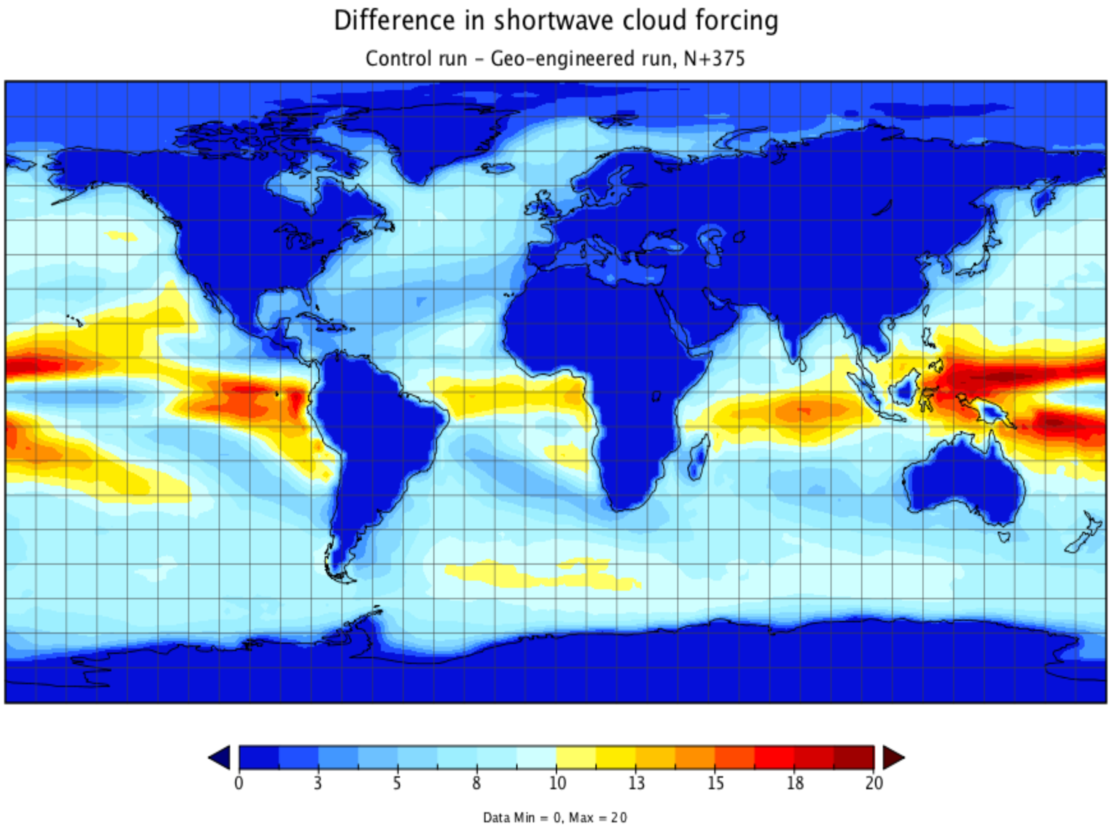


The enhancement of cloud albedo in low marine clouds

Simulations in a Global Climate Model

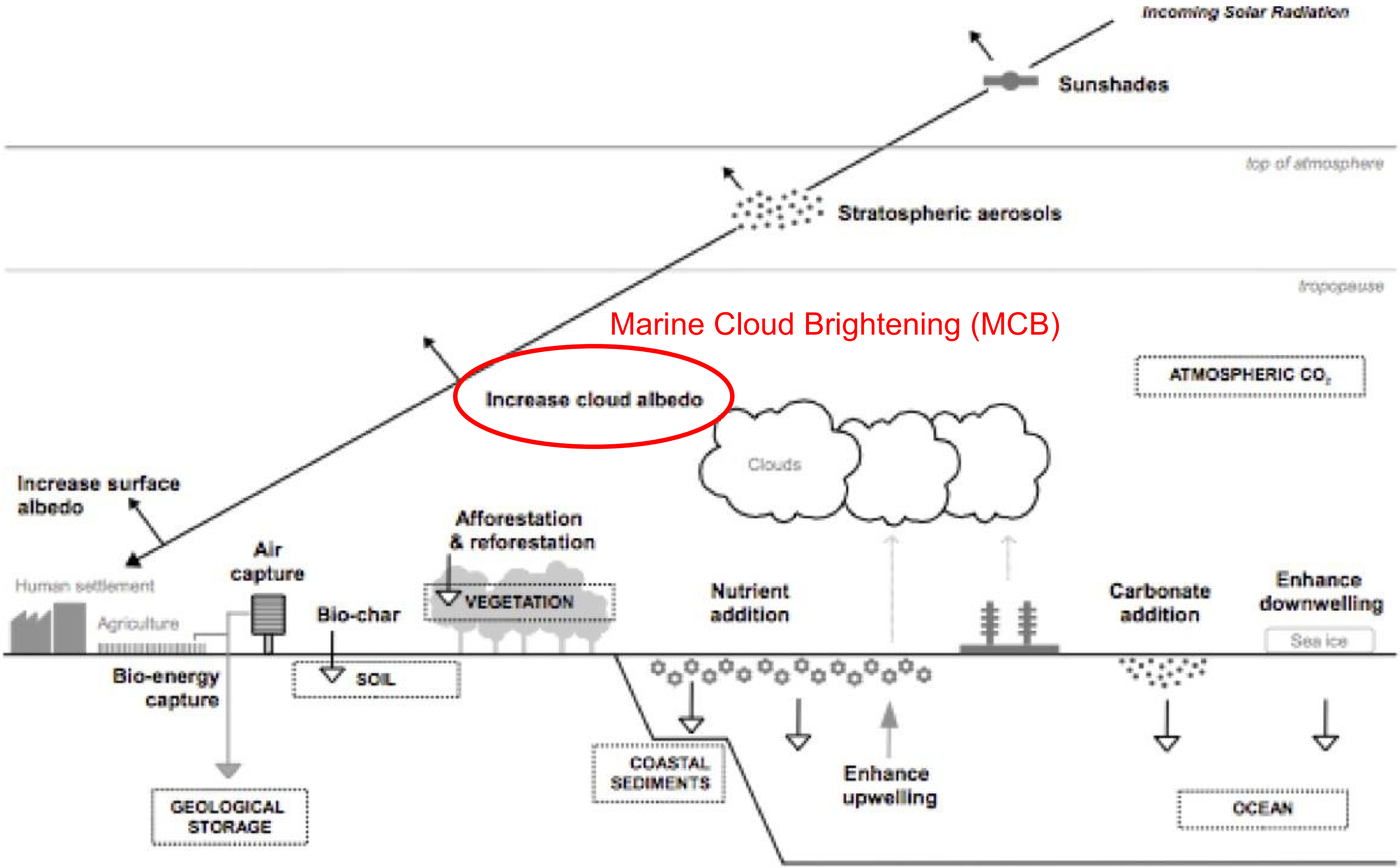
Elín Björk Jónasdóttir

Introduction

- Release of greenhouse gases into the atmosphere causes an imbalance in the earth's radiative budget

 International agreements have not had significant impact on the emission rates

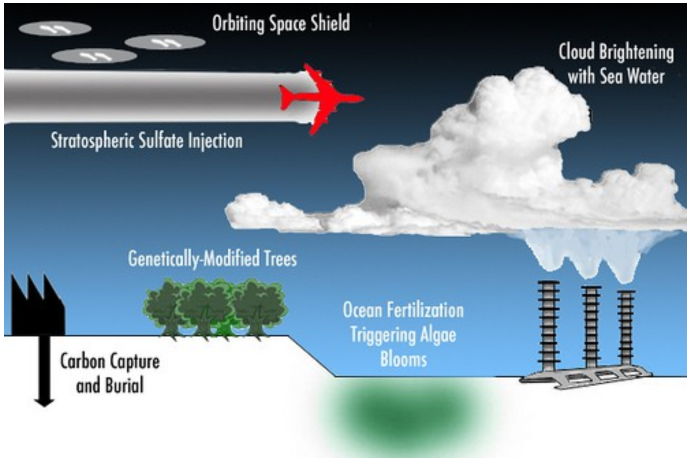
 Geoengineering:"*The large scale intervention in the Earth's climate system, in order to moderate global warming*" (Royal Society, 2009)



Geoengineering options, a schematic overview from Lenton and Vaughan, 2009.

Project aim

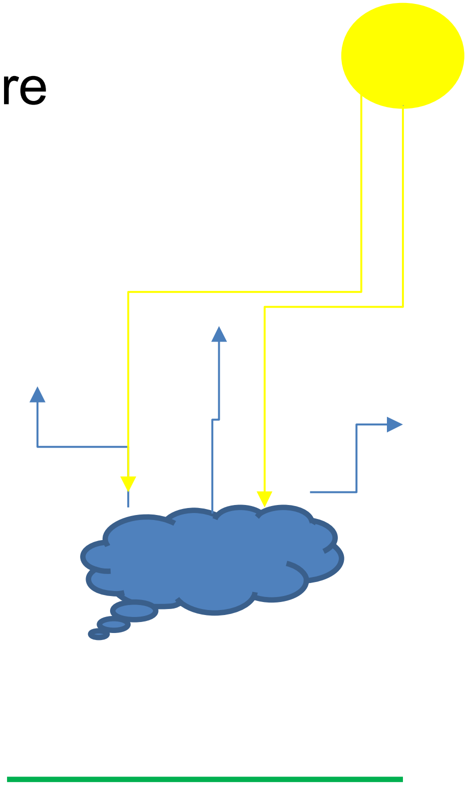
- To explore and quantify the changes in cloud forcing in response to prescribed changes in cloud droplet number concentrations
  - – such as associated with marine cloud brightening



Short wave cloud forcing (SWCF)

Reflection of solar radiation away from the earth: SWCF= $F_{SW,down}(\alpha_{clr} - \alpha_c)$
Net cloud forcing SWCF+LWCF produces cooling
According to Ramanathan et al,1989 the global annual average is -13 Wm^{-2}
Newer studies suggest -14 to -20 Wm^{-2}

α_c is the albedo in a cloudy atmosphere
α_{clr} is the albedo in a hypothetical cloud-free atmosphere

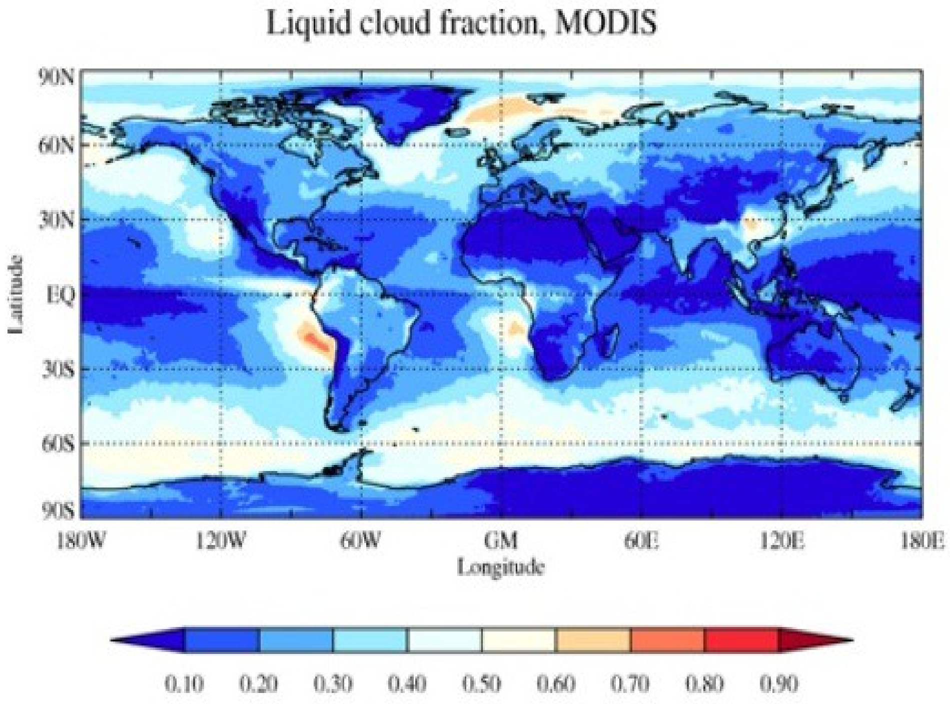


Twomey effects

North Pacific Ocean, March 4th 2009
NASA Satellite Terra

The practical aspect

- Low marine clouds are common in large areas of the ocean
- Salter et al. (2008) suggested a fleet of unmanned wind driven spray vessels be used to seed marine clouds with sea salt particles



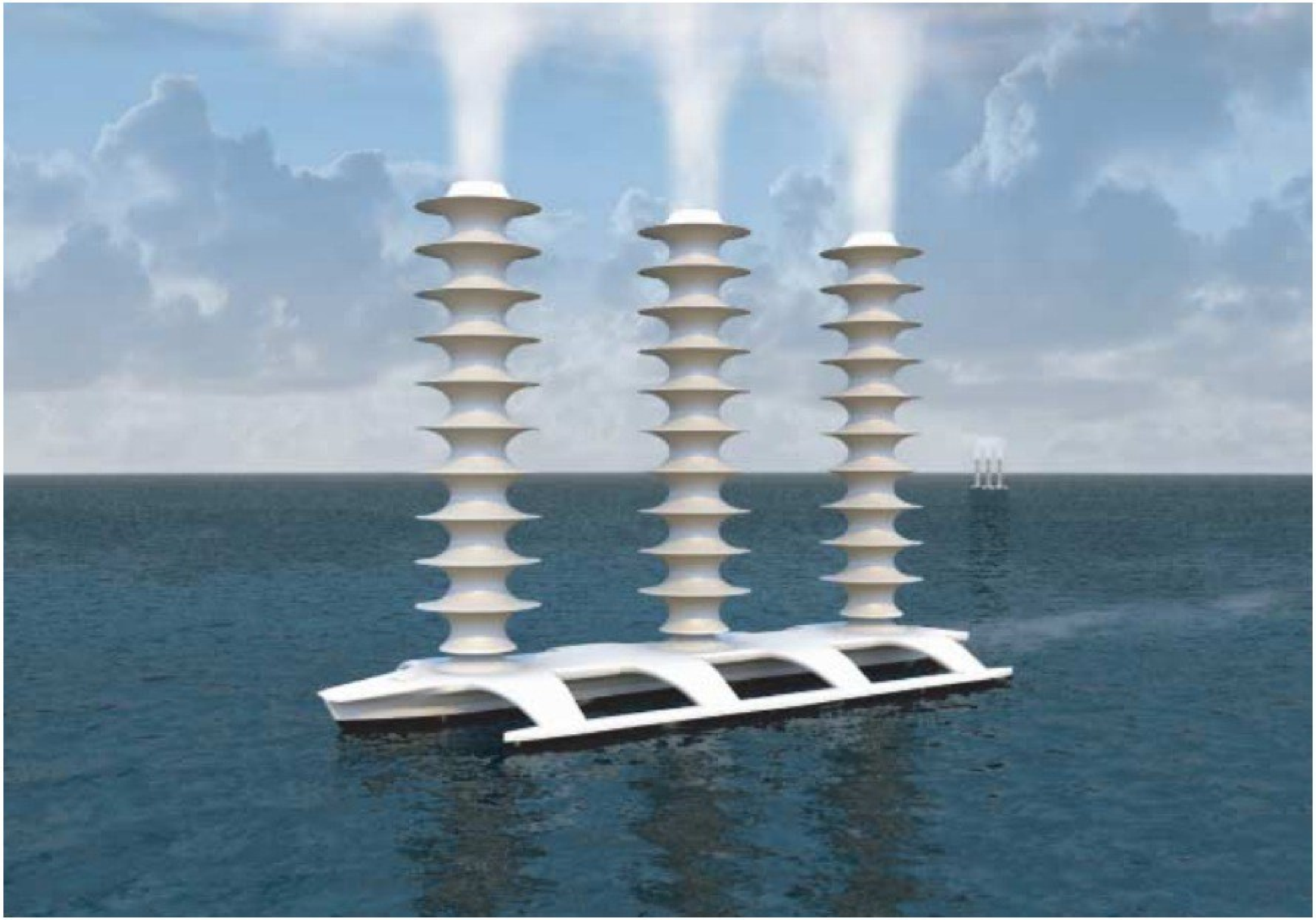


Image from Salter et. Al. 2008

Methodology

Simulations were carried out in the Norwegian Earth System Model (NorESM)
Spatial resolution of 1.9° x 2.6°

26 vertical levels

CAM4-Oslo, the atmospheric component of NorESM includes a prognostic double-moment cloud microphysics shceme and a detailed aerosol module which allow for the calculations of aerosol indirect effects.

Geo-engineering simulations

Simulations were run for 7 years and 5 years were analyzed
Runs were offline
Simulations were run with a fully coupled ocean, land carbon cycle, year 2000 greenhouse gas concentrations and year 2000 CIMP5 aerosol emissions

Experiments

Four expriments were carried out
Control run
Two runs with added CDNC

- -CDNC+50 cm-3

- -CDNC+375 cm-3

One run with CDNC=375 cm-3
Changes only made over ocean

Comparison between control and N+50 simulations

Control run

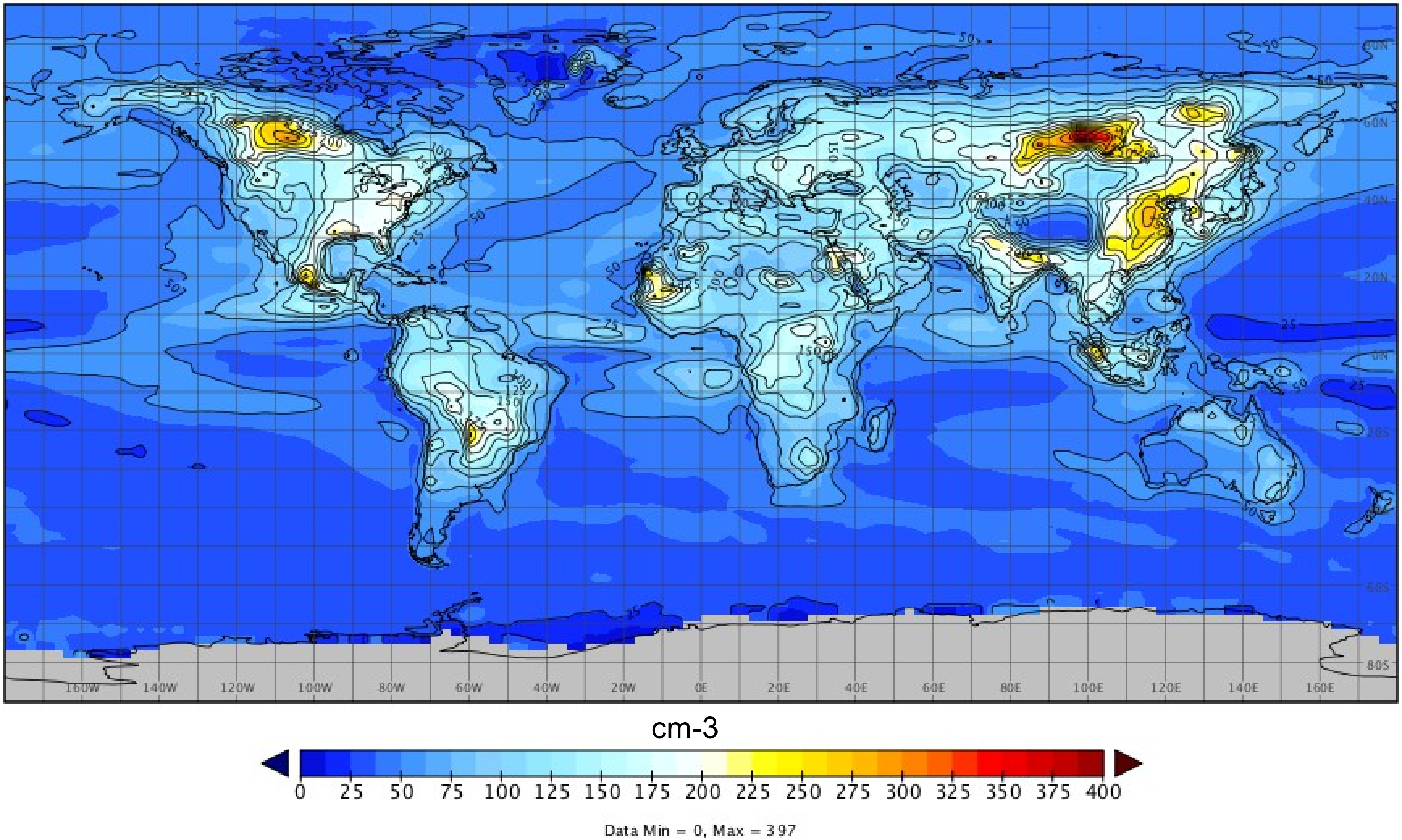
Mean value of SWCF -45.39 W/m2
Mean value of in-cloud re is 10 μm
Mean value of CDNC is 48.97 cm-3

N+50 cm-3

Mean value of SWCF -47.55 W/m2
Difference of -2.47 W/m2 from control run
Mean value of in-cloud re is 8.55 μm

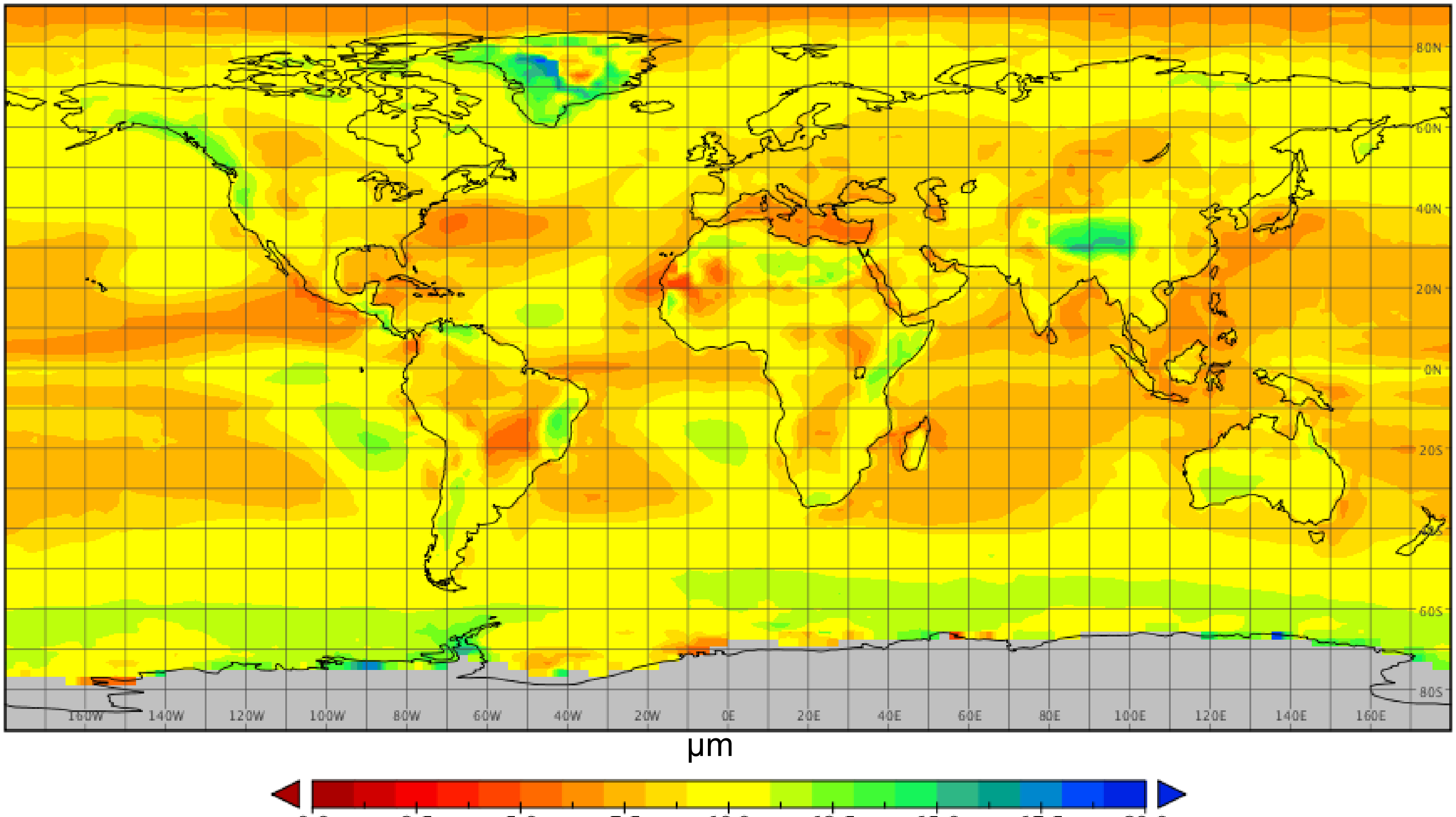
Cloud Droplet Number Concentration

Control run

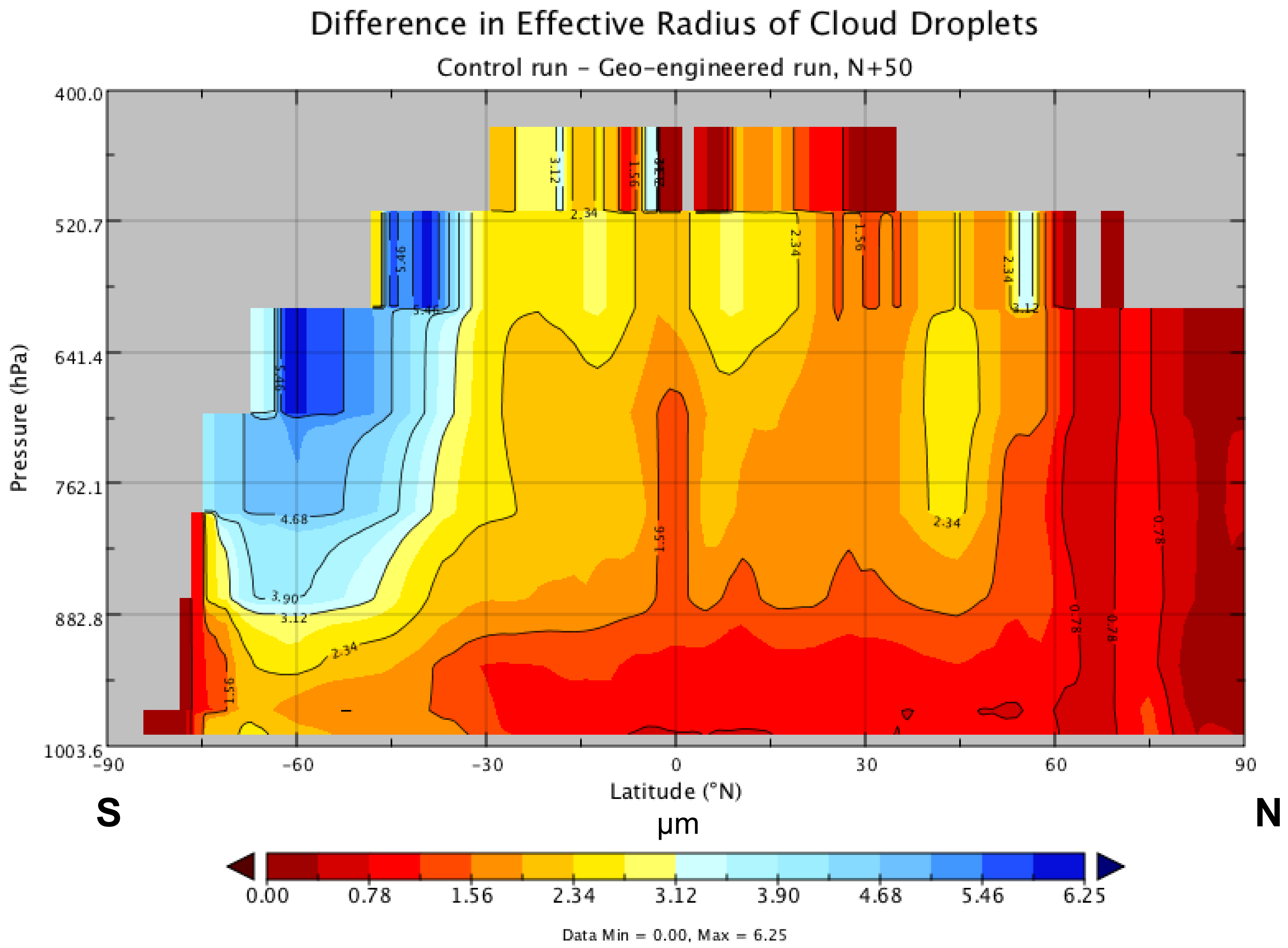


Effective Radius of Cloud Droplets

Control run



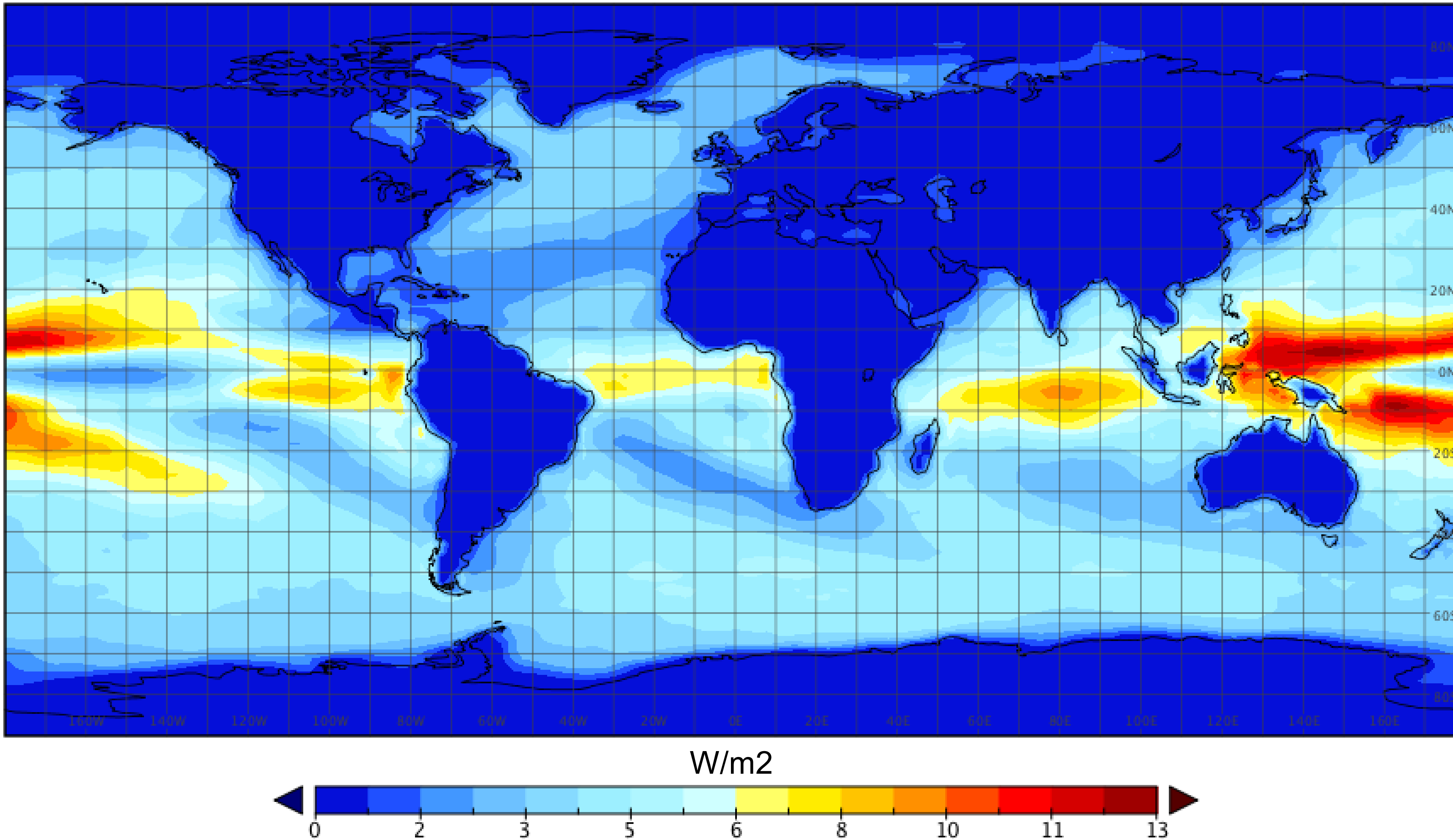
Data Min = 4.1, Max = 18.7



Difference in Effective Radius of Cloud Droplets
Control run - Geo-engineered run, N+50
Pressure (hPa)
400.0
520.7
641.4
762.1
882.8
1003.6
-90
-60
-30
0
30
60
90
Latitude (°N)
S
N
μm
0.00
0.78
1.56
2.34
3.12
3.90
4.68
5.46
6.25
Data Min = 0.00, Max = 6.25

Difference in shortwave cloud forcing

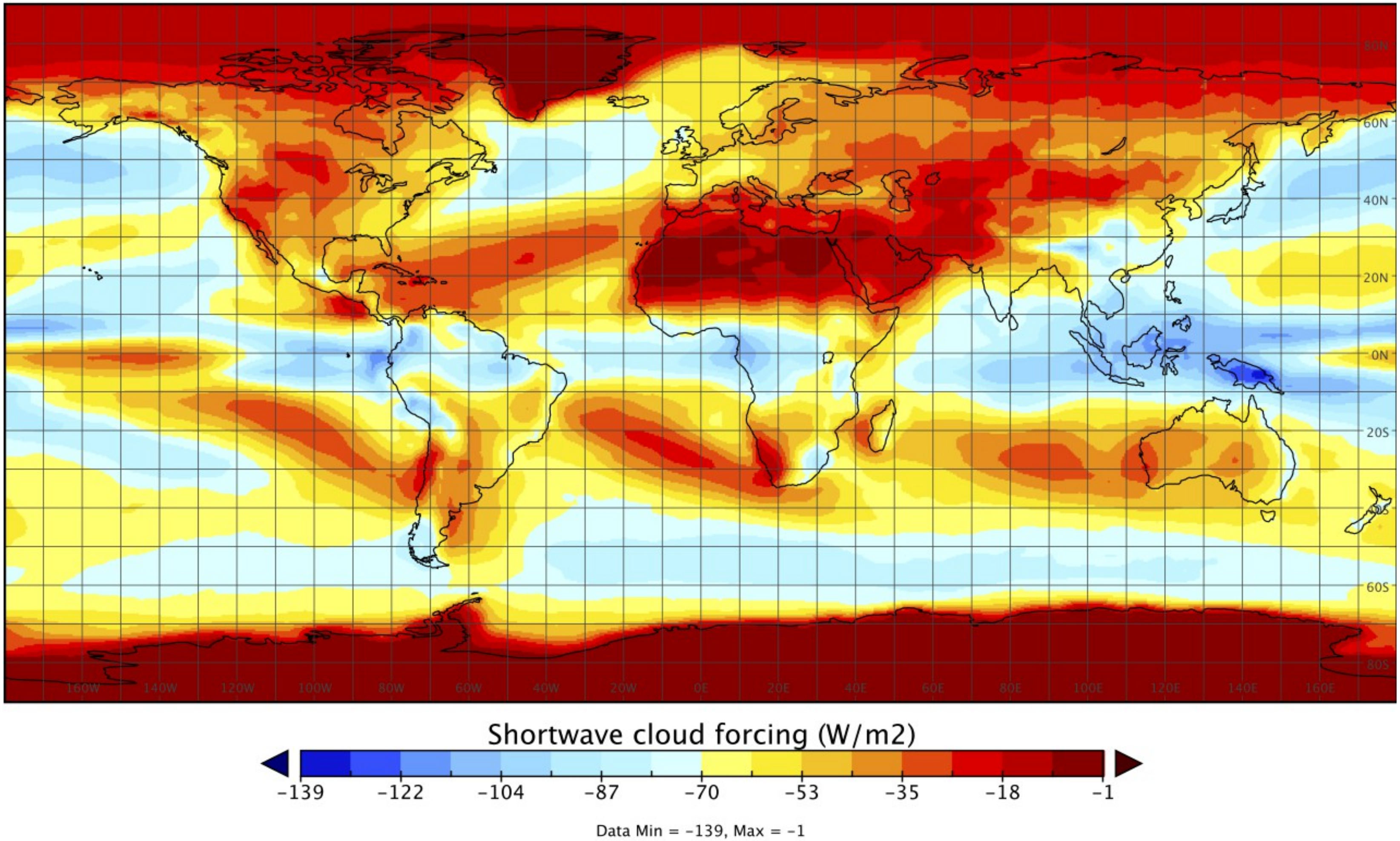
Control run - Geo-engineered run, N+50



Data Min = 0, Max = 13

Shortwave cloud forcing

Geo-engineered run, N+50



Comparison between N+375 and N=375 simulations

N+375 cm-3

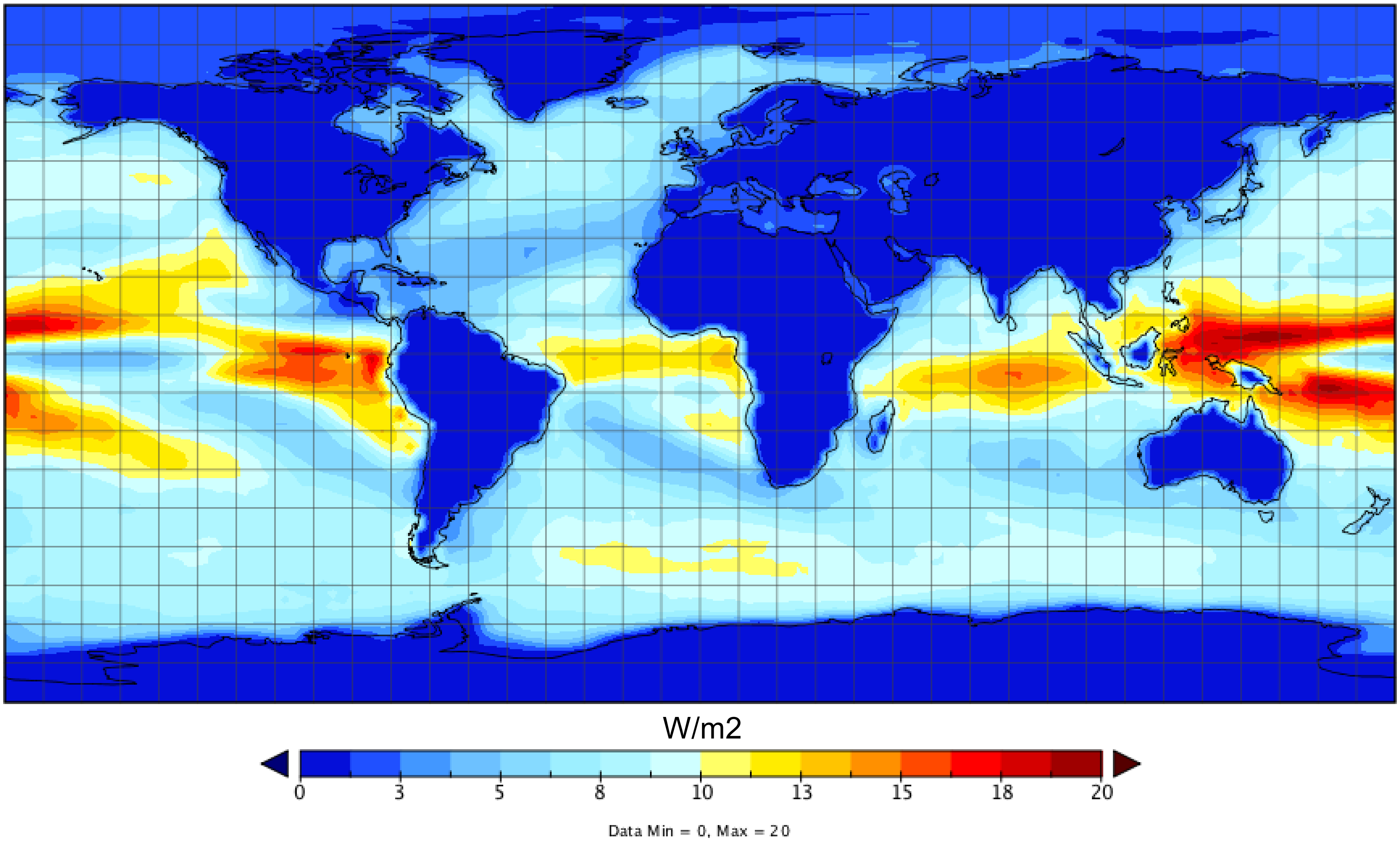
Mean value of SWCF -50.35 W/m2
Difference of -4.96 W/m2 from control run
Mean value of in-cloud re is 7.28 μm

N=375 cm-3

Mean value of SWCF -50.56 W/m2
Difference of -5.17 W/m2 from control run
Mean value of in-cloud re is 8.55 μm

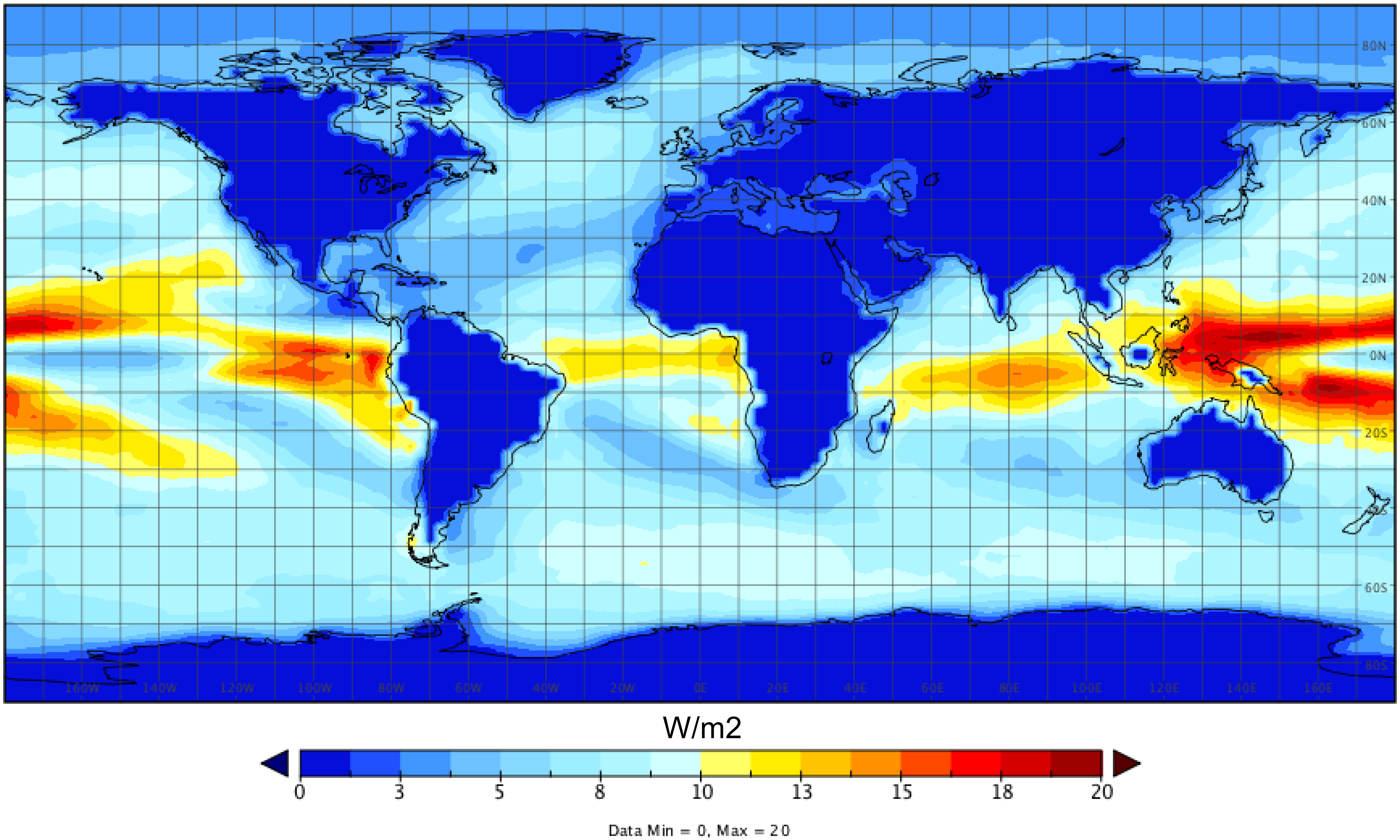
Difference in shortwave cloud forcing

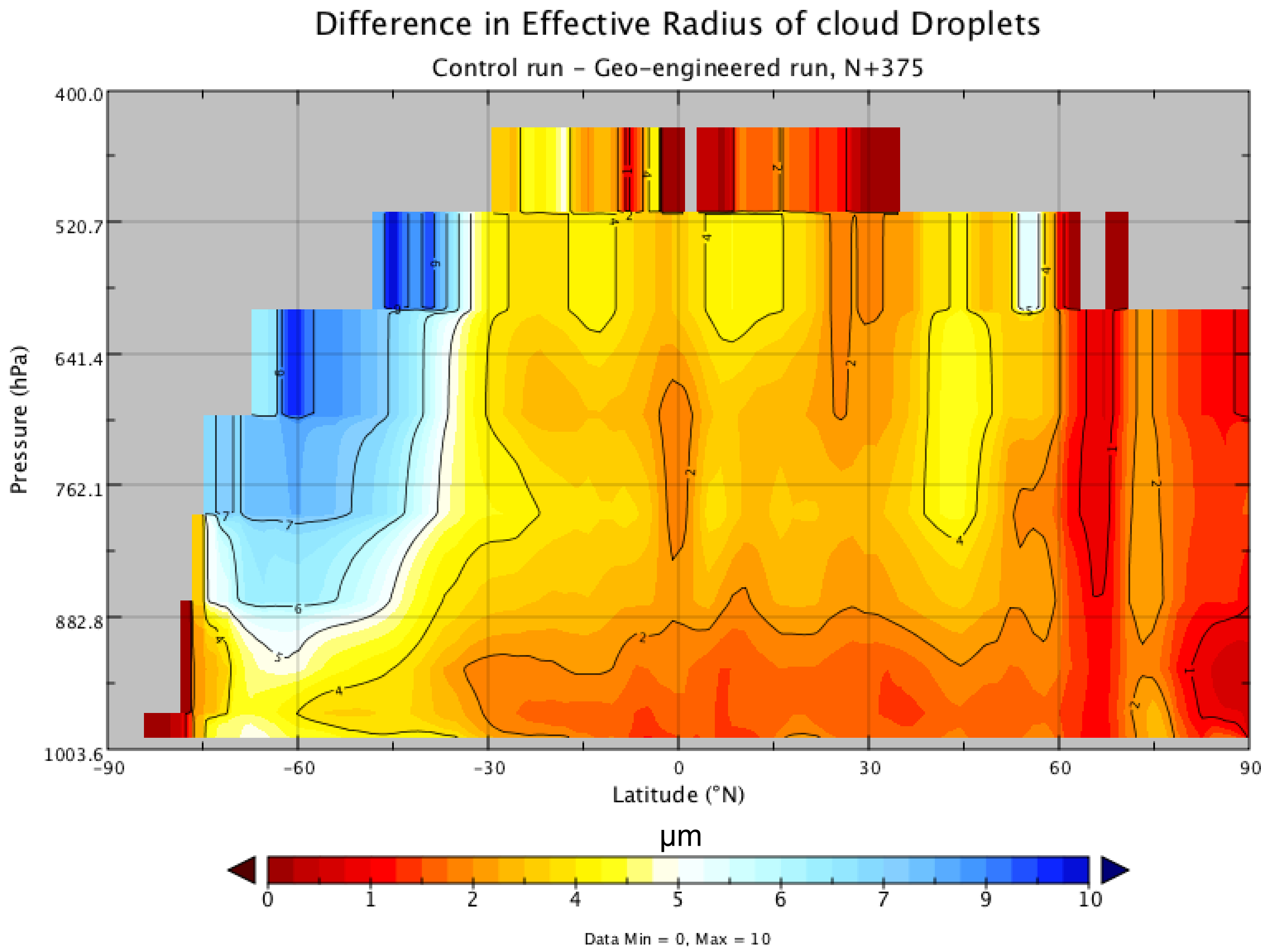
Control run – Geo-engineered run, N+375

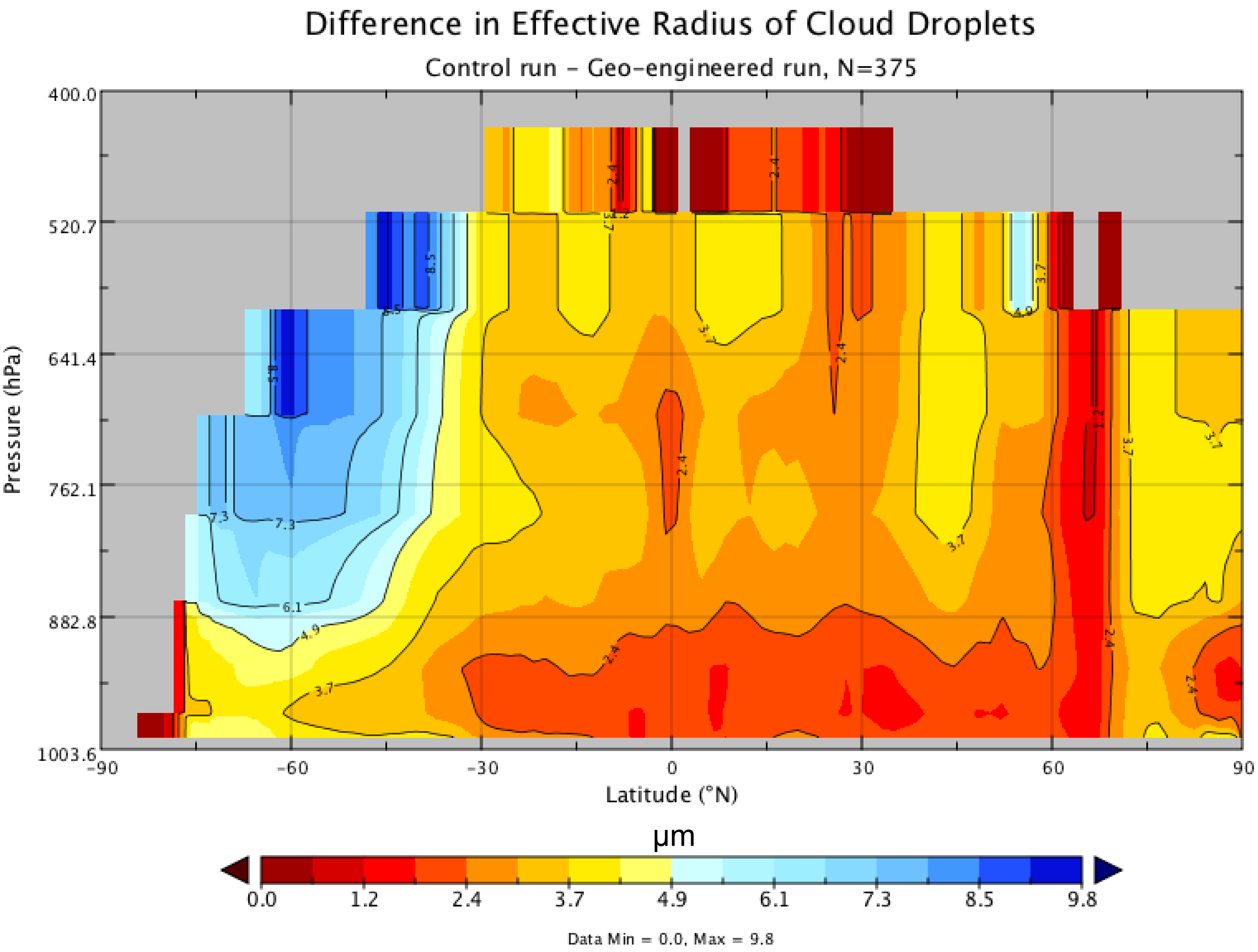


Difference in shortwave cloud forcing

Control run - Geo-engineered run, N=375 over ocean

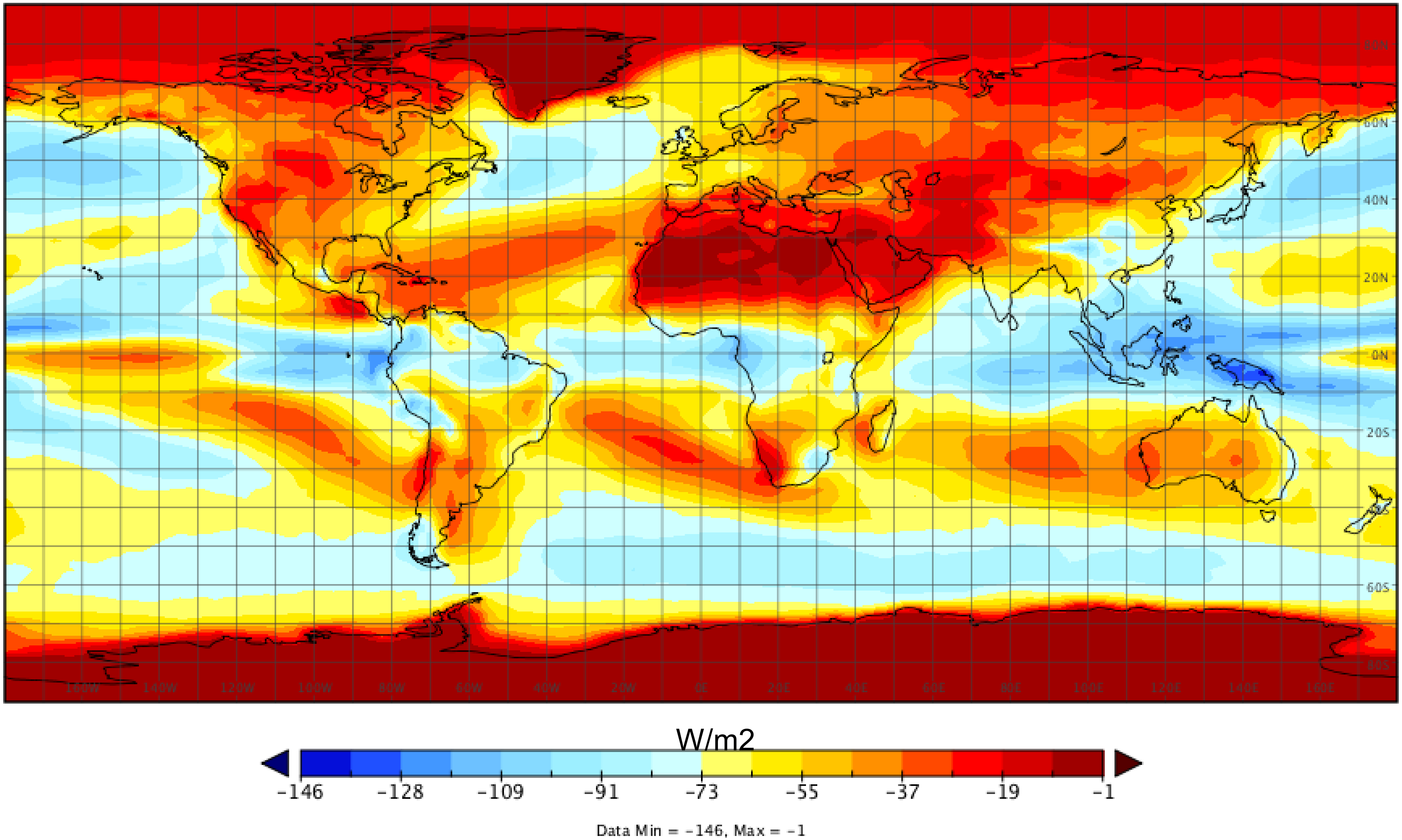



Difference in Effective Radius of cloud Droplets
Control run - Geo-engineered run, N+375
Pressure (hPa)
400.0
520.7
641.4
762.1
882.8
1003.6
-90
-60
-30
0
30
60
90
Latitude (°N)
μm
0
1
2
4
5
6
7
9
10
Data Min = 0, Max = 10


Difference in Effective Radius of Cloud Droplets
Control run - Geo-engineered run, N=375
Pressure (hPa)
400.0
520.7
641.4
762.1
882.8
1003.6
-90
-60
-30
0
30
60
90
Latitude (°N)
μm
0.0
1.2
2.4
3.7
4.9
6.1
7.3
8.5
9.8
Data Min = 0.0, Max = 9.8

Shortwave cloud forcing

Geo-engineered run, N+375



Summary and conclusions

Marine cloud brightening has the potential to counteract global warming
Results compare to the results of previous studies
Experiments are highly idealized

Worth mentioning

Global climate models have a coarse spatial resolution
Further experiments are neccesary to increase level of confidence in this field
The idea is good but much work remains to be done