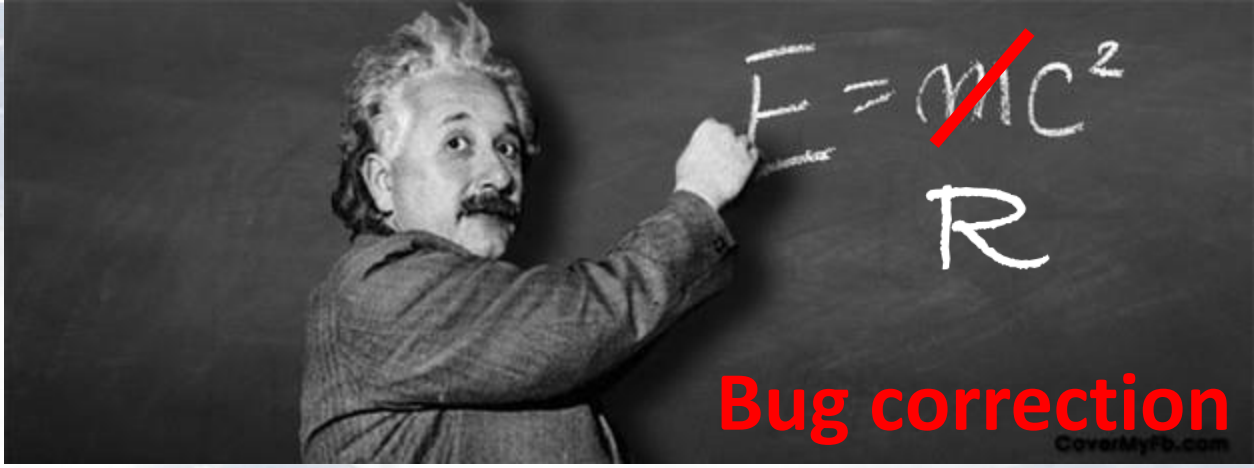

RC^2: sensitivities to the new radiation scheme parameters

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COSMO General Meeting, Wroclaw, September 2015

Problem: **New radiation scheme – 32 new parameters. 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	Stratus	Mixed phase	SGS Strato-cumulus	Shallow convective cumulus	Anvil of Cumulonimbus
p1,p2,p3,p4, p5,p7,p8,p9, p12,p14,p21, p22,p23,p27, p28,p29,p30	p1,p2,p4, p6,p13,p15, p16,p17,p24, p25, p26,p30	p1,p2,p3,p4,p5, p6,p7,p8,p9,p12, p13,p14,p15,p16, p17,p21,p22,p23, p24,p25,p26,p27, p28,p29,p30	p2,p4,p5,p6,p13,p15, p16,p17,p30	p2,p4,p5,p6,p13,p15, p16,p17, p30	p1,p2,p3,p4,p5,p7,p8,p9,p12, p14,p21,p22,p23,p27,p28, p29,p30

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

p6,p7,p13,p18,p19,p20,p30 – new tuning namelist parameters in the future version

All the others – predefine in the code

Outline

1. Example: Stratus cloud
    a. Radiation parameters for stratus cloud
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1a. Radiation parameters for stratus cloud

What do we need to define optical properties ?

Effective Cloud Water Content - CWC

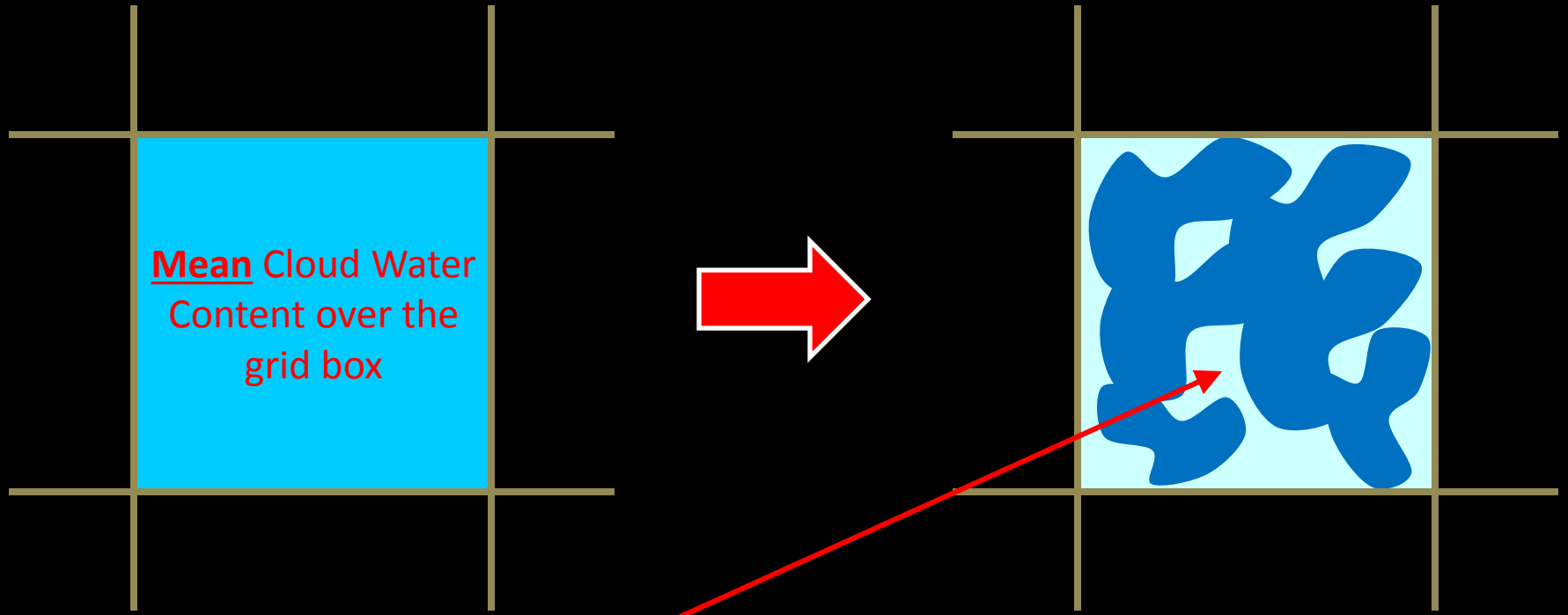
+

Effective radius of droplets R_{eff}

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

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

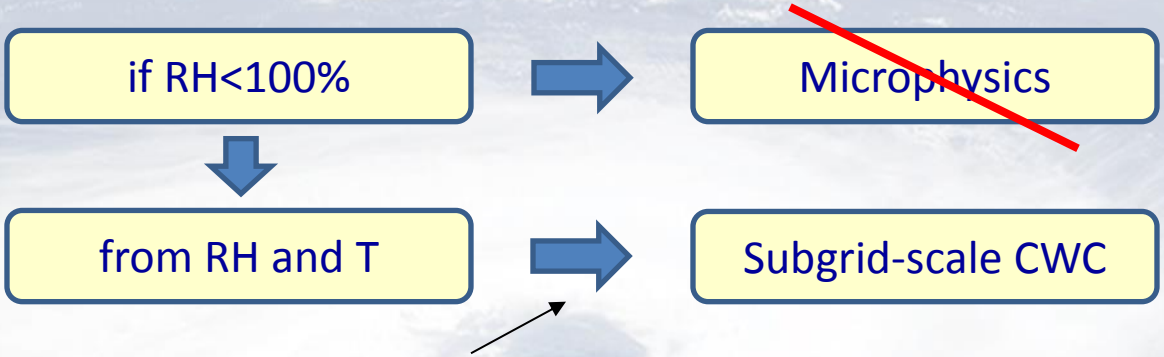
Parameter 1: Subgrid-scale variability factor „radqcfact”

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”

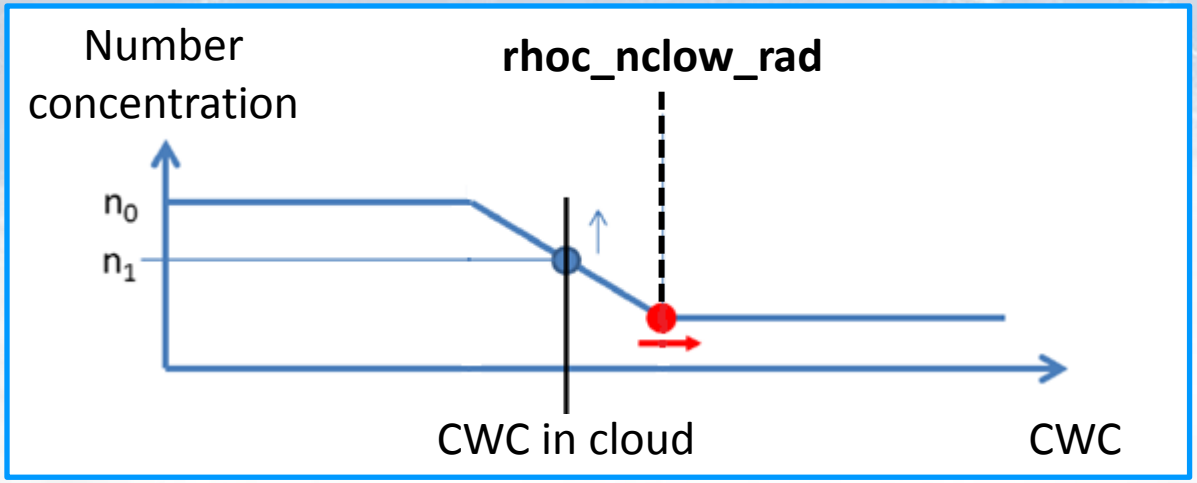


Where „qvsatfact_sgscl_rad” takes effect ?

	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 3: „rhoc_nclow_rad”



Parameterization in radiation scheme:

higher CWC

⇩

lower number concentration due to collisions

Where „rhoc_nclow_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 rhoc_nclow_rad ⇨ higher number concentration ⇨ lower R_{eff} ⇨ 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

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1b. Idealized simulation of stratus cloud

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

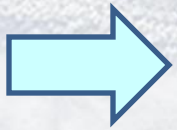
Resolution: 0.025°

Periodic B.C.

Stable layer
(1.5-3.3km)
with initial RH=101%

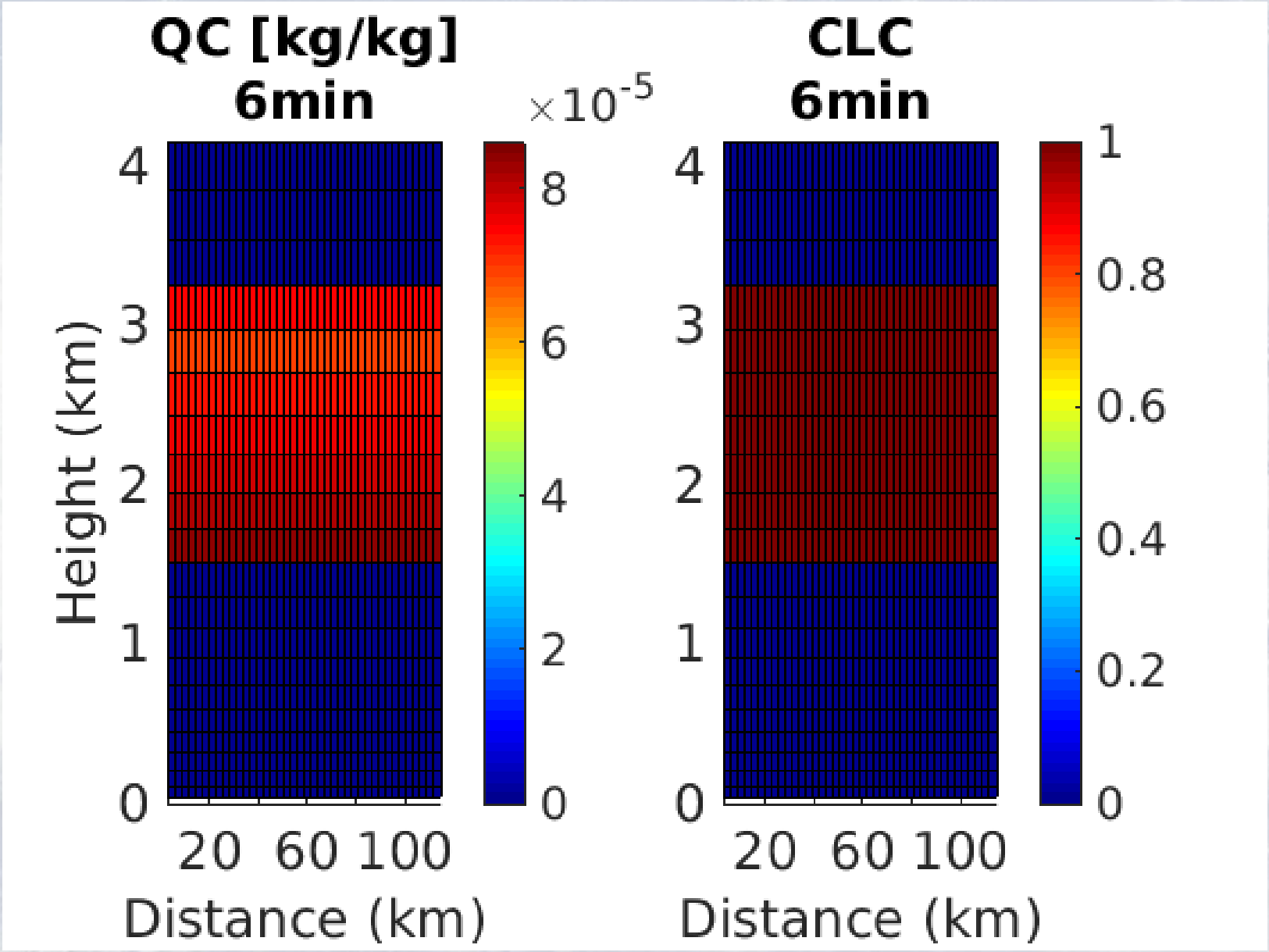
Set zenith angle to
constant=30°

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

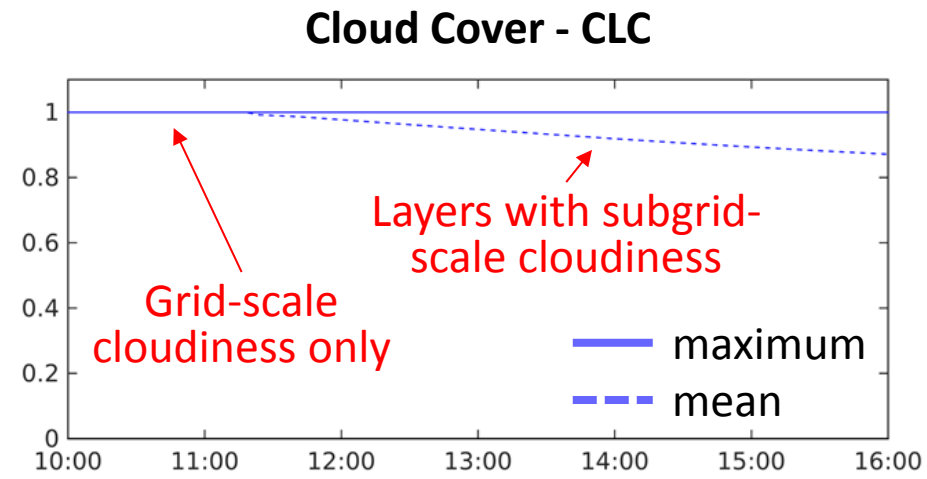


"Same" cloud for any radiation parameters

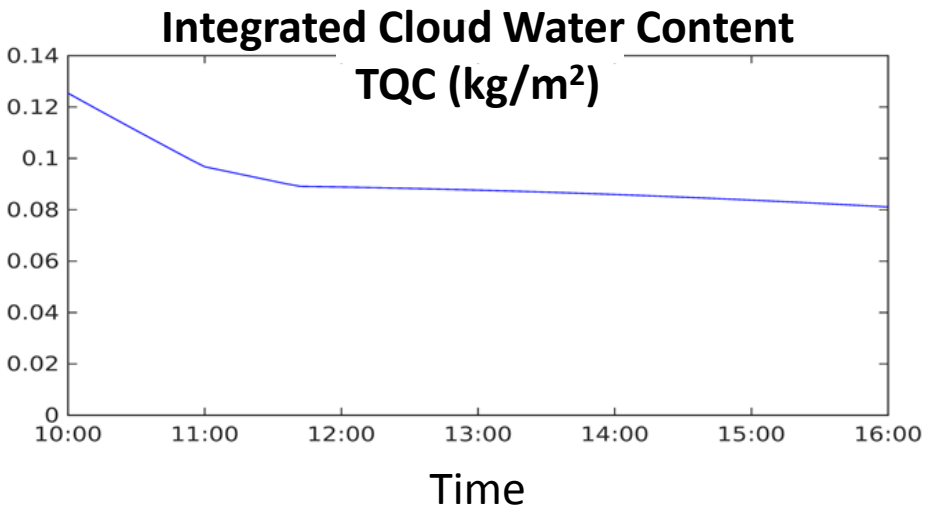
1b. Idealized simulation of stratus cloud



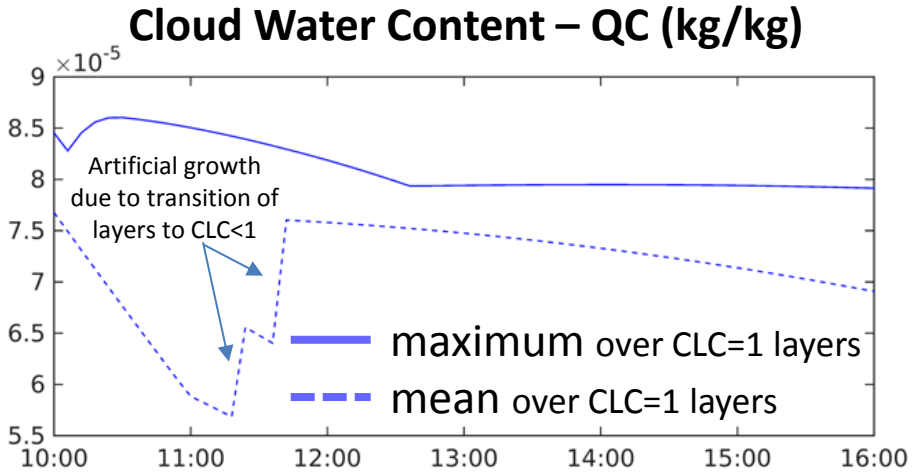
1b. Idealized simulation of stratus cloud



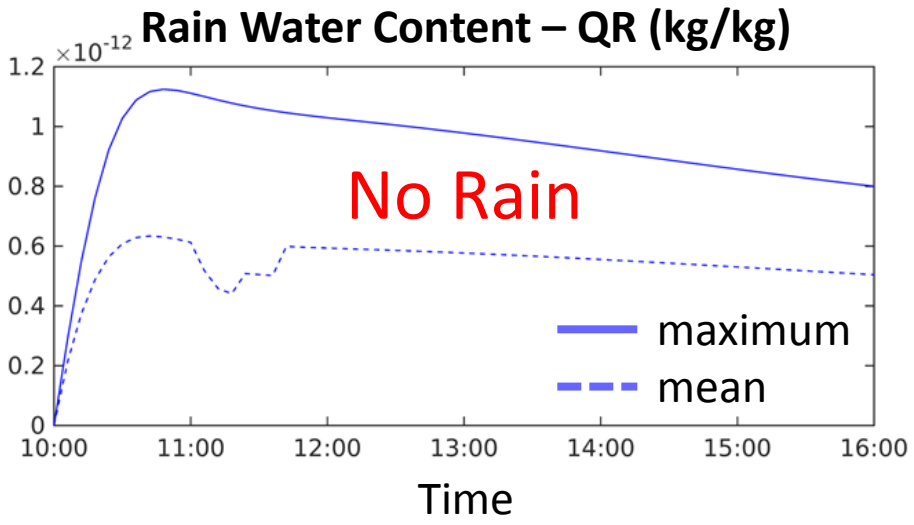
1b. Idealized simulation of stratus cloud



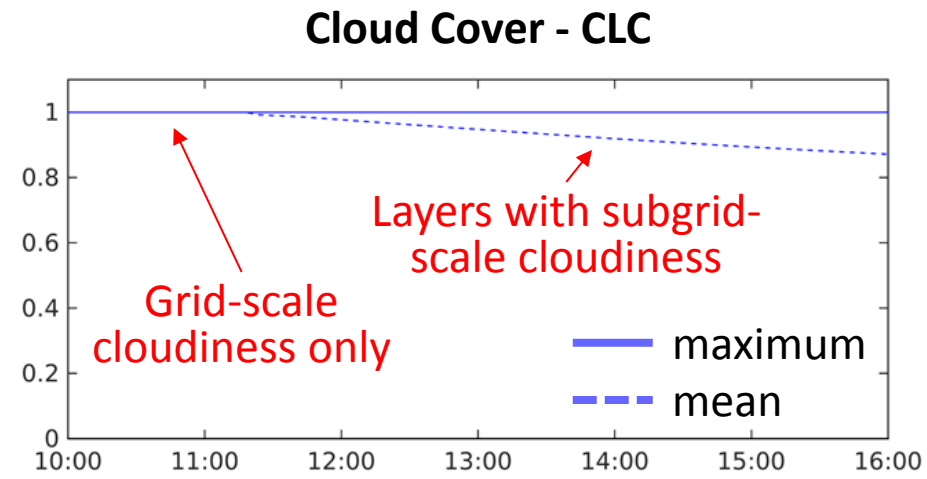
1b. Idealized simulation of stratus cloud

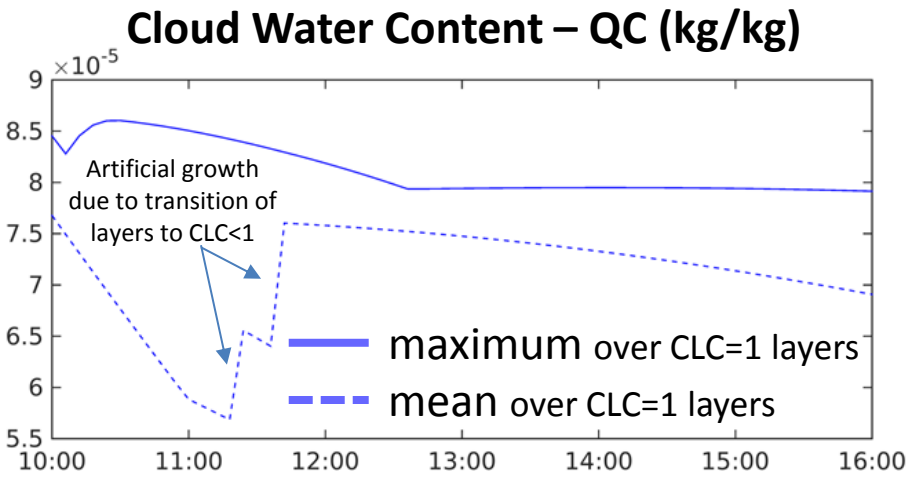


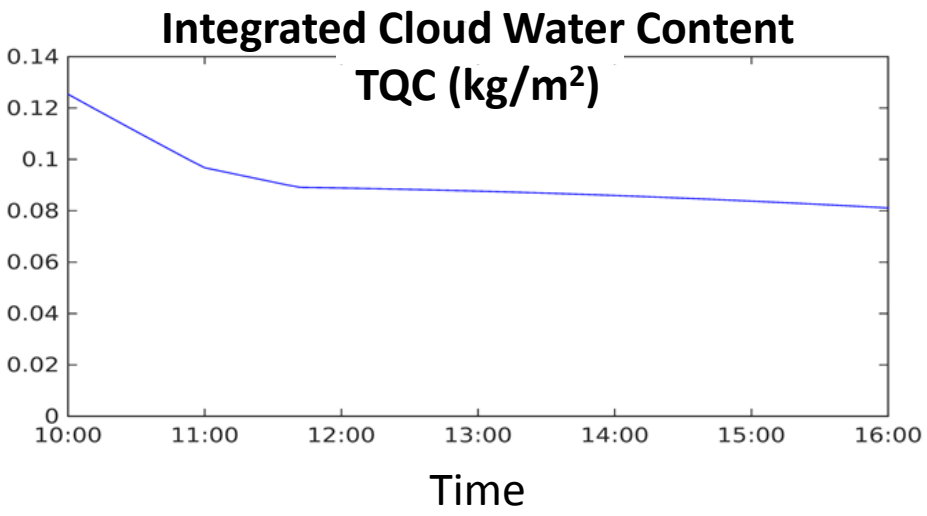
1b. Idealized simulation of stratus cloud

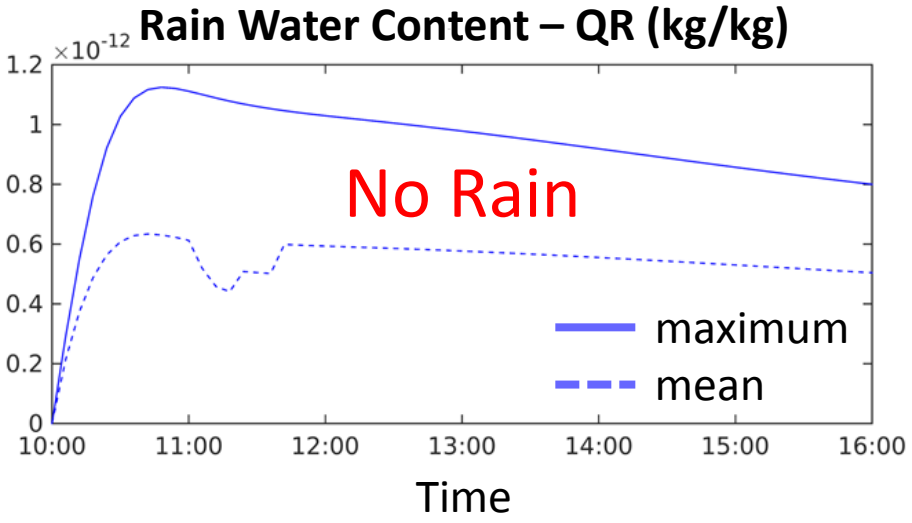


1b. Idealized simulation of stratus cloud

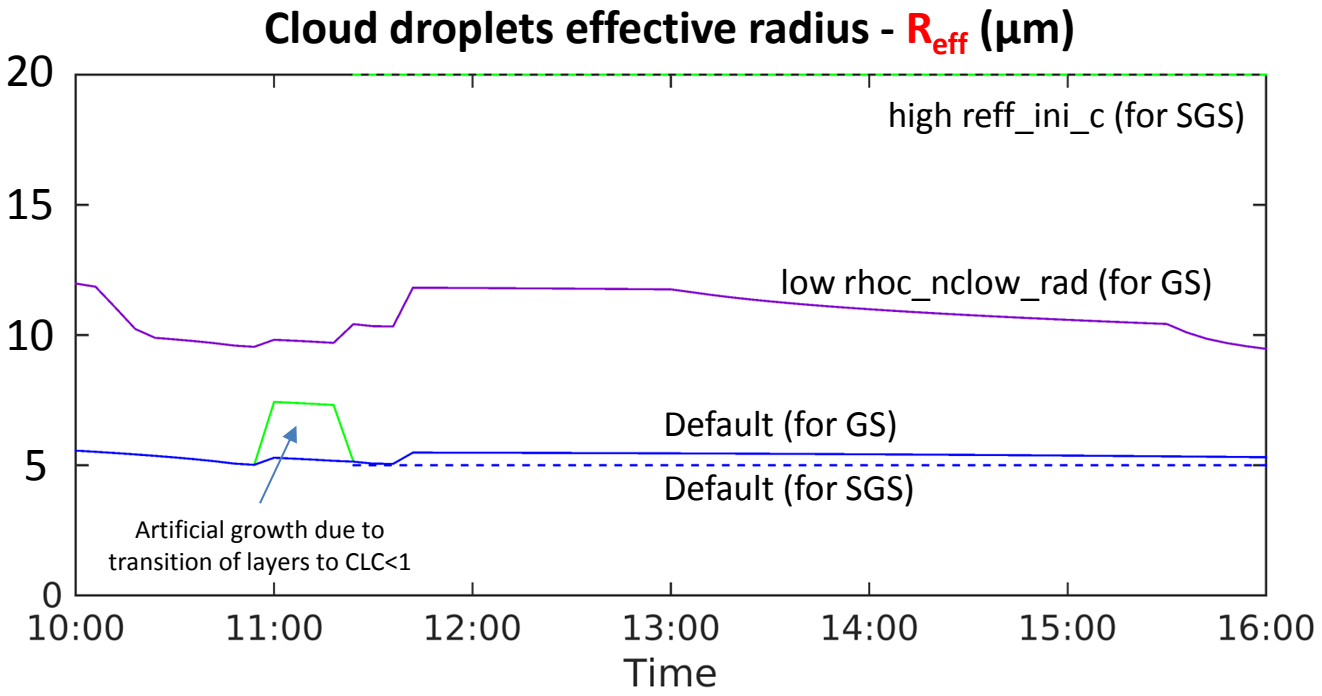








1b. Idealized simulation of stratus cloud

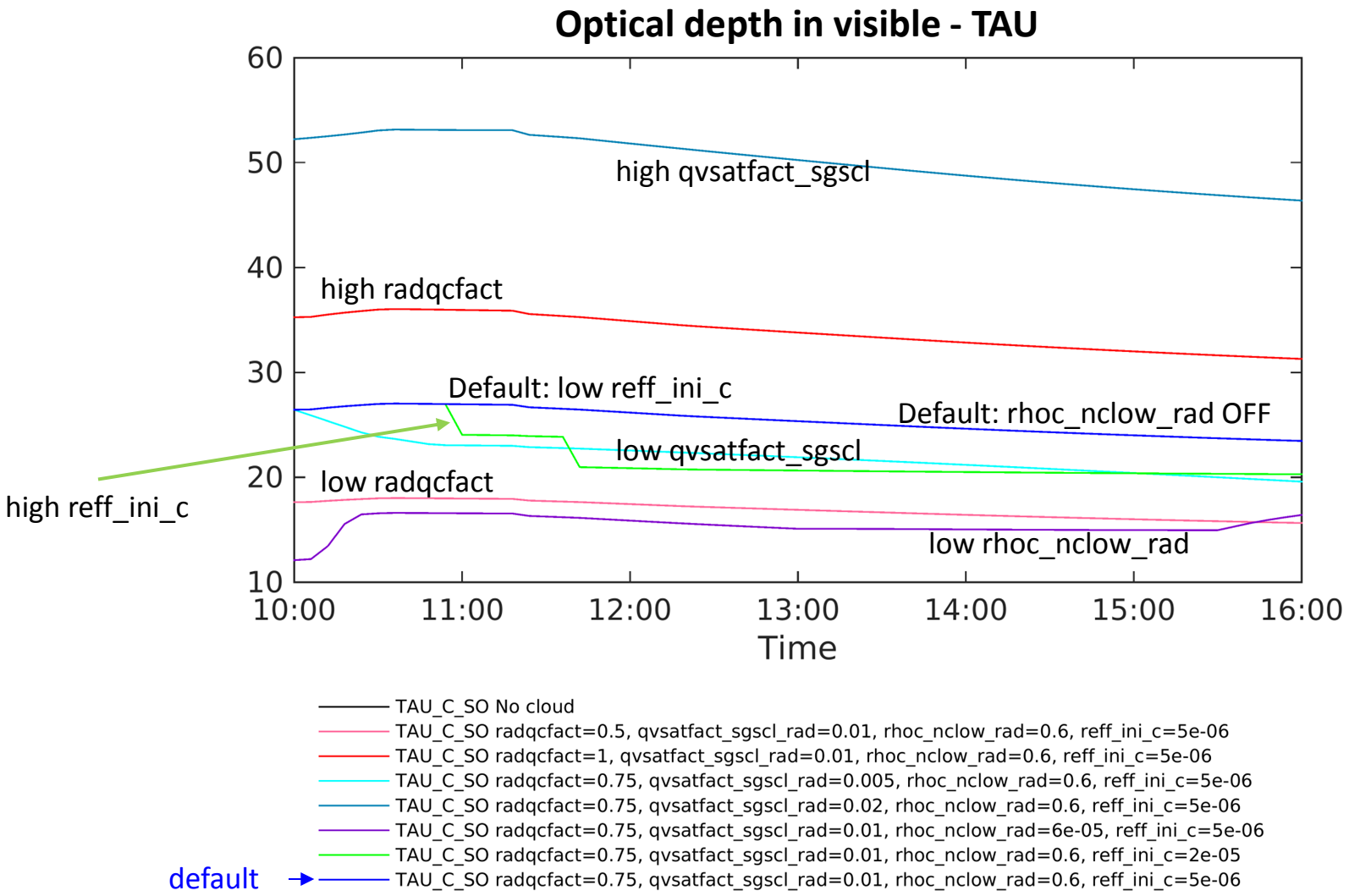


Reff_c_gs No cloud
Reff_c_sgs
Reff_c_gs radqcfact=0.5, qvsatfact_sgscl_rad=0.01, rhoc_nclow_rad=0.6, reff_ini_c=5e-06
Reff_c_sgs
Reff_c_gs radqcfact=1, qvsatfact_sgscl_rad=0.01, rhoc_nclow_rad=0.6, reff_ini_c=5e-06
Reff_c_sgs
Reff_c_gs radqcfact=0.75, qvsatfact_sgscl_rad=0.005, rhoc_nclow_rad=0.6, reff_ini_c=5e-06
Reff_c_sgs
Reff_c_gs radqcfact=0.75, qvsatfact_sgscl_rad=0.02, rhoc_nclow_rad=0.6, reff_ini_c=5e-06
Reff_c_sgs
Reff_c_gs radqcfact=0.75, qvsatfact_sgscl_rad=0.01, rhoc_nclow_rad=6e-05, reff_ini_c=5e-06
Reff_c_sgs
Reff_c_gs radqcfact=0.75, qvsatfact_sgscl_rad=0.01, rhoc_nclow_rad=0.6, reff_ini_c=2e-05
Reff_c_sgs
default → Reff_c_gs radqcfact=0.75, qvsatfact_sgscl_rad=0.01, rhoc_nclow_rad=0.6, reff_ini_c=5e-06
Reff_c_sgs

Reff_c_gs : mean effective radius for CLC=1 layers

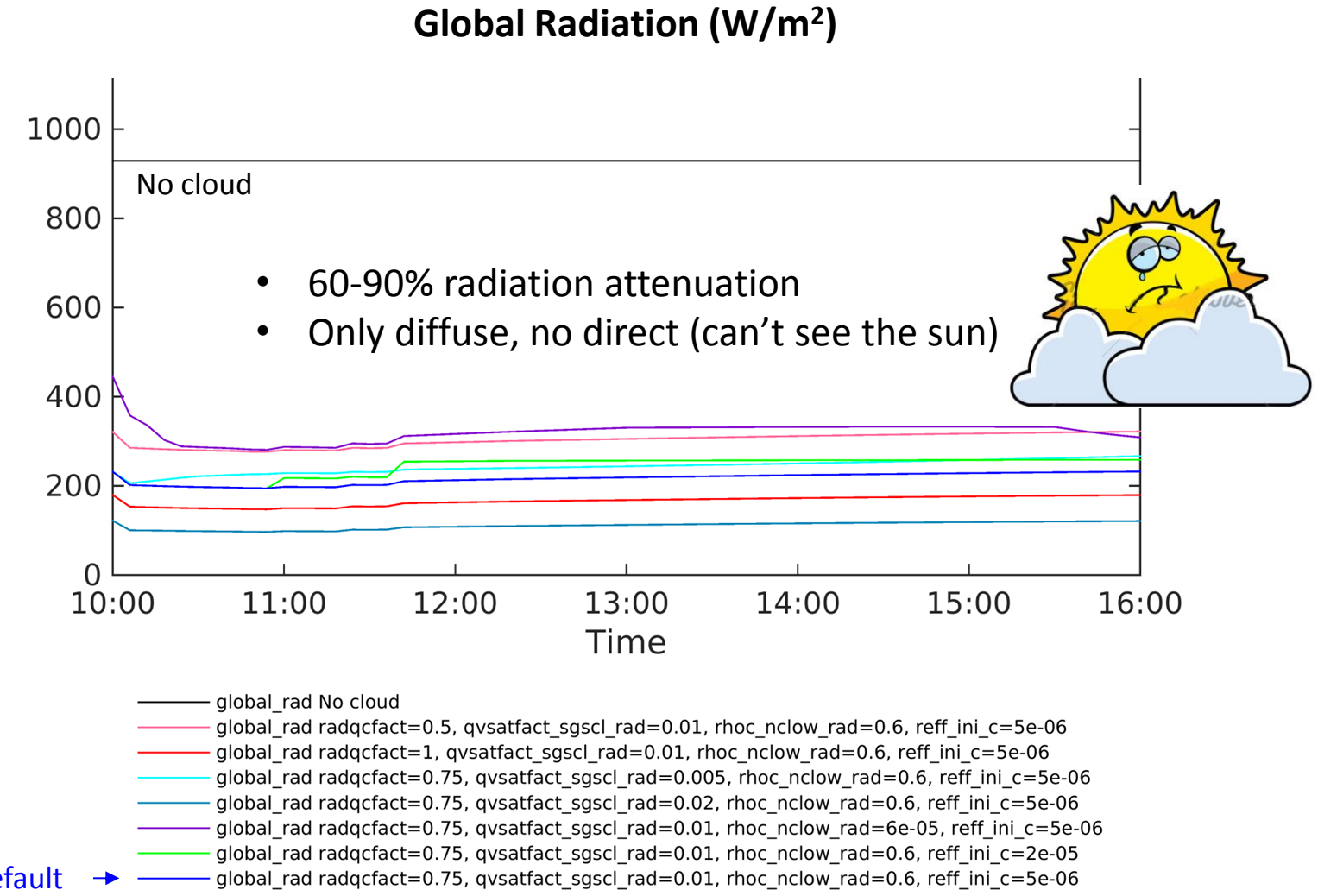
Reff_c_sgs : mean effective radius for 0<CLC<1 layers

1b. Idealized simulation of stratus cloud

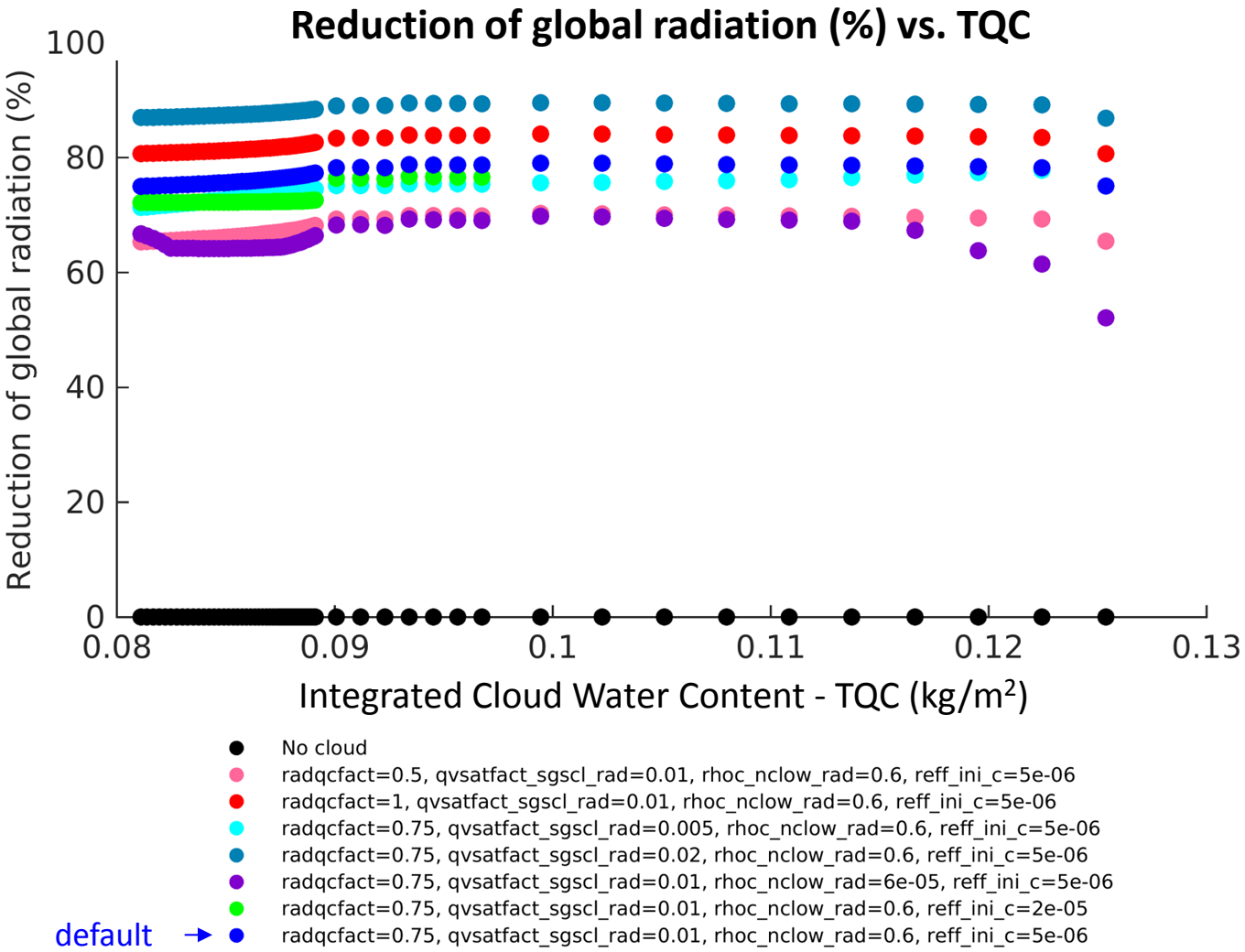


exp(-TAU) ≈ 0 ⇒ No direct radiation ⇒ But there is diffuse radiation ! (forward scattering)

1b. Idealized simulation of stratus cloud



1b. Idealized simulation of stratus cloud



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2. Method: How to define sensitivity to model parameters ?

For given time step t:

- Perform idealized COSMO simulations for many parameters combinations
- Replace the radiation dependency on the model parameters by an analytic function or a Meta-Model (MM):

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

Attenuation of global radiation (%)

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

"Effective" parameter

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

More about f_p on the next slide…

$x_1 \equiv radqcfact$
$x_2 \equiv qvsatfact\_sgscl\_rad$
$x_3 \equiv rhoc\_nclow\_rad$
$x_4 \equiv reff\_ini\_c$

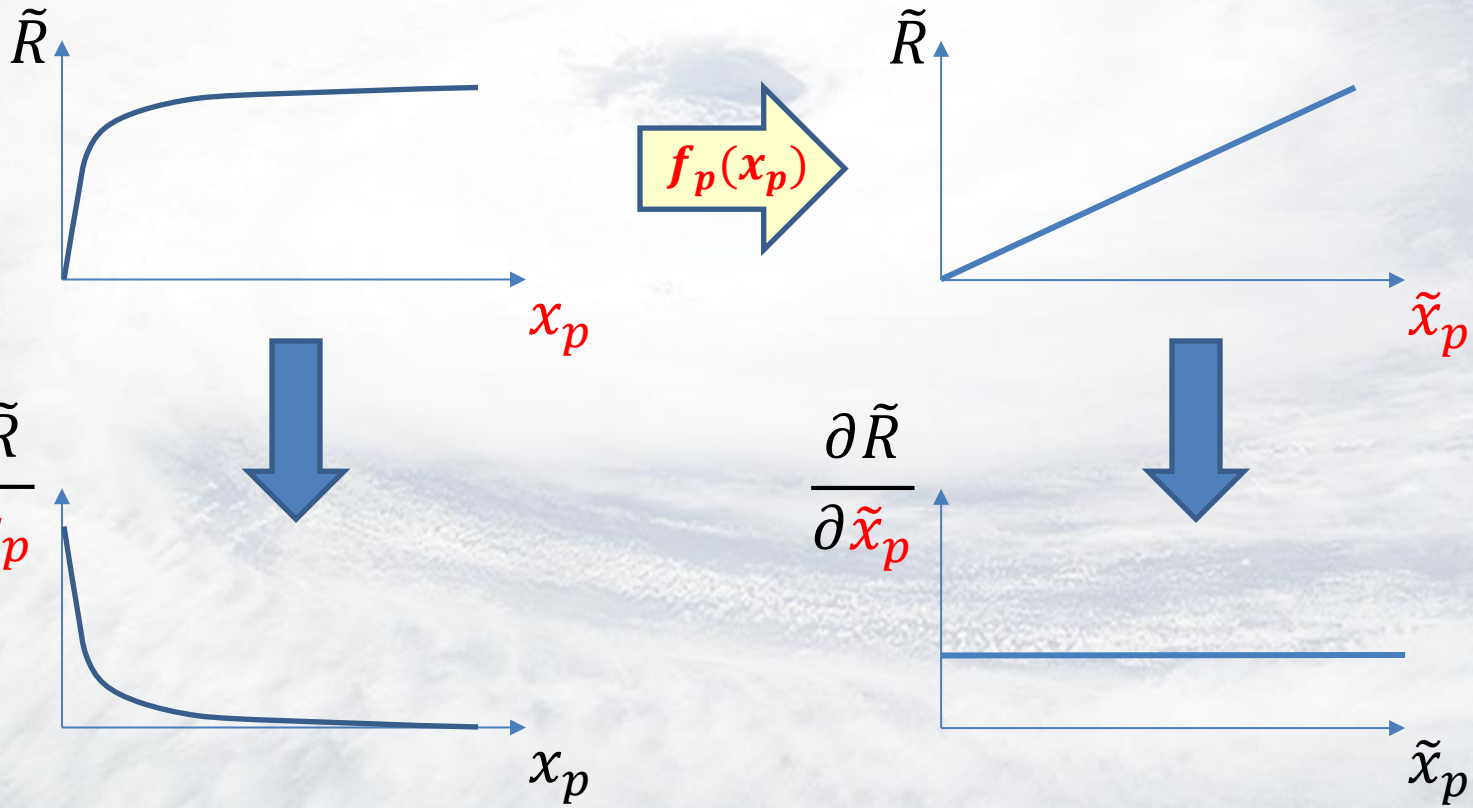
f_p chosen to get ***smoothed*** dependence on x_p

$f_1(x_1) \equiv x_1$
$f_2(x_2) \equiv x_2$
$f_3(x_3) \equiv -1/(x_3 - q_0)$
$f_4(x_4) \equiv x_4$

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

Why f_p ?

"Effective" parameter: $\tilde{x}_p = \frac{f_p(x_p) - f_p(x_{p,def})}{MAX\{f_p(x_p)\} - MIN\{f_p(x_p)\}}$



Model sensitivity on parameter x_p too much depends on parameter value

Model sensitivity on parameter $\tilde{x}_p$ similar to any parameter value

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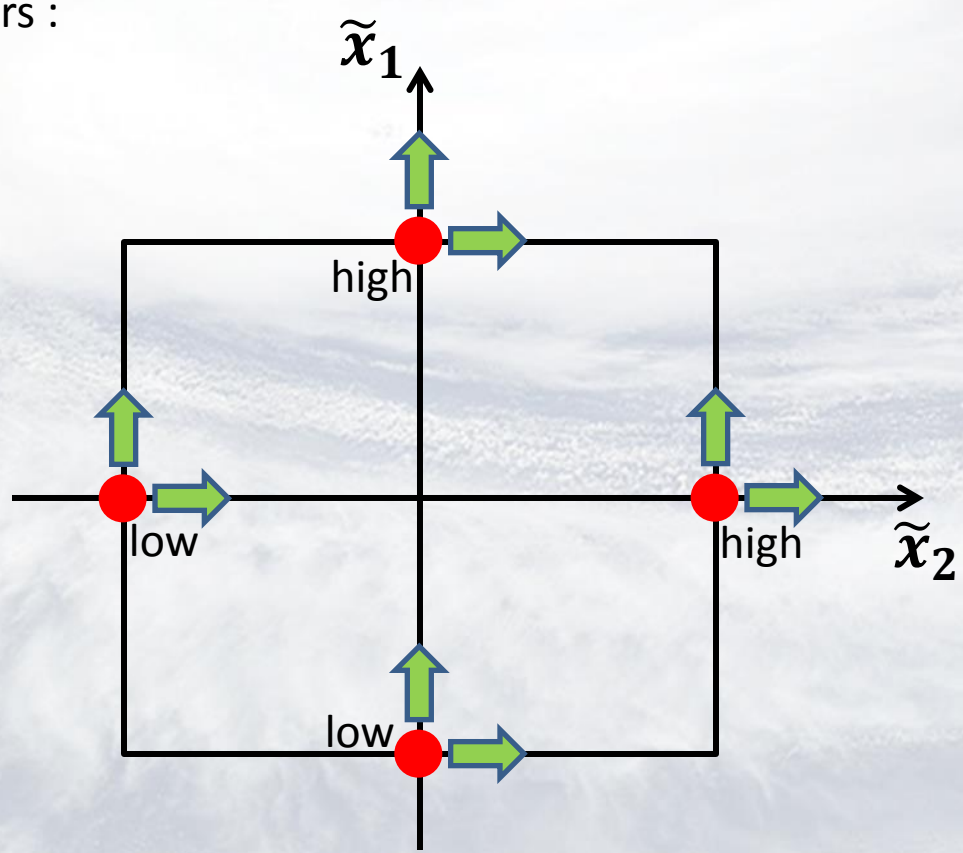
3. Sensitivity results: which parameter is no. 1 for stratus?

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

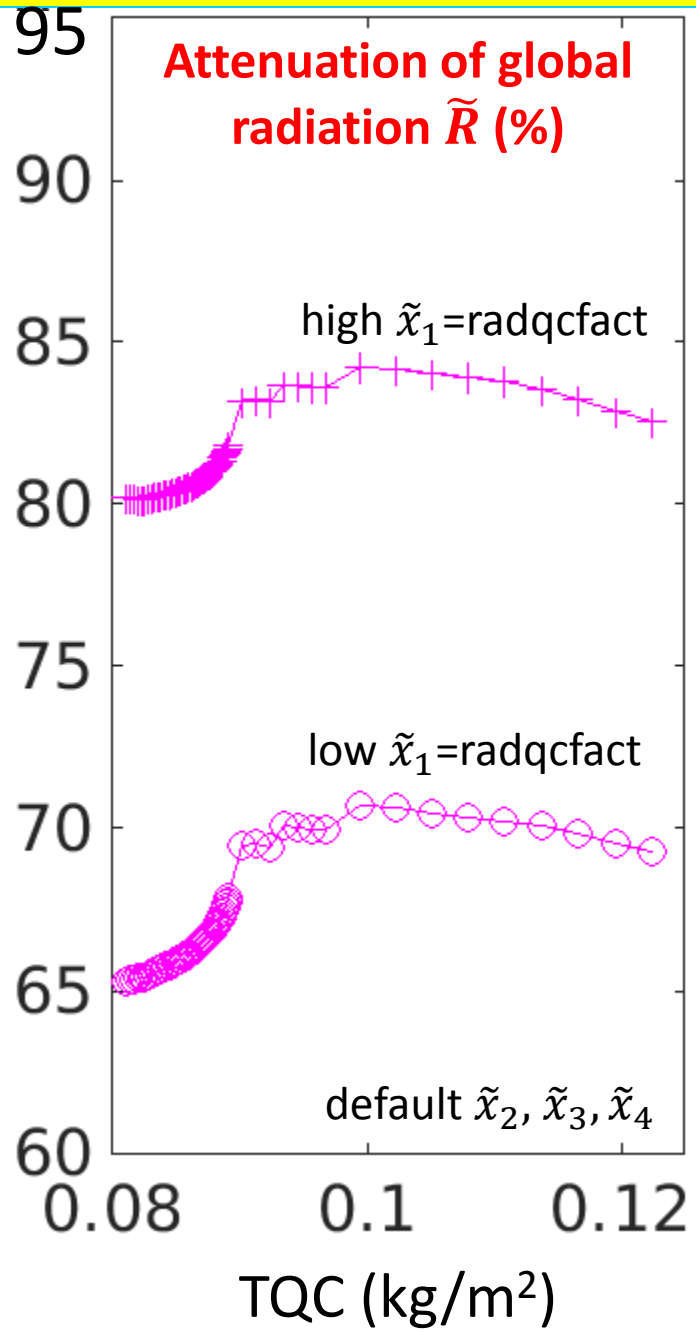
In the following slides, we look at the values of $\tilde{R}$ and $\frac{\partial \tilde{R}}{\partial \tilde{x}_p}$ at

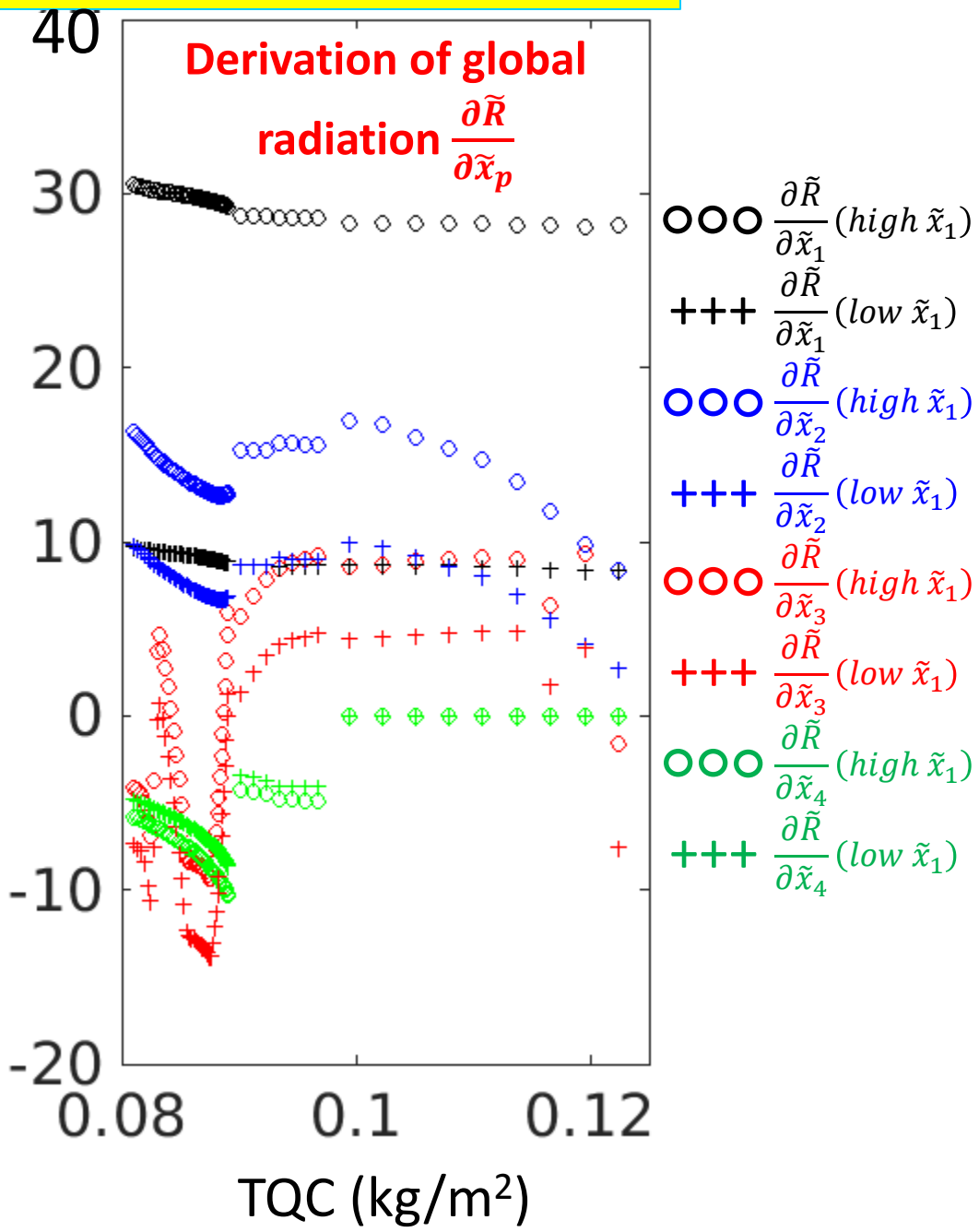
1. High $\tilde{x}_1$
2. Low $\tilde{x}_1$
3. High $\tilde{x}_2$
4. Low $\tilde{x}_2$
5. High $\tilde{x}_3$
6. Low $\tilde{x}_3$
7. High $\tilde{x}_4$
8. Low $\tilde{x}_4$

Example for 2 parameters :

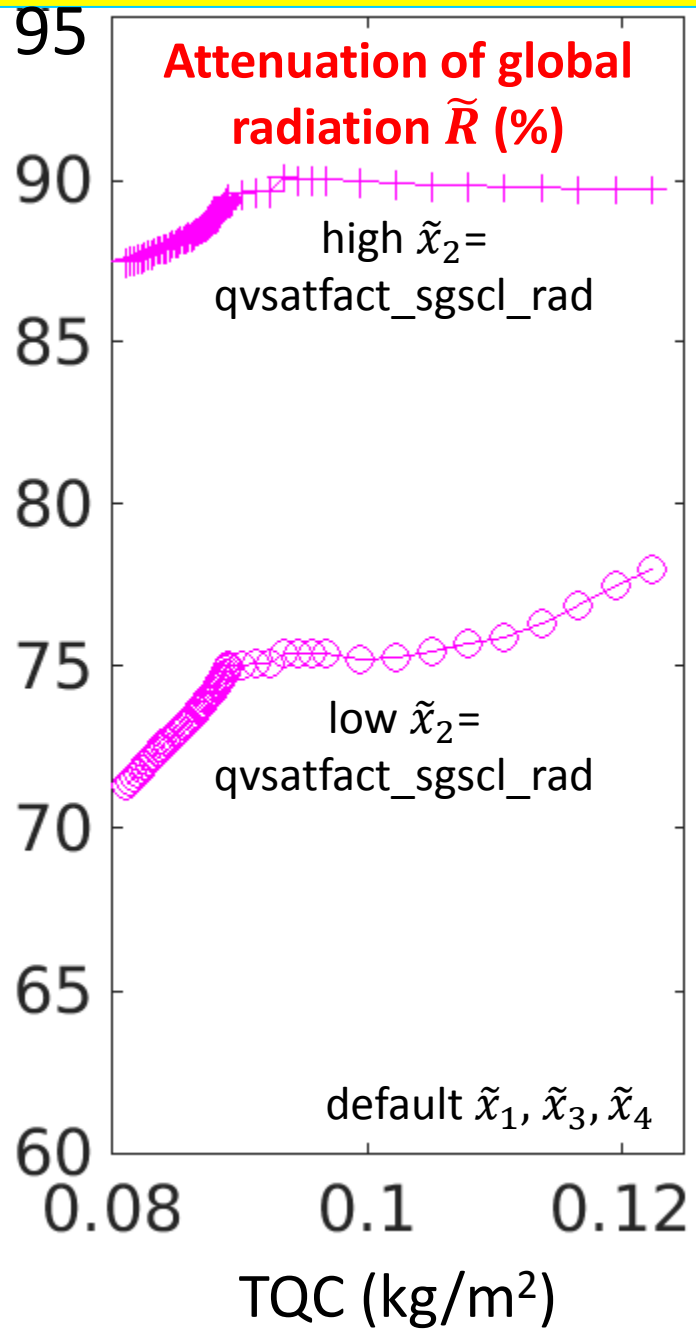


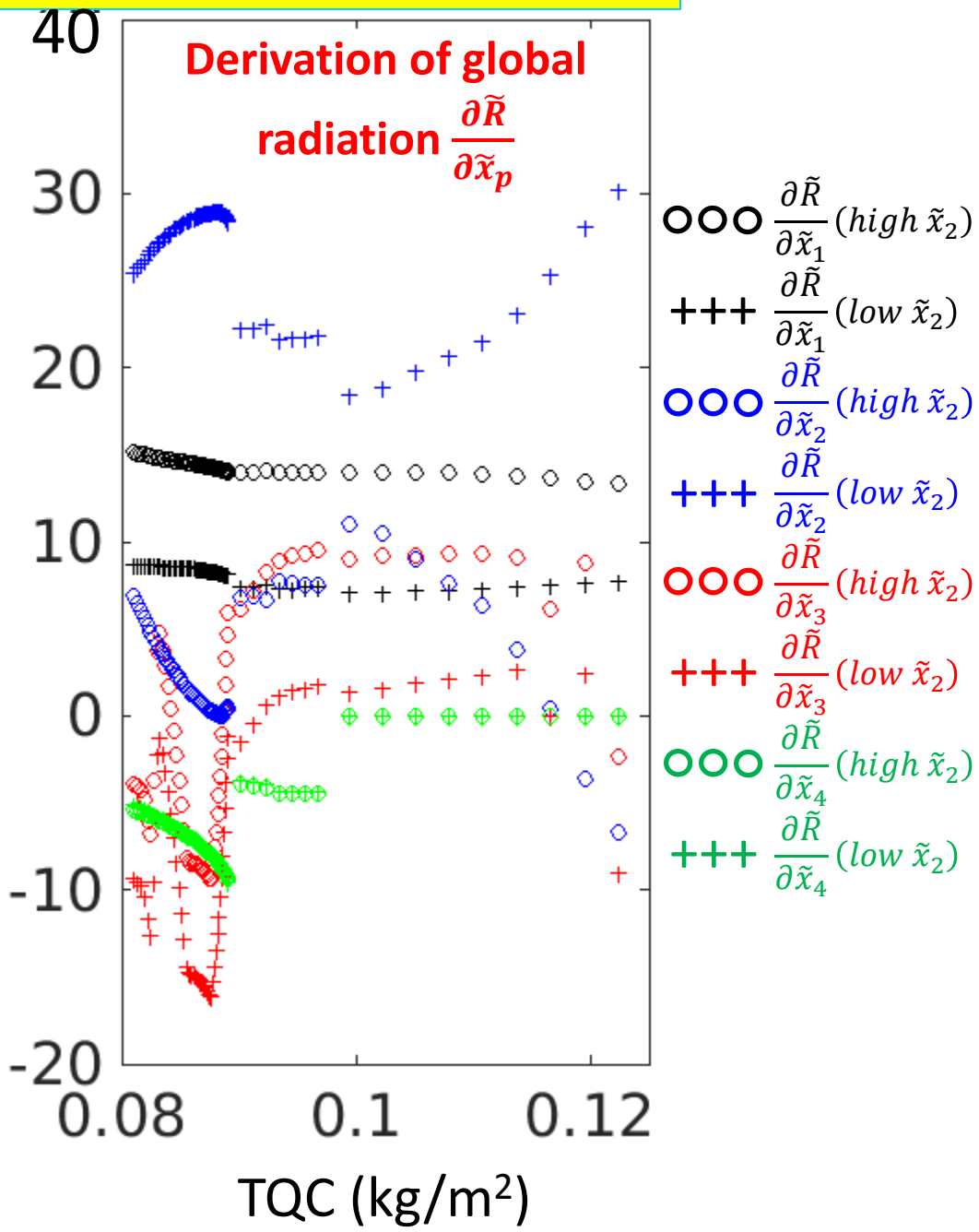
3. Sensitivity results: which parameter is no. 1 for stratus?



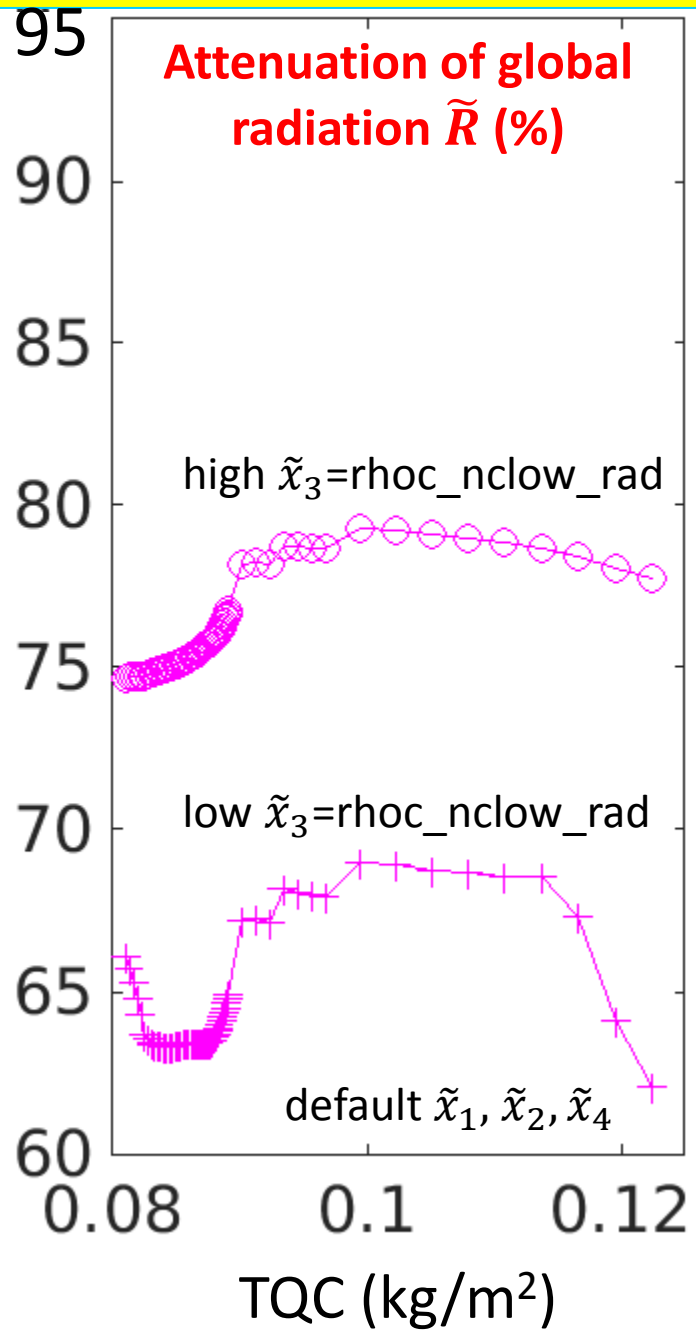


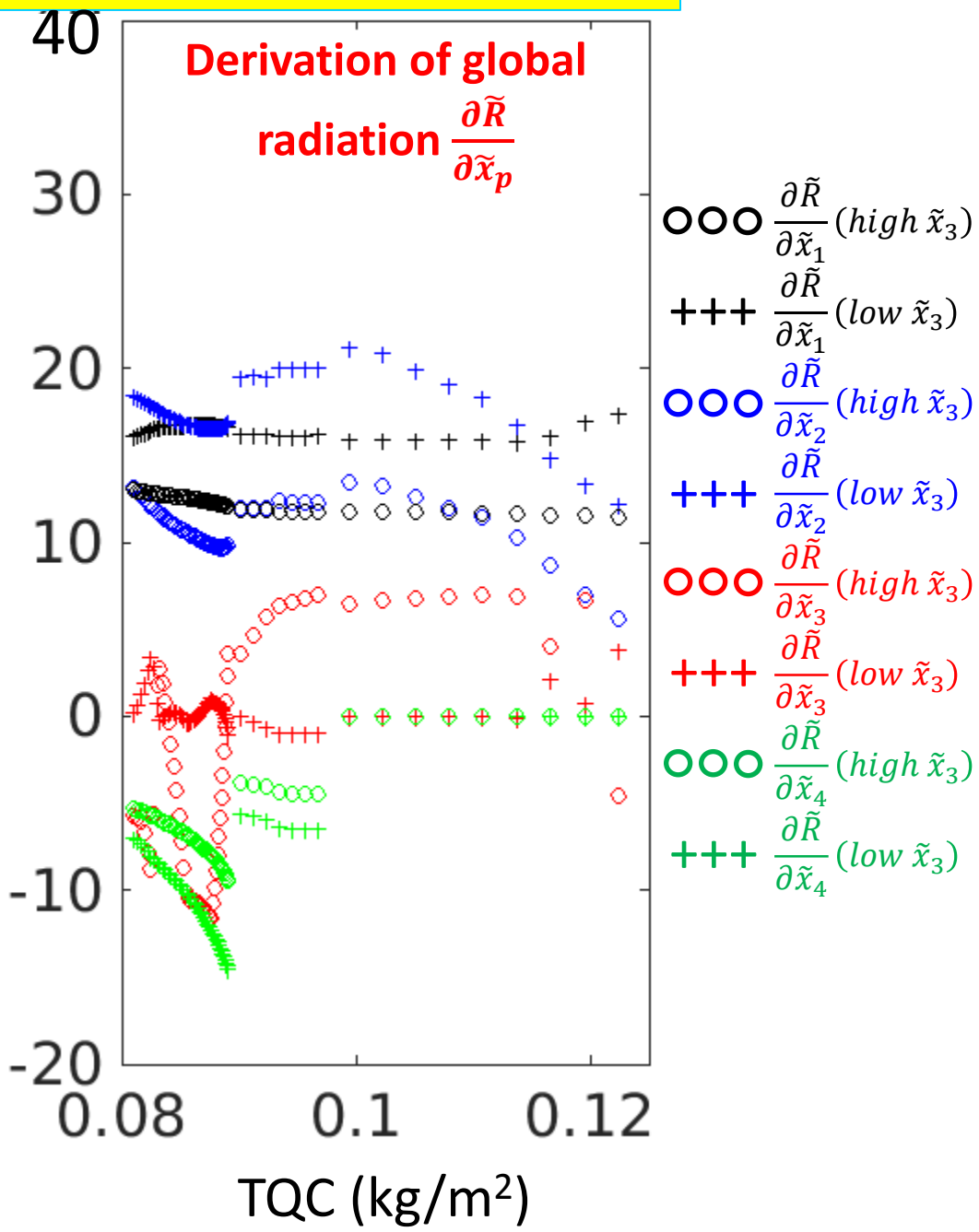
3. Sensitivity results: which parameter is no. 1 for stratus?



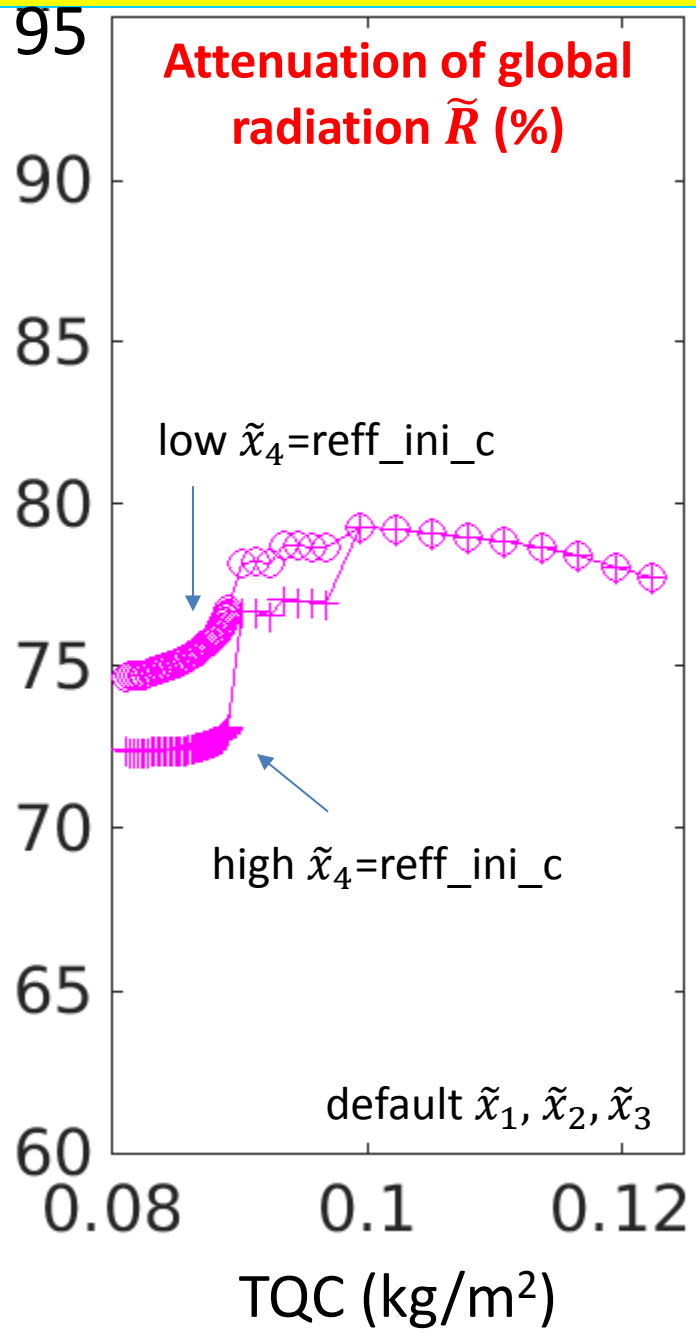


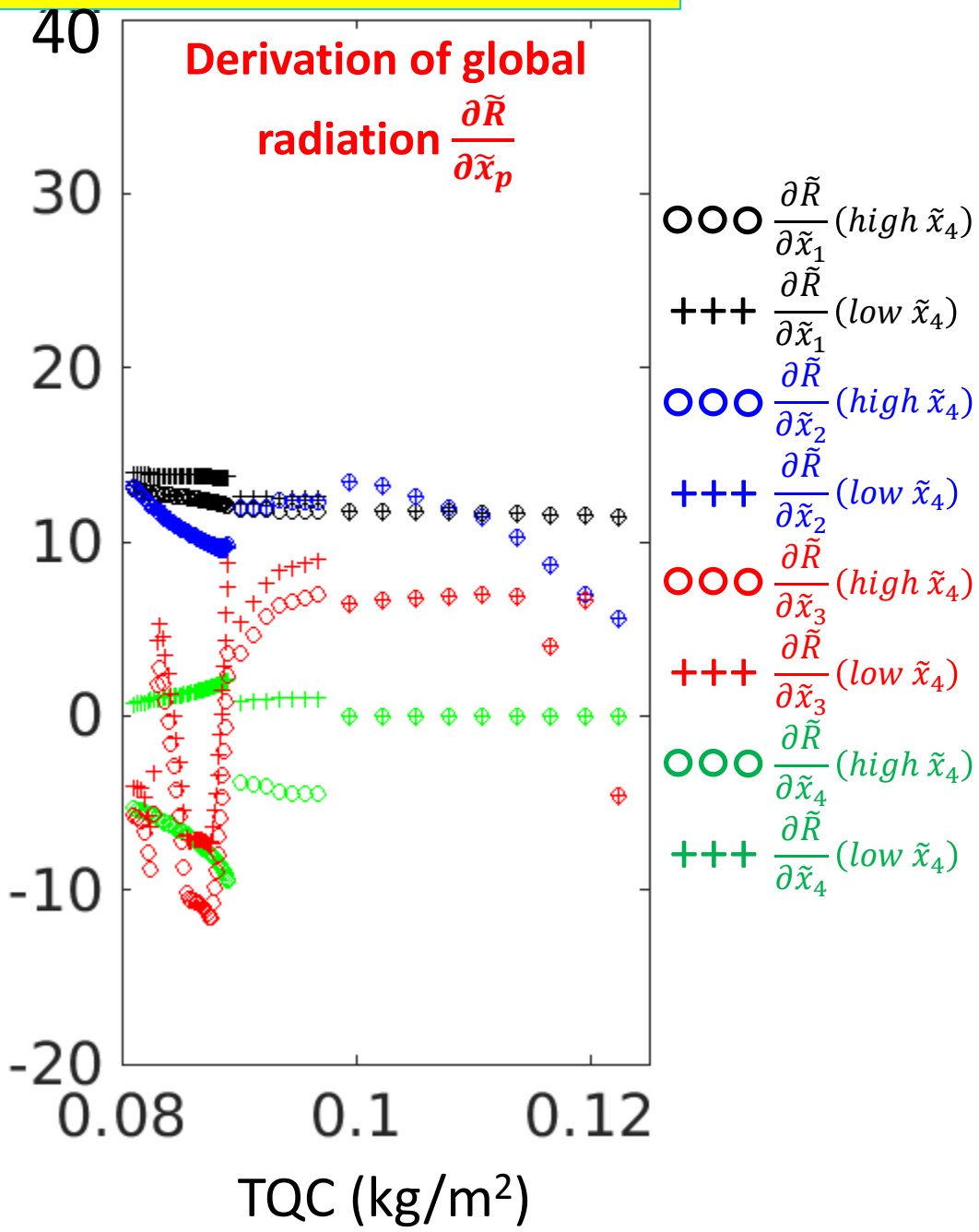
3. Sensitivity results: which parameter is no. 1 for stratus?





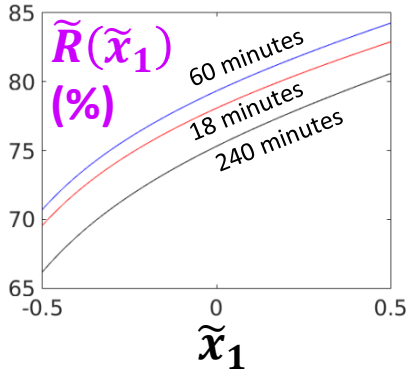
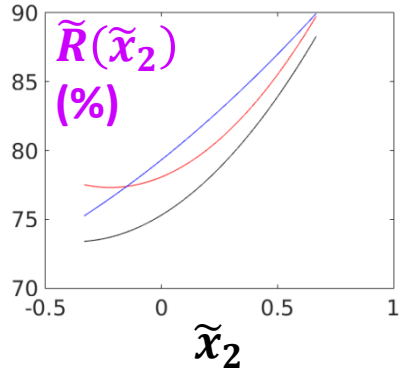
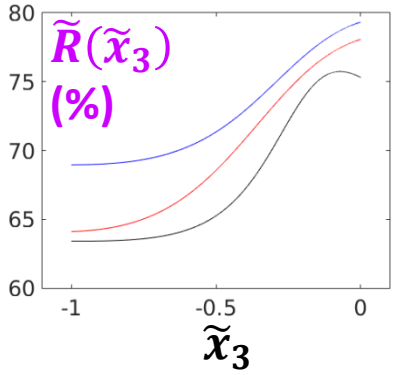
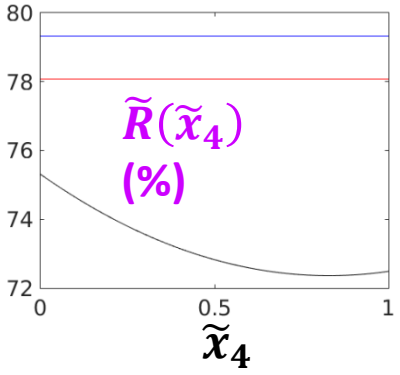
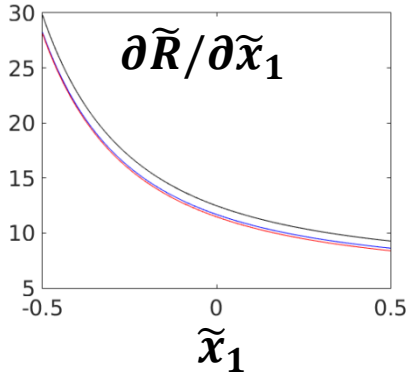
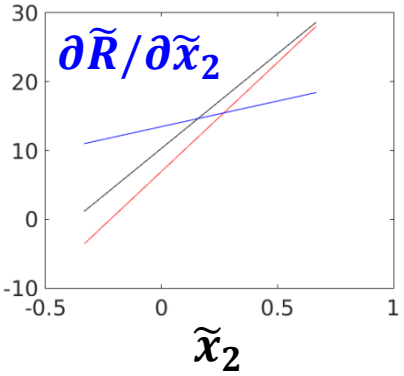
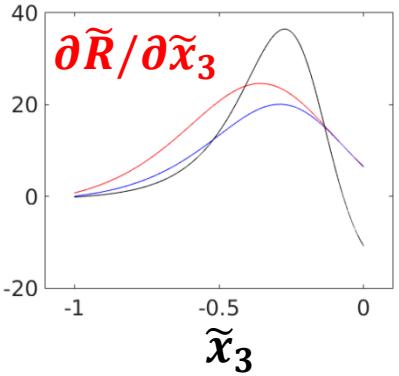
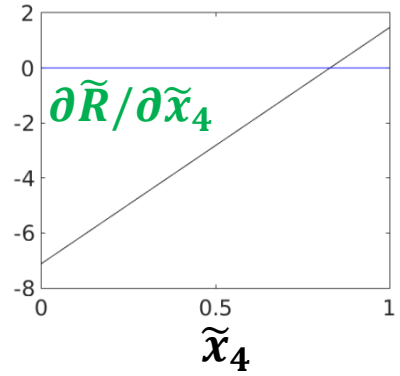
3. Sensitivity results: which parameter is no. 1 for stratus?





3. Sensitivity results: which parameter is no. 1 for stratus?

$\widetilde{R}$ = global radiation attenuation (%)

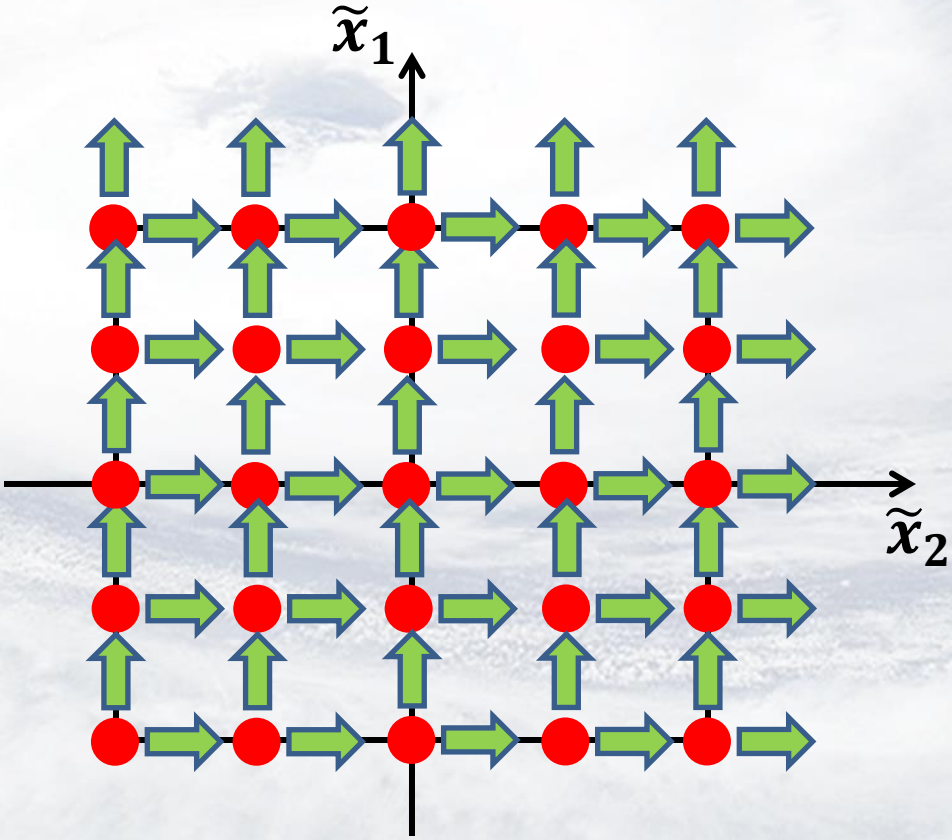
radqcfact	qvsatfact_sgscl_rad	rhoc_nclow_rad	reff_ini_c
			
			
1. Large attenuation 2. Higher TQC → higher attenuation 3. Higher $\widetilde{x}_1$ → higher attenuation 4. $\partial\widetilde{R}/\partial\widetilde{x}_1$ reaches ~30%	1. Large attenuation 2. Higher TQC → higher attenuation 3. Higher $\widetilde{x}_2$ → higher attenuation 4. $\partial\widetilde{R}/\partial\widetilde{x}_2$ reaches ~30%	1. Large attenuation 2. Higher TQC → higher attenuation 3. Higher $\widetilde{x}_3$ → higher attenuation 4. $\partial\widetilde{R}/\partial\widetilde{x}_3$ reaches ~30%	1. Large attenuation 2. Higher TQC → higher attenuation 3. Higher $\widetilde{x}_4$ → lower attenuation 4. $\partial\widetilde{R}/\partial\widetilde{x}_4$ reaches ~7%

3. Sensitivity results: which parameter is no. 1 for stratus?

Last steps:

- 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.

Example for 2 parameters :



- Average over all points.

- The most important parameters are those who have the highest $\overline{\frac{\partial \tilde{R}}{\partial \tilde{x}_p}}$

Outline

1. Example: Stratus cloud
    a. Radiation parameters for stratus cloud
    b. Idealized simulation of stratus cloud
2. Method: How to define sensitivity to model parameters ?
3. Sensitivity results: which parameter is no. 1 for stratus ?
4. Summary

Summary

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

Example: Stratus cloud

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 for stratus cloud:

- More important: radqcfact ; qvsatfact_sgscl_rad ; rhoc_nclow_rad
- Less important: reff_ini_c

Thank you !