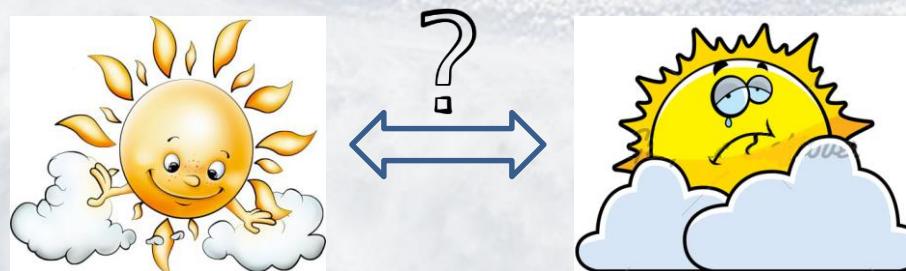


Priority Project T²RC²:

Determination of governing parameters in the new radiation scheme

P. Khain¹, H. Muskatel¹, U. Blahak²

¹Israel Meteorological Service, ²Deutscher Wetterdienst



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,p 16,p23,p24,p25, p29,p30,p31,p32	p1,p2,p6, p8,p15,p17, p18,p19,p26,p 27, p28,p32	p1,p2,p3,p6,p7, p8,p9,p10, p11,p14,p15,p16,p17,p18,p 19,p23,p24,p25,p26,p27,p2 8,p29,p30,p31,p32	p2,p6,p7, p8,p15, p17,p18,p19,p32	p1,p2,p3,p6,p7, p9,p10,p11,p1 4, p16,p23,p24,p25,p29,p30, p31,p32

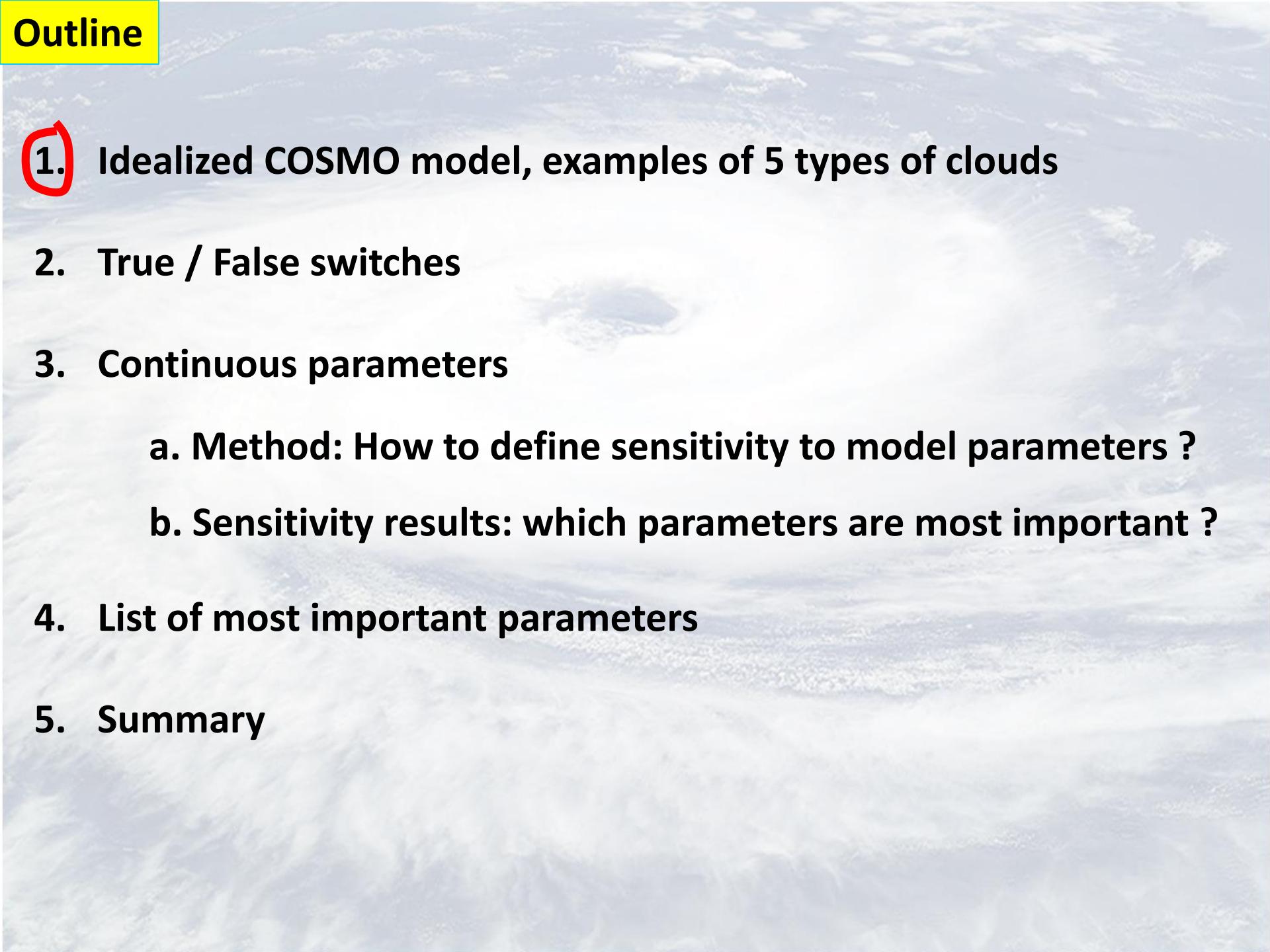
- 1. lrad_incl_qrqsgq
- 2. iradpar_cloud
- 3. lrad_use_largesizeapprox
- 4. lrad_ice_smooth_surfaces
- 5. lrad_ice_fd_is_gsquared
- 6. itype_aerosol
- 7. icloud_num_type_rad
- 8. radqcfact
- 9. radqifact
- 10. rad_arearat_ls_i
- 11. rad_arearat_ls_s
- 12. rad_arearat_ls_g
- 13. rad_arearat_ls_h
- 14. 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_n0high_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

true / false switches
continuous parameters

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

All the others – predefine in the code

- 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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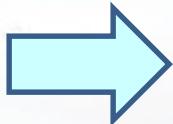
1. Idealized COSMO model

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

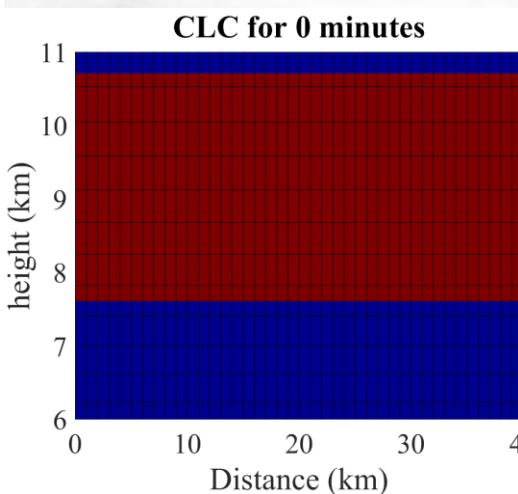
1. Idealized COSMO model

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

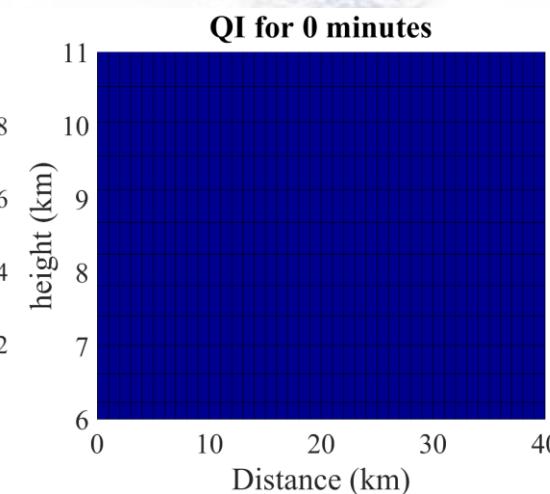
Cloud type	Altitude	RH over water	Temperature
Warm Stratus	stable layer 1.5-3km	101%	8.9 C till 2.9 C
Cirrus	stable layer 7.5-10.75km	80%	-23 C till -54 C
Mixed phase	stable layer 3.2-6km	101%	-2.8 C till -16.8 C
Fair weather Cu	stable layer 1.5-1.8km	95%	8.9 C till 7.7 C
Anvil of CB	Weisman-Klemp wind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

Cirrus (idealized simulation)

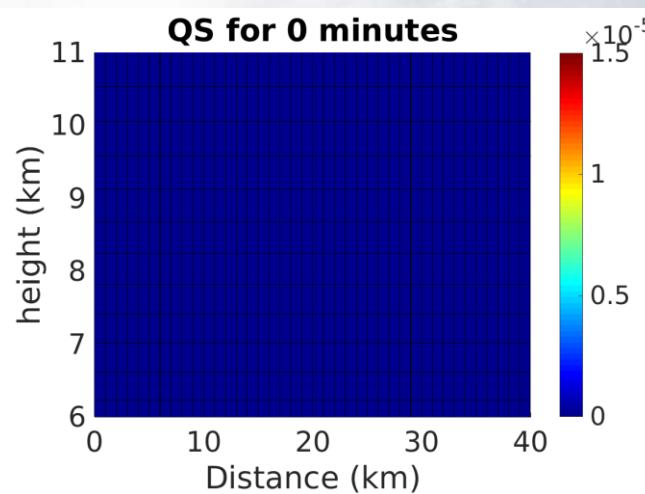
Cloud cover



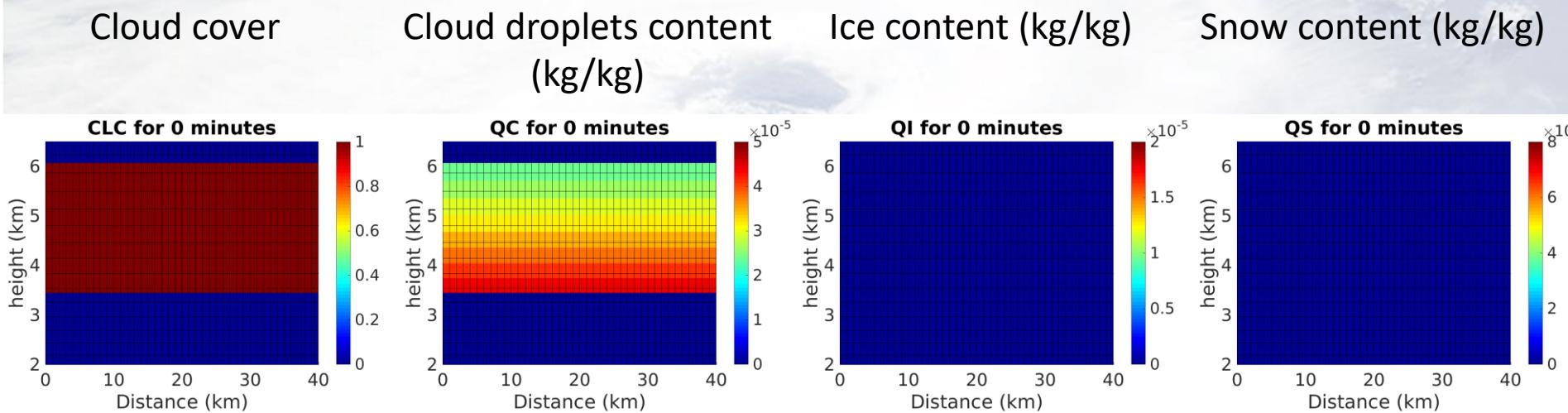
Ice content (kg/kg)



Snow content (kg/kg)

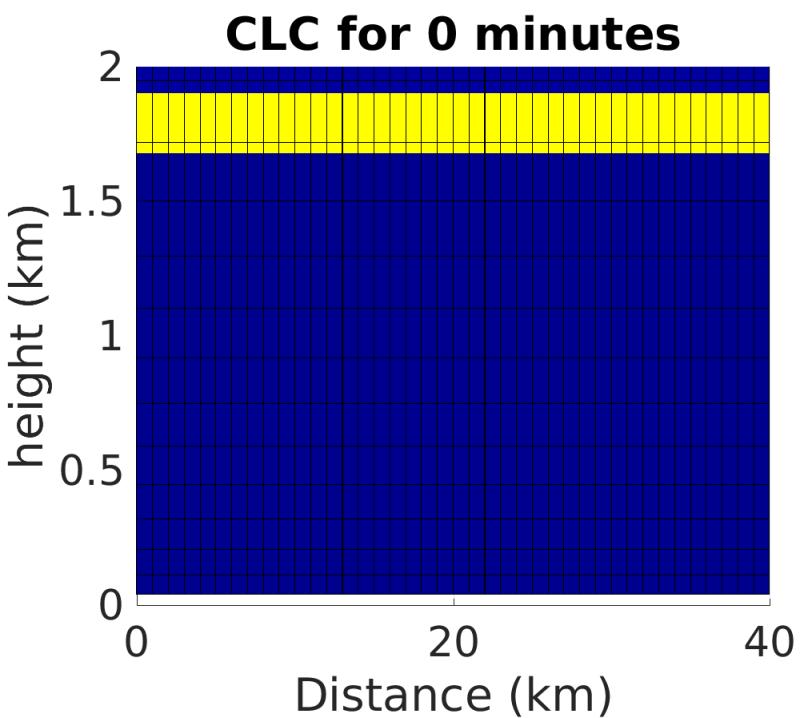


Mixed phase cloud (idealized simulation)

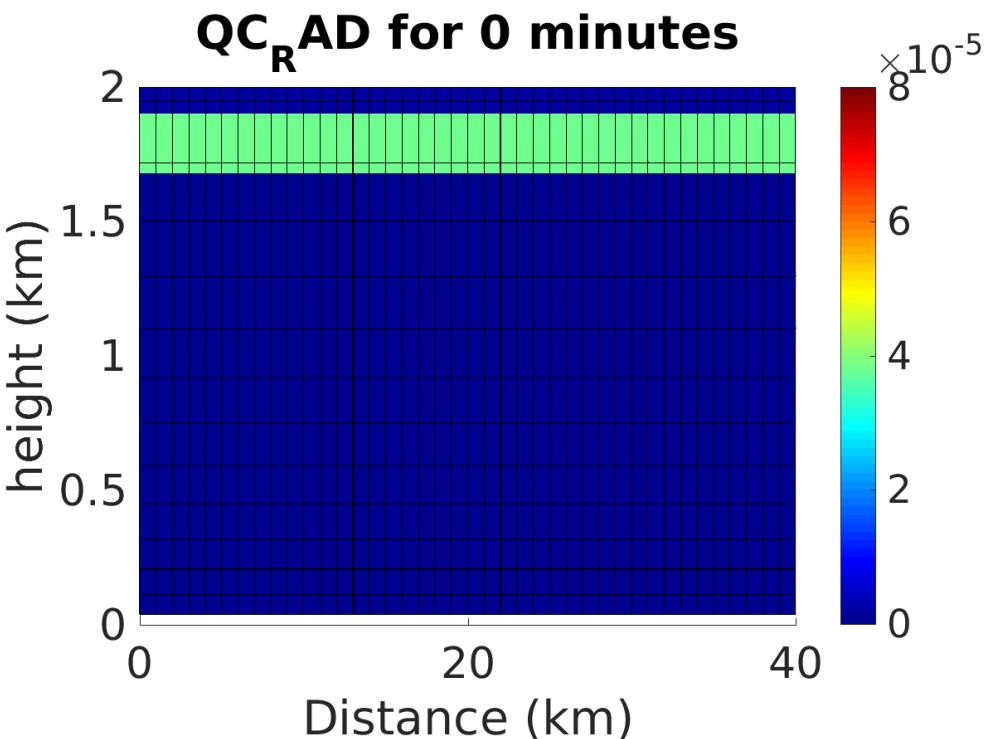


Fair weather Cu (idealized simulation)

Cloud cover

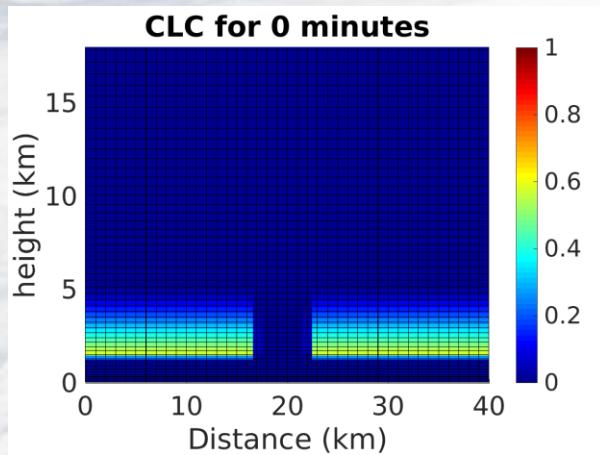


Subgrid cloud droplets content (kg/kg)

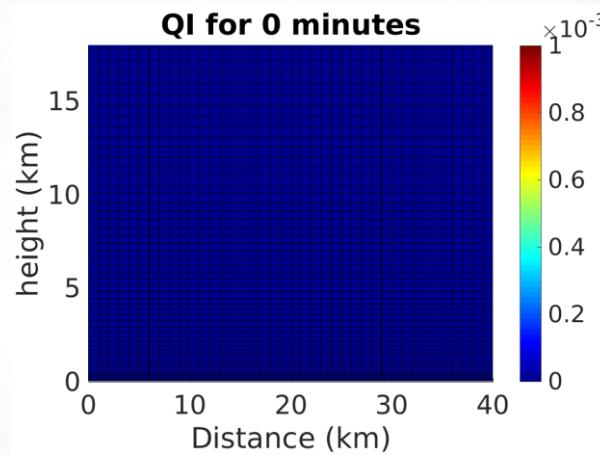


Anvil of CB (idealized simulation)

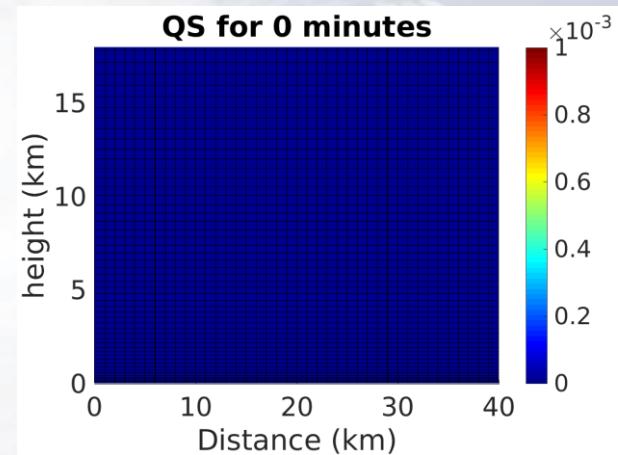
Cloud cover



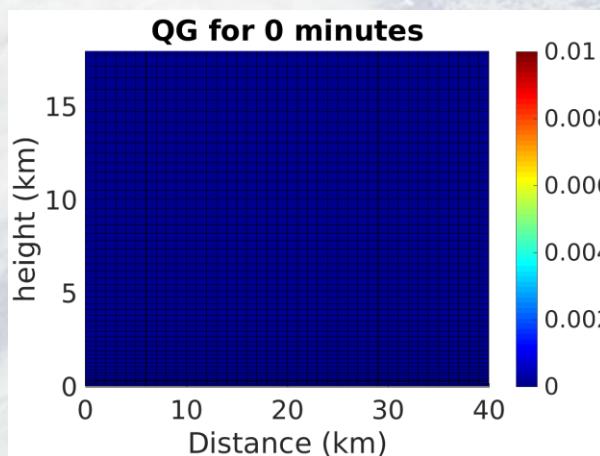
Ice content (kg/kg)



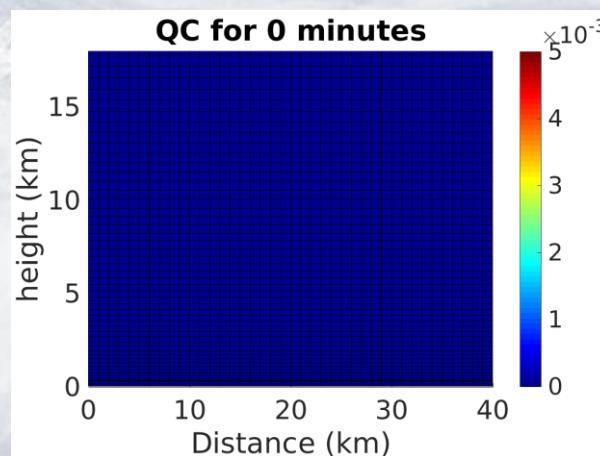
Snow content (kg/kg)



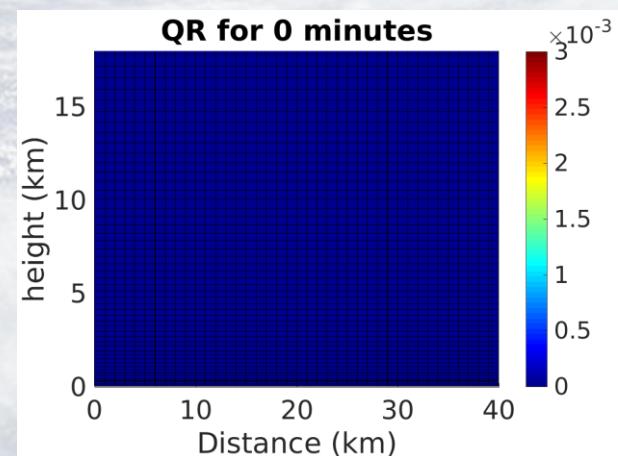
Graupel content (kg/kg)



Droplets content (kg/kg)

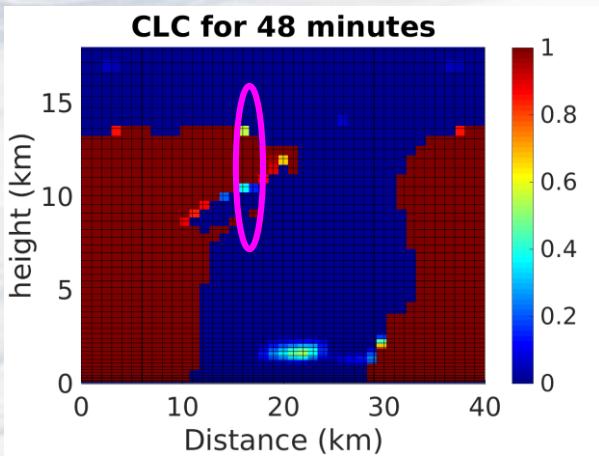


Rain content (kg/kg)

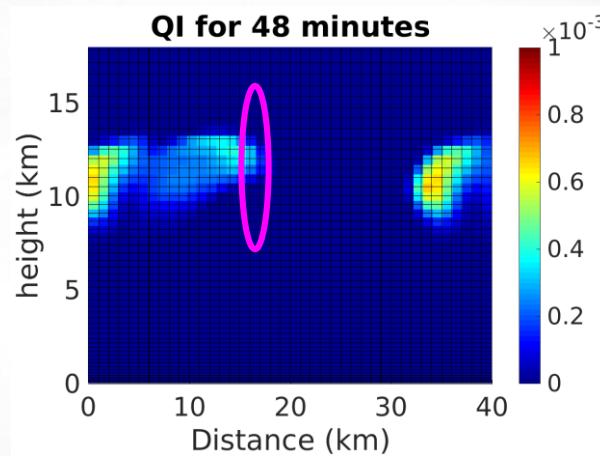


Anvil of CB (idealized simulation)

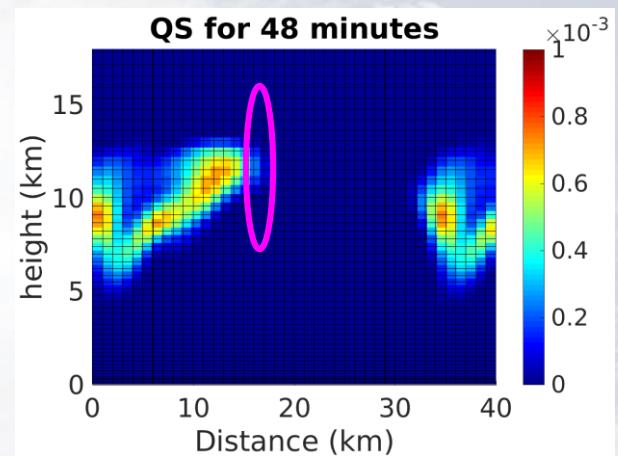
Cloud cover



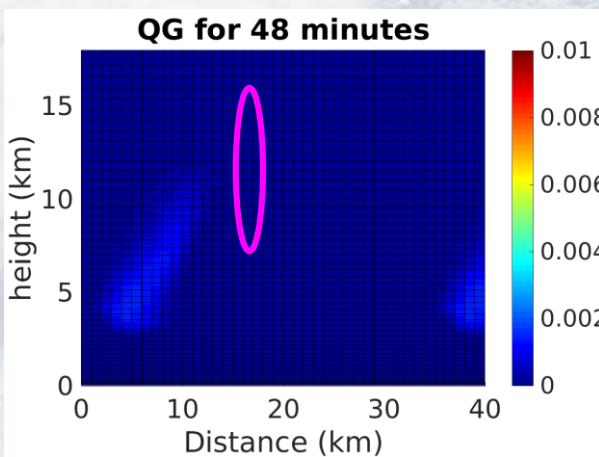
Ice content (kg/kg)



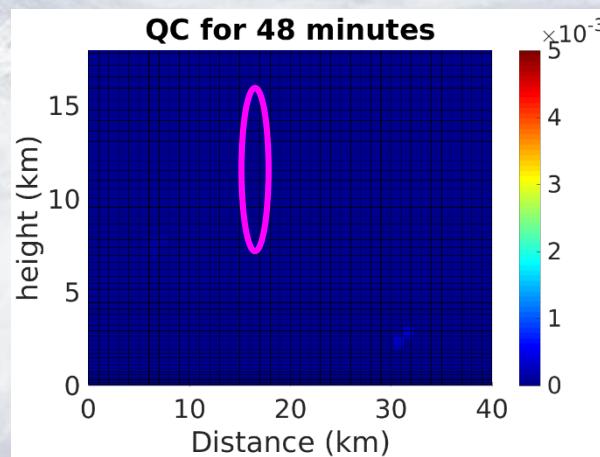
Snow content (kg/kg)



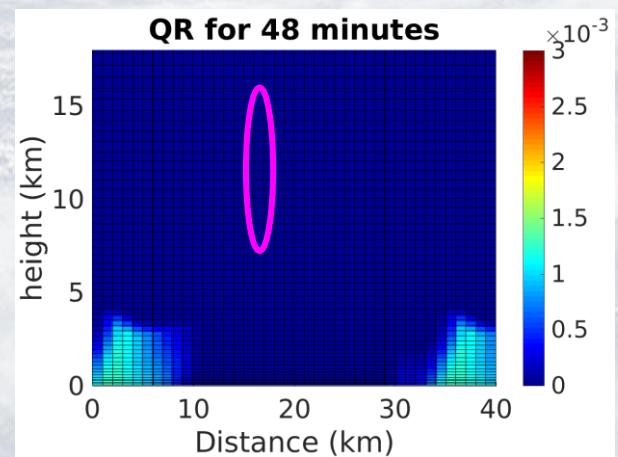
Graupel content (kg/kg)



Droplets content (kg/kg)



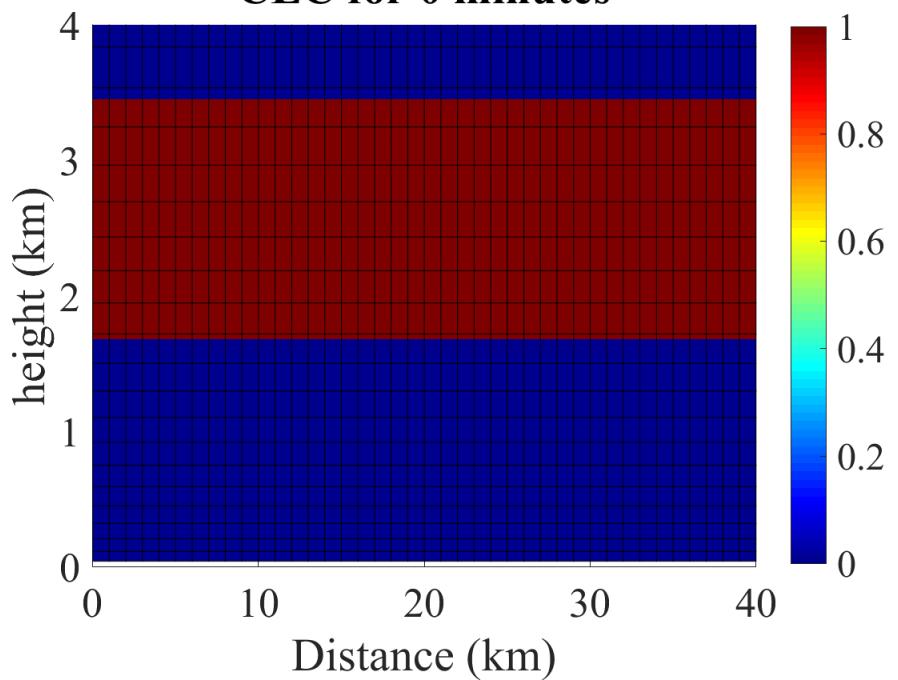
Rain content (kg/kg)



Warm Stratus (idealized simulation)

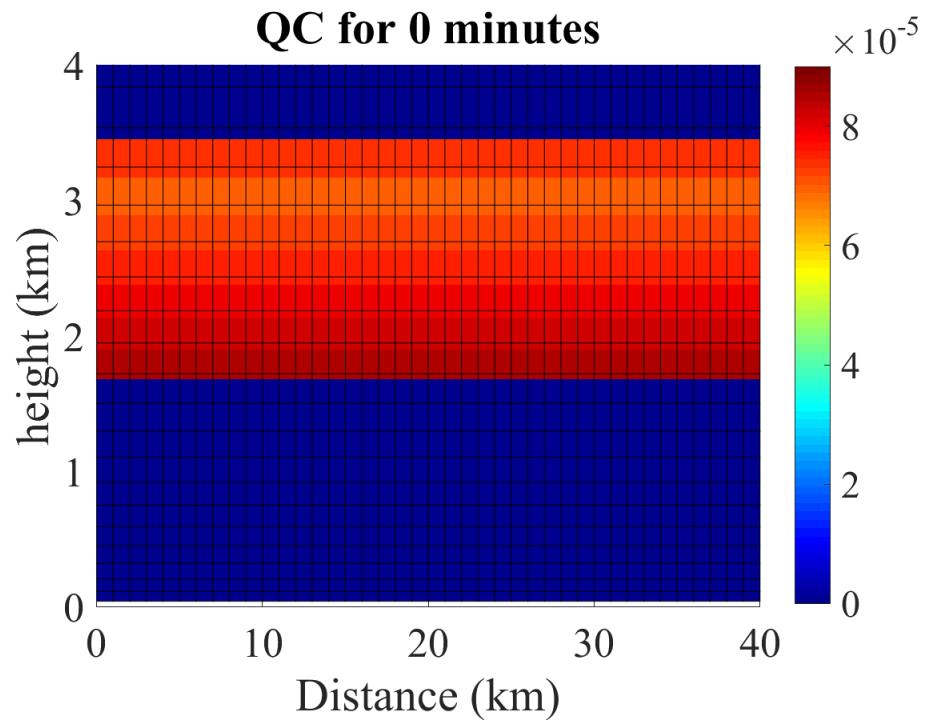
Cloud cover

CLC for 0 minutes

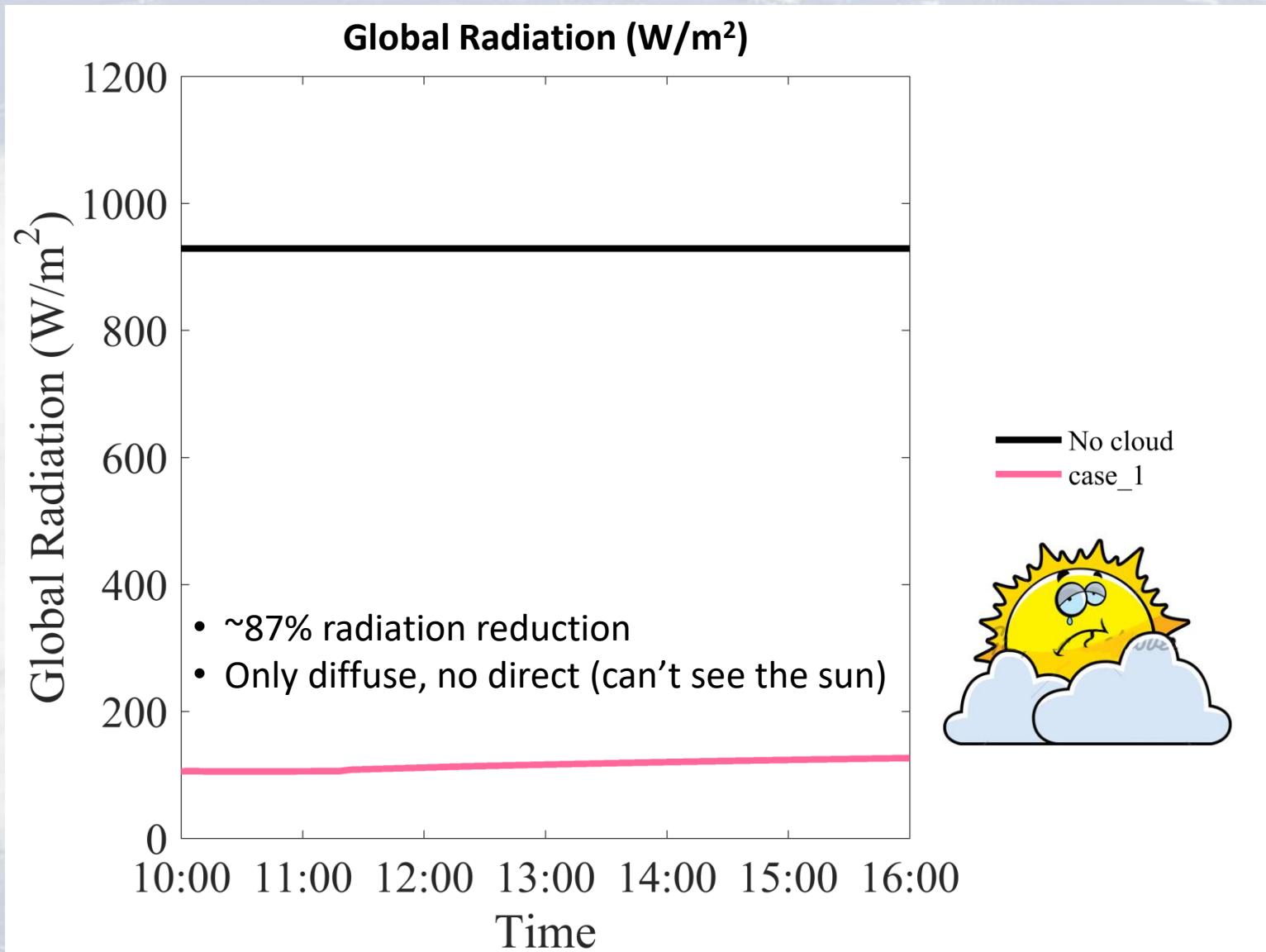


Cloud droplets content (kg/kg)

QC for 0 minutes



Example: warm Stratus (idealized simulation)



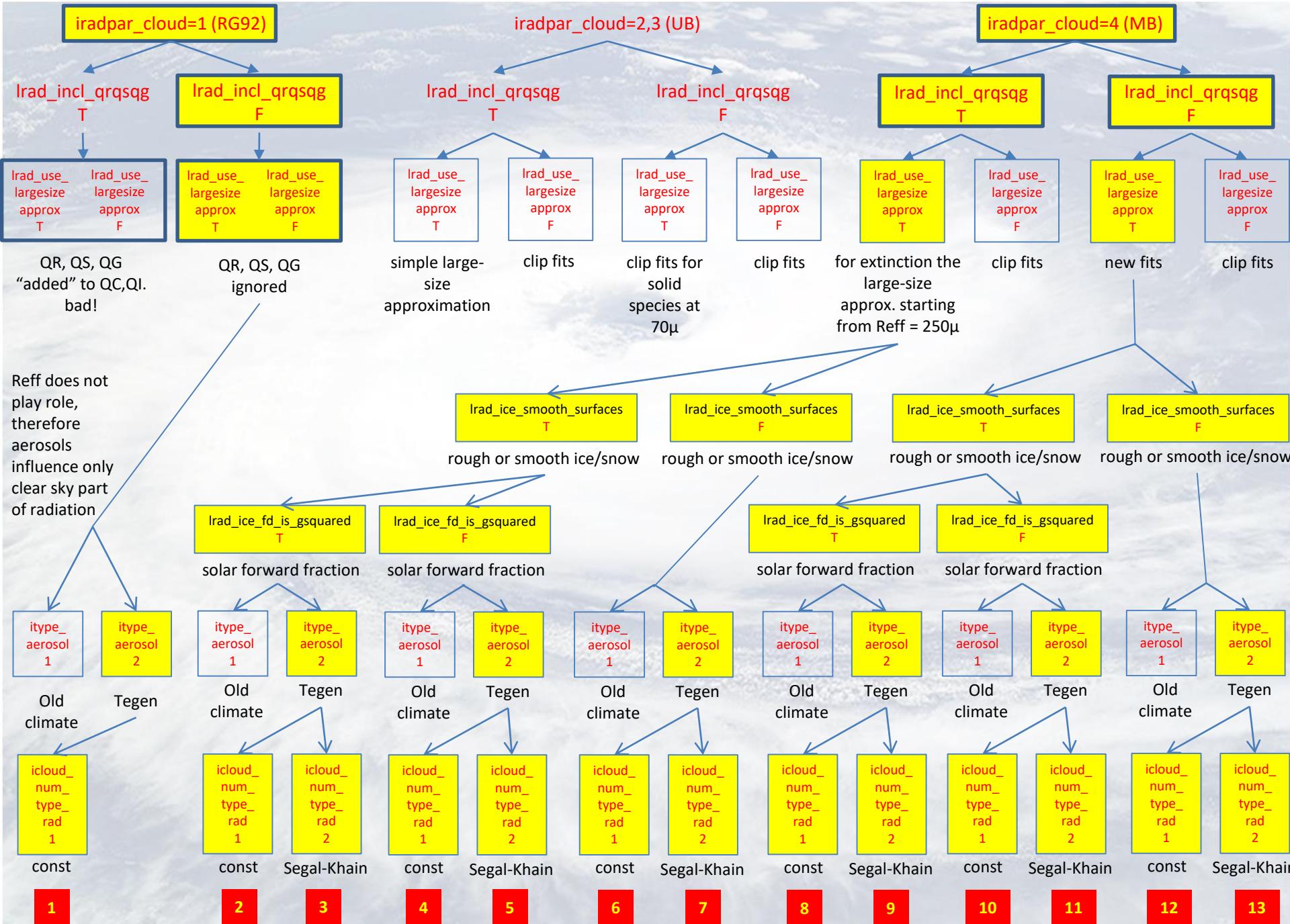
- 1. Idealized COSMO model, examples of 5 types of clouds**
- 2. True / False switches**
- 3. Continuous parameters**
 - a. Method: How to define sensitivity to model parameters ?**
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- 5. Summary**

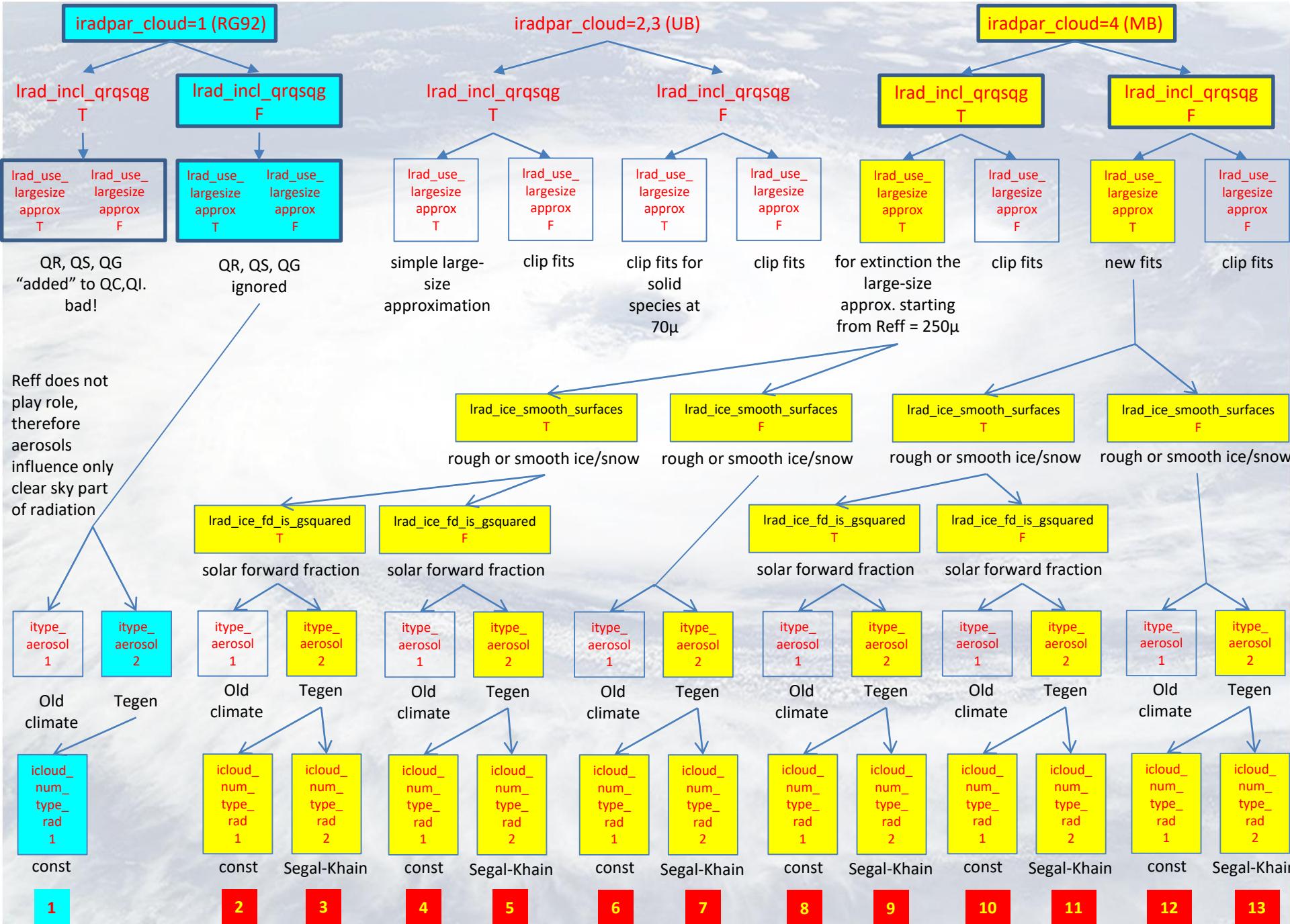
1. Idealized COSMO model, examples of 5 types of clouds
2. True / False switches
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 - a. Method: How to define sensitivity to model parameters ?
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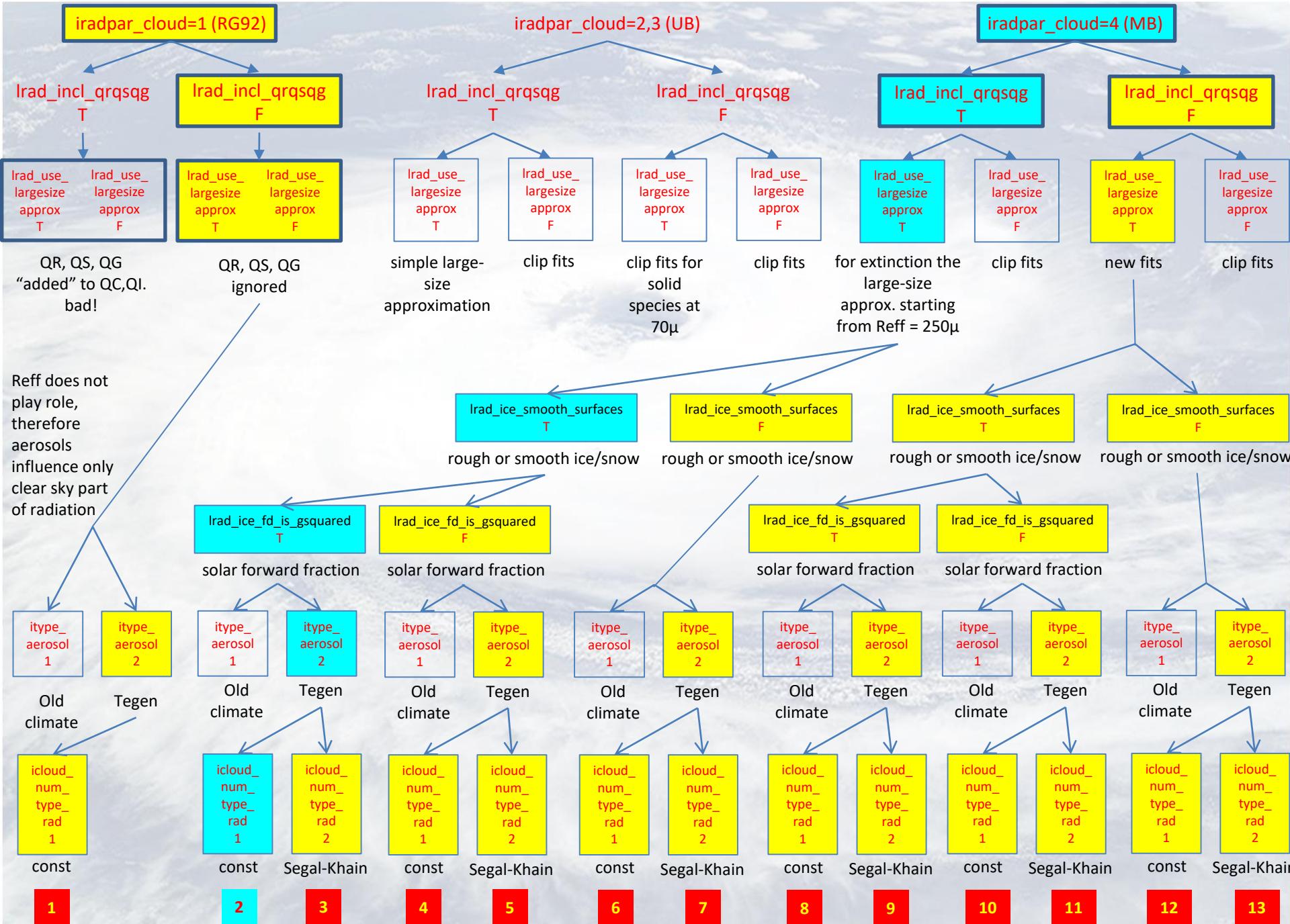
2. True / False switches

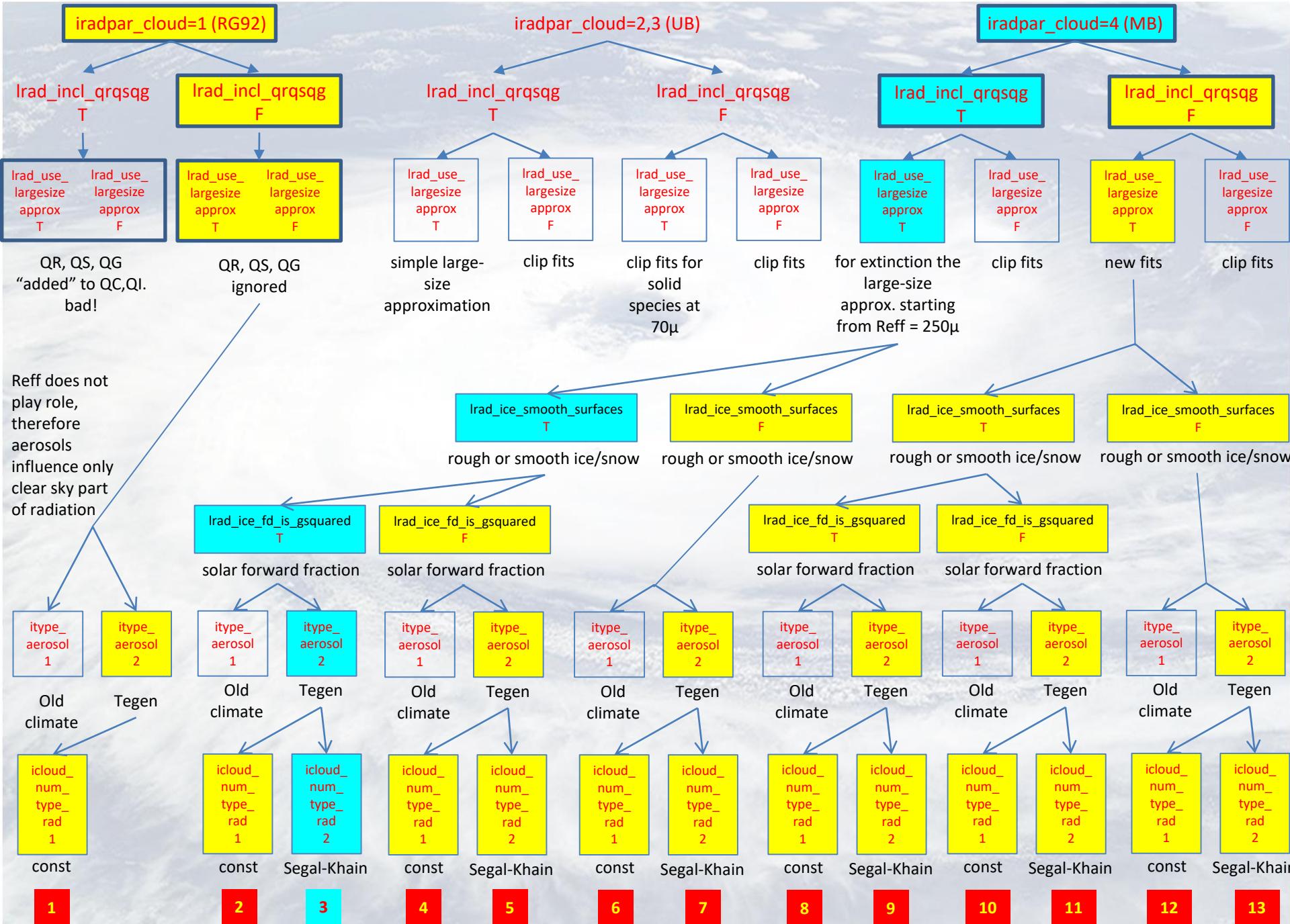


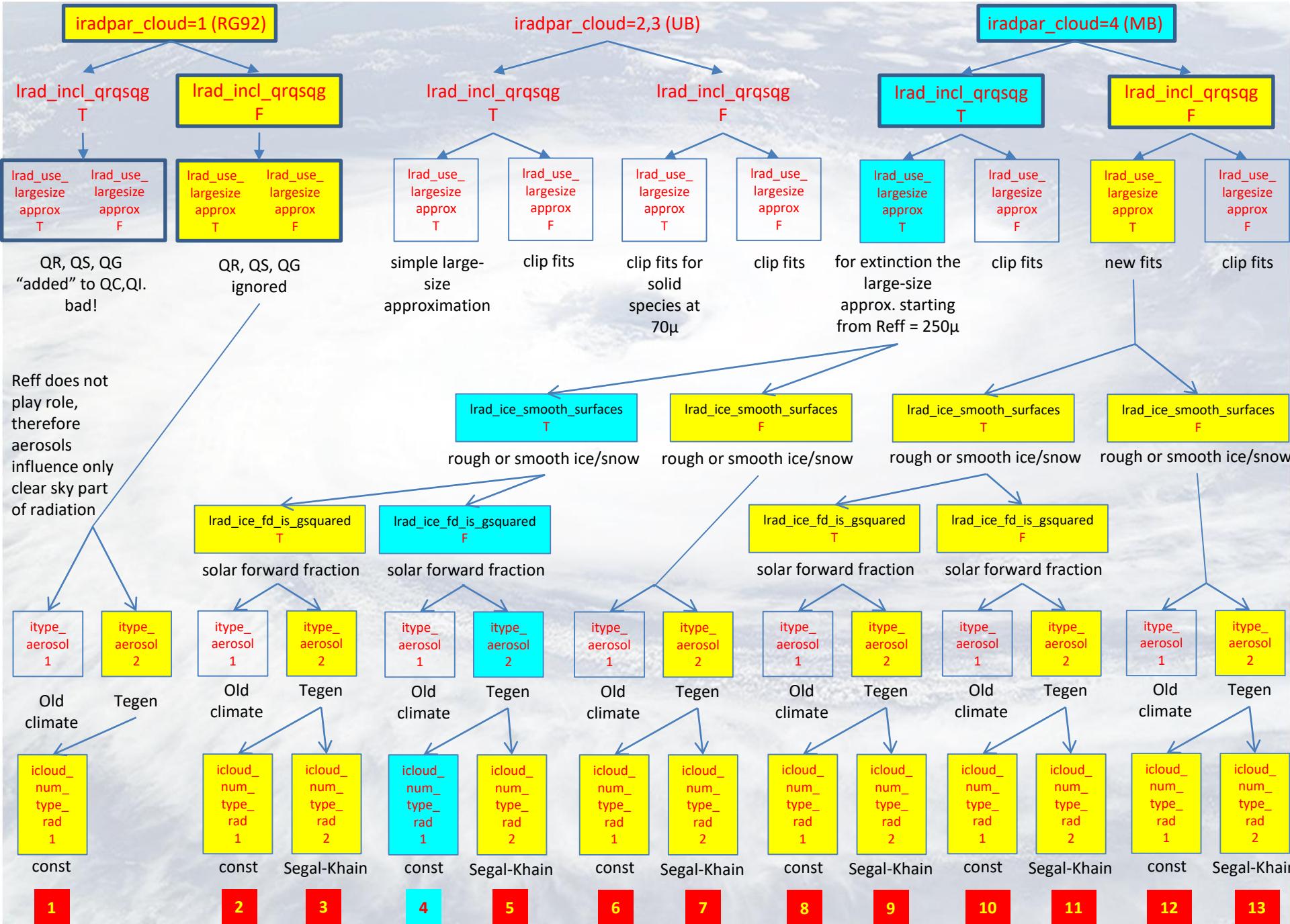
- | | |
|-----------------------------|-----------------------|
| 1. lrad_incl_qrqsqg | true / false switches |
| 2. iradpar_cloud | |
| 3. lrad_use_largesizeapprox | |
| 4. lrad_ice_smooth_surfaces | |
| 5. lrad_ice_fd_is_gsquared | |
| 6. itype_aerosol | continuous parameters |
| 7. icloud_num_type_rad | |
| 8. radqcfact | |
| 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 | |

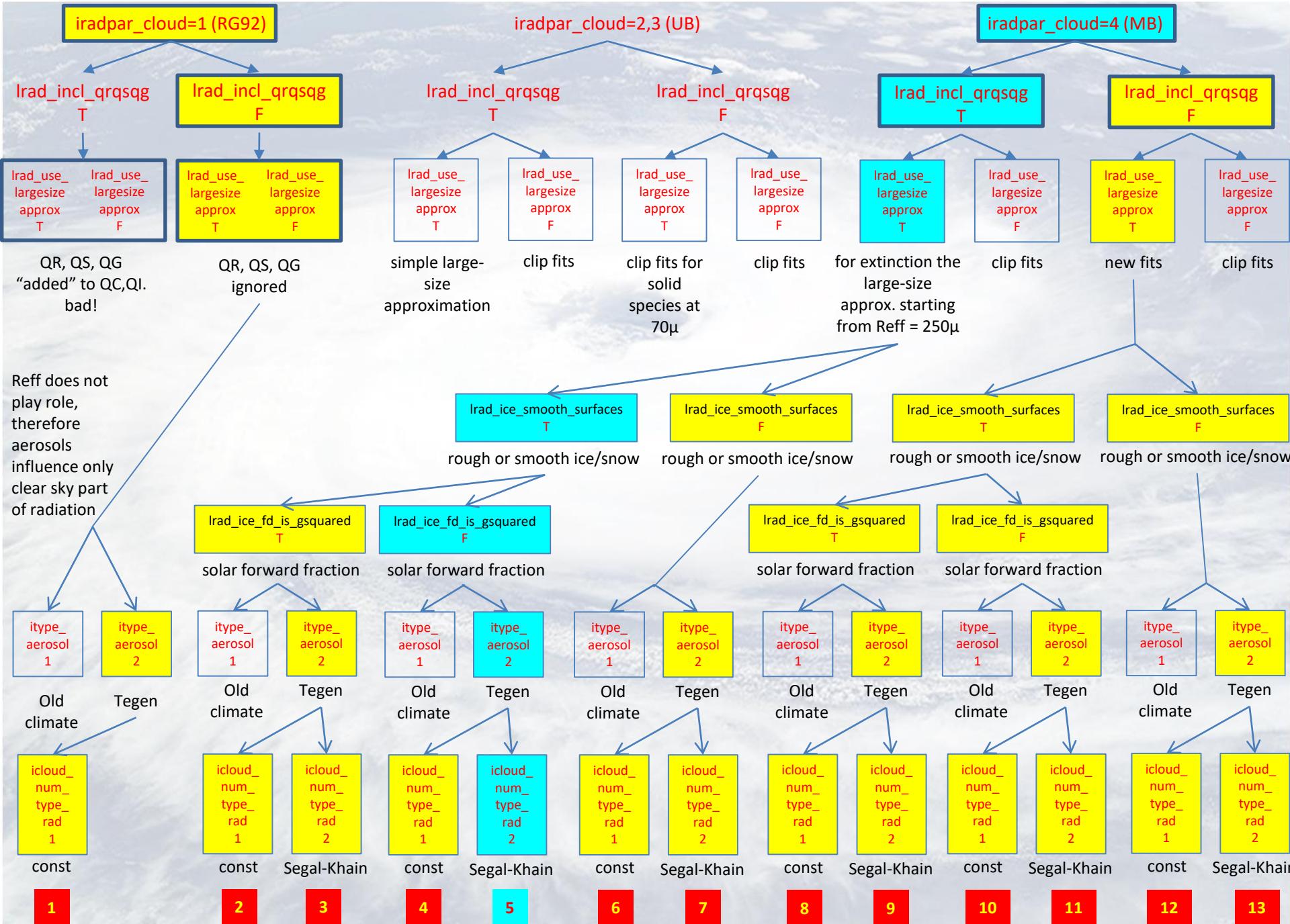


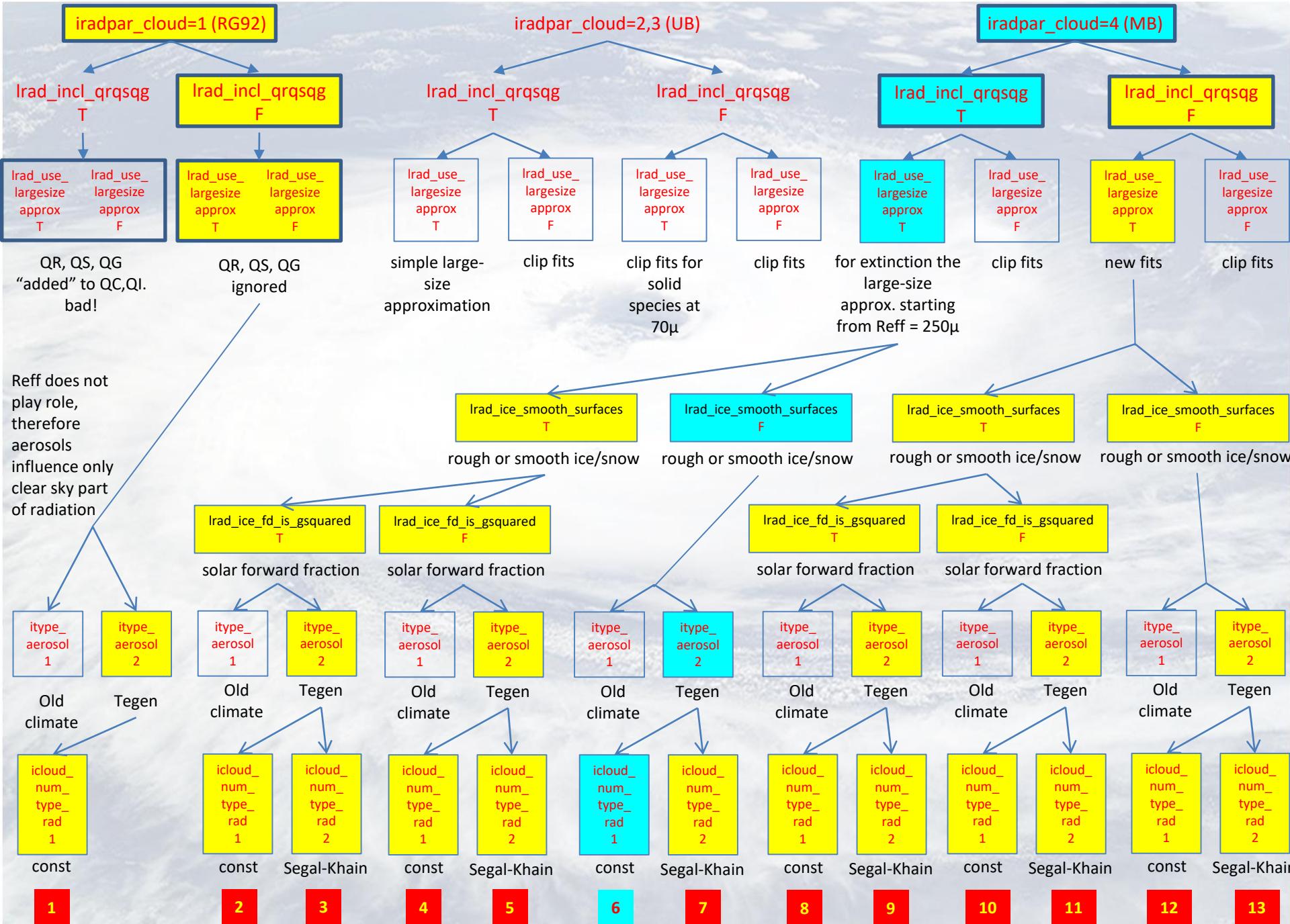


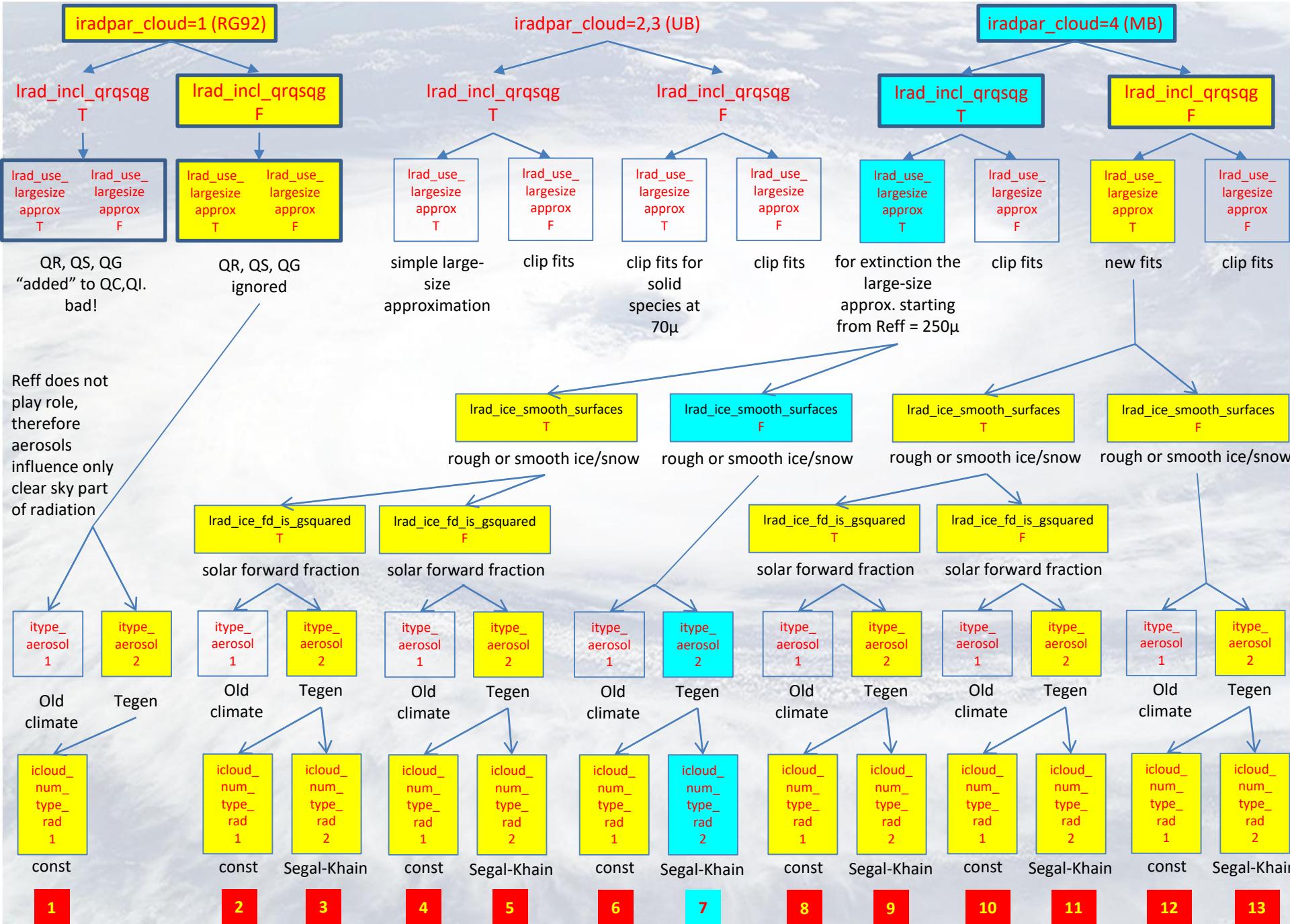


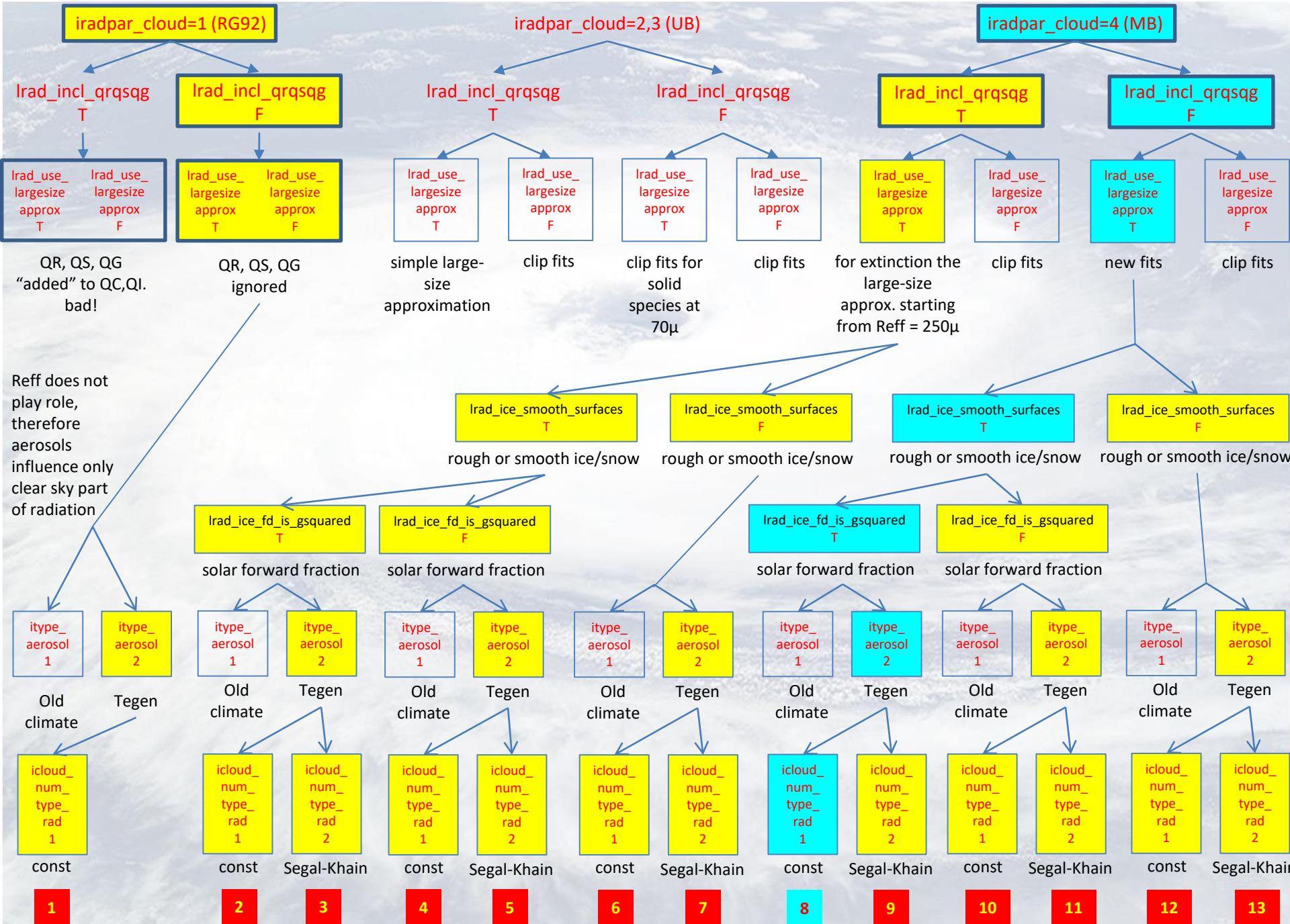


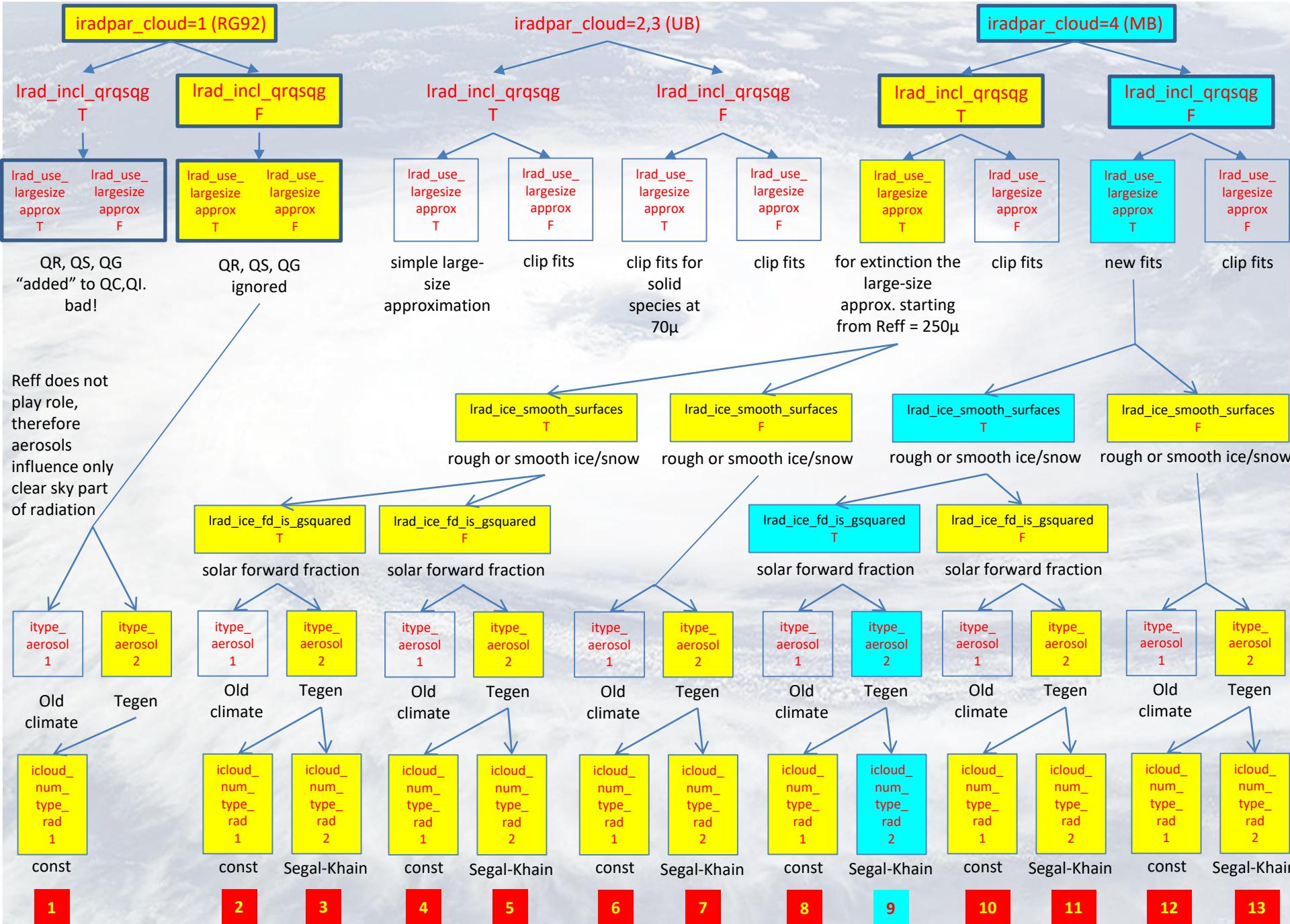


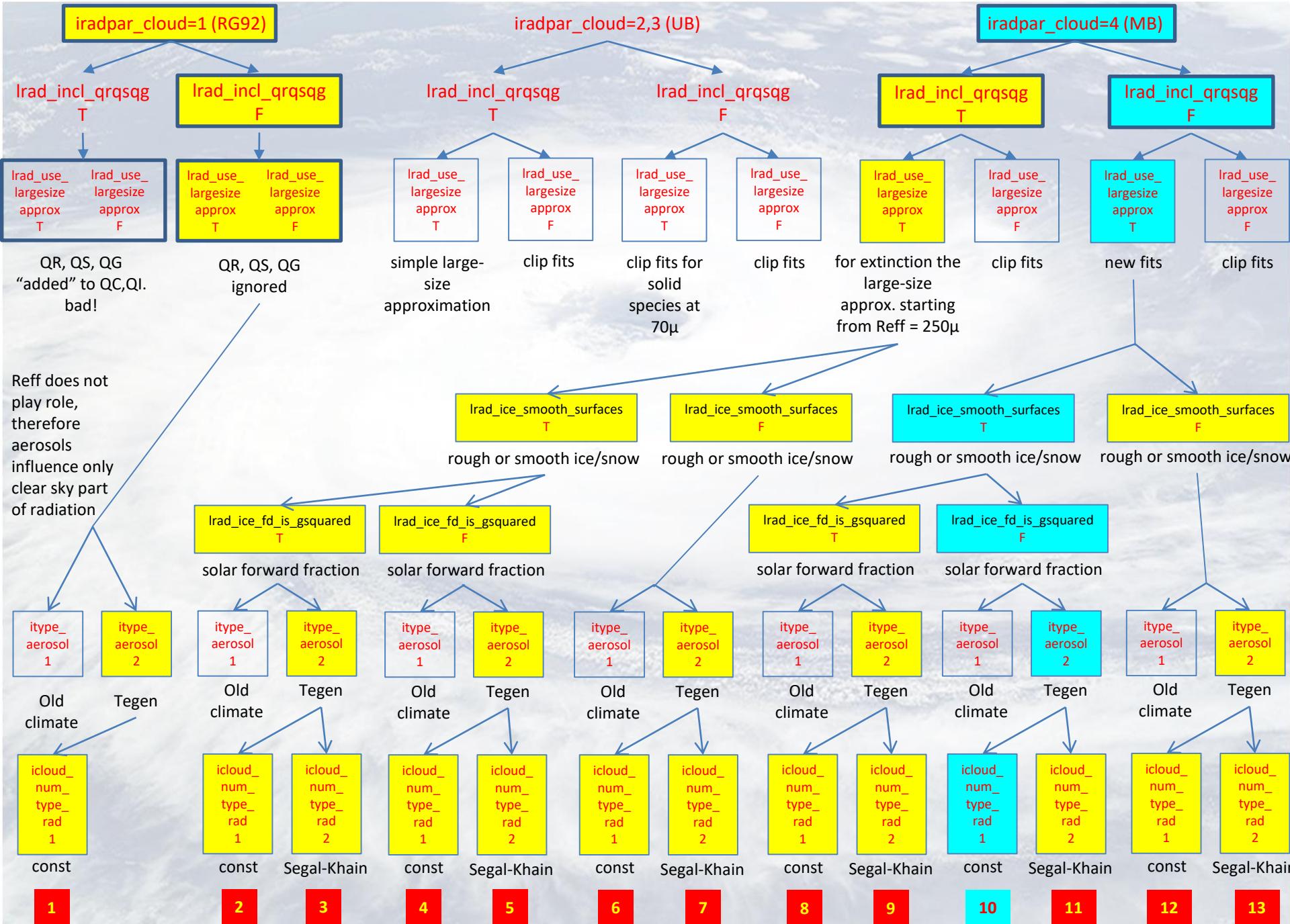


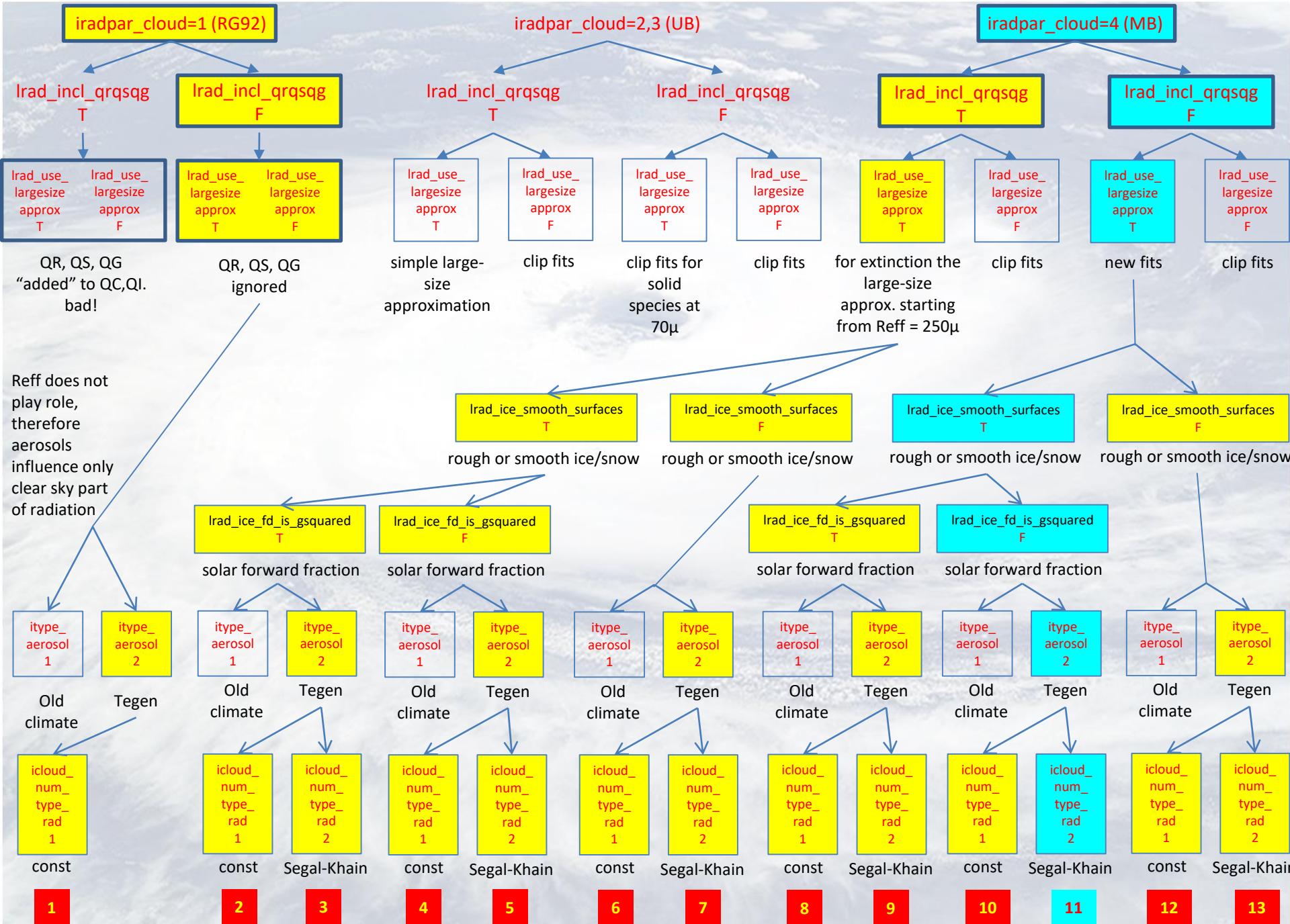


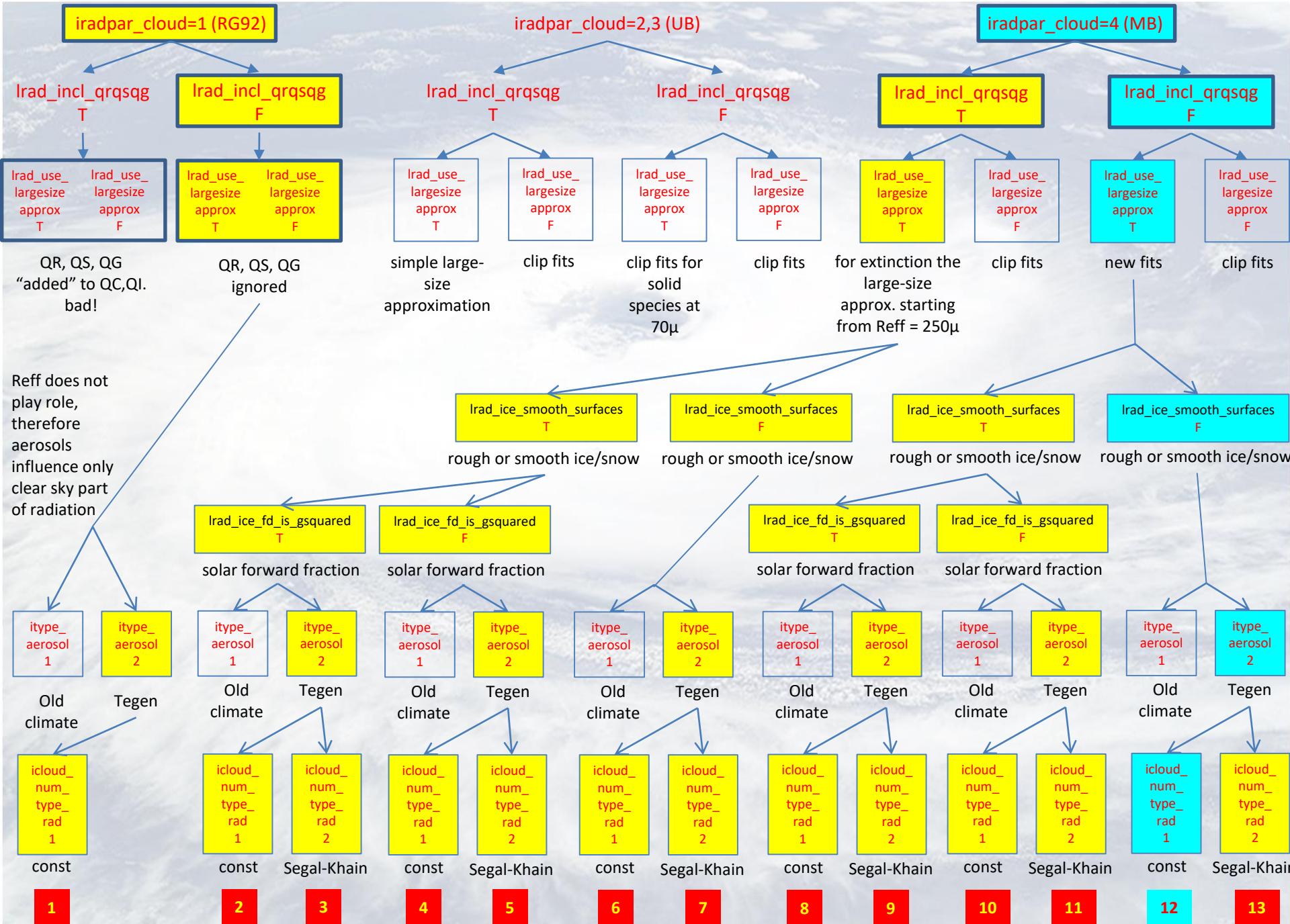


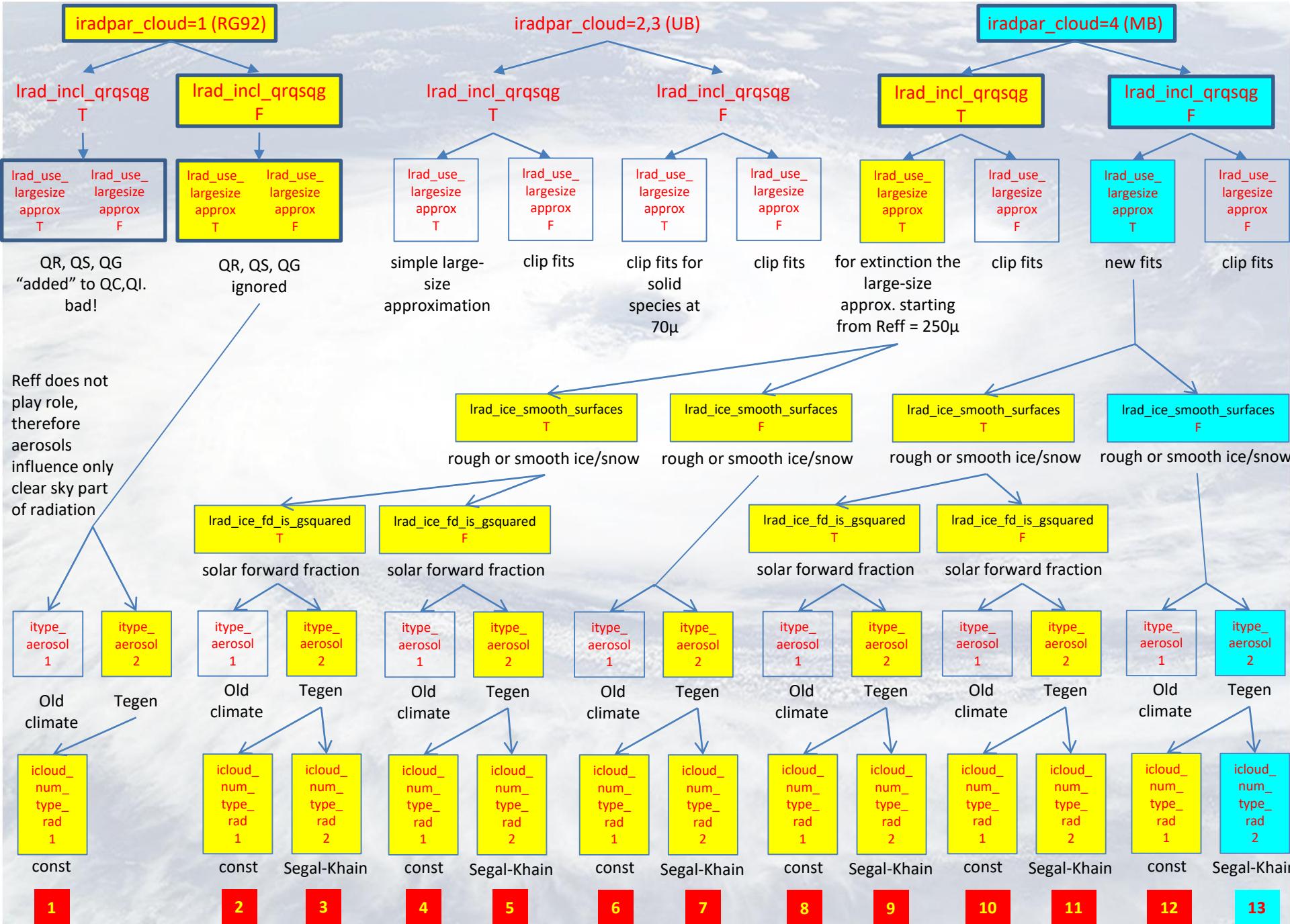




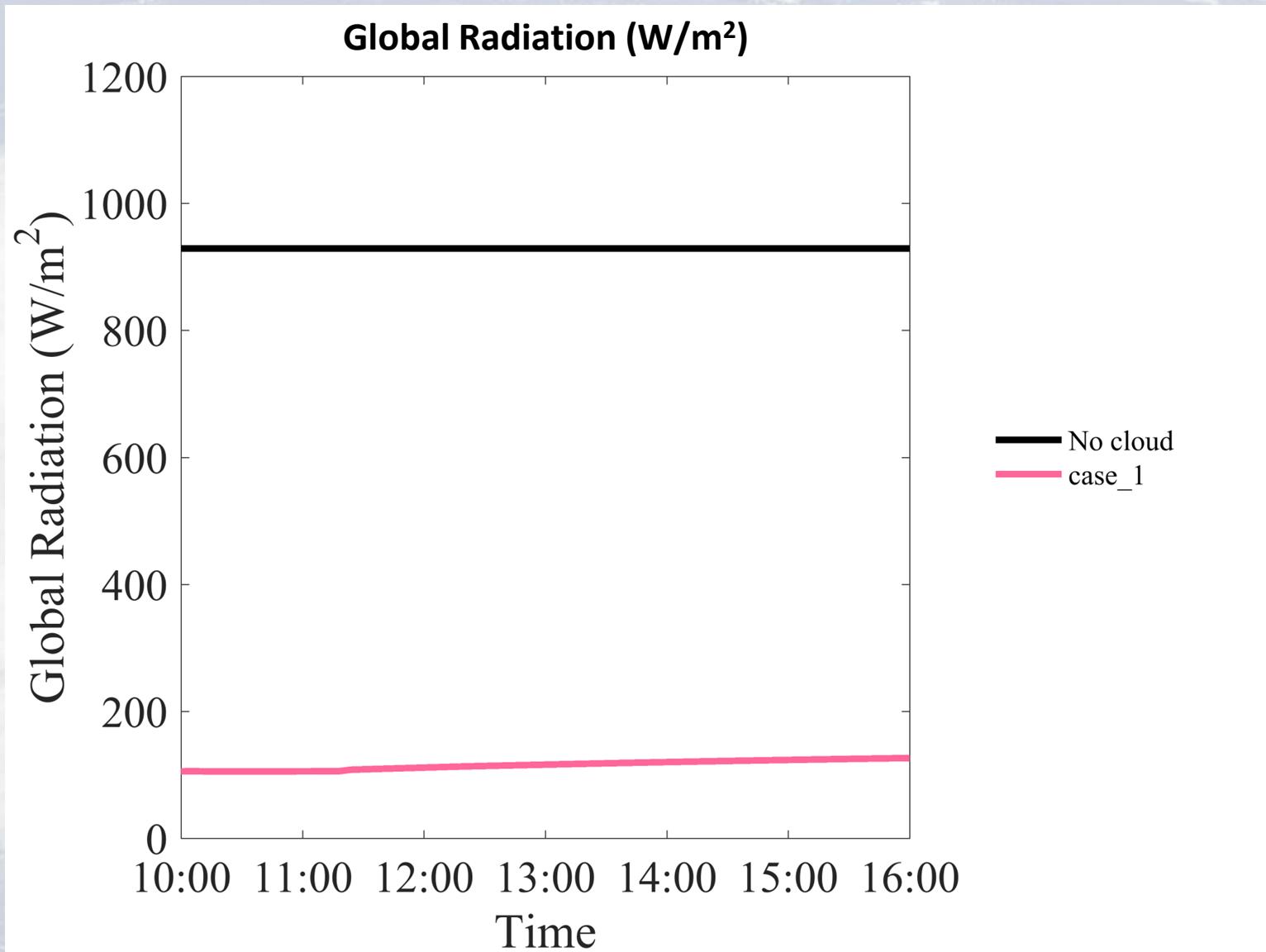




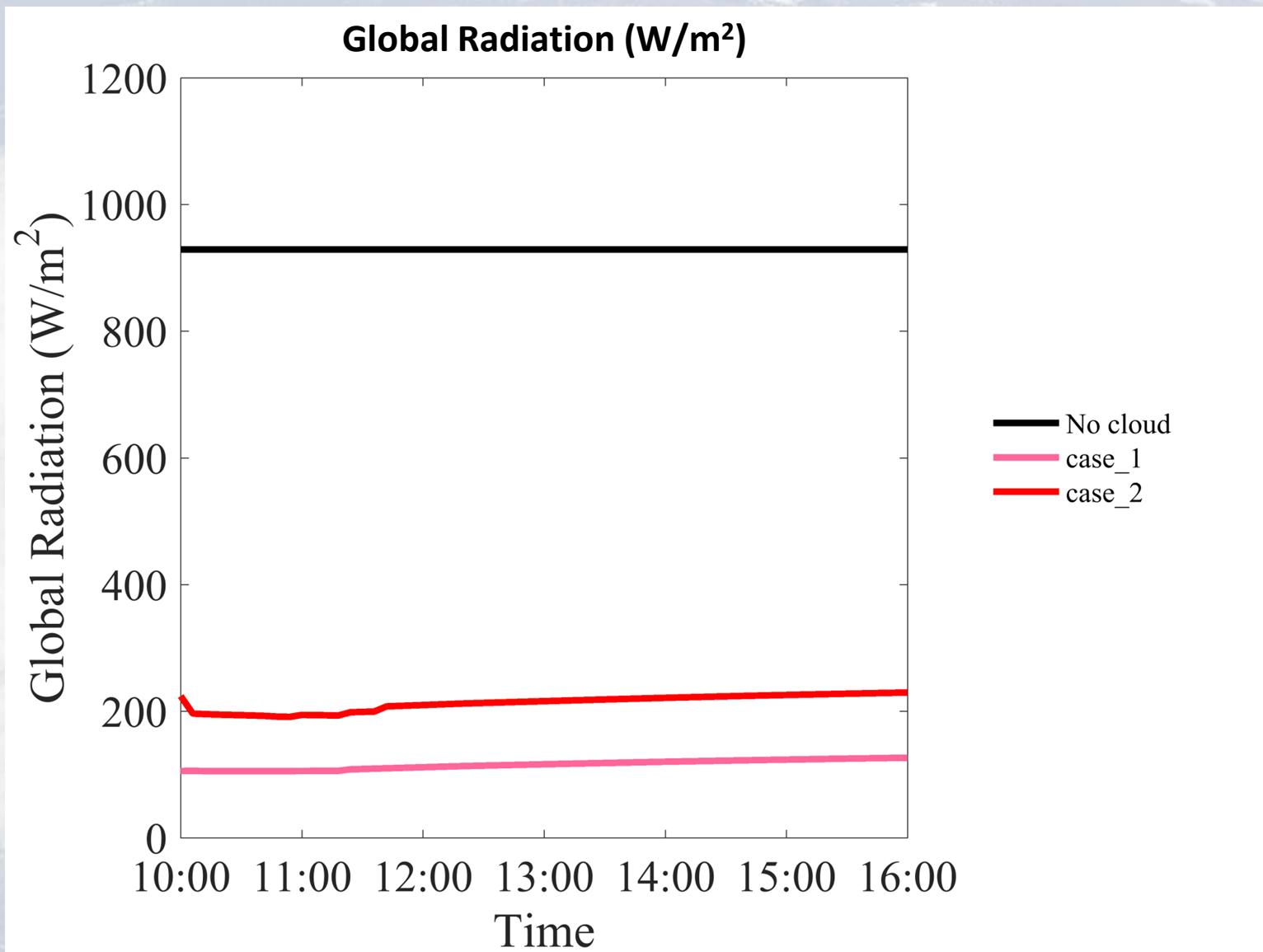




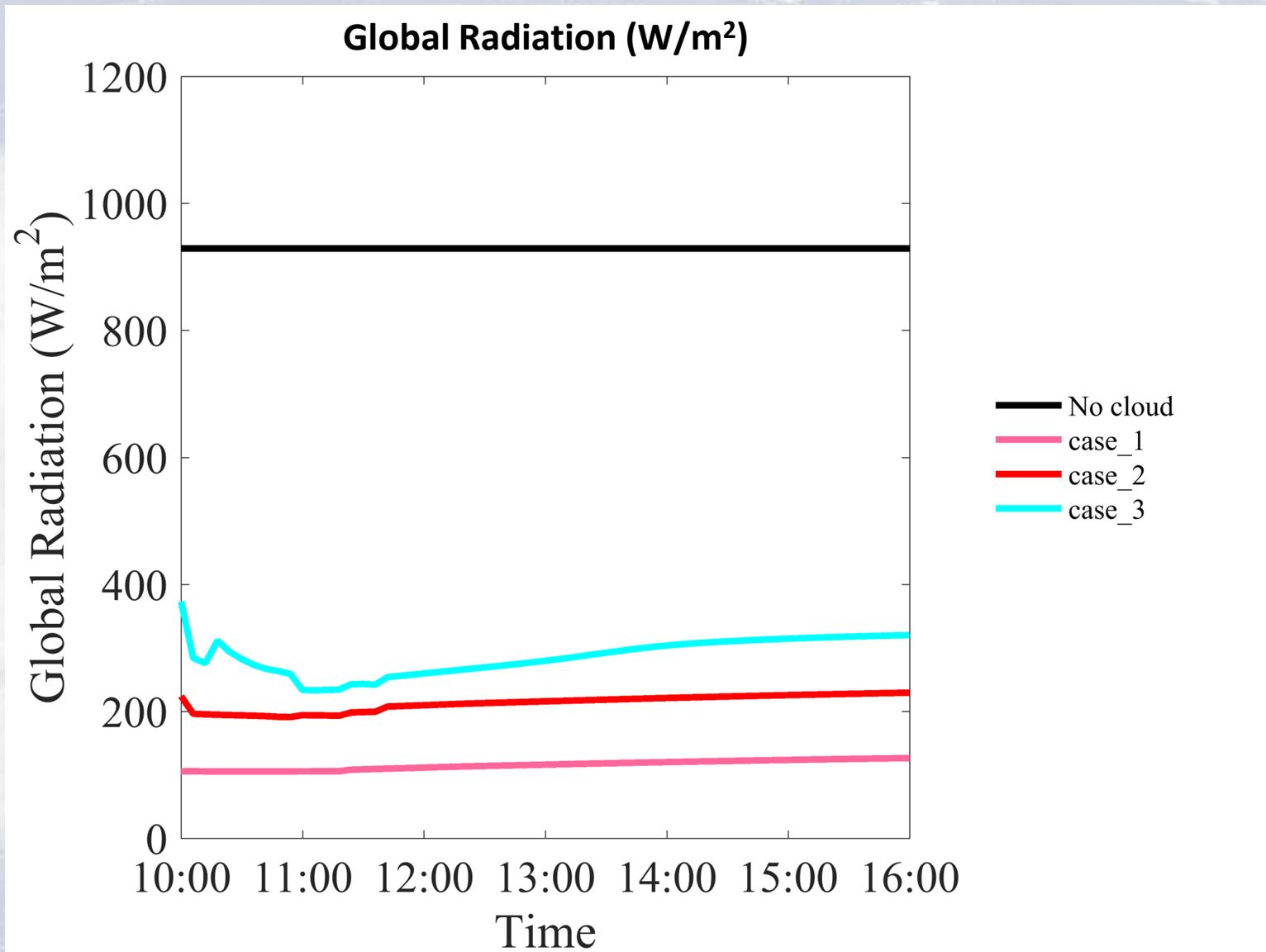
Warm Stratus: True / False switches



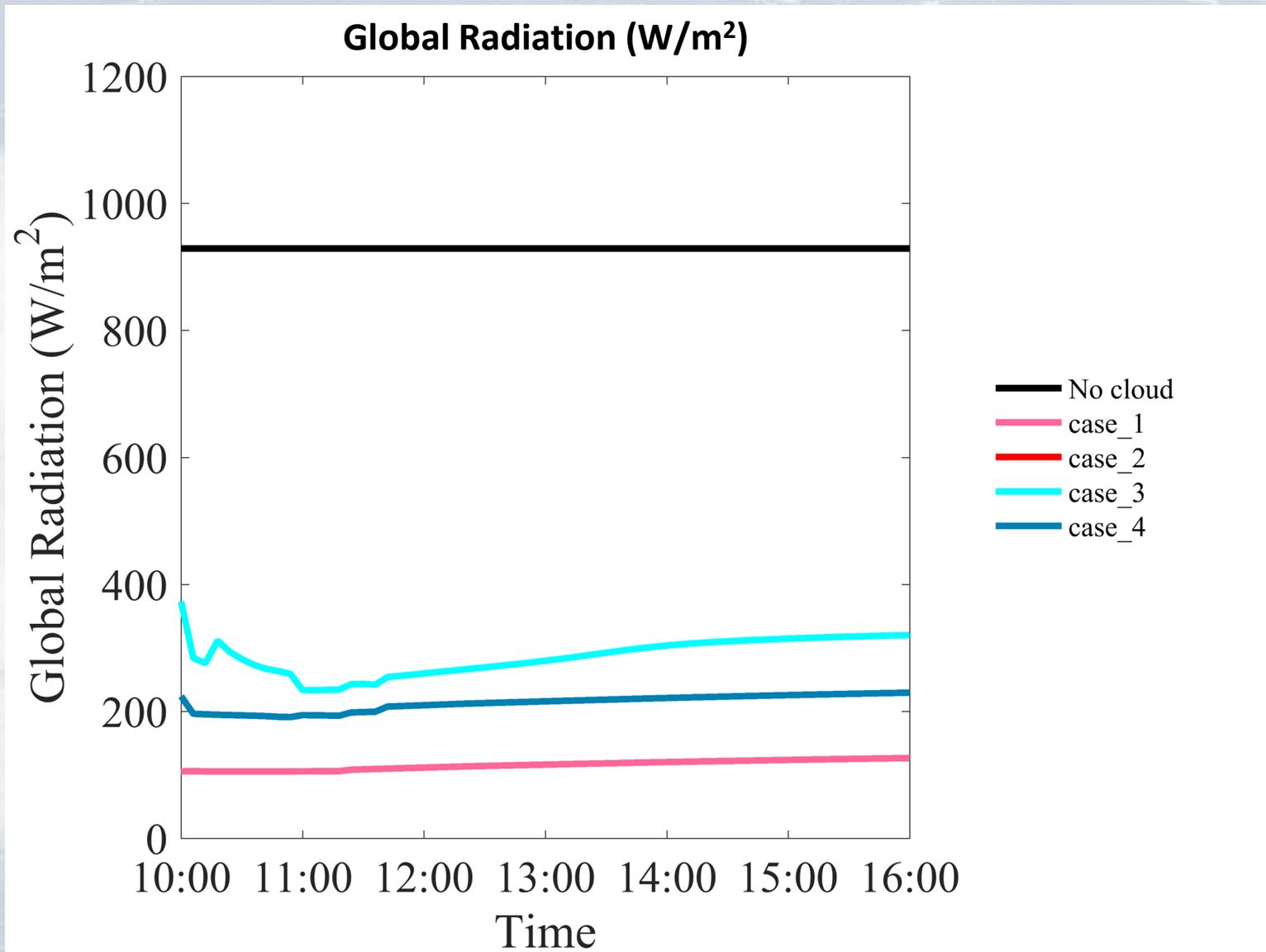
Warm Stratus: True / False switches



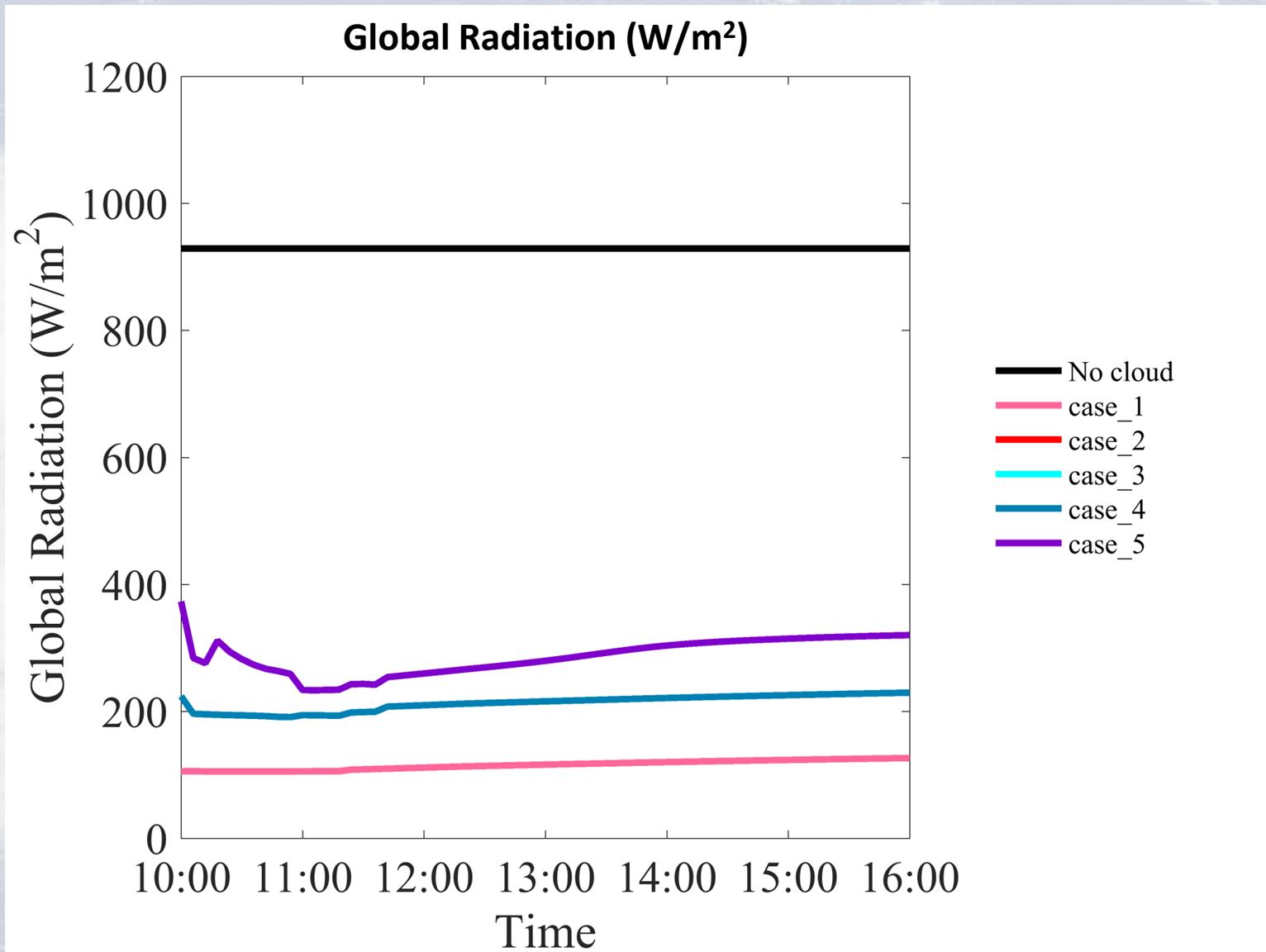
Warm Stratus: True / False switches



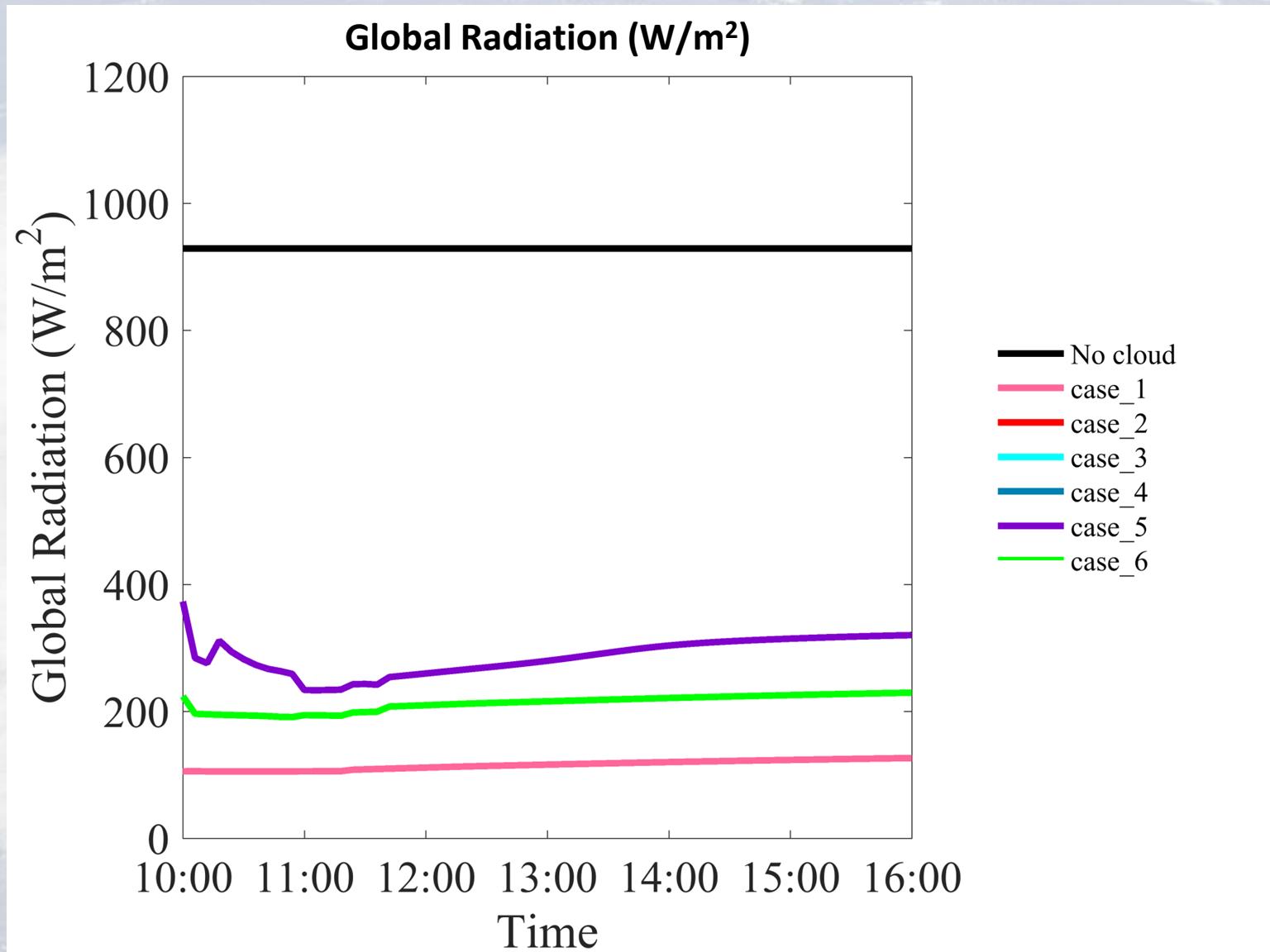
Warm Stratus: True / False switches



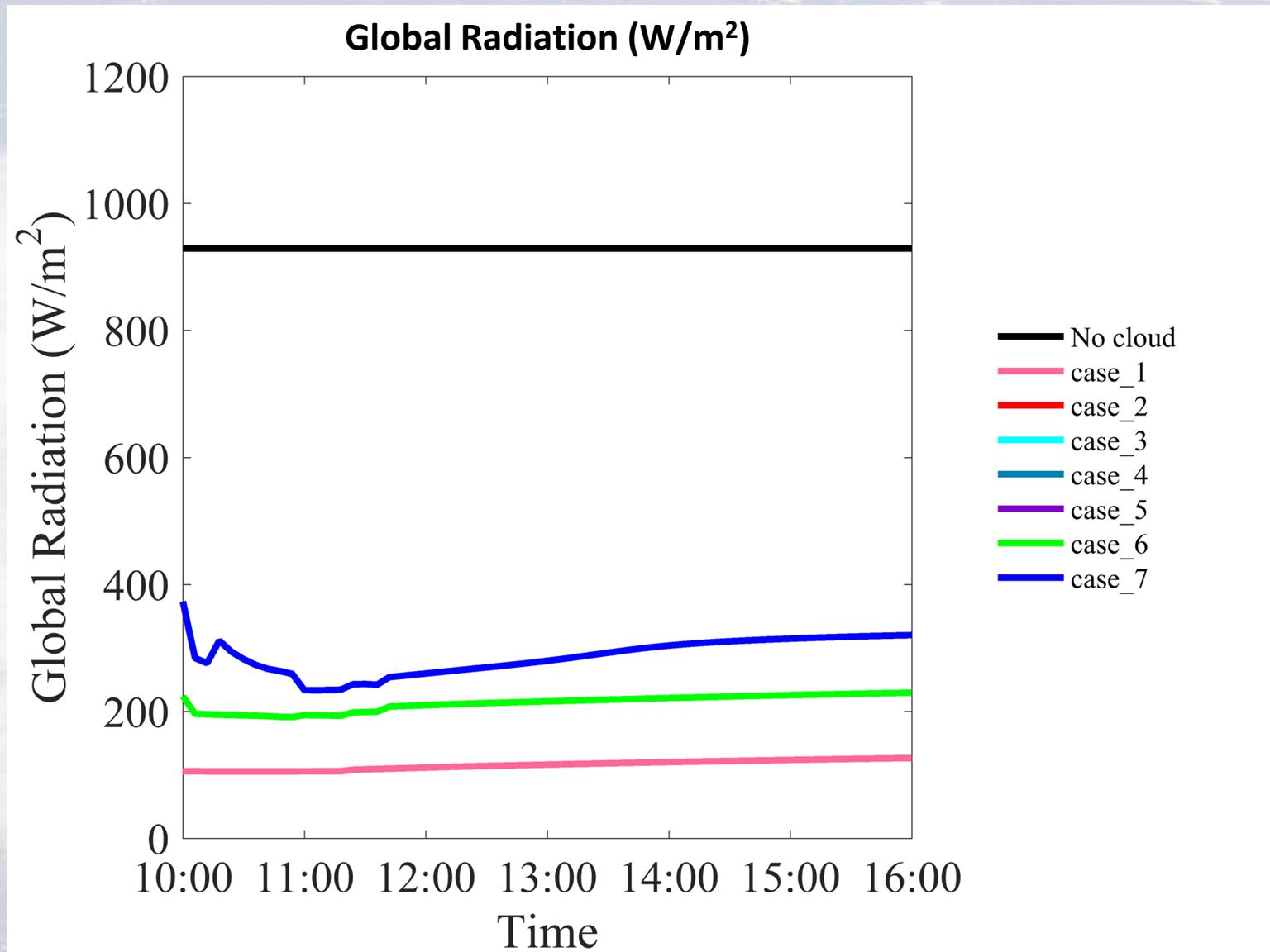
Warm Stratus: True / False switches



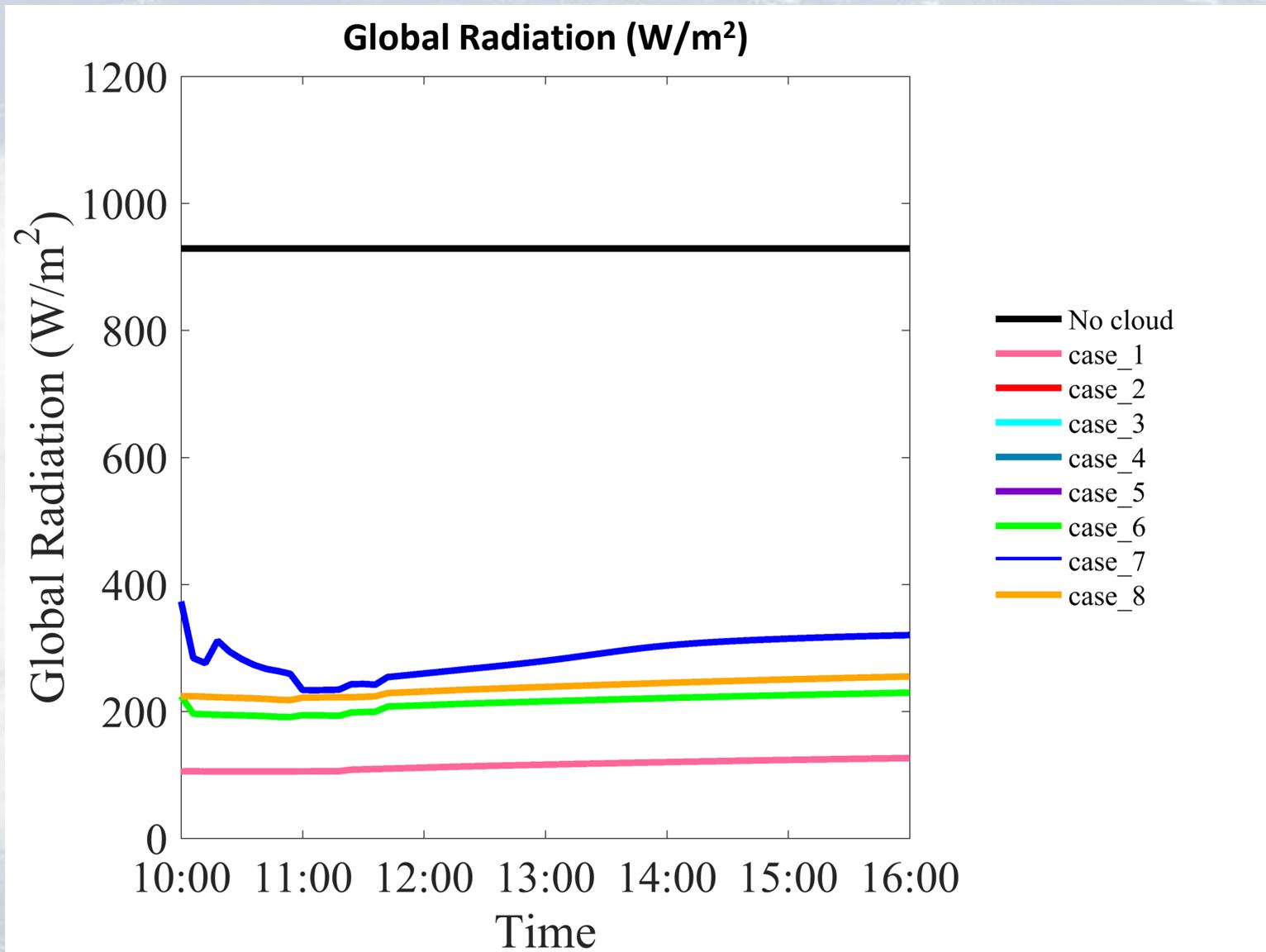
Warm Stratus: True / False switches



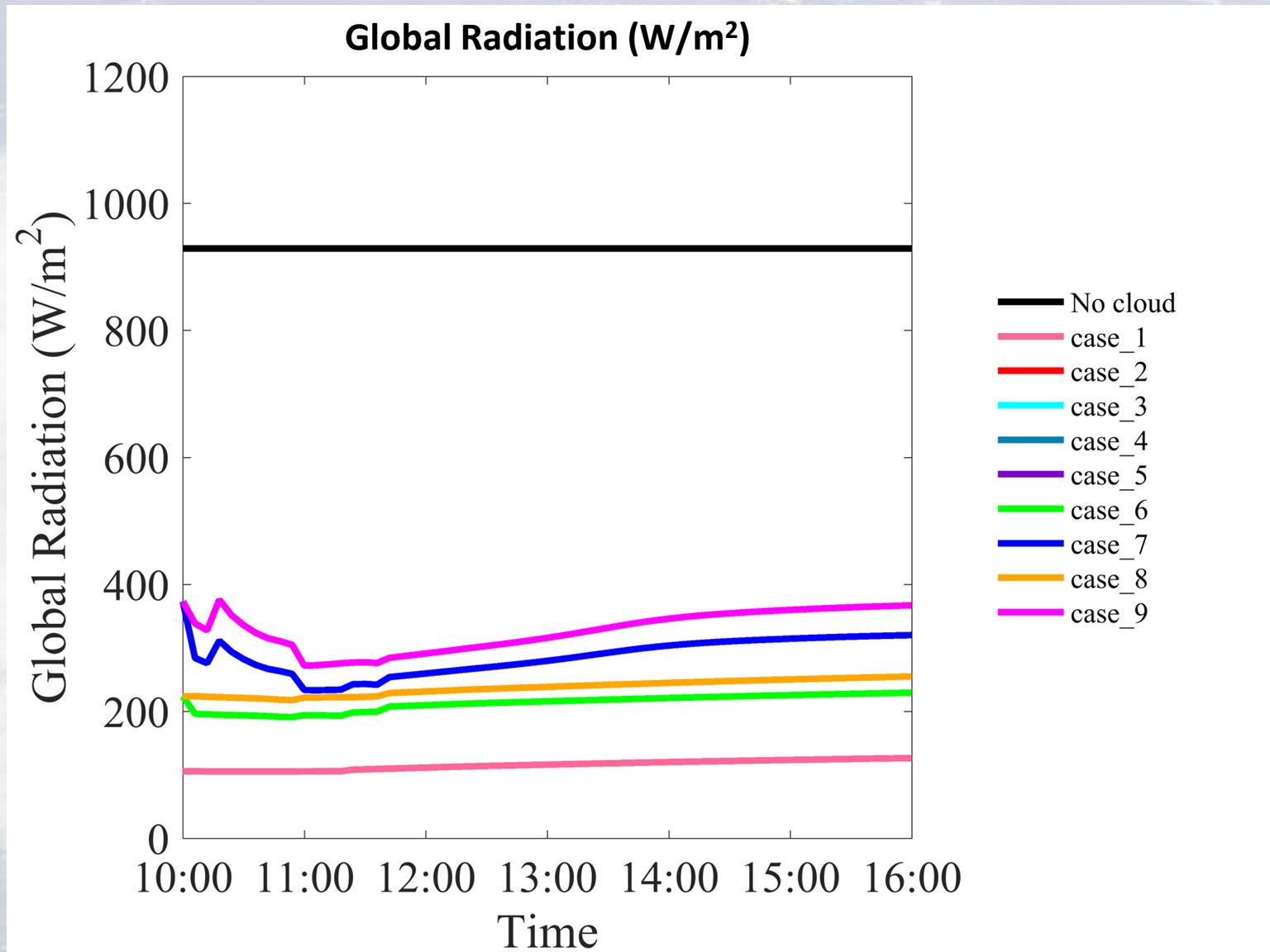
Warm Stratus: True / False switches



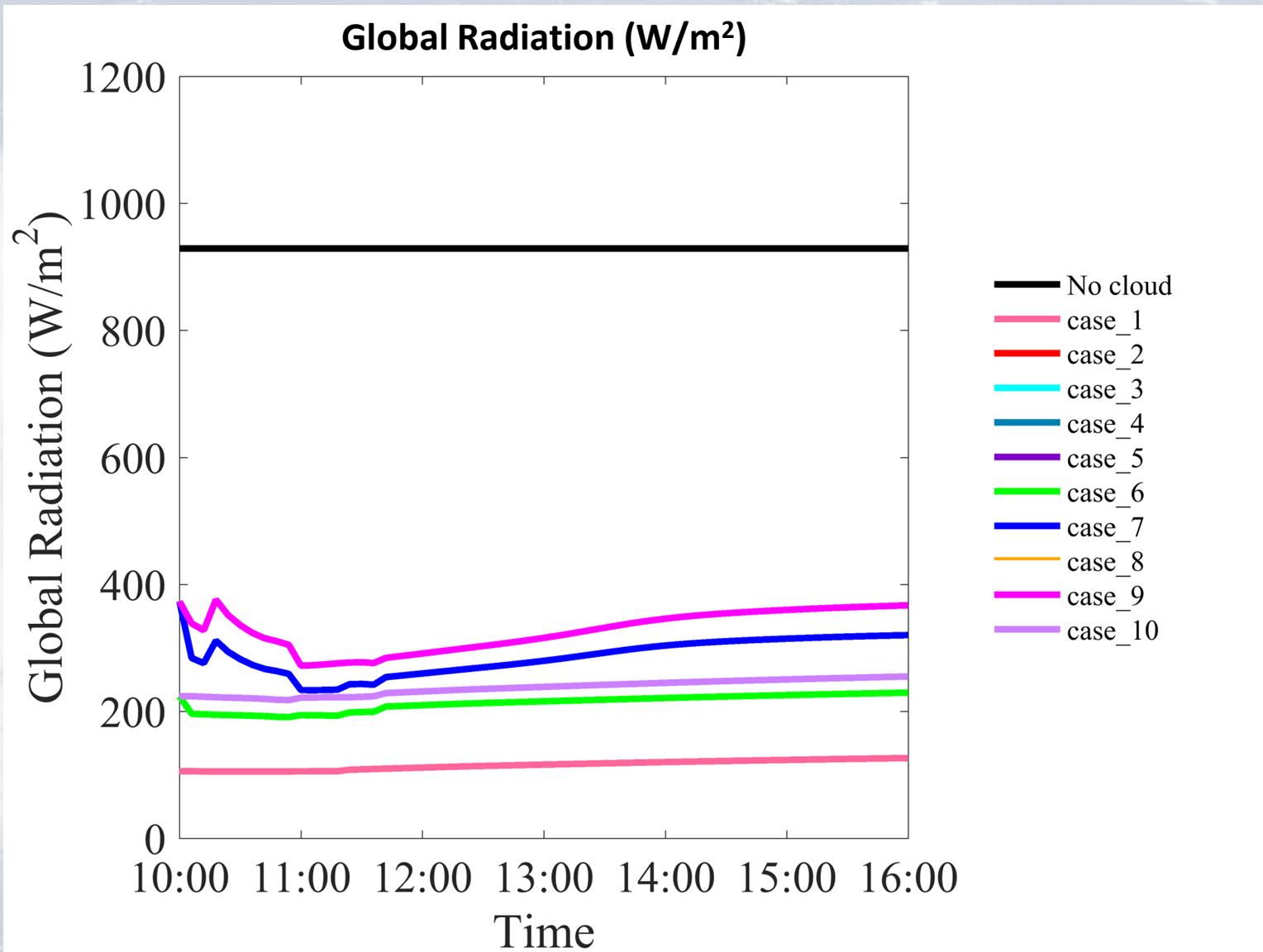
Warm Stratus: True / False switches



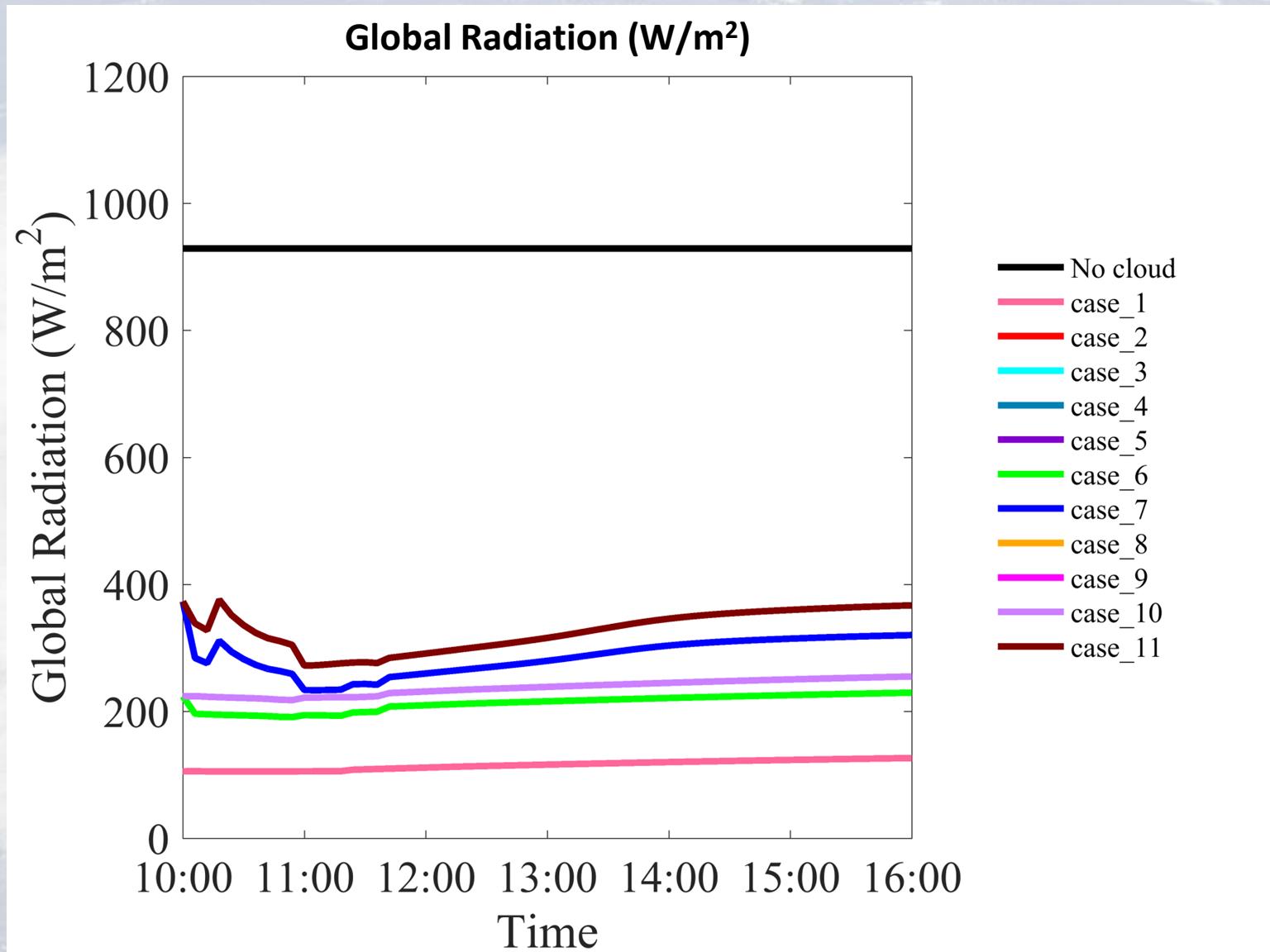
Warm Stratus: True / False switches



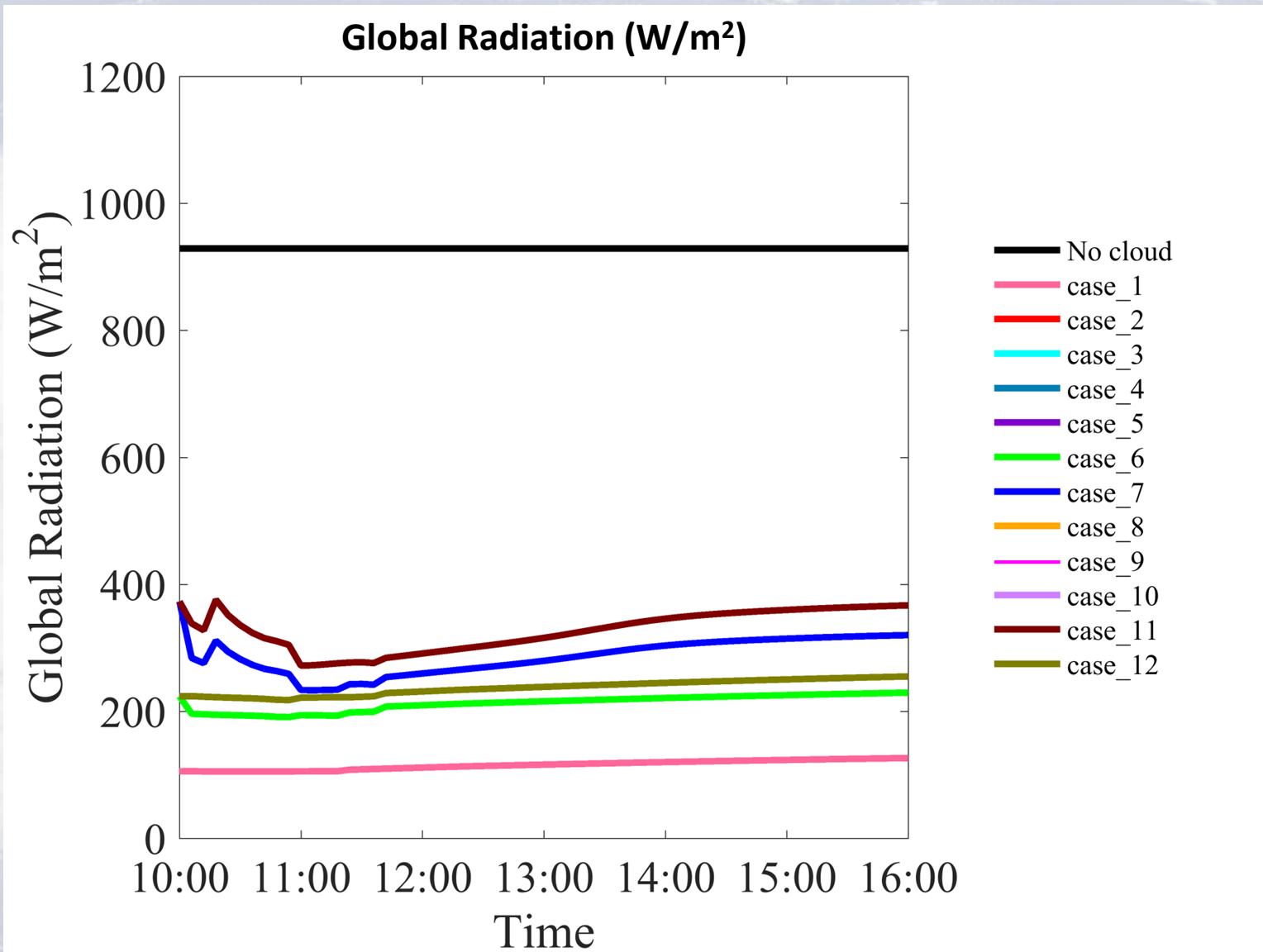
Warm Stratus: True / False switches



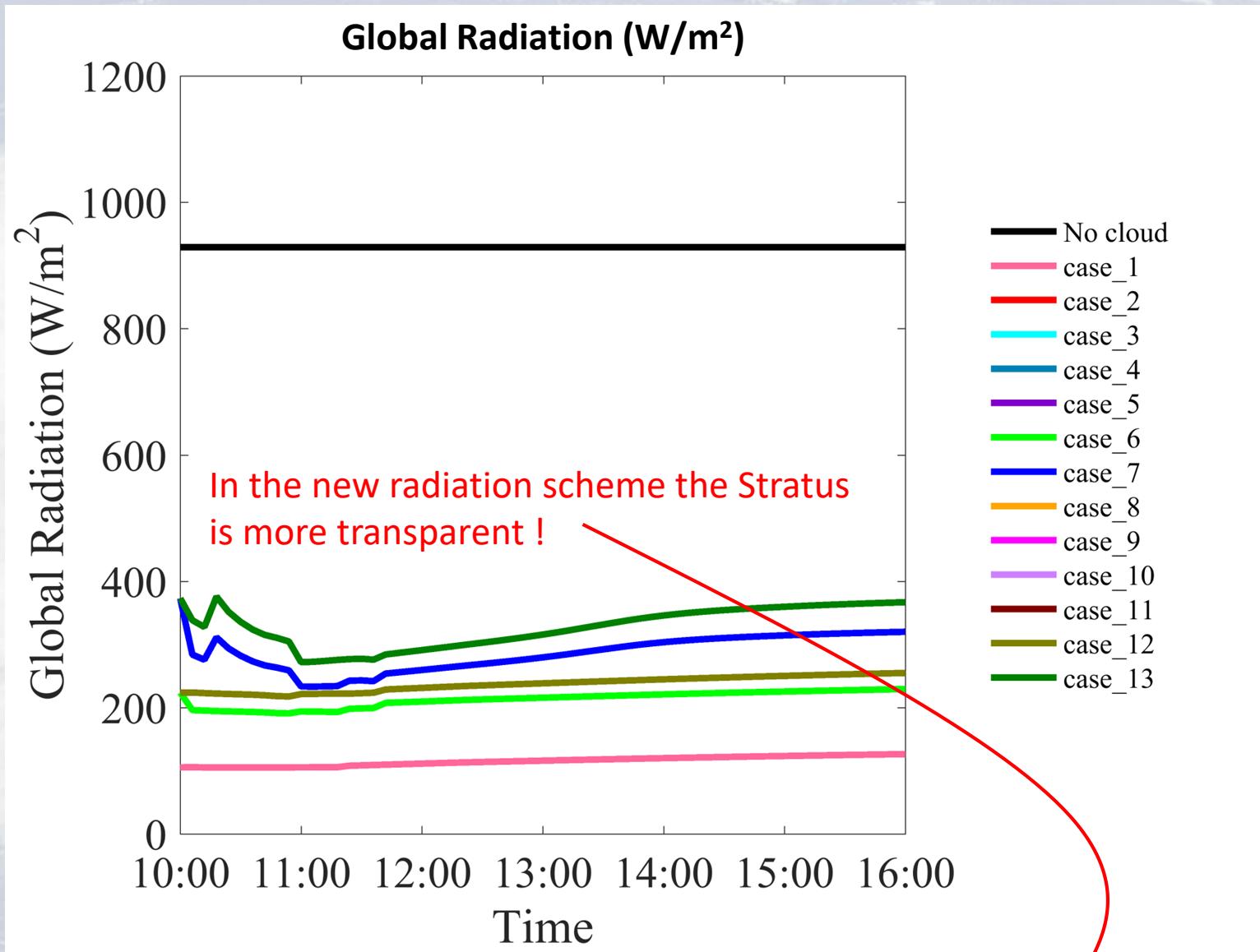
Warm Stratus: True / False switches



Warm Stratus: True / False switches



Warm Stratus: True / False switches



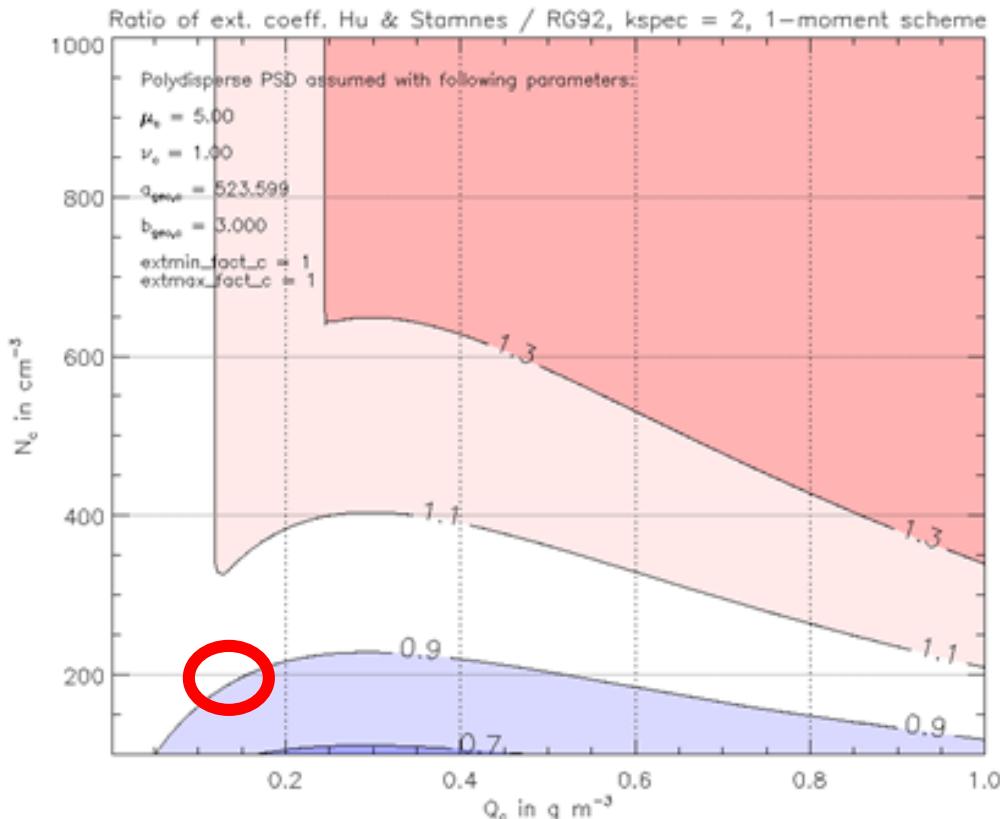
Cloud droplets comparison to RG92



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

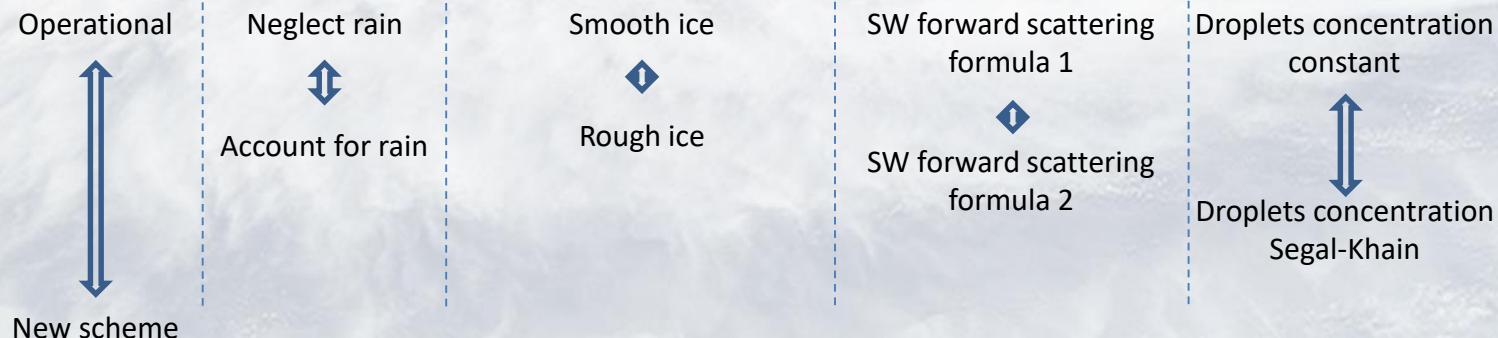
Time averaged global radiation reduction (%)

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	Irad_incl_qrqsgq	Irad_ice_smooth_surfaces	Irad_ice_fd_is_gsquared	Icloud_num_type_rad
Warm Stratus	~22%	~4%	0	0	~9%



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_qrqsgq	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_qrqsgq	lrad_ice_smooth_surfaces	lrad_ice_fd_is_gsquared	lcloud_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

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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 ?
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5. Summary

3. Continuous parameters (within the switches)

Can be important for
Warm Stratus

	true / false switches	continuous parameters
1.	lrad_incl_qrqssqg	
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	
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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Outline

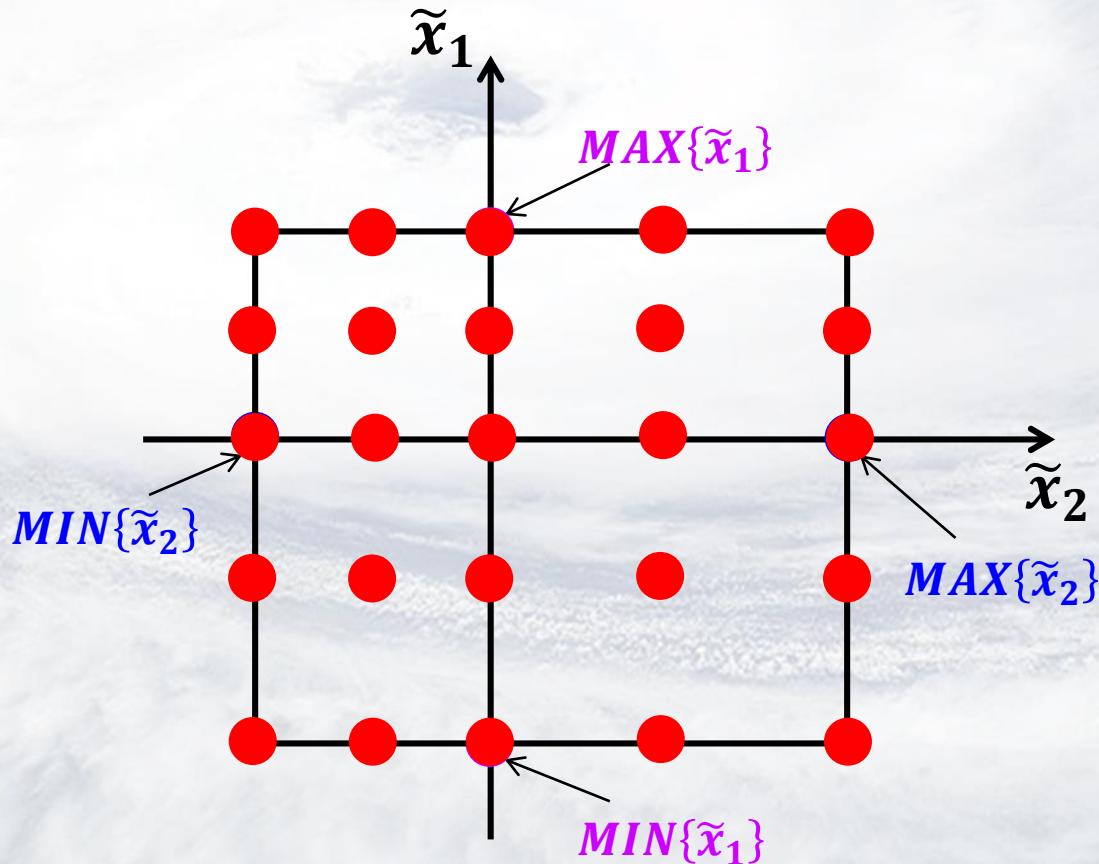
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3a. Method: How to define sensitivity to model parameters ?

Example for 2 parameters :

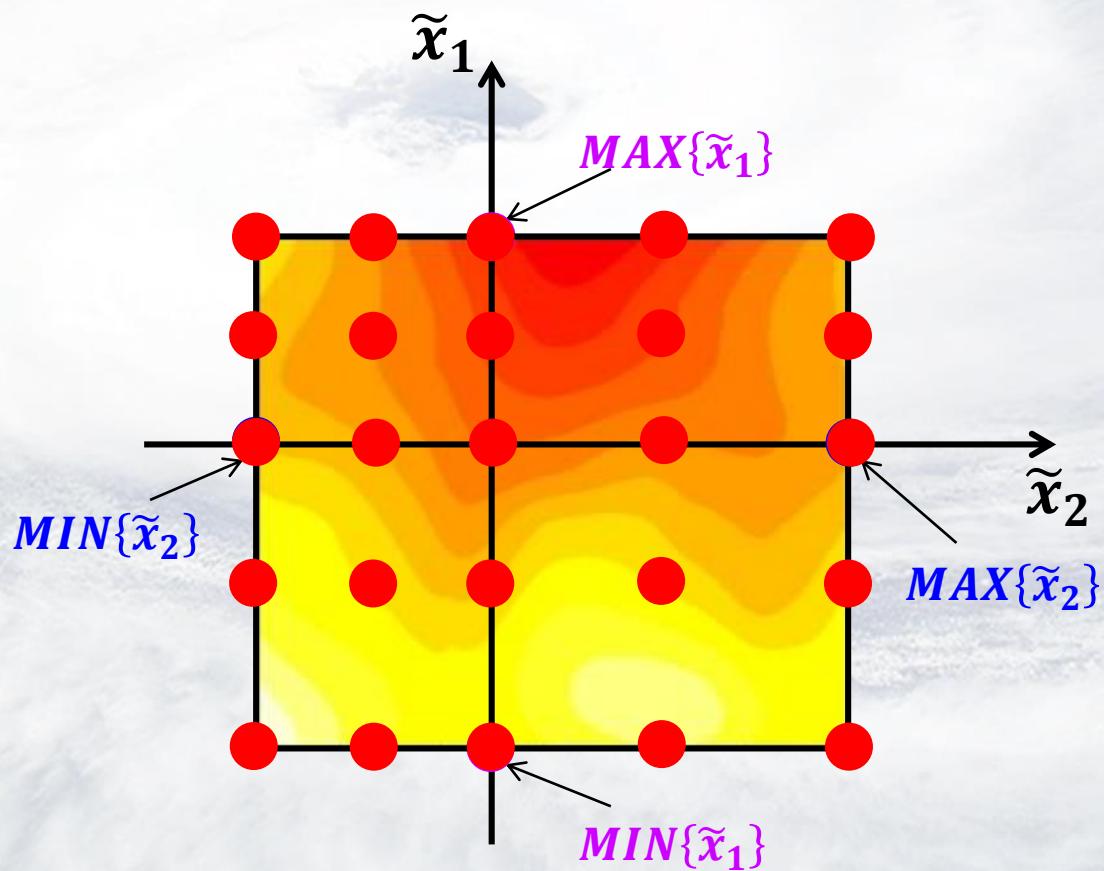
STEP 1: Perform several idealized simulations to “fill the parameters space”

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)

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

Reduction of global radiation (%)

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

normalized parameter

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

$$x_1 \equiv radqcfact$$

$$x_2 \equiv qvsatfact_sgscl_rad$$

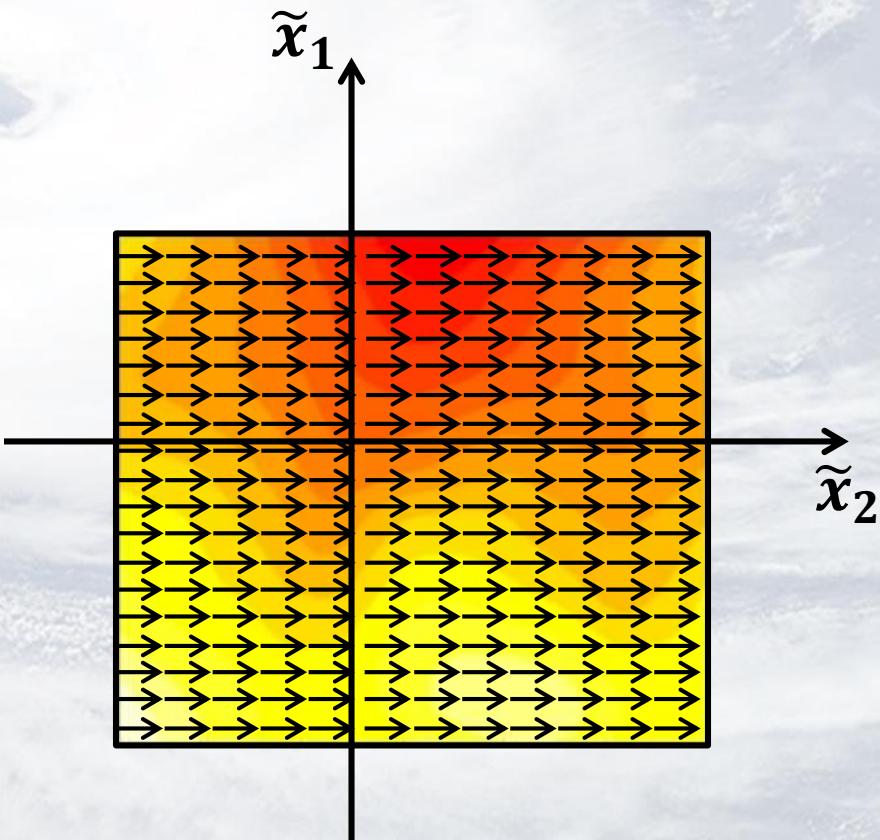
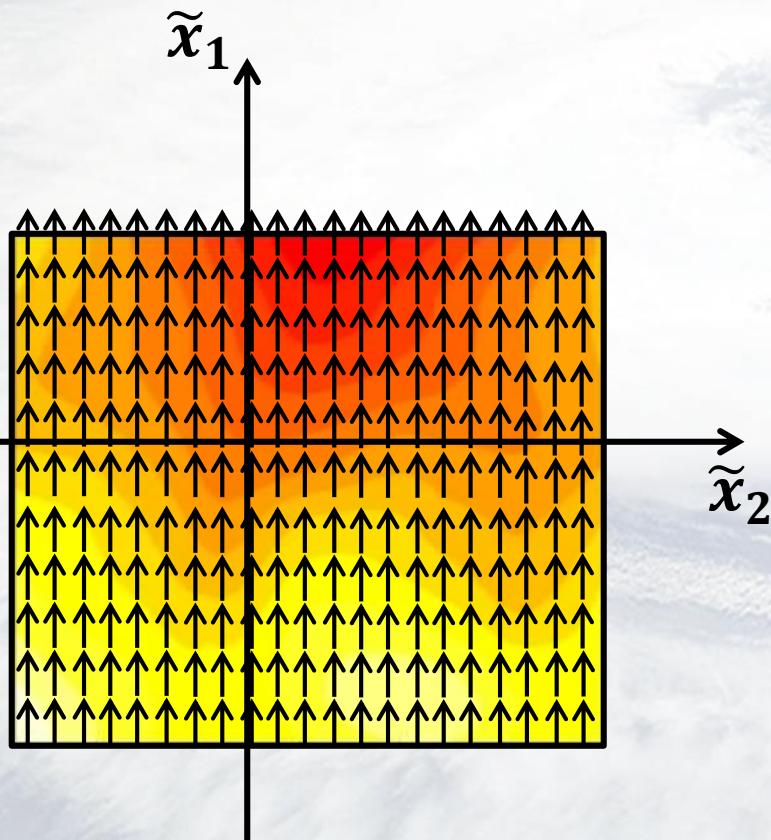
$$x_3 \equiv cloud_num_rad$$

$$x_4 \equiv reff_ini_c$$

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

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

Outline

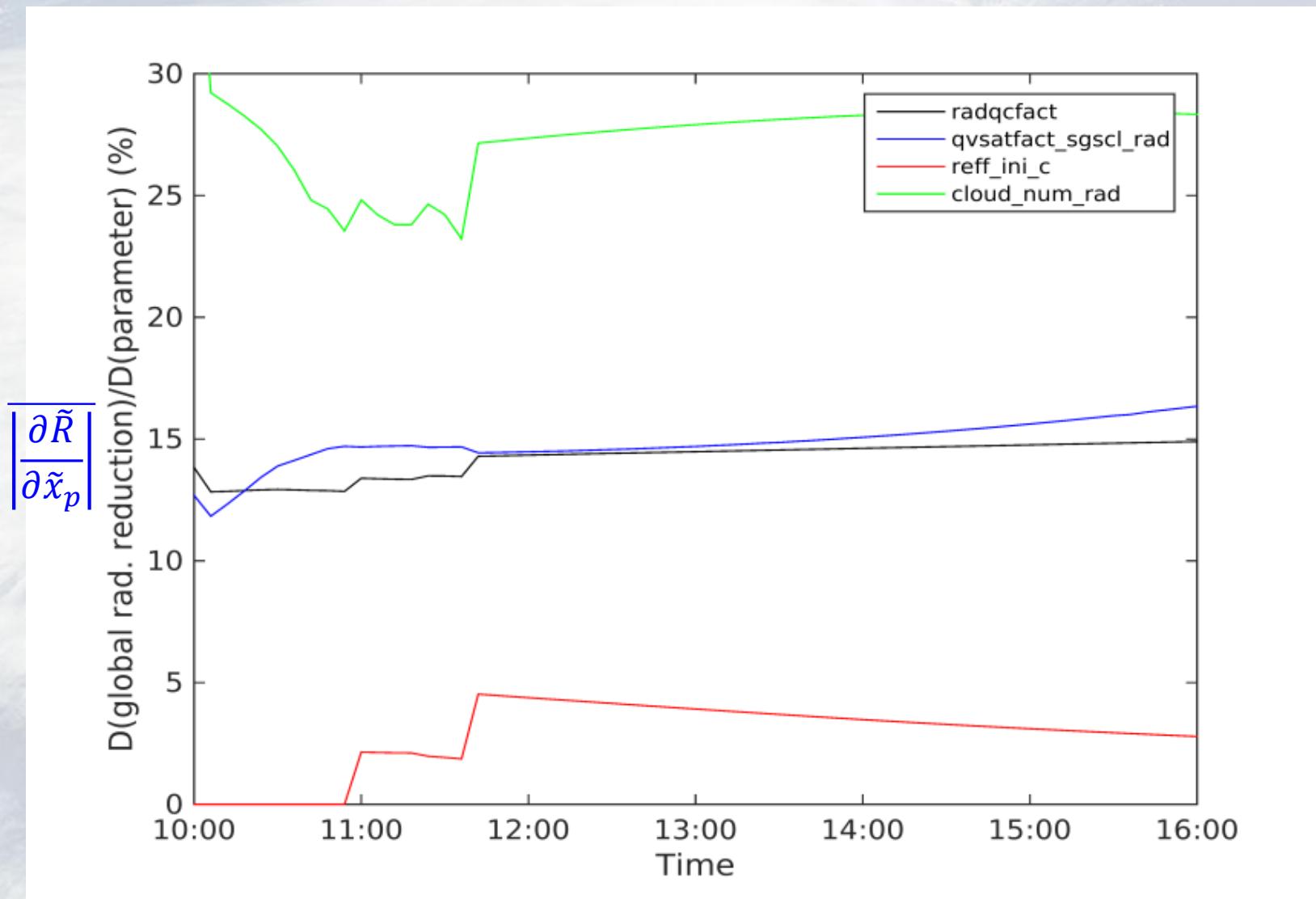
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3b. Sensitivity results: which parameters are most important ?

Example: Case 4, warm Stratus



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

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

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

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](#)

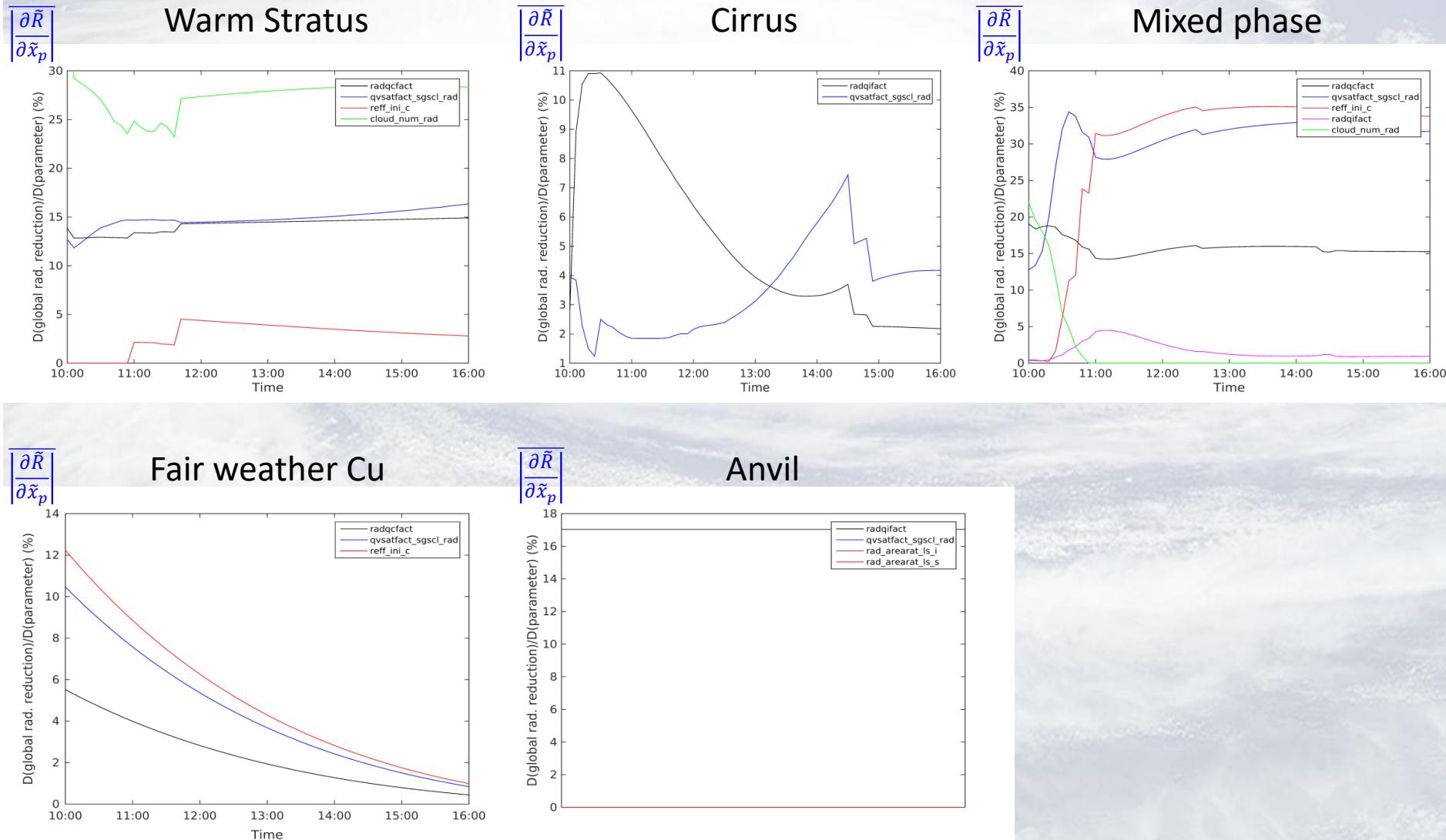
Subgrid effective radius

[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



All clouds : continuous parameters - summary

Time averaged D(global rad. reduction)/D(parameter) (%)

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

Warm
Stratus:

Cirrus:

Mixed
phase:

Fair
weather
Cu:

Anvil:

All clouds : continuous parameters - summary

Time averaged D(global rad. reduction)/D(parameter) (%)

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

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

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
qvstfact_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

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

All clouds : continuous parameters - summary

Global radiation sensitivity (%)

parameter:	radqifact	radqcfact	qvsatfact_sg scl_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. irad_incl_qrqsqg
2. iradpar_cloud
3. irad_use_largesizeapprox
4. irad_ice_smooth_surfaces
5. irad_ice_fd_is_gsquared
6. itype_aerosol
7. icloud_num_type_rad
8. radqcfact
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

true / false switches
continuous parameters

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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_qrsqg; icloud_num_type_rad;
cloud_num_rad; qvsatfact_sgscl_rad; reff_ini_c; radqcfact; radqifact

Thank you !

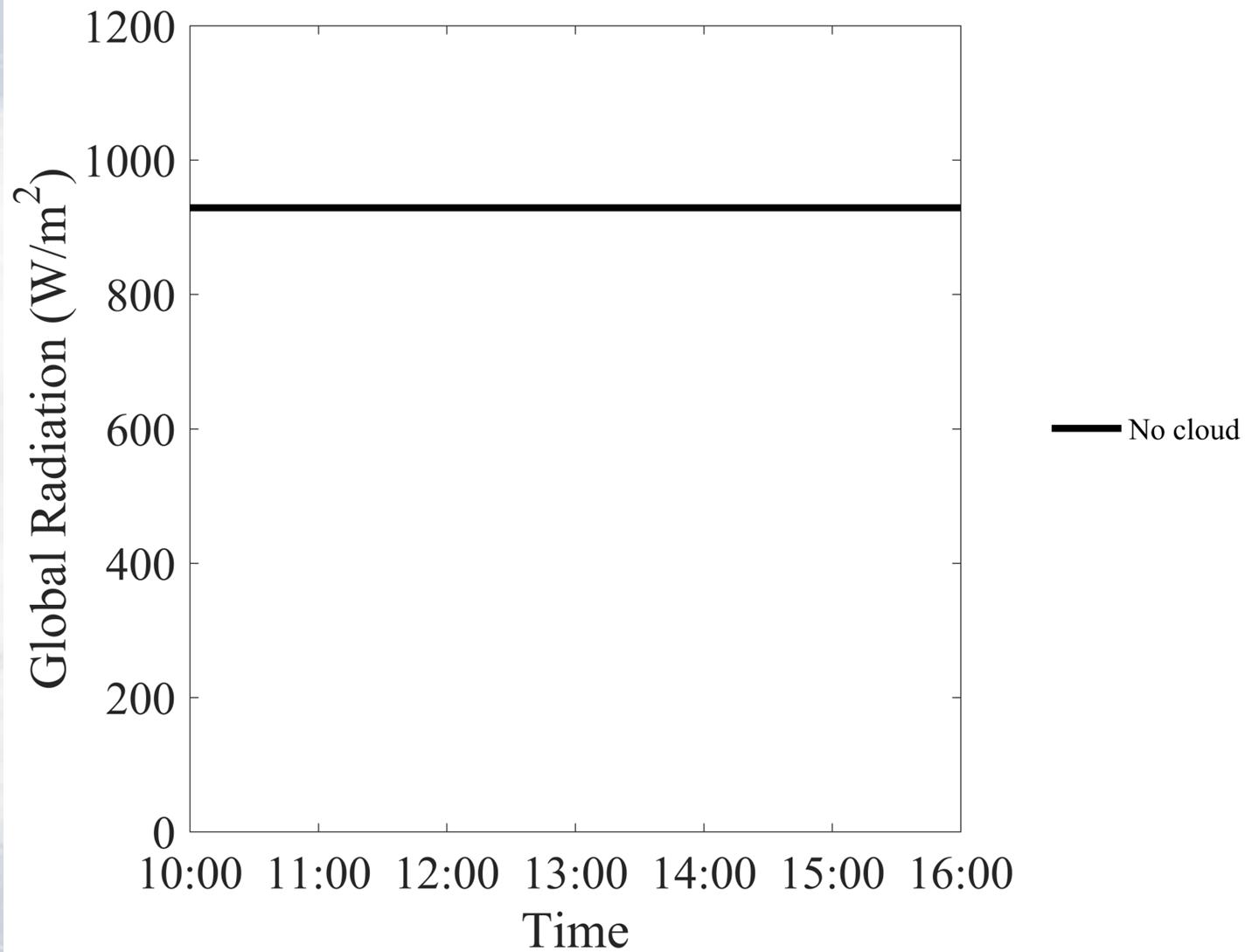


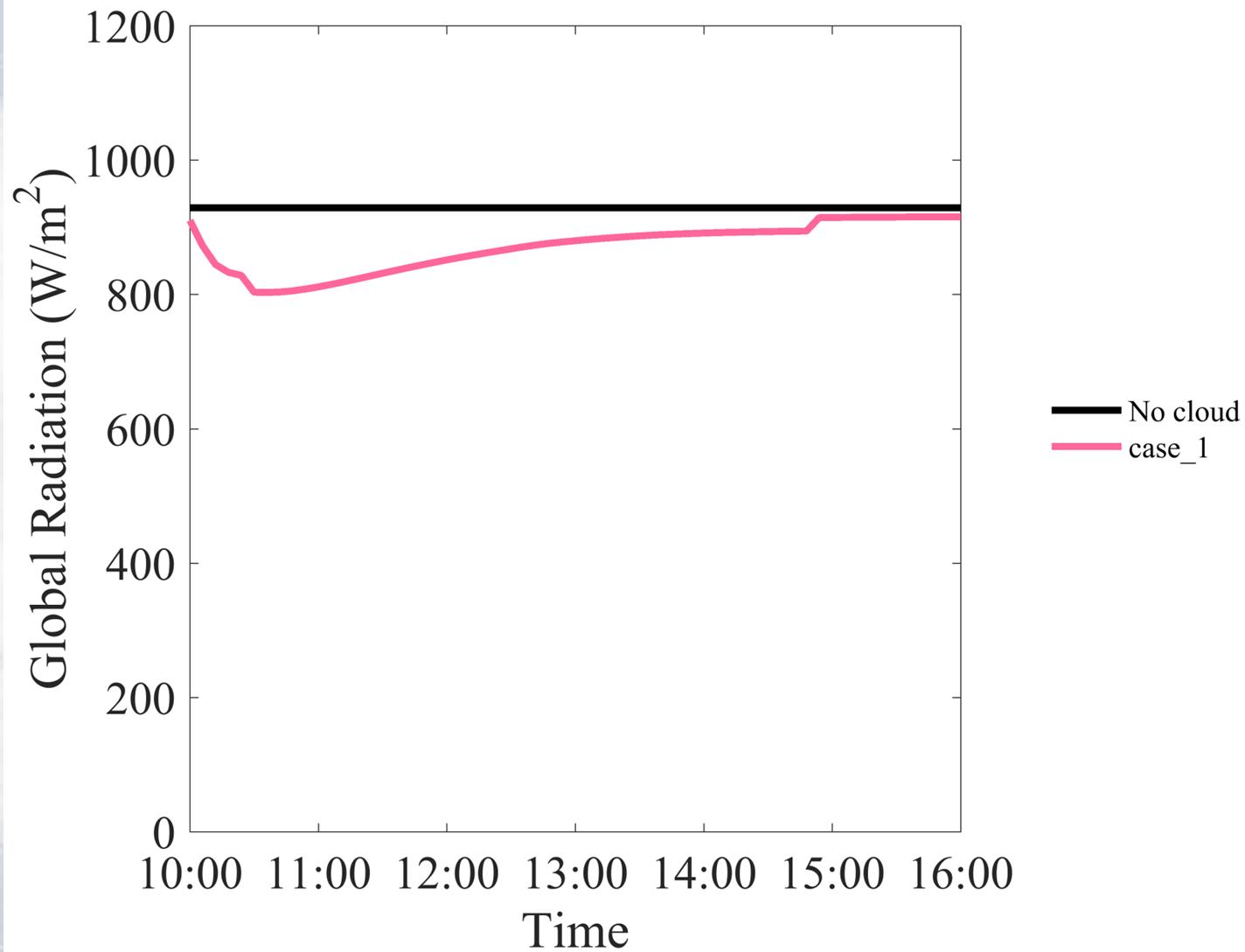
The background of the slide is a grayscale aerial photograph of a coastal area. It shows a small, irregularly shaped body of water in the center-left, surrounded by land. To the right of the water, there are several low, rolling hills or mountains covered in vegetation. The overall scene is hazy and lacks sharp details due to the aerial perspective.

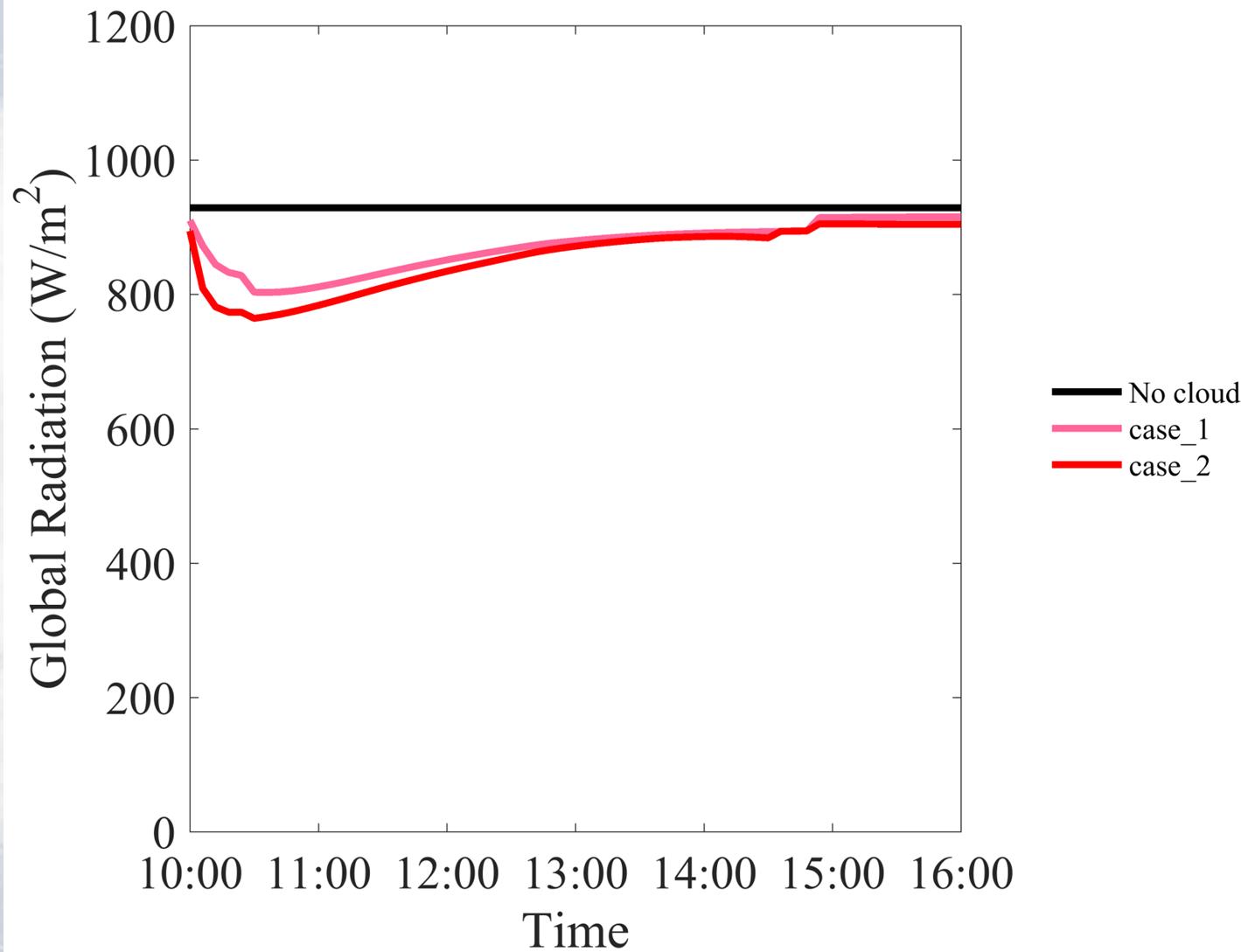
Additional slides ...

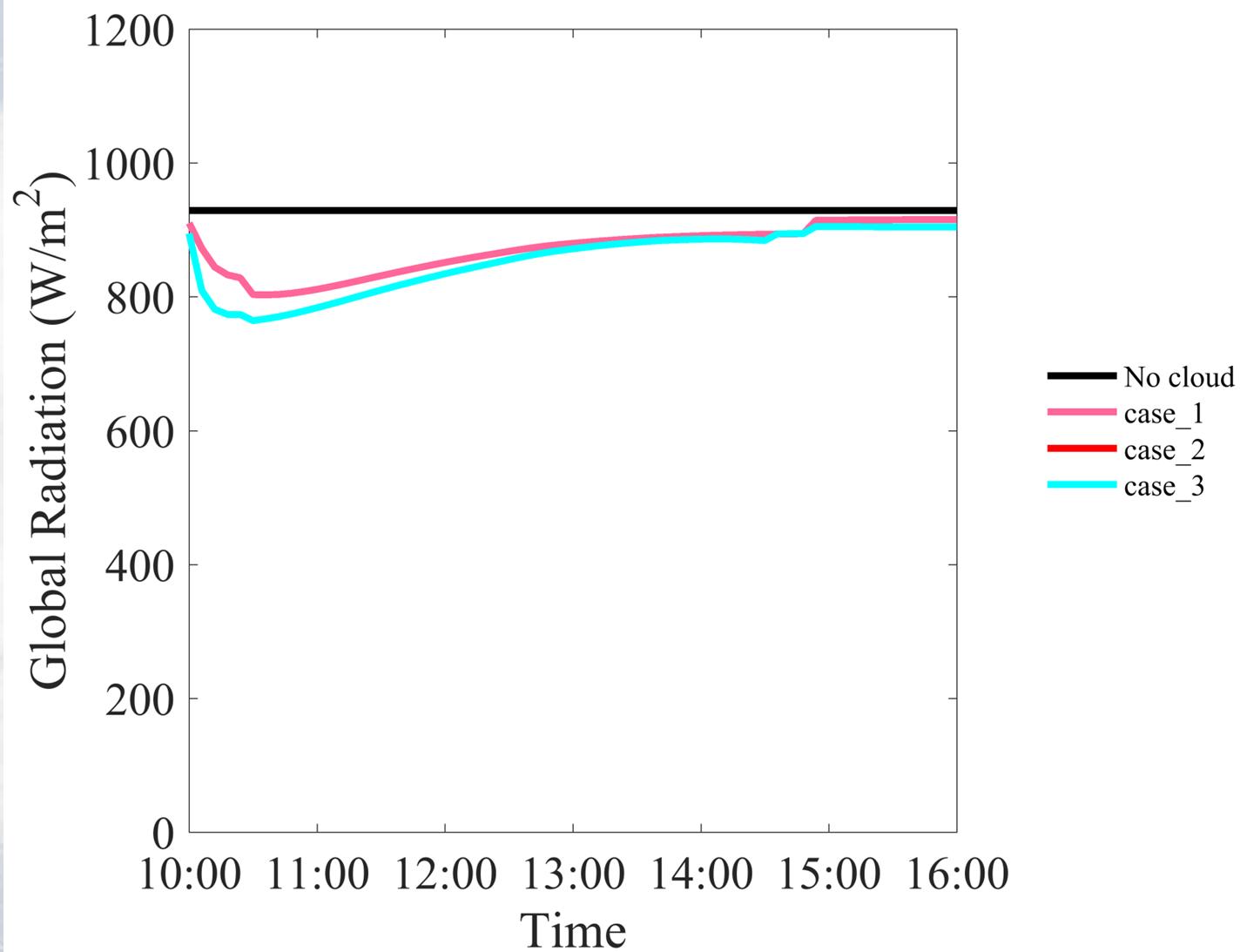
The background image shows a coastal landscape from an aerial perspective. In the foreground, there are green hills and fields. A large body of water, possibly a lake or a wide river, stretches across the middle ground. The sky above is filled with wispy, white clouds.

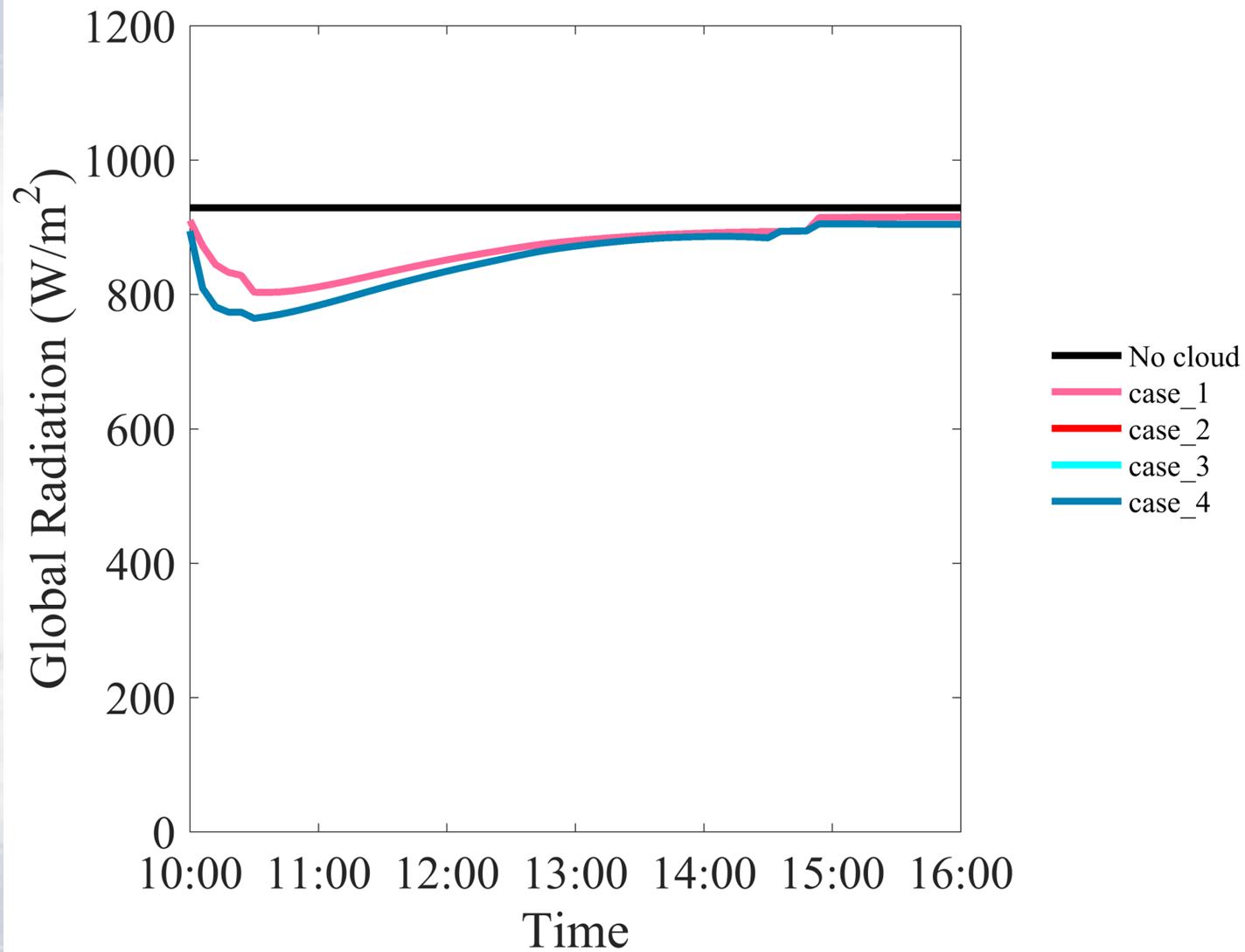
True / False switches on Cirrus:

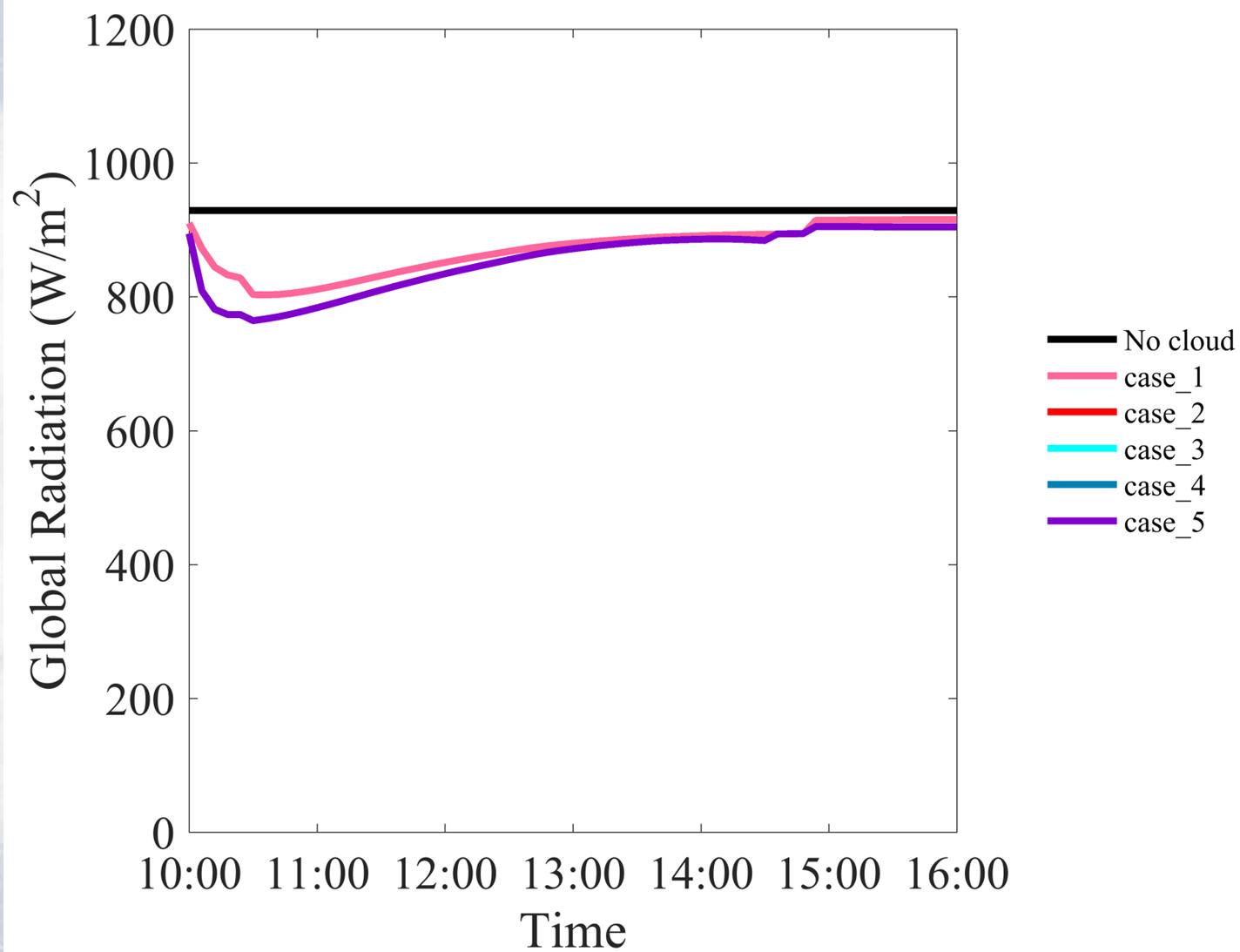


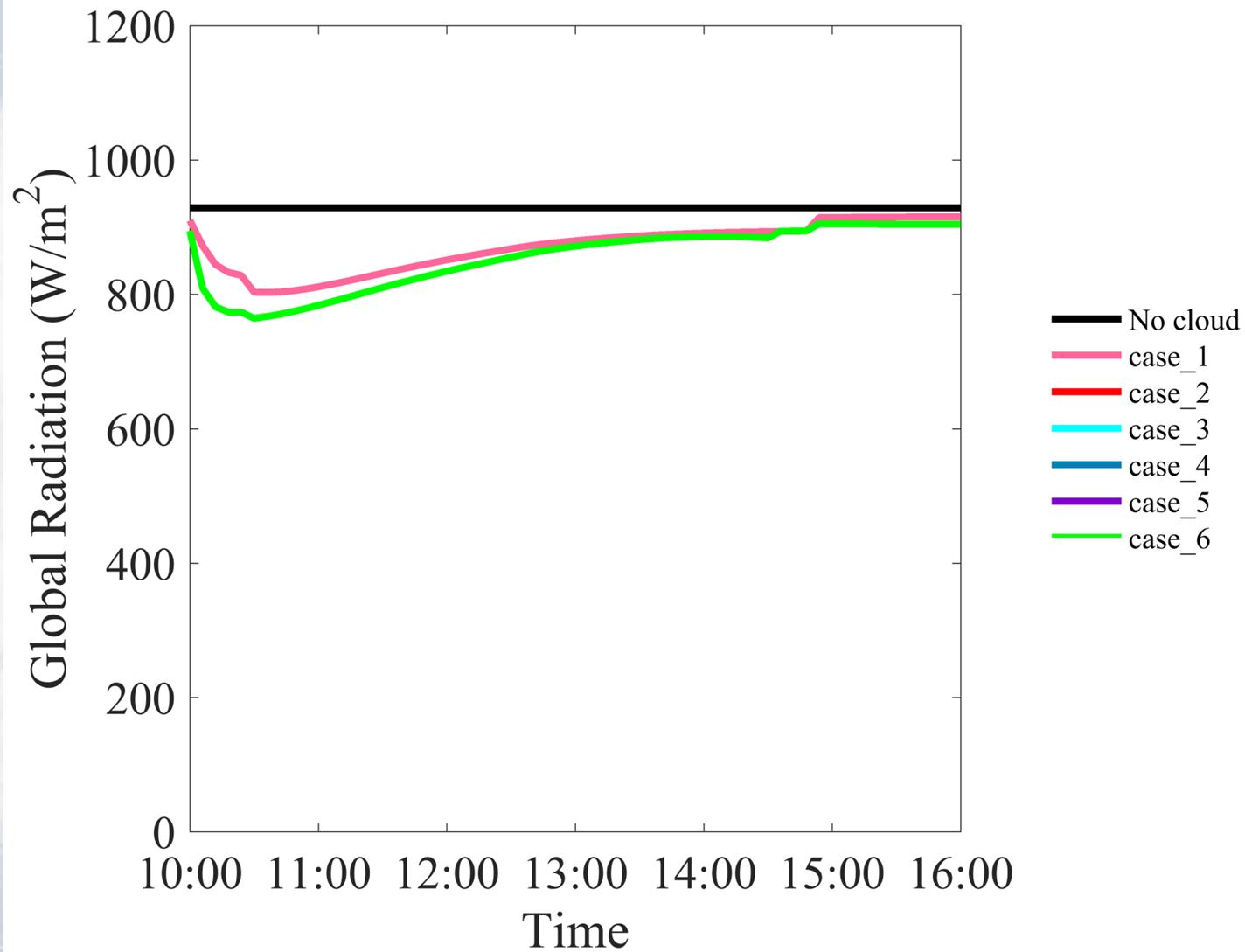


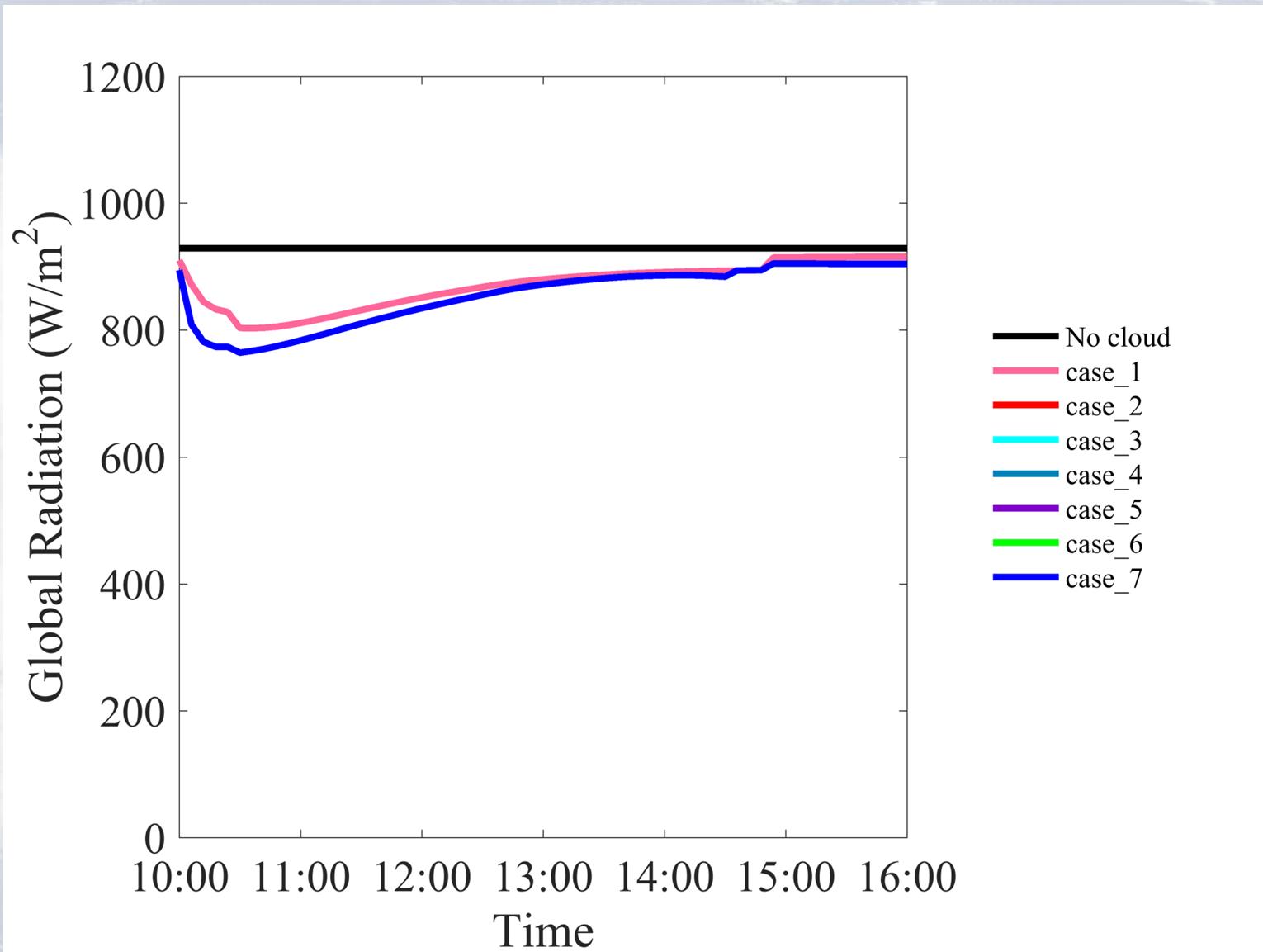


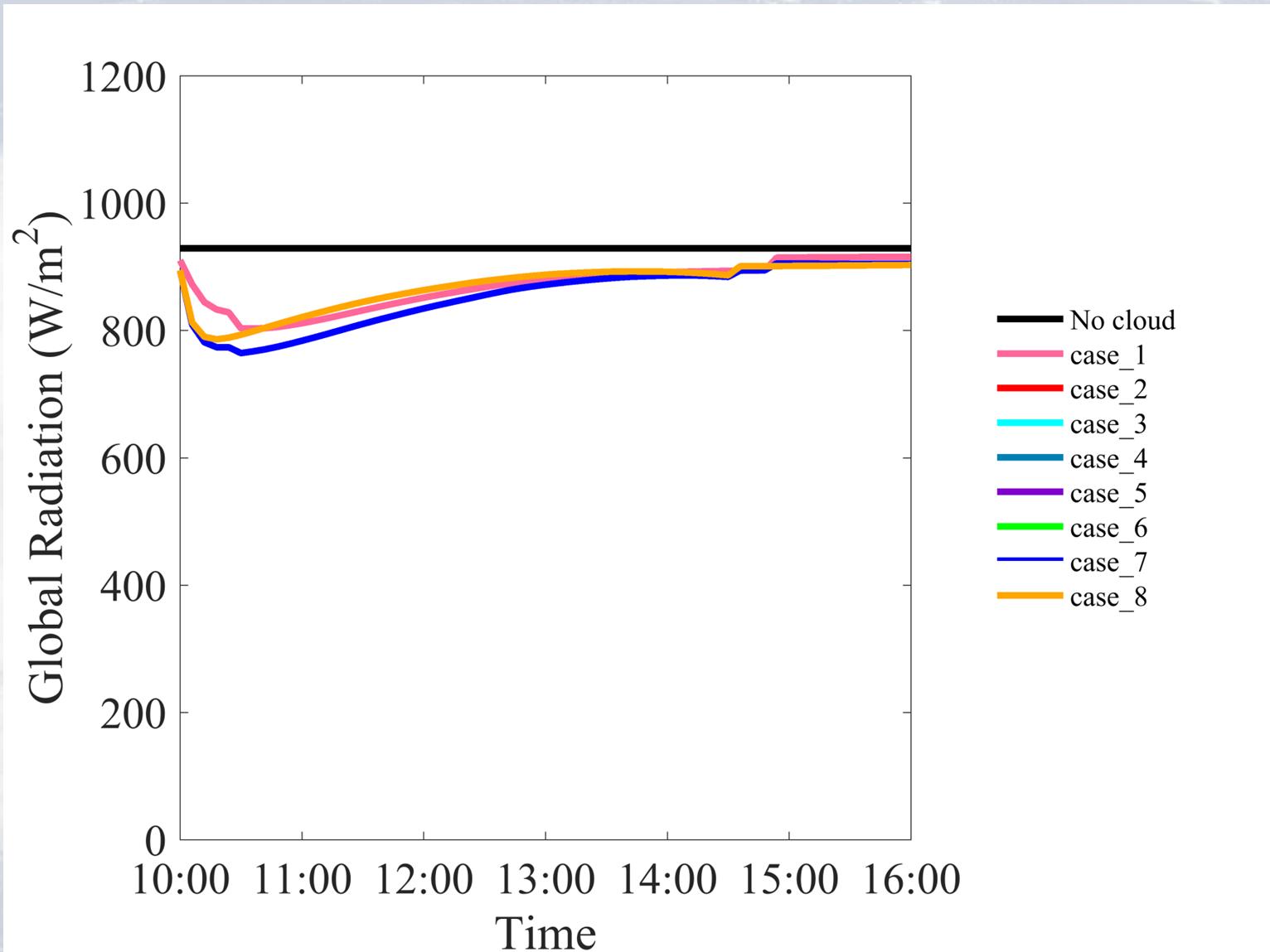


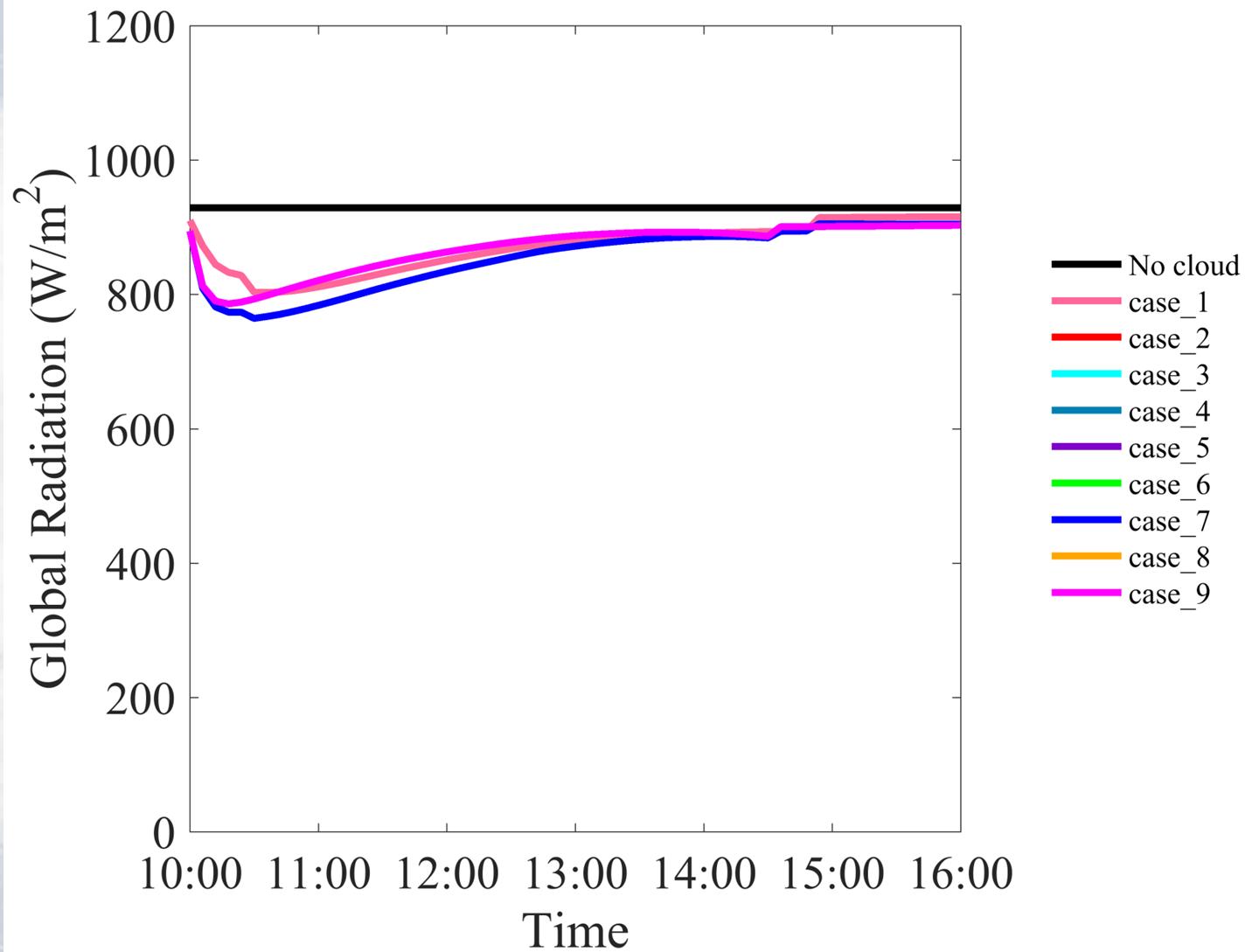


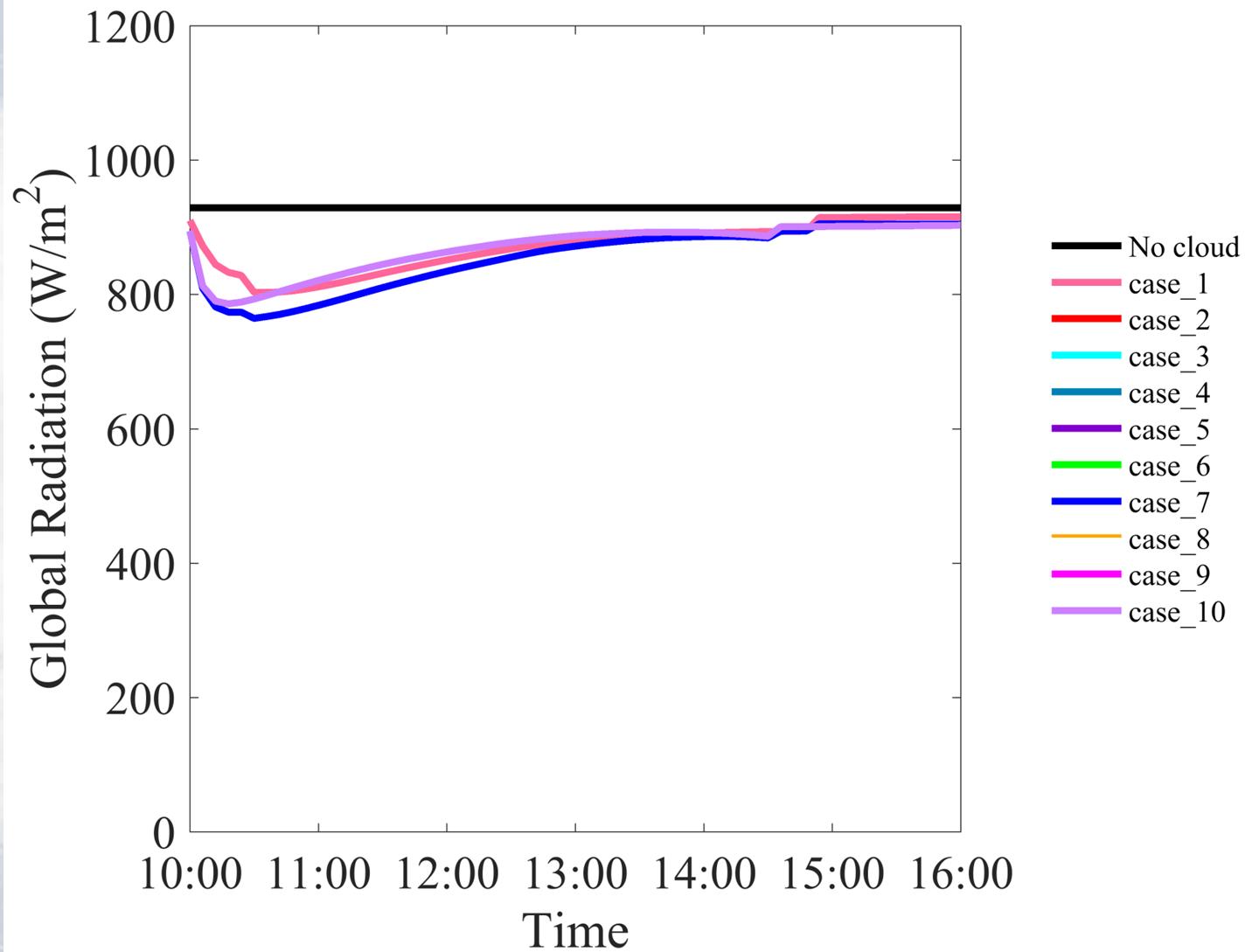


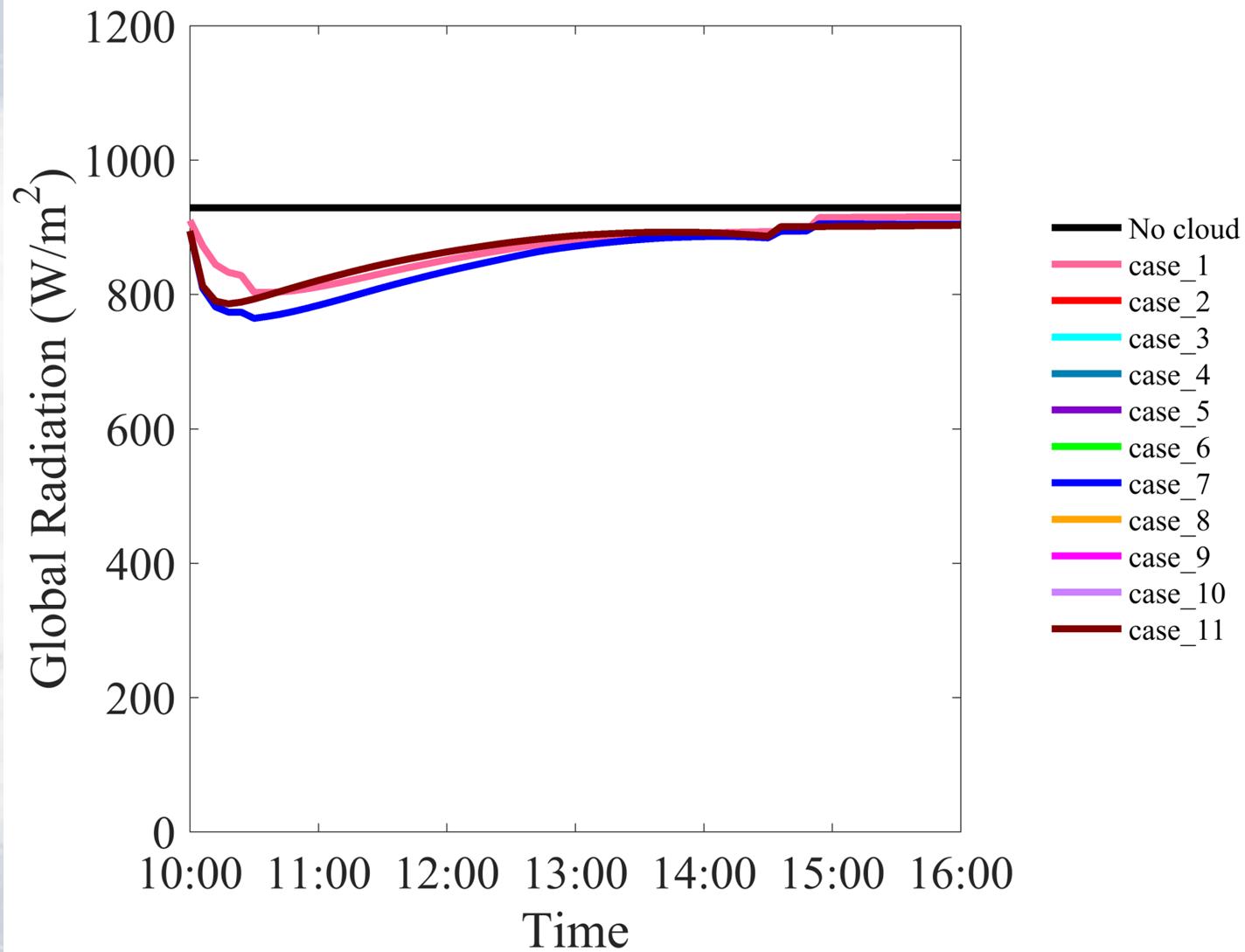


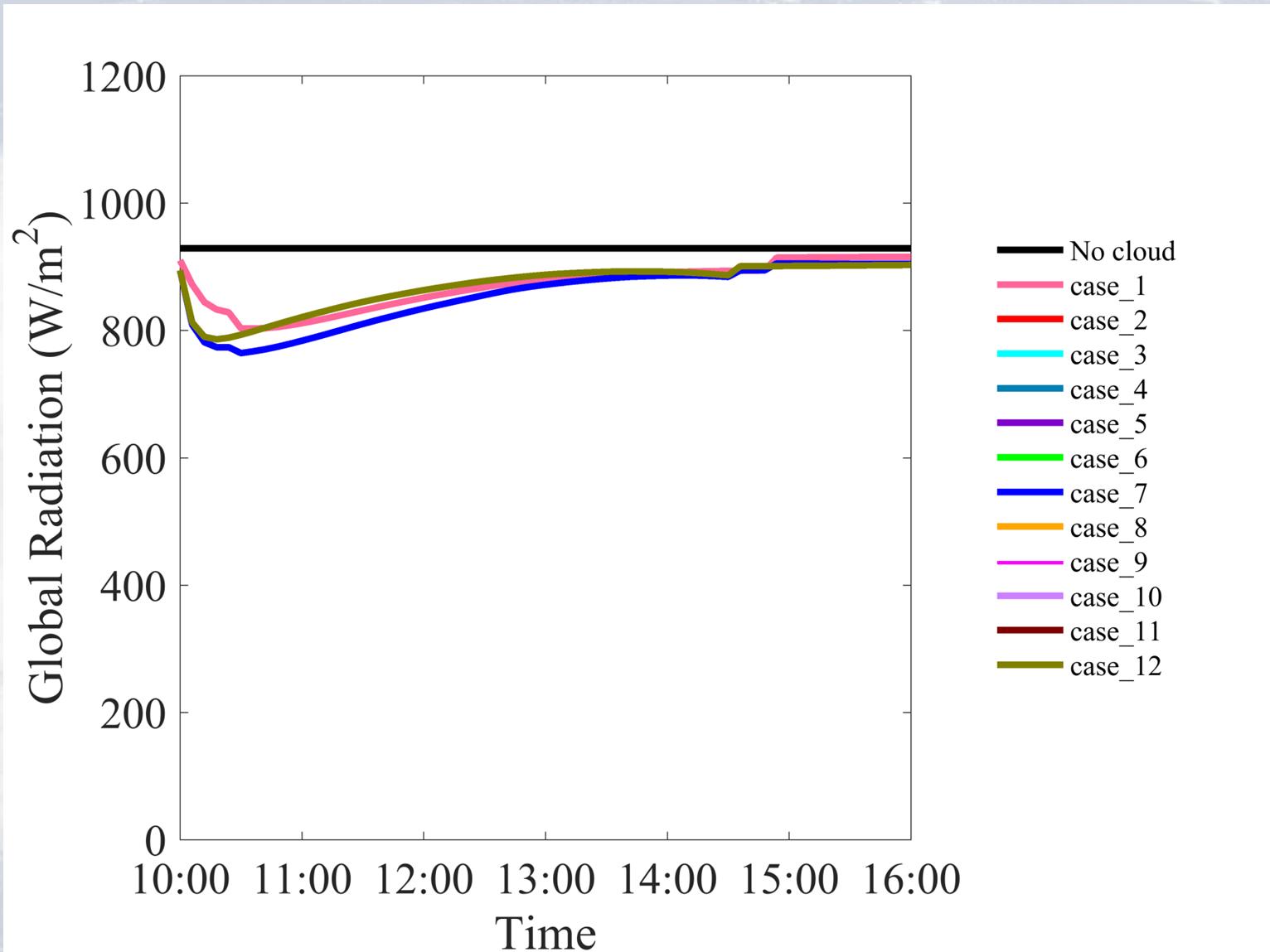


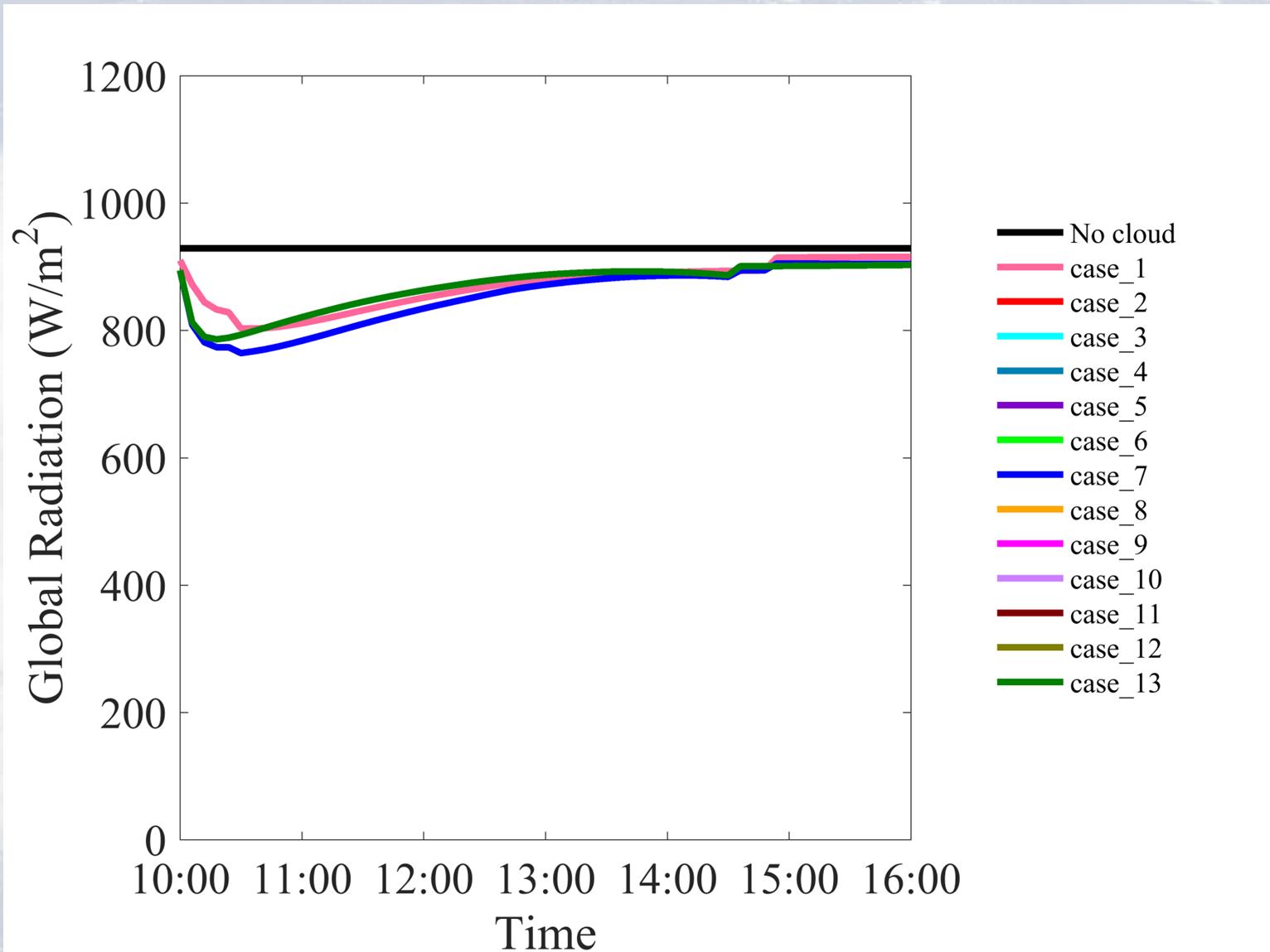






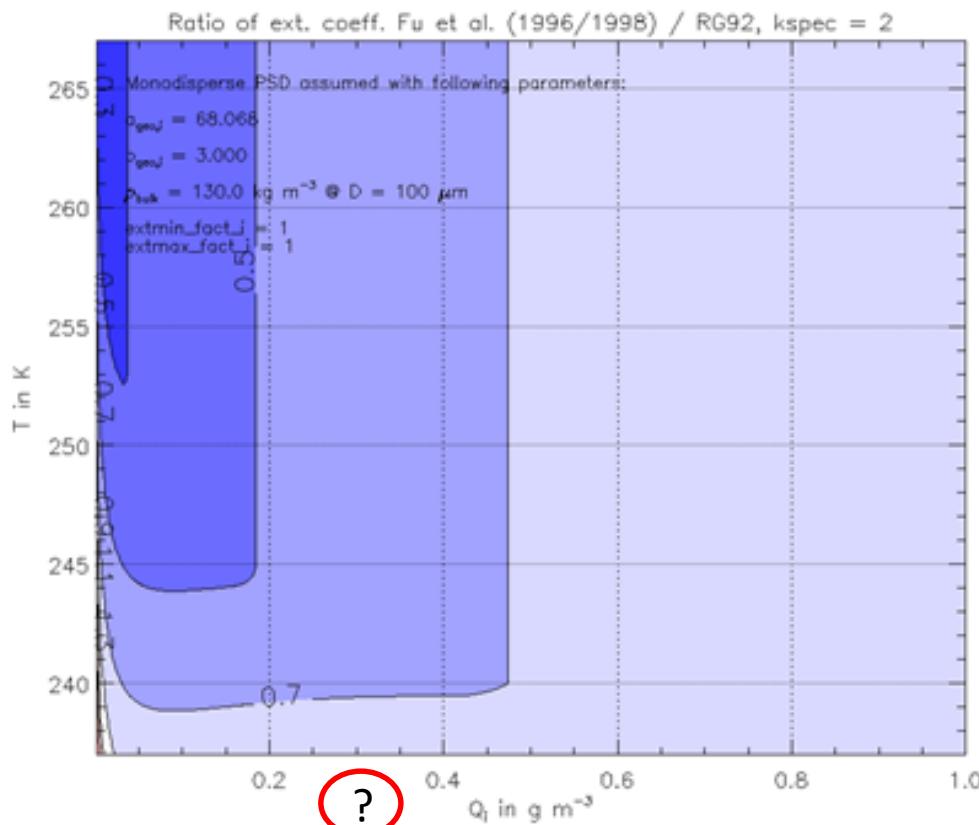






Cloud ice (visible; Fu et al.)

→ If grid scale $q_i > 0$: from cloud microphysics:



$f(D)$ = monodispers

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

q_i prognostic

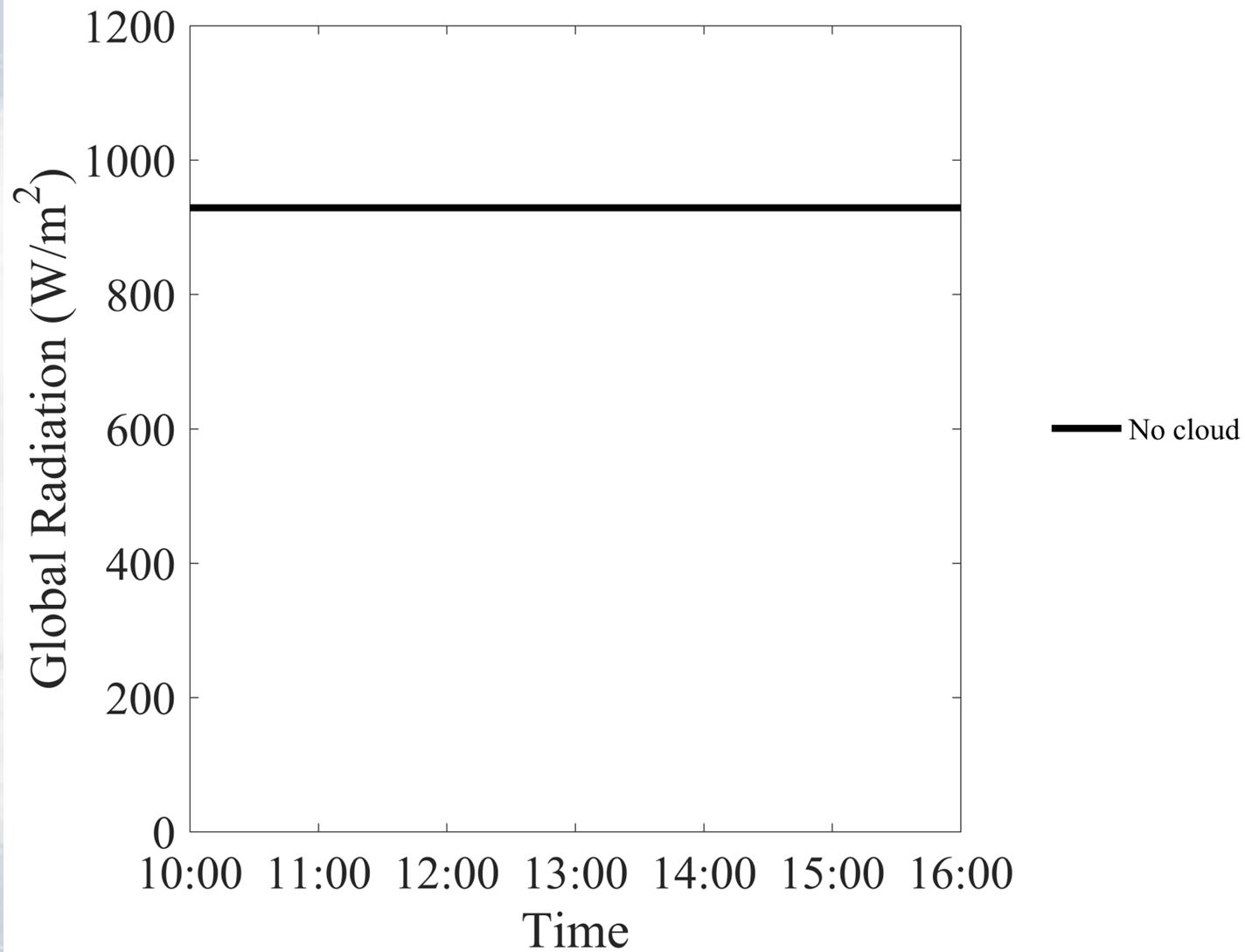
$m_i = 130 D^3$ (SI-units)

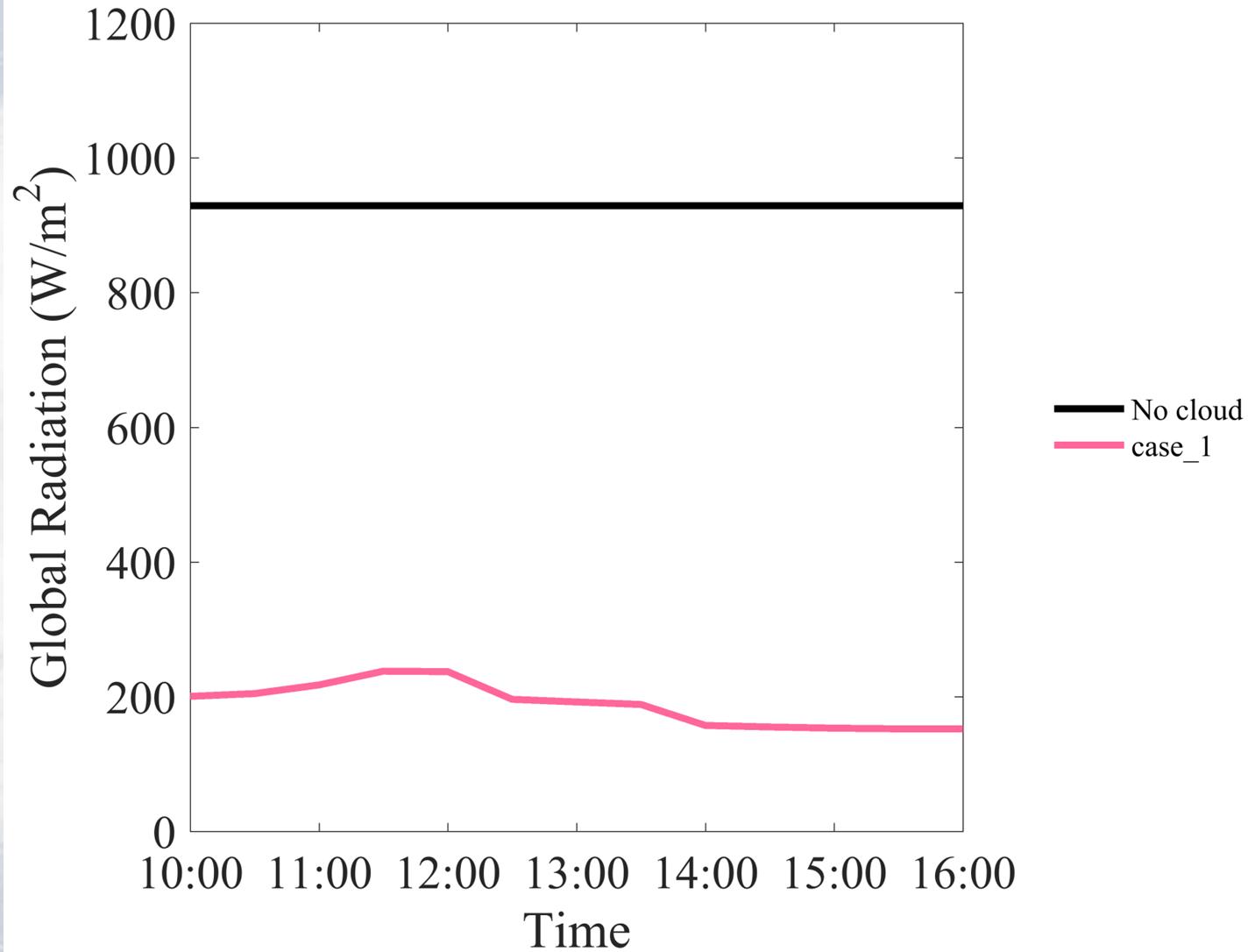
Spectral interval „2“
(visible range)

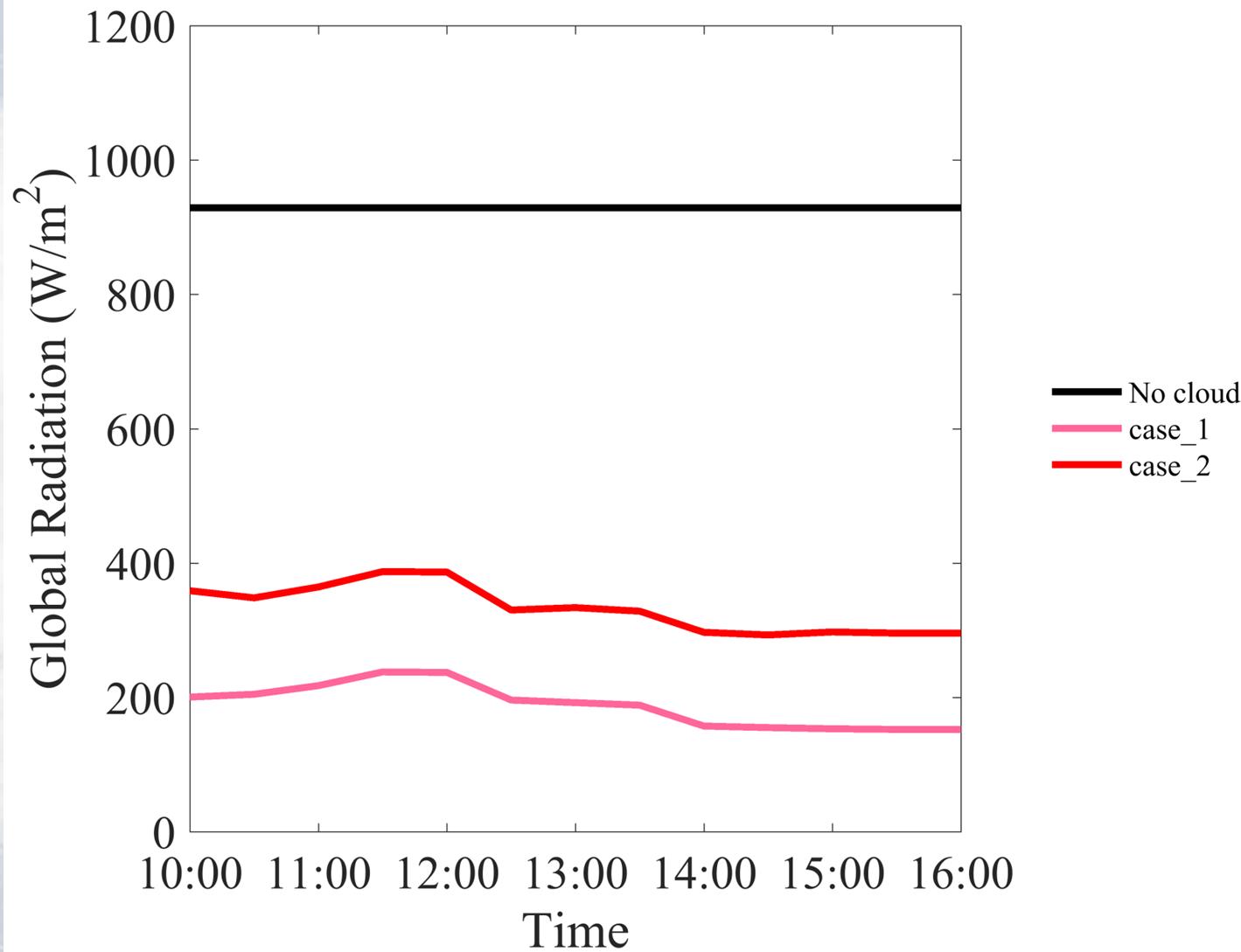
β_{ext} ratio Fu / RG92

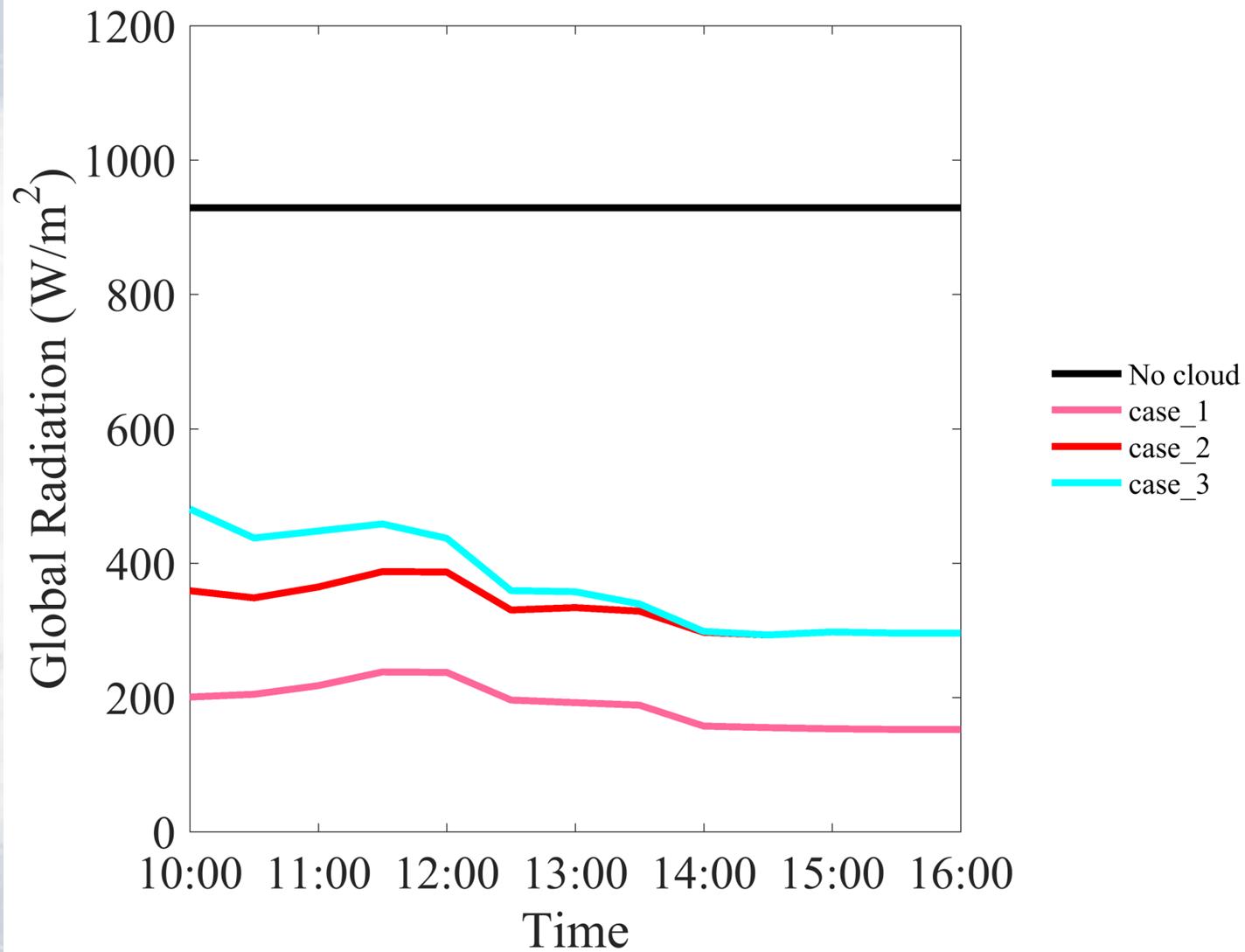
The background of the slide is a grayscale aerial photograph of a coastal region. It shows rolling hills or mountains in the distance, a winding river or coastal path leading towards a body of water, and some low-lying vegetation or buildings near the shore.

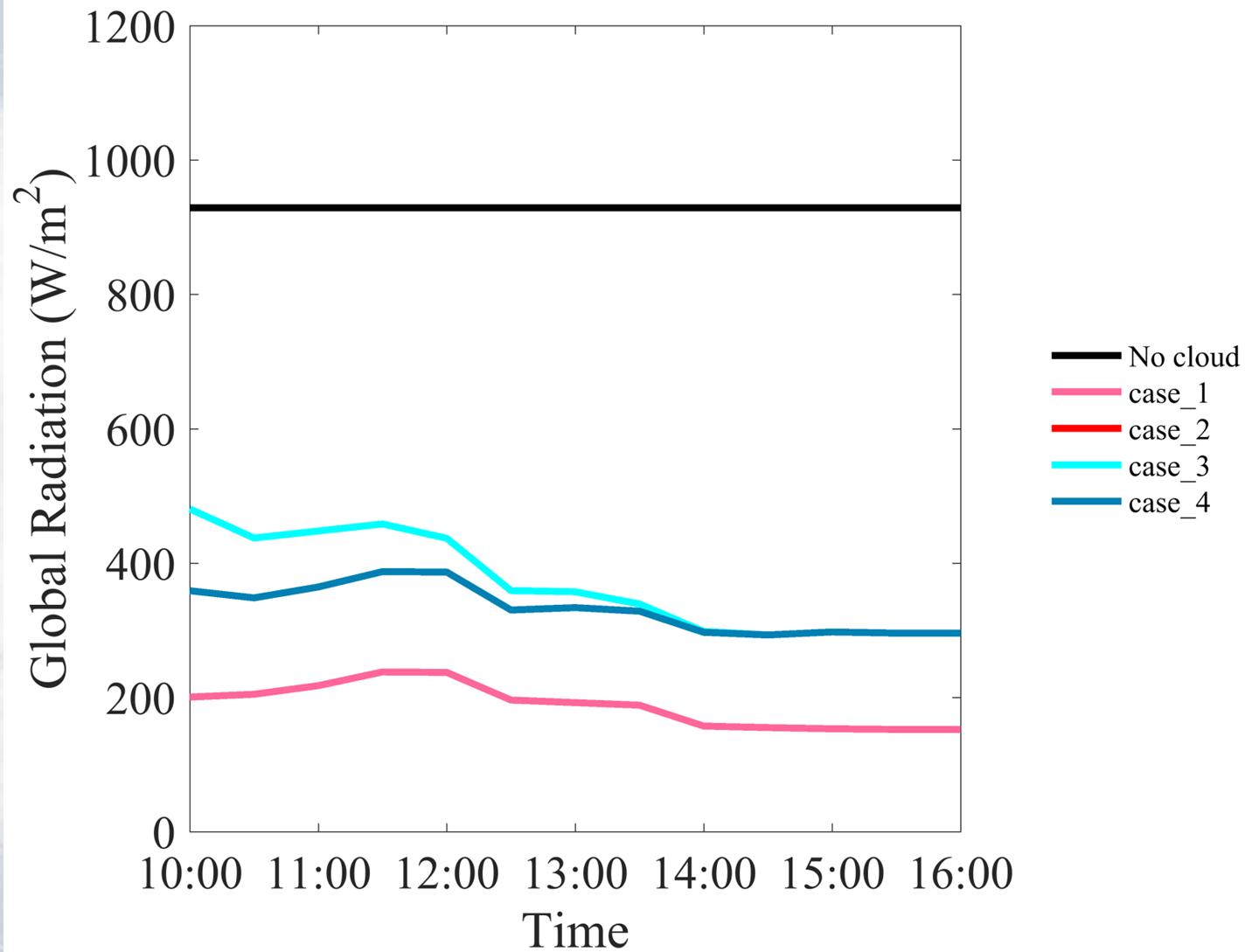
True / False switches on Mixed Phase cloud:

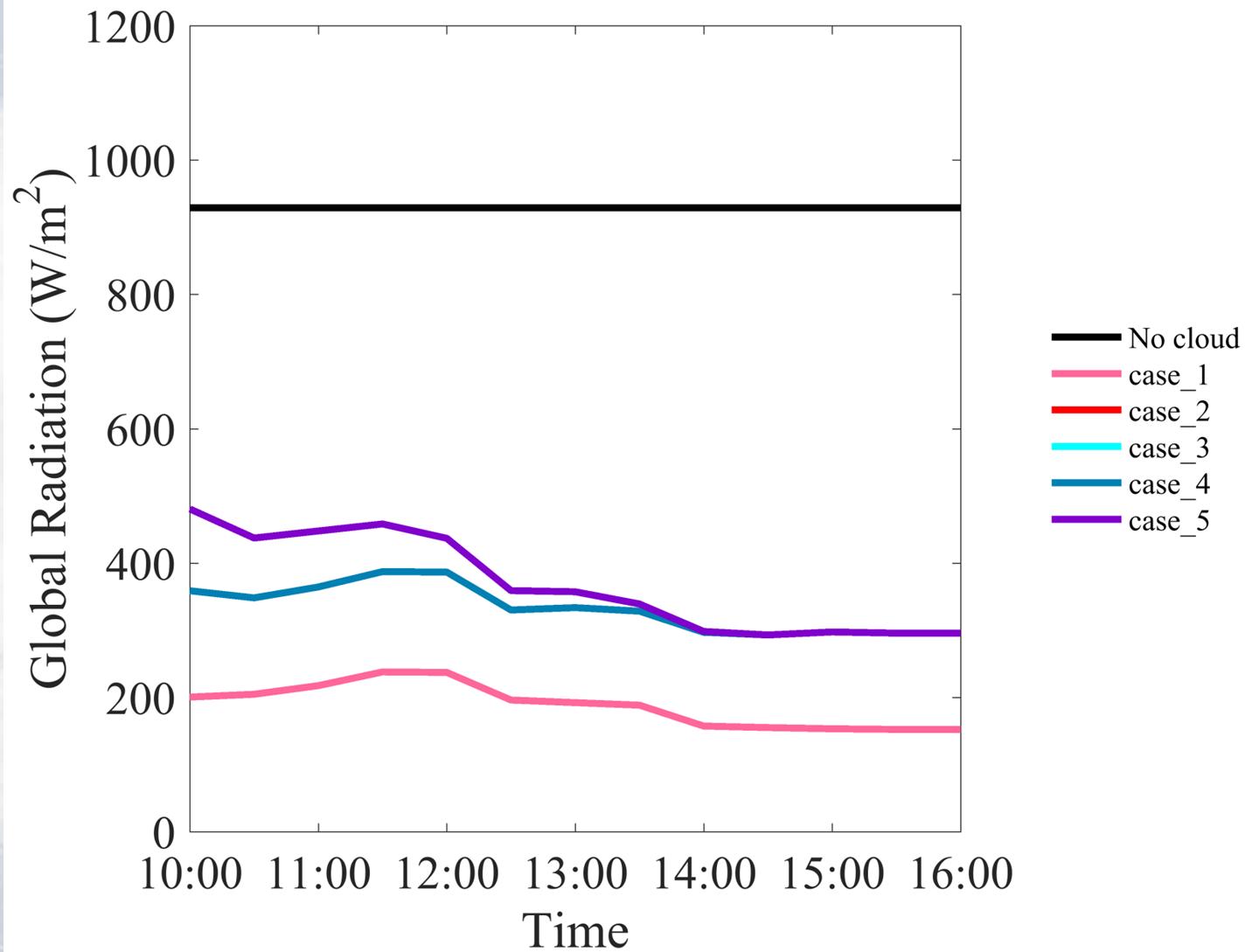


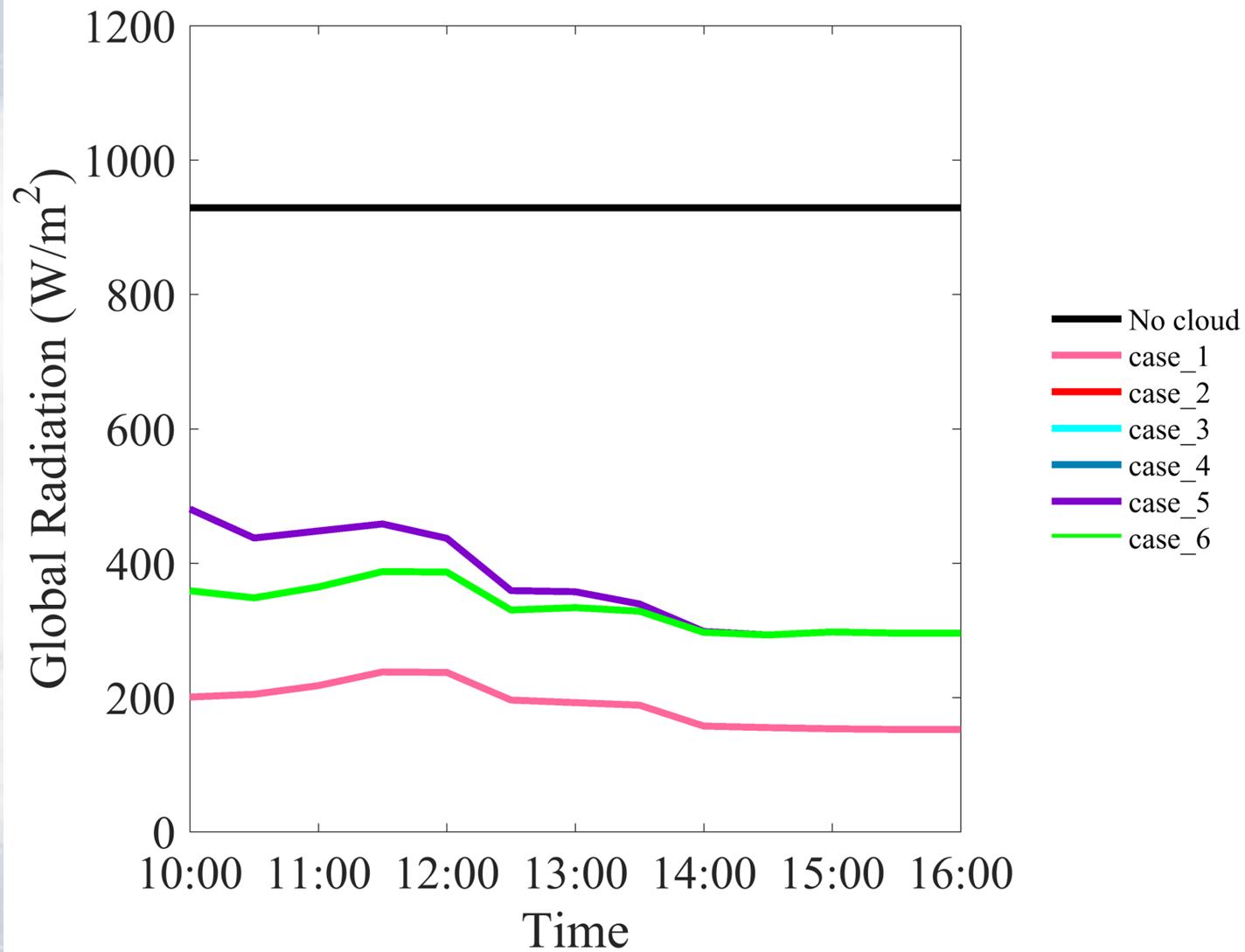


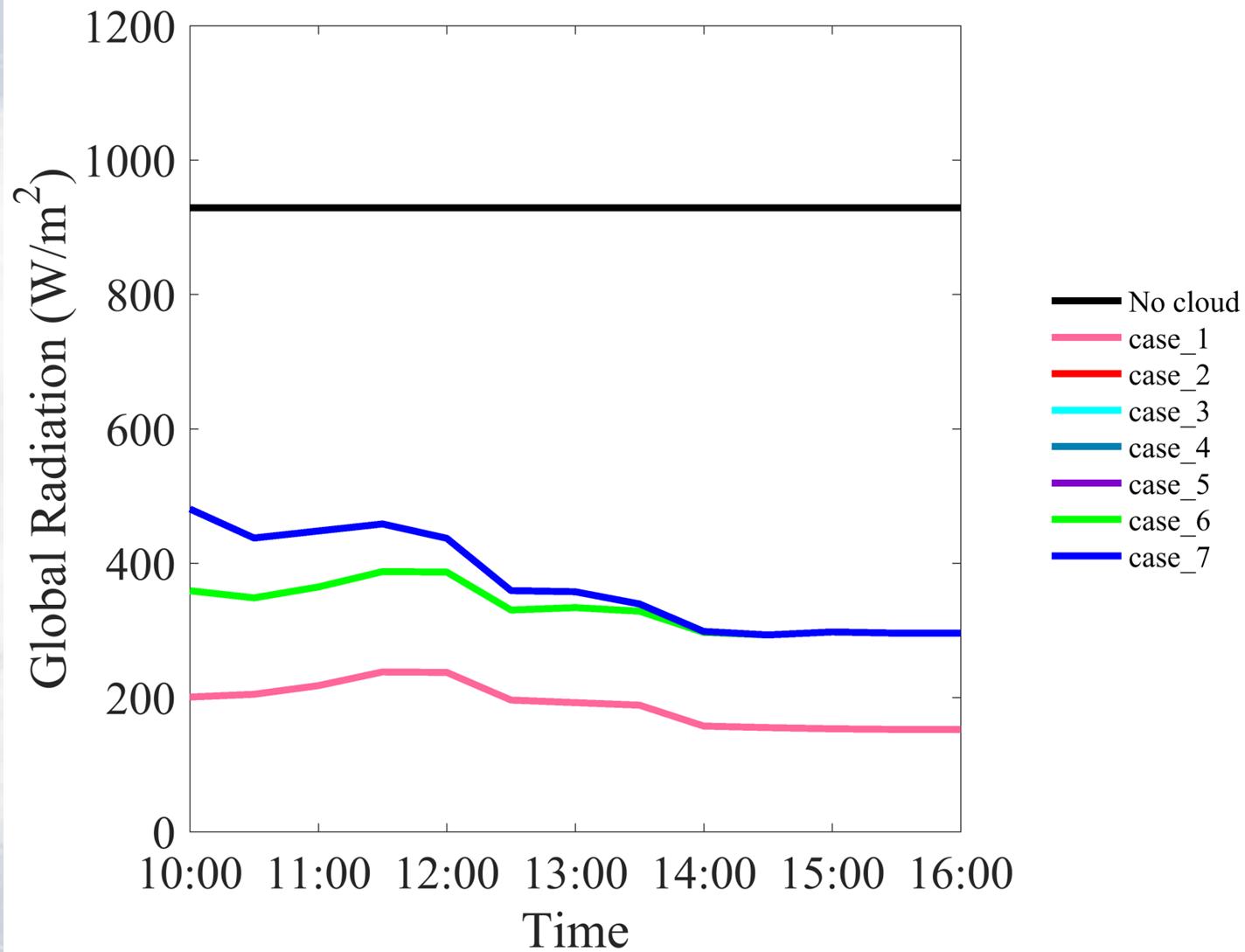


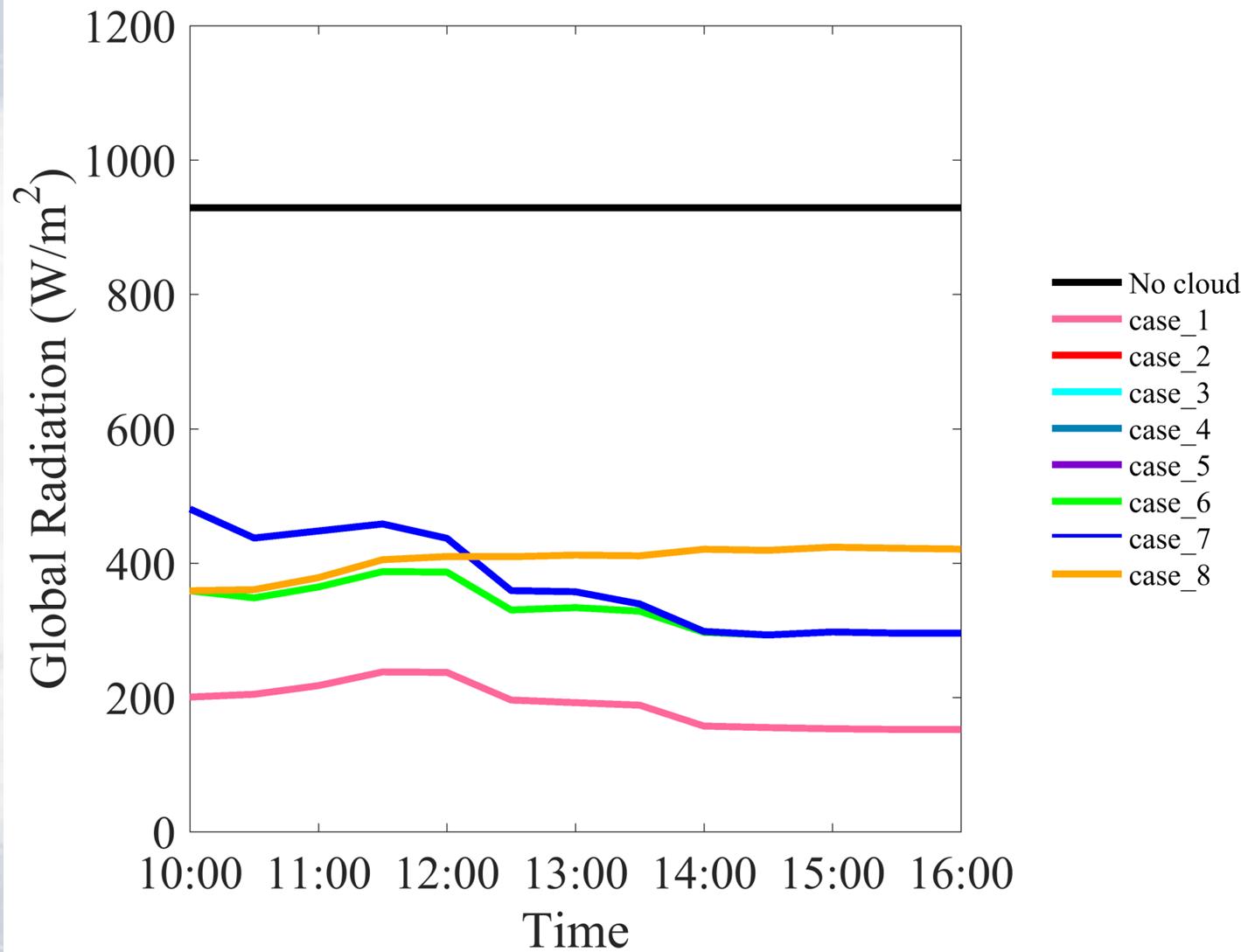


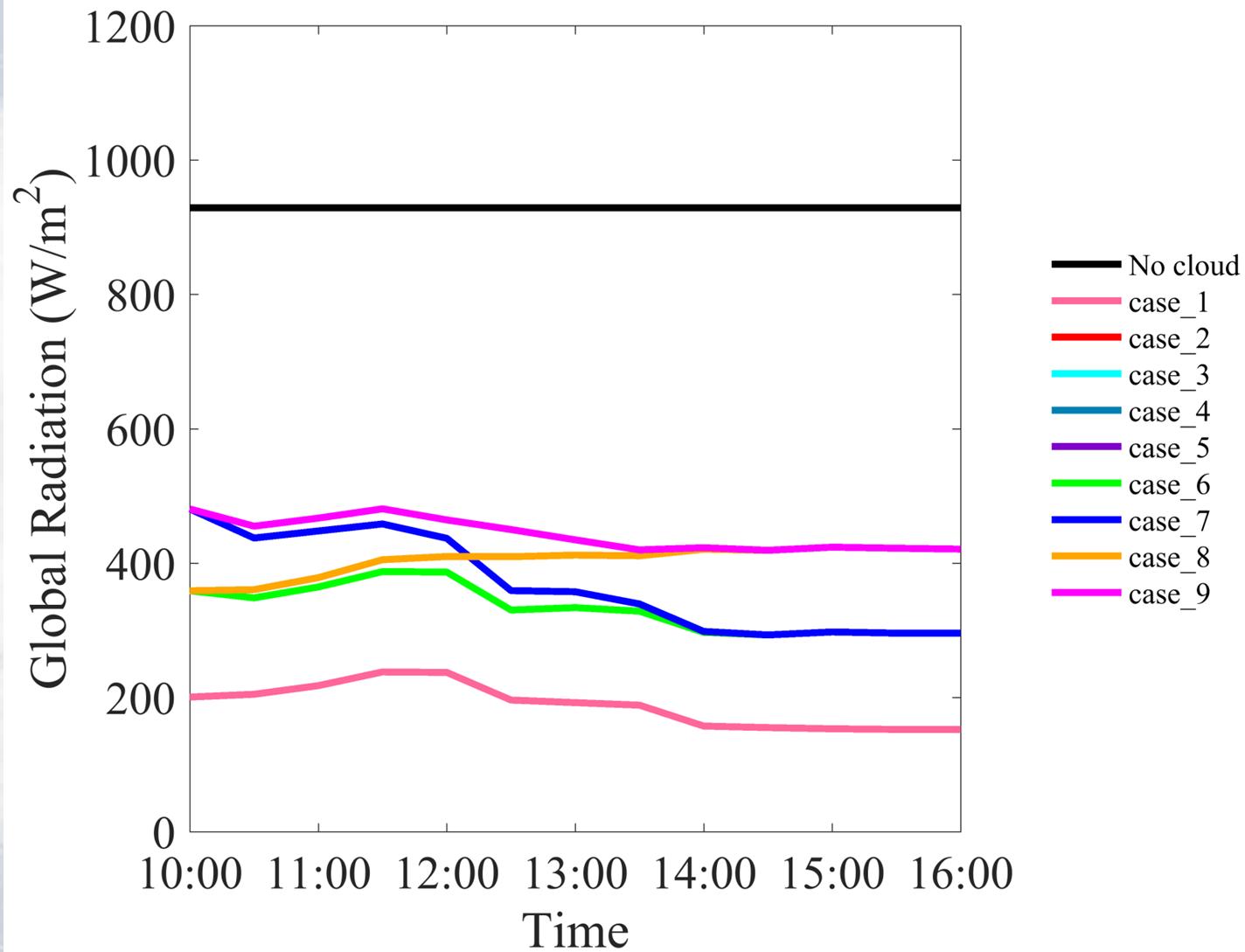


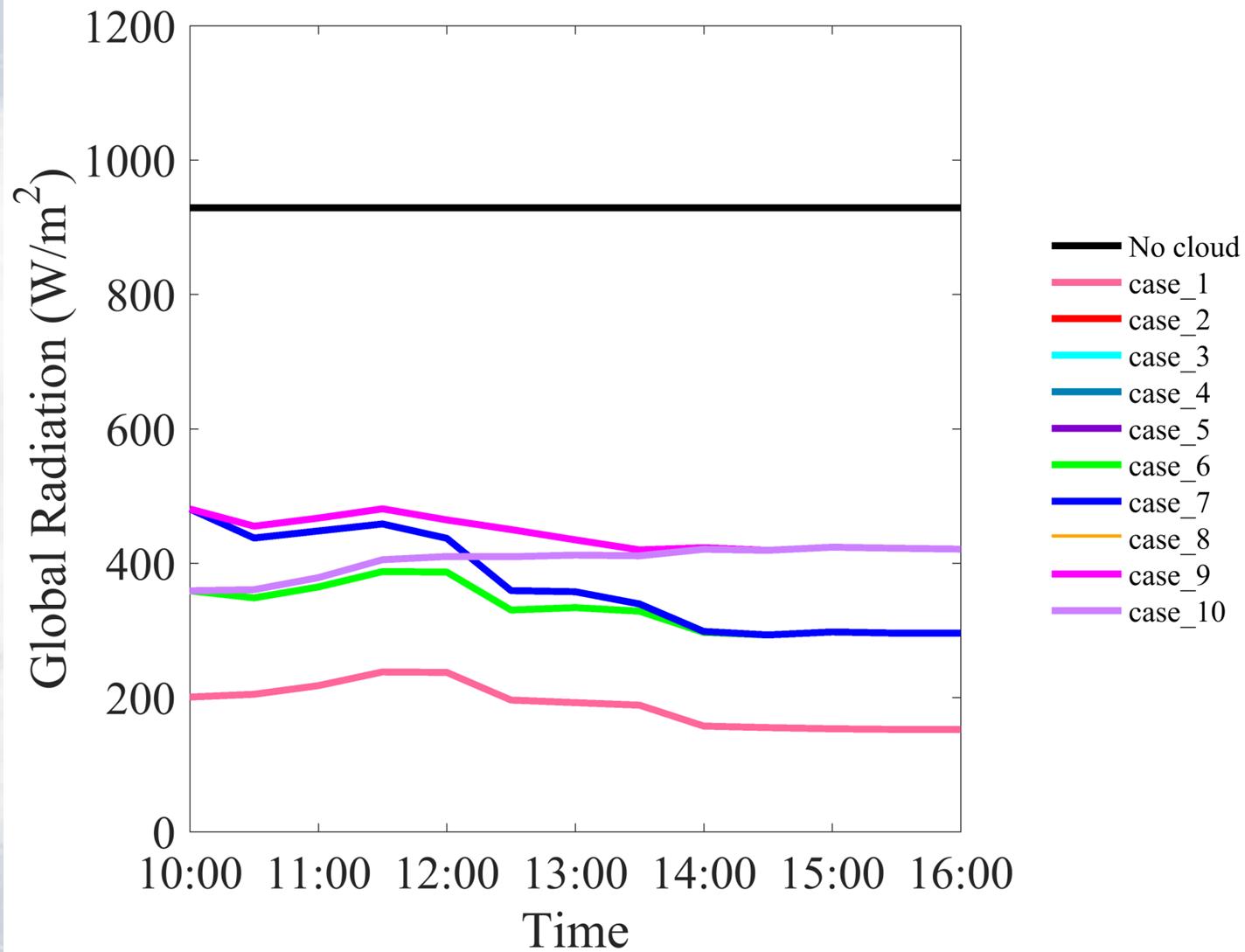


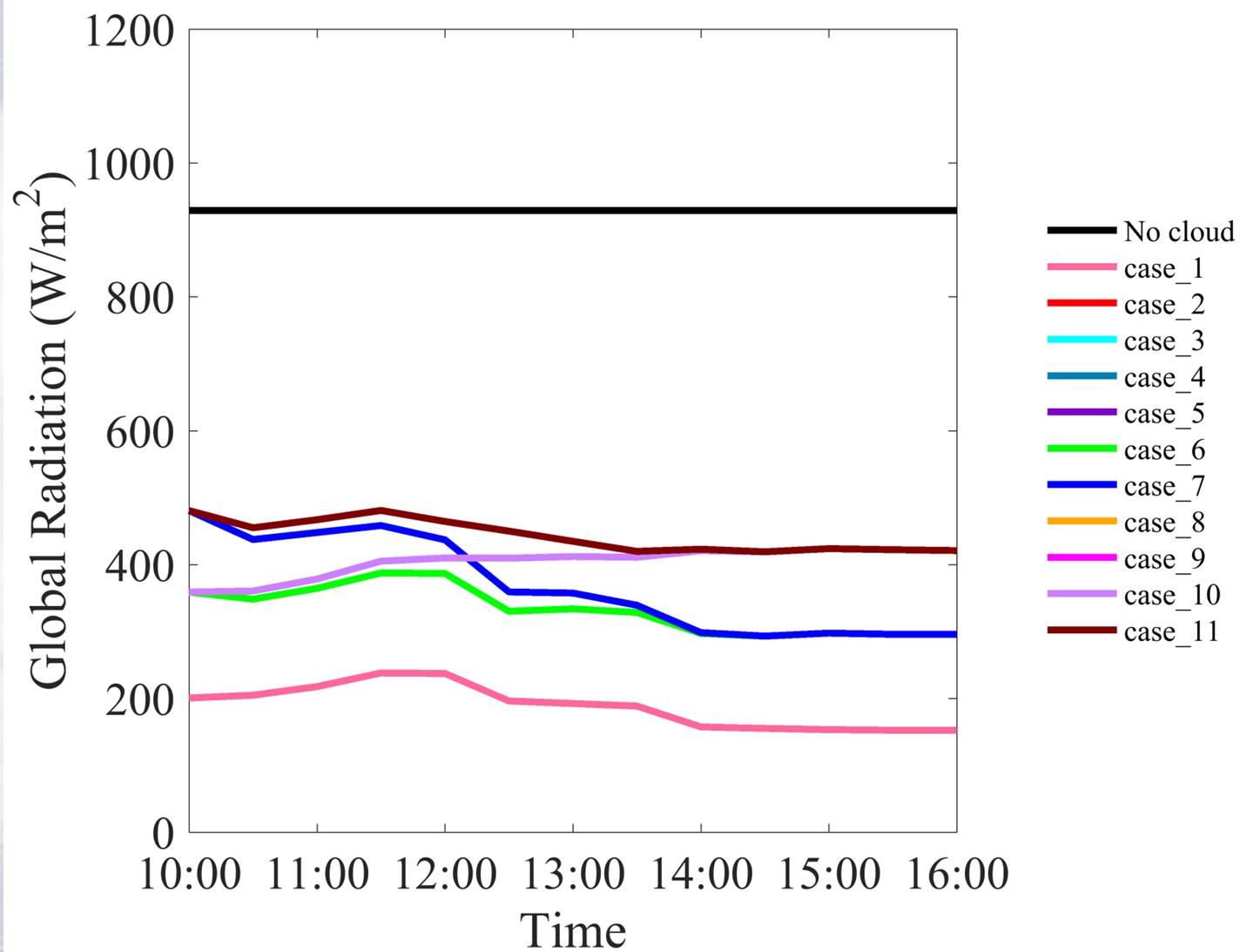


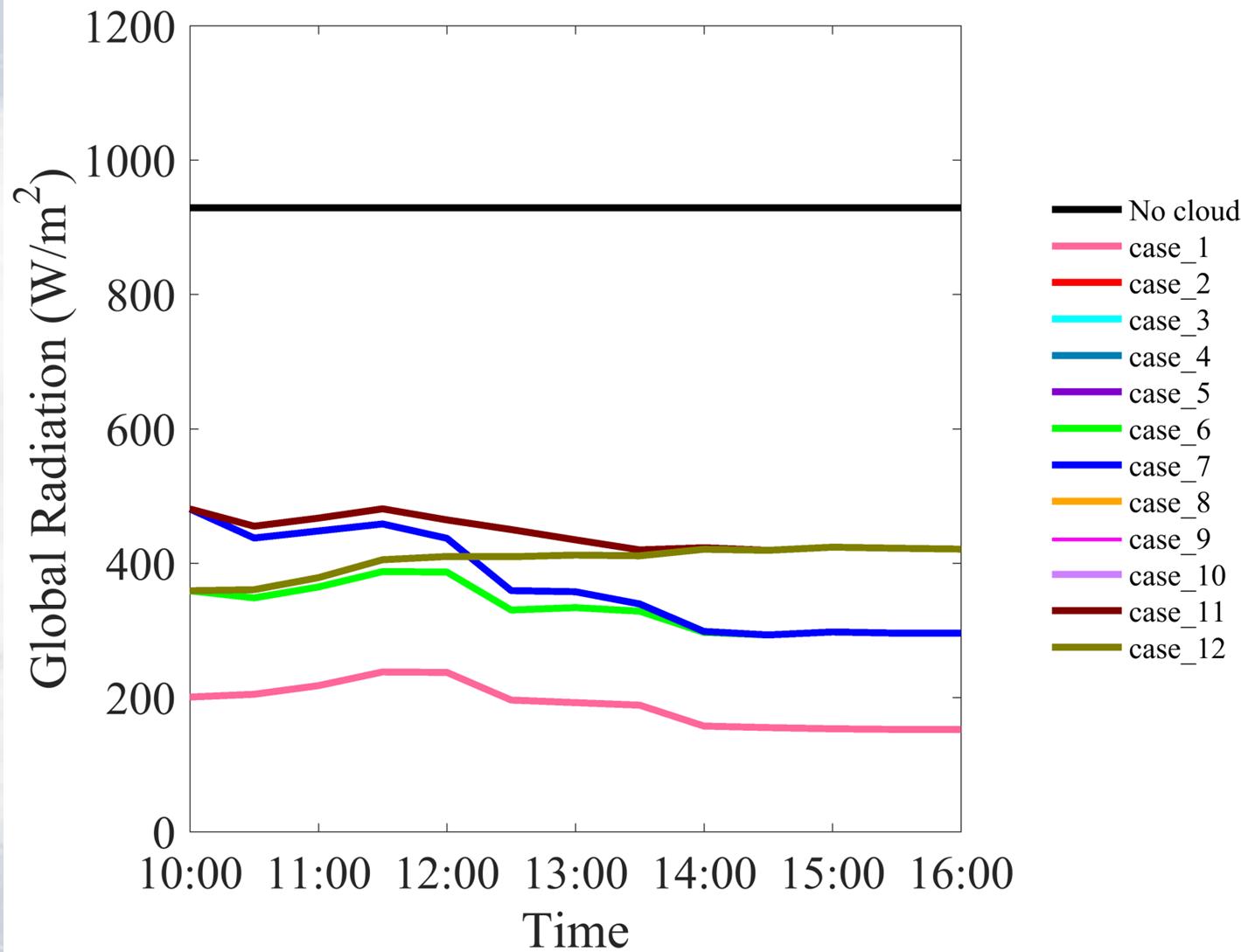












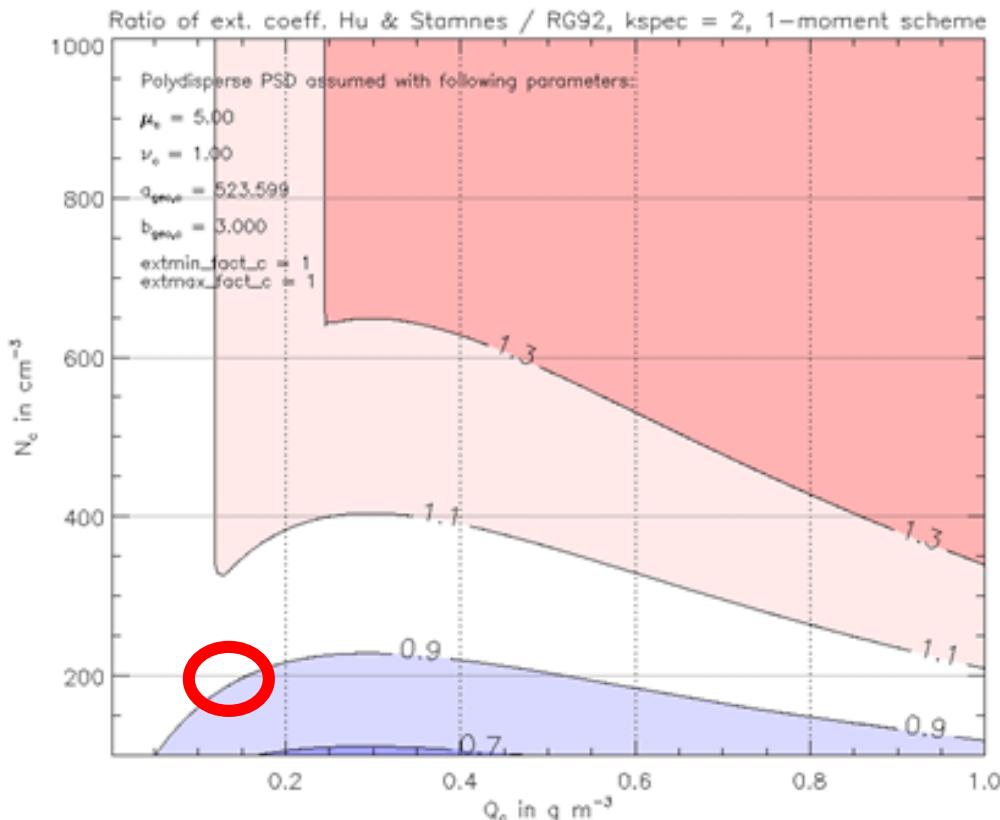
Cloud droplets comparison to RG92



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

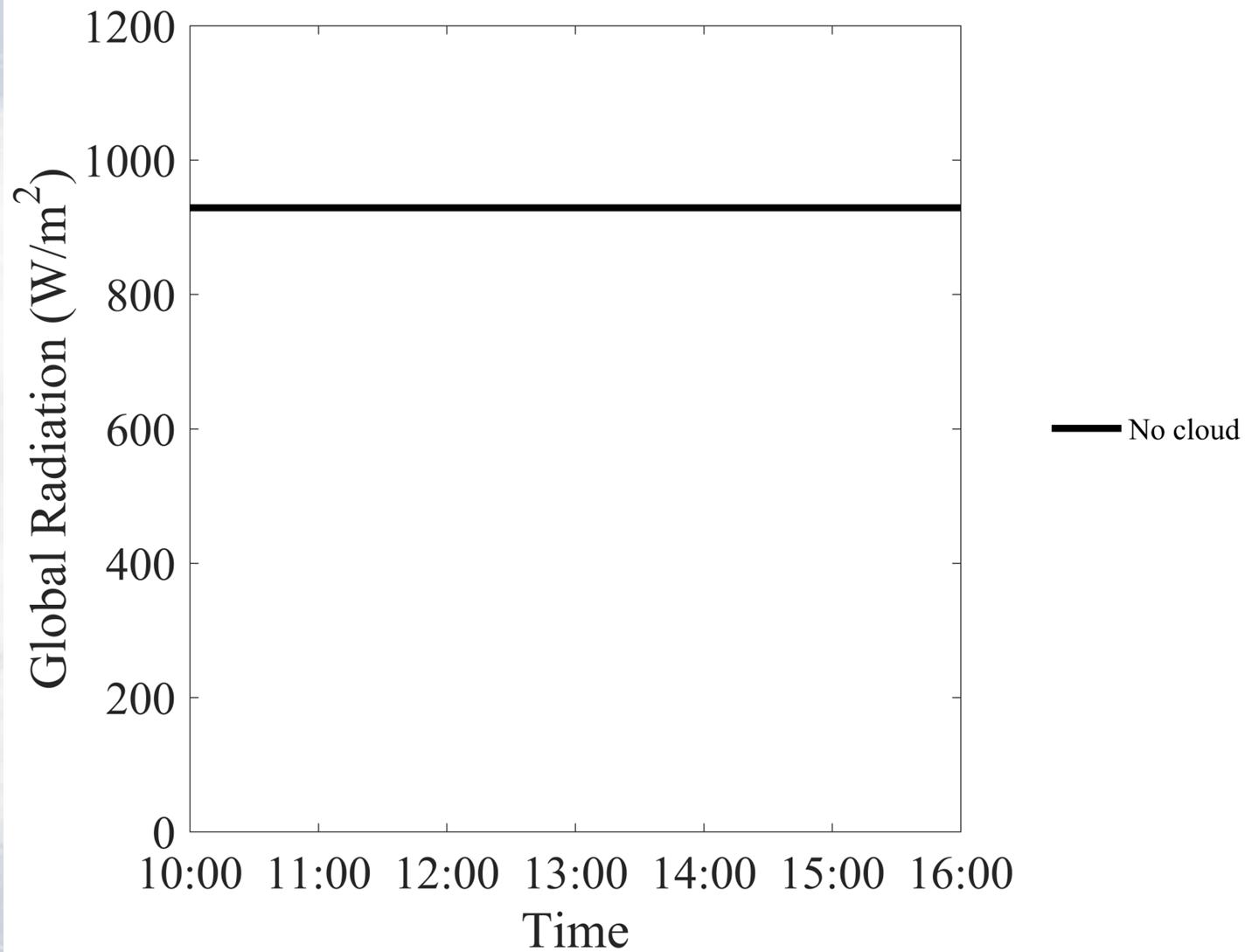
Spectral interval „2“
(visible range)

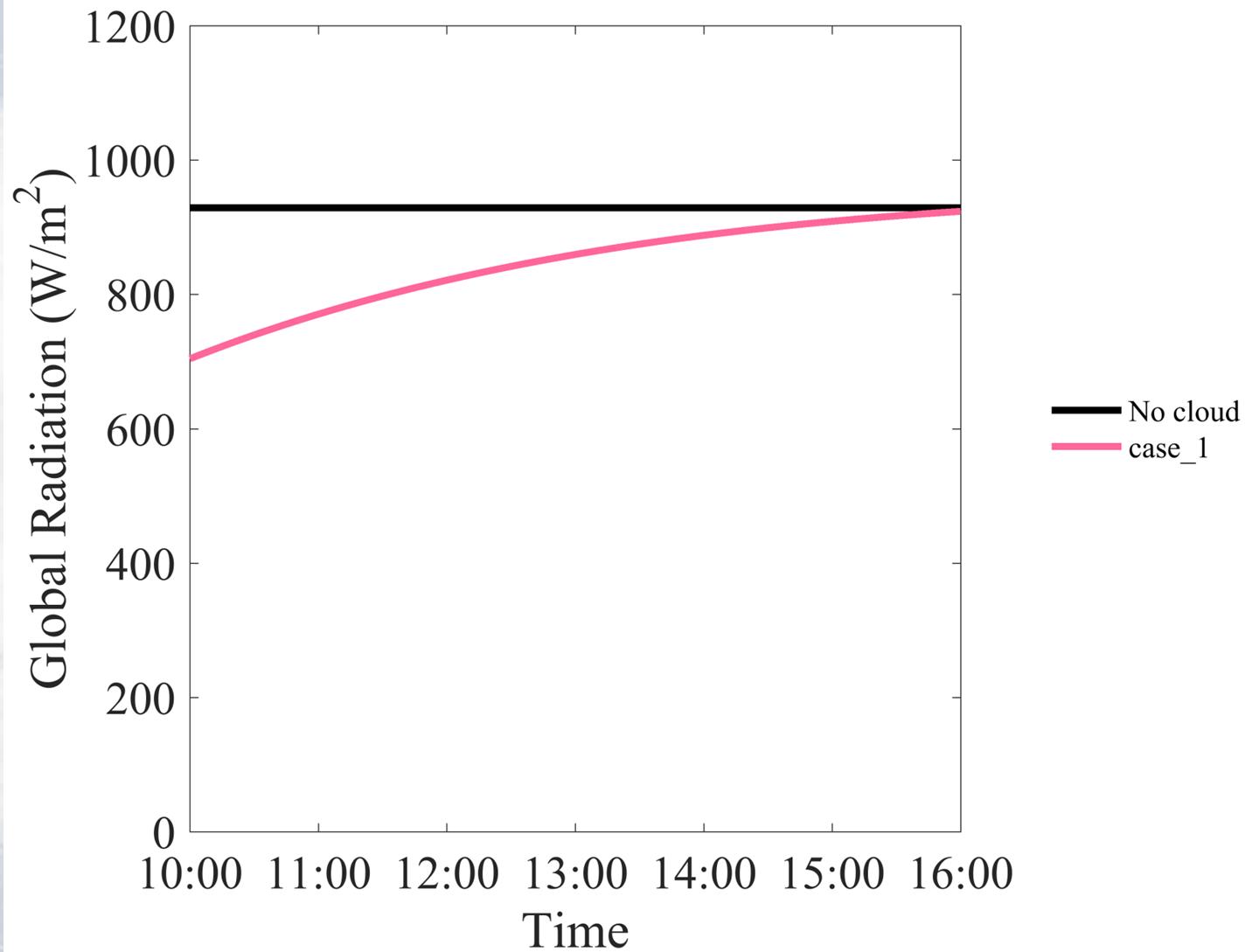
β_{ext} ratio HS / RG92

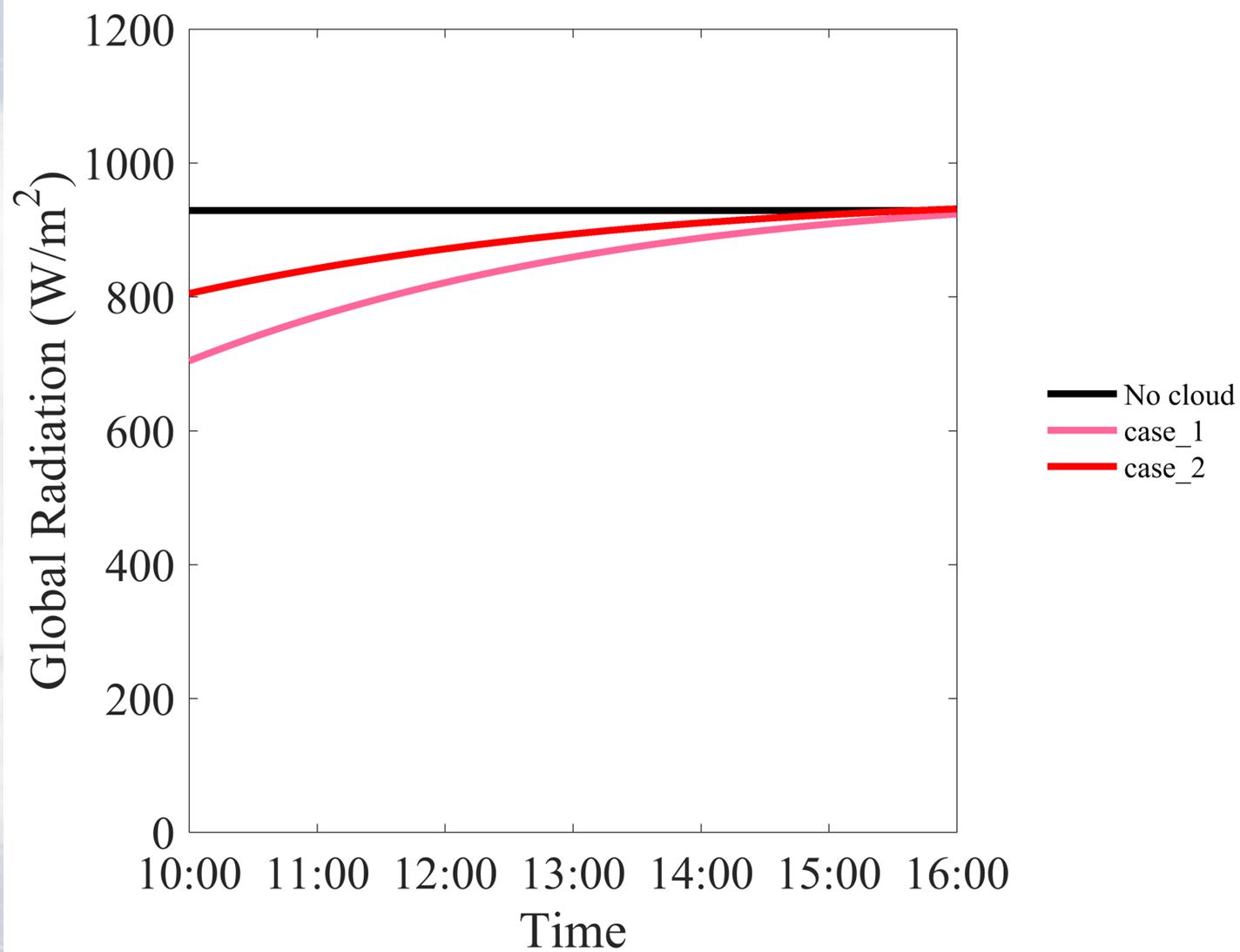


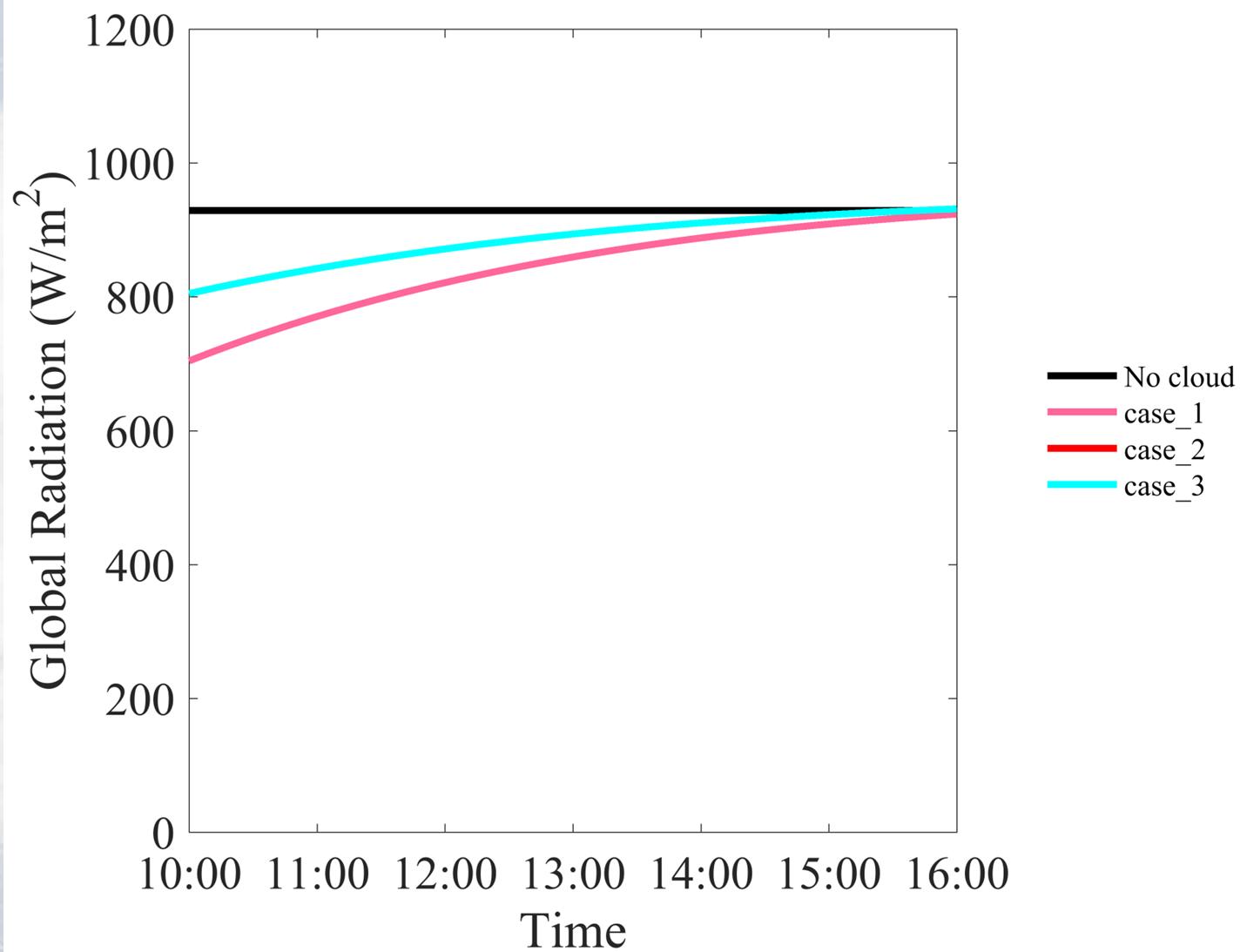
The background of the slide is a grayscale aerial photograph of a coastal region. It shows rolling hills or mountains in the distance, a winding river or coastal path leading towards a body of water, and a small, dark, irregular shape that could be a small island or a cluster of buildings.

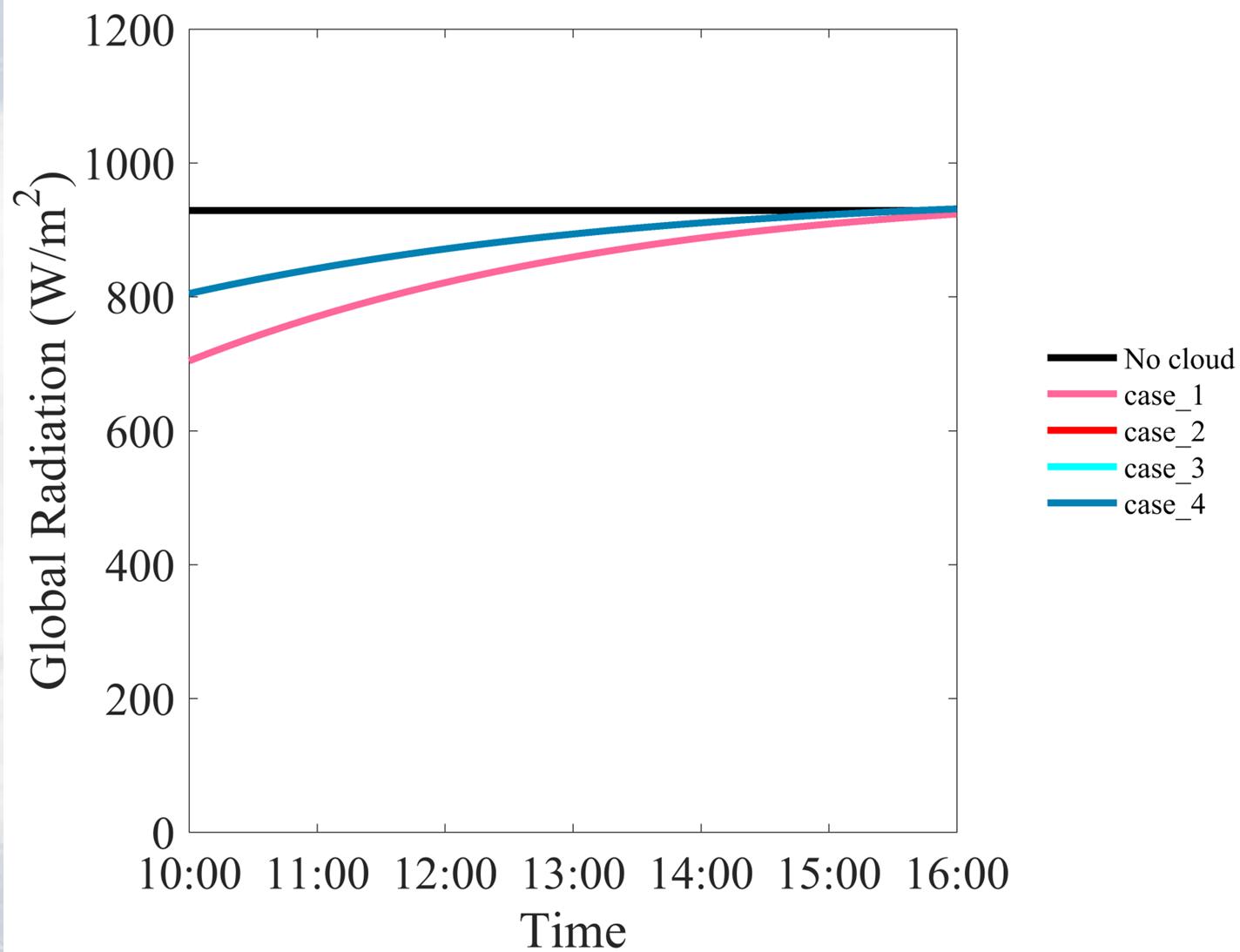
True / False switches on Fair weather Cu:

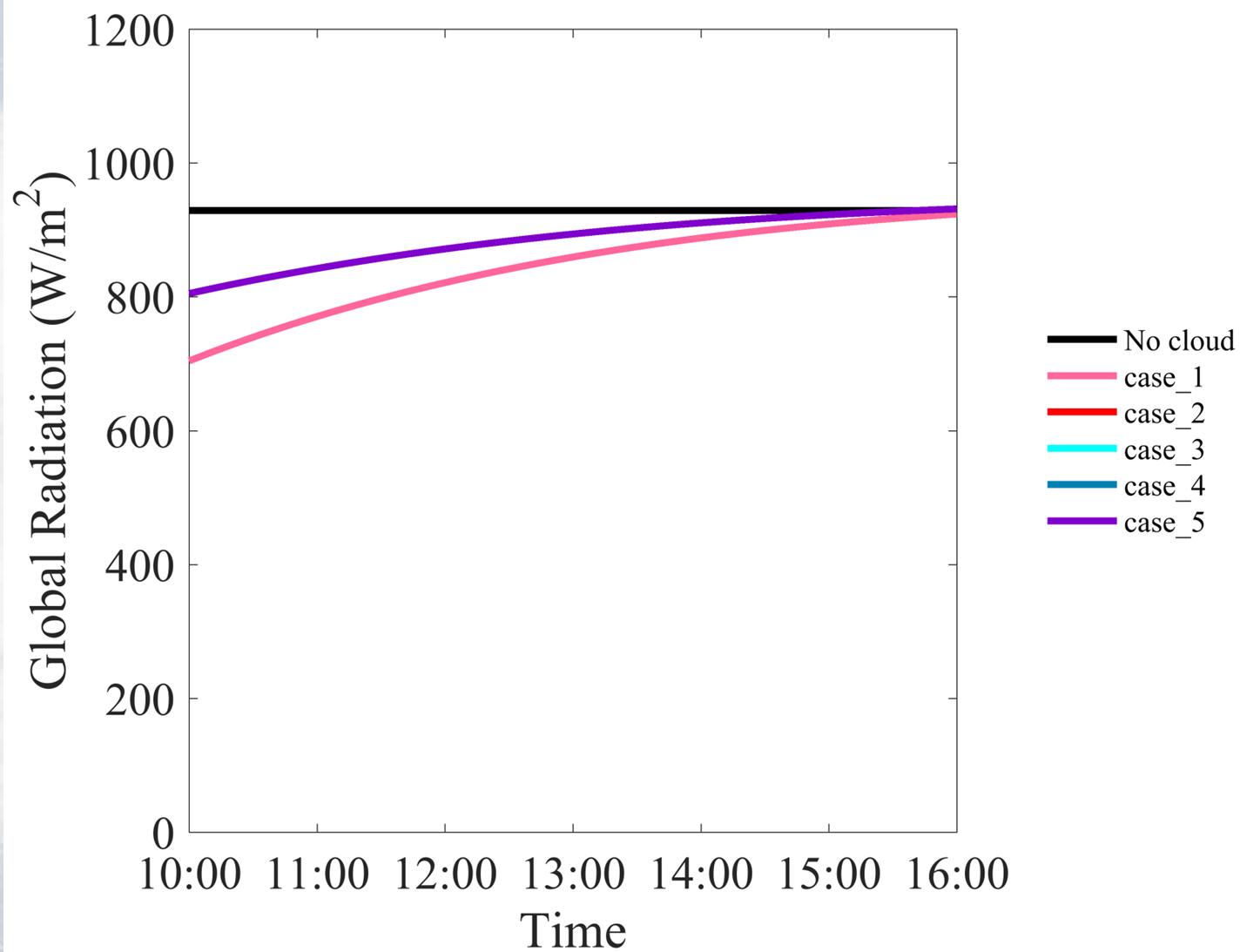


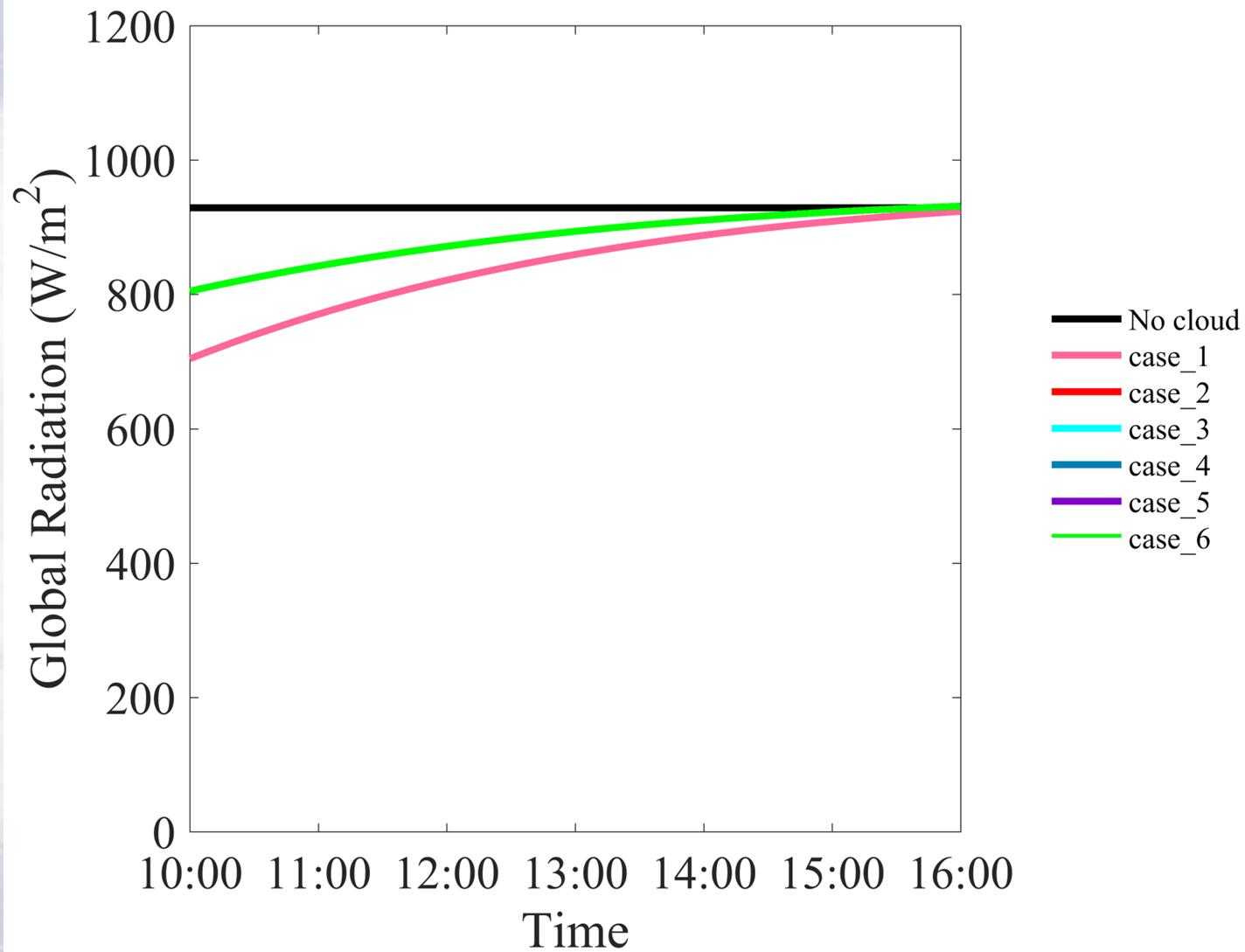


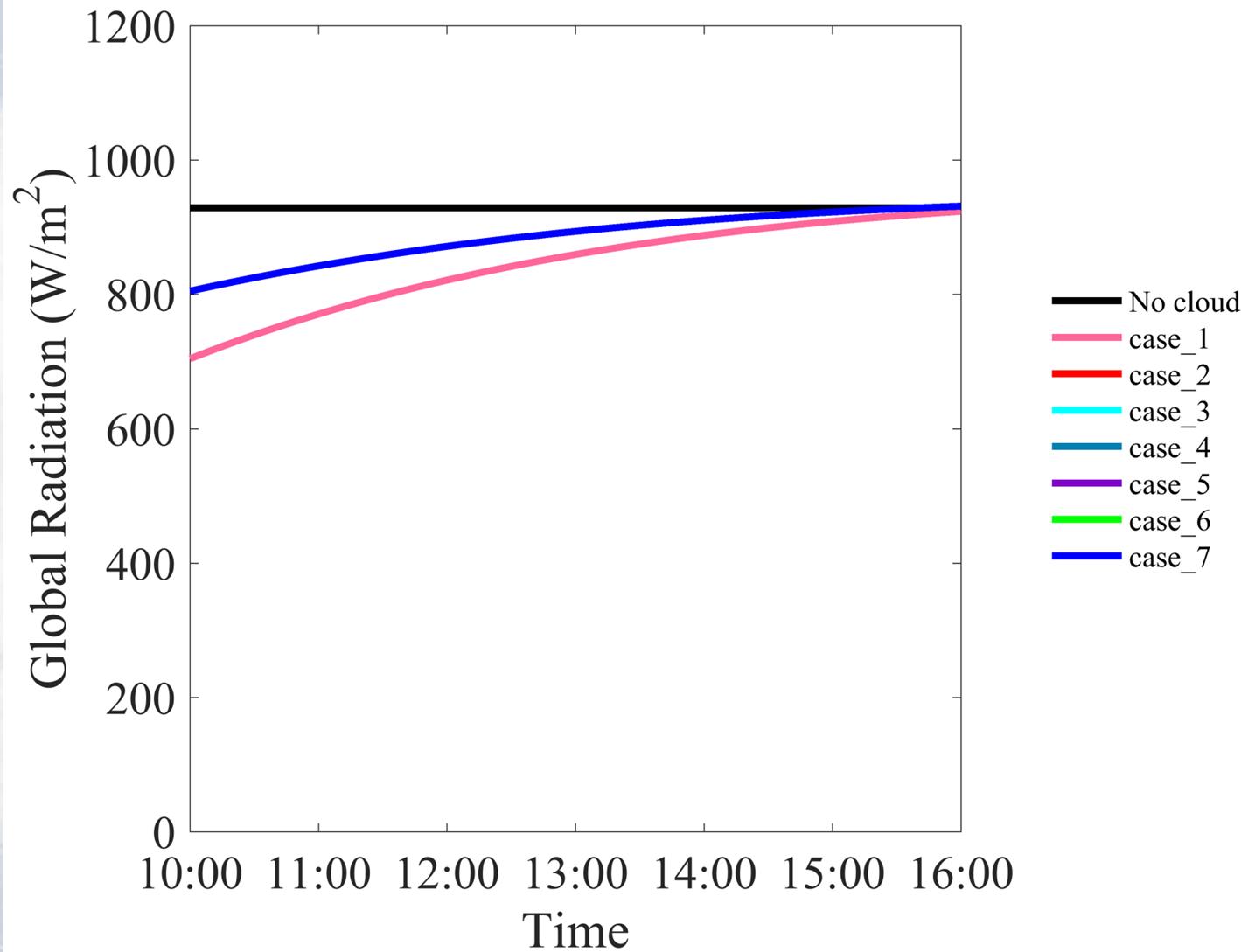


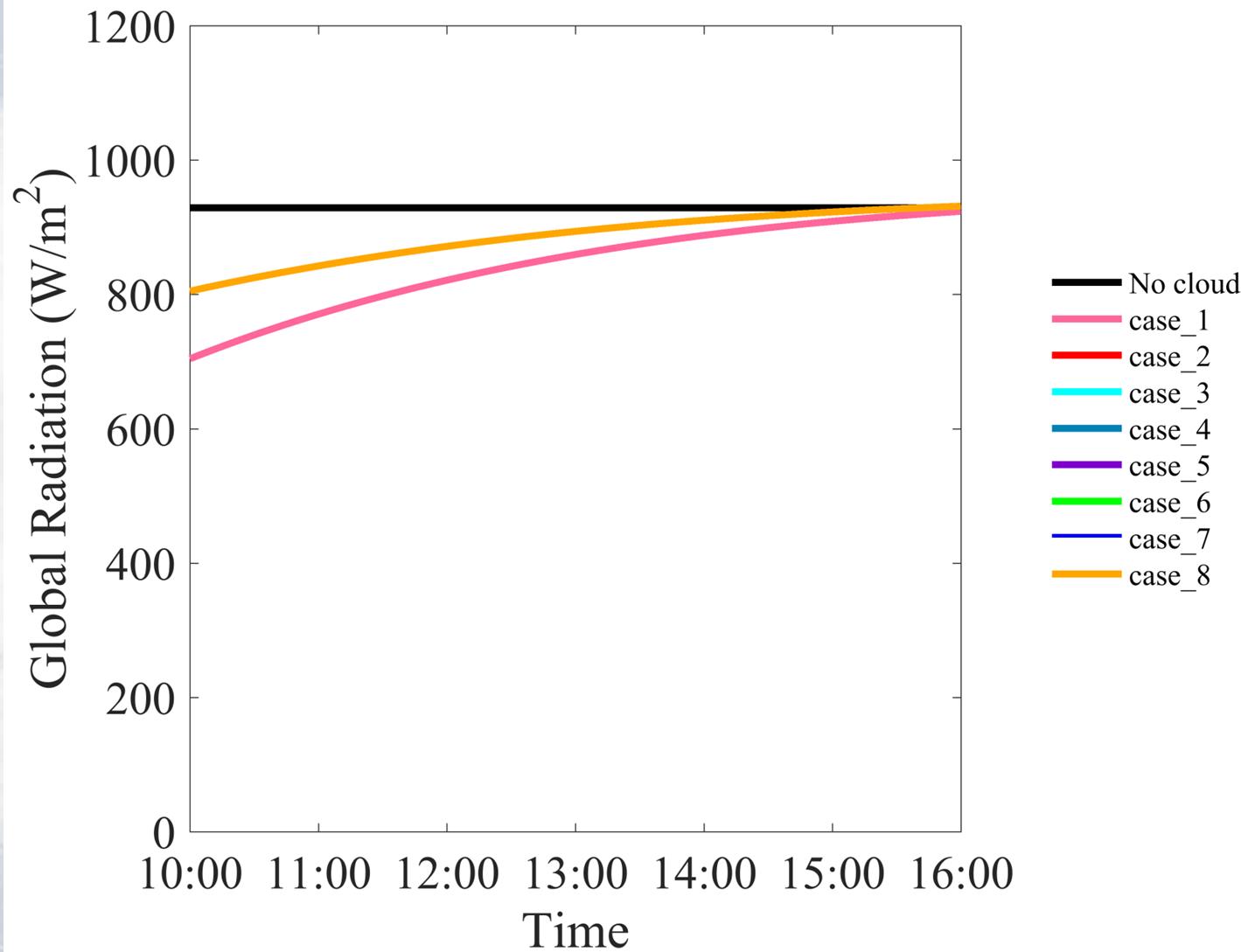


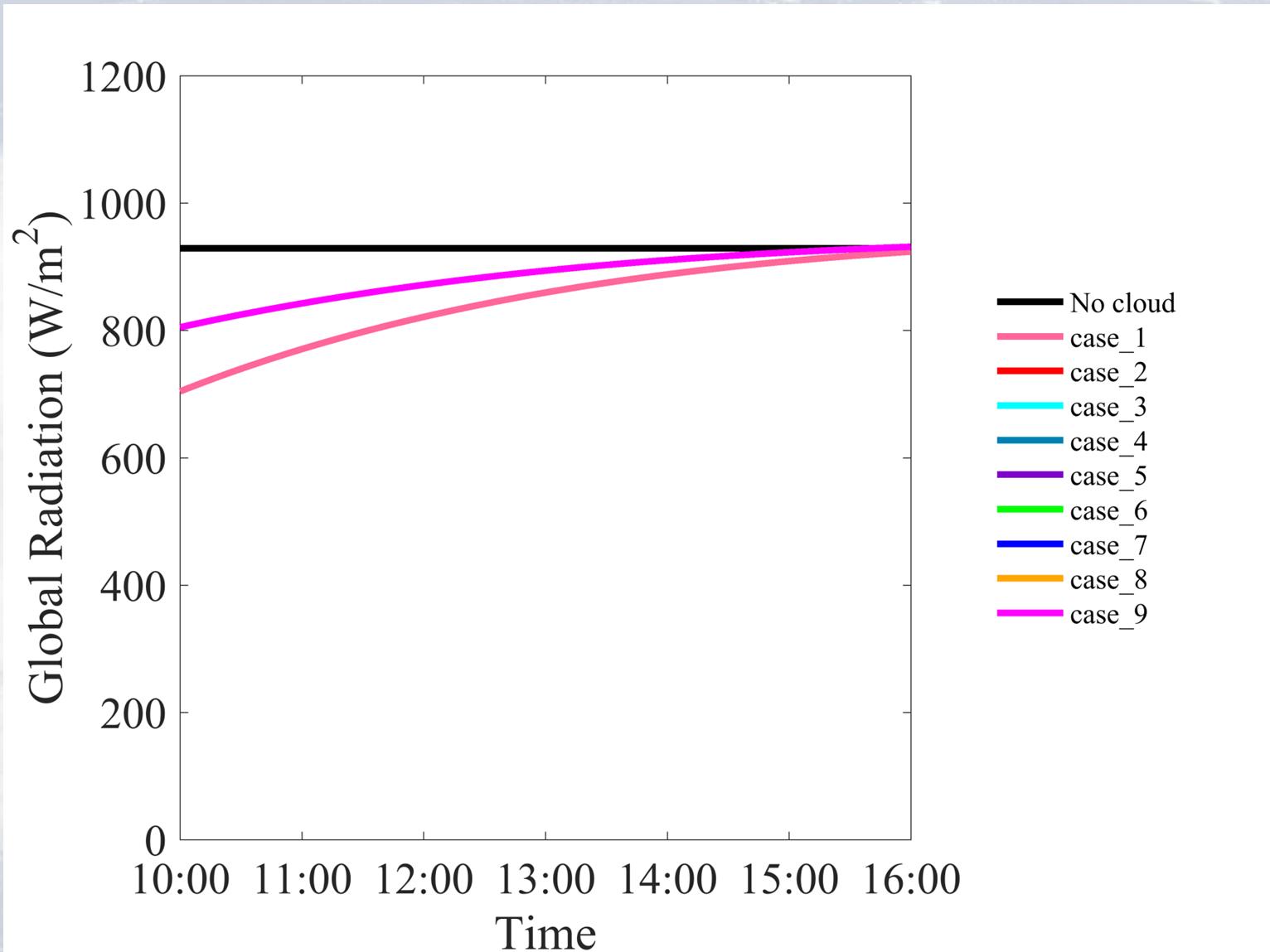


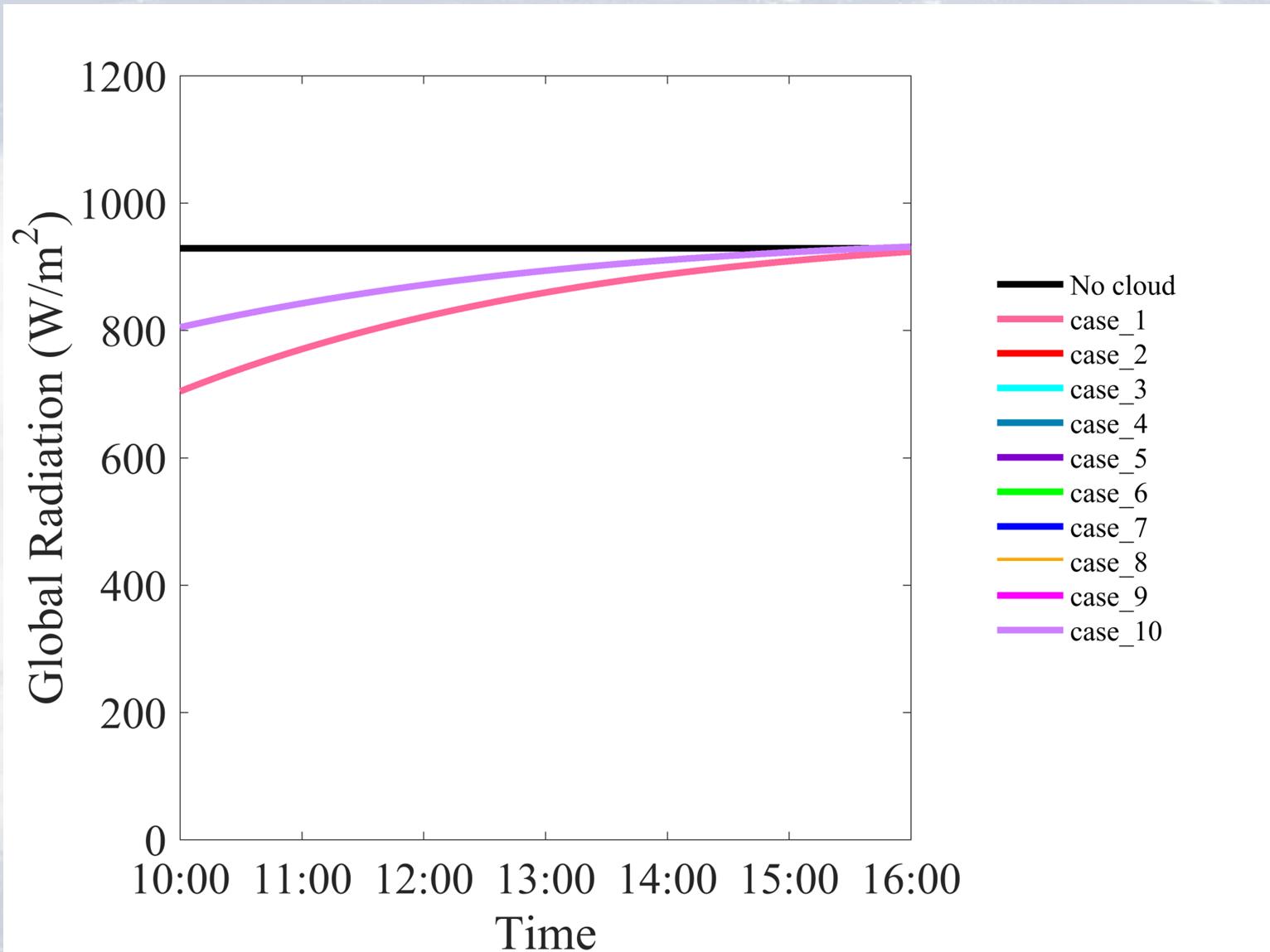


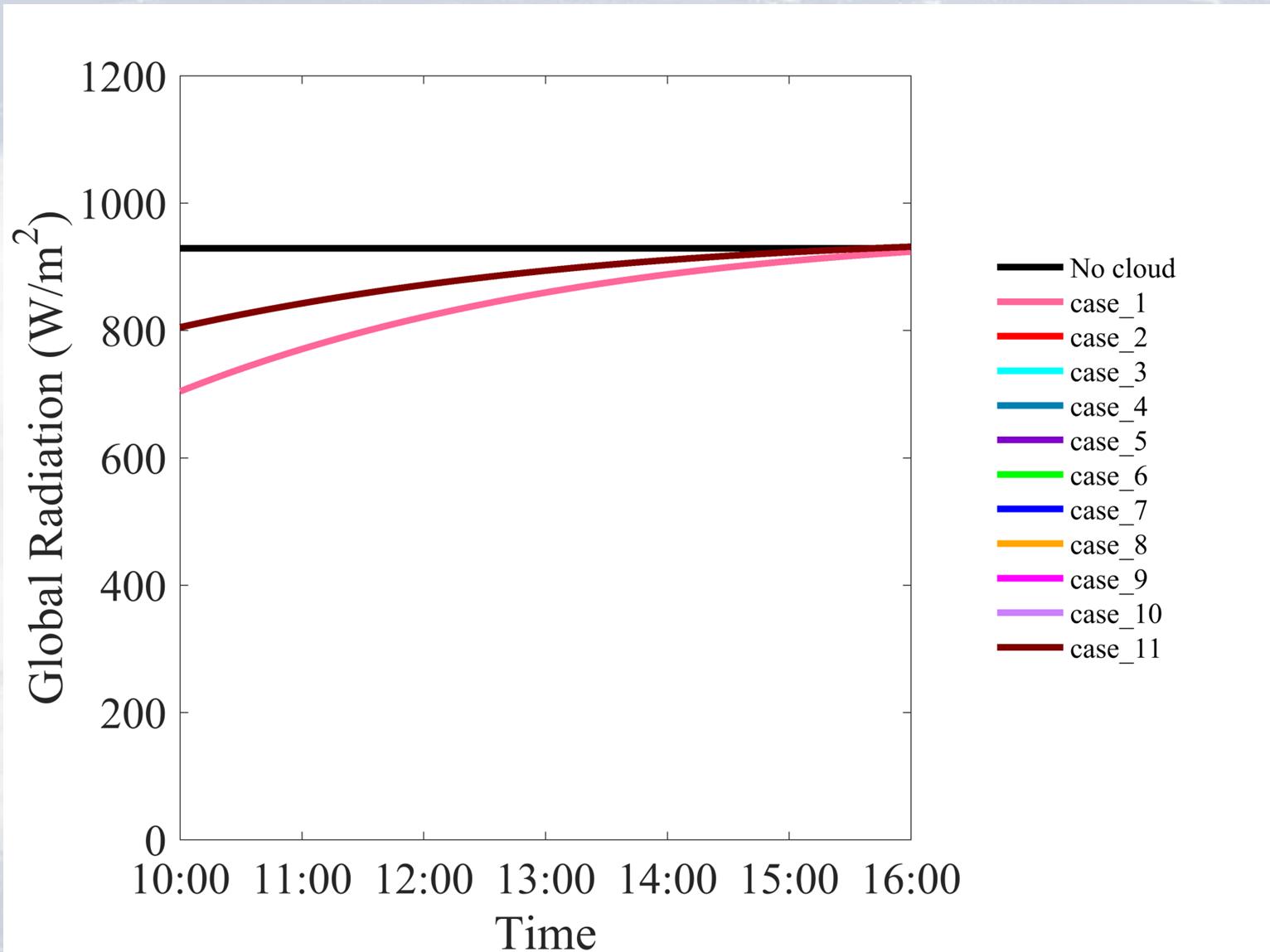


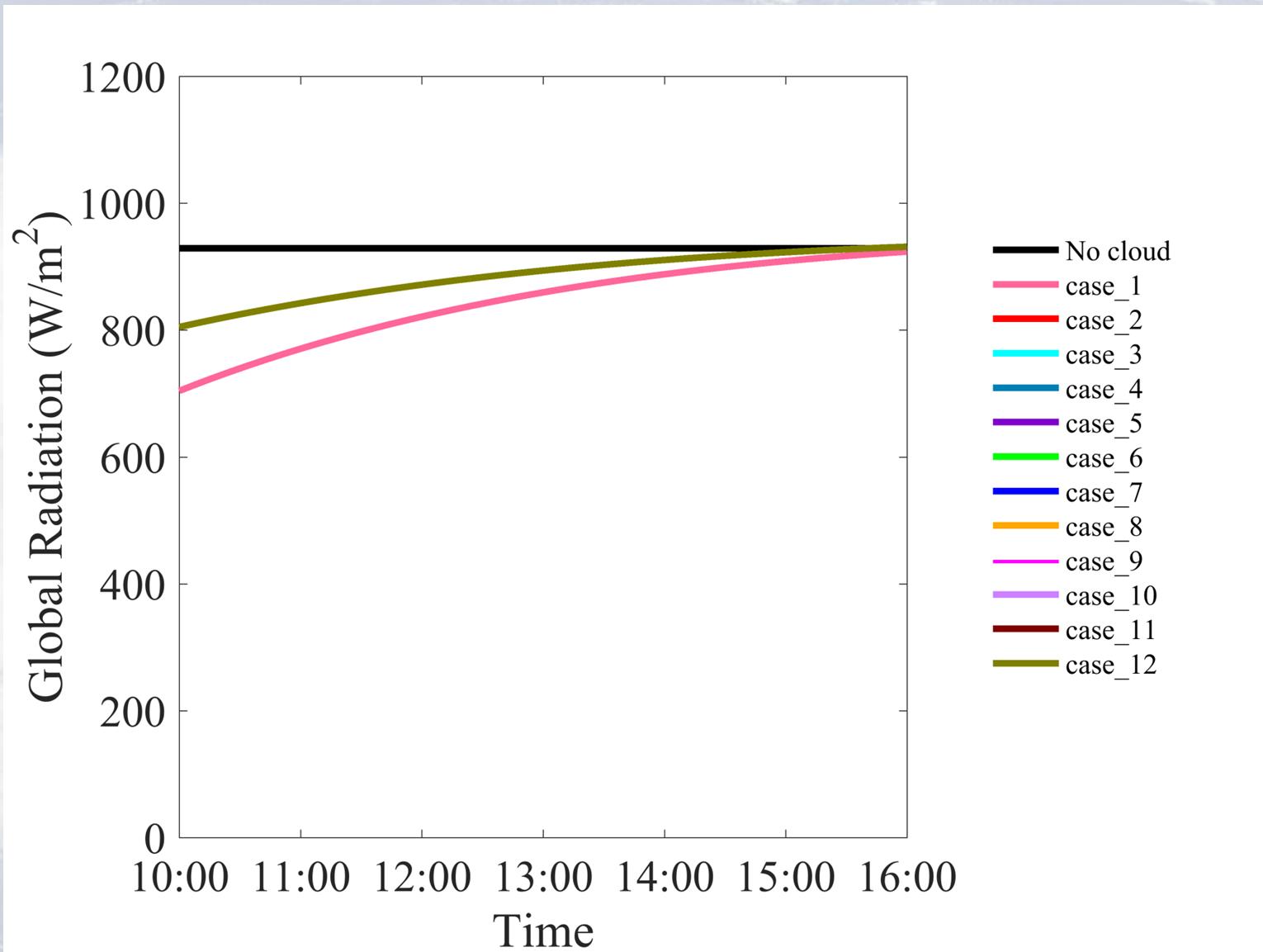


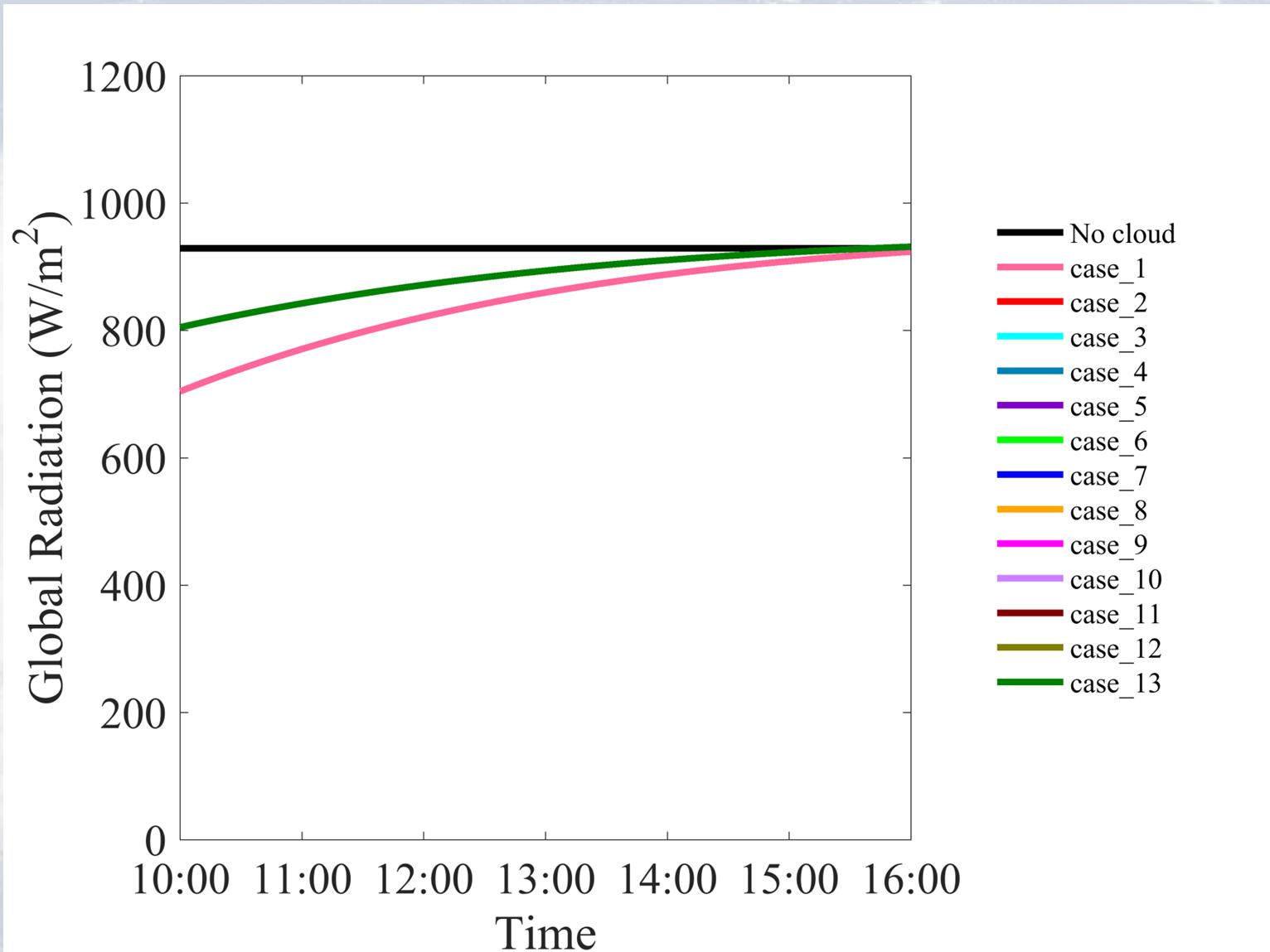












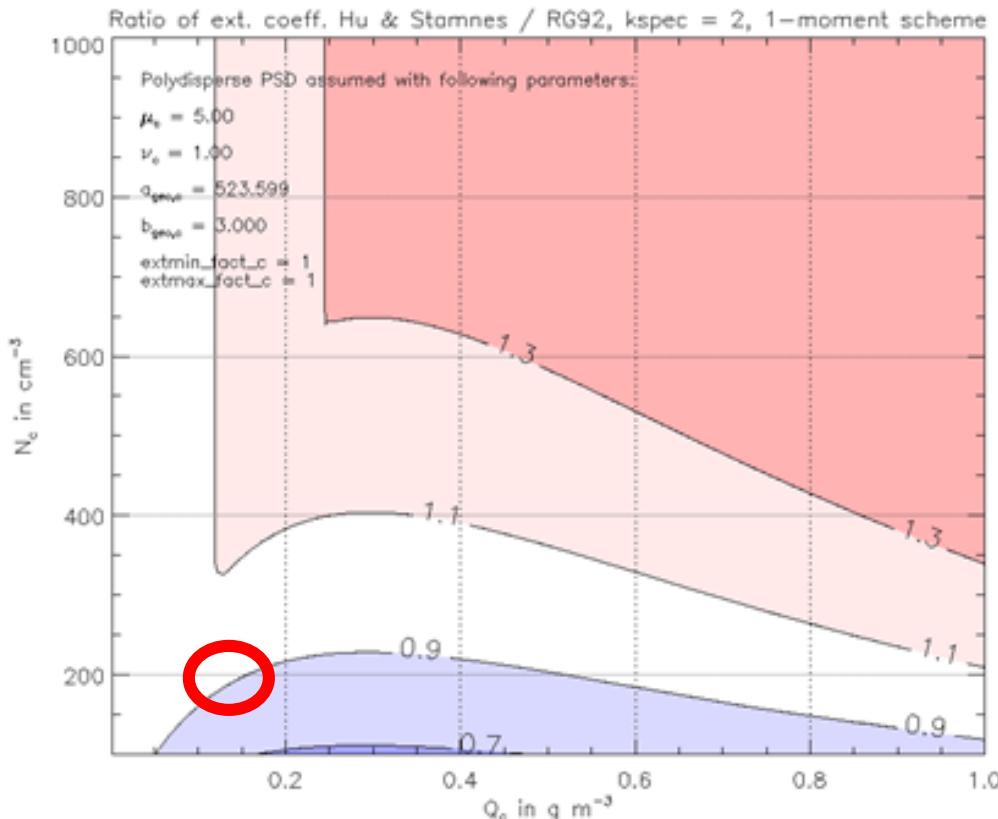
Cloud droplets comparison to RG92



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

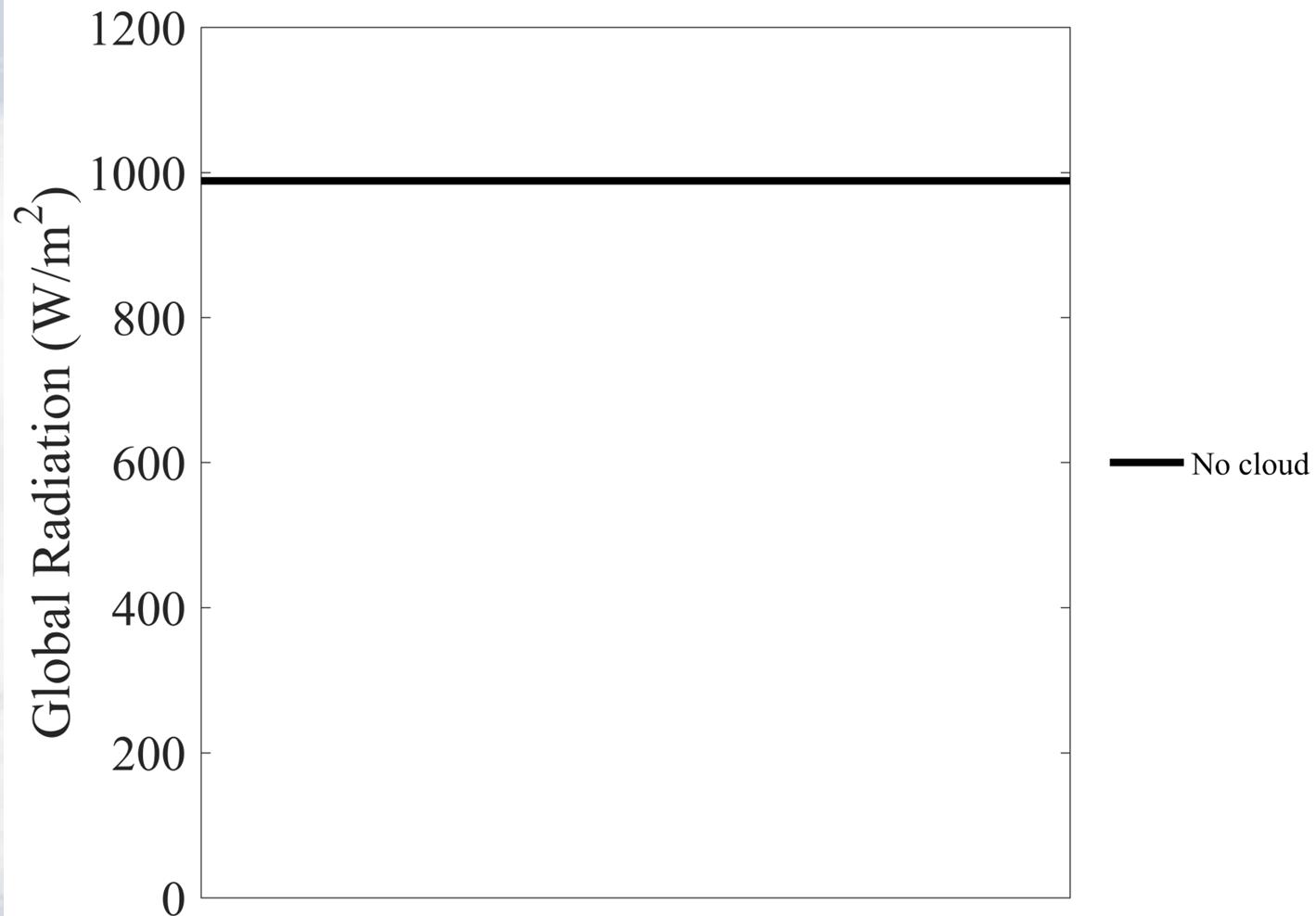
q_c prognostic

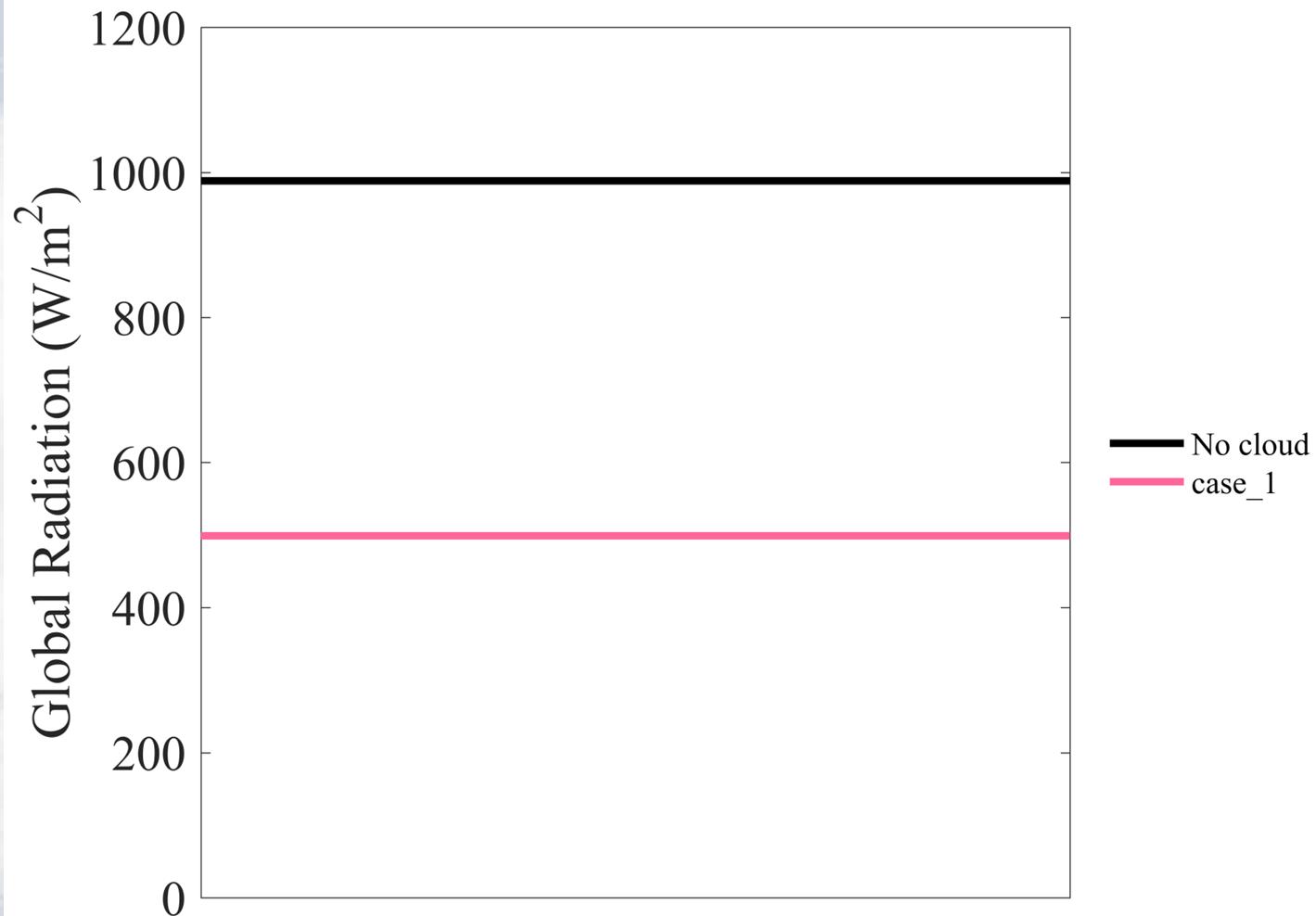
Spectral interval „2“
(visible range)

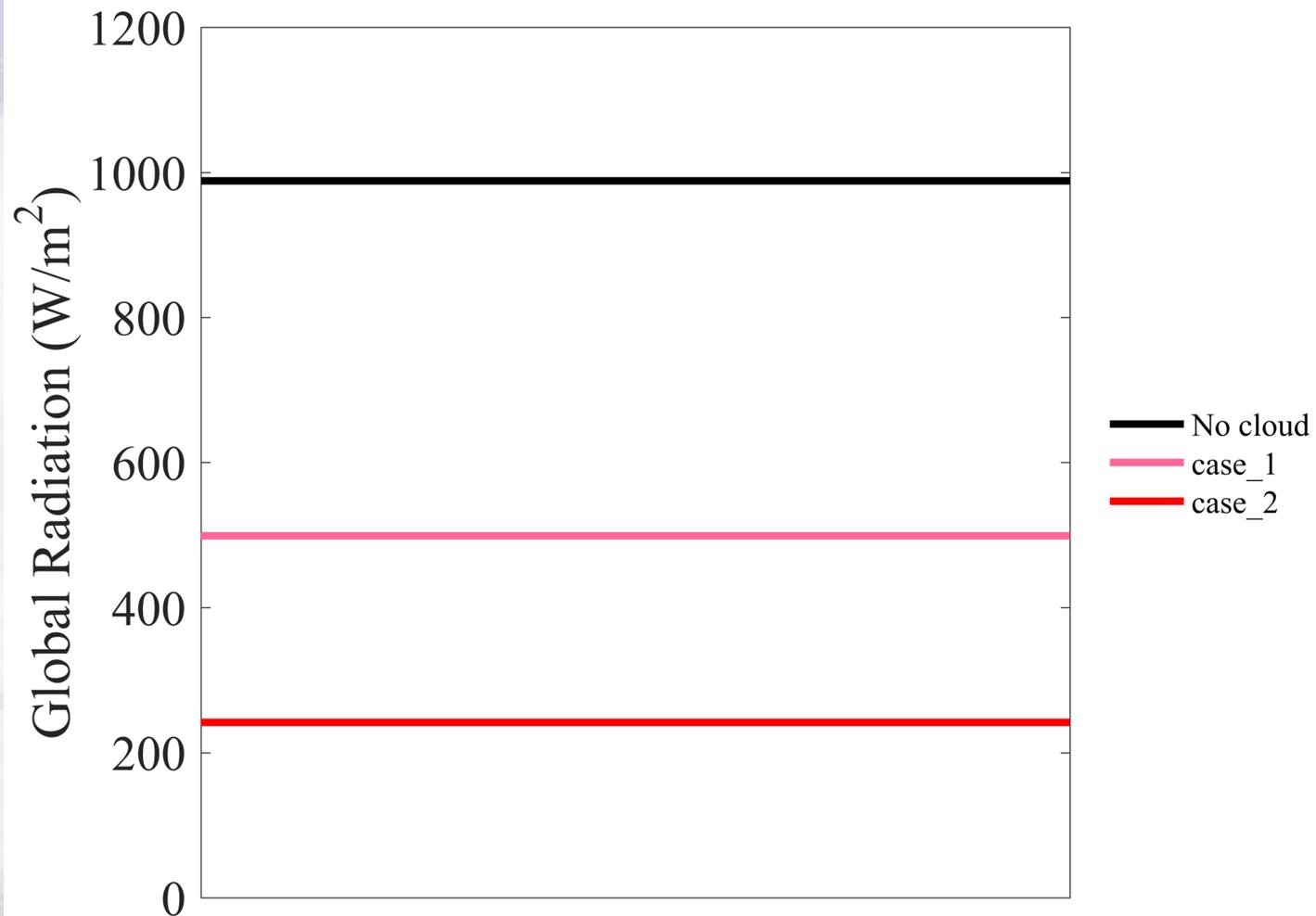
β_{ext} ratio HS / RG92

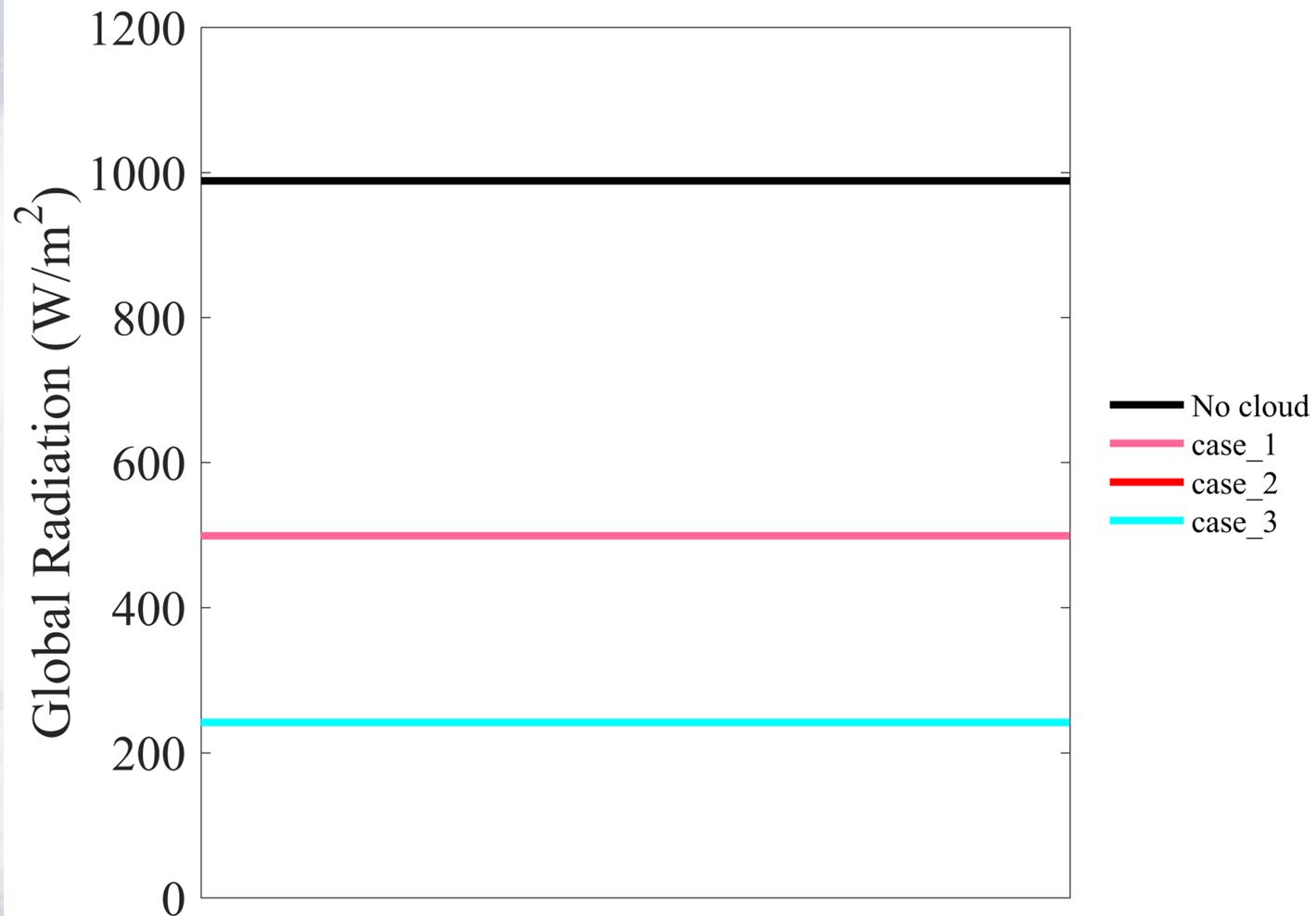


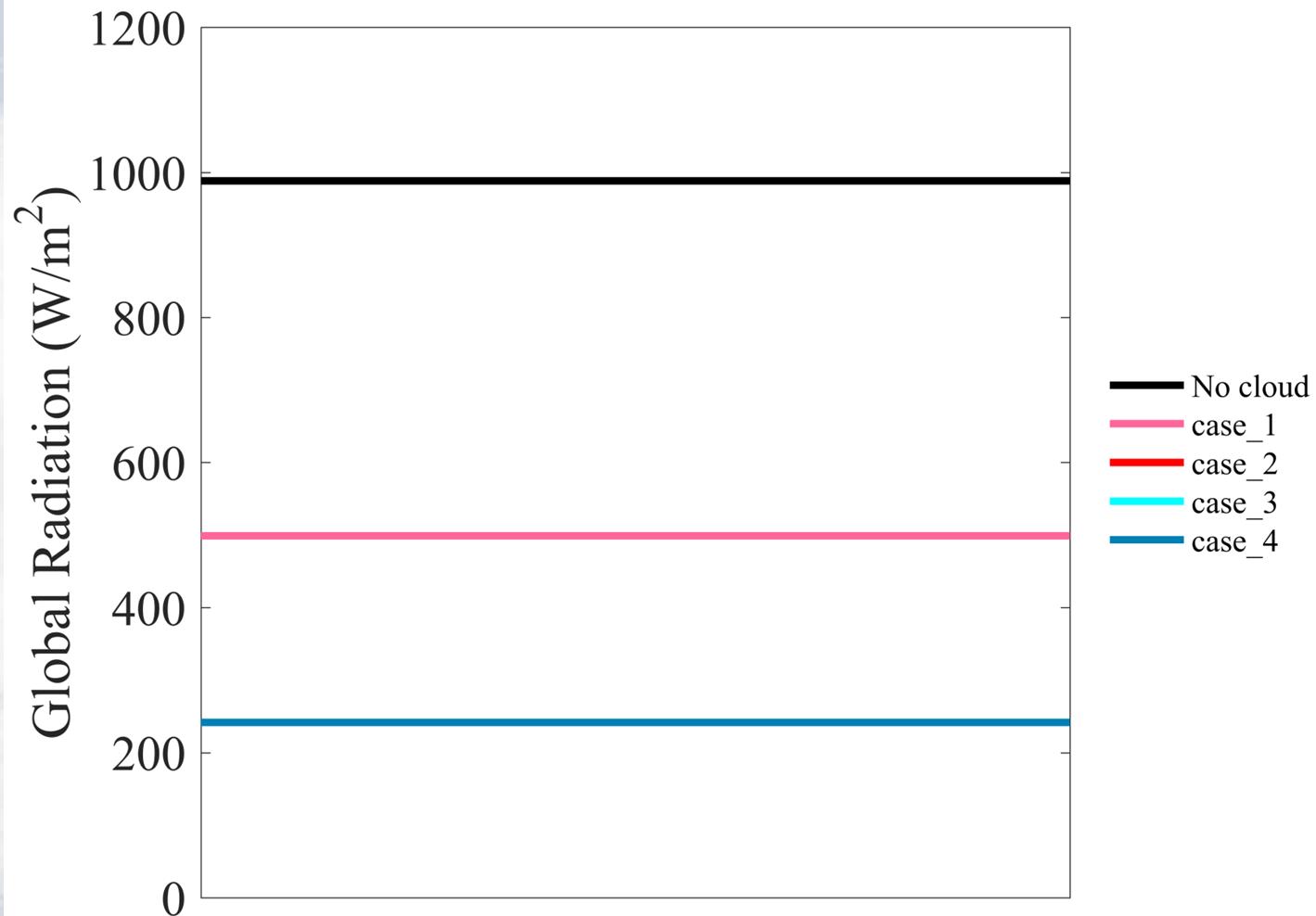
True / False switches on Anvil:

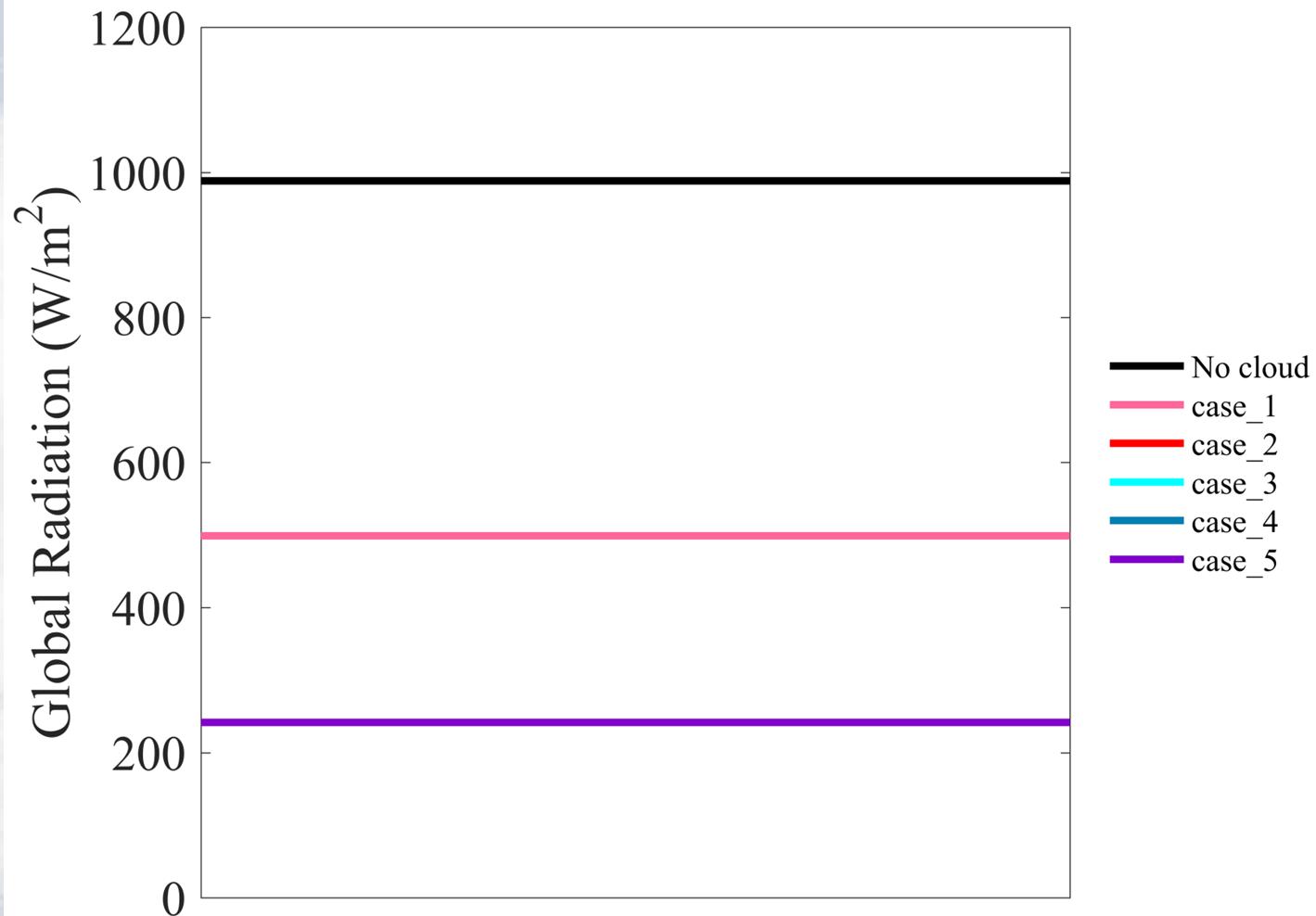


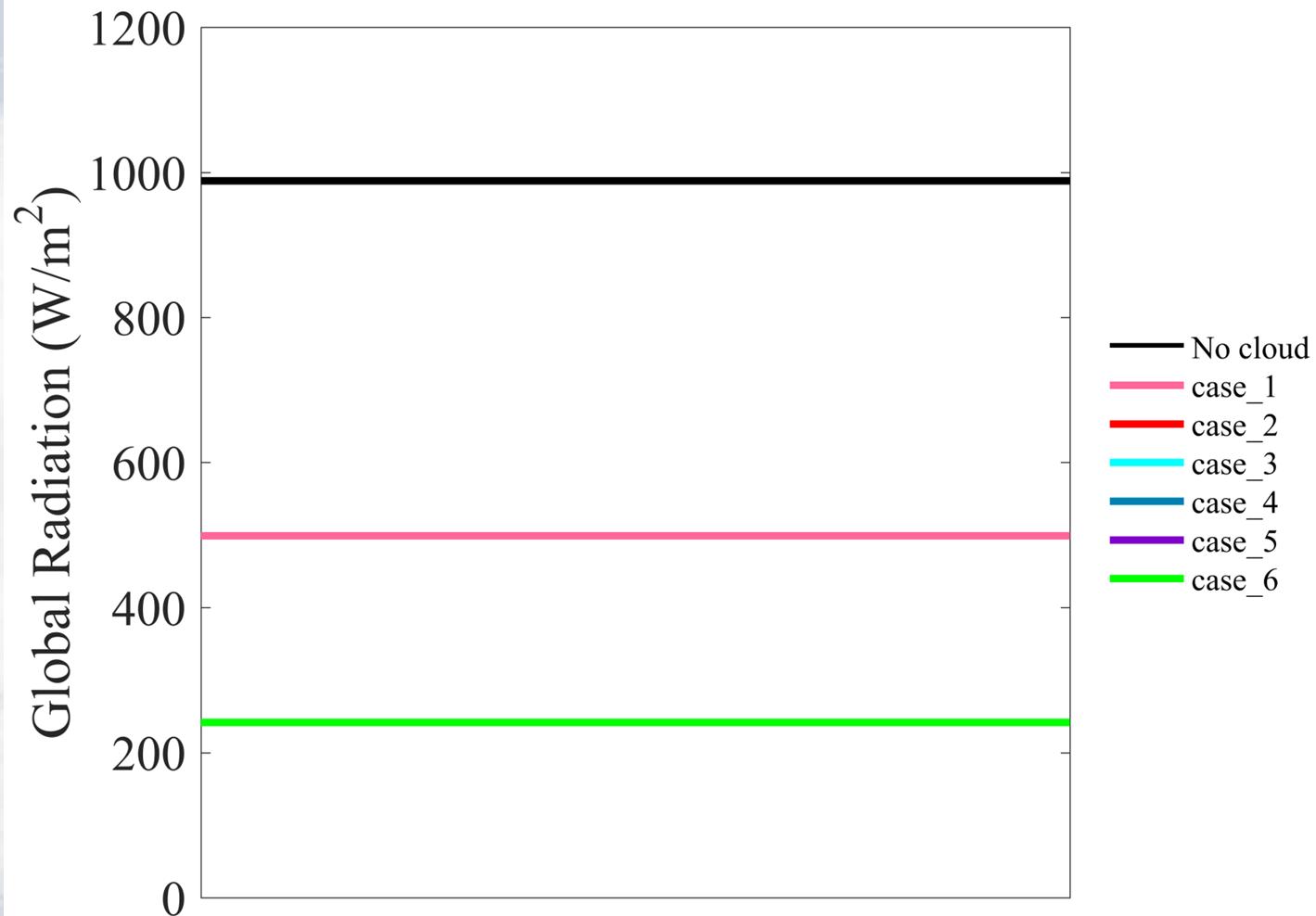


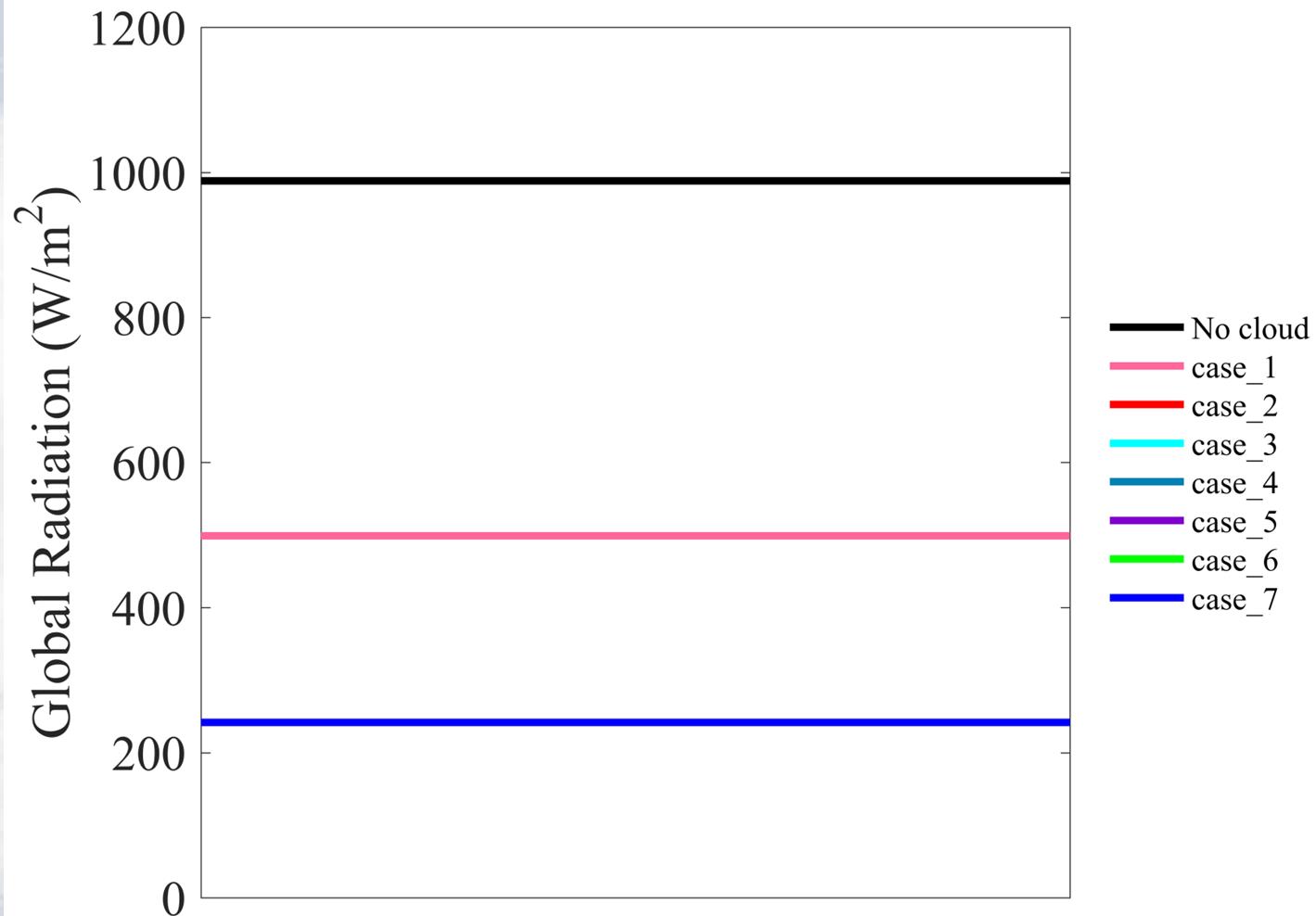


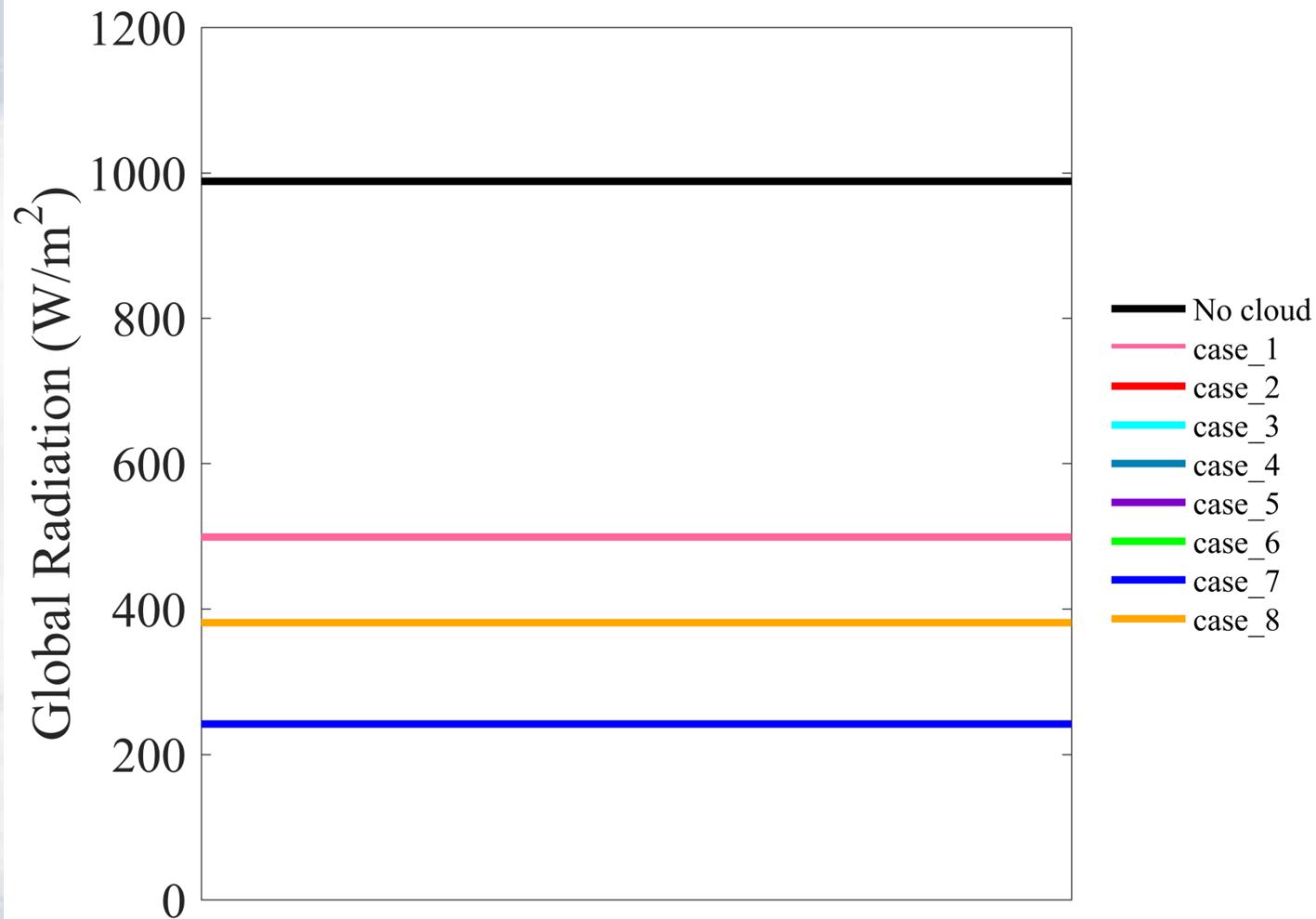


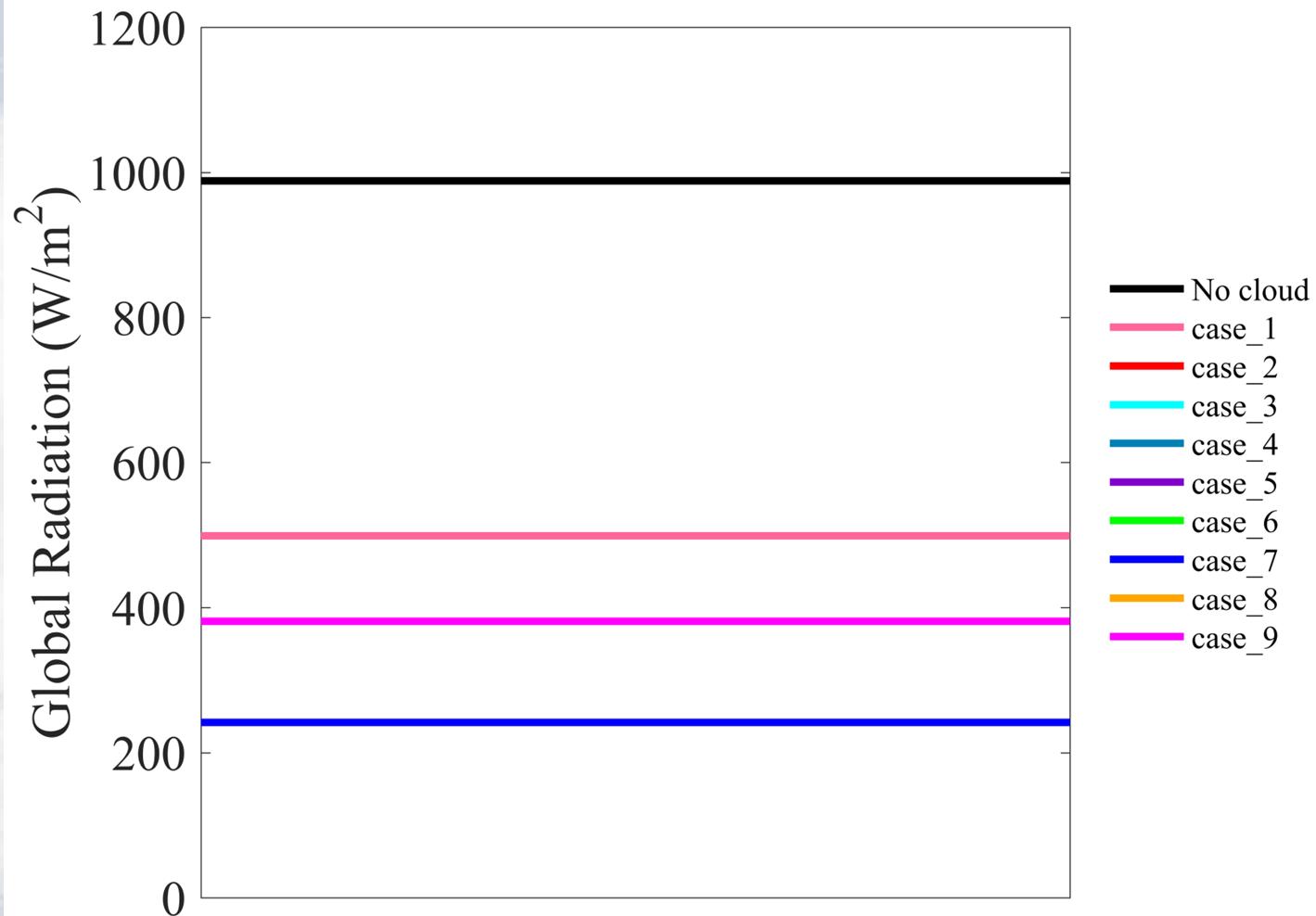


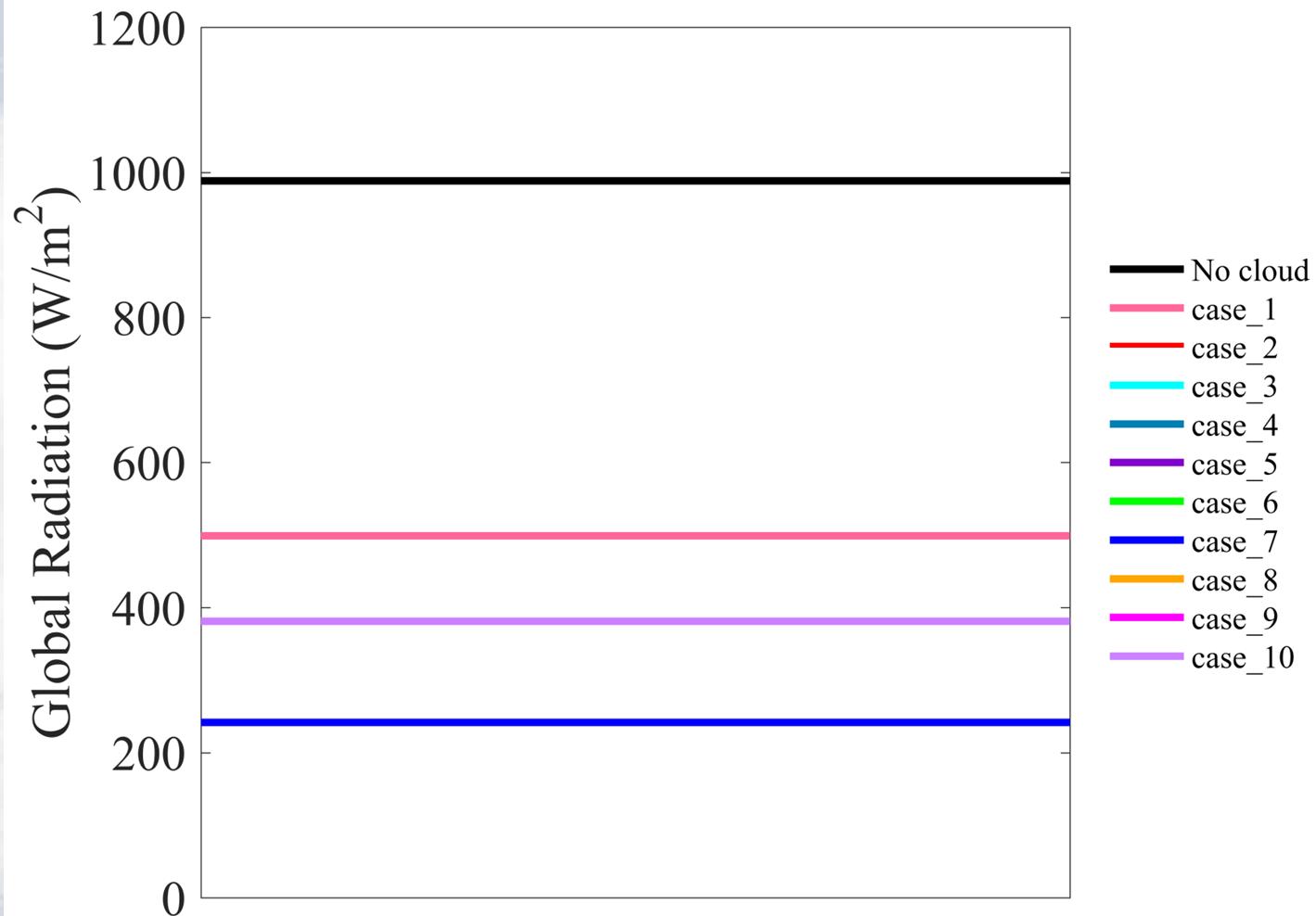


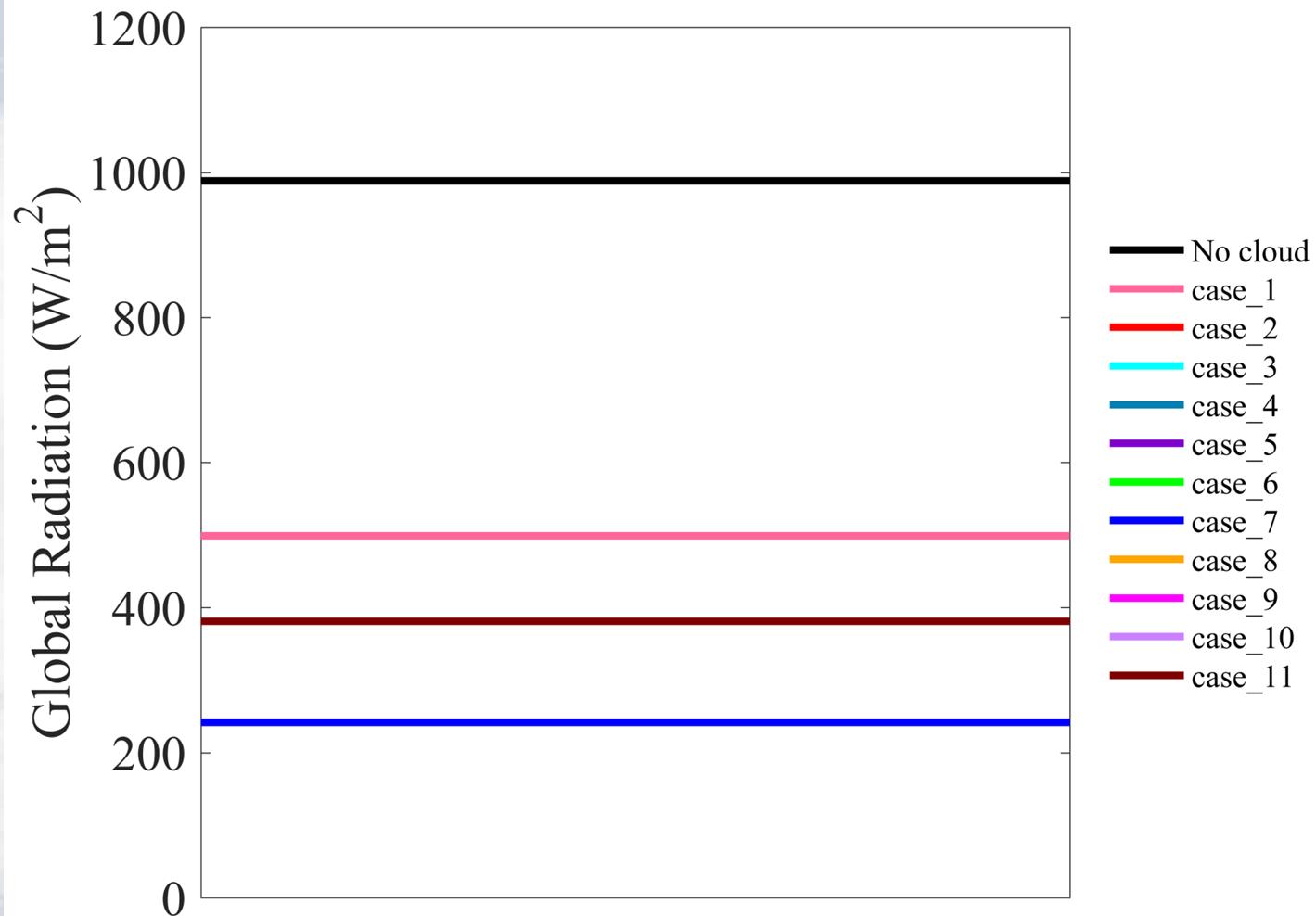


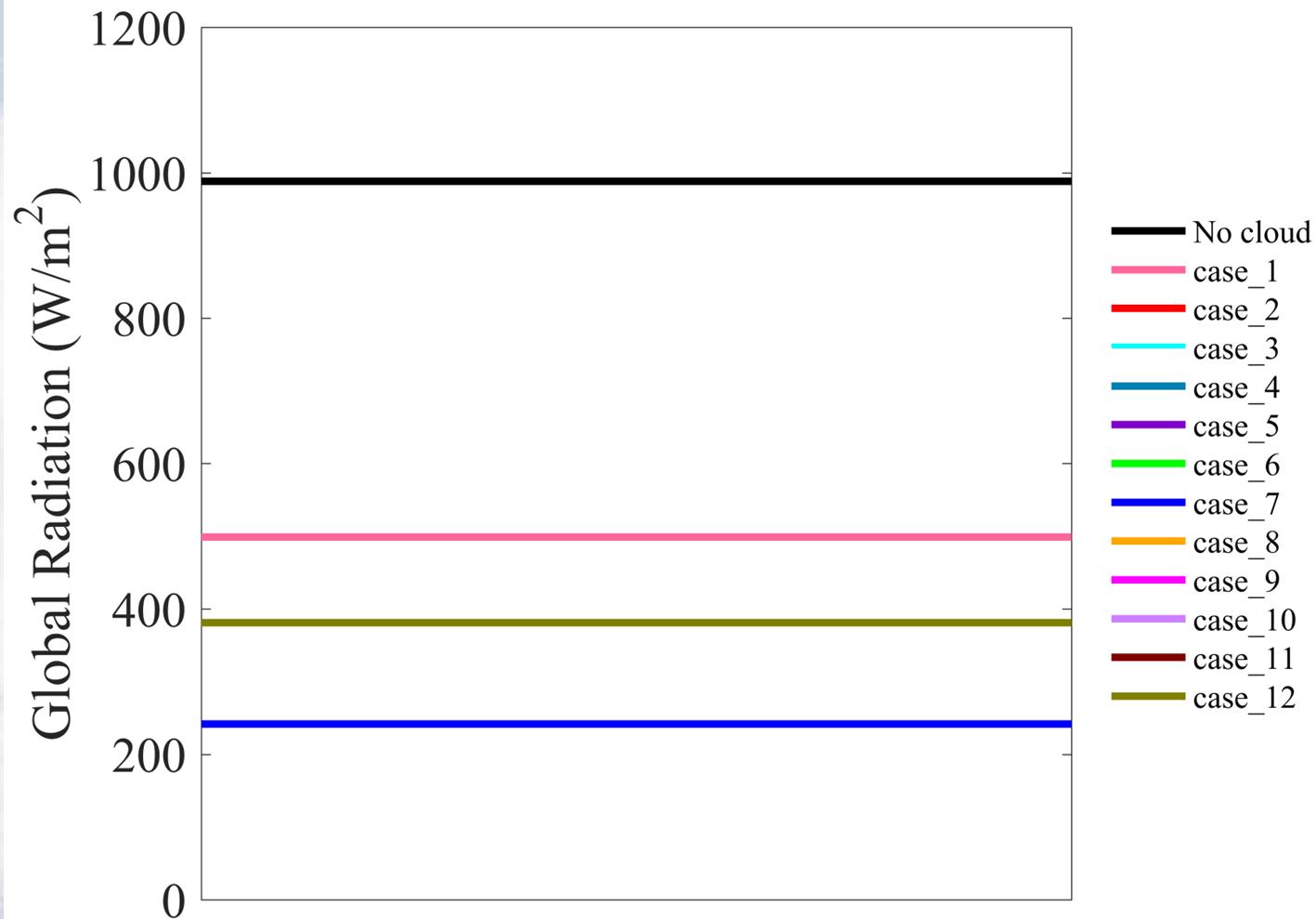


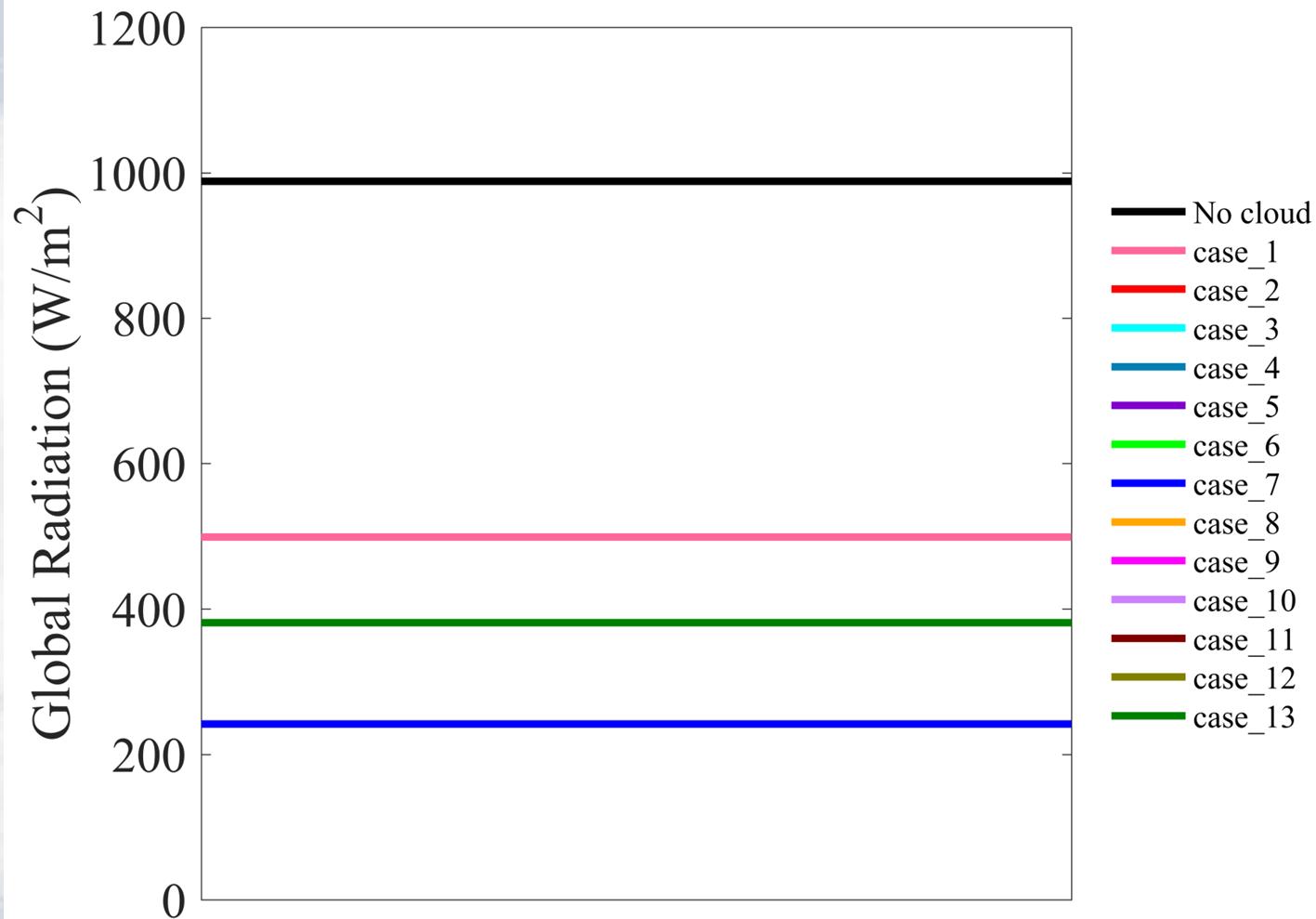






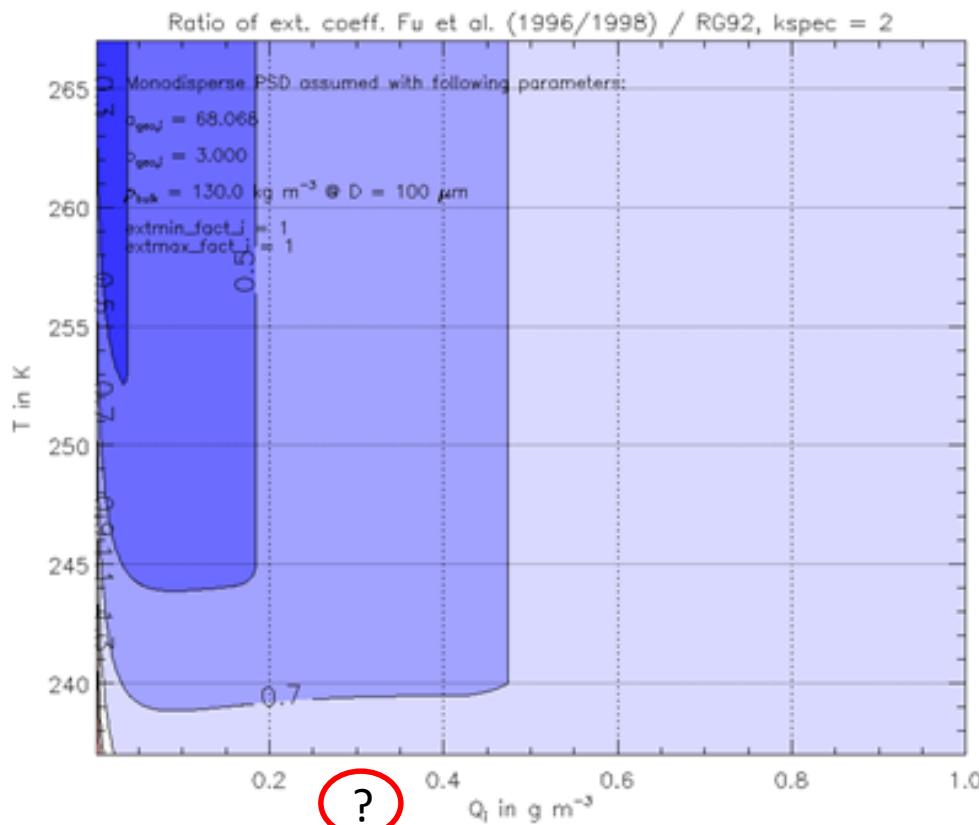






Cloud ice (visible; Fu et al.)

→ If grid scale $q_i > 0$: 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)

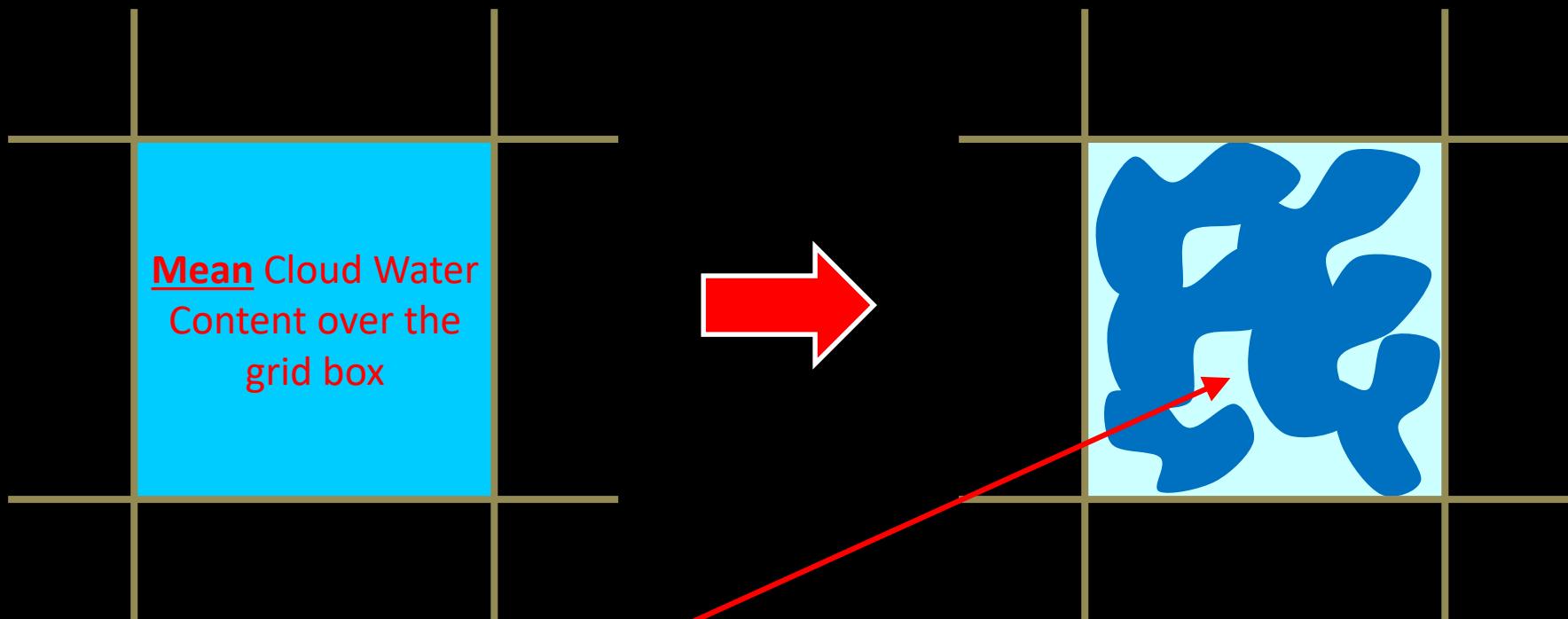
β_{ext} ratio Fu / RG92

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 \rightarrow (**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”

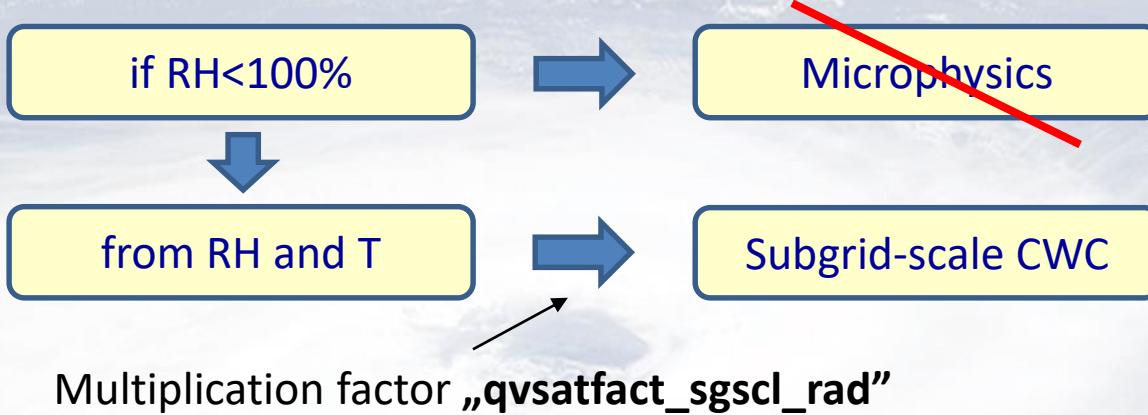


higher effective CWC



higher radiation attenuation

Parameter 2: „qvsatfact_sgscl_rad”

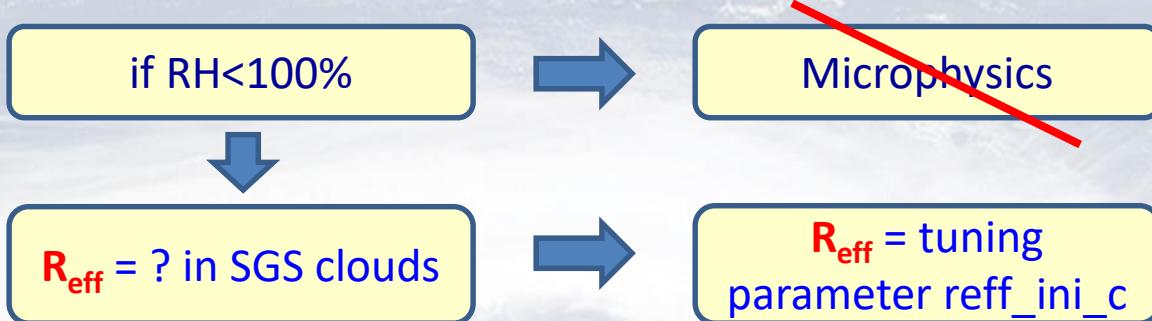


Where „qvsatfact_sgscl_rad” takes effect ?

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



Parameter 4: „reff_ini_c”



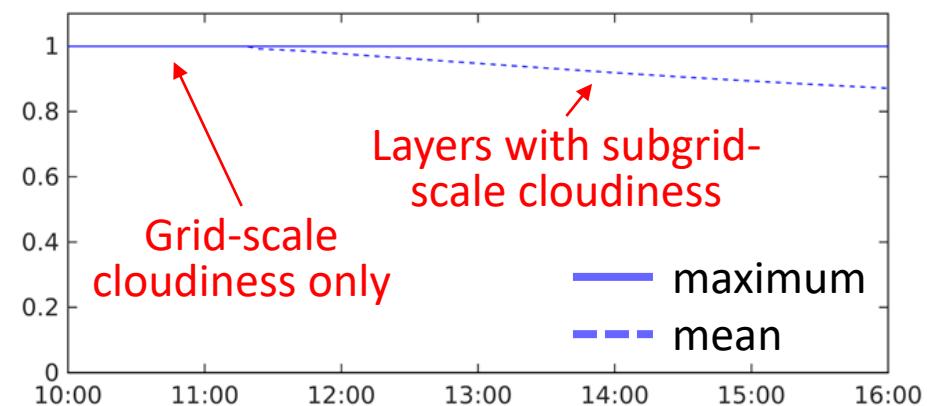
Where „reff_ini_c” takes effect ?

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

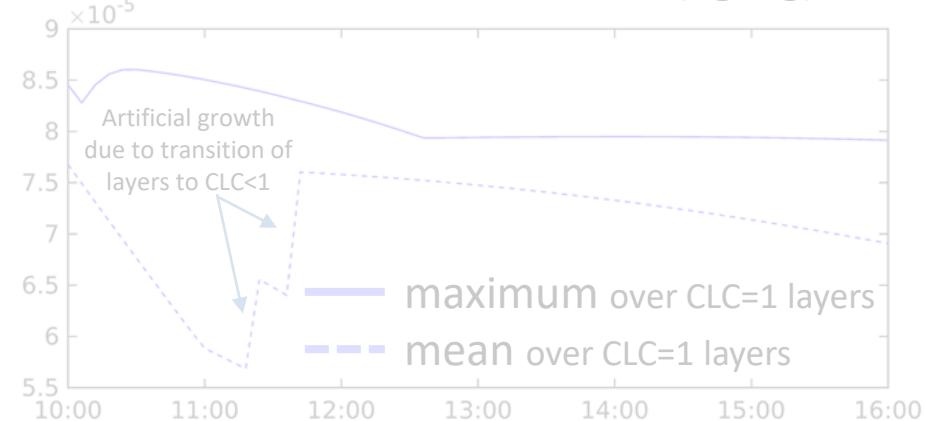


Example: Warm Stratus cloud (idealized simulation)

Cloud Cover - CLC

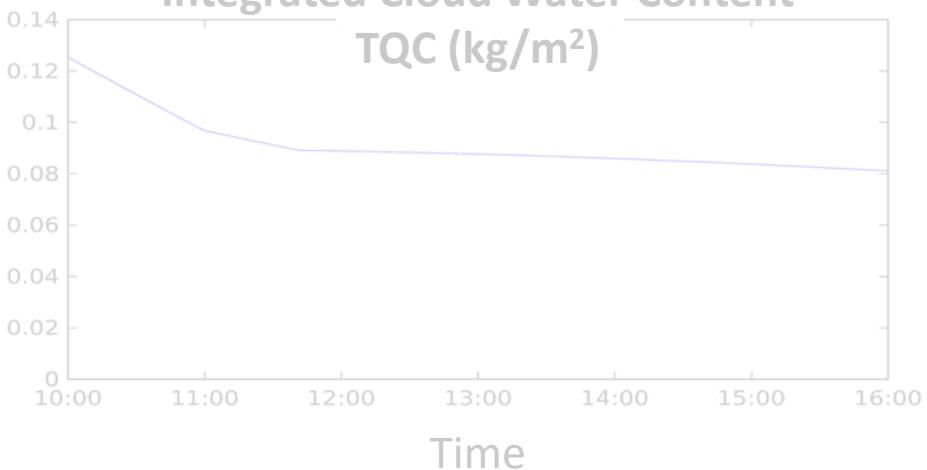


Cloud Water Content – QC (kg/kg)



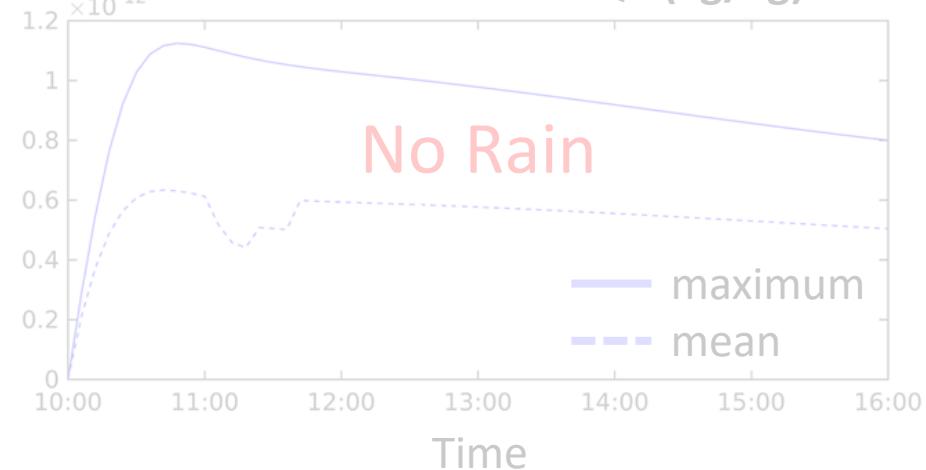
Integrated Cloud Water Content

TQC (kg/m²)



Time

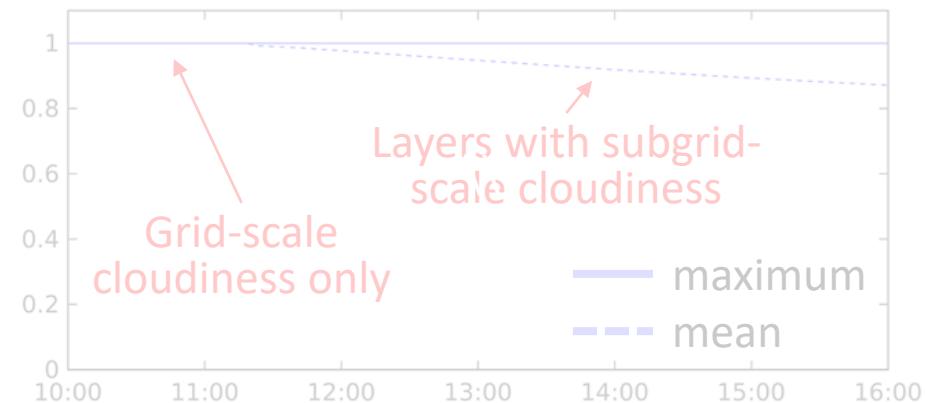
Rain Water Content – QR (kg/kg)



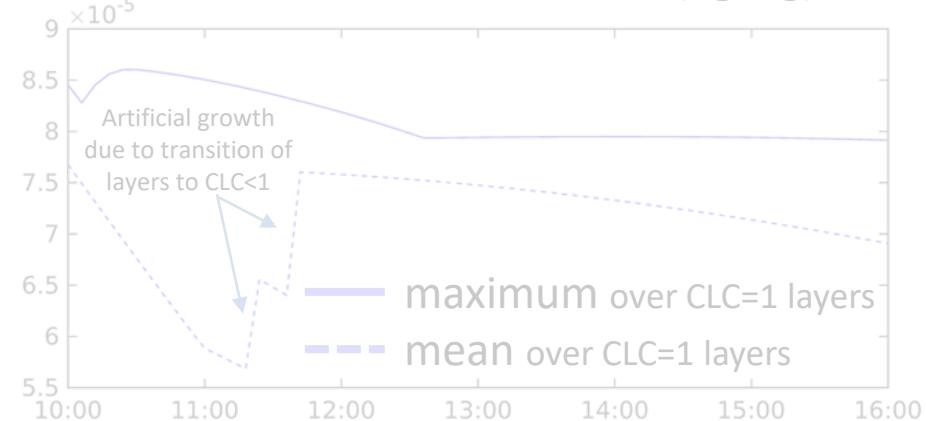
Time

Example: Warm Stratus cloud (idealized simulation)

Cloud Cover - CLC

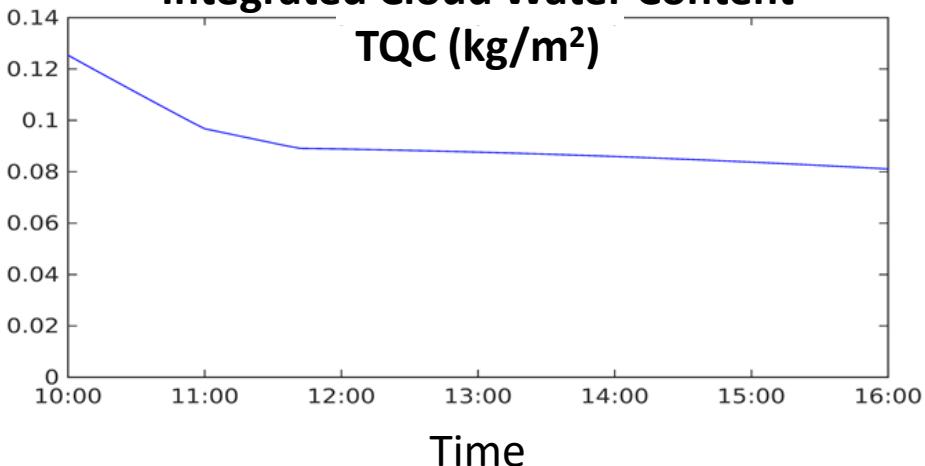


Cloud Water Content – QC (kg/kg)

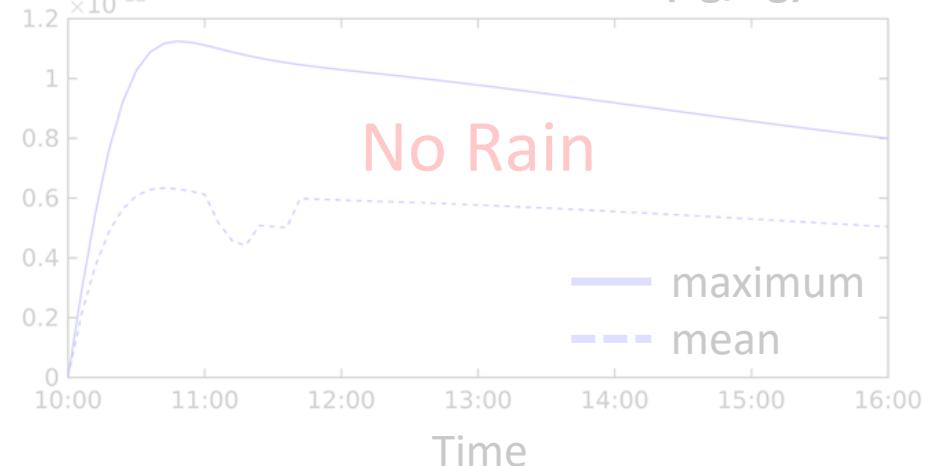


Integrated Cloud Water Content

TQC (kg/m²)

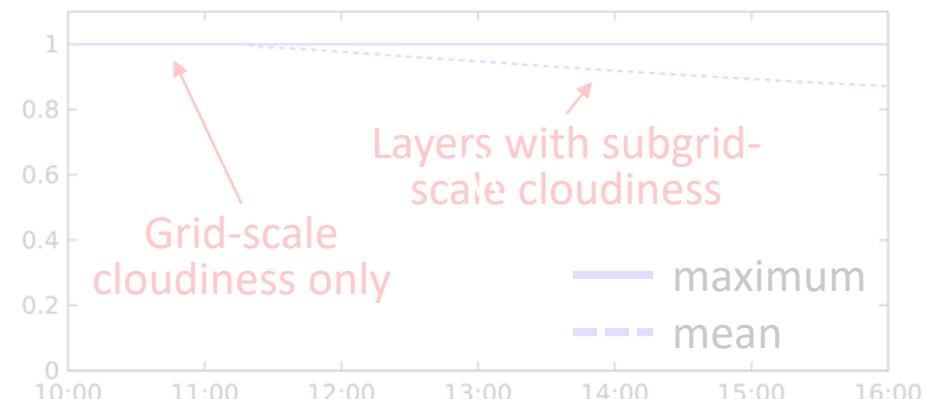


Rain Water Content – QR (kg/kg)

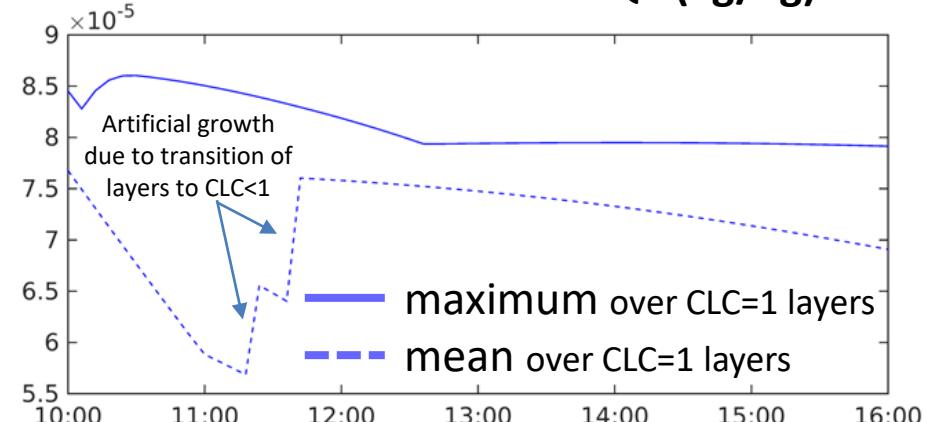


Example: Warm Stratus cloud (idealized simulation)

Cloud Cover - CLC

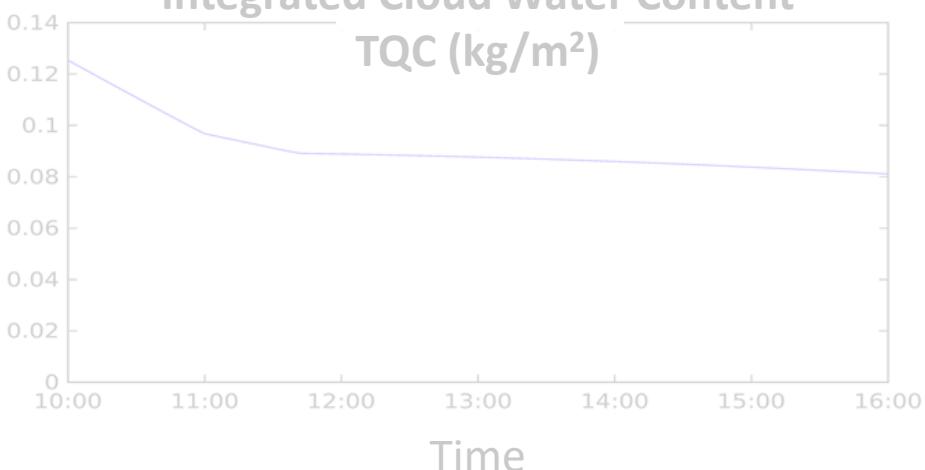


Cloud Water Content – QC (kg/kg)

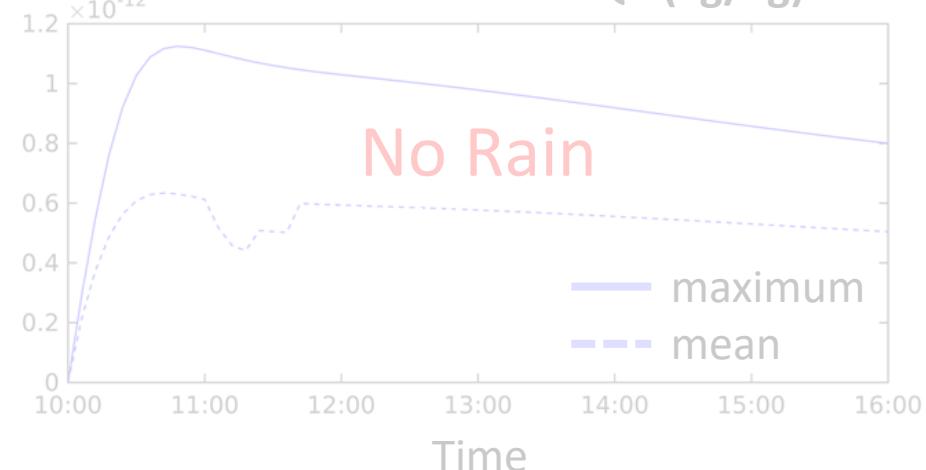


Integrated Cloud Water Content

TQC (kg/m²)

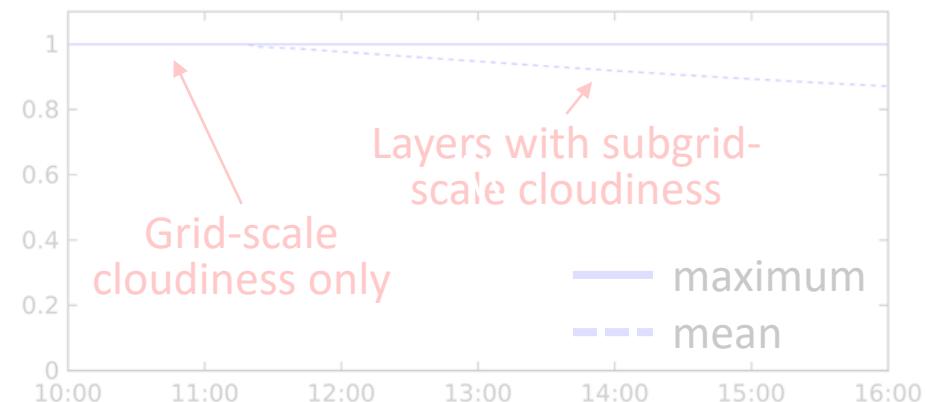


Rain Water Content – QR (kg/kg)

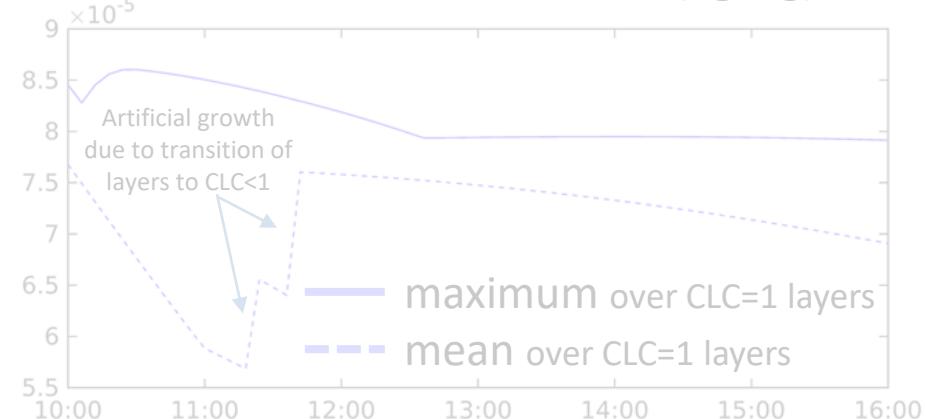


Example: Warm Stratus cloud (idealized simulation)

Cloud Cover - CLC

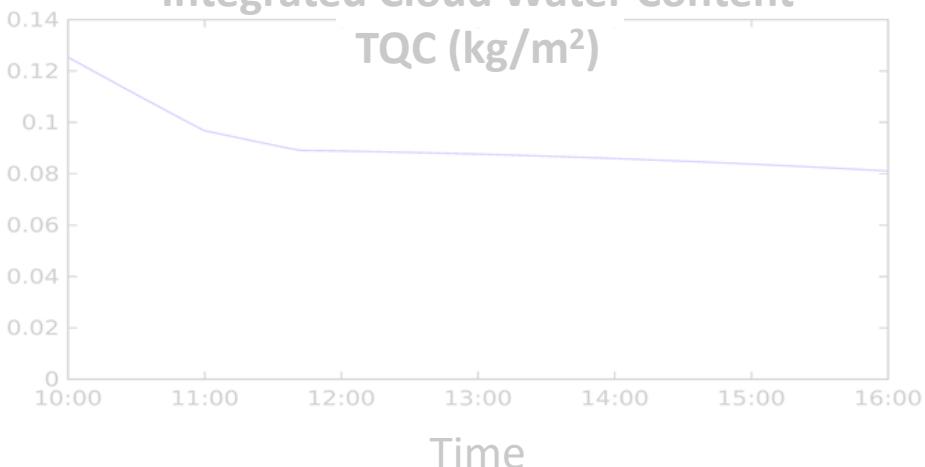


Cloud Water Content – QC (kg/kg)

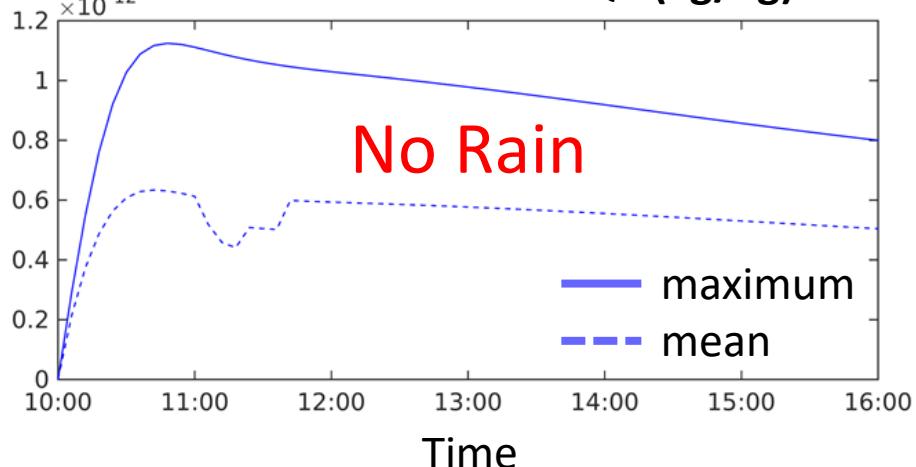


Integrated Cloud Water Content

TQC (kg/m²)

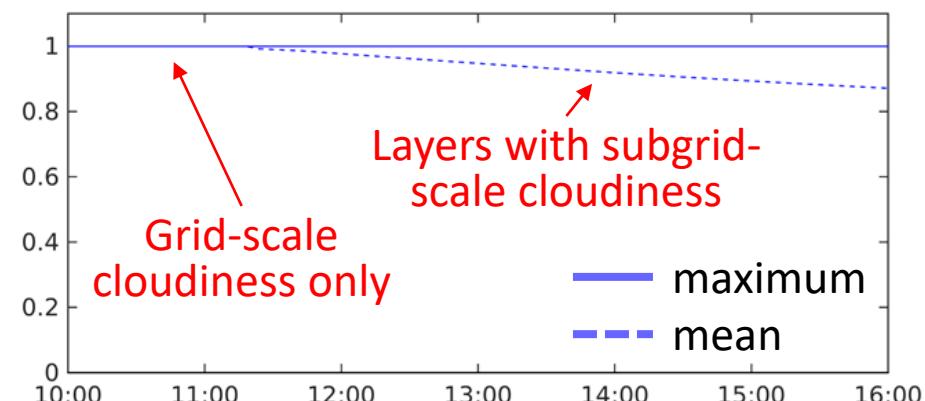


Rain Water Content – QR (kg/kg)

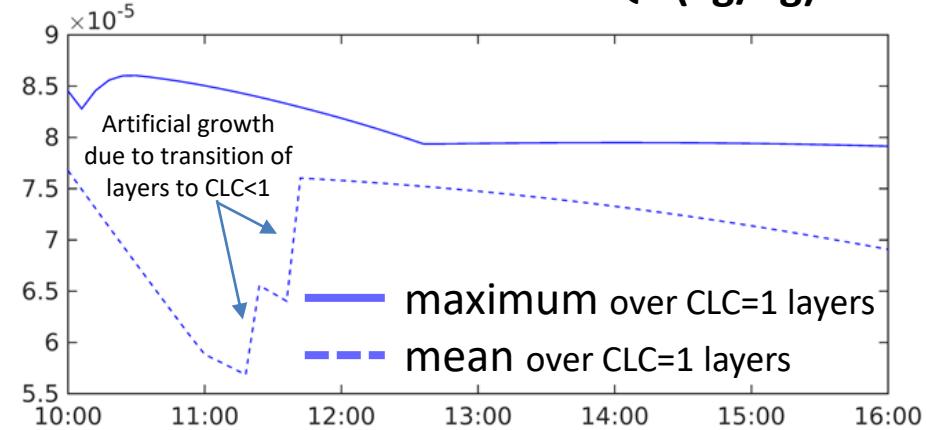


Example: Warm Stratus cloud (idealized simulation)

Cloud Cover - CLC

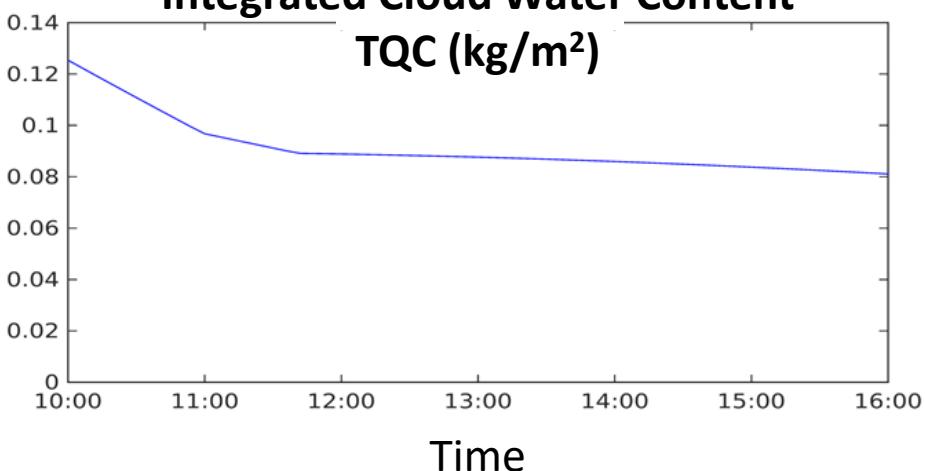


Cloud Water Content – QC (kg/kg)



Integrated Cloud Water Content

TQC (kg/m²)



Rain Water Content – QR (kg/kg)

