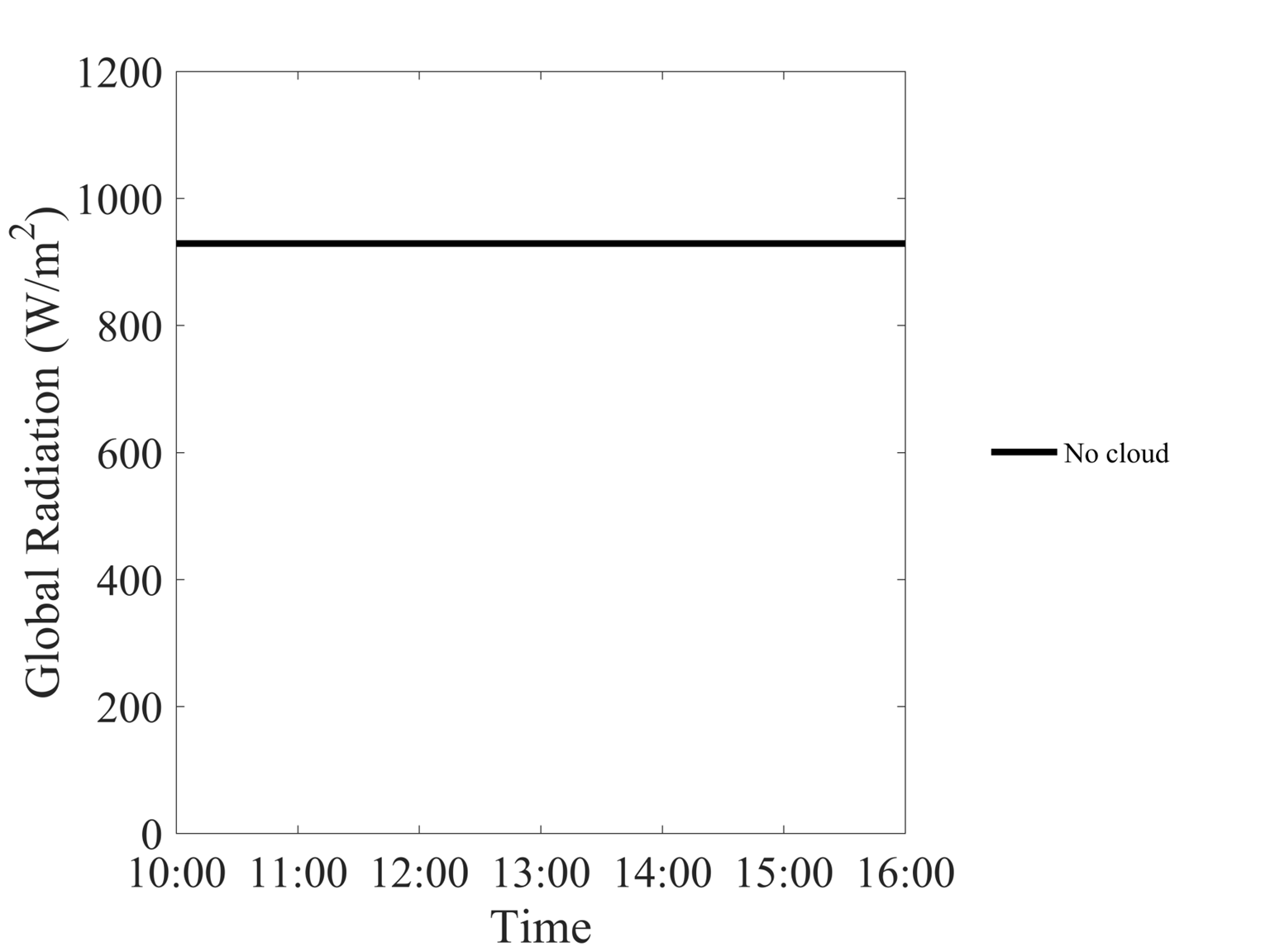
q_i prognostic

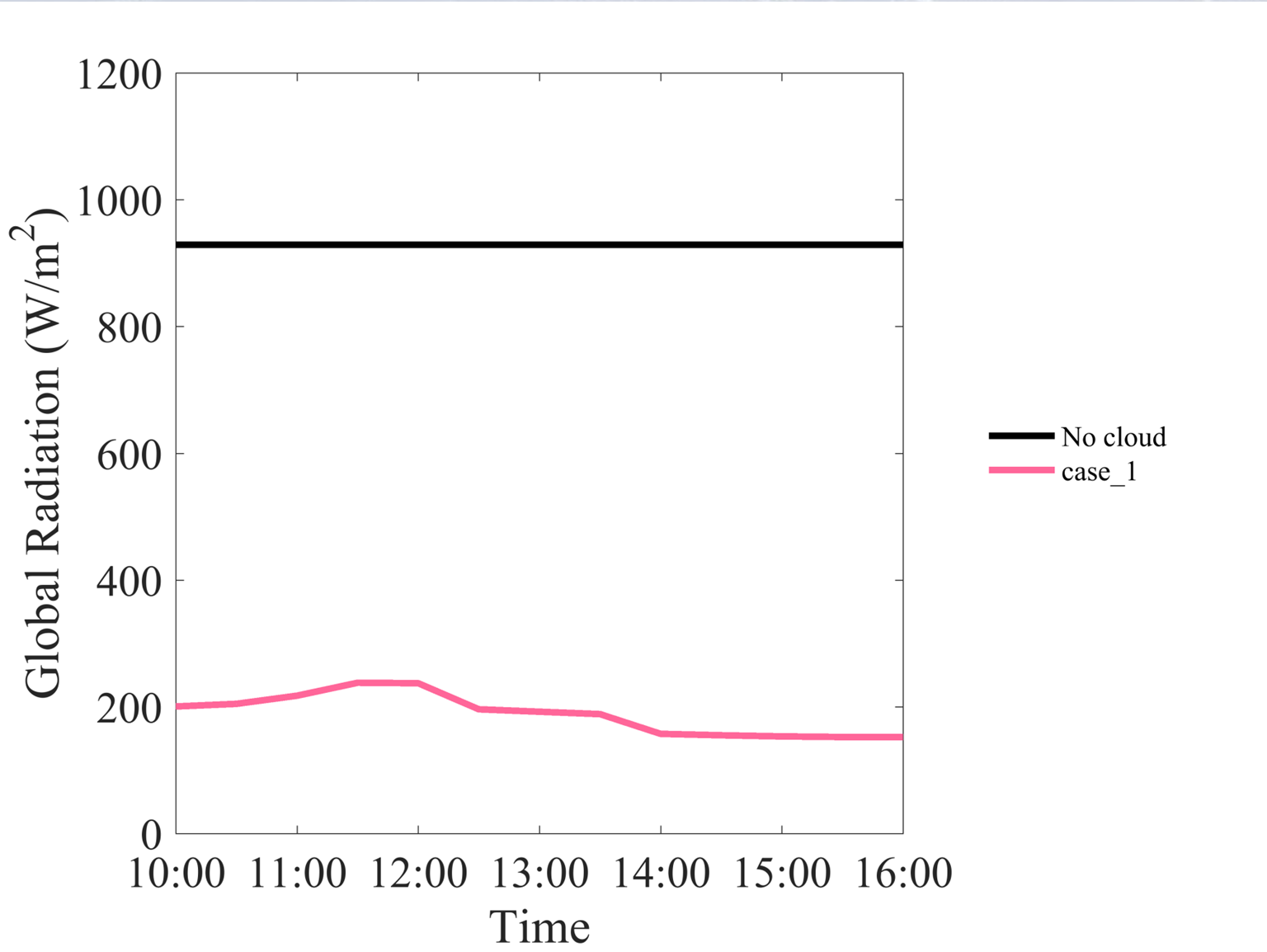
$m_i = 130\, D^3$ (SI-units)

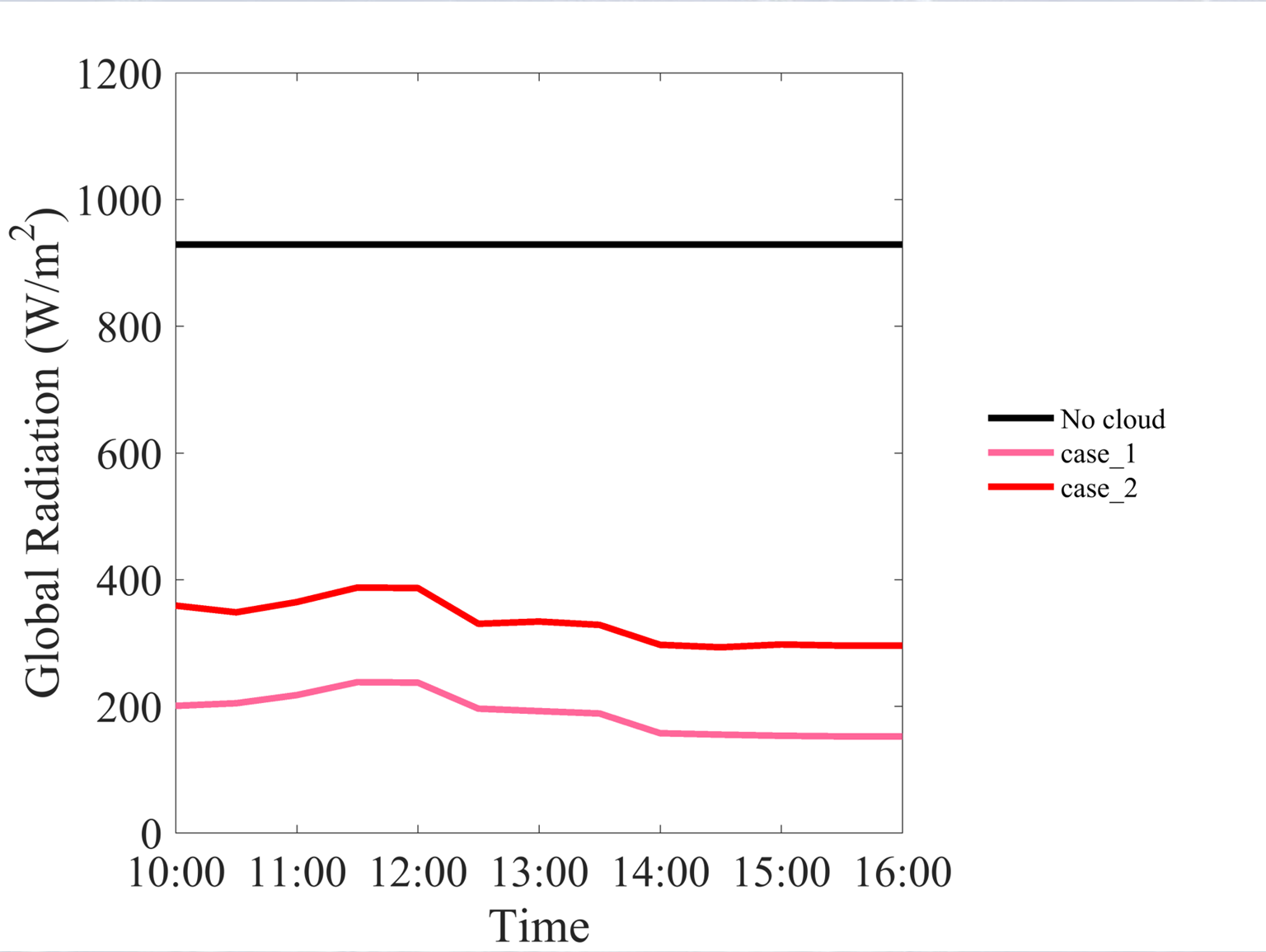
Spectral interval „2“ (visible range)

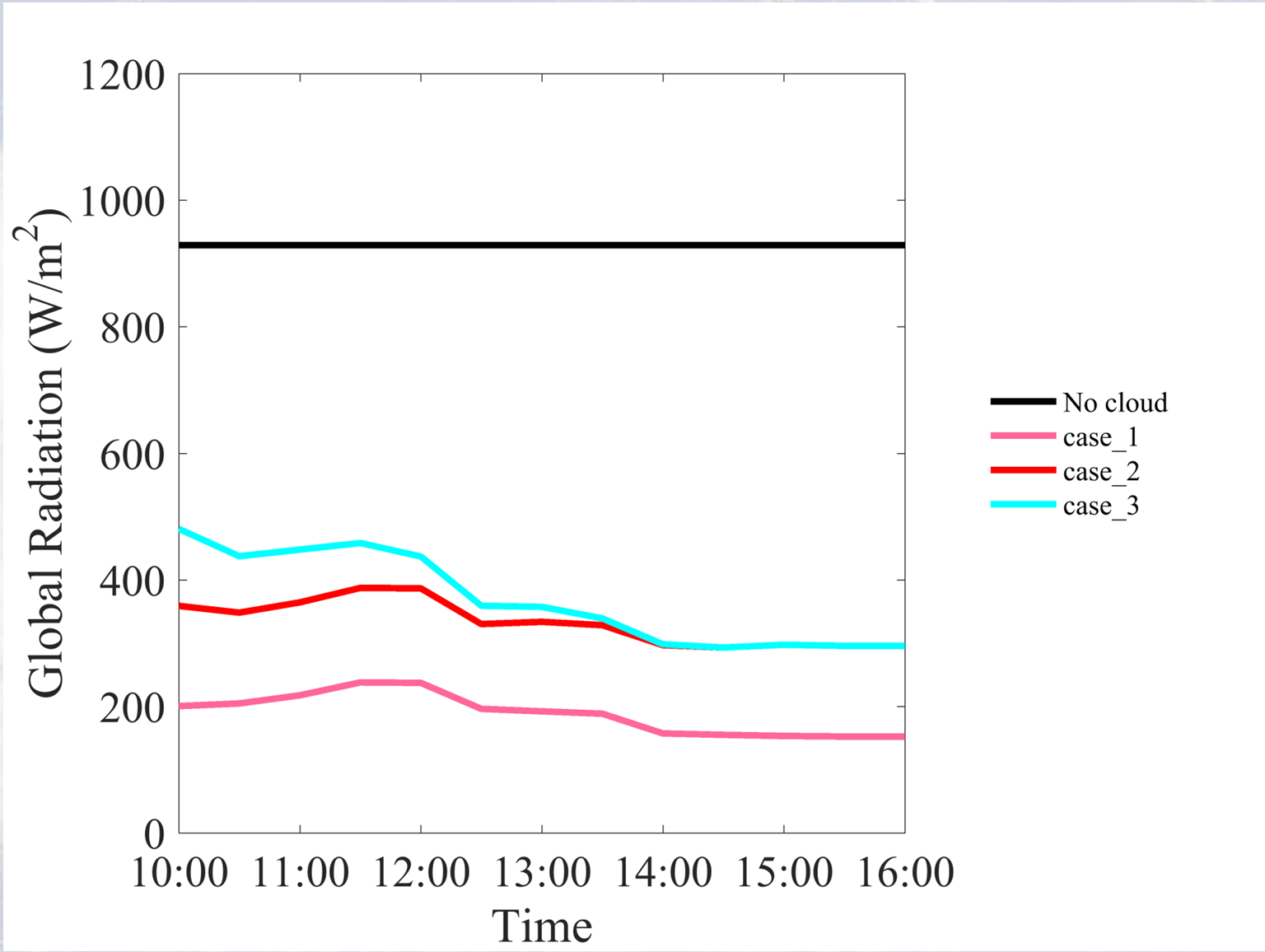
β_{ext} ratio Fu / RG92

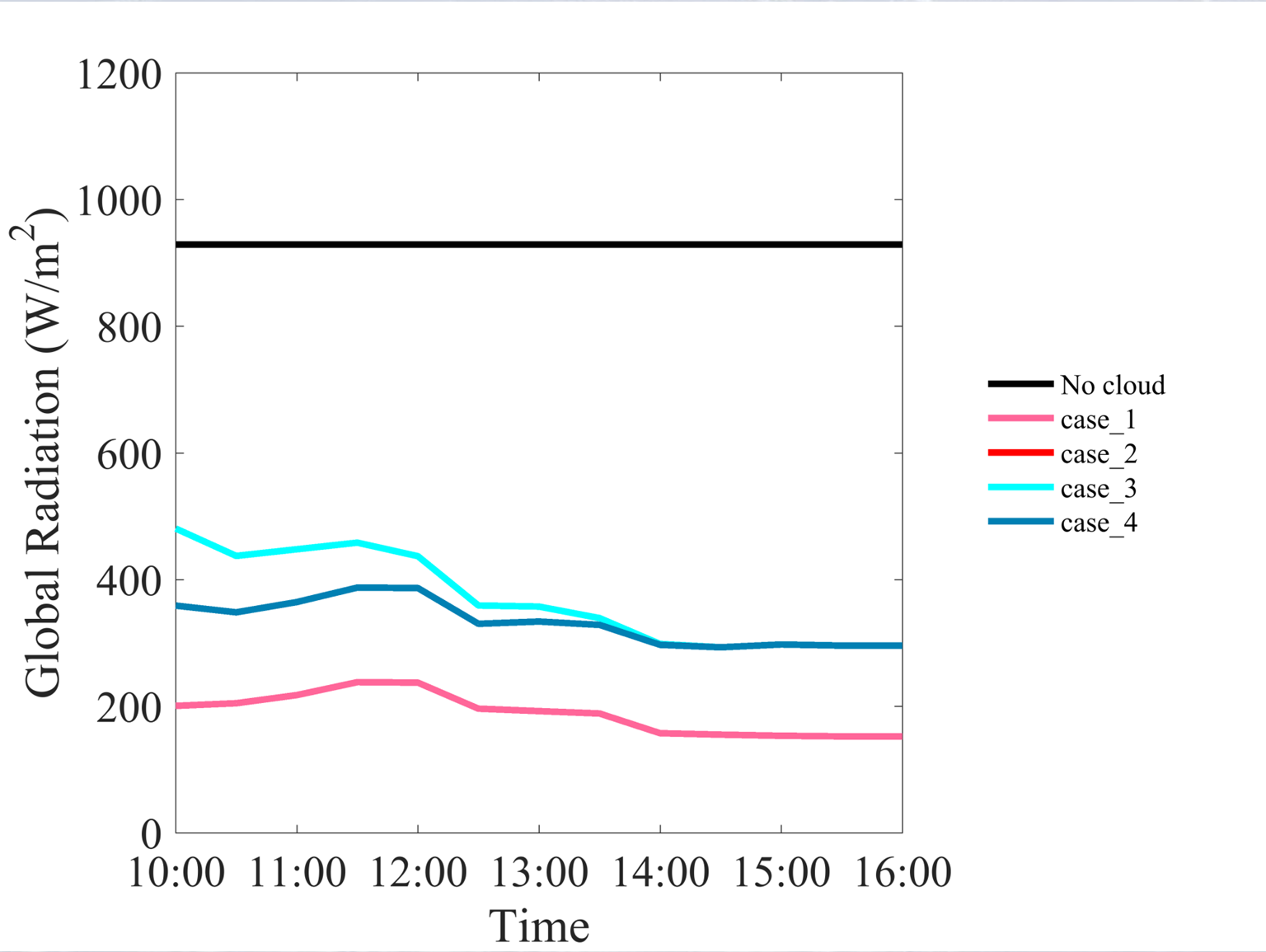
True / False switches on Mixed Phase cloud:


1200
1000
800
600
400
200
0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud


1200
1000
800
600
400
200
0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1


1200
1000
800
600
400
200
0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1
case_2


1200
1000
800
600
400
200
0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1
case_2
case_3


1200
1000
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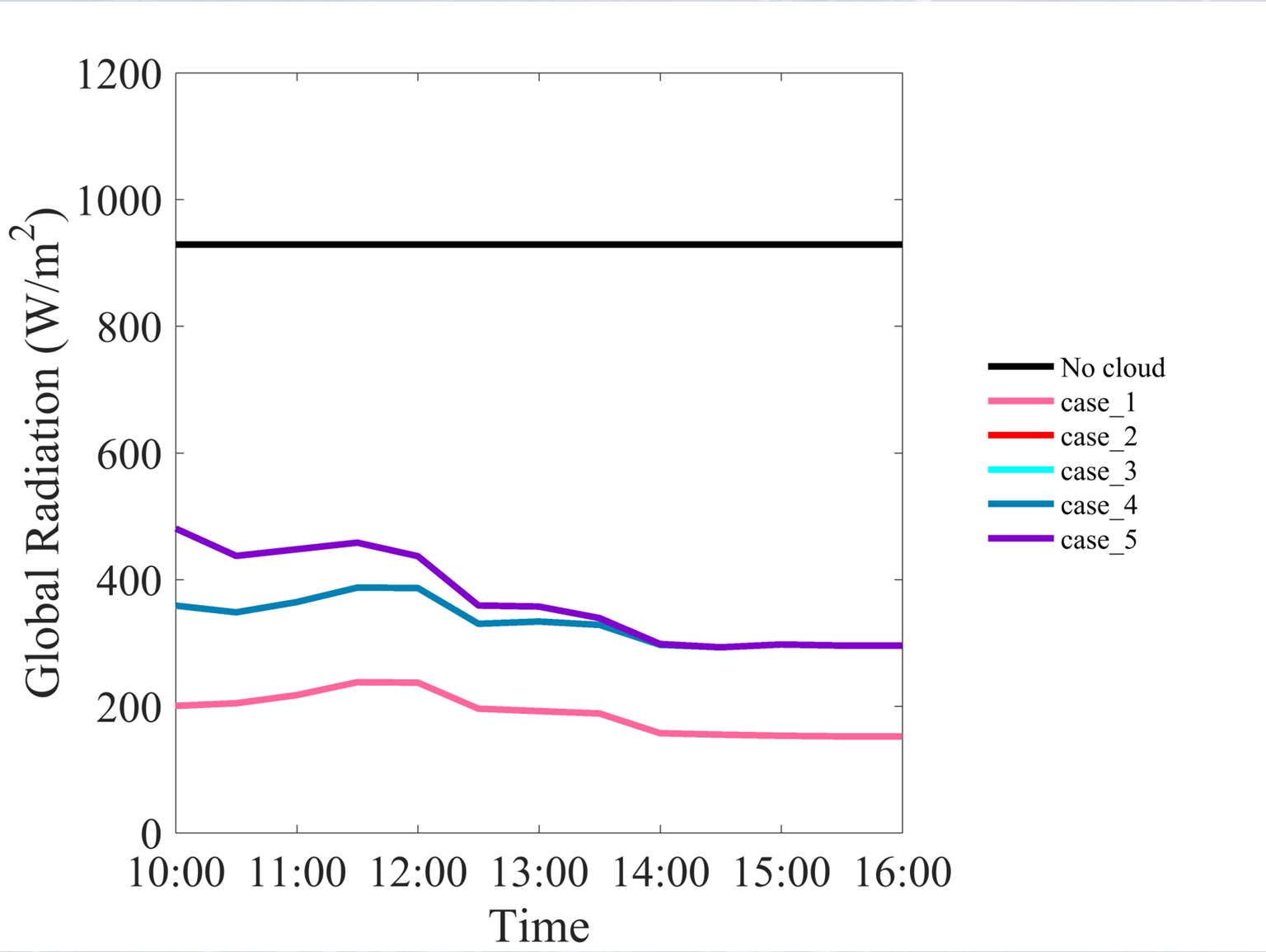
200
0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1
case_2
case_3
case_4


1200
1000
800
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400
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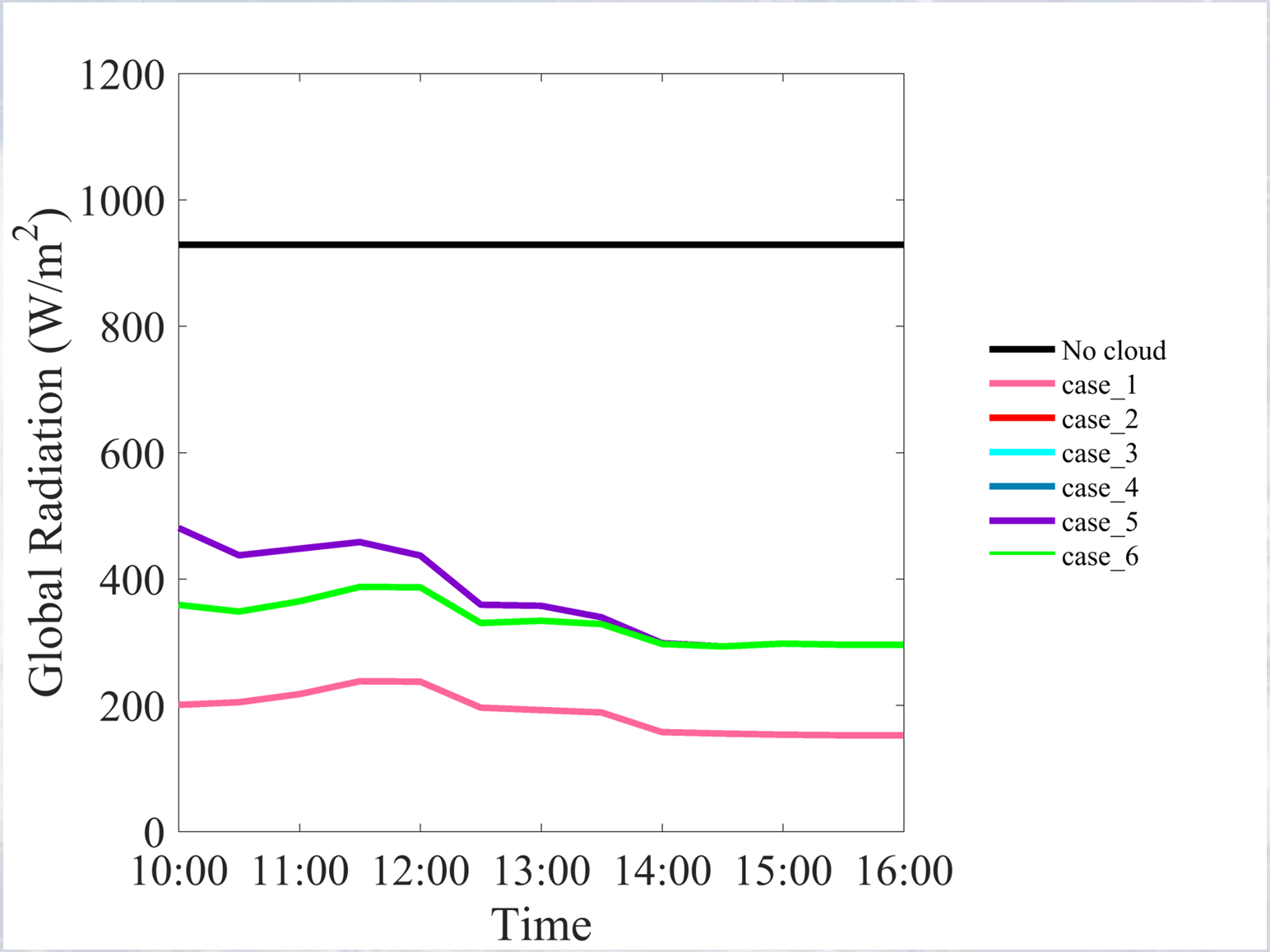
0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1
case_2
case_3
case_4
case_5


1200
1000
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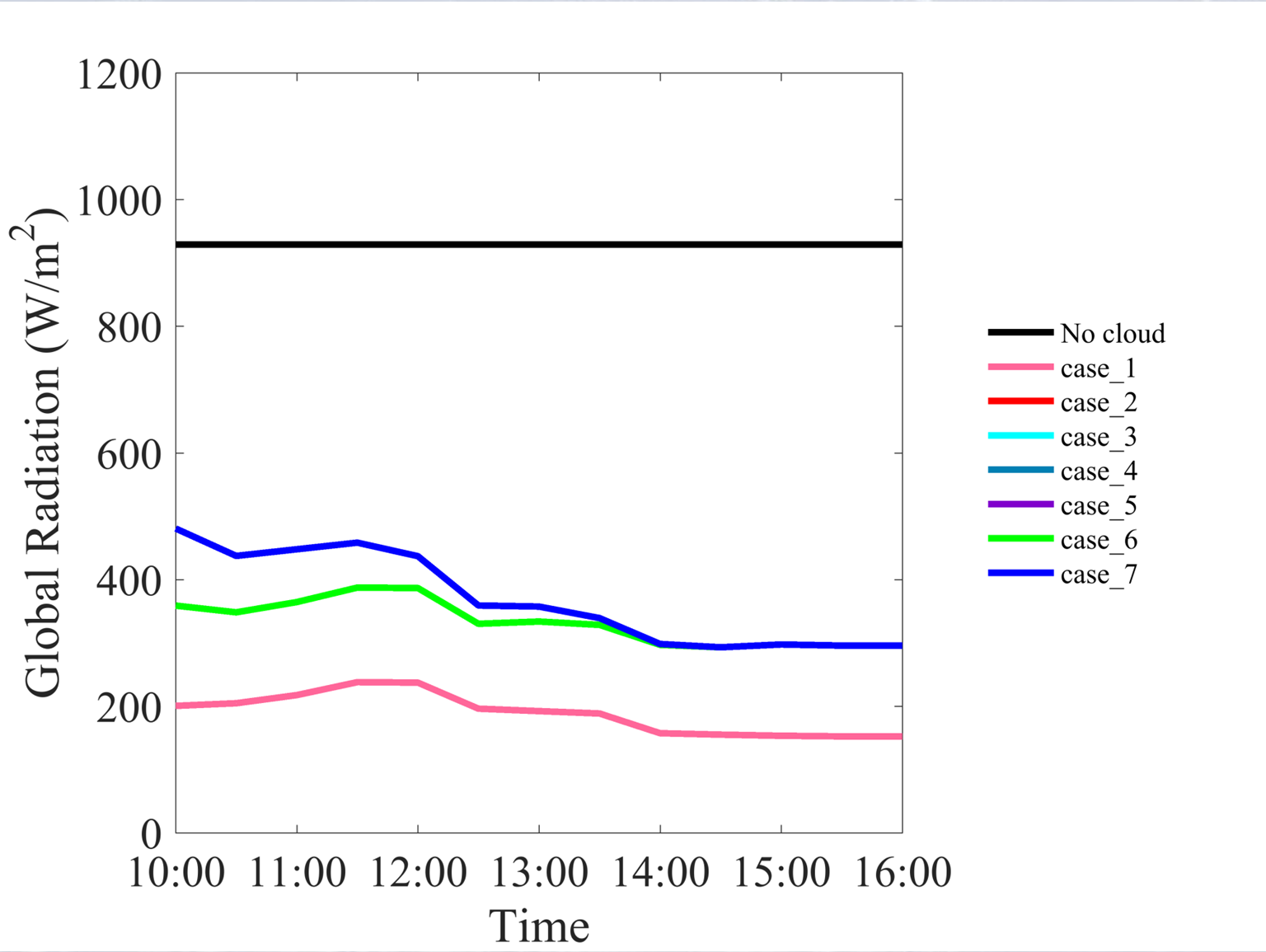
0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1
case_2
case_3
case_4
case_5
case_6


1200
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0
Global Radiation (W/m2)
10:00
11:00
12:00
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14:00
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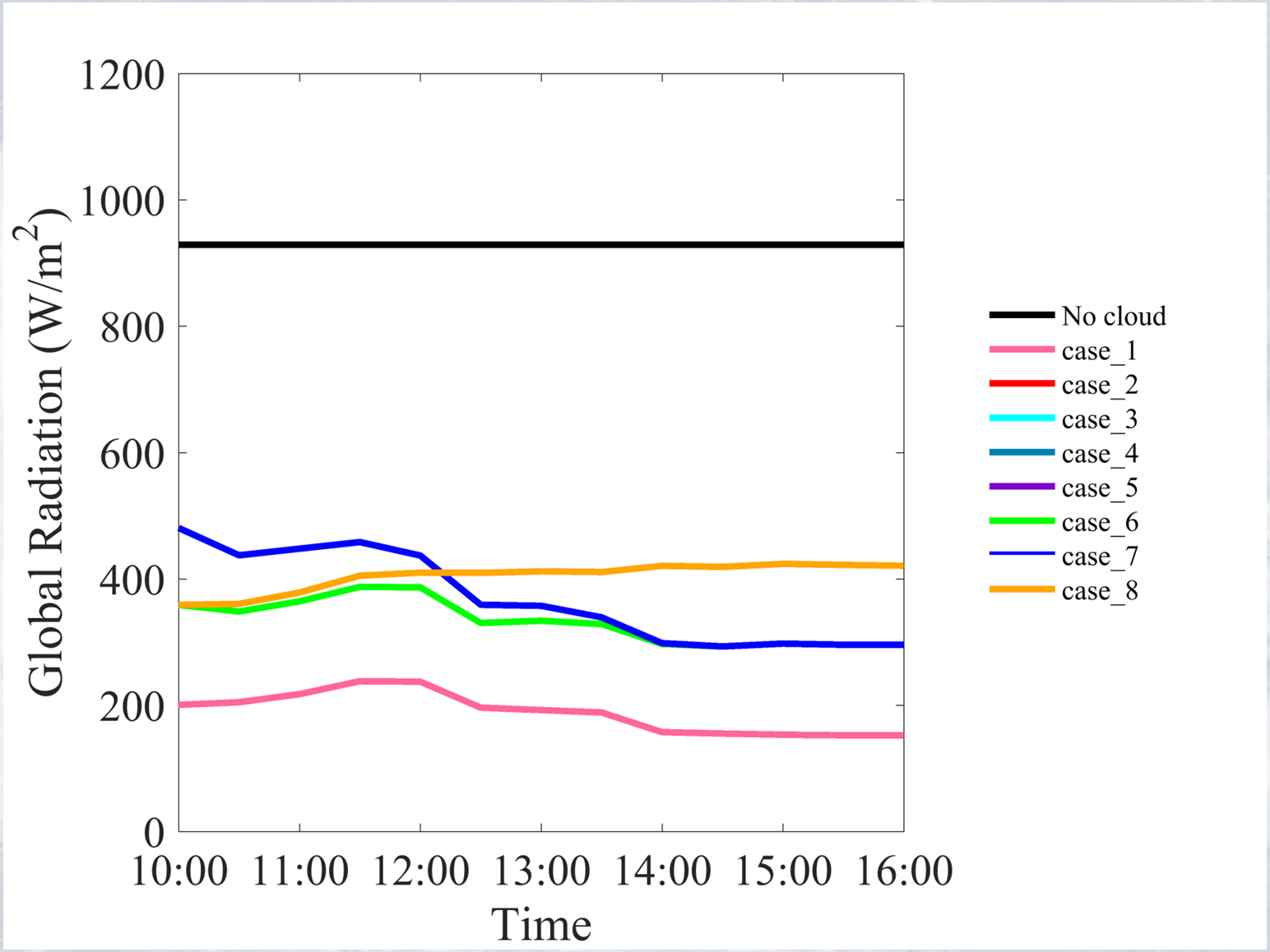
Time
No cloud
case_1
case_2
case_3
case_4
case_5
case_6
case_7


1200
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0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
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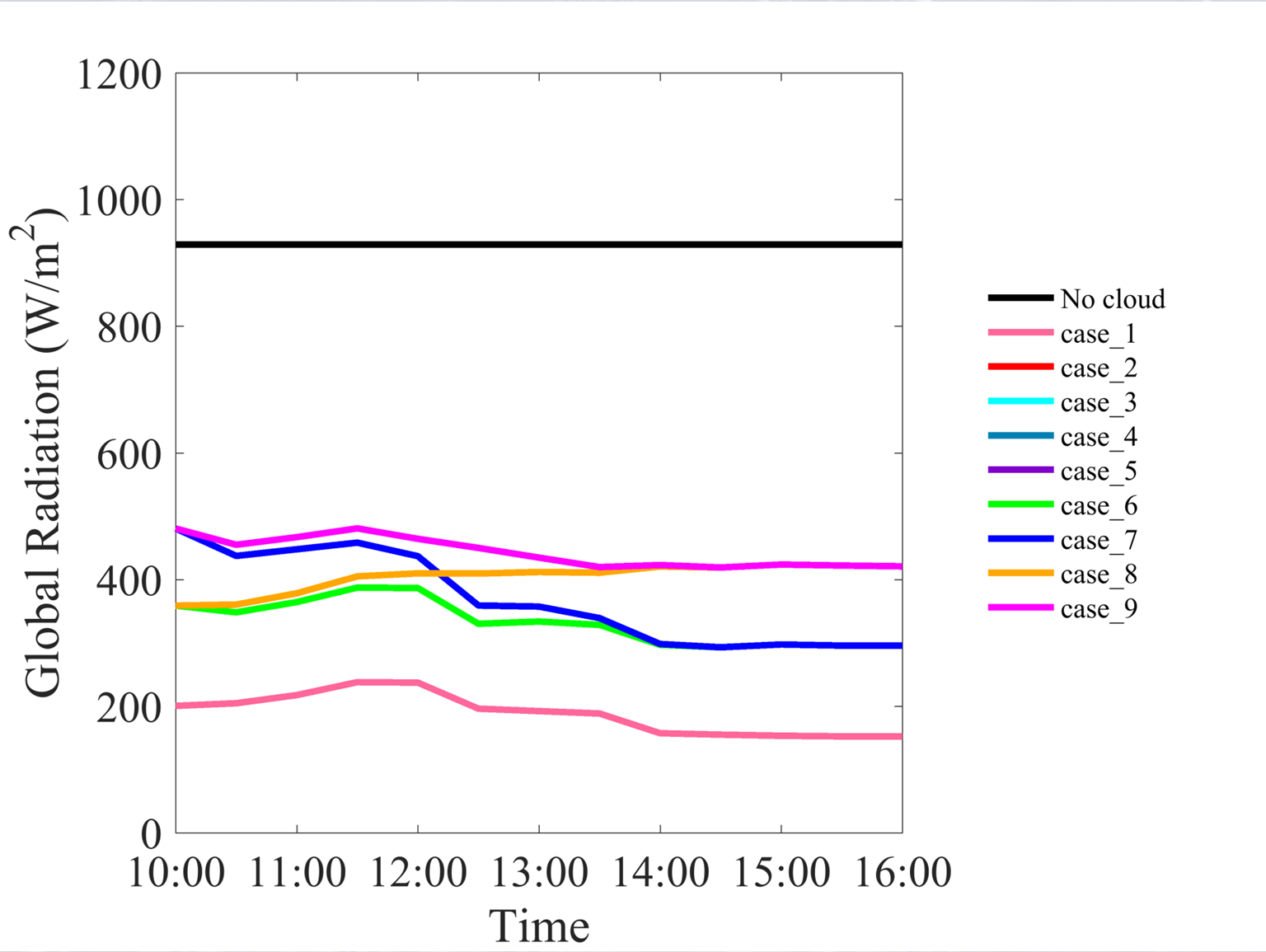
Time
No cloud
case_1
case_2
case_3
case_4
case_5
case_6
case_7
case_8


1200
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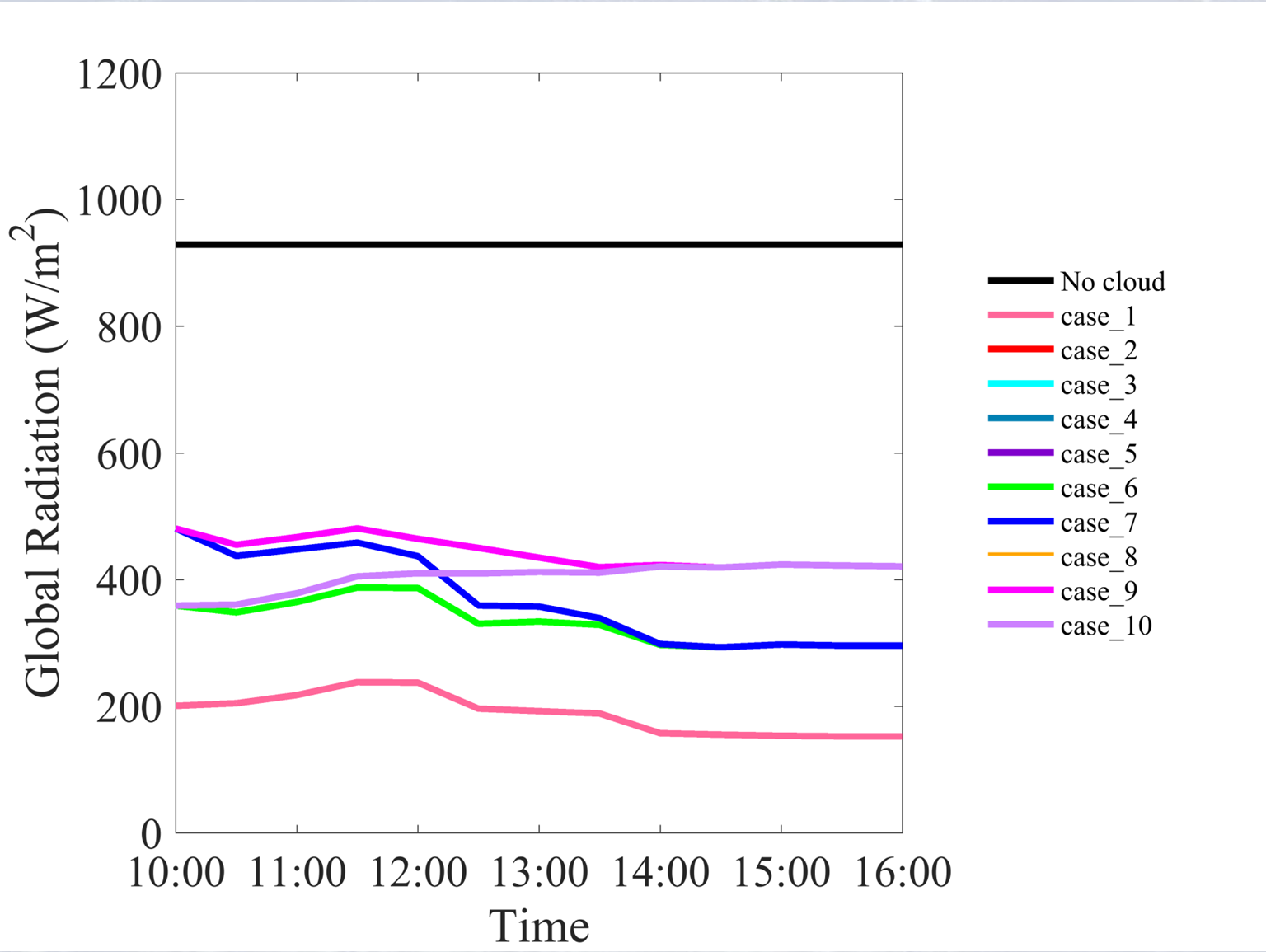
0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1
case_2
case_3
case_4
case_5
case_6
case_7
case_8
case_9


1200
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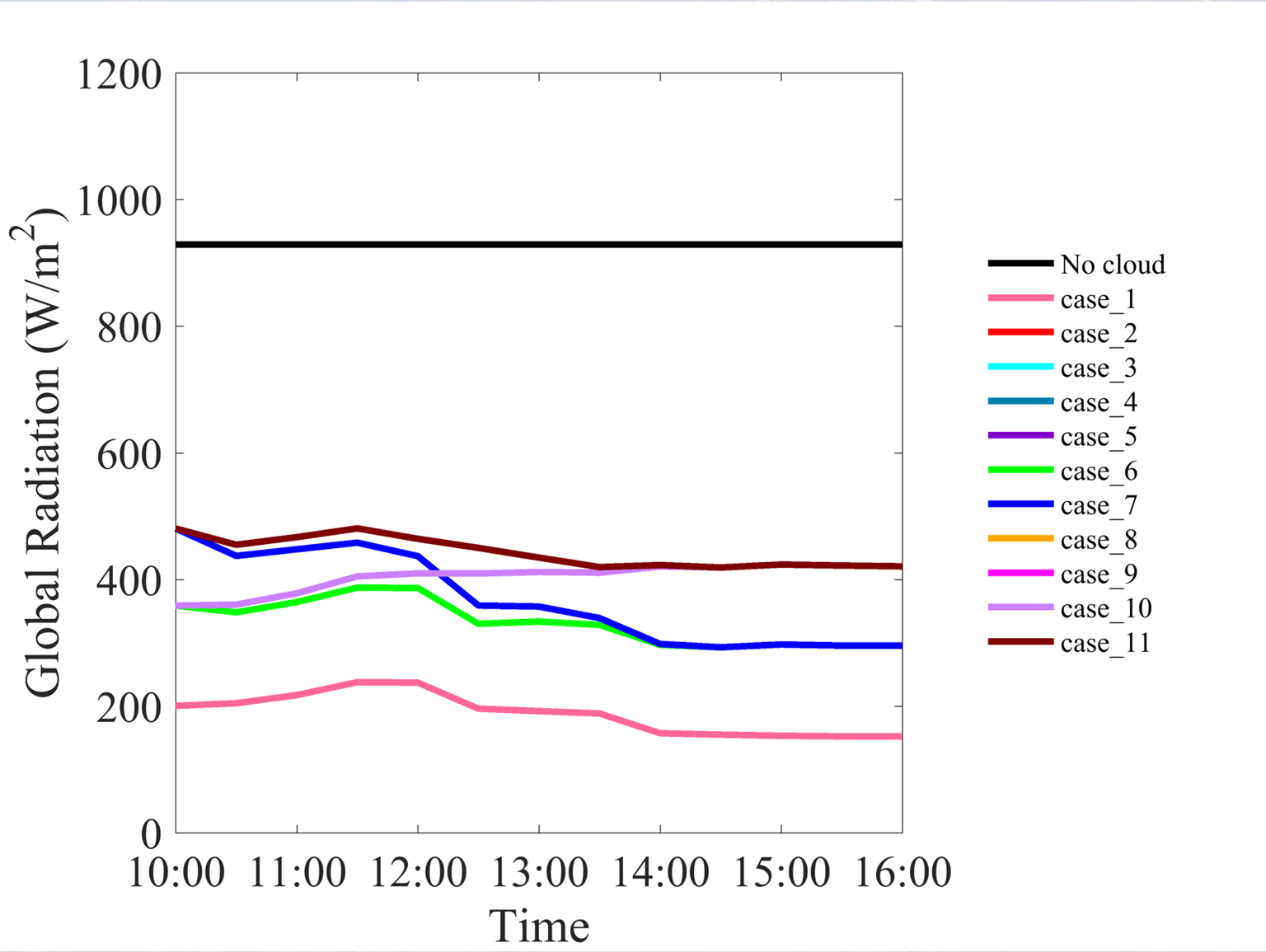
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1
case_2
case_3
case_4
case_5
case_6
case_7
case_8
case_9
case_10


1200
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Global Radiation (W/m2)
10:00
11:00
12:00
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14:00
15:00
16:00
Time
No cloud
case_1
case_2
case_3
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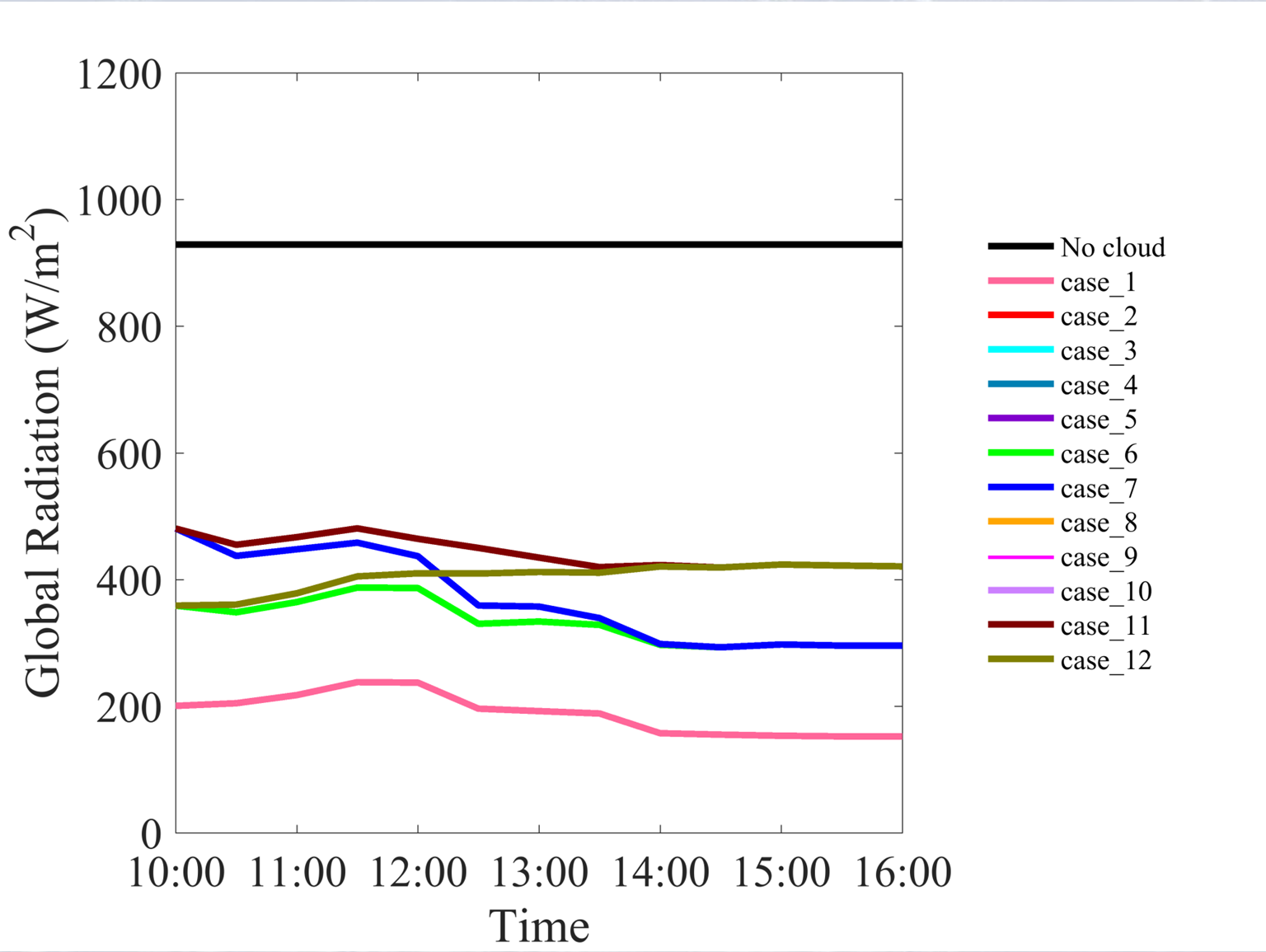
case_5
case_6
case_7
case_8
case_9
case_10
case_11


1200
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Global Radiation (W/m2)
10:00
11:00
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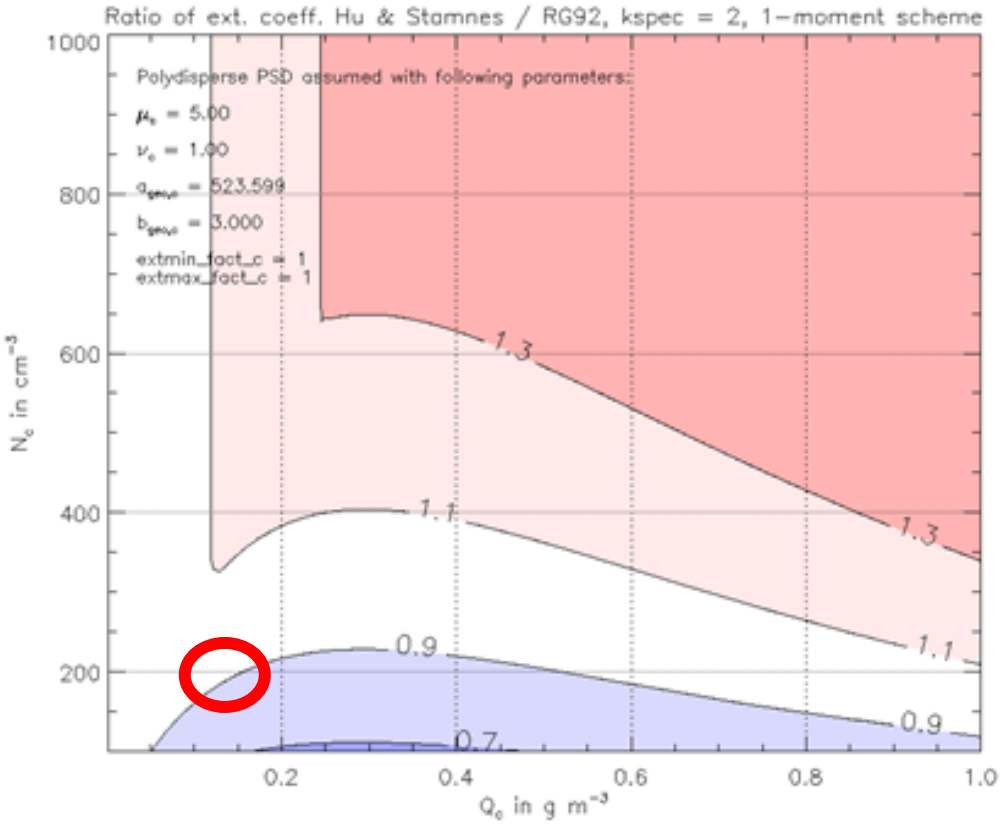
13:00
14:00
15:00
16:00
Time
No cloud
case_1
case_2
case_3
case_4
case_5
case_6
case_7
case_8
case_9
case_10
case_11
case_12

From Uli's Blahak presentation:

Cloud droplets comparison to RG92

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

➔If grid scale qc > 0: from cloud microphysics:



$$f(D) = N_0 D^{\mu} e^{-\lambda D}$$

$\mu = 5.0$

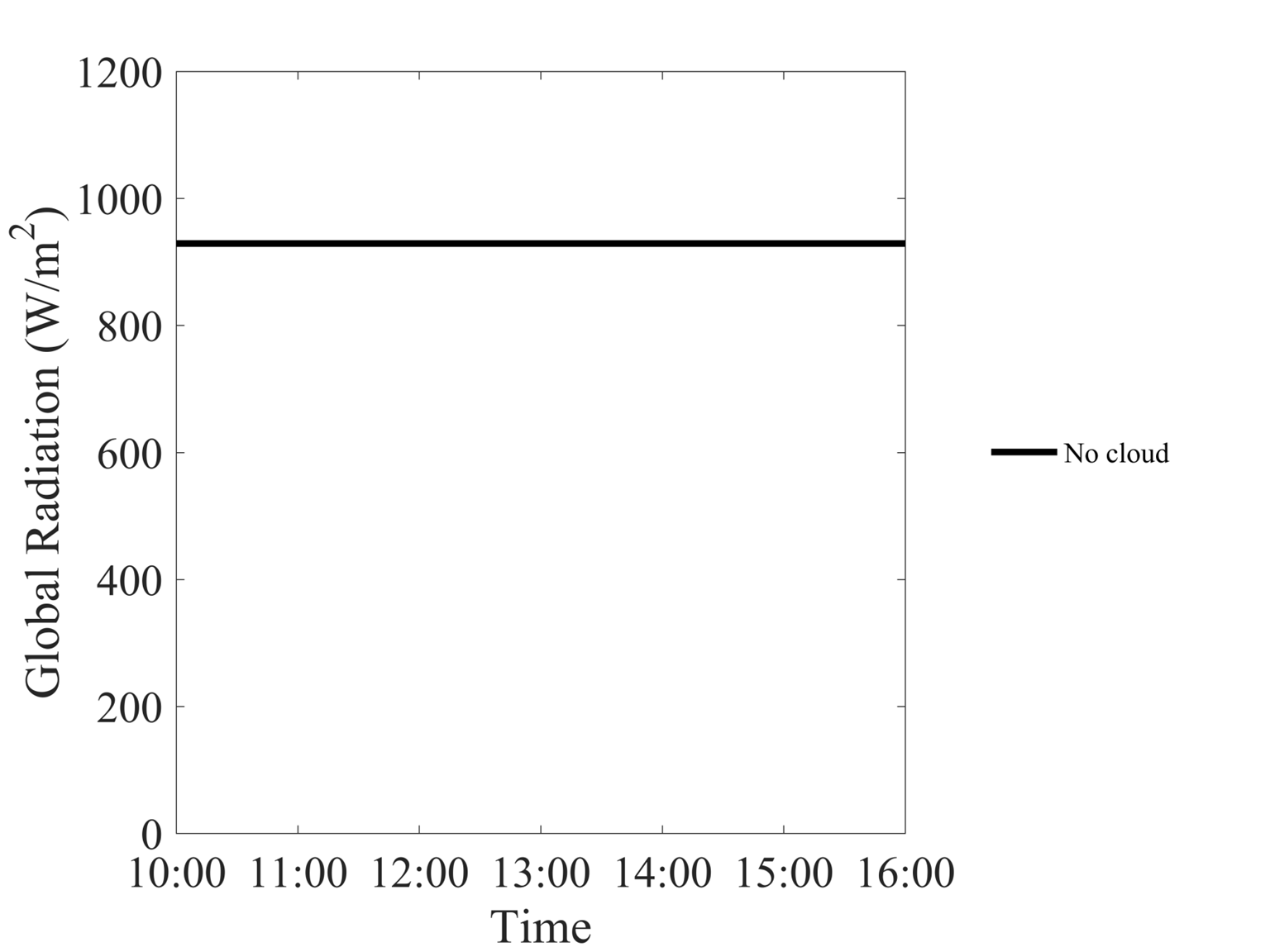
N_c = cloud_num

q_c prognostic

Spectral interval „2“ (visible range)

β_{ext} ratio HS / RG92

True / False switches on Fair weather Cu:


1200
1000
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600
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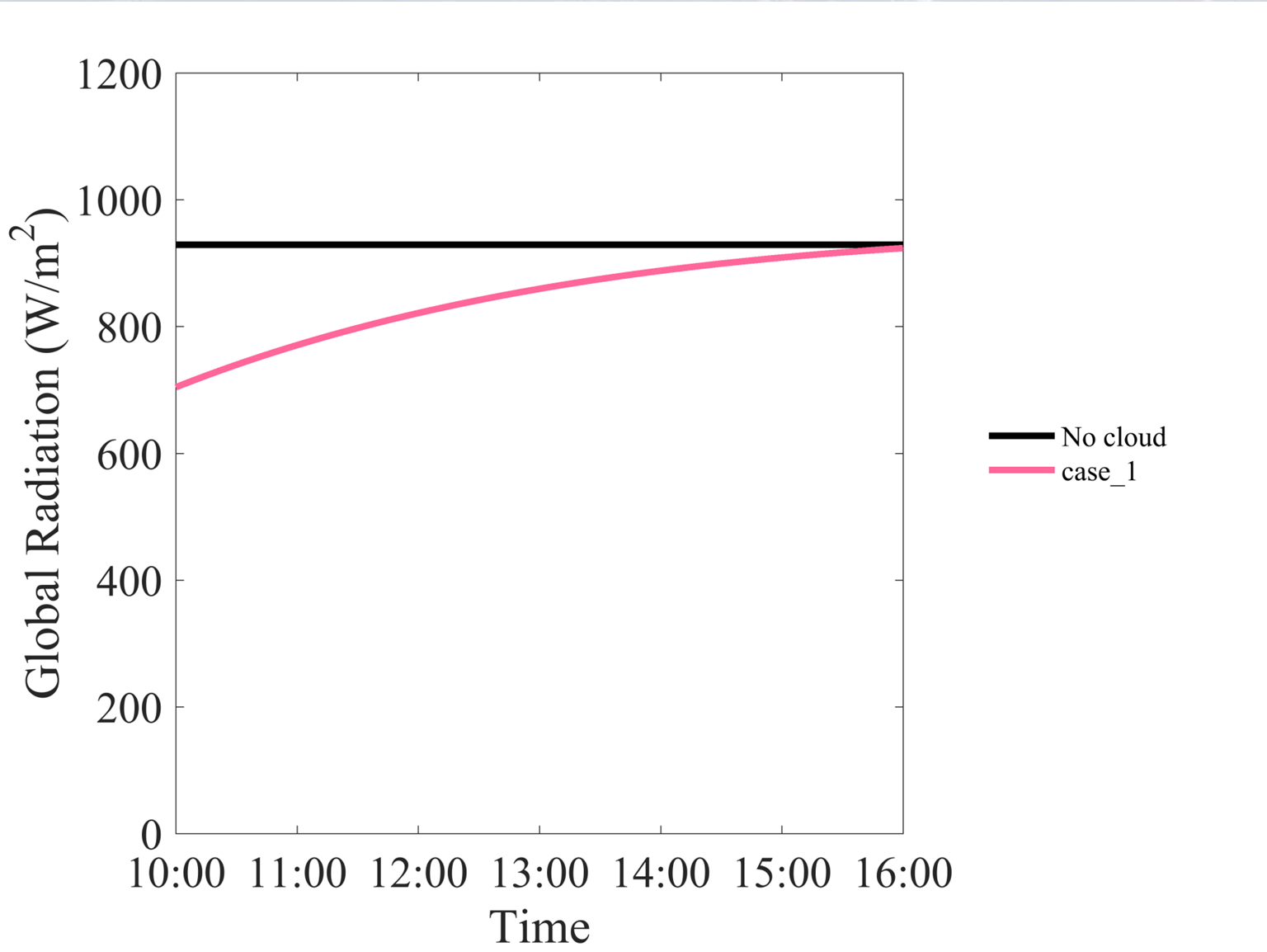
200
0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud


1200
1000
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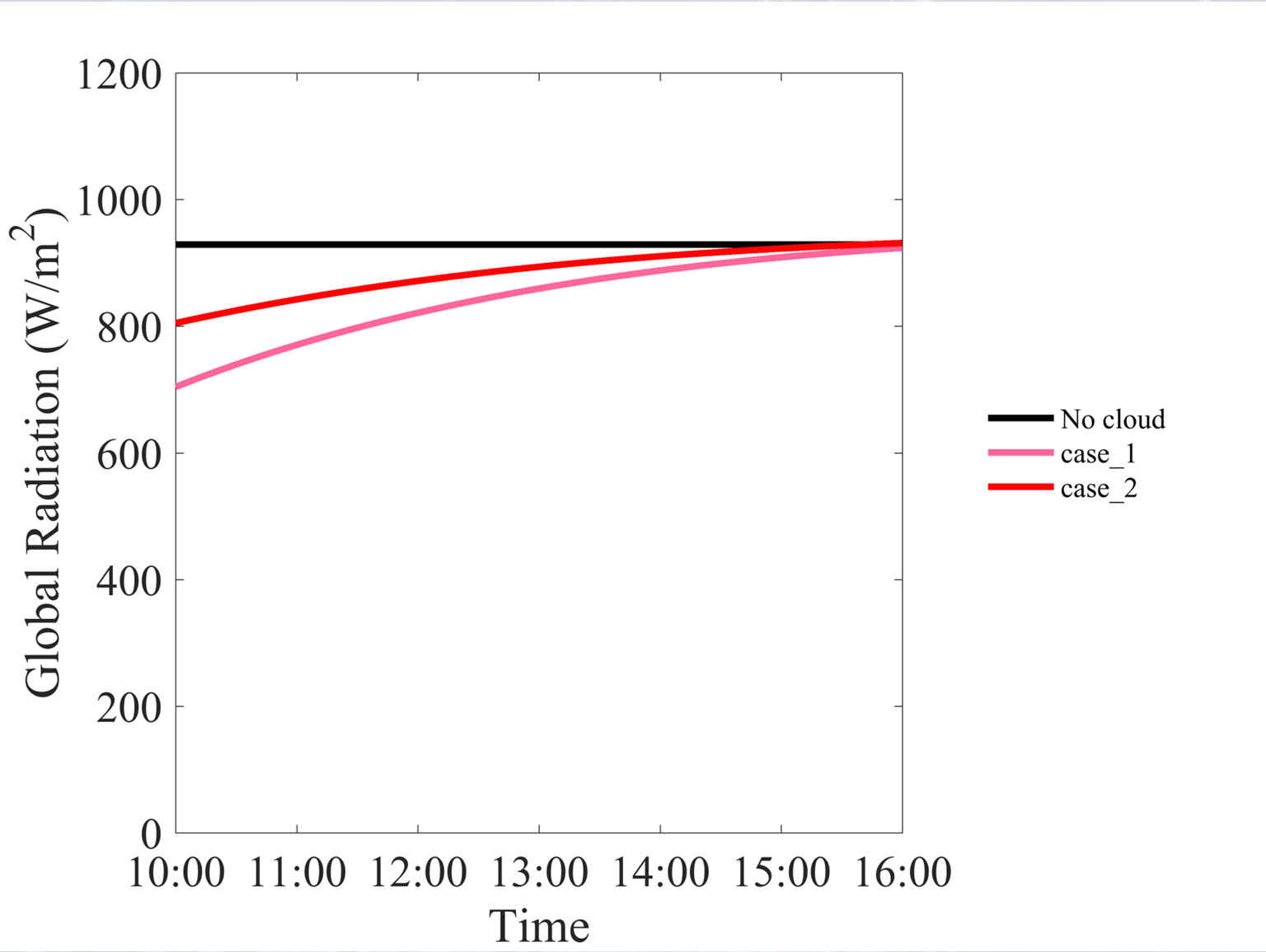
600
400
200
0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1


1200
1000
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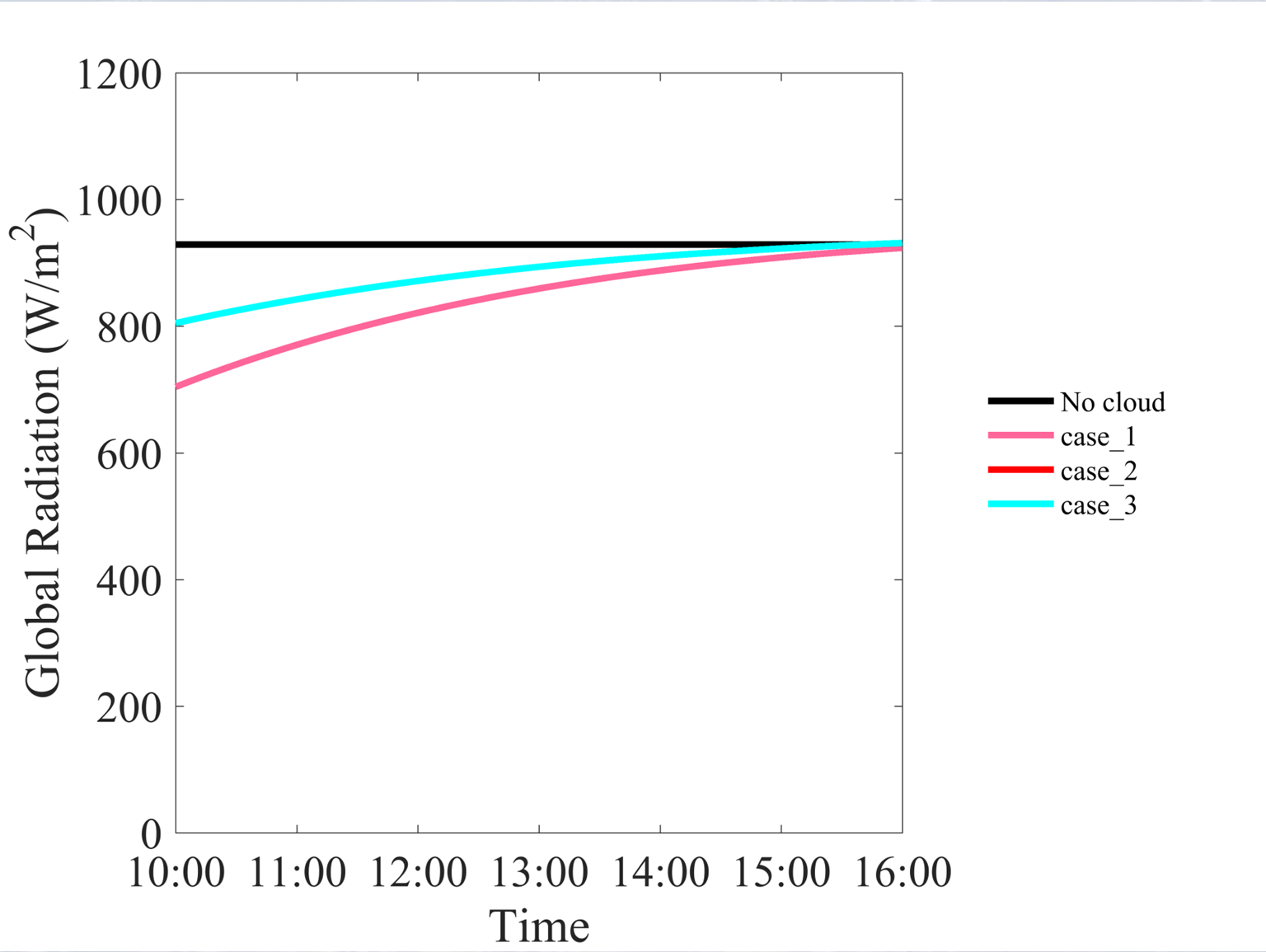
600
400
200
0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1
case_2


1200
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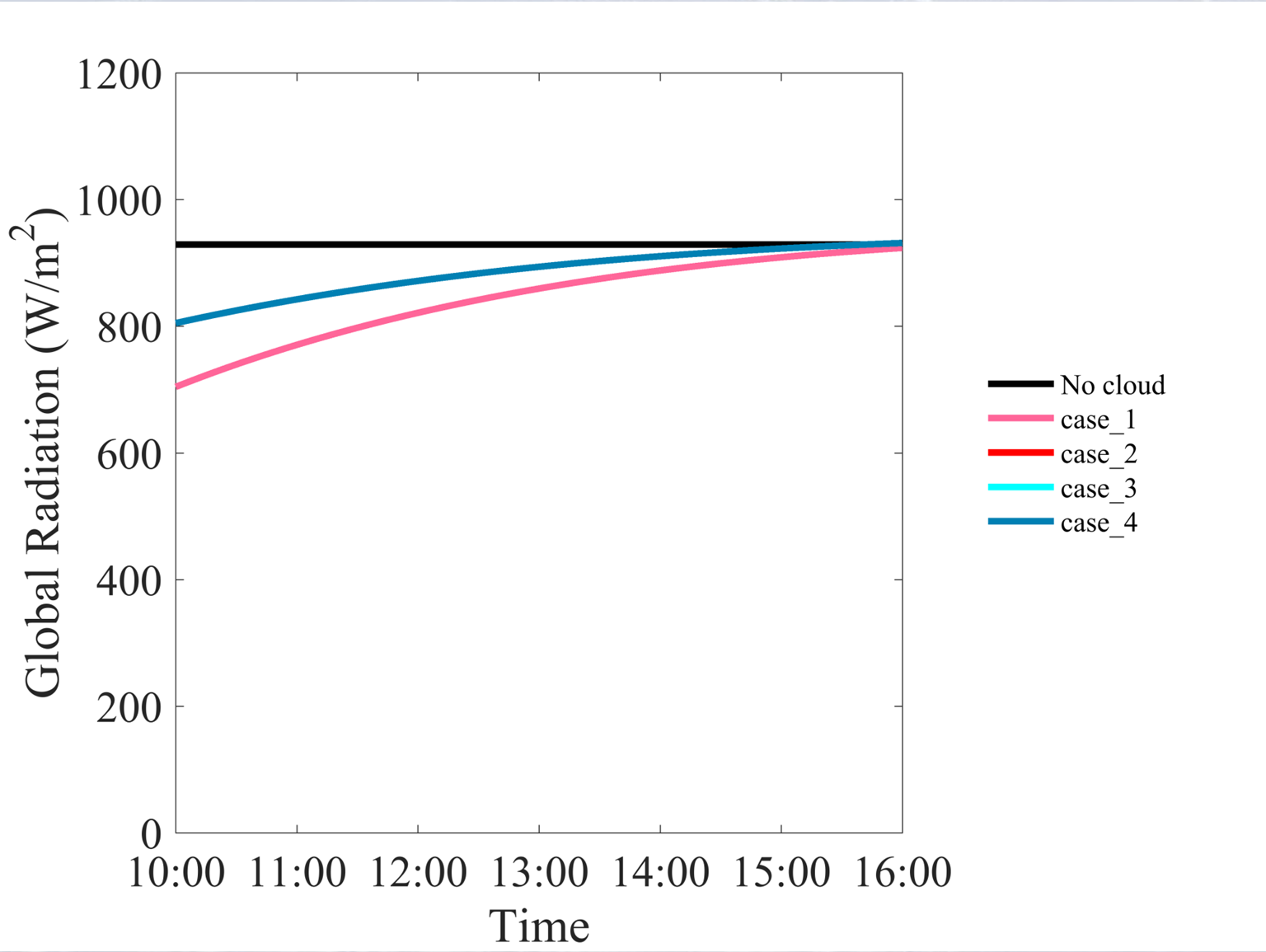
0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1
case_2
case_3


1200
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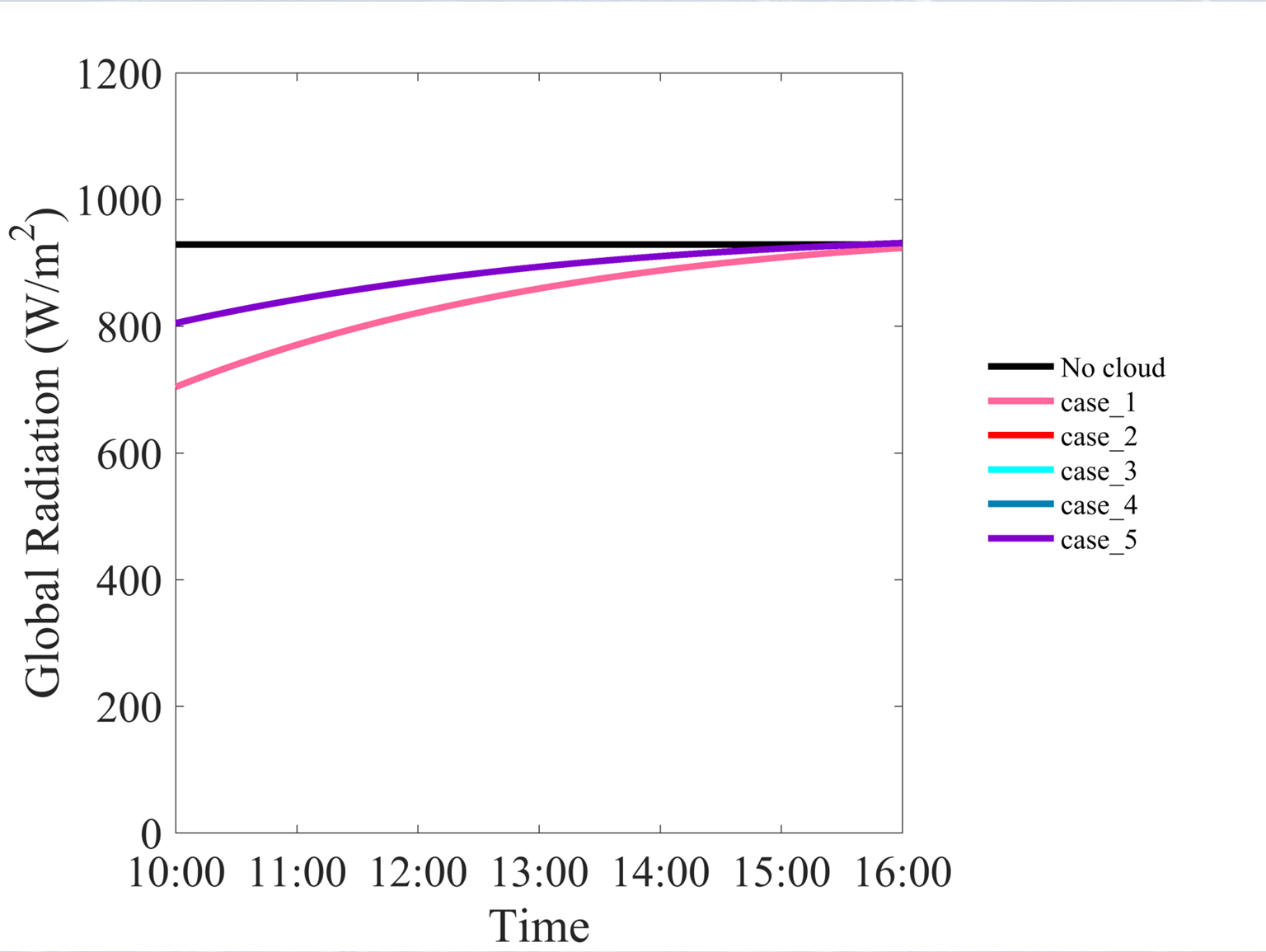
200
0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1
case_2
case_3
case_4


1200
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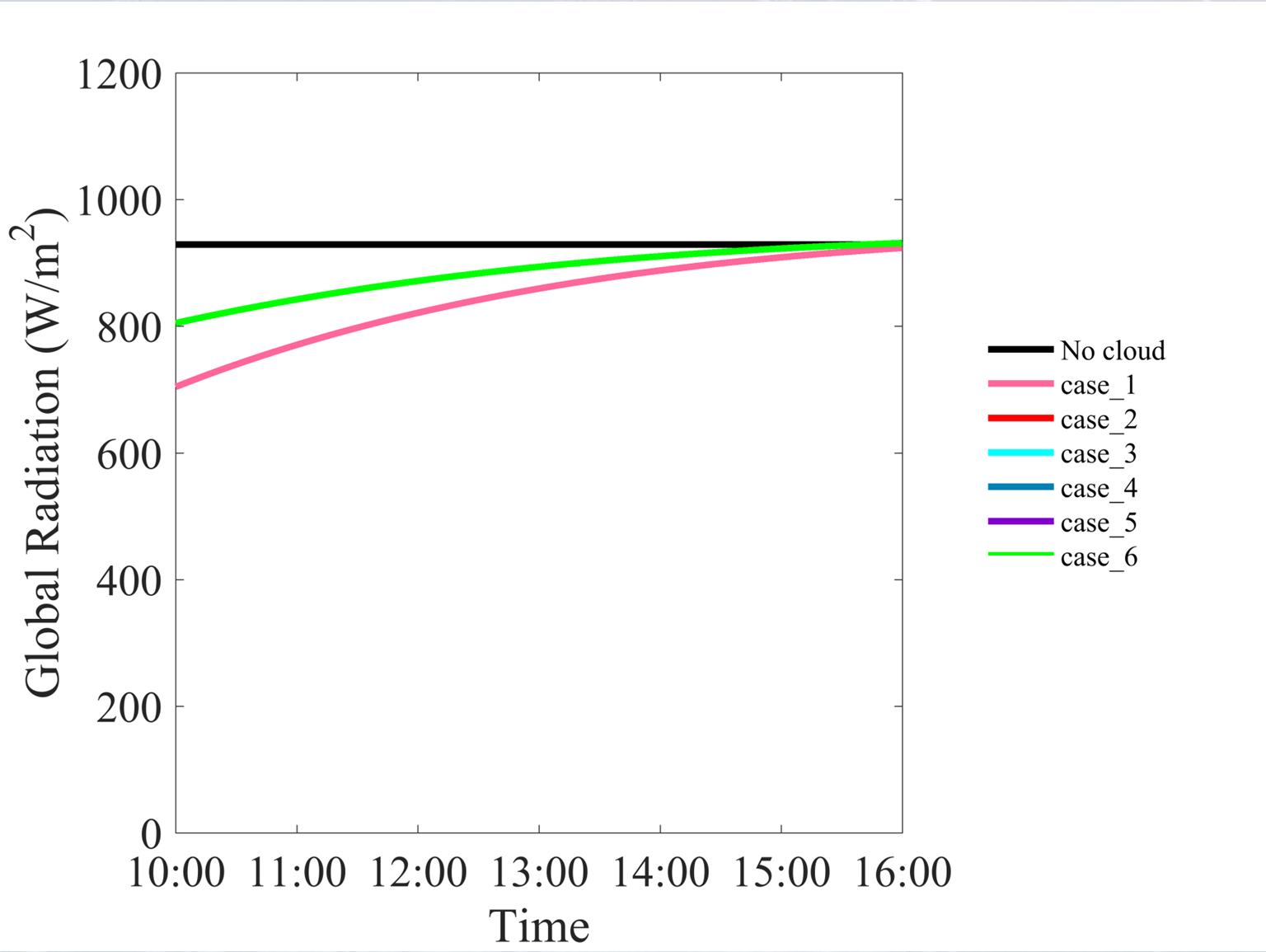
0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1
case_2
case_3
case_4
case_5


1200
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0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
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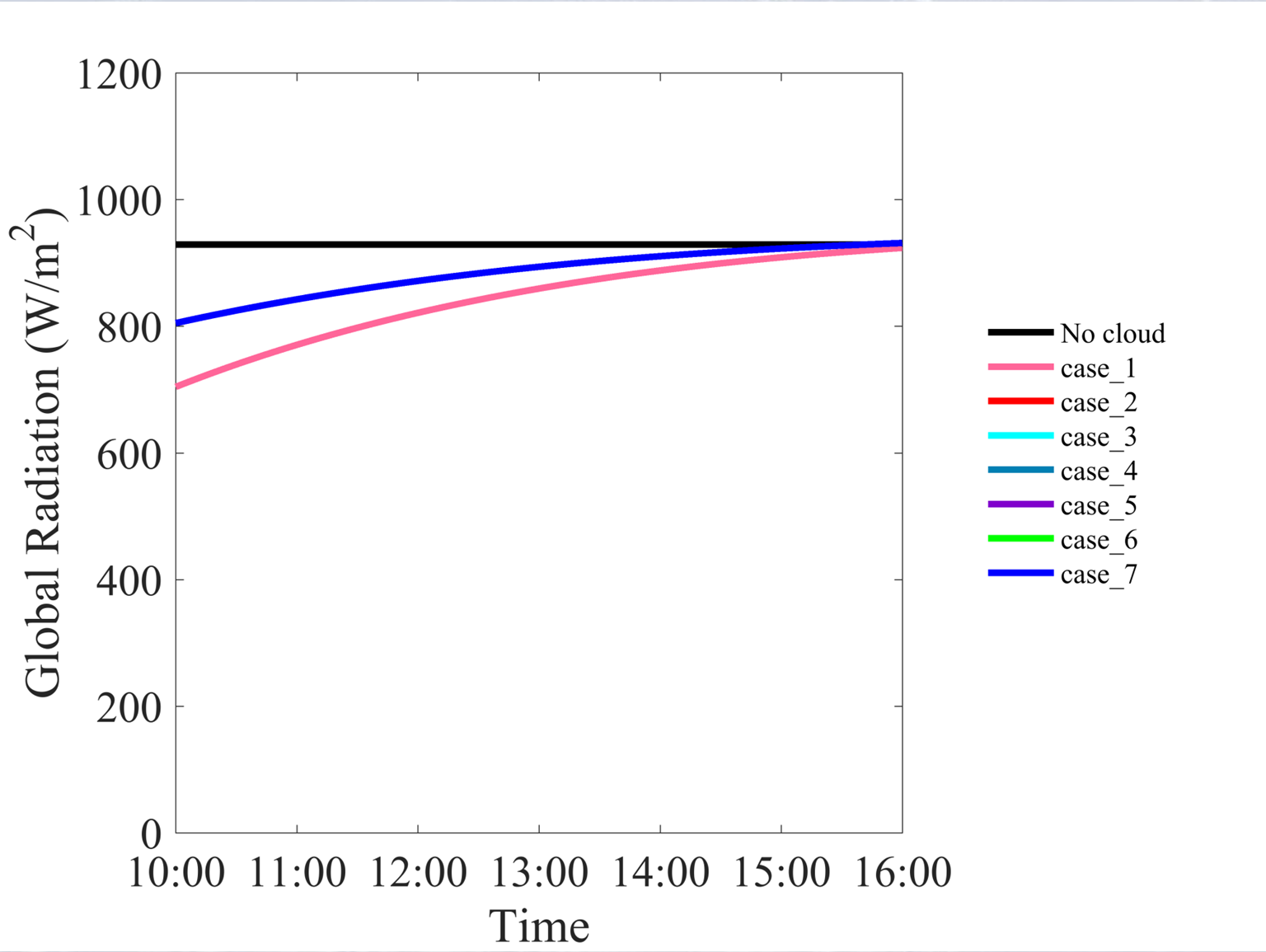
16:00
Time
No cloud
case_1
case_2
case_3
case_4
case_5
case_6


1200
1000
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200
0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
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Time
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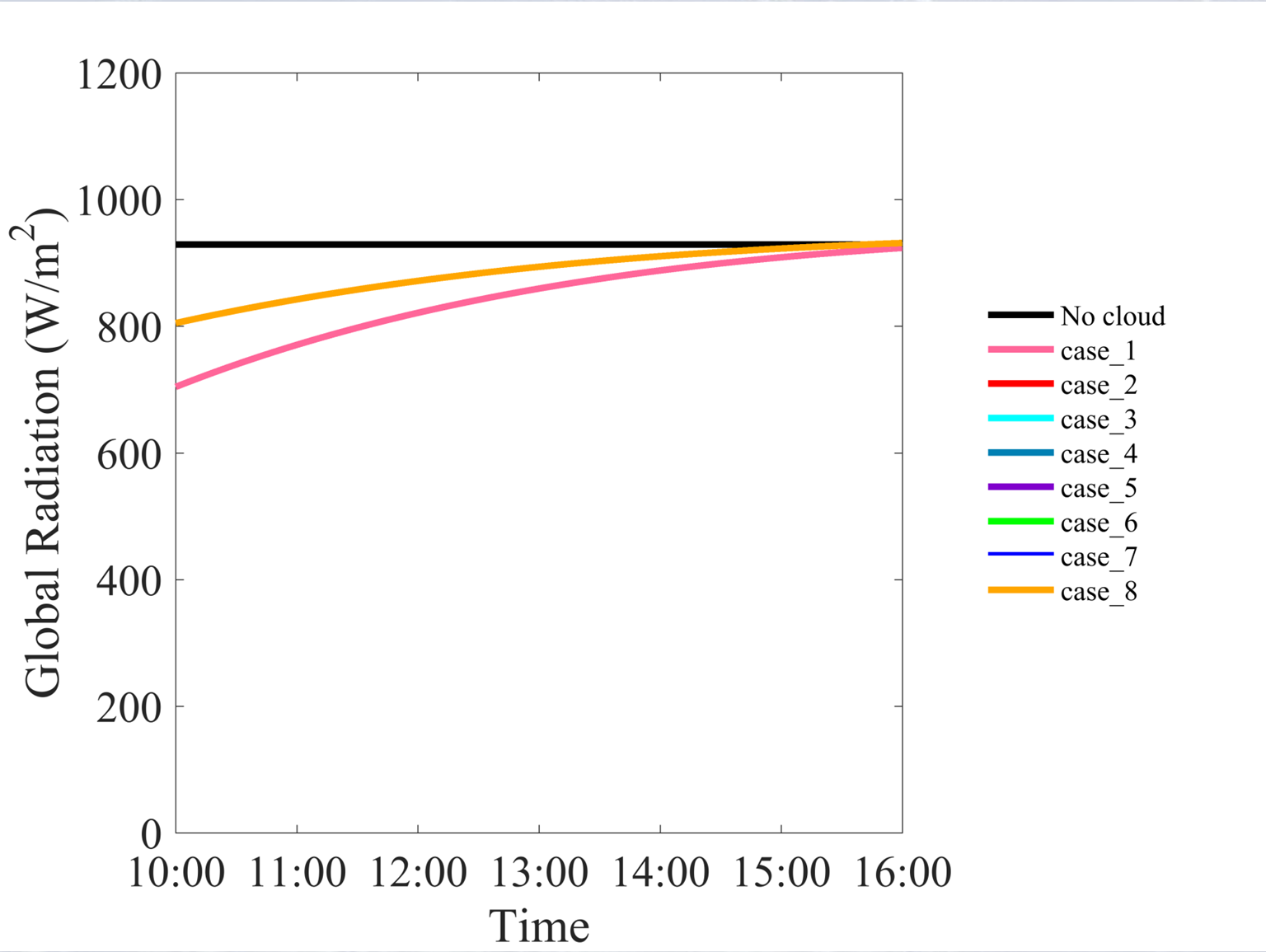
case_1
case_2
case_3
case_4
case_5
case_6
case_7


1200
1000
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Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
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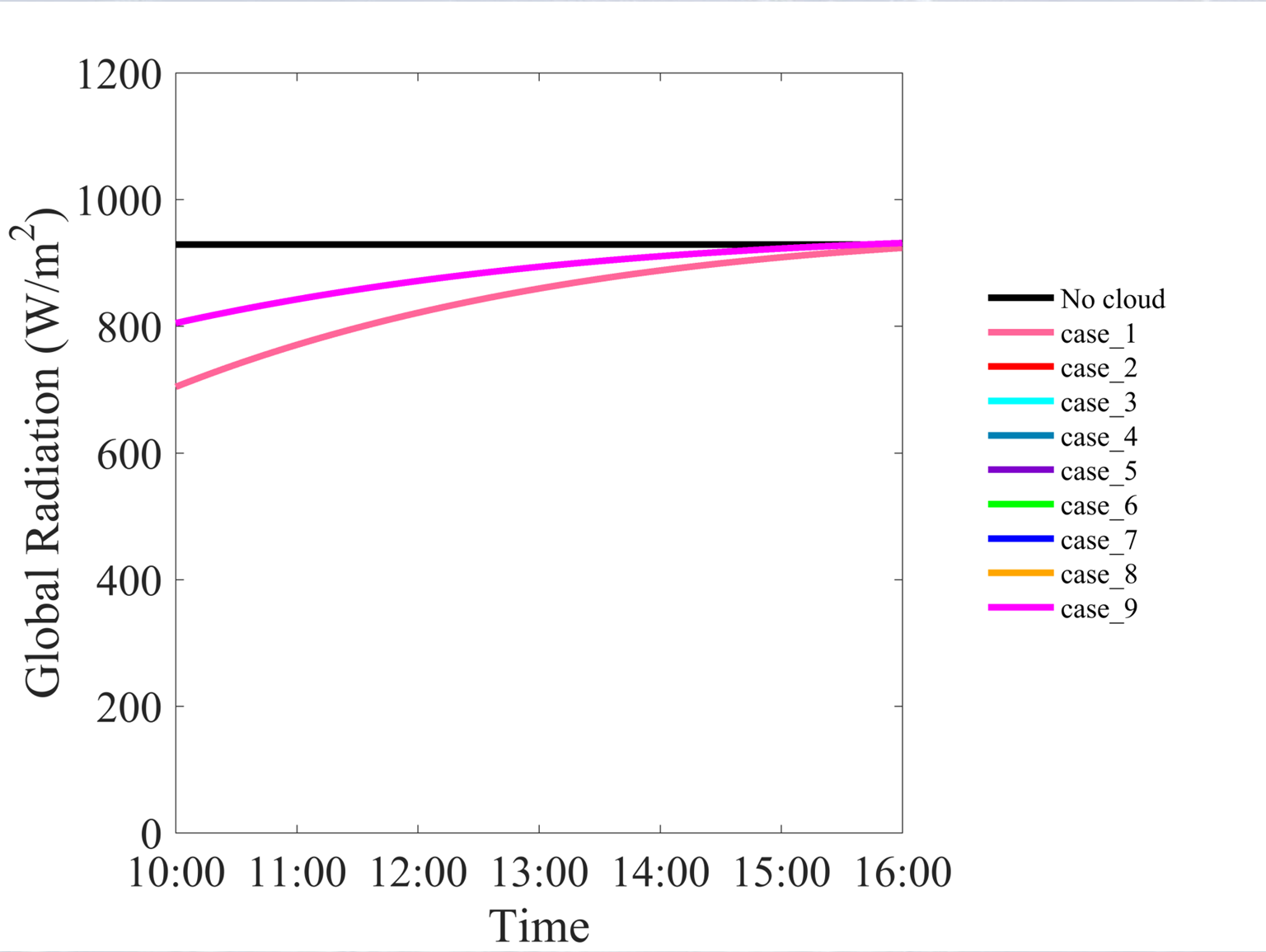
Time
No cloud
case_1
case_2
case_3
case_4
case_5
case_6
case_7
case_8


1200
1000
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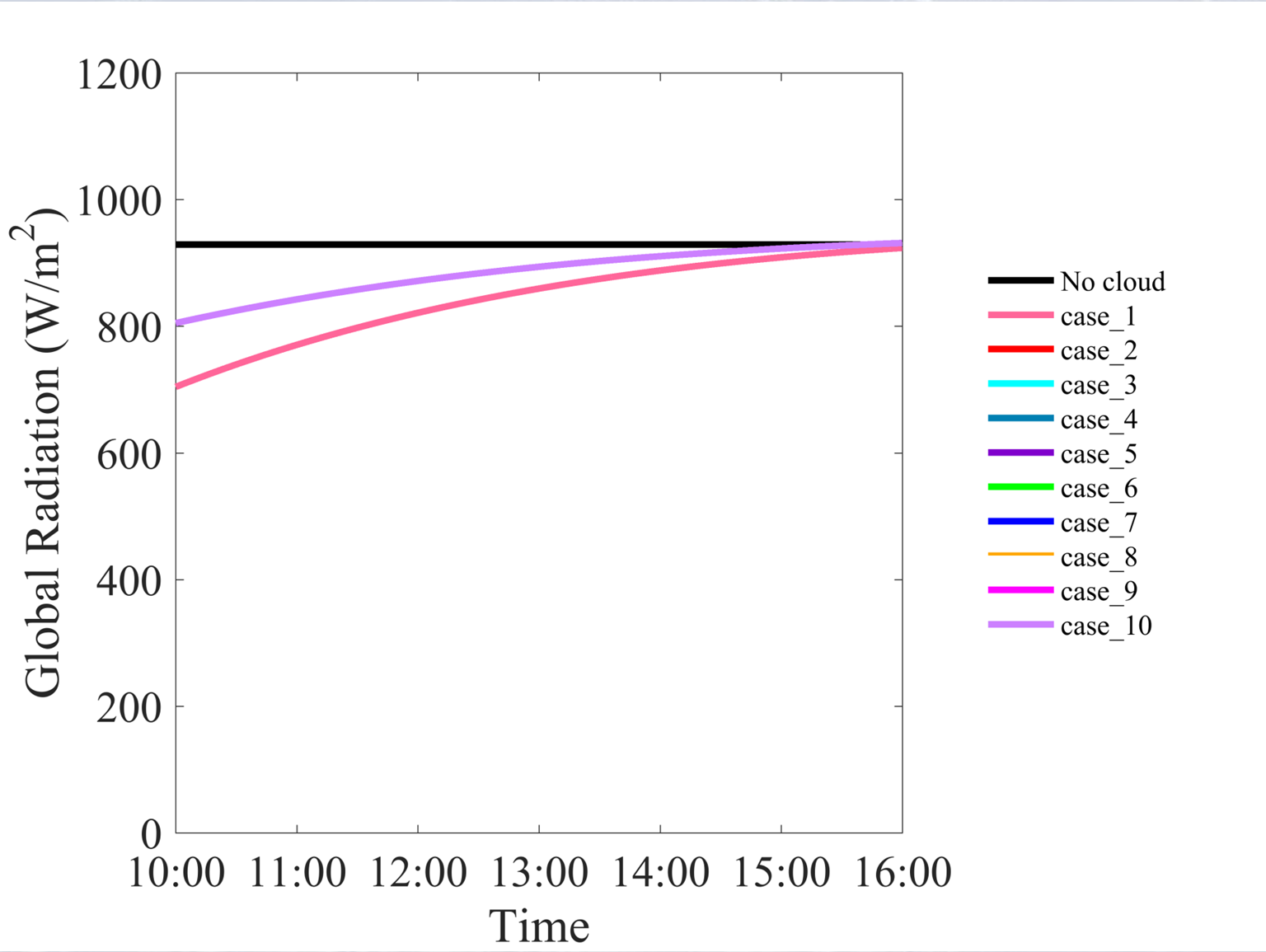
0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1
case_2
case_3
case_4
case_5
case_6
case_7
case_8
case_9


1200
1000
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400
200
0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1
case_2
case_3
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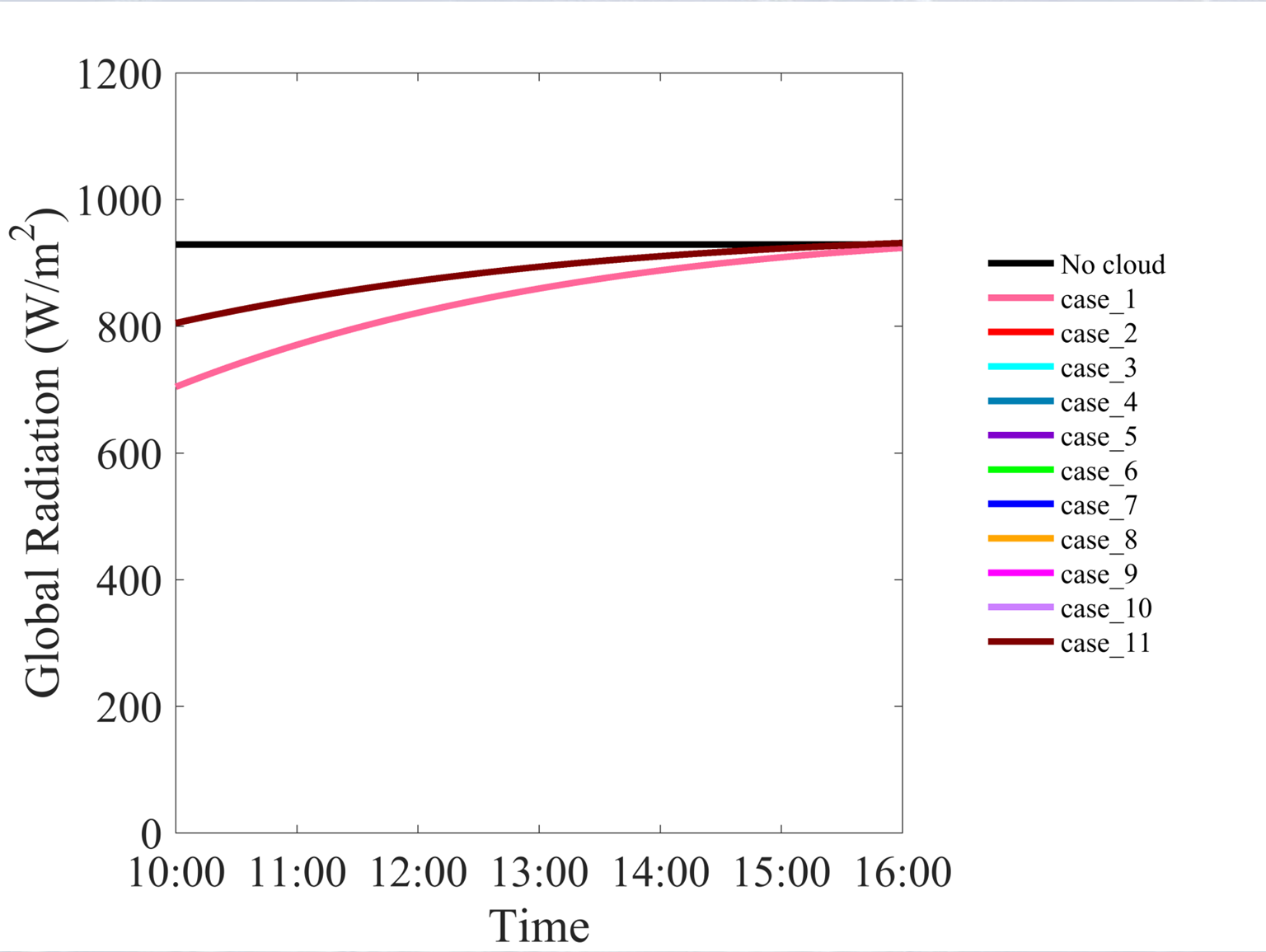
case_5
case_6
case_7
case_8
case_9
case_10


1200
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0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1
case_2
case_3
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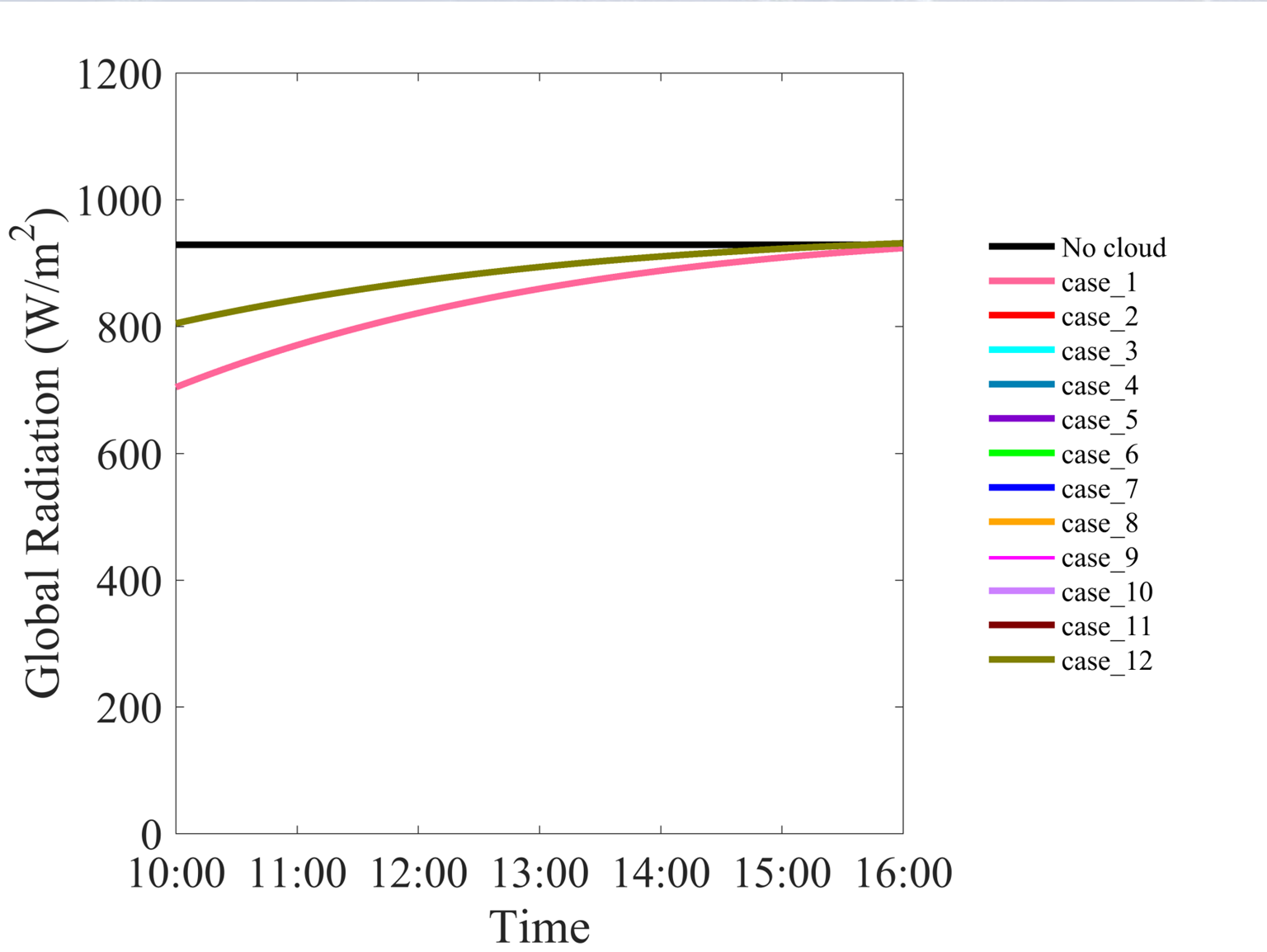
case_6
case_7
case_8
case_9
case_10
case_11


1200
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0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1
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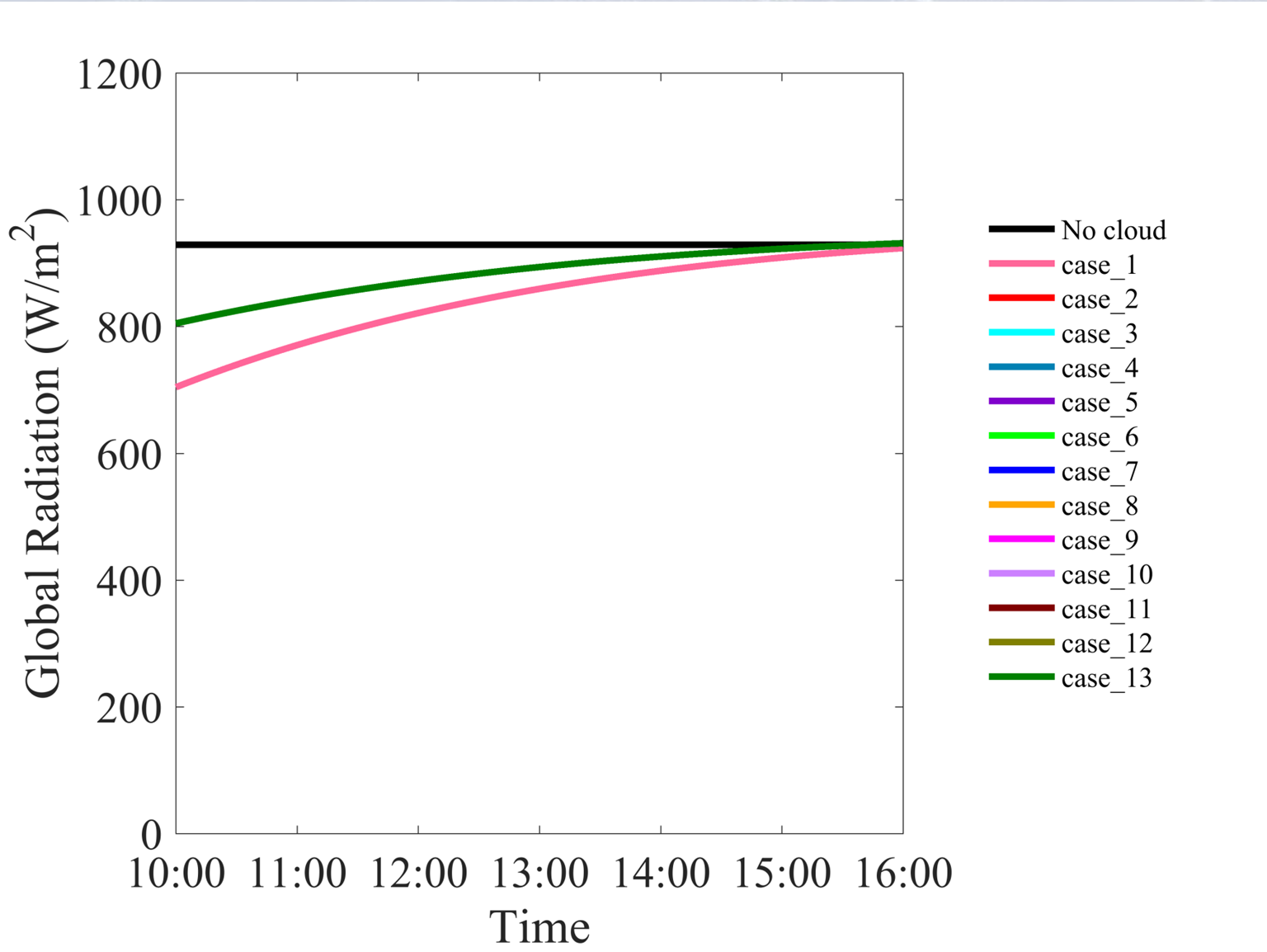
case_7
case_8
case_9
case_10
case_11
case_12


1200
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400
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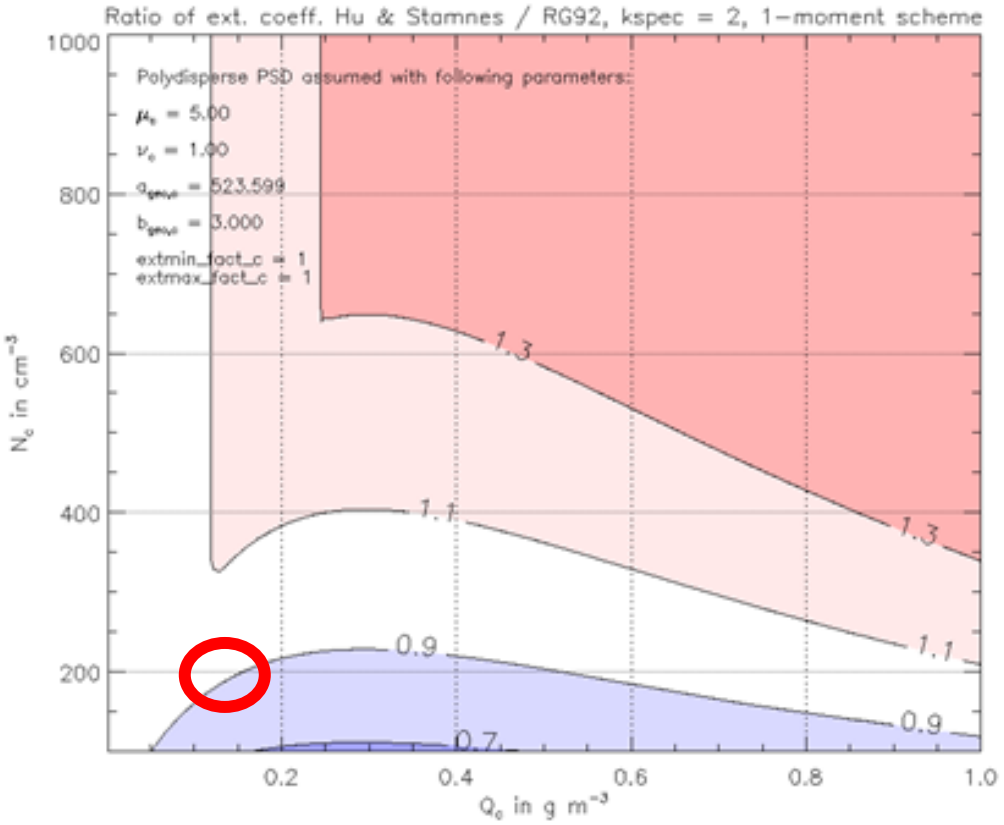
0
Global Radiation (W/m2)
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time
No cloud
case_1
case_2
case_3
case_4
case_5
case_6
case_7
case_8
case_9
case_10
case_11
case_12
case_13

From Uli's Blahak presentation:

Cloud droplets comparison to RG92

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

➔If grid scale qc > 0: from cloud microphysics:



$$f(D) = N_0 D^{\mu} e^{-\lambda D}$$

$\mu = 5.0$

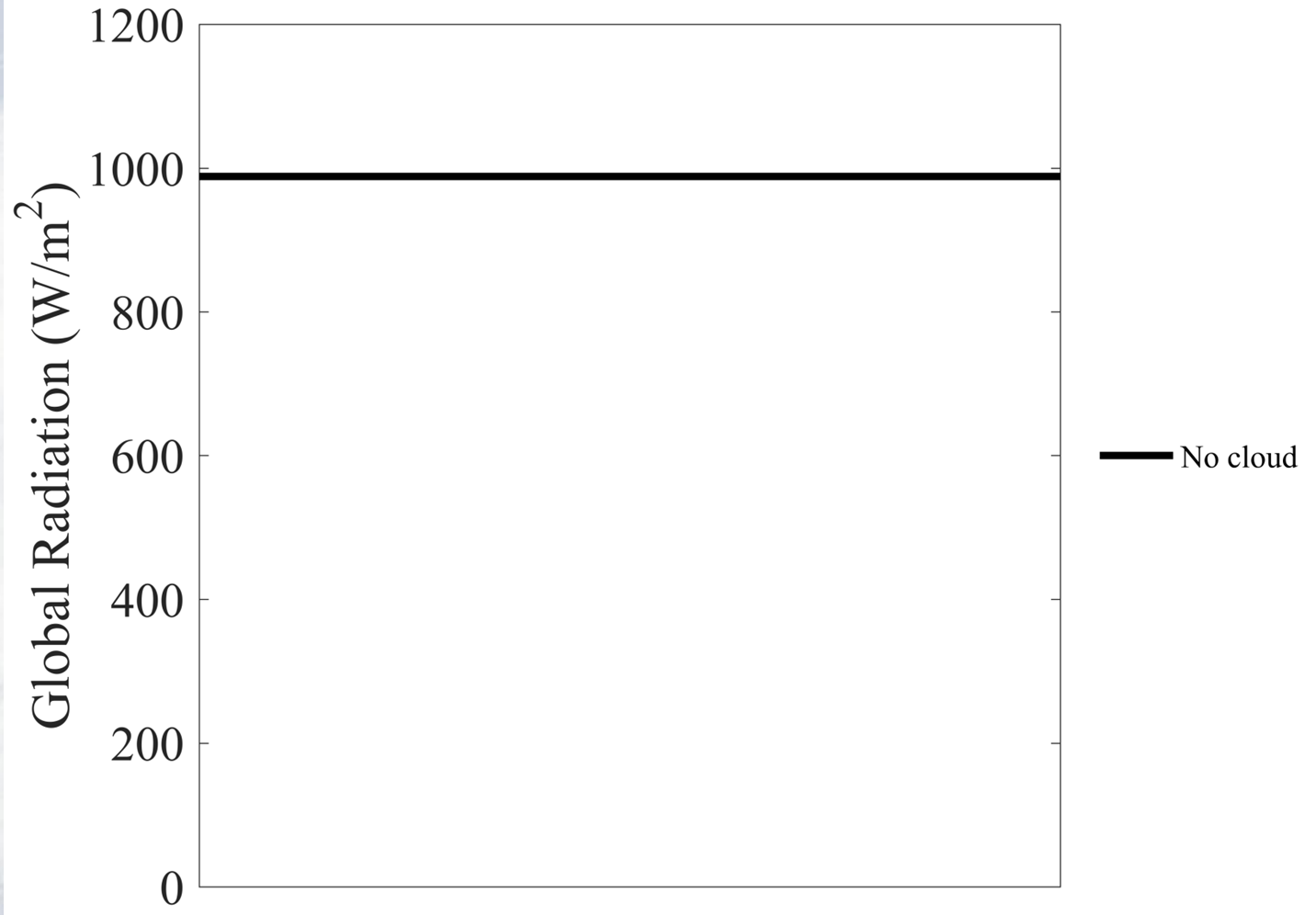
N_c = cloud_num

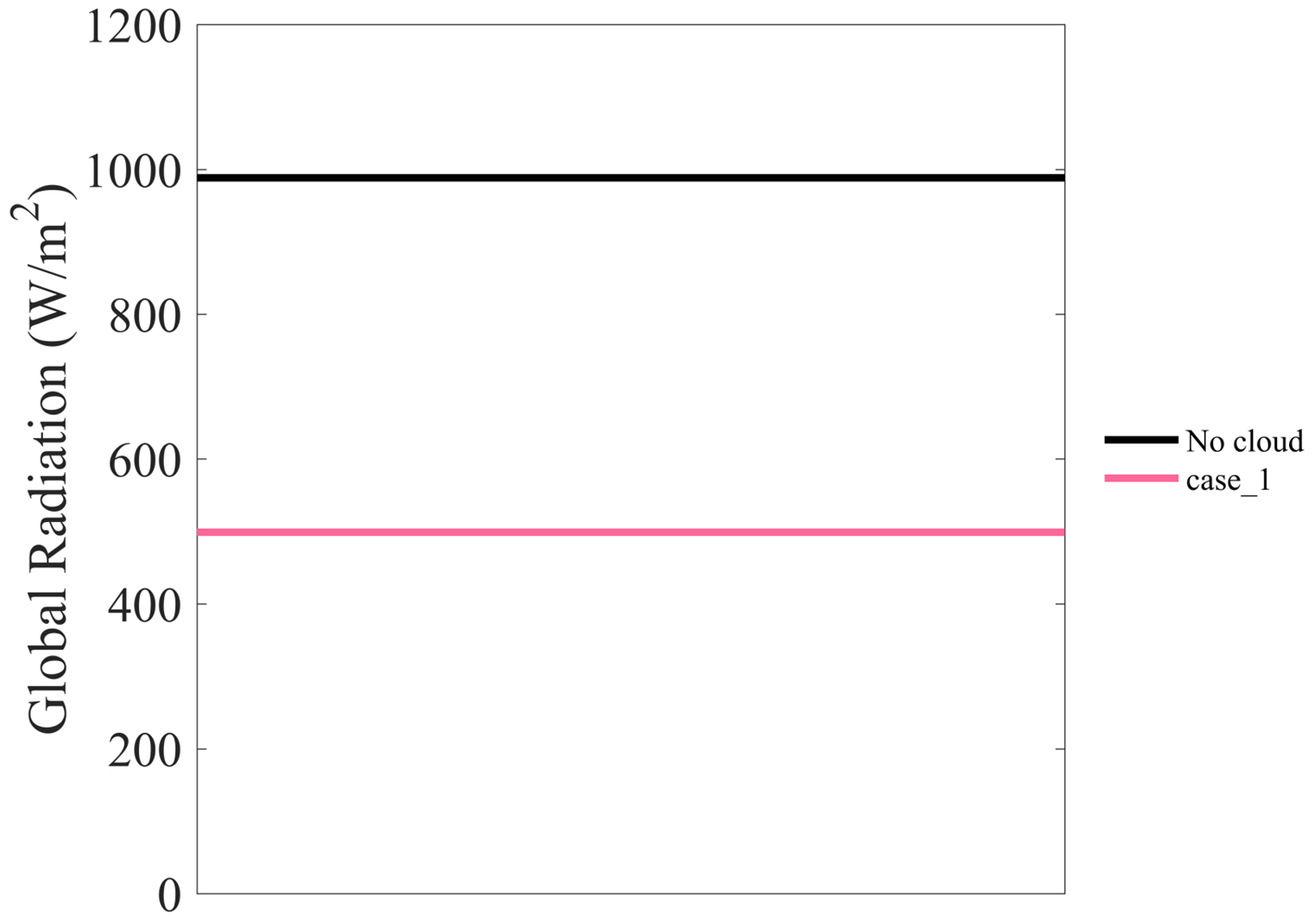
q_c prognostic

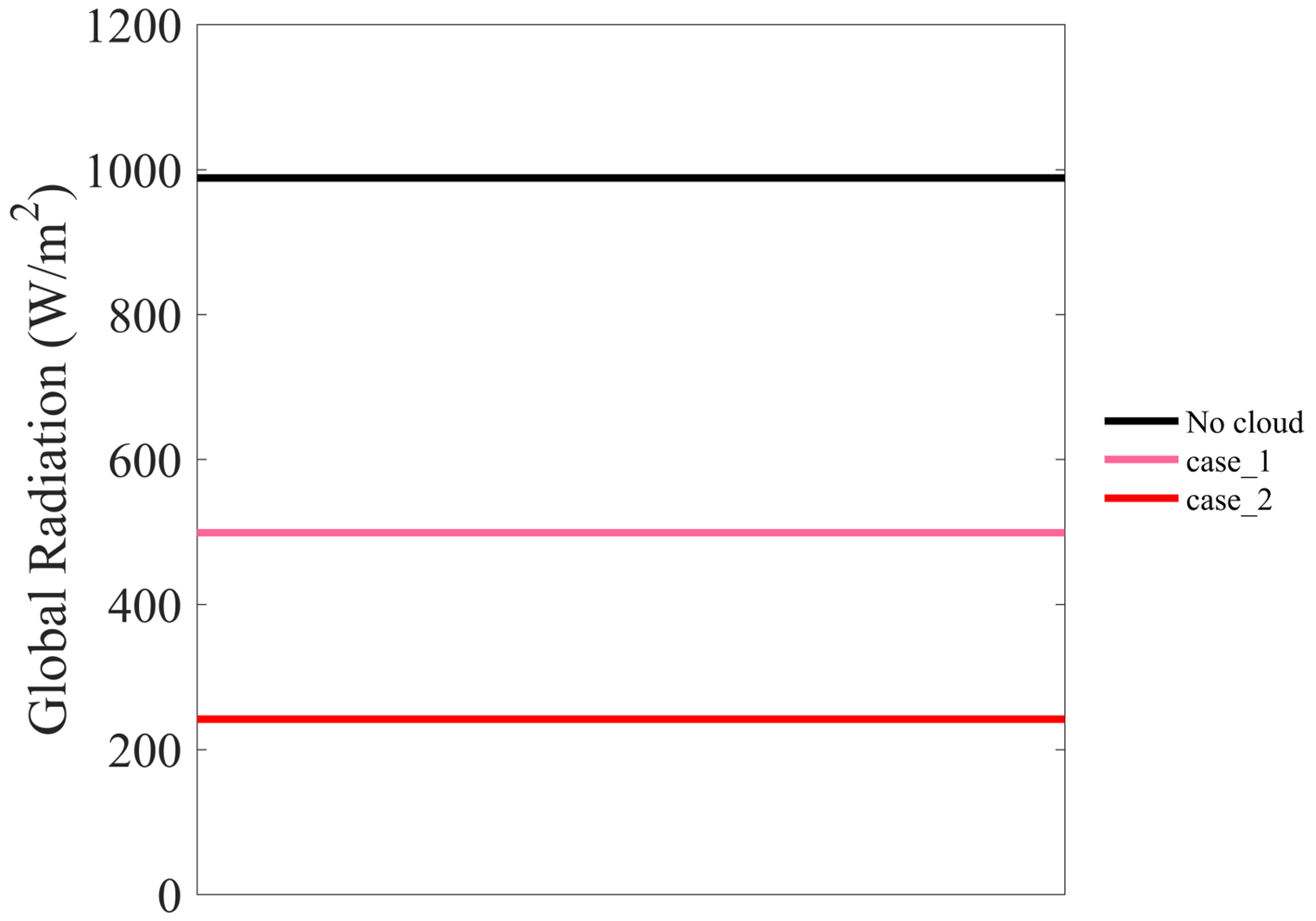
Spectral interval „2“ (visible range)

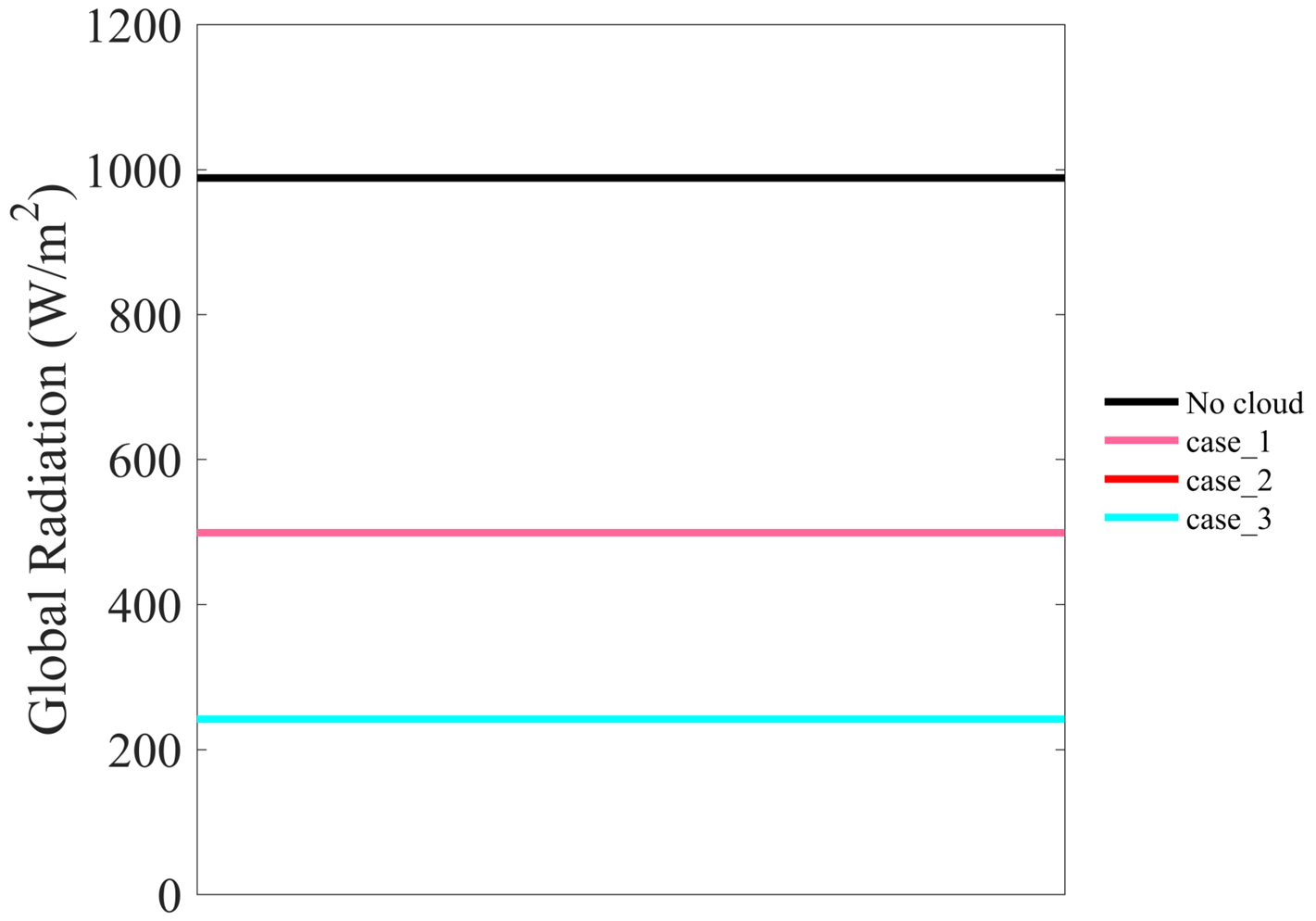
β_{ext} ratio HS / RG92

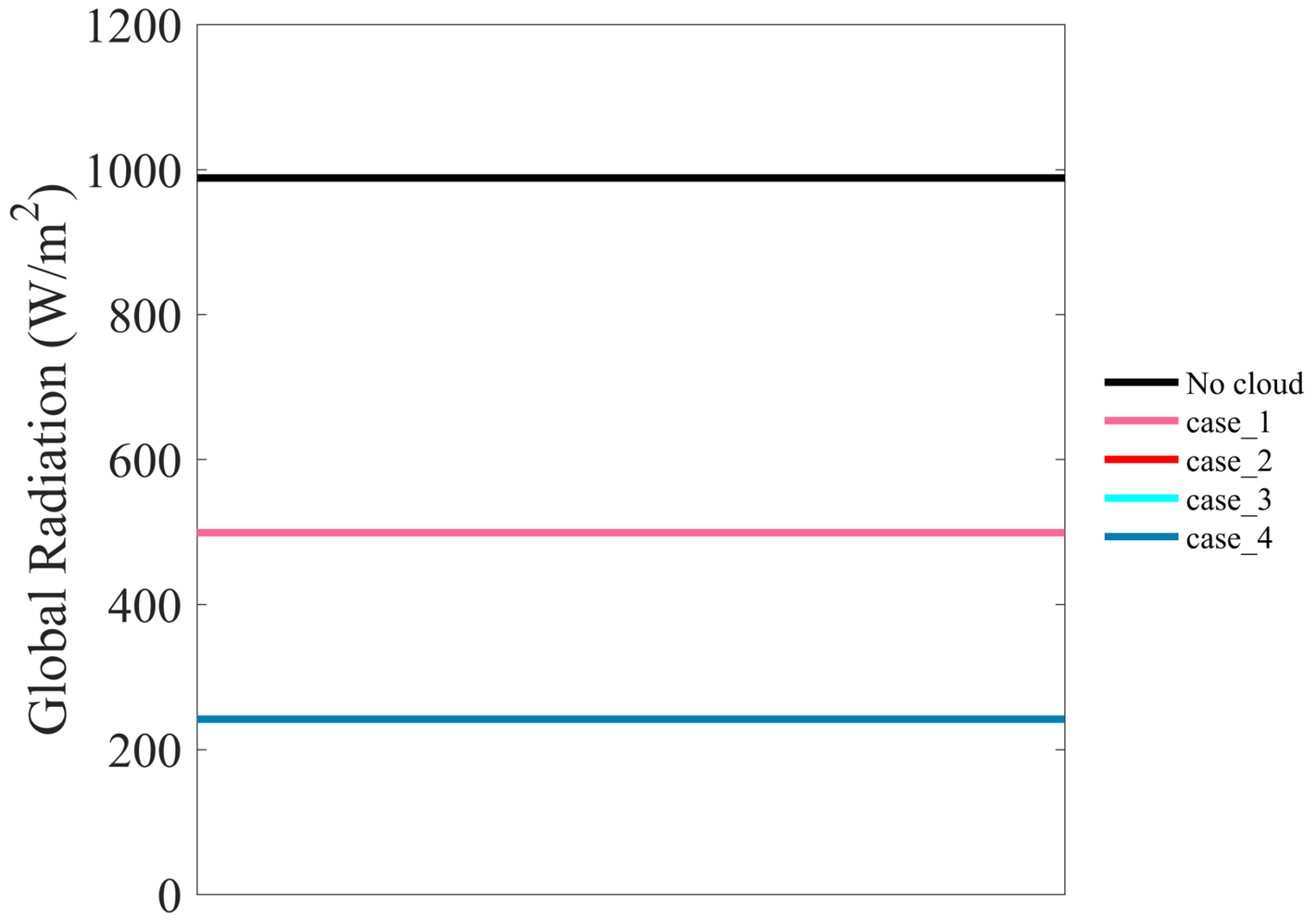
True / False switches on Anvil:


1200
1000
800
600
400
200
0
Global Radiation (W/m2)
No cloud


1200
1000
800
600
400
200
0
Global Radiation (W/m2)
No cloud
case_1


1200
1000
800
600
400
200
0
Global Radiation (W/m2)
No cloud
case_1
case_2


1200
1000
800
600
400
200
0
Global Radiation (W/m2)
No cloud
case_1
case_2
case_3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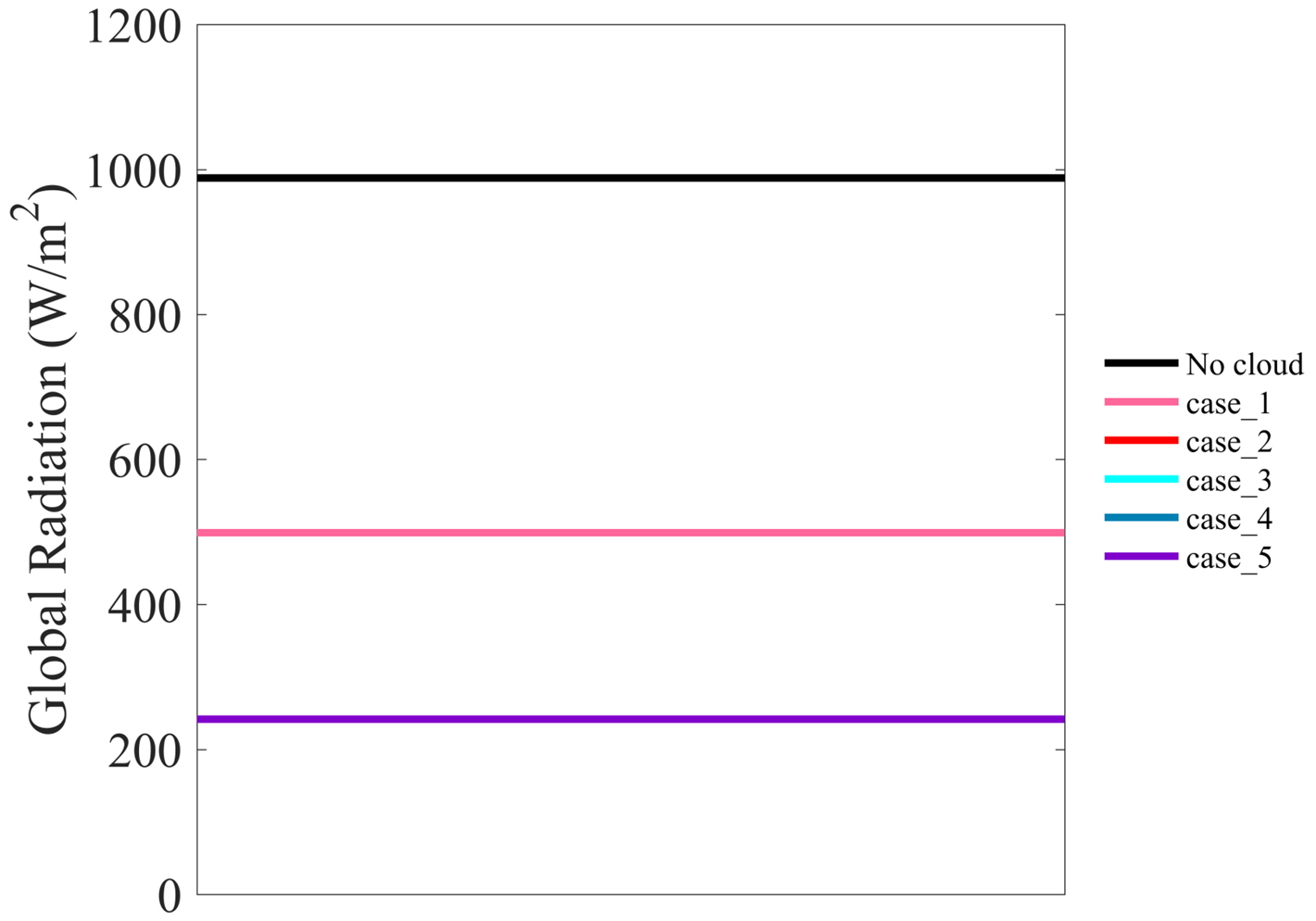
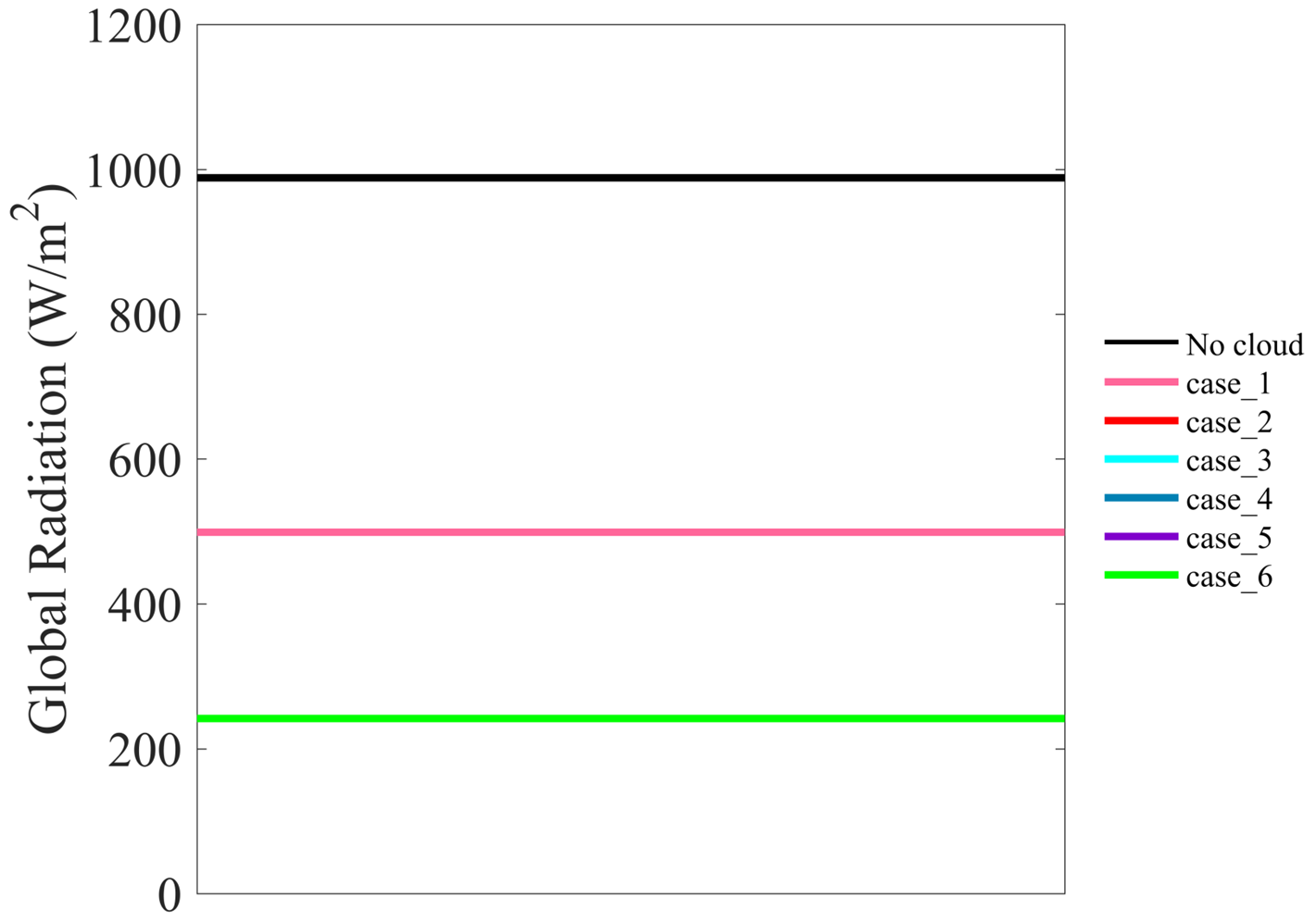
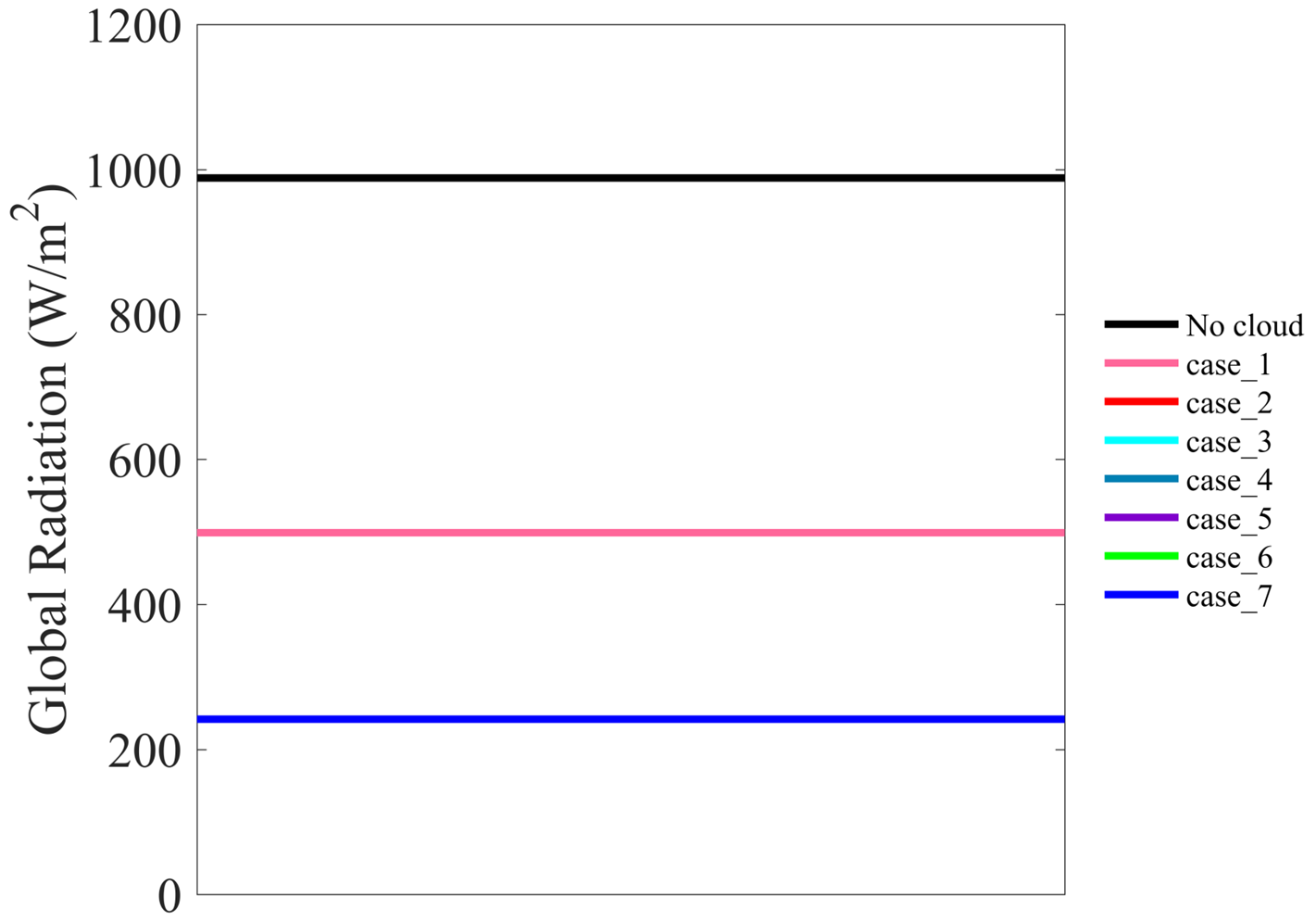
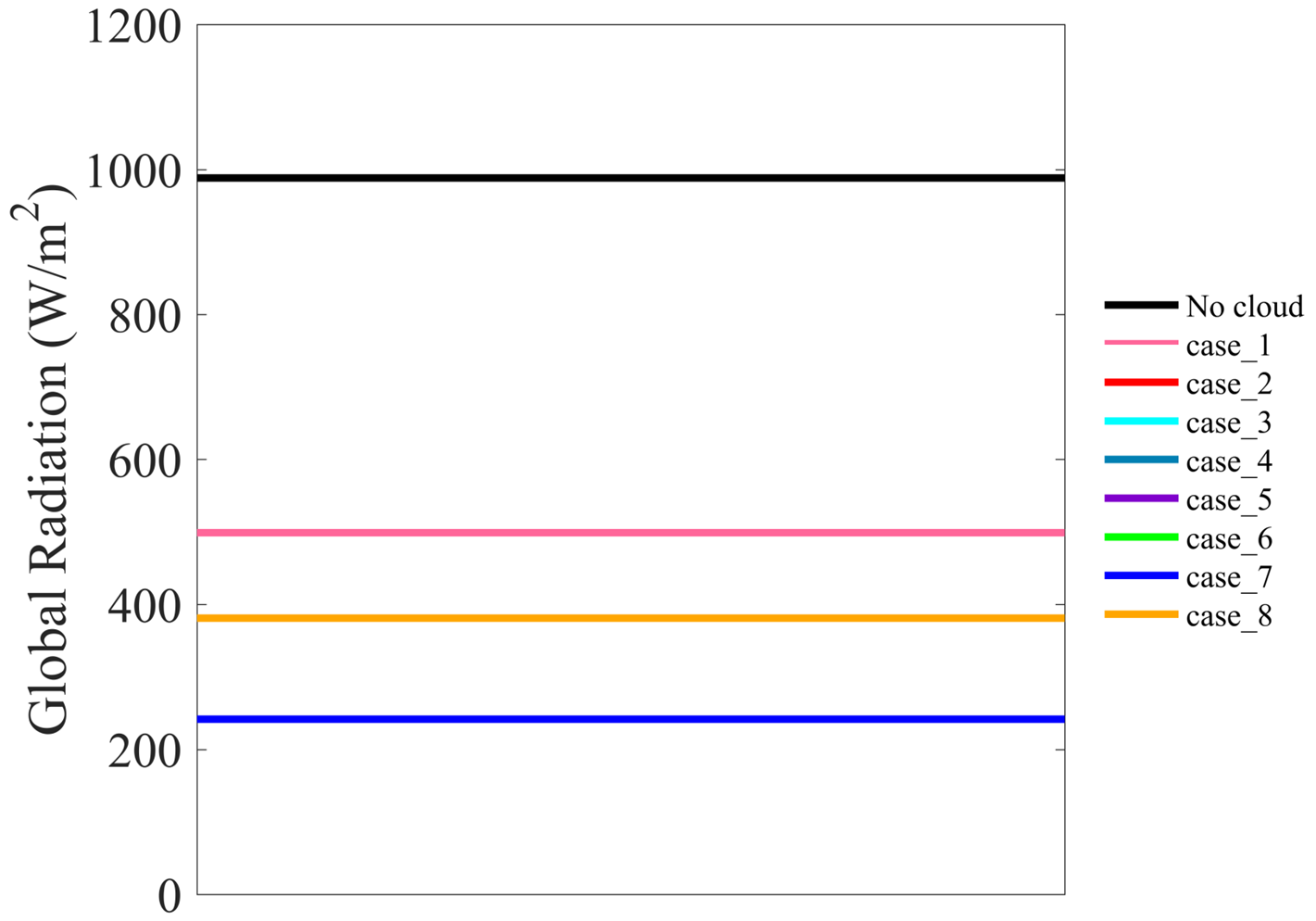
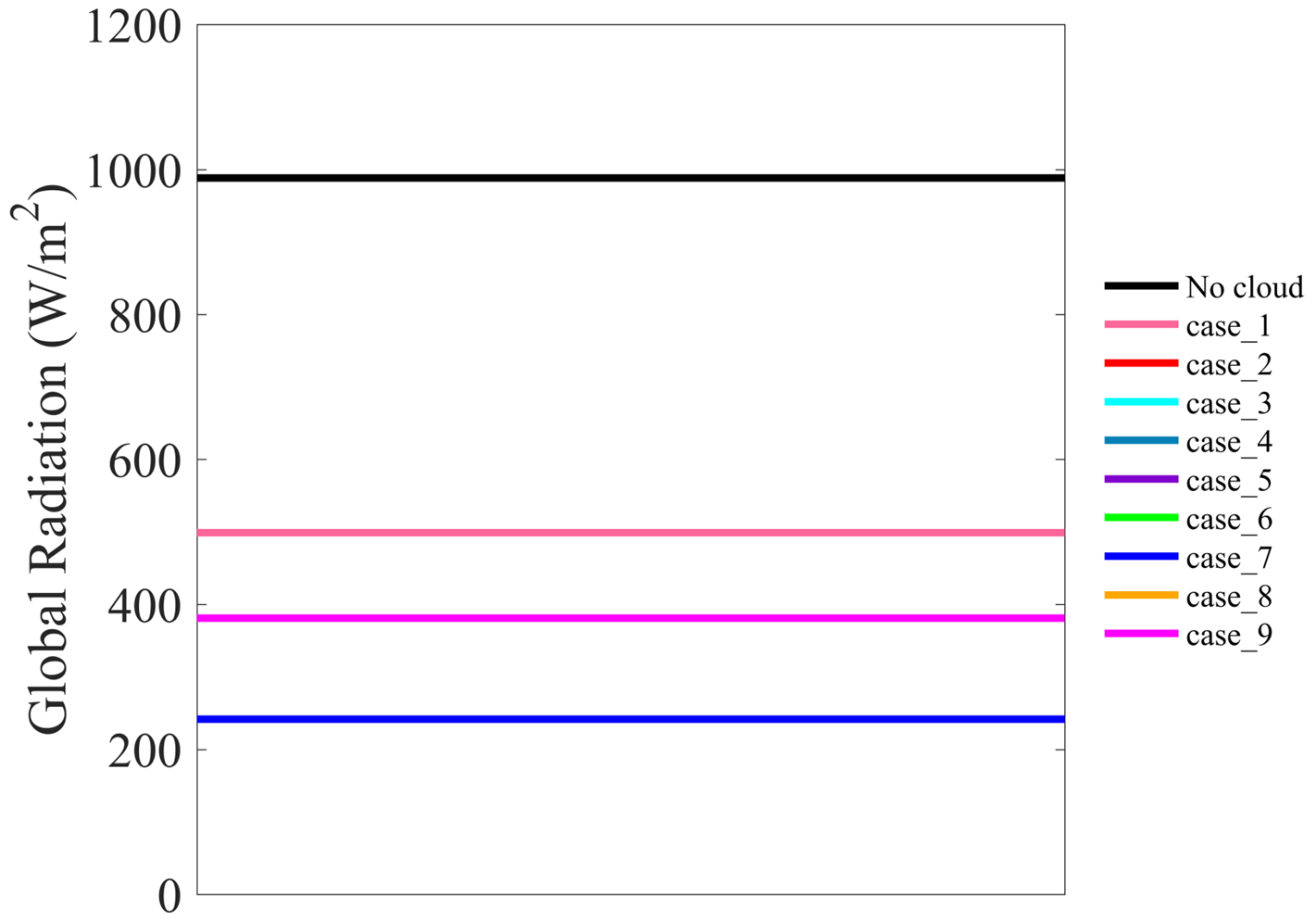
1000
800
600
400
200
0
Global Radiation (W/m2)
No cloud
case_1
case_2
case_3
case_4

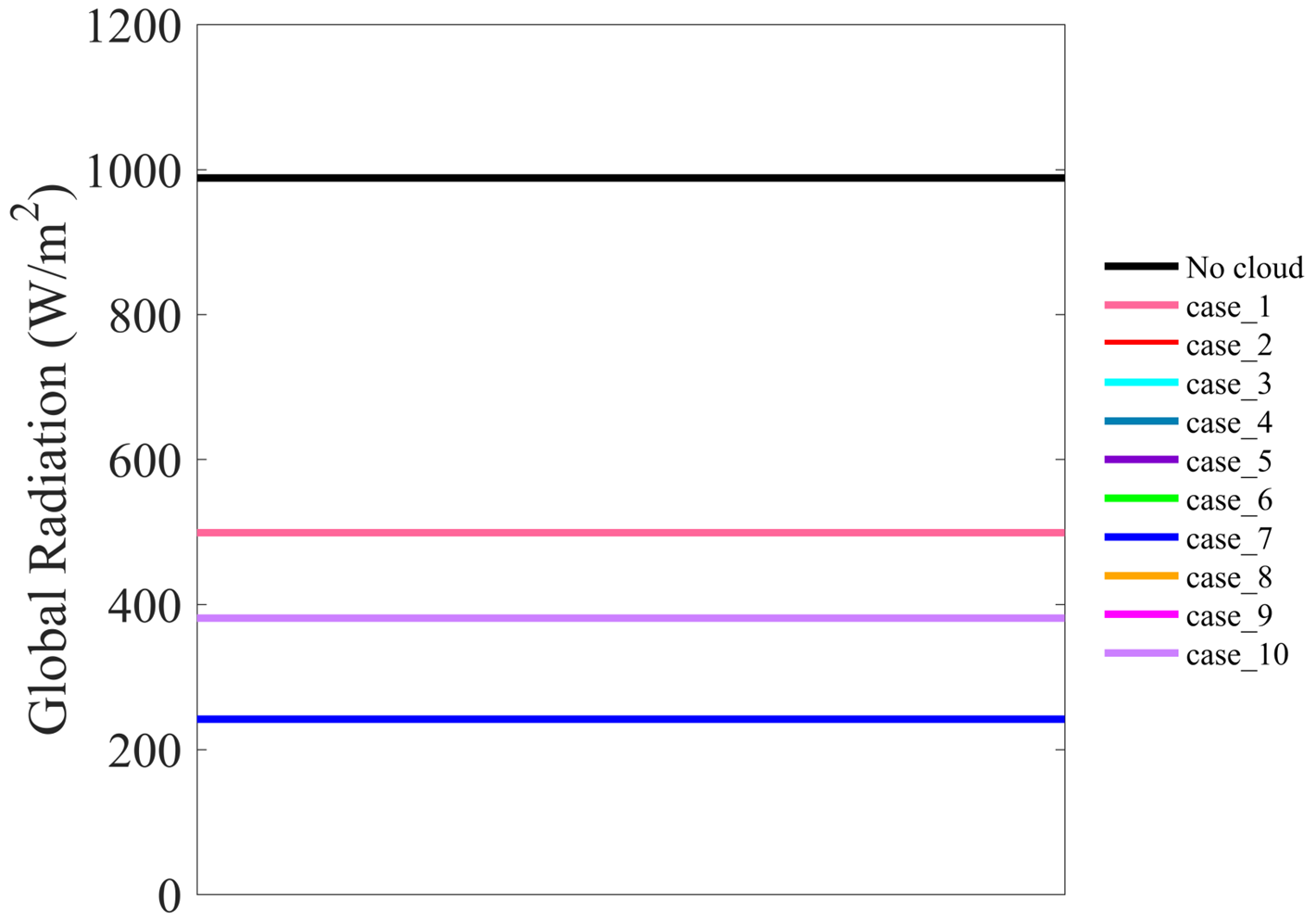

1200
1000
800
600
400
200
0
Global Radiation (W/m2)
No cloud
case_1
case_2
case_3
case_4
case_5

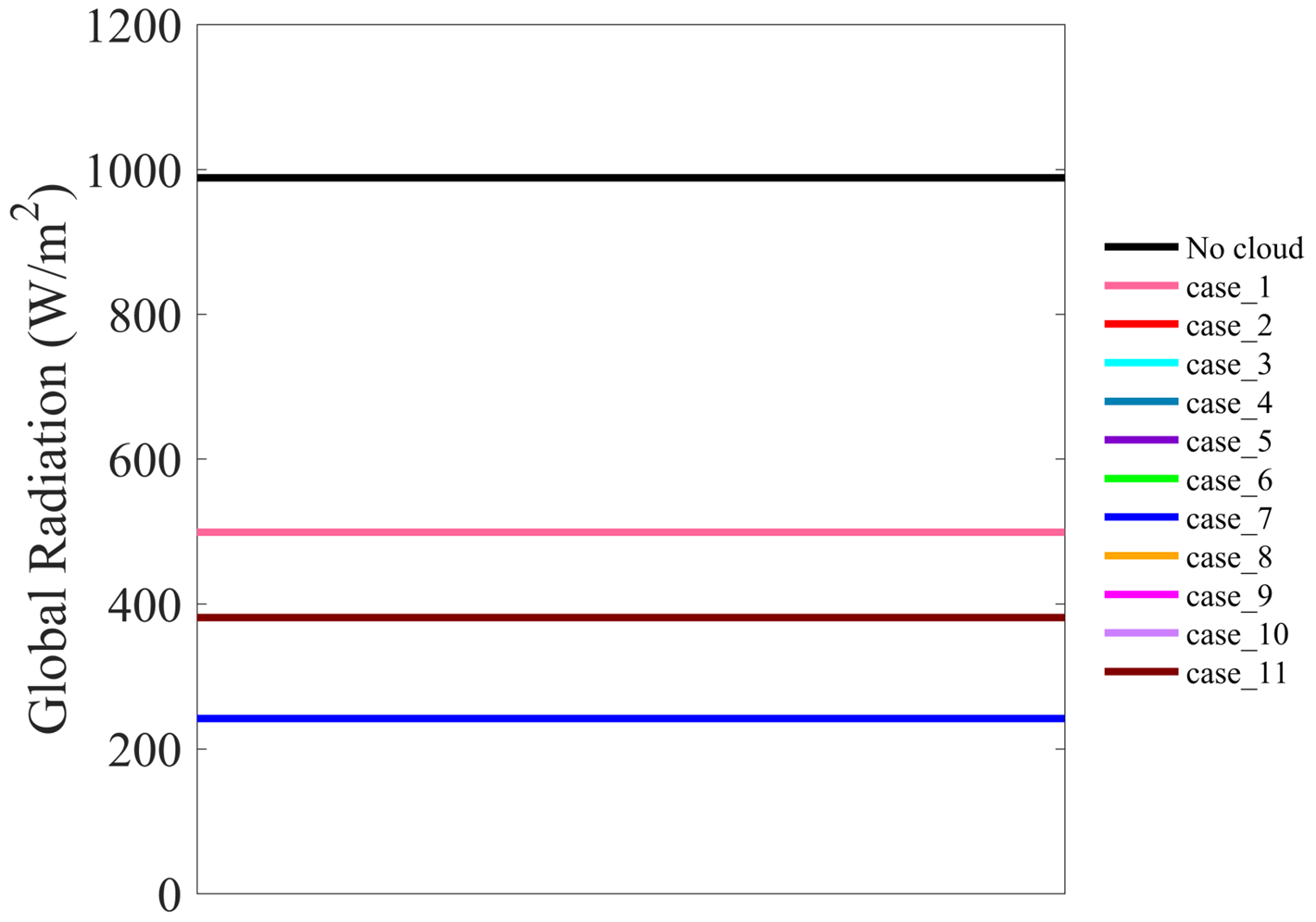

1200
1000
800
600
400
200
0
Global Radiation (W/m2)
No cloud
case_1
case_2
case_3
case_4
case_5
case_6

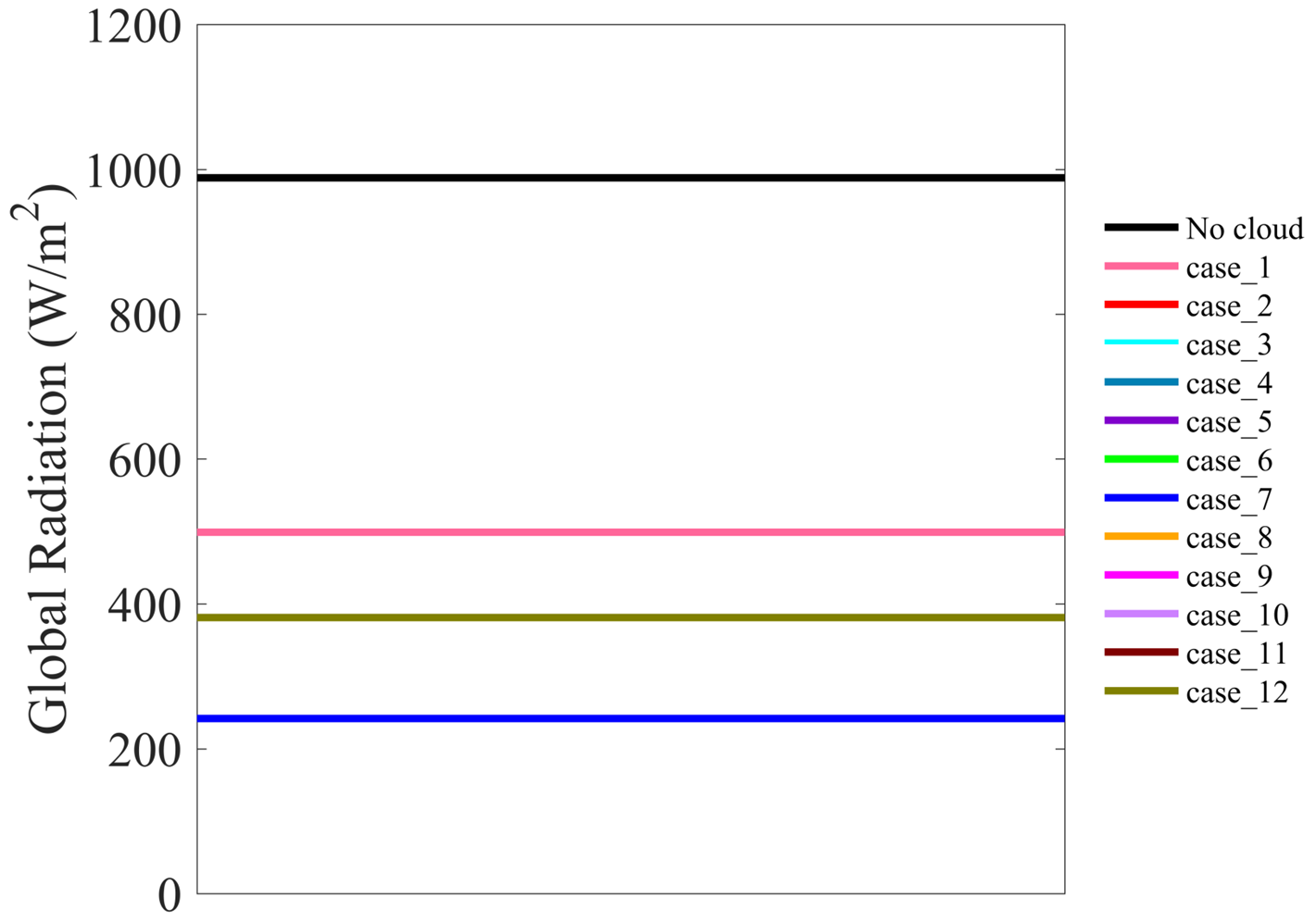

1200
1000
800
600
400
200
0
Global Radiation (W/m2)
No cloud
case_1
case_2
case_3
case_4
case_5
case_6
case_7

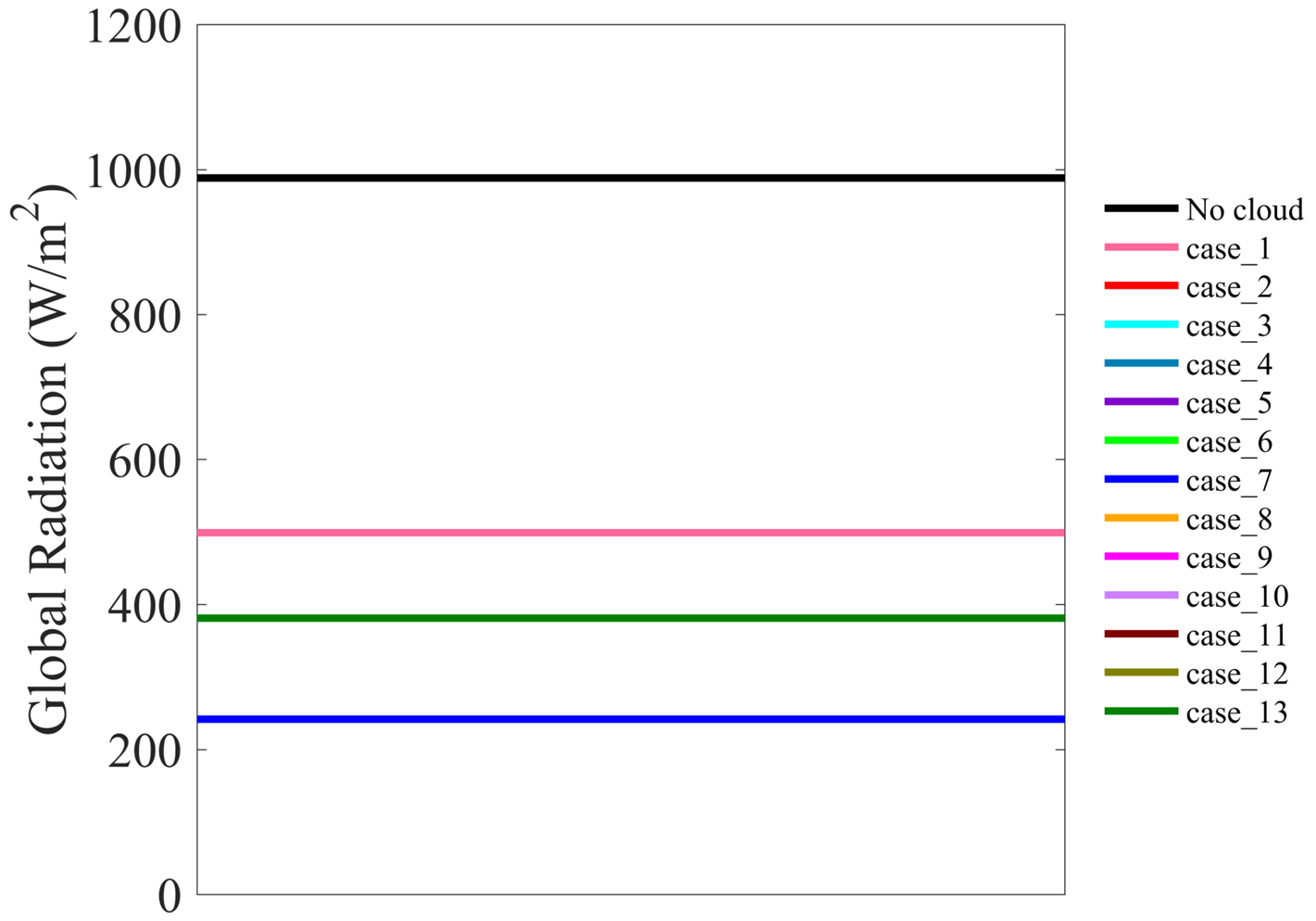

1200
1000
800
600
400
200
0
Global Radiation (W/m2)
No cloud
case_1
case_2
case_3
case_4
case_5
case_6
case_7
case_8


1200
1000
800
600
400
200
0
Global Radiation (W/m2)
No cloud
case_1
case_2
case_3
case_4
case_5
case_6
case_7
case_8
case_9


1200
1000
800
600
400
200
0
Global Radiation (W/m2)
No cloud
case_1
case_2
case_3
case_4
case_5
case_6
case_7
case_8
case_9
case_10


1200
1000
800
600
400
200
0
Global Radiation (W/m2)
No cloud
case_1
case_2
case_3
case_4
case_5
case_6
case_7
case_8
case_9
case_10
case_11


1200
1000
800
600
400
200
0
Global Radiation (W/m2)
No cloud
case_1
case_2
case_3
case_4
case_5
case_6
case_7
case_8
case_9
case_10
case_11
case_12

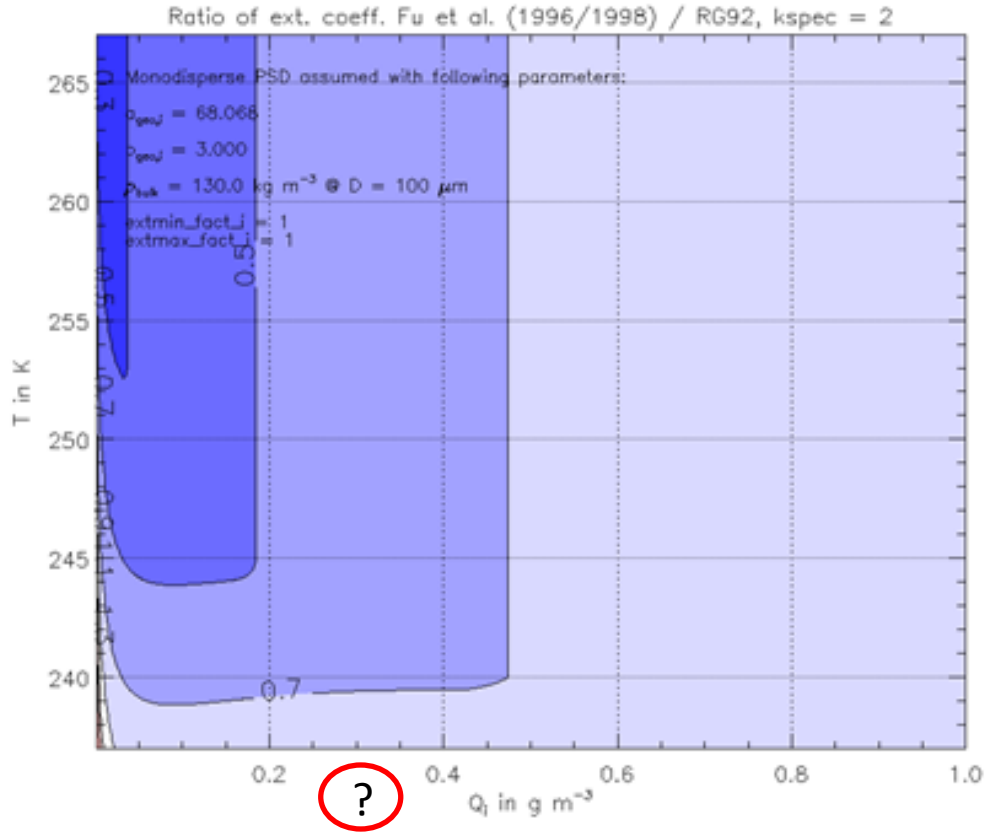

1200
1000
800
600
400
200
0
Global Radiation (W/m2)
No cloud
case_1
case_2
case_3
case_4
case_5
case_6
case_7
case_8
case_9
case_10
case_11
case_12
case_13

From Uli's Blahak presentation:

Cloud ice (visible; Fu et al.)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

➔If grid scale qi > 0: from cloud microphysics:



$f(D)$ = monodispers

$N_i(T) = a \exp(b(T_3 - T))$

q_i prognostic

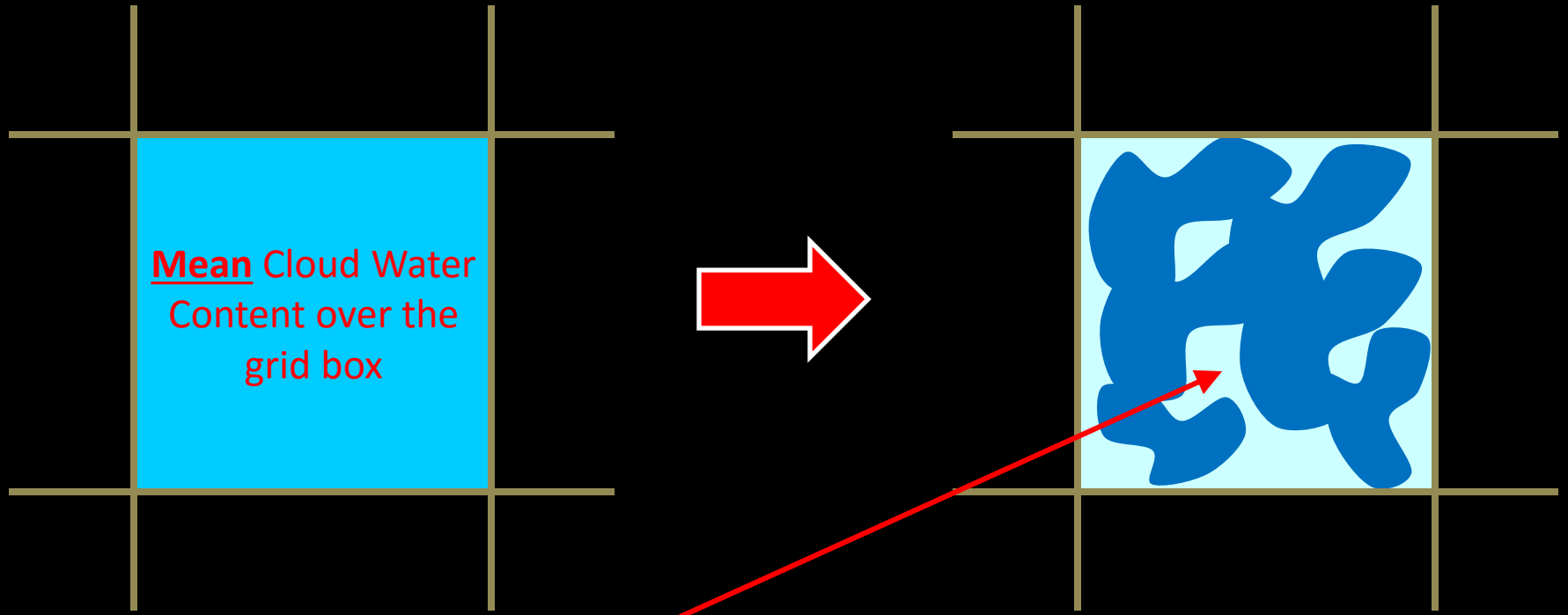
$m_i = 130\, D^3$ (SI-units)

Spectral interval „2“ (visible range)

β_{ext} ratio Fu / RG92

Parameter 1: Subgrid-scale variability factor „radqcfact”

Assume: Microphysics → Cloud Water Content in a grid box



Higher radiation through “empty” areas → Effective CWC: **lower** → CWC → (**radqcfact**) X CWC

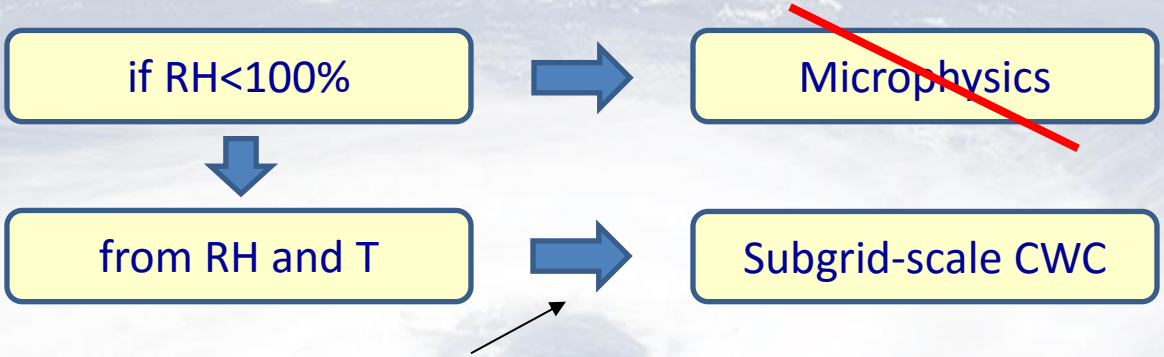
Parameter 1: Subgrid-scale variability factor „radqcfact”

Where „radqcfact” takes effect ?

	Grid-Scale Cloudiness	**Subgrid-Scale** Cloudiness
Effective CWC	(from microphysics)*correction	Parameterization
R_{eff}	from CWC + assuming number concentration	Tuning parameter

higher „radqcfact” ⇨ higher effective CWC ⇨ higher radiation attenuation

Parameter 2: „qvsatfact_sgscl_rad”



Where „qvsatfact_sgscl_rad” takes effect ?

	Grid-Scale Cloudiness	**Subgrid-Scale** Cloudiness
Effective CWC	(from microphysics)*correction	Parameterization
R_{eff}	from CWC + assuming number concentration	Tuning parameter

higher qvsatfact_sgscl_rad → higher effective CWC → higher radiation attenuation

Parameter 4: „reff_ini_c”

if RH<100% → ~~Microphysics~~

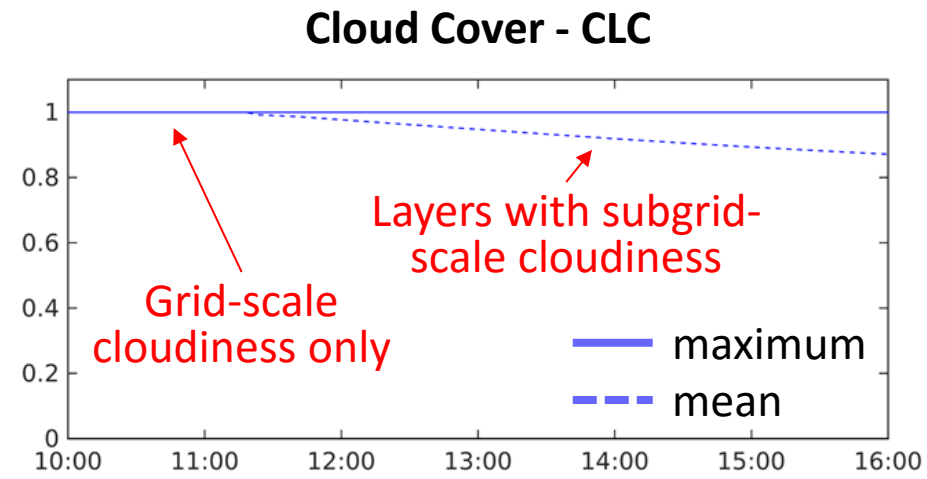
R_{eff} = ? in SGS clouds → R_{eff} = tuning parameter reff_ini_c

Where „reff_ini_c” takes effect ?

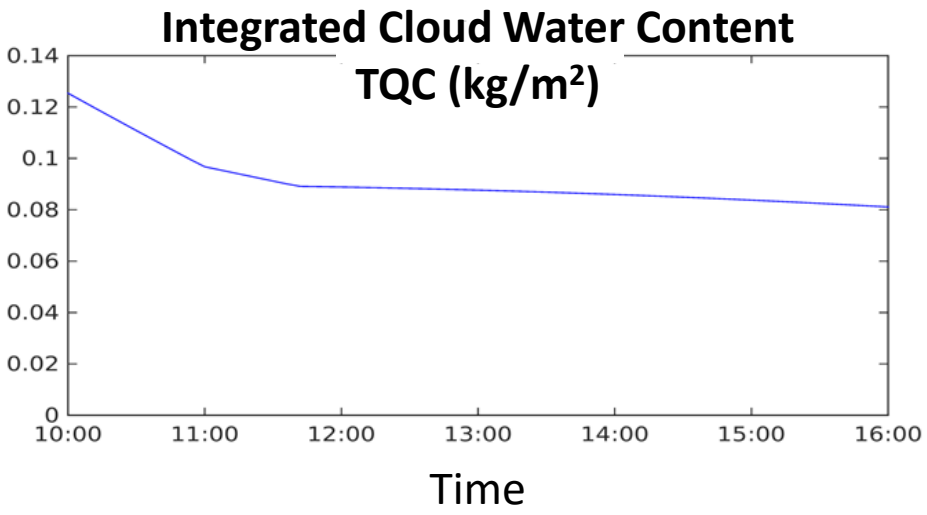
	Grid-Scale Cloudiness	**Subgrid-Scale** Cloudiness
Effective CWC	(from microphysics)*correction	Parameterization
R_{eff}	from CWC + assuming number concentration	Tuning parameter

higher reff_ini_c (R_{eff}) → lower radiation attenuation

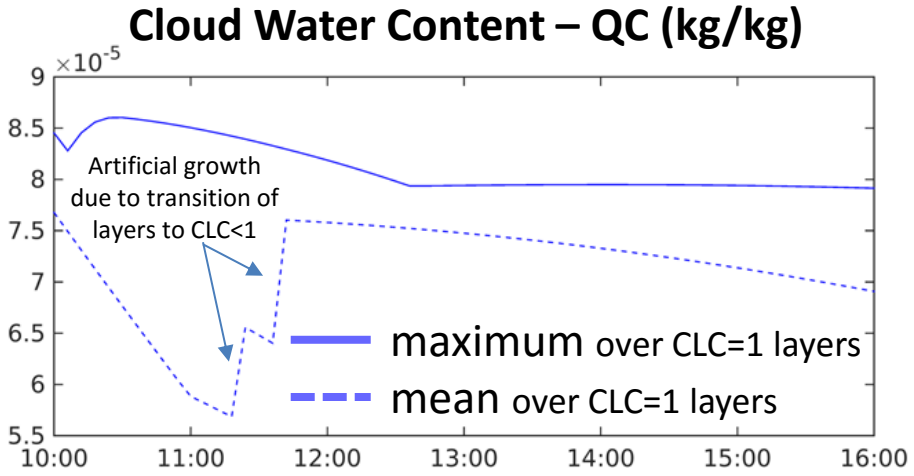
Example: Warm Stratus cloud (idealized simulation)



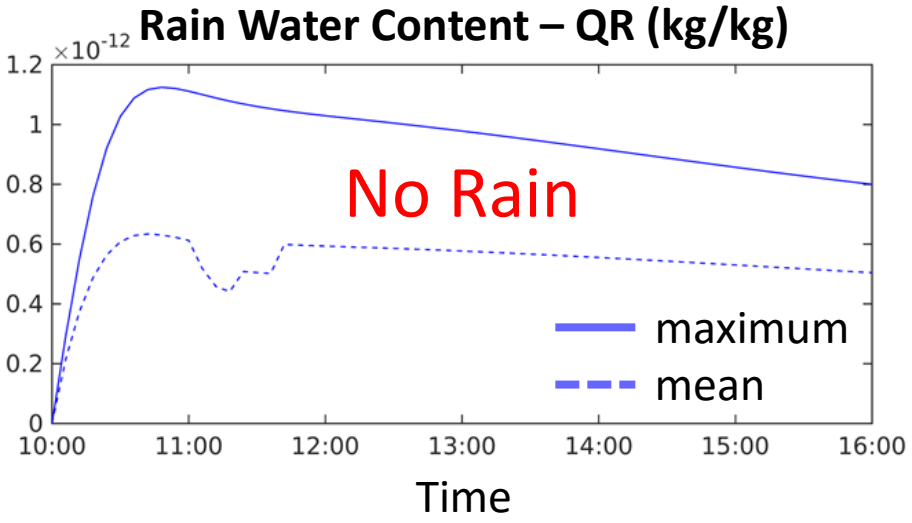
Example: Warm Stratus cloud (idealized simulation)



Example: Warm Stratus cloud (idealized simulation)

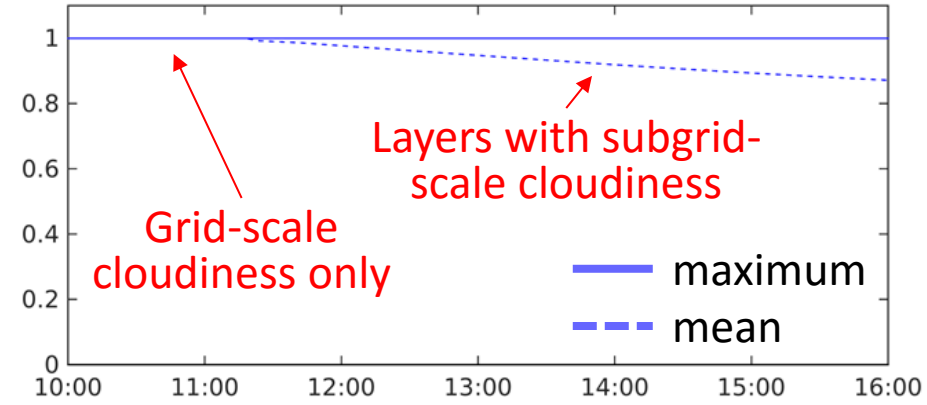


Example: Warm Stratus cloud (idealized simulation)

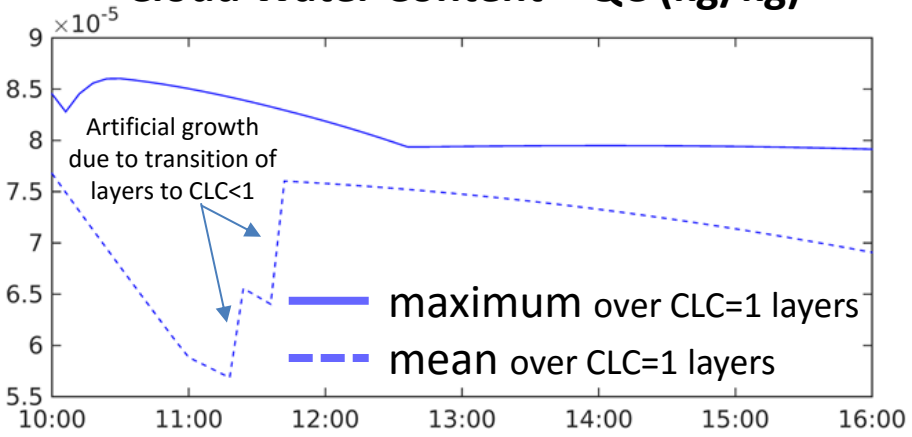


Example: Warm Stratus cloud (idealized simulation)

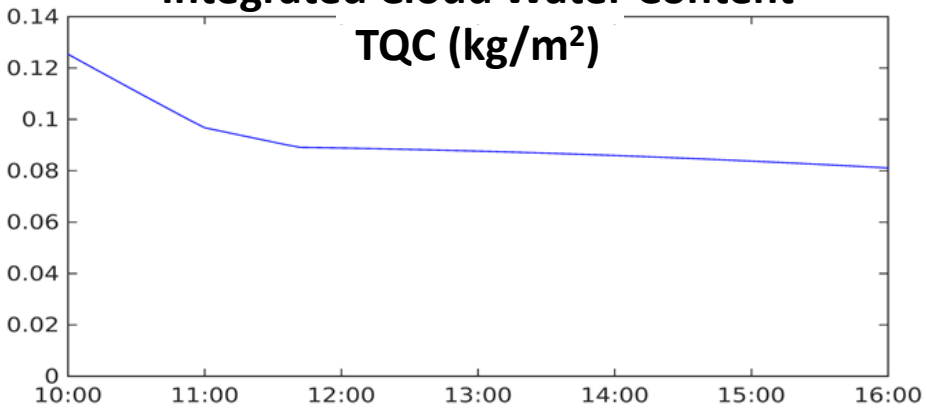
Cloud Cover - CLC



Cloud Water Content – QC (kg/kg)



Integrated Cloud Water Content TQC (kg/m²)



Rain Water Content – QR (kg/kg)