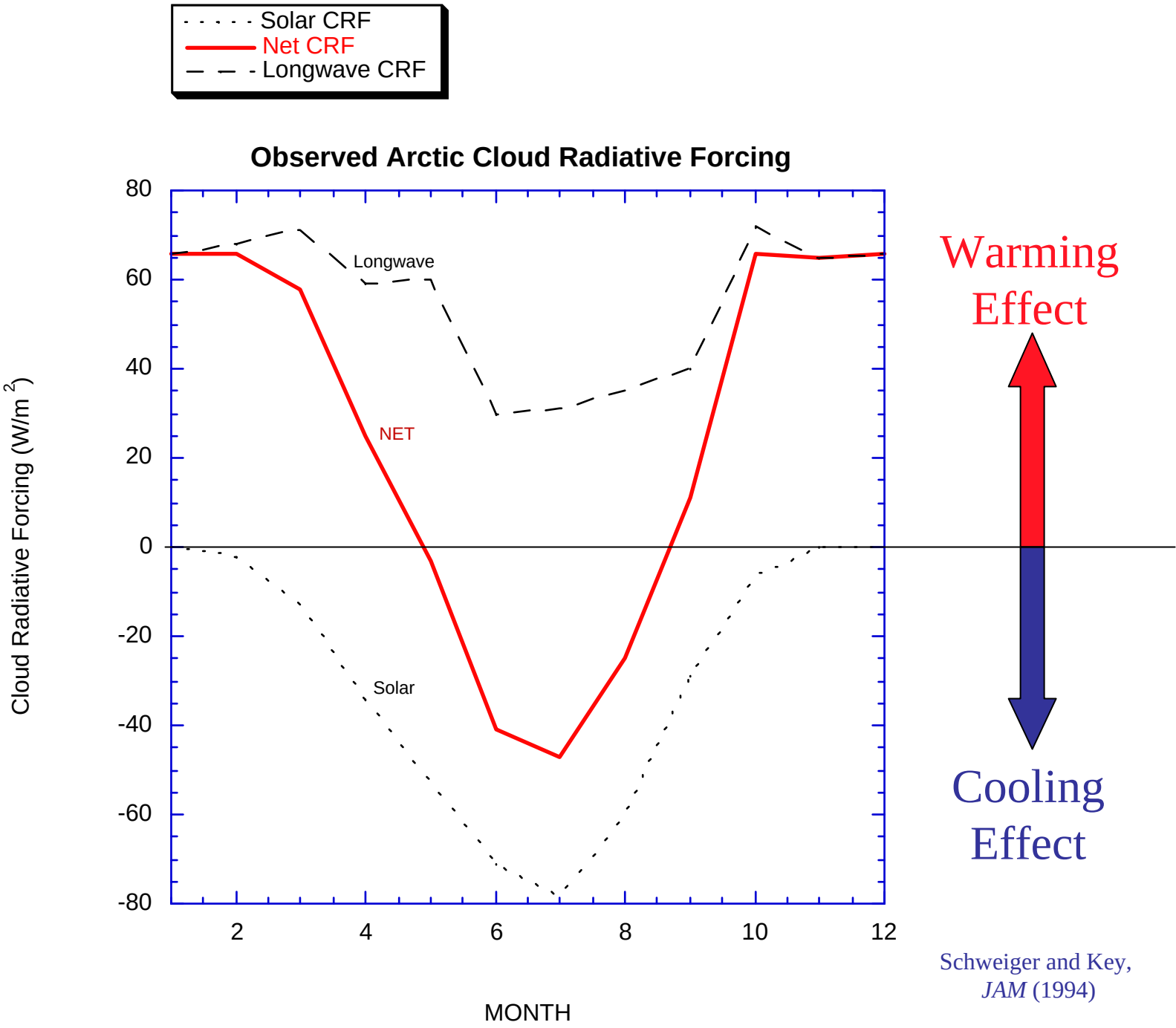
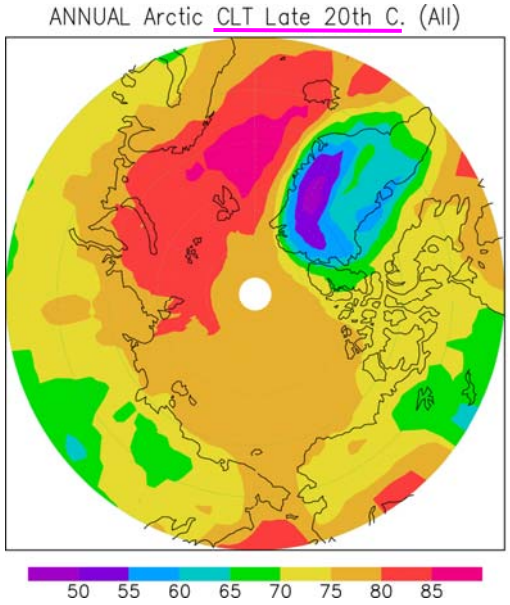
Arctic Cloud Changes in the CMIP3 Models Assessed for the IPCC AR4

Steve Vavrus (U. of Wisconsin)
Duane Waliser (Jet Propulsion Lab)
Jennifer Francis (Rutgers University)
Axel Schweiger (U. of Washington)


Solar CRF
Net CRF
Longwave CRF
Observed Arctic Cloud Radiative Forcing
Cloud Radiative Forcing (W/m 2)
80
60
40
20
0
-20
-40
-60
-80
2
4
6
8
10
12
MONTH
Longwave
NET
Solar
Warming Effect
Cooling Effect
Schweiger and Key, JAM (1994)

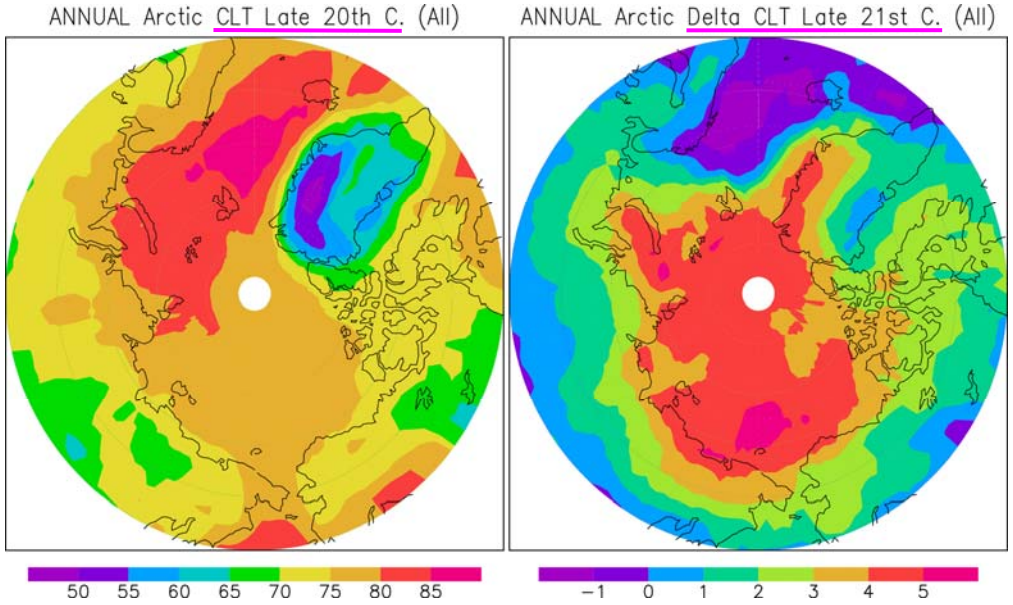
Simulated Annual Cloud Amount and Projected Changes

All Models



Simulated Annual Cloud Amount and Projected Changes

All Models

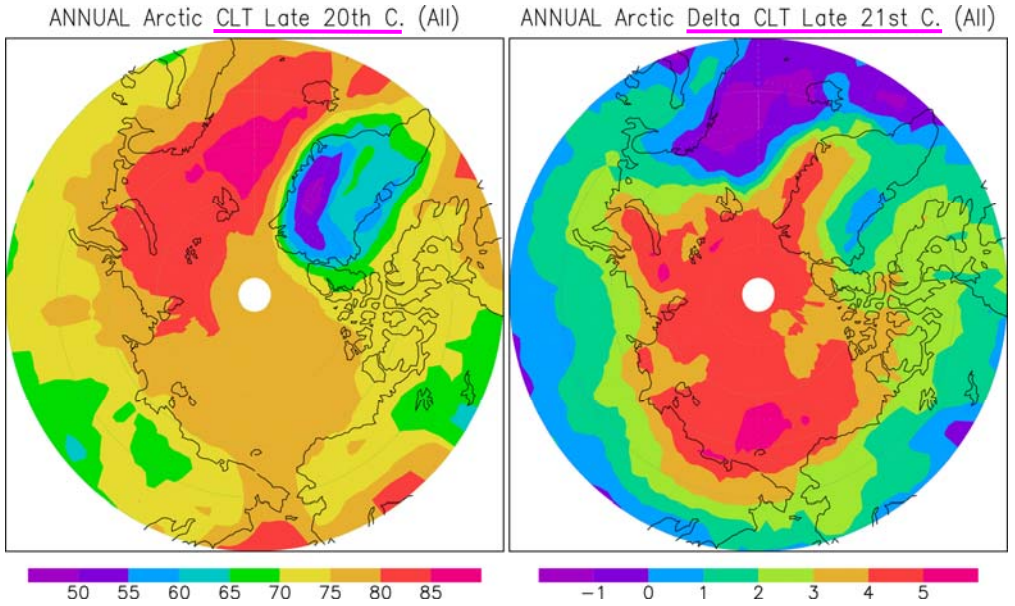


SRES A1B

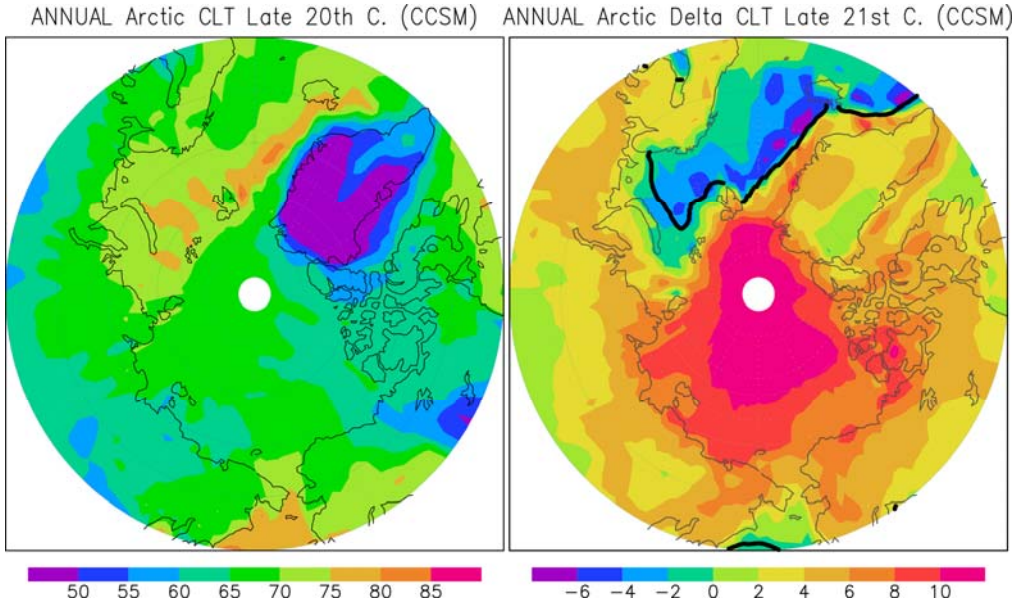
Simulated Annual Cloud Amount and Projected Changes

All Models

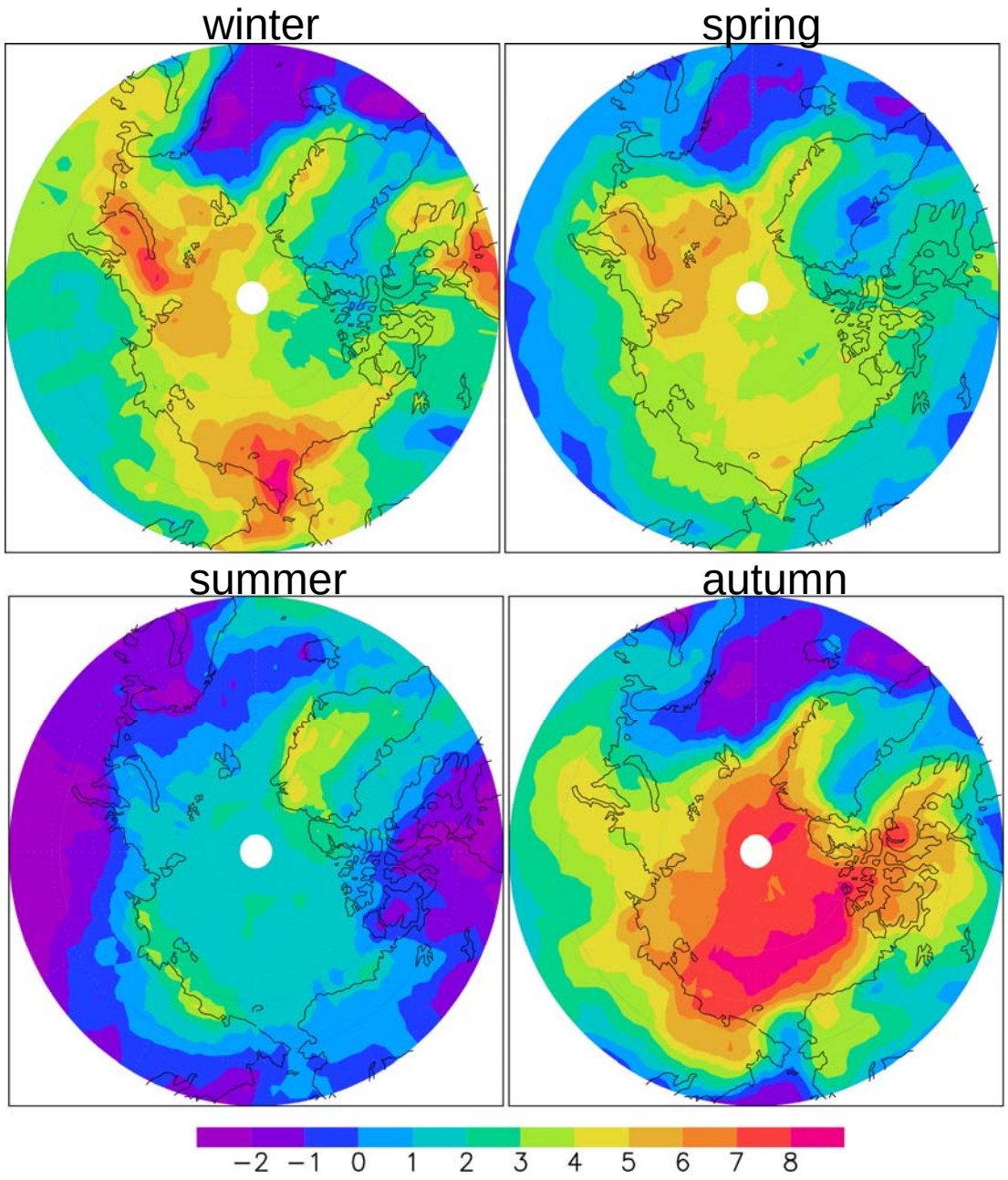
SRES A1B



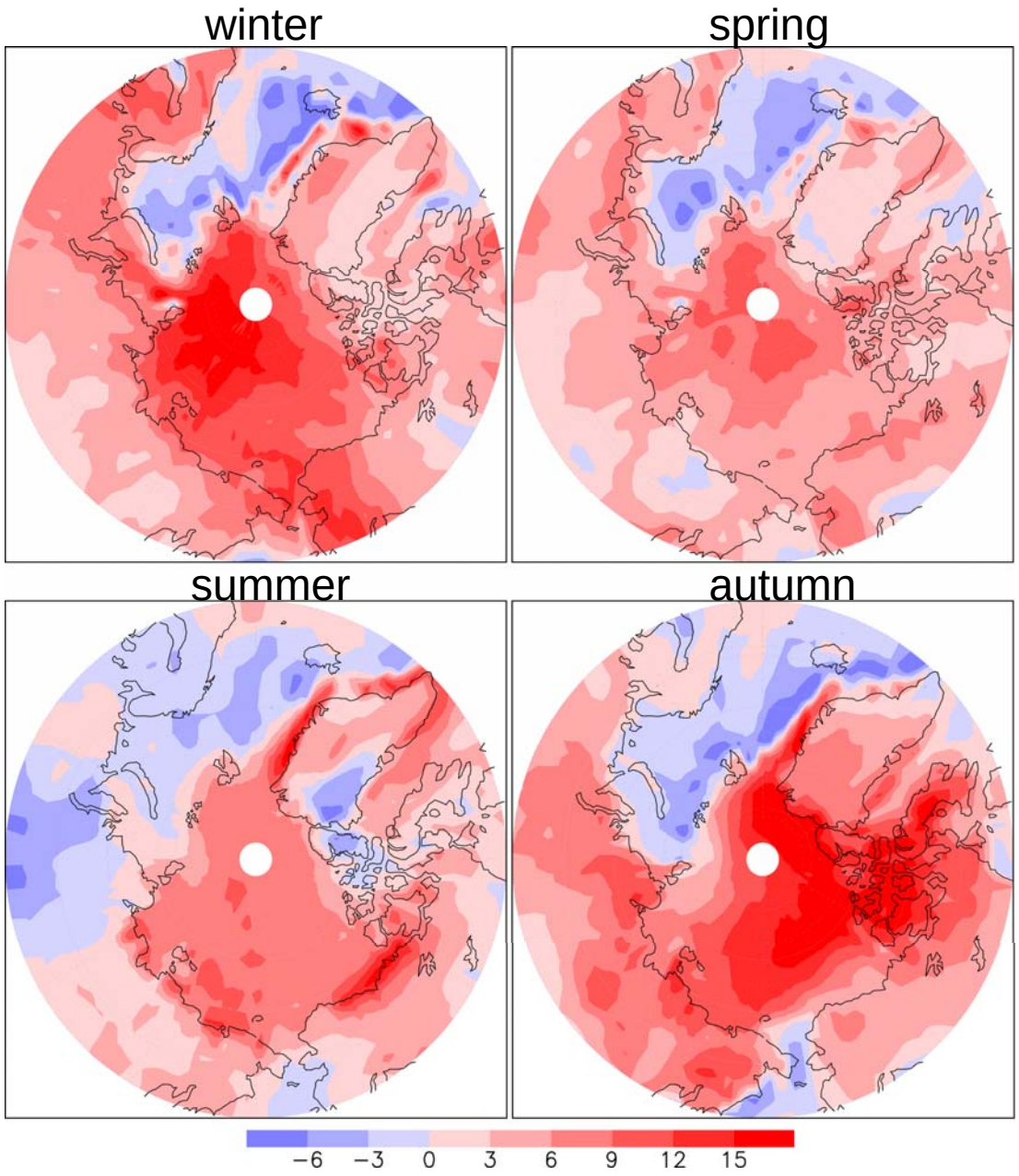
CCSM

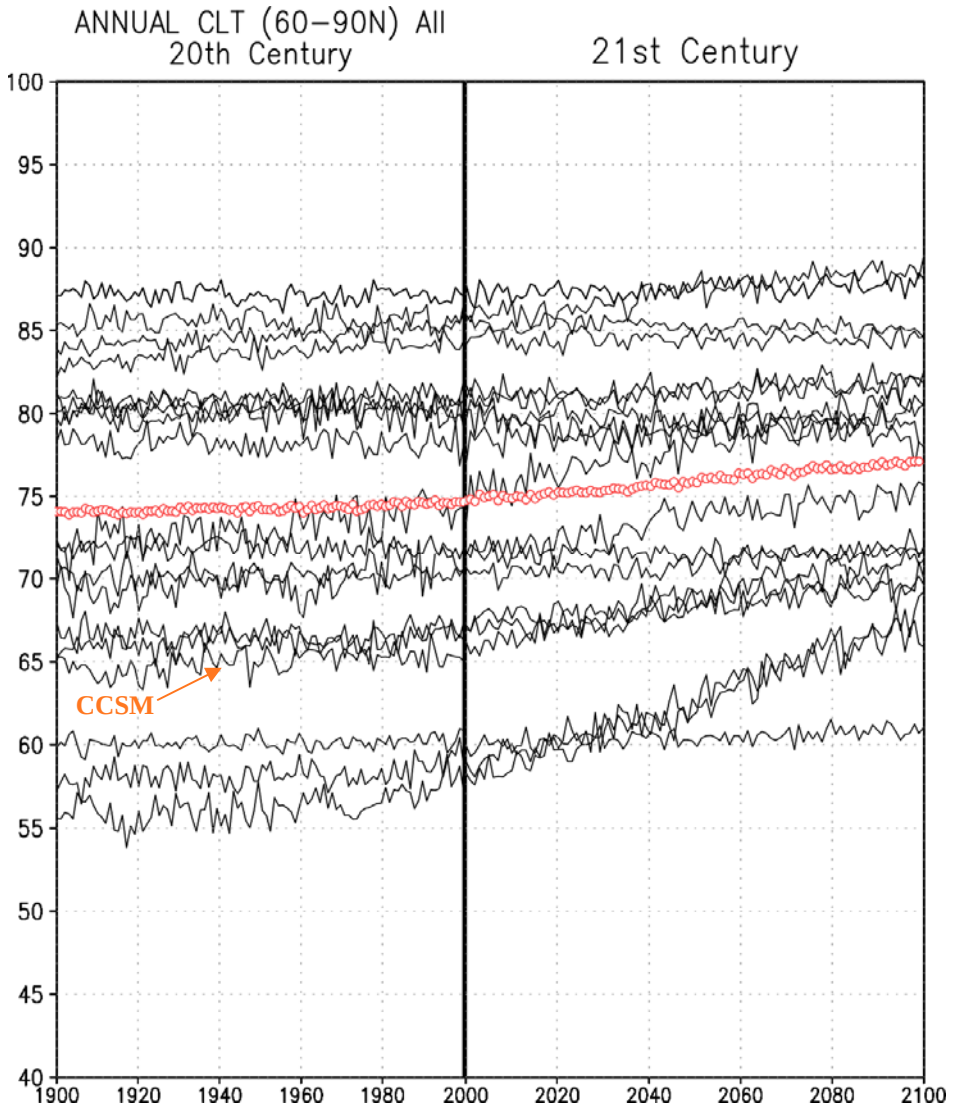


Seasonal Changes in Cloud Amount (20 GCMs)



Seasonal Changes in Cloud Amount (CCSM)




ANNUAL CLT (60–90N) All
20th Century
21st Century
100
95
90
85
80
75
70
65
60
55
50
45
40
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
CCSM

Why should the Arctic become cloudier?

1. Warmer climate ---> More liquid condensate ---> Longer residence time (Beesley and Moritz, 1999)

2. Sea ice retreat ---> Injection of moisture aloft ---> Spread of excess moisture over ice pack (regional effect)

3. Melting within ice pack ---> More evaporation ---> Excess moisture above sea ice (local effect)

4. Greater evaporation outside of Arctic ---> Excess moisture advected into Arctic (remote effect)

Why should the Arctic become cloudier?

1. Warmer climate ---> More liquid condensate ---> Longer residence time (Beesley and Moritz, 1999)

2. Sea ice retreat ---> Injection of moisture aloft ---> Spread of excess moisture over ice pack (regional effect)

3. Melting within ice pack ---> More evaporation ---> Excess moisture above sea ice (local effect)

4. Greater evaporation outside of Arctic ---> Excess moisture advected into Arctic (remote effect)

Why should the Arctic become cloudier?

1. Warmer climate ---> More liquid condensate ---> Longer residence time (Beesley and Moritz, 1999)

2. Sea ice retreat ---> Injection of moisture aloft ---> Spread of excess moisture over ice pack (regional effect)

3. Melting within ice pack ---> More evaporation ---> Excess moisture above sea ice (local effect)

4. Greater evaporation outside of Arctic ---> Excess moisture advected into Arctic (remote effect)

Why should the Arctic become cloudier?

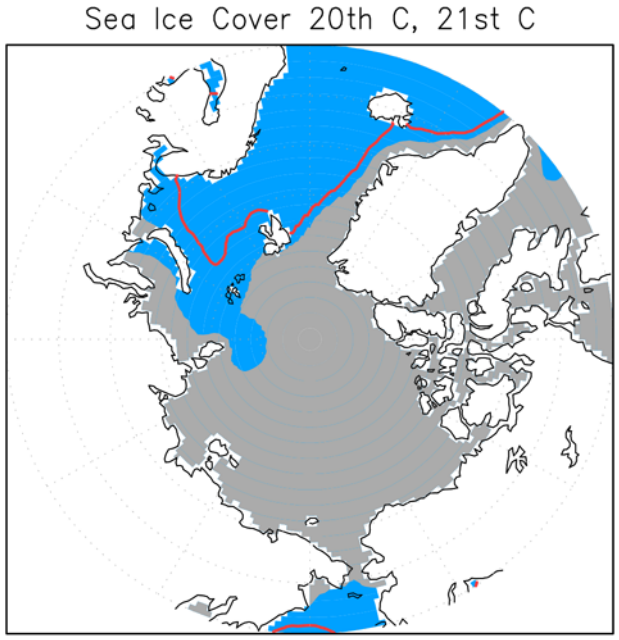
1. Warmer climate ---> More liquid condensate ---> Longer residence time (Beesley and Moritz, 1999)

2. Sea ice retreat ---> Injection of moisture aloft ---> Spread of excess moisture over ice pack (regional effect)

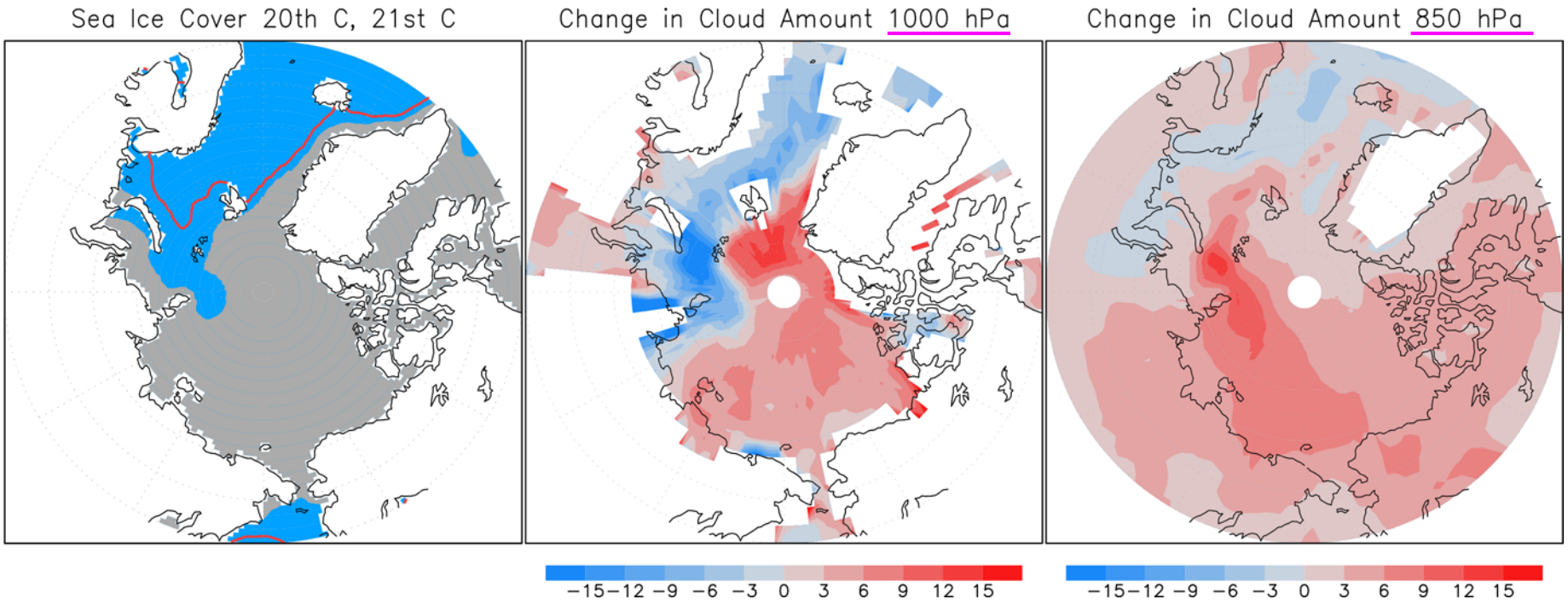
3. Melting within ice pack ---> More evaporation ---> Excess moisture above sea ice (local effect)

4. Greater evaporation outside of Arctic ---> Excess moisture advected into Arctic (remote effect)

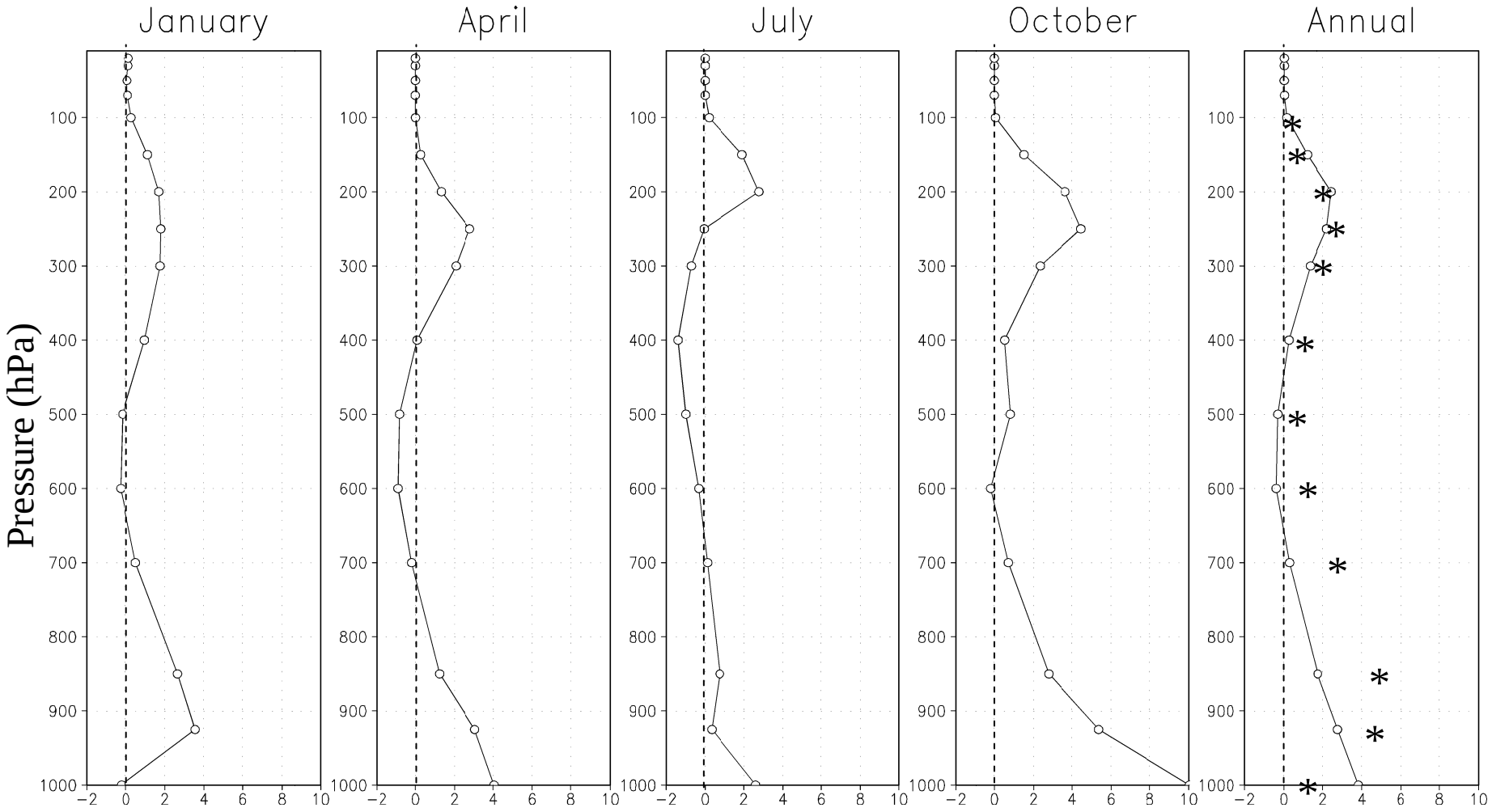
CCSM Changes in Sea Ice and Clouds (Late 21st Century)



CCSM Changes in Sea Ice and Clouds (Late 21st Century)

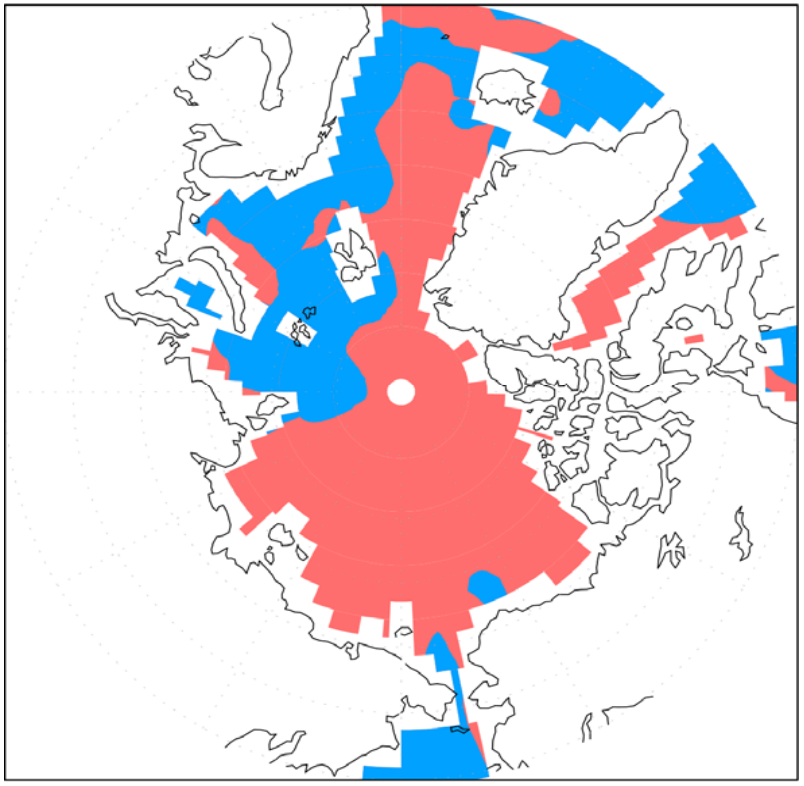


Changes in Late-21st Century Cloud Amount at 80N
(BCCR, CCCMAT47(63), CCSM, MIROCMR, MRI)



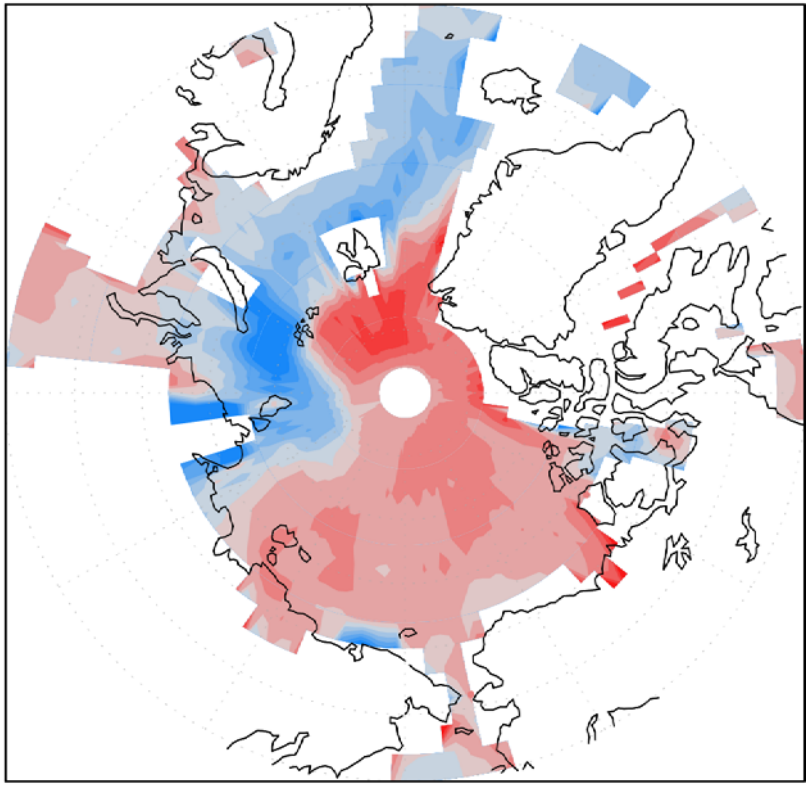
*CCSM

Change in LH Flux Late 21st Century
CCSM Annual



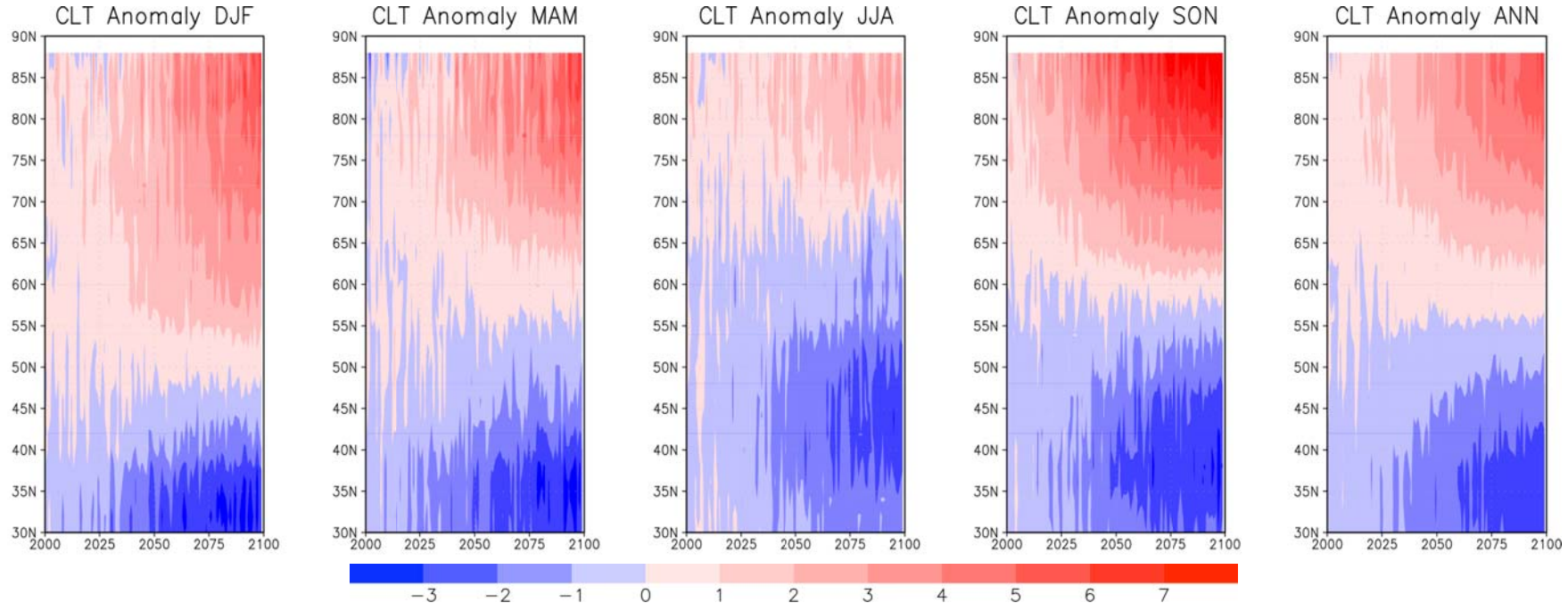
10

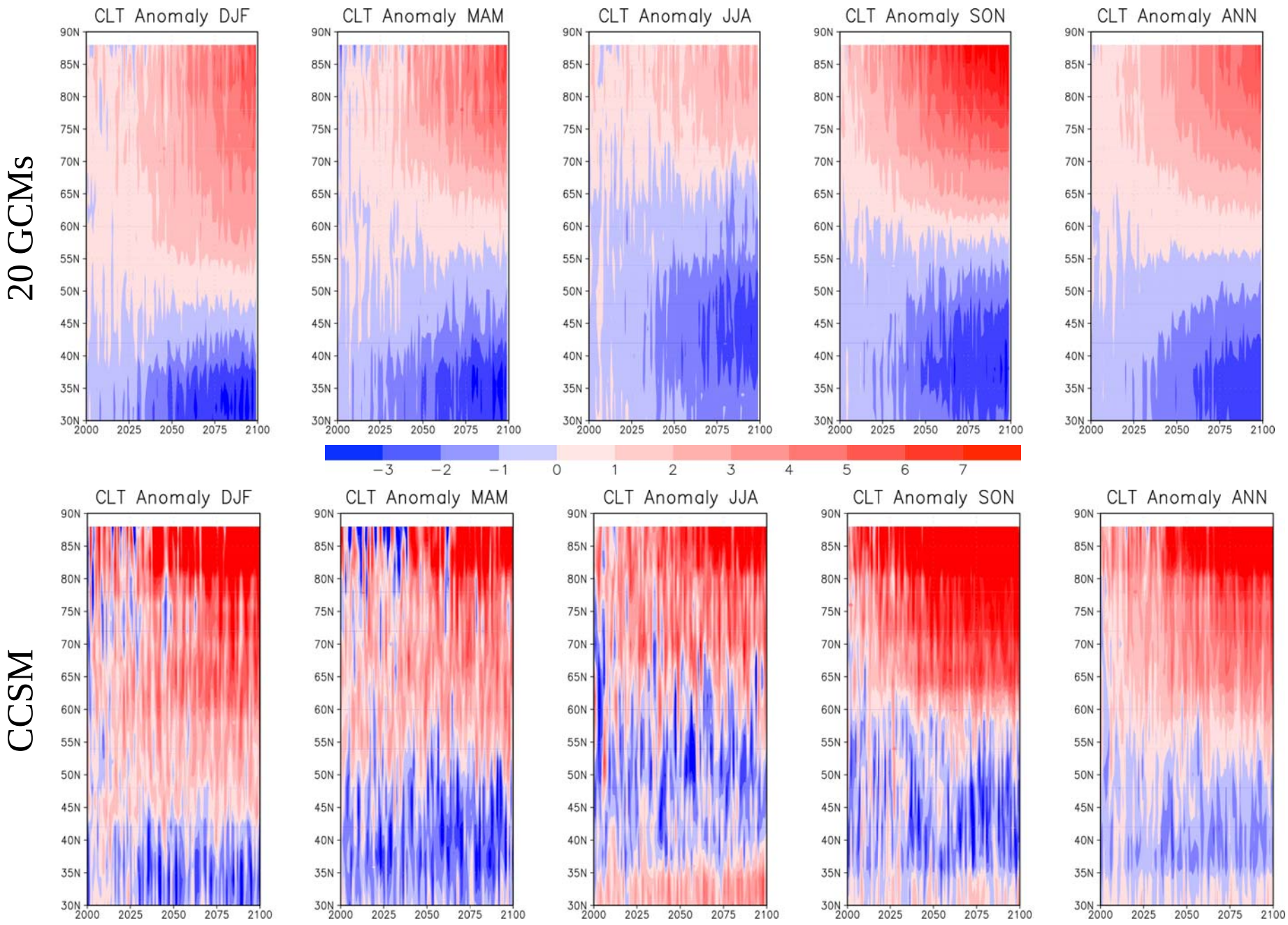
Change in Cloud Amount 1000 hPa



−15 −12 −9 −6 −3 0 3 6 9 12 15

20 GCMs


CLT Anomaly DJF
CLT Anomaly MAM
CLT Anomaly JJA
CLT Anomaly SON
CLT Anomaly ANN
90N
85N
80N
75N
70N
65N
60N
55N
50N
45N
40N
35N
30N
2000
2025
2050
2075
2100
−3
−2
−1
0
1
2
3
4
5
6
7

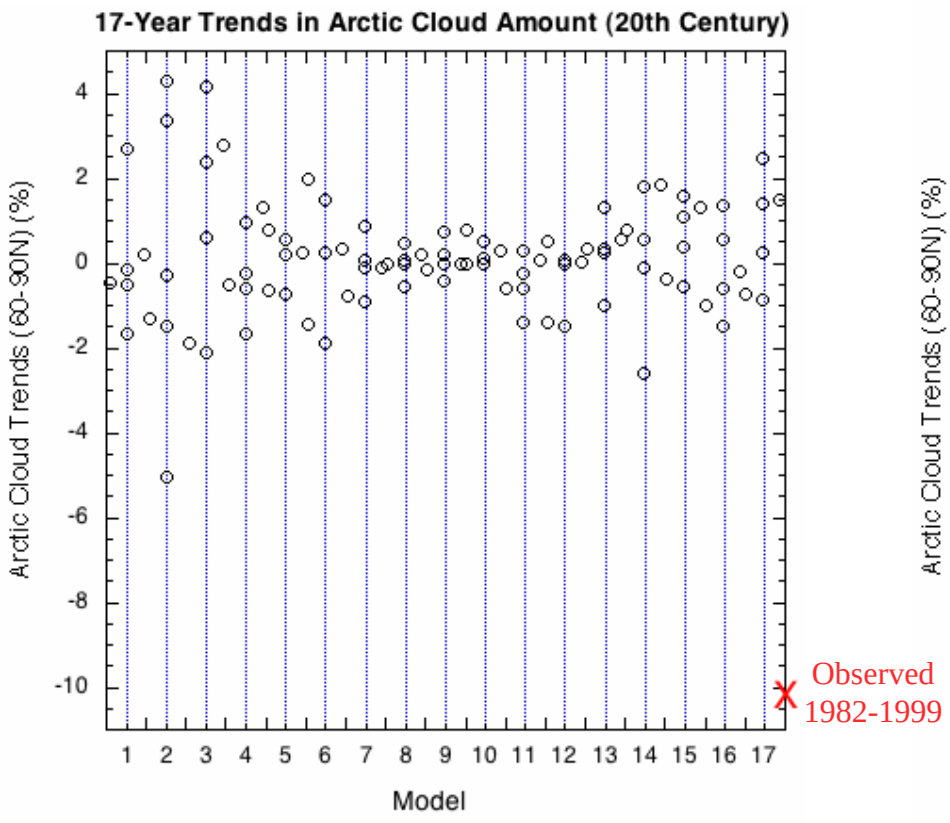

20 GCMs
CCSM
CLT Anomaly DJF
CLT Anomaly MAM
CLT Anomaly JJA
CLT Anomaly SON
CLT Anomaly ANN
90N
85N
80N
75N
70N
65N
60N
55N
50N
45N
40N
35N
30N
2000
2025
2050
2075
2100
−3
−2
−1
0
1
2
3
4
5
6
7

Summary

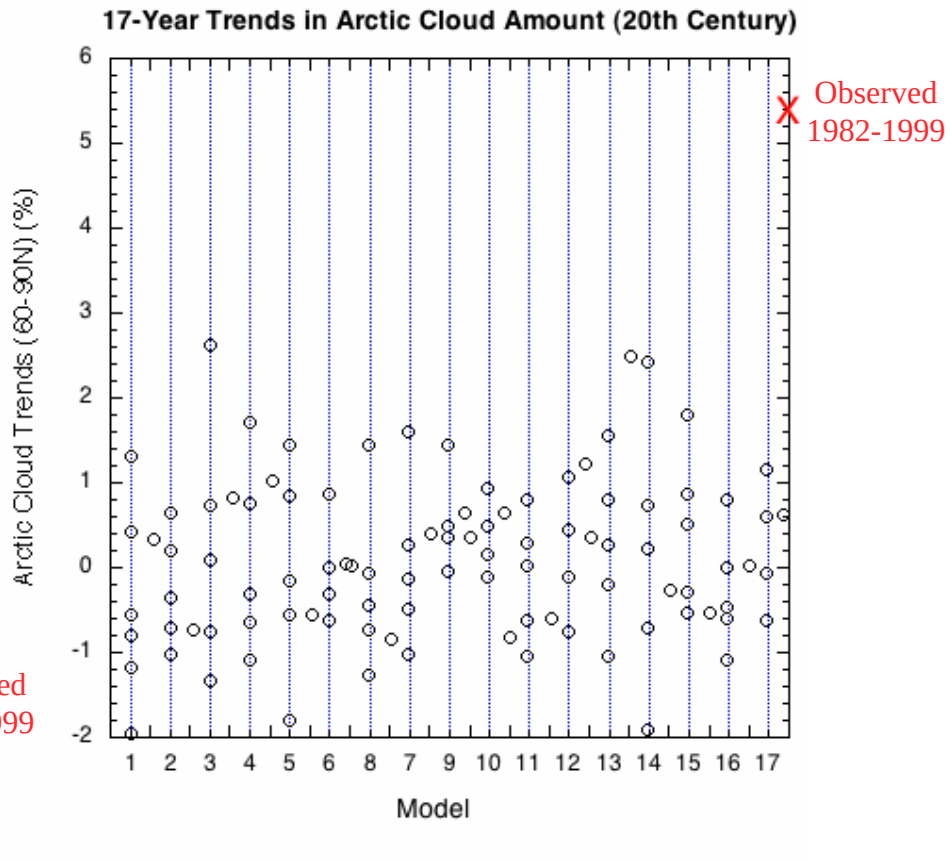
- Arctic clouds are generally a warming influence on surface climate
- GCMs simulate greater Arctic cloudiness under greenhouse warming, but fewer clouds in middle latitudes and Nordic Seas
- Future Arctic cloud increases peak at low and high levels, during autumn-winter, and over sea ice
- CCSM agrees with other models but has accentuated response
- *Primary* cause of projected Arctic cloud increases is “up in the air”

Simulated and Observed Arctic Cloud Variability

WINTER



SPRING



Observations from Wang and Key (2003)