# Sensitivity of Cloud-resolving RCE Simulations to SST, Horizontal Grid Size, Microphysics, and Turbulence Closure

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# Goals

- Tompkins and Craig (1999) used a domain of 60 km x 60 km with 35 levels and a horizontal grid size of 2 km to study RCE.

- Use a larger domain with higher resolution.

- Test sensitivity to horizontal grid size, microphysics, and turbulence closure.

# RCE Simulations

- Fixed SST: 301 K or 305 K
- Interactive radiation and surface fluxes
- No mean wind
- Domain size: 256 km by 256 km
- 50-day simulation; analyze last 25 days

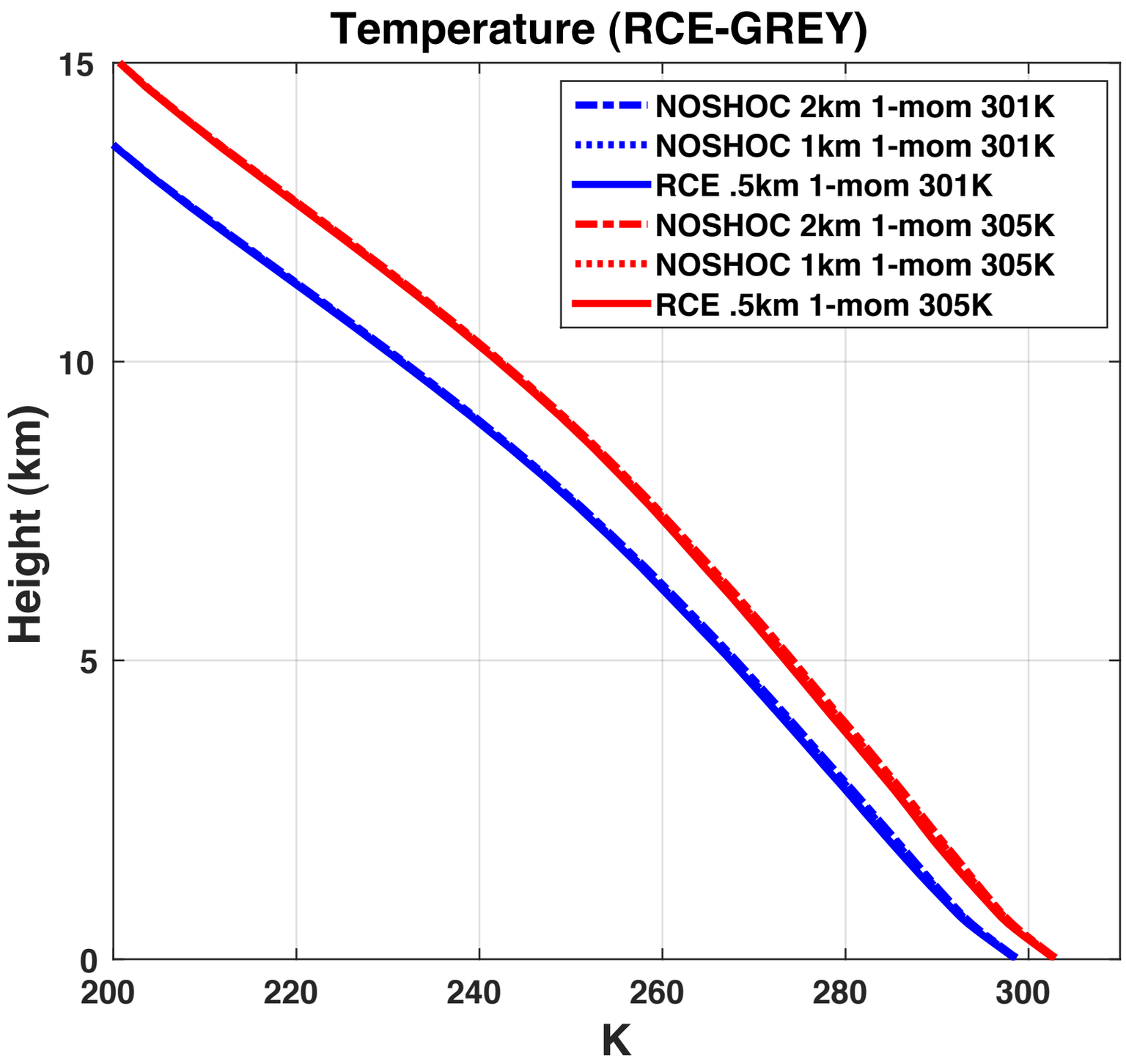
# RCE Simulations

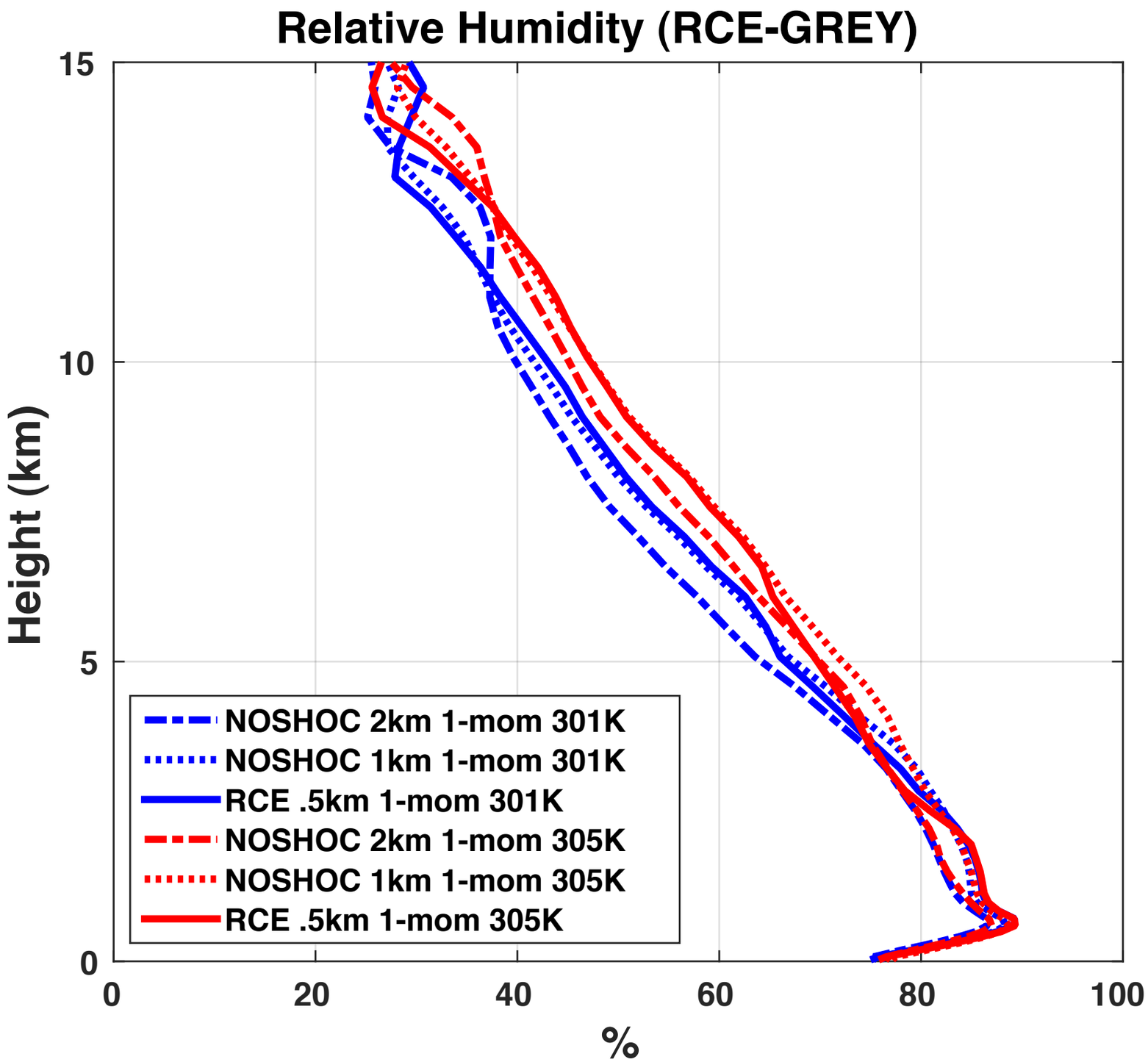
- SAM (System for Atmospheric Modeling)
- ***Microphysics:*** SAM single-moment or Morrison et al. (2005) double-moment
- ***Turbulence closure:*** SAM TKE or SHOC (Simplified Higher Order Closure)
- ***Horizontal grid size:*** 0.5, 1, 2, 4, 8, or 16 km

# Two commonly used assumptions for SST-change simulations are that

- the temperature profile shifts uniformly at all heights within the troposphere

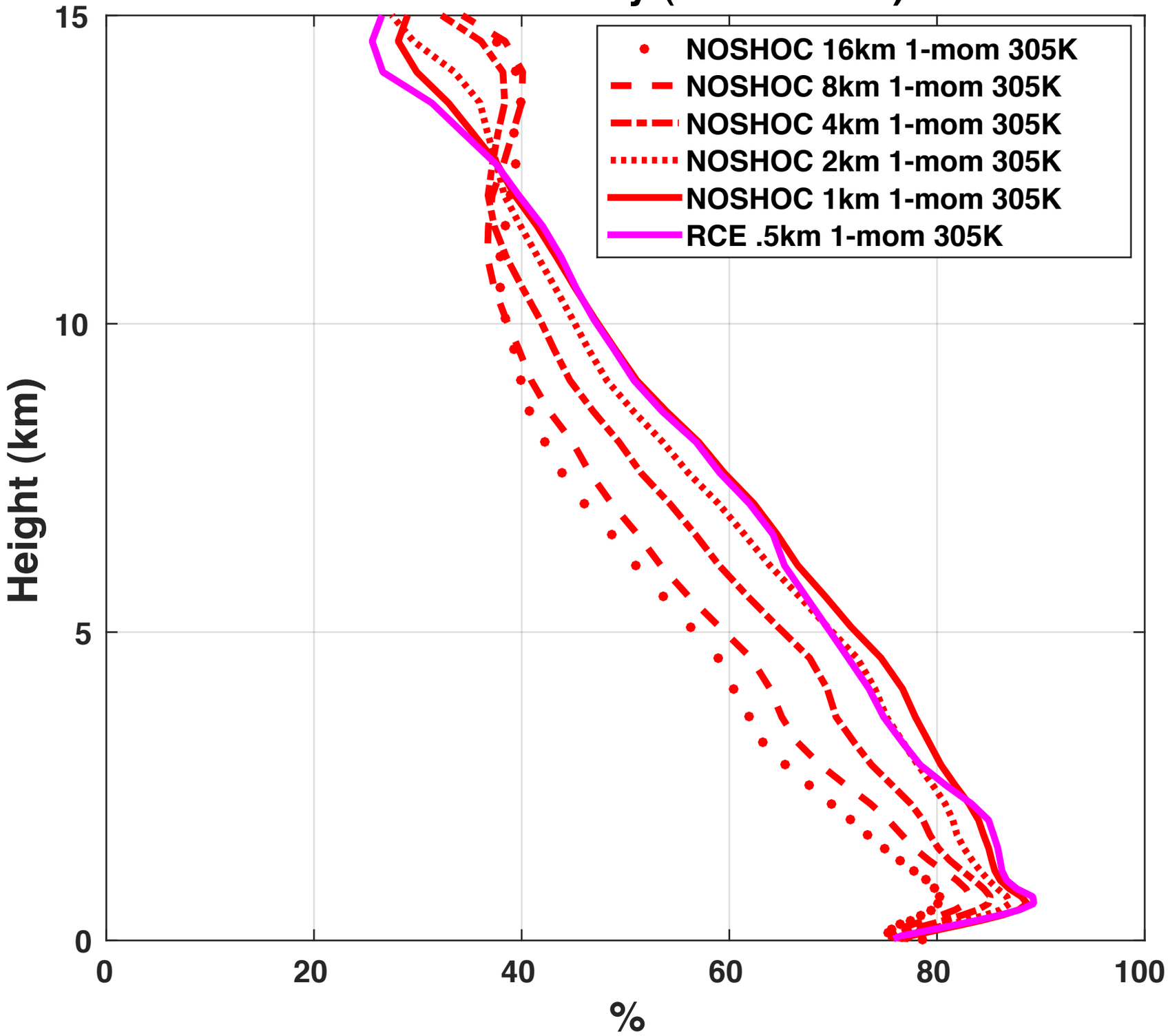
- the tropospheric relative humidity profile does not change

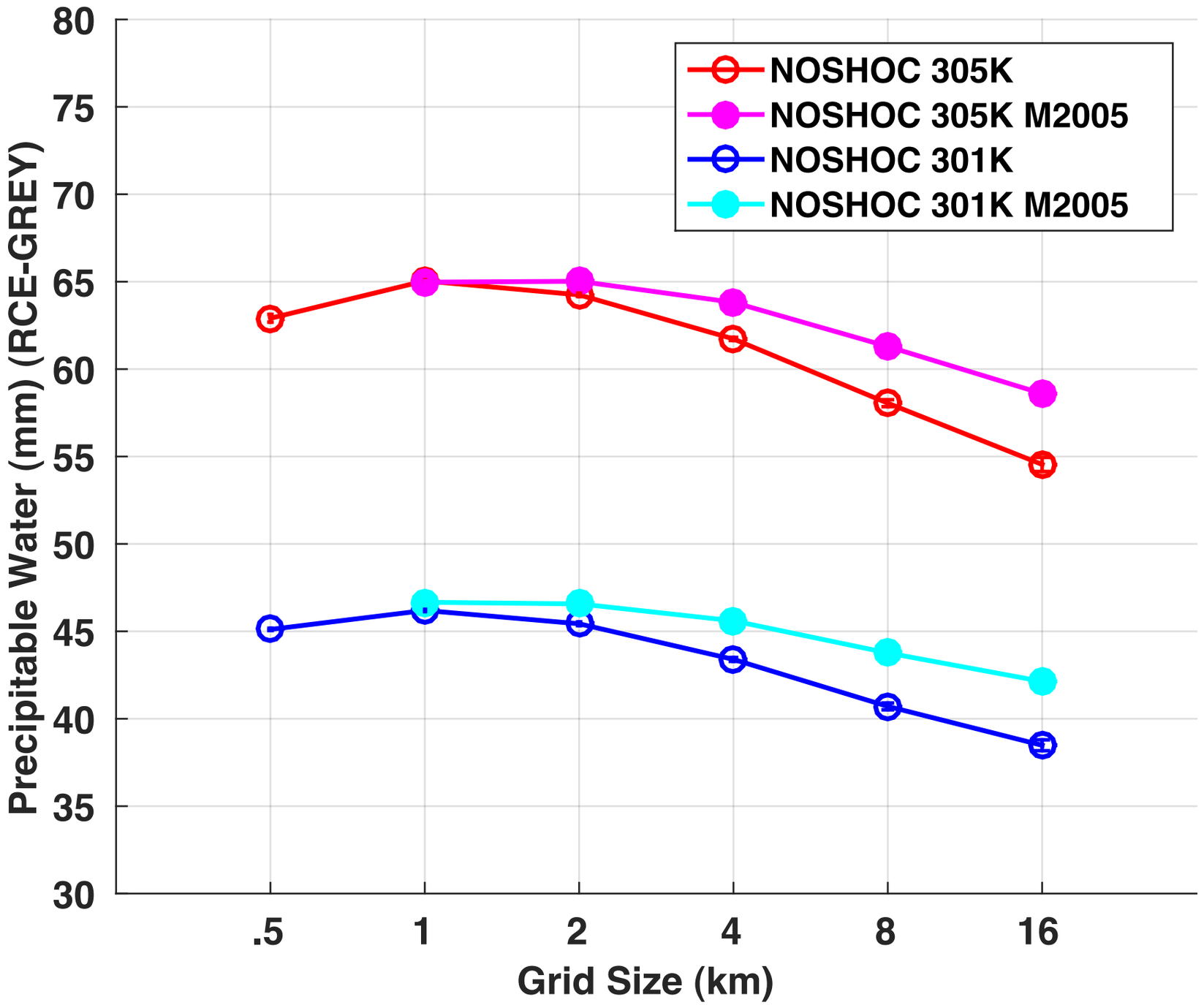

Temperature (RCE-GREY)
NOSHOC 2km 1-mom 301K
NOSHOC 1km 1-mom 301K
RCE .5km 1-mom 301K
NOSHOC 2km 1-mom 305K
NOSHOC 1km 1-mom 305K
RCE .5km 1-mom 305K
Height (km)
15
10
5
0
200
220
240
260
280
300
K

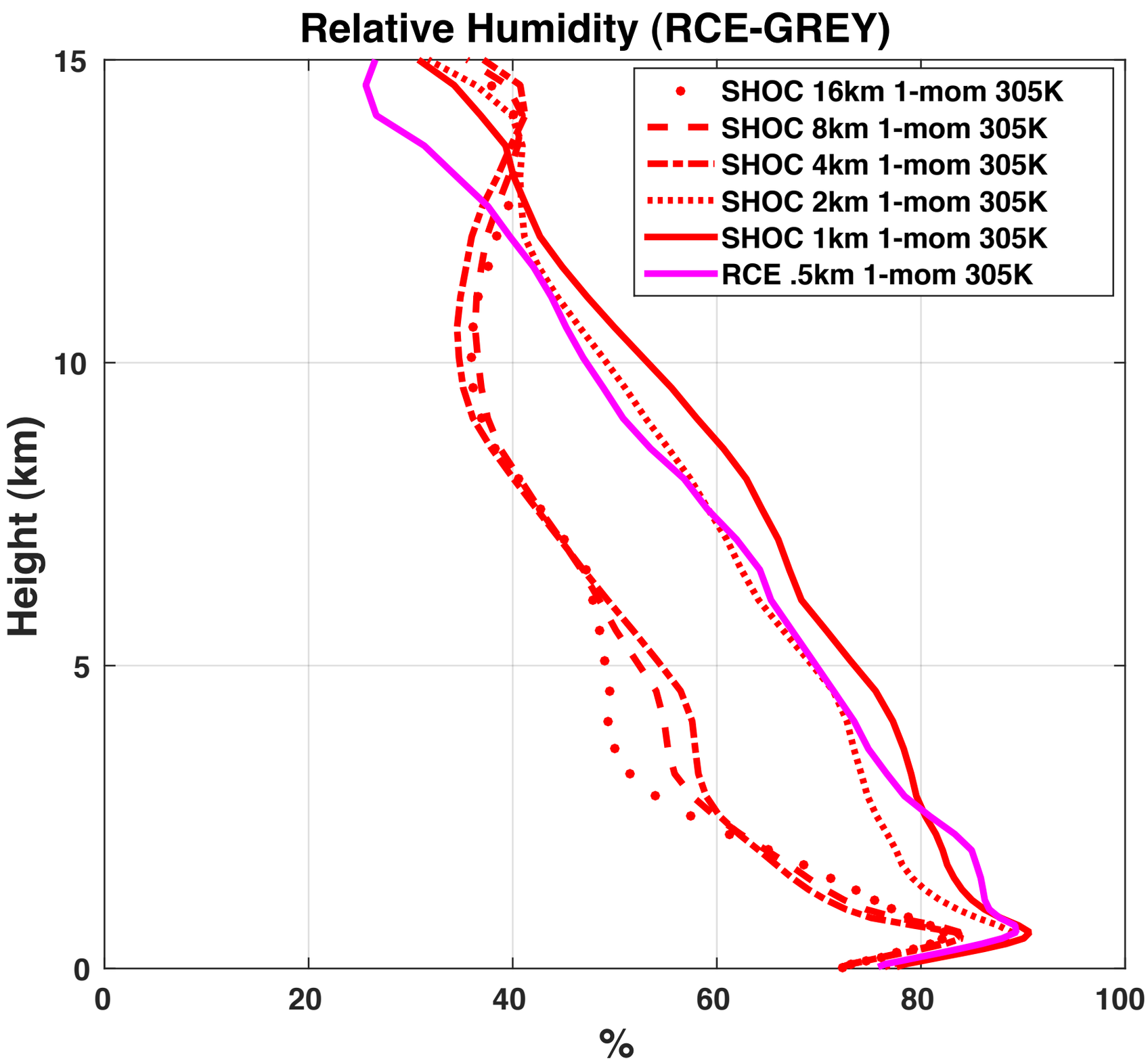

Relative Humidity (RCE-GREY)
Height (km)
15
10
5
0
0
20
40
60
80
100
%
NOSHOC 2km 1-mom 301K
NOSHOC 1km 1-mom 301K
RCE .5km 1-mom 301K
NOSHOC 2km 1-mom 305K
NOSHOC 1km 1-mom 305K
RCE .5km 1-mom 305K

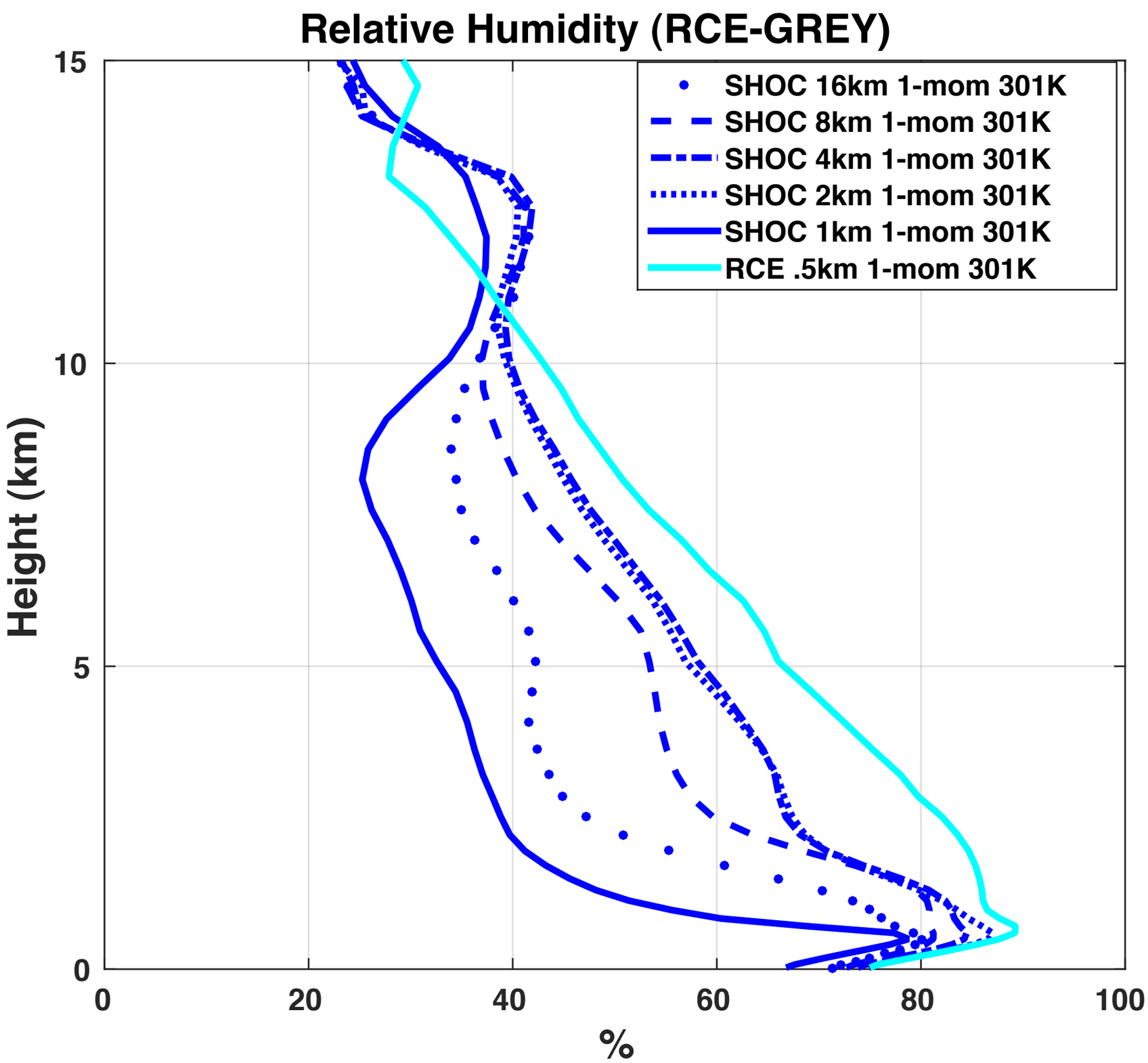
# How does the RH profile change as the horizontal grid size changes?

# Relative Humidity (RCE-GREY)

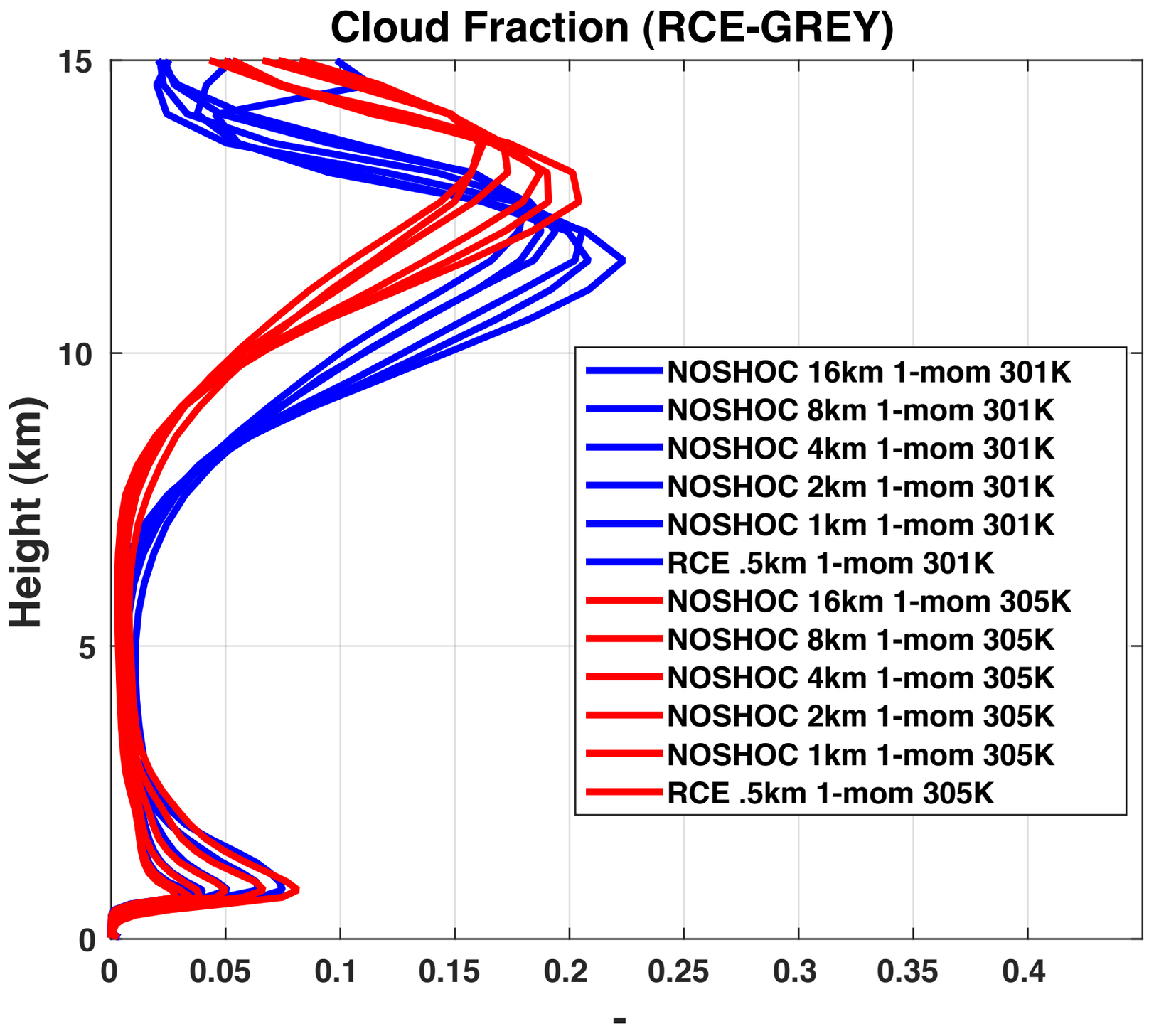



NOSHOC 305K
NOSHOC 305K M2005
NOSHOC 301K
NOSHOC 301K M2005
Precipitable Water (mm) (RCE-GREY)
80
75
70
65
60
55
50
45
40
35
30
.5
1
2
4
8
16
Grid Size (km)

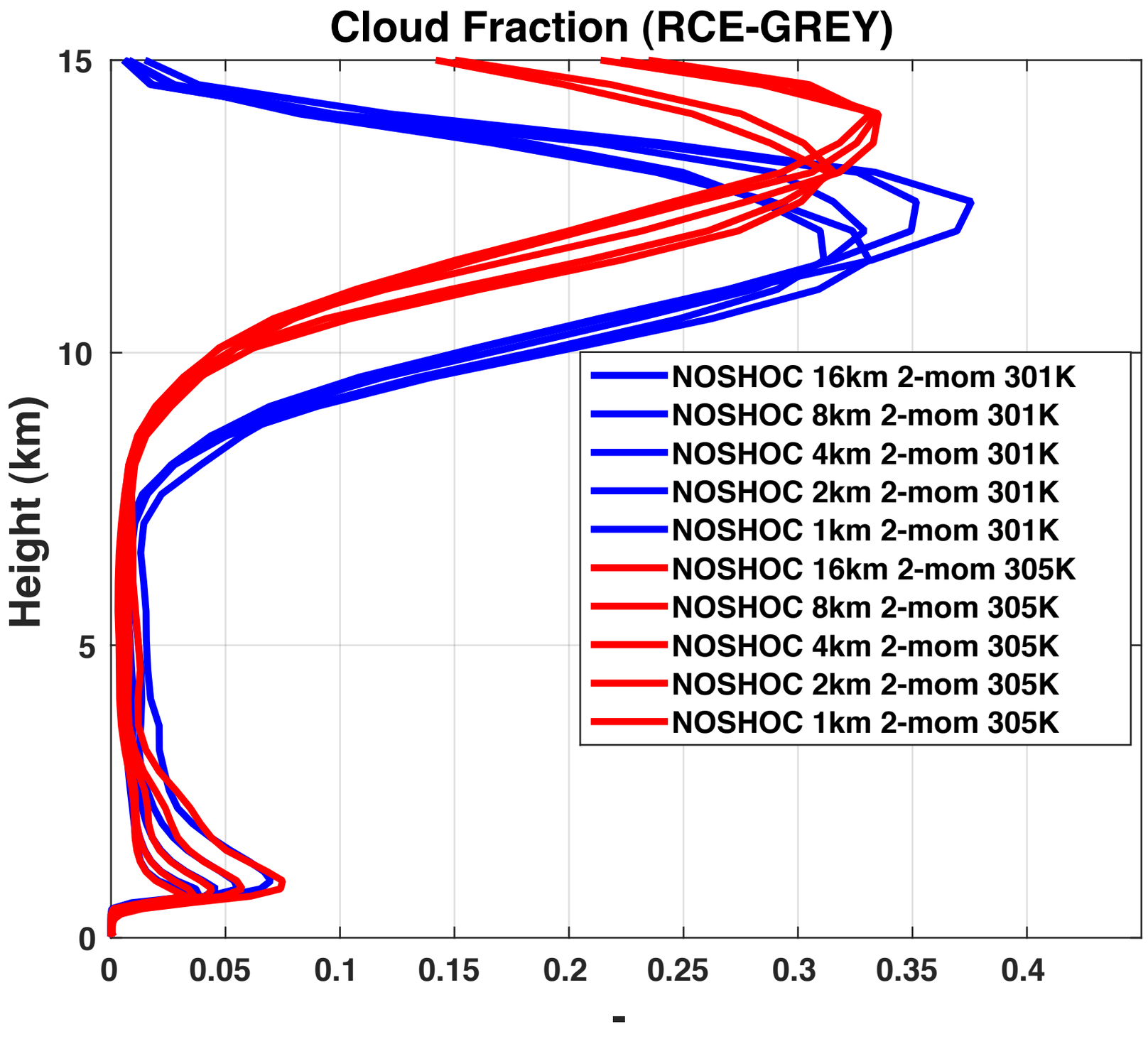

Relative Humidity (RCE-GREY)
SHOC 16km 1-mom 305K
SHOC 8km 1-mom 305K
SHOC 4km 1-mom 305K
SHOC 2km 1-mom 305K
SHOC 1km 1-mom 305K
RCE .5km 1-mom 305K
Height (km)
15
10
5
0
0
20
40
60
80
100
%


Relative Humidity (RCE-GREY)
SHOC 16km 1-mom 301K
SHOC 8km 1-mom 301K
SHOC 4km 1-mom 301K
SHOC 2km 1-mom 301K
SHOC 1km 1-mom 301K
RCE .5km 1-mom 301K
Height (km)
15
10
5
0
0
20
40
60
80
100
%

# 1-moment microphysics



# 2-moment microphysics



# Cloud Fraction (RCE-GREY)

Height (km)

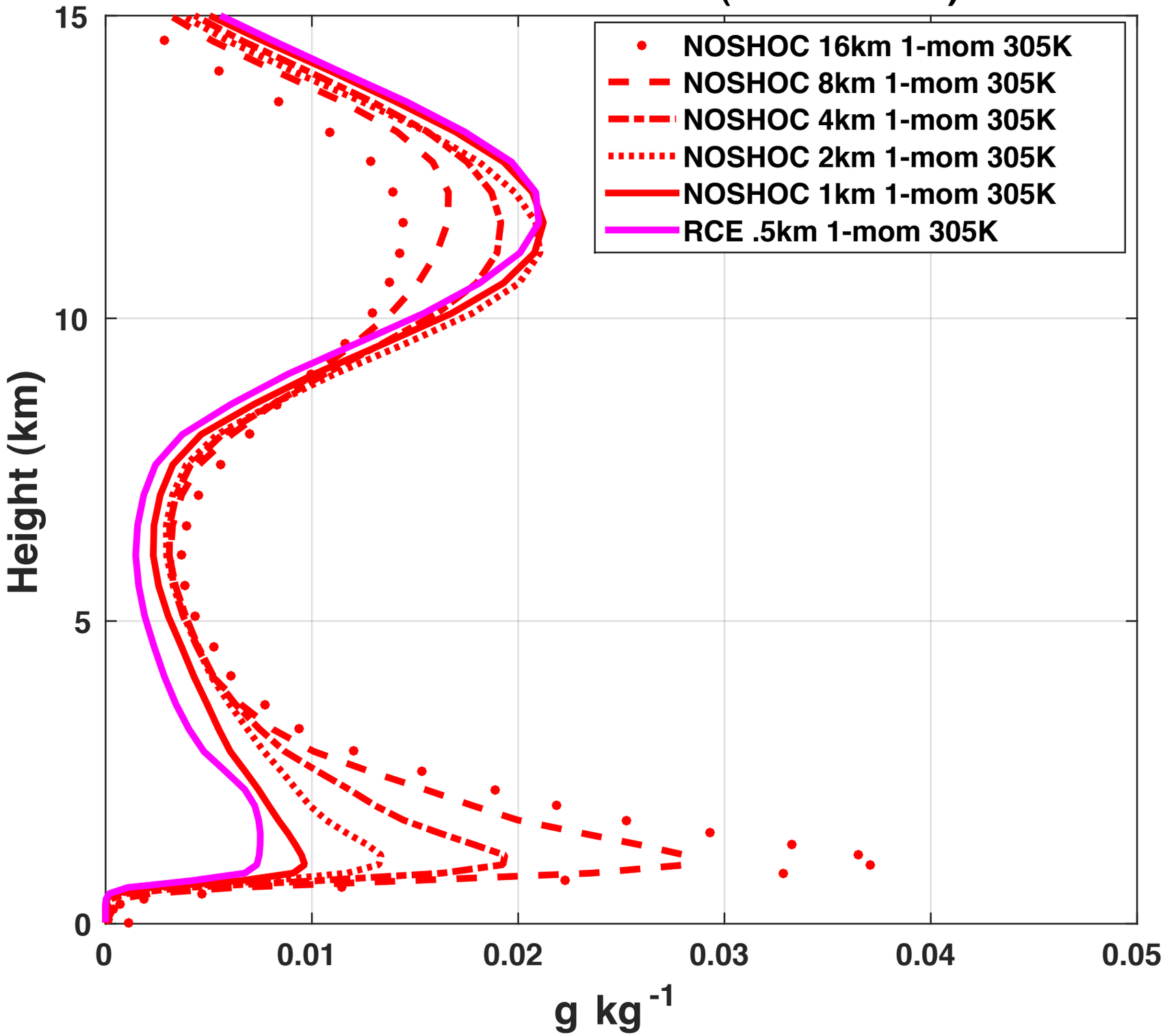
15
10
5
0

0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4

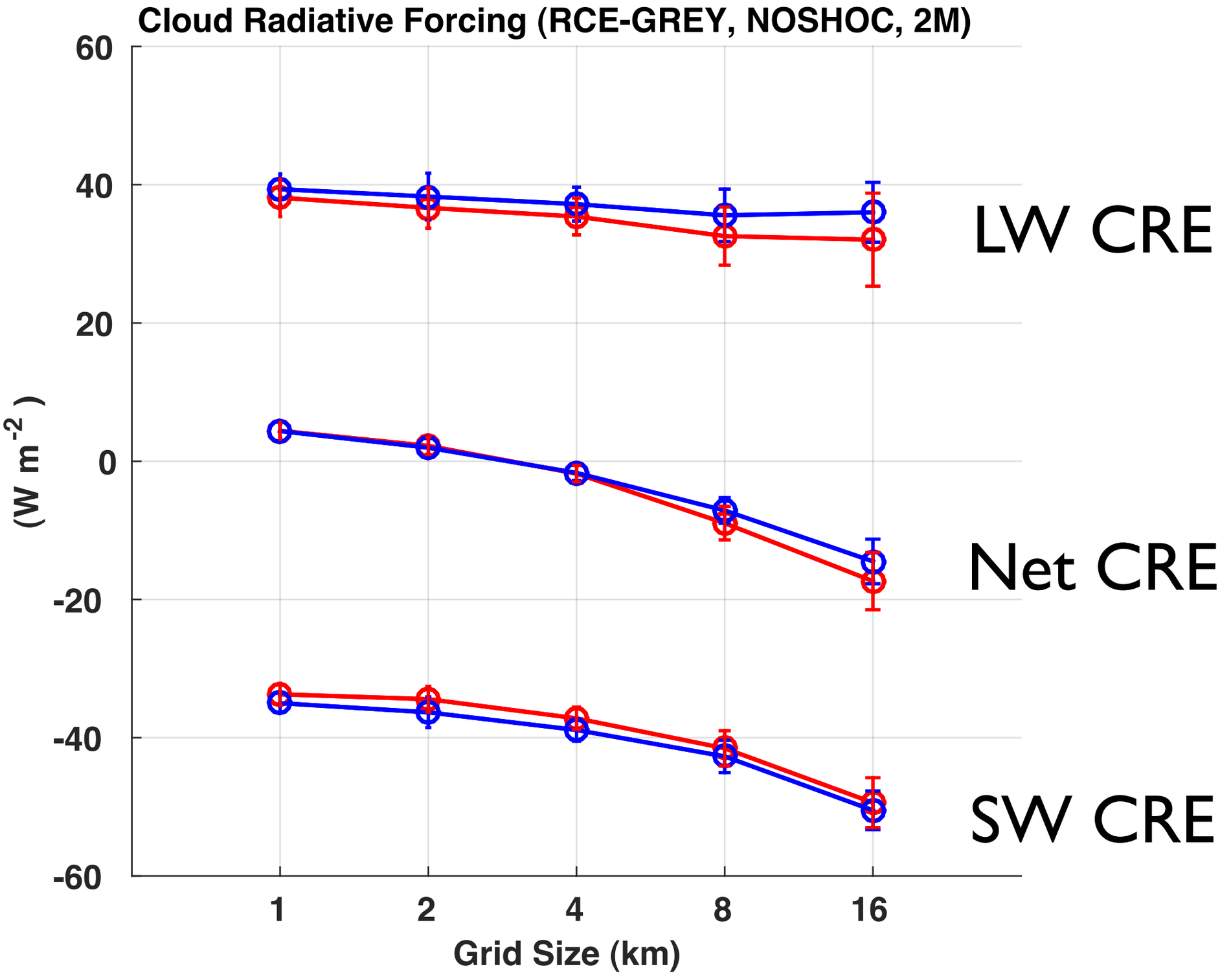
-

NOSHOC 16km 1-mom 305K
NOSHOC 8km 1-mom 305K
NOSHOC 4km 1-mom 305K
NOSHOC 2km 1-mom 305K
NOSHOC 1km 1-mom 305K
RCE .5km 1-mom 305K

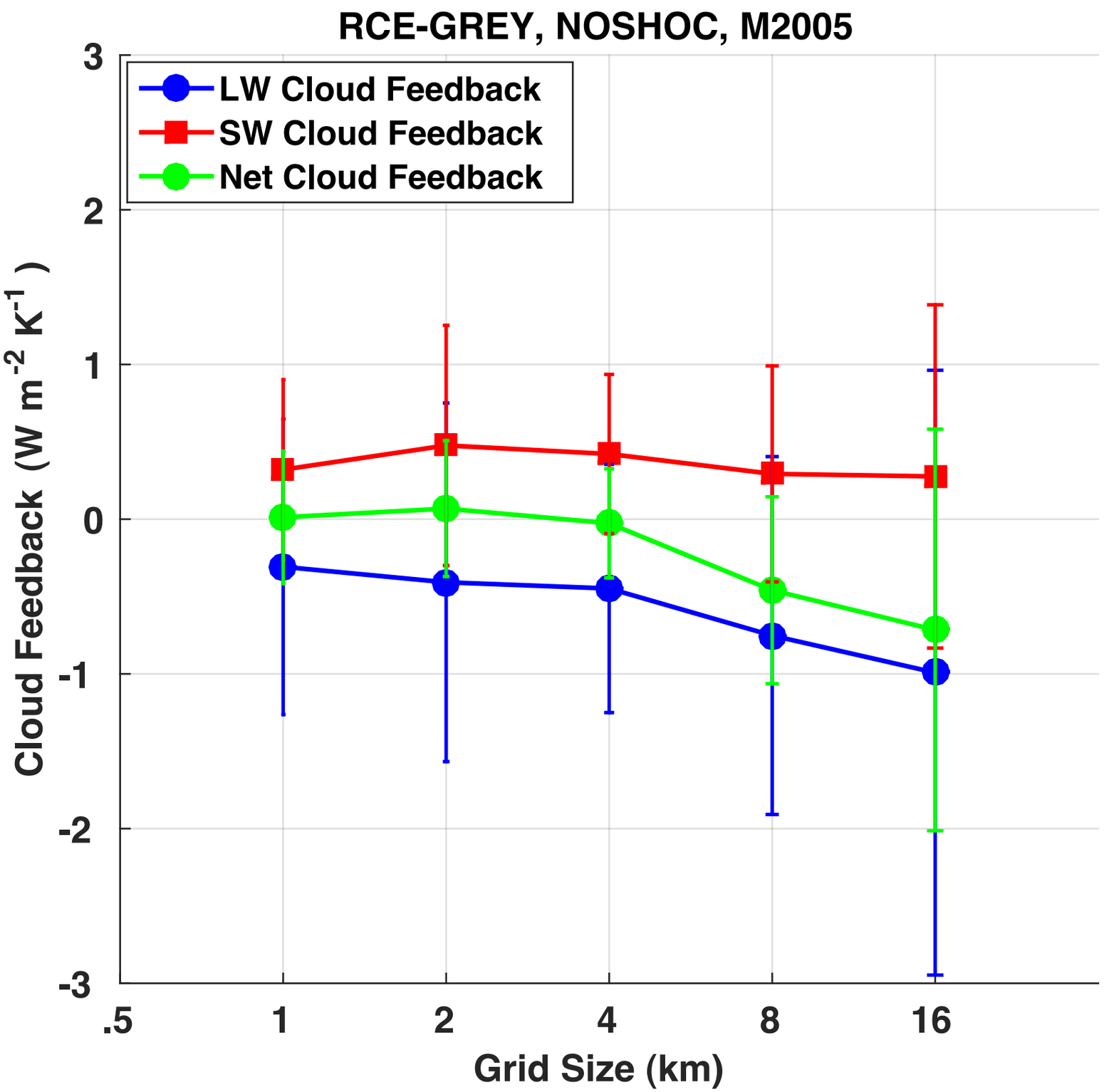
# Total Cloud Condensate (RCE-GREY)



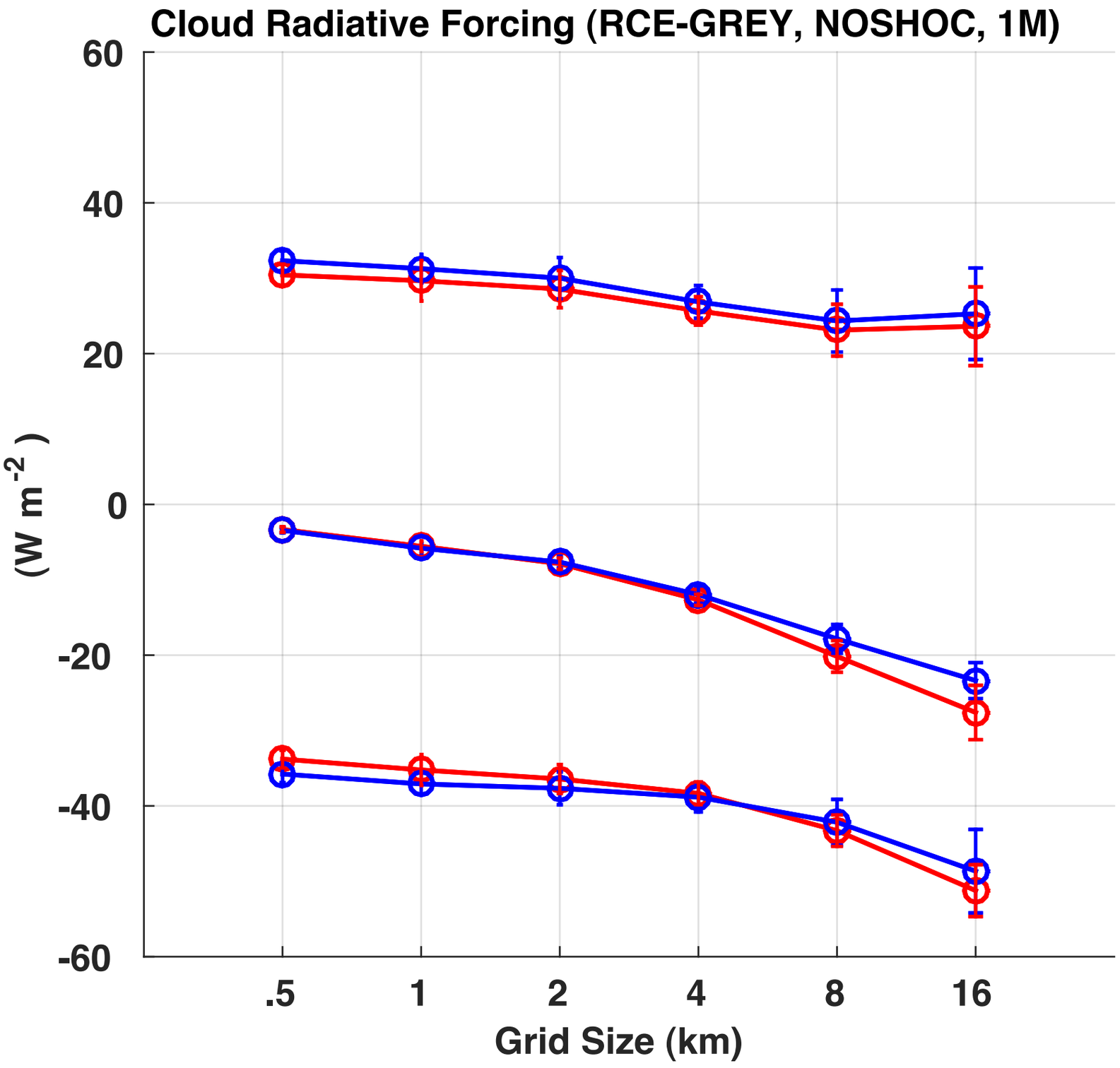
# Cloud Radiative Effects for SST = 301 K and 305 K



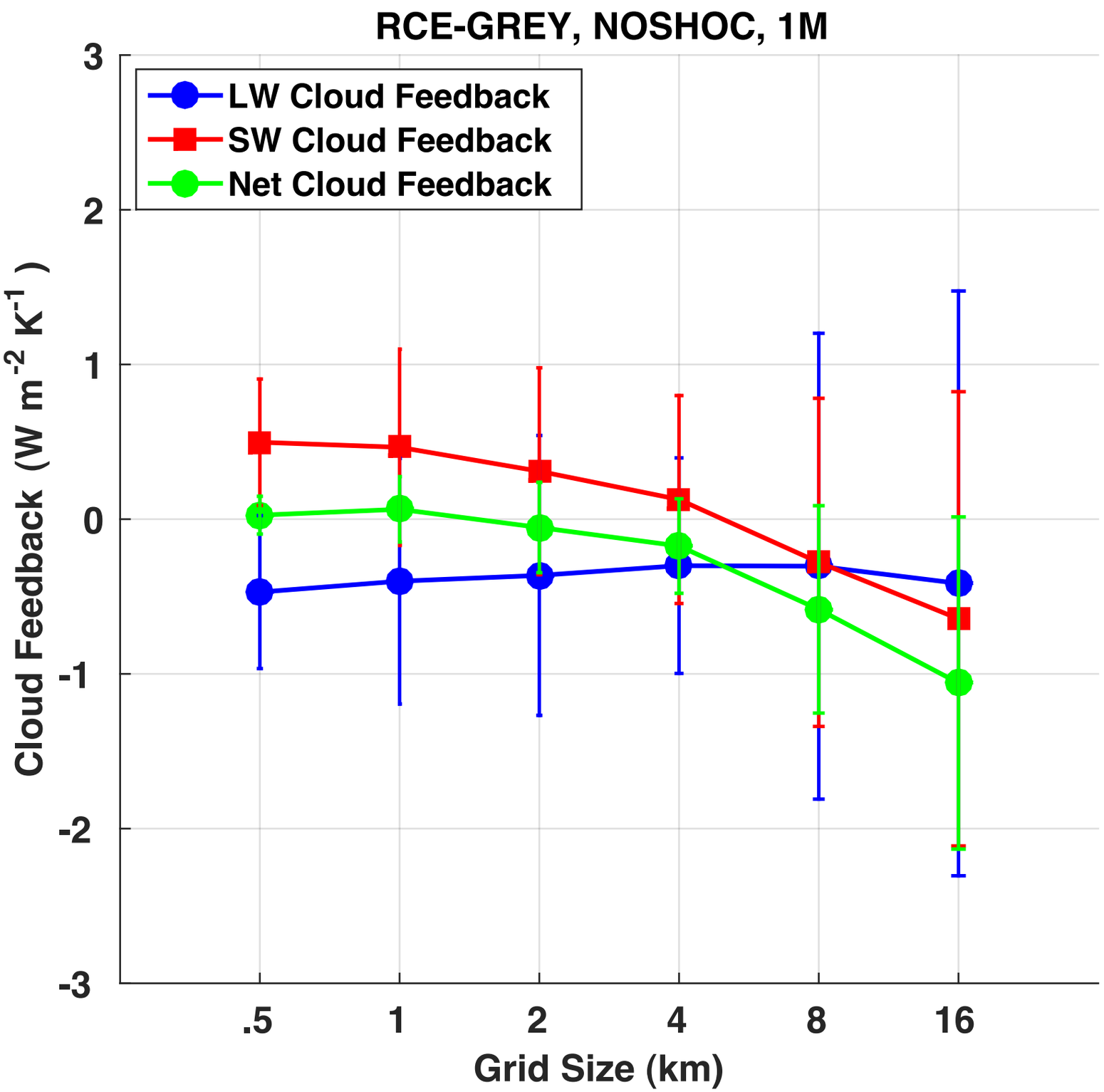
# Cloud Feedbacks



# Cloud Radiative Effects for SST = 301 K and 305 K



# Cloud Feedbacks

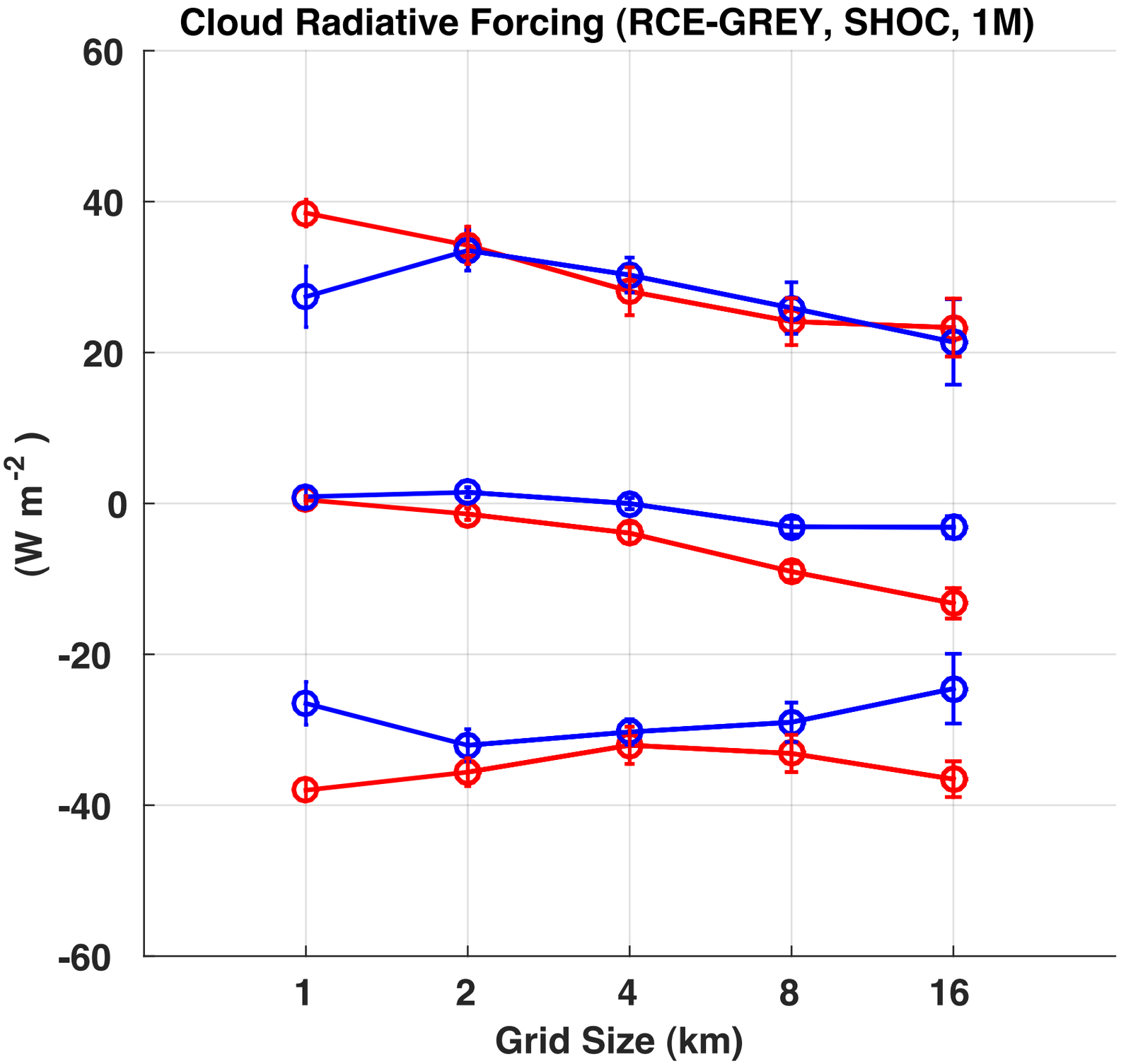


# Tompkins and Craig (1999)

TABLE 3. Cloud feedbacks in the CRM.

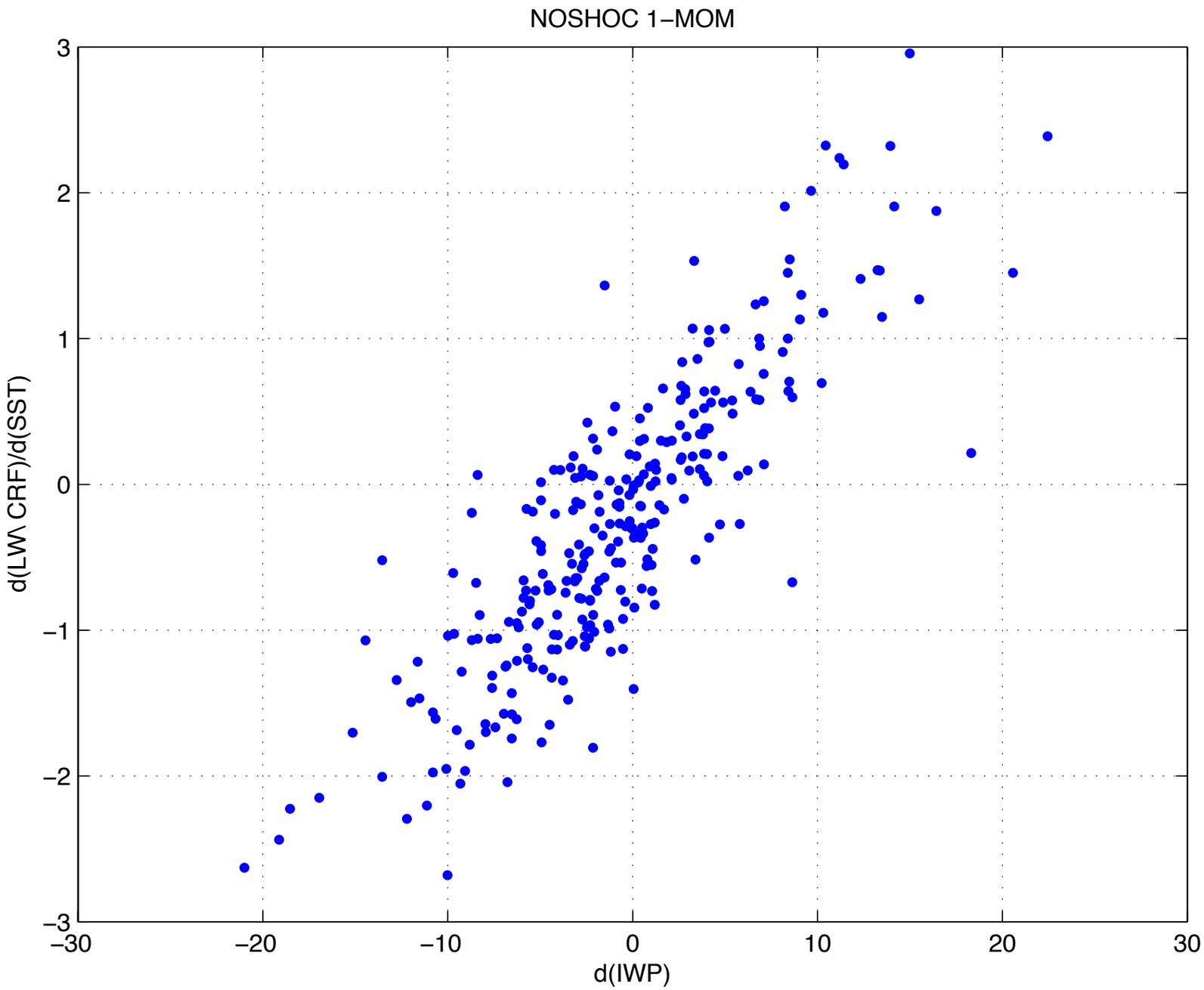
| Feedback effect | Value (W $m^{-2}$ $K^{-1}$) |
|---|---|
| $\alpha_C$ (IR) | −0.56 |
| $\alpha_C$ (SW) | +0.49 |
| Total cloudy-sky feedback $[\alpha_C\ (\mathrm{IR}) + \alpha_C\ (\mathrm{SW})]$ | −0.07 |

# Cloud Radiative Effects for SST = 301 K and 305 K



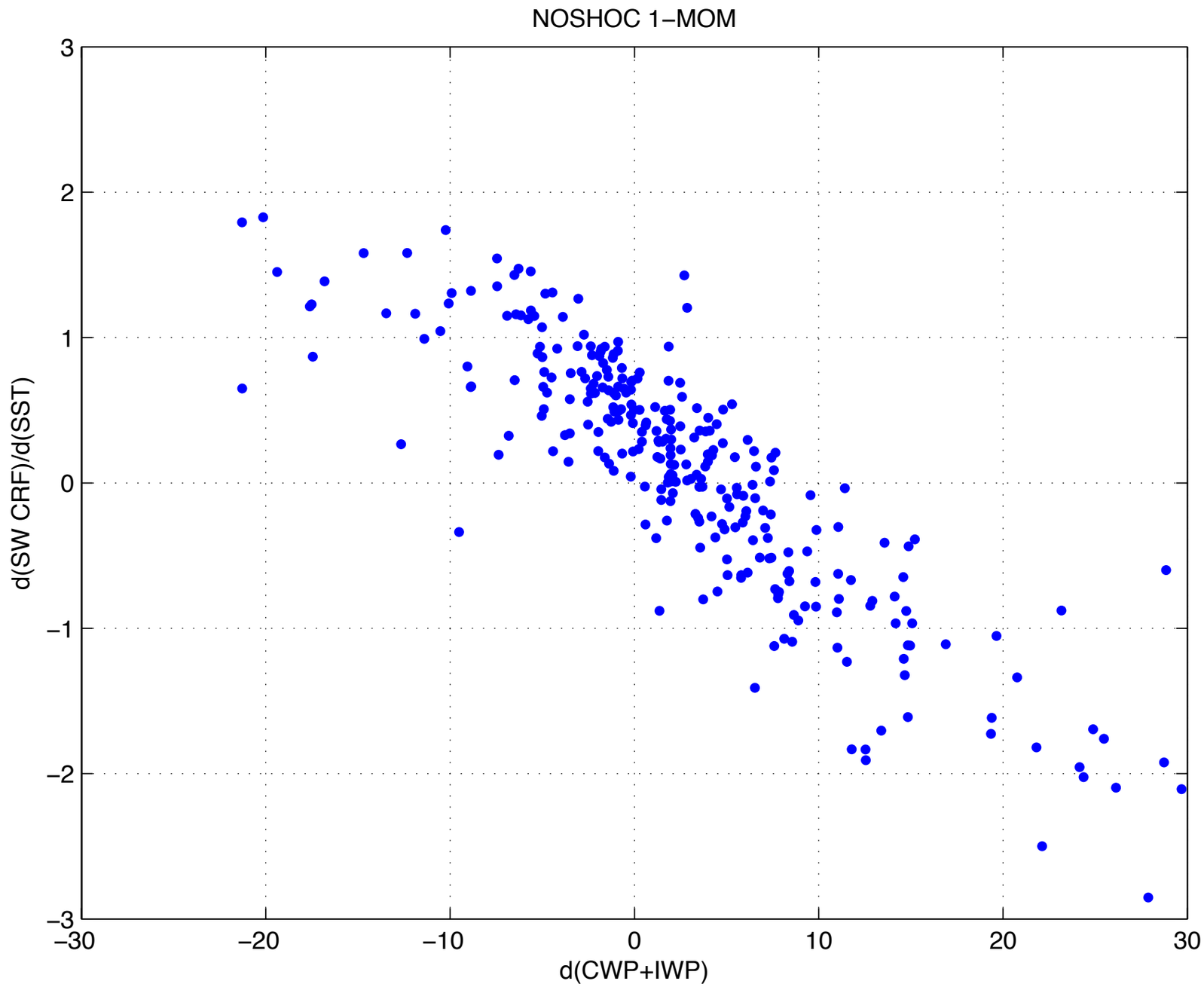
# Which cloud properties change to produce the cloud feedbacks?

# Changes in IWP produce the LW cloud feedback.



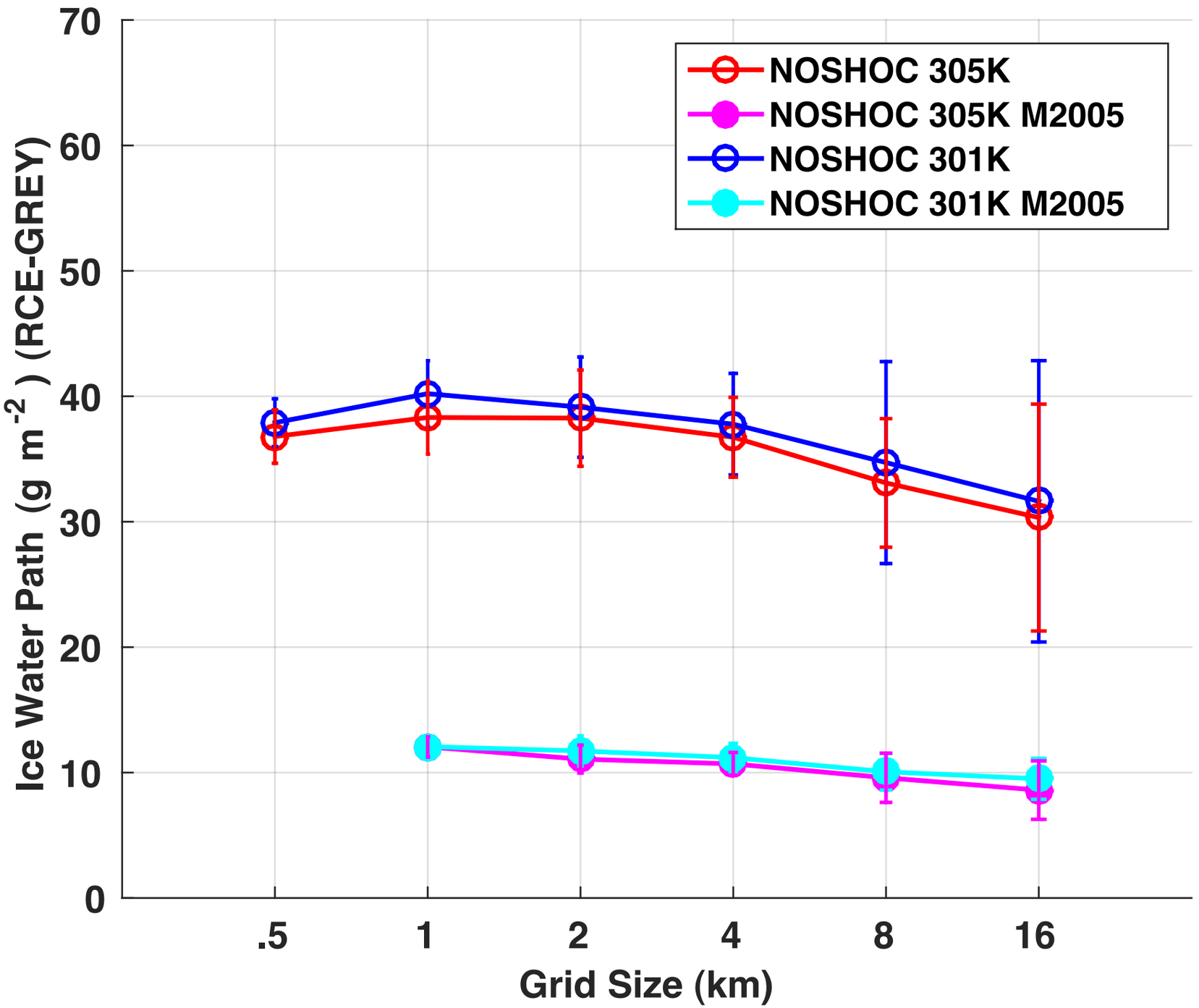

Daily values for NOSHOC 1-MOM for all grid  sizes

# Changes in CWP+IWP produce the SW cloud feedback.

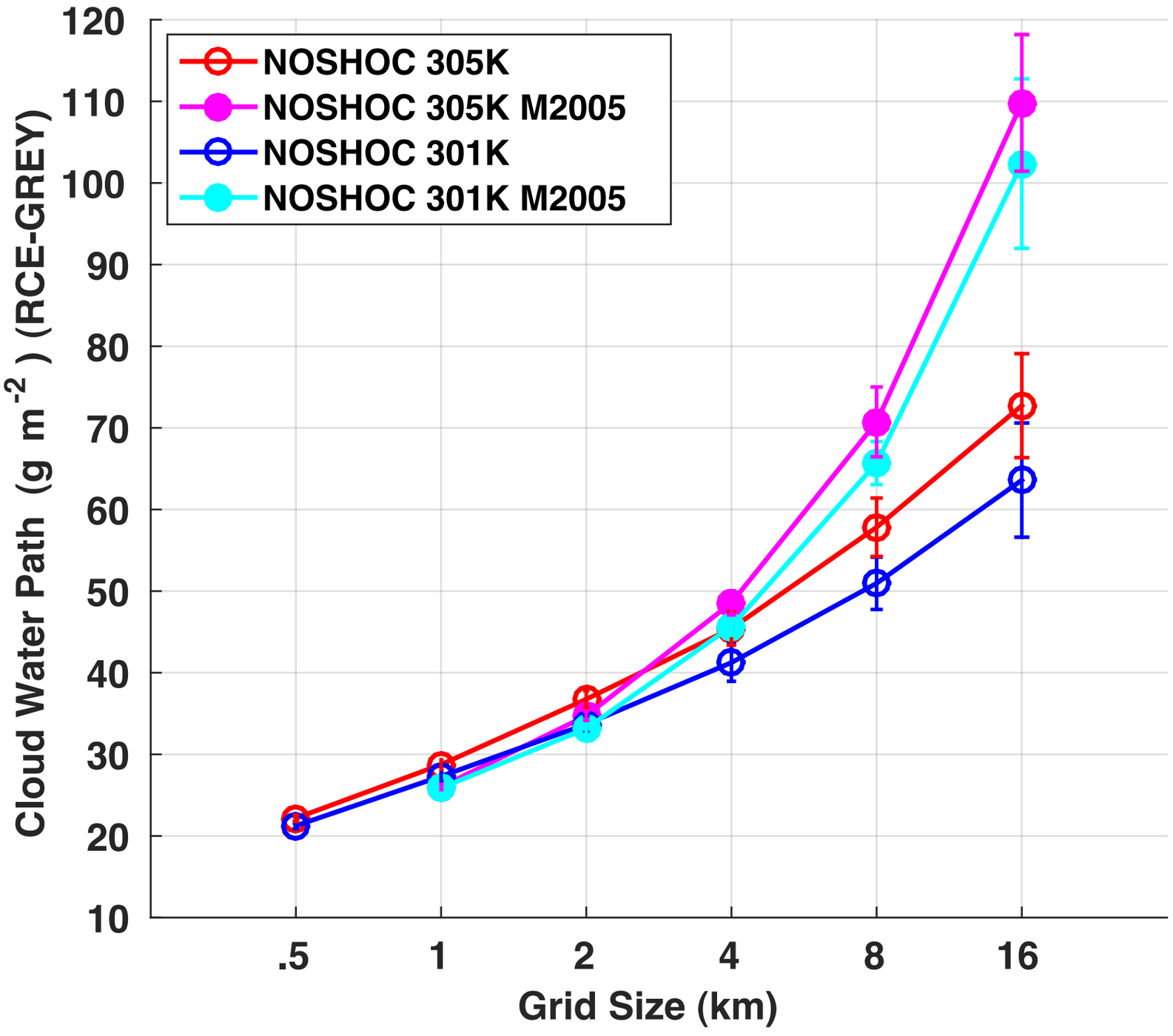



Daily values for NOSHOC 1-MOM for all grid  sizes

# IWP versus grid size



# CWP versus grid size



# Summary

High-resolution CRM simulations of RCE with two microphysics schemes produced SW and LW cloud feedbacks of 0.4 and -0.4 W $m^{-2}$ $K^{-1}$, respectively, and a net cloud feedback of 0 W $m^{-2}$ $K^{-1}$.

- The same results were obtained with horizontal grid sizes up to 4 km.
- The net cloud feedback decreased for larger grid sizes.
- Simulations with SHOC differed from those without SHOC due to convection aggregation.