Priority Project $T^2RC^2$: Determination of governing parameters in the new radiation scheme

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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**
  - p1, p2, p6, p8, p15, p17, p18, p19, p26, p27, p28, p32
- **Mixed phase**
- **Fair weather Cu**
  - p2, p6, p7, p8, p15, p17, p18, p19, p32
- **Anvil of CB**

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
1. Idealized COSMO model, examples of 5 types of clouds

2. True / False switches

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5. Summary
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:

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

Ice content (kg/kg)

Snow content (kg/kg)
Fair weather Cu (idealized simulation)

Cloud cover

Subgrid cloud droplets content (kg/kg)

CLC for 0 minutes

QC$_R$AD for 0 minutes
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)

- ~87% radiation reduction
- Only diffuse, no direct (can’t see the sun)
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
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
2. True / False switches

- lrad_incl_qrqsqg
- iradpar_cloud
- lrad_use_largesizeapprox
- lrad_ice_smooth_surfaces
- lrad_ice_fd_is_gsquared
- itype_aerosol
- icloud_num_type_rad
- radqcfact
- radqifact
- rad_areaarat_ls_i
- rad_areaarat_ls_s
- rad_areaarat_ls_g
- rad_areaarat_ls_h
- rhobulk_ls_ini_i
- refi_ini_c
- refi_ini_i
- cloud_num_rad
- zref_cloud_num_rad
- dz_oe_cloud_num_rad
- tqc_thresh_rad
- tqi_thresh_rad
- tqs_thresh_rad
- rhos_n0shigh_rad
- rhos_n0slow_rad
- n0s_low_rad
- rhoc_nchigh_rad
- rhoc_nclow_rad
- ncfact_low_rad
- rhoi_nihigh_rad
- rhoi_nilow_rad
- nifact_low_rad
- qvsatfact_sgscl_rad
Operational in COSMO

Reff does not play role, therefore aerosols influence only clear sky part of radiation

clip fits for solid species at 70 µm

new fits for extinction the large-size approximation

"QR, QS, QG" added to QC, QI.

old climate

Old climate

Old climate

Old climate

Old climate

Old climate

Old climate

Old climate

Old climate

Old climate

Old climate

Old climate

Old climate

Old climate

Old climate

Old climate

Old climate

Old climate

Old climate

Old climate

Old climate

**irad_incl_qrqsqg**

- **irad_incl_qrqsqg = T**: Simple large-size approximation
- **irad_incl_qrqsqg = F**: Clip fits for solid species at 70 µ

**irad_use_largesize approx**

- **irad_use_largesize approx = T**: Clip fits
- **irad_use_largesize approx = F**: Clip fits for extinction the large-size approx. starting from Reff = 250 µ

**lrad_ice_smooth_surfaces**

- **lrad_ice_smooth_surfaces = T**: Rough or smooth ice/snow
- **lrad_ice_smooth_surfaces = F**: Solar forward fraction

**itype_aerosol**

- **itype_aerosol_1**: Old climate
- **itype_aerosol_2**: Tegen

**icloud_num_type_rad**

- **icloud_num_type_rad_1**: Old climate
- **icloud_num_type_rad_2**: Segal-Khain

**iradpar_cloud**

- **iradpar_cloud = 1 (RG92)**: QR, QS, QG “added” to QC, QI. Bad!
- **iradpar_cloud = 2,3 (UB)**: New fits
- **iradpar_cloud = 4 (MB)**: Old climate
QR, QS, QG "added" to QC,QI. bad!

Reff does not play role, therefore aerosols influence only clear sky part of radiation

Old climate

Tegen

const

1 2 3 4 5 6 7 8 9 10 11 12 13
lrad_incl_qrqsqg

**lradpar_cloud=1 (RG92)**

- lrad_incl_qrqsqg
  - T
  - F

**lradpar_cloud=2,3 (UB)**

- lrad_incl_qrqsqg
  - T
  - F

- lrad_use_largesize approx
  - T
  - F

- Reff does not play role, therefore aerosols influence only clear sky part of radiation

**lradpar_cloud=4 (MB)**

- lrad_incl_qrqsqg
  - T
  - F

- clip fits for solid species at 70µ

- for extinction the large-size approx. starting from Reff = 250µ

Current fits added to QC,QI. bad!

- simple large-size approximation

- new fits

- rough or smooth ice/snow

- solar forward fraction

- lrad_use_largesize approx
  - T
  - F

- iftype_aerosol
  - 1
  - 2

- icloud_num_type_rad
  - 1
  - 2

- const
  - 1
  - 2
  - 3
  - 4
  - 5
  - 6
  - 7
  - 8
  - 9
  - 10
  - 11
  - 12
  - 13
QR, QS, QG “added” to QC, QI. bad!

Reff does not play role, therefore aerosols influence only clear sky part of radiation.

 QR, QS, QG ignored
QR, QS, QG "added" to QC, QI. bad!

Reff does not play role, therefore aerosols influence only clear sky part of radiation

QR, QS, QG ignored

simple large-size approximation

clip fits for solid species at 70µ

for extinction the large-size approx. starting from Reff = 250µ

new fits

rough or smooth ice/snow

rough or smooth ice/snow

rough or smooth ice/snow

rough or smooth ice/snow

rough or smooth ice/snow

rough or smooth ice/snow

old fits

old fits

old fits

old fits

old fits

old fits

old fits

old fits

old fits

old fits

old fits

old fits

old fits

old fits
**iradpar_cloud=1 (RG92)**

- **T**
- **F**

**irad_incl_qrqsqg**

- **T**
- **F**

**irad_use_largesize approx**

- **T**
- **F**

** 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**

**for extinction the large-size approx. starting from Reff = 250µ**

**clip fits**

**new fits**

**rough or smooth ice/snow**

**lrad_use_largesize approx**

- **T**
- **F**

**lrad_ice_smooth_surfaces**

- **T**
- **F**

**lrad_ice_fd_is_gsquared**

- **T**
- **F**

**solar forward fraction**

**Reff does not play role, therefore aerosols influence only clear sky part of radiation**

**itype_aerosol**

- **1**
- **2**

**Old climate**

**Tegen**

**icloud_num_type_rad**

- **1**
- **2**

**const**

**Segal-Khain**

**1**

**2**

**3**

**4**

**5**

**6**

**7**

**8**

**9**

**10**

**11**

**12**

**13**
QR, QS, QG “added” to QC, QI. bad!

Reff does not play role, therefore aerosols influence only clear sky part of radiation

itype_aerosol_1
itype_aerosol_2
Old climate
Tegen

itype_aerosol_1
itype_aerosol_2
Old climate
Tegen

icitype_aerosol_1
icitype_aerosol_2
Old climate
Tegen

icitype_aerosol_1
icitype_aerosol_2
Old climate
Tegen

icitype_aerosol_1
icitype_aerosol_2
Old climate
Tegen

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icitype_aerosol_2
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icitype_aerosol_1
icitype_aerosol_2
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icitype_aerosol_2
Old climate
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icitype_aerosol_1
icitype_aerosol_2
Old climate
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icitype_aerosol_1
icitype_aerosol_2
Old climate
Tegen

icitype_aerosol_1
icitype_aerosol_2
Old climate
Tegen

icitype_aerosol_1
icitype_aerosol_2
Old climate
Tegen
QR, QS, QG "added" to QC, QI. bad!

Reff does not play role, therefore aerosols influence only clear sky part of radiation

type_aerosol_1

Old climate

const

1

icloud_num_type_rad_1

Segal-Khain

2

Tegen

3

icloud_num_type_rad_1

const

4

icloud_num_type_rad_2

Segal-Khain

5

icloud_num_type_rad_2

const

6

icloud_num_type_rad_2

Segal-Khain

7

icloud_num_type_rad_2

const

8

icloud_num_type_rad_2

Segal-Khain

9

icloud_num_type_rad_1

const

10

icloud_num_type_rad_1

Segal-Khain

11

icloud_num_type_rad_1

const

12

icloud_num_type_rad_1

Segal-Khain

13
QR, QS, QG "added" to QC, QI. bad!

Reff does not play role, therefore aerosols influence only clear sky part of radiation

Old climate

Tegen

Segal-Khain

const

1

2

3

4

5

6

7

8

9

10

11

12

13
**Radpar Cloud Parameters**

- **iradpar_cloud=1 (RG92)**
  - **irad_incl_qrqsqg**
    - T
    - F

- **iradpar_cloud=2,3 (UB)**
  - **irad_incl_qrqsqg**
    - T
    - F

- **iradpar_cloud=4 (MB)**
  - **irad_incl_qrqsqg**
    - T
    - F

**Additional Parameters**

- **lrad_use_largesize approx**
  - T
  - F

**Miscellaneous Notes**

- QR, QS, QG "added" to QC,QI. bad!
- QR, QS, QG ignored
- clip fits for solid species at 70 \( \mu \)m
- simple large-size approximation
- for extinction the large-size approx. starting from \( Reff = 250 \mu \m
- Reff does not play role, therefore aerosols influence only clear sky part of radiation
- rough or smooth ice/snow

**Other Parameters**

- **itype_aerosol**
  - 1
  - 2
- **itrad_ice_fd_is_gsquared**
  - T
  - F
- **lrad_ice_fd_is_gsquared**
  - T
  - F
- **lrad_ice_smooth_surfaces**
  - T
  - F
  - T
  - F

**Climate Types**

- Old climate
- Tegen
- Tegen
- Tegen
- Tegen
- Tegen
- Tegen
- Tegen
- Tegen
- Tegen
- Tegen
- Tegen
- Tegen

**Modeling Approaches**

- Segal-Khain
- Segal-Khain
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Reff does not play role, therefore aerosols influence only clear sky part of radiation.

QR, QS, QG “added” to QC,QI. bad!

clip fits for solid species at 70µ

new fits for extinction the large-size approx. starting from Reff = 250µ
Global Radiation (W/m²)

- No cloud
- case_1

Time

10:00 11:00 12:00 13:00 14:00 15:00 16:00

Global Radiation (W/m²)

0 200 400 600 800 1000 1200
Global Radiation ($W/m^2$)

- No cloud
- case_1
- case_2

Time:
10:00, 11:00, 12:00, 13:00, 14:00, 15:00, 16:00

Global Radiation ($W/m^2$):
0, 200, 400, 600, 800, 1000, 1200

Warm Stratus: True / False switches
Warm Stratus: True / False switches
Global Radiation (W/m²)

Warm Stratus: True / False switches

Global Radiation (W/m²)
Global Radiation (W/m²)

Warm Stratus: True / False switches

Graph showing the Global Radiation (W/m²) over time for different cases and scenarios.
Global Radiation (W/m$^2$)

Warm Stratus: True / False switches

- No cloud
- case_1
- case_2
- case_3
- case_4
- case_5
- case_6

Time vs. Global Radiation (W/m$^2$)
Global Radiation (W/m$^2$)

Warm Stratus: True / False switches

- No cloud
- case_1
- case_2
- case_3
- case_4
- case_5
- case_6
- case_7
Global Radiation (W/m^2)

Warm Stratus: True / False switches

- **No cloud**
- case_1
- case_2
- case_3
- case_4
- case_5
- case_6
- case_7
- case_8
Warm Stratus: True / False switches

Global Radiation (W/m^2)

- No cloud
- case_1
- case_2
- case_3
- case_4
- case_5
- case_6
- case_7
- case_8
- case_9

Time

10:00 11:00 12:00 13:00 14:00 15:00 16:00

Global Radiation (W/m^2)
Global Radiation (W/m$^2$)

Warm Stratus: True / False switches
Global Radiation (W/m²)

Global Radiation (W/m²) over Time for different cases and conditions.
Global Radiation (W/m²)

Global Radiation (W/m²)

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

Warm Stratus: True / False switches
Warm Stratus: True / False switches

In the new radiation scheme the Stratus is more transparent!
From Uli’s Blahak presentation:

Cloud droplets comparison to RG92

If grid scale $q_c > 0$: from cloud microphysics:

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

$\mu = 5.0$

$N_c = \text{cloud\_num}$

$q_c$ prognostic

Spectral interval „2“ (visible range)

$\beta_{\text{ext\ ratio\ HS}} / \text{RG92}$
Warm Stratus: True / False switches - summary

Time averaged global radiation reduction (%)

<table>
<thead>
<tr>
<th>case:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm Stratus</td>
<td>87</td>
<td>77</td>
<td>69</td>
<td>77</td>
<td>69</td>
<td>77</td>
<td>69</td>
<td>74</td>
<td>65</td>
<td>74</td>
<td>65</td>
<td>74</td>
<td>65</td>
</tr>
</tbody>
</table>

Global radiation sensitivity (%)

<table>
<thead>
<tr>
<th>switch:</th>
<th>iradpar_cloud</th>
<th>Irad_incl_qrqsqg</th>
<th>Irad_ice_smooth_surfaces</th>
<th>Irad_ice_fd_is_gsquared</th>
<th>Icloud_num_type_rad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm Stratus</td>
<td>~22%</td>
<td>~4%</td>
<td>0</td>
<td>0</td>
<td>~9%</td>
</tr>
</tbody>
</table>

Operational
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**

<table>
<thead>
<tr>
<th>case:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<td>74</td>
<td>65</td>
<td>74</td>
<td>65</td>
<td>74</td>
<td>65</td>
</tr>
</tbody>
</table>

**Global radiation sensitivity (%)**

<table>
<thead>
<tr>
<th>switch:</th>
<th>iradpar_cloud</th>
<th>lrad_incl_qrqsqg</th>
<th>lrad_ice_smooth_surfaces</th>
<th>lrad_ice_fd_is_gsquared</th>
<th>Icloud_num_type_rad</th>
</tr>
</thead>
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<td>~4%</td>
<td>0</td>
<td>0</td>
<td>~9%</td>
</tr>
</tbody>
</table>
### All clouds: True / False switches - summary

**Global radiation reduction (%)**

<table>
<thead>
<tr>
<th>case:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
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<td>74</td>
<td>65</td>
<td>74</td>
<td>65</td>
<td>74</td>
<td>65</td>
</tr>
<tr>
<td>Cirrus</td>
<td>6.2</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>6.4</td>
<td>6.4</td>
<td>6.4</td>
<td>6.4</td>
<td>6.4</td>
<td>6.4</td>
<td>6.4</td>
</tr>
<tr>
<td>Mixed phase</td>
<td>80</td>
<td>64</td>
<td>60</td>
<td>64</td>
<td>60</td>
<td>64</td>
<td>60</td>
<td>57</td>
<td>52</td>
<td>57</td>
<td>52</td>
<td>57</td>
<td>52</td>
</tr>
<tr>
<td>Fair weather Cu</td>
<td>9</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Anvil</td>
<td>50</td>
<td>76</td>
<td>76</td>
<td>76</td>
<td>76</td>
<td>76</td>
<td>76</td>
<td>61</td>
<td>61</td>
<td>61</td>
<td>61</td>
<td>61</td>
<td>61</td>
</tr>
</tbody>
</table>

### Global radiation sensitivity (%)

<table>
<thead>
<tr>
<th>switch:</th>
<th>iradpar__cloud</th>
<th>irad_incl__qrqsgq</th>
<th>lrad_ice__smooth_surfaces</th>
<th>lrad_ice__fd_is_gsquared</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Warm Stratus</td>
<td>~22%</td>
<td>~4%</td>
<td>0</td>
<td>0</td>
<td>~9%</td>
</tr>
<tr>
<td>Cirrus</td>
<td>~1.8%</td>
<td>~1.6%</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mixed phase</td>
<td>~28%</td>
<td>~8%</td>
<td>0</td>
<td>0</td>
<td>~5%</td>
</tr>
<tr>
<td>Fair weather Cu</td>
<td>~4%</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</table>
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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5. Summary
3. Continuous parameters (within the switches)

Can be important for Warm Stratus
1. Idealized COSMO model, examples of 5 types of clouds

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5. Summary
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:

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

(thanks to Harel Muskatel and Uli Blahak)

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

\[
x_p - x_{p,def} \quad \text{MAX}\{x_p\} - \text{MIN}\{x_p\}
\]

\[
\frac{\partial \tilde{R}}{\partial \tilde{x}_p} \quad \text{Sensitivity to parameter } \tilde{x}_p
\]

\[
\begin{align*}
x_1 & \equiv \text{radqcfact} \\
x_2 & \equiv \text{qvsatfact_sgscl_rad} \\
x_3 & \equiv \text{cloud_num_rad} \\
x_4 & \equiv \text{reff_ini_c}
\end{align*}
\]
3a. Method: How to define sensitivity to model parameters?

STEP 4: Calculate derivatives of the fit for global radiation reduction in different “parameters directions”
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 $\left|\frac{\partial \tilde{R}}{\partial \tilde{x}_p}\right|$. 

---

**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.

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

Example: Case 4, warm Stratus

\[ \frac{\partial \tilde{R}}{\partial \tilde{x}_p} \]

\[ D(\text{global rad. reduction})/D(\text{parameter}) \% \]
### 3b. Sensitivity results: which parameters are most important?

Time averaged $\frac{D(\text{global rad. reduction})}{D(\text{parameter})} (\%)$

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</table>
### 3b. Sensitivity results: which parameters are most important?

**Time averaged** \( \frac{D(\text{global rad. reduction})}{D(\text{parameter})} \cdot (\%) \)

\[
\frac{\partial \hat{R}}{\partial \tilde{x}_p}
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**parameter:**

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- **Subgrid-scale variability**: \( \text{Link to explanation} \)
- **Subgrid Cloud Water Content factor**: \( \text{Link to explanation} \)
- **Subgrid effective radius**: \( \text{Link to explanation} \)
- **Constant number concentration of cloud droplets** (can see through rain but not through fog...)
All clouds: continuous parameters - summary

Example: Case 4

Warm Stratus

Cirrus

Mixed phase

Fair weather Cu

Anvil
### All clouds: continuous parameters - summary

**Time averaged $D(\text{global rad. reduction})/D(\text{parameter})$ (%)**

\[ \frac{\partial \tilde{R}}{\partial \tilde{x}_p} \]

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### All clouds: continuous parameters - summary

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<tr>
<td><strong>Fair weather:</strong></td>
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<td><strong>Cu:</strong></td>
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<td><strong>Anvil:</strong></td>
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</tbody>
</table>

**Time averaged** \( \frac{\partial \tilde{R}}{\partial \tilde{x}_p} \) \( \text{D(global rad. reduction)/D(parameter)} \) (%)
### Global radiation sensitivity (%)

<table>
<thead>
<tr>
<th>parameter:</th>
<th>radqifact</th>
<th>radqcfact</th>
<th>qvsatfact_sgscl_rad</th>
<th>reff_ini_i</th>
<th>reff_ini_c</th>
<th>cloud_num_rad</th>
<th>rad_arearat_Ls_i</th>
<th>rad_arearat_Ls_s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm Stratus</td>
<td>not relev.</td>
<td>8-18%</td>
<td>9-20%</td>
<td>not relev.</td>
<td>0-5%</td>
<td>0-34%</td>
<td>not relev.</td>
<td>not relev.</td>
</tr>
<tr>
<td>Cirrus</td>
<td>2.3-5.2%</td>
<td>not relev.</td>
<td>1.9-3.5%</td>
<td>low sens.</td>
<td>not relev.</td>
<td>not relev.</td>
<td>low sens.</td>
<td>low sens.</td>
</tr>
<tr>
<td>Mixed phase</td>
<td>low sens.</td>
<td>15-16%</td>
<td>29-31%</td>
<td>0.4-1.6%</td>
<td>0-29%</td>
<td>0-2.3%</td>
<td>low sens.</td>
<td>low sens.</td>
</tr>
<tr>
<td>Fair weather Cu</td>
<td>not relev.</td>
<td>2.3-3.8%</td>
<td>4.4-7.8%</td>
<td>not relev.</td>
<td>0-5.1%</td>
<td>not relev.</td>
<td>not relev.</td>
<td>not relev.</td>
</tr>
<tr>
<td>Anvil</td>
<td>13-19%</td>
<td>not relev.</td>
<td>0.02-0.07%</td>
<td>low sens.</td>
<td>not relev.</td>
<td>not relev.</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**All clouds**: continuous parameters - summary
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
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
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. 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
**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:
Global Radiation (W/m²)

- No cloud
- case_1
- case_2
- case_3
- case_4
- case_5
- case_6
- case_7
- case_8

Time

10:00 11:00 12:00 13:00 14:00 15:00 16:00
The graph shows the global radiation (W/m²) over time from 10:00 to 16:00. The cases are compared against a baseline case (No cloud) represented by a black line. The cases include:

- case_1
- case_2
- case_3
- case_4
- case_5
- case_6
- case_7
- case_8
- case_9

The radiation values decrease initially and then stabilize, indicating the impact of different cases on global radiation over the time period.
From Uli’s Blahak presentation:

**Cloud ice (visible; Fu et al.)**

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

  - $f(D) = \text{monodispers}$
  - $N_i(T) = a \exp (b (T_3 - T))$
  - $q_i$ prognostic
  - $m_i = 130 D^3$ (SI-units)

  Spectral interval “2”
  (visible range)

  $\beta_{\text{ext ratio Fu / RG92}}$
True / False switches on Mixed Phase cloud:
Global Radiation (W/m²)

Time

No cloud
From Uli’s Blahak presentation:

Cloud droplets comparison to RG92

If grid scale $q_c > 0$: from cloud microphysics:

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

$\mu = 5.0$

$N_c = \text{cloud\_num}$

$q_c$ prognostic

Spectral interval “2”
(visible range)

$\beta_{\text{ext ratio HS / RG92}}$
True / False switches on Fair weather Cu:
The graph shows the global radiation (W/m²) over time from 10:00 to 16:00. The y-axis represents the global radiation, and the x-axis represents time.

Legend:
- **No cloud**
- **case_1**
- **case_2**
- **case_3**
- **case_4**
- **case_5**
- **case_6**
- **case_7**
- **case_8**
- **case_9**
Cloud droplets comparison to RG92

If grid scale $q_c > 0$: from cloud microphysics:

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

$\mu = 5.0$

$N_c = \text{cloud\_num}$

$q_c$ prognostic

Spectral interval „2“ (visible range)

$\beta_{\text{ext\ ratio HS / RG92}}$
True / False switches on Anvil:
Cloud ice (visible; Fu et al.)

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

- $f(D) = \text{monodispers}$
- $N_i(T) = a \exp (b (T_3 - T))$
- $q_i$ prognostic
- $m_i = 130 D^3$ (SI-units)

Spectral interval “2”
(visible range)

$\beta_{ext} \text{ ratio Fu / RG92}$
Parameter 1: Subgrid-scale variability factor „radqcfact“

Assume:

- **Microphysics**
- **Cloud Water Content in a grid box**

**Mean Cloud Water Content over the grid box**

Higher radiation through “empty” areas

Effective CWC: **lower**

\[ CWC \rightarrow (\text{radqcfact}) \times CWC \]
### Parameter 1: Subgrid-scale variability factor „radqcfact”

**Where „radqcfact” takes effect?**

<table>
<thead>
<tr>
<th></th>
<th><strong>Grid-Scale</strong> Cloudiness</th>
<th><strong>Subgrid-Scale</strong> Cloudiness</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Effective CWC</strong></td>
<td>(from microphysics)*correction</td>
<td>Parameterization</td>
</tr>
<tr>
<td><strong>$R_{eff}$</strong></td>
<td>from CWC + assuming number concentration</td>
<td>Tuning parameter</td>
</tr>
</tbody>
</table>

- higher „radqcfact”  ➔  higher effective CWC  ➔  higher radiation attenuation
Parameter 2: „qvsatfact_sgscl_rad”

If RH < 100% → Microphysics

From RH and T → Subgrid-scale CWC

Multiplication factor „qvsatfact_sgscl_rad”

Where „qvsatfact_sgscl_rad” takes effect?

<table>
<thead>
<tr>
<th>Grid-Scale Cloudiness</th>
<th>Subgrid-Scale Cloudiness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective CWC</td>
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<td></td>
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</tr>
<tr>
<td>$R_{\text{eff}}$</td>
<td>from CWC + assuming number concentration</td>
</tr>
<tr>
<td></td>
<td>Tuning parameter</td>
</tr>
</tbody>
</table>

Higher $q\text{vsatfact}_\text{sgscl}_{\text{rad}}$ → Higher effective CWC → Higher radiation attenuation
Parameter 4: „reff_ini_c”

if RH<100%

$R_{\text{eff}} = \text{? in SGS clouds}$

Microphysics

$R_{\text{eff}} = \text{tuning parameter reff_ini_c}$

Where „reff_ini_c” takes effect?

<table>
<thead>
<tr>
<th>Effective CWC</th>
<th>(from microphysics)*correction</th>
<th>Parameterization</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{\text{eff}}$</td>
<td>from CWC + assuming number concentration</td>
<td>Tuning parameter</td>
</tr>
</tbody>
</table>

higher $\text{reff_ini_c} (R_{\text{eff}})$ → lower radiation attenuation
Example: Warm Stratus cloud (idealized simulation)

- **Cloud Cover - CLC**
  - Grid-scale cloudiness only
  - Layers with subgrid-scale cloudiness

- **Integrated Cloud Water Content (TQC)**

- **Cloud Water Content - QC (kg/kg)**
  - Artificial growth due to transition of layers to CLC<1

- **Rain Water Content - QR (kg/kg)**
  - No Rain
Example: Warm Stratus cloud (idealized simulation)

**Cloud Cover - CLC**
- Grid-scale cloudiness only
- Layers with subgrid-scale cloudiness
- Maximum and mean values over time from 10:00 to 16:00

**Cloud Water Content – QC (kg/kg)**
- Artificial growth due to transition of layers to CLC<1
- Maximum and mean values over time from 10:00 to 16:00

**Integrated Cloud Water Content**
- TQC (kg/m²)
- Graph showing time from 10:00 to 16:00

**Rain Water Content – QR (kg/kg)**
- No Rain
- Maximum and mean values over time from 10:00 to 16:00
Example: Warm Stratus cloud (idealized simulation)

- Cloud Cover - CLC
  - Layers with subgrid-scale cloudiness
  - Grid-scale cloudiness only
- Integrated Cloud Water Content
  - TQC (kg/m²)
- Cloud Water Content – QC (kg/kg)
  - Maximum over CLC=1 layers
  - Mean over CLC=1 layers
  - Artificial growth due to transition of layers to CLC<1
- Rain Water Content – QR (kg/kg)
  - No Rain
  - Maximum
  - Mean
Example: Warm Stratus cloud (idealized simulation)
Example: Warm Stratus cloud (idealized simulation)

Cloud Cover - CLC

- Grid-scale cloudiness only
- Layers with subgrid-scale cloudiness

Cloud Water Content – QC (kg/kg)

- Artificial growth due to transition of layers to CLC<1

Integrated Cloud Water Content

TQC (kg/m²)

Rain Water Content – QR (kg/kg)

- No Rain

Maximum and mean values over CLC=1 layers.