Arctic Clouds and Climate Change

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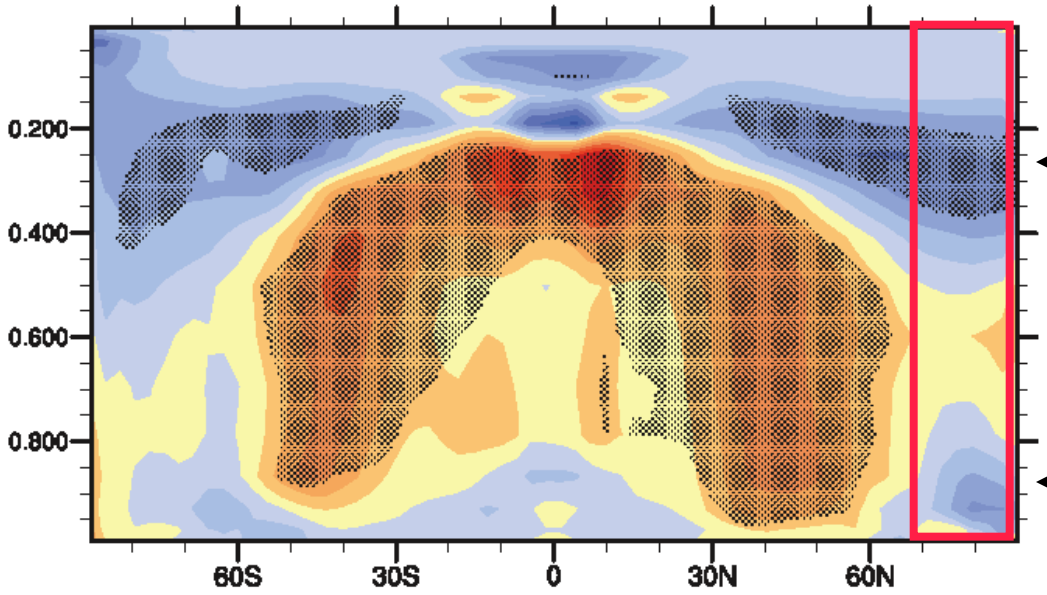
* Future time-mean Arctic cloud response (CMIP3, CCSM)

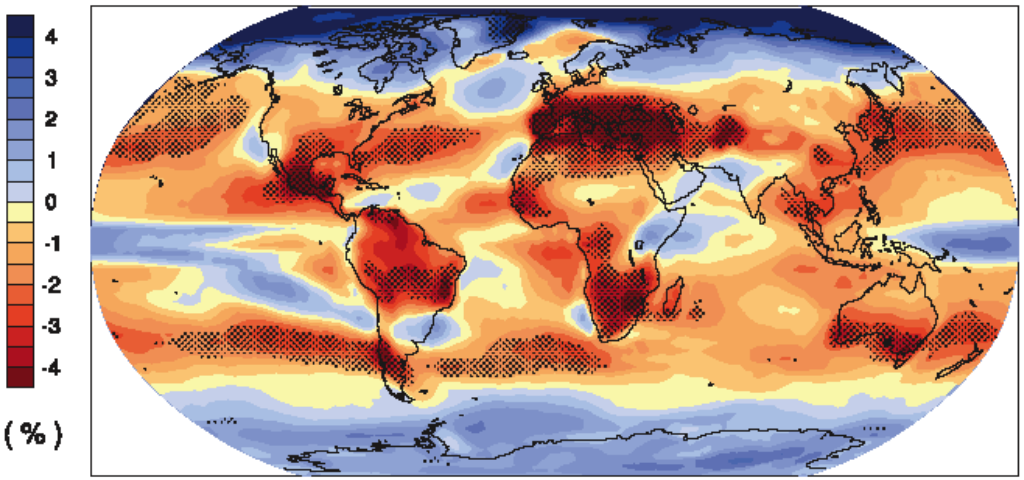
* Role of Arctic clouds in abrupt change (rapid ice loss)

Intermodel Mean Cloud Changes (CMIP3)



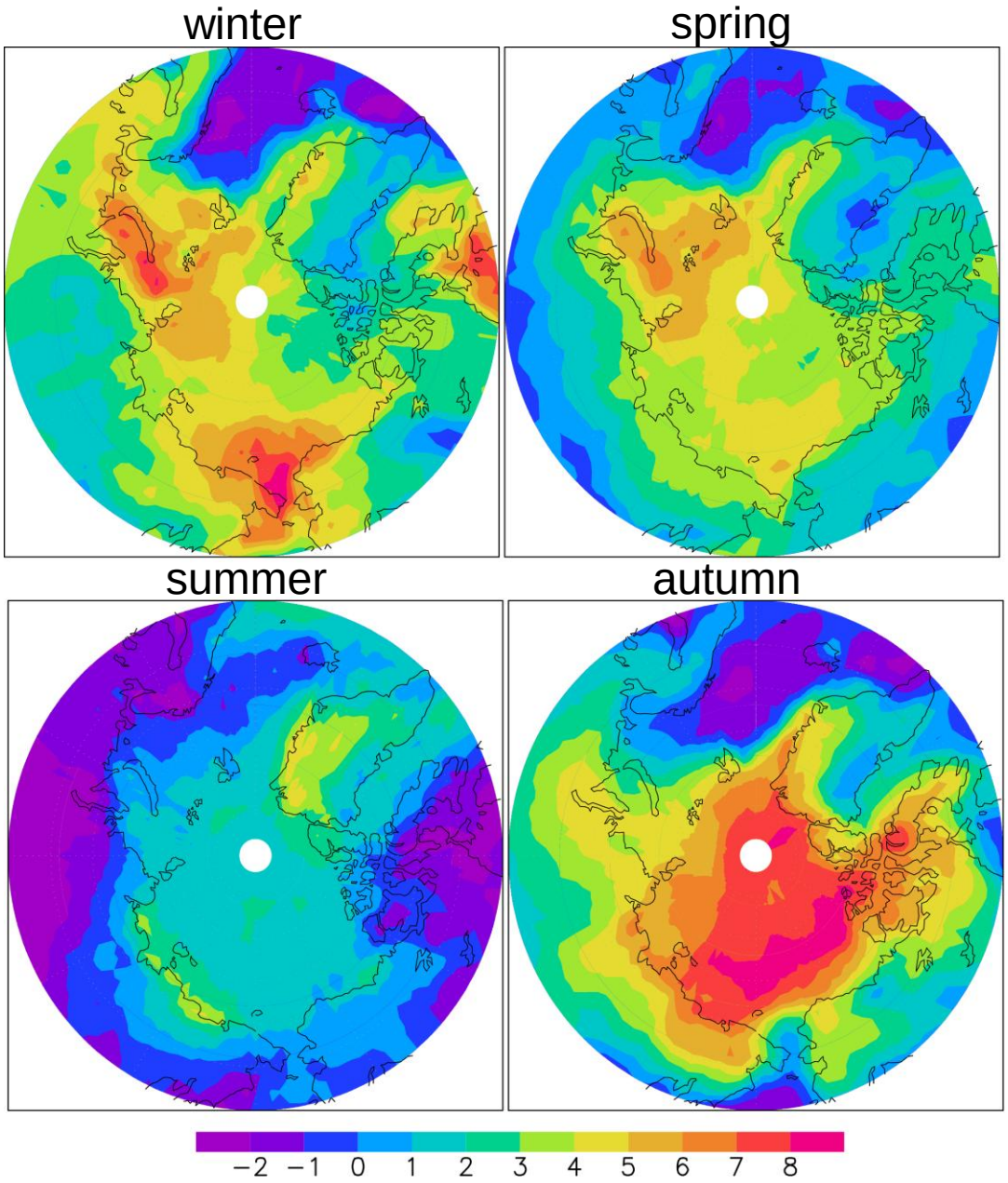
Global
High Cloud
Increase

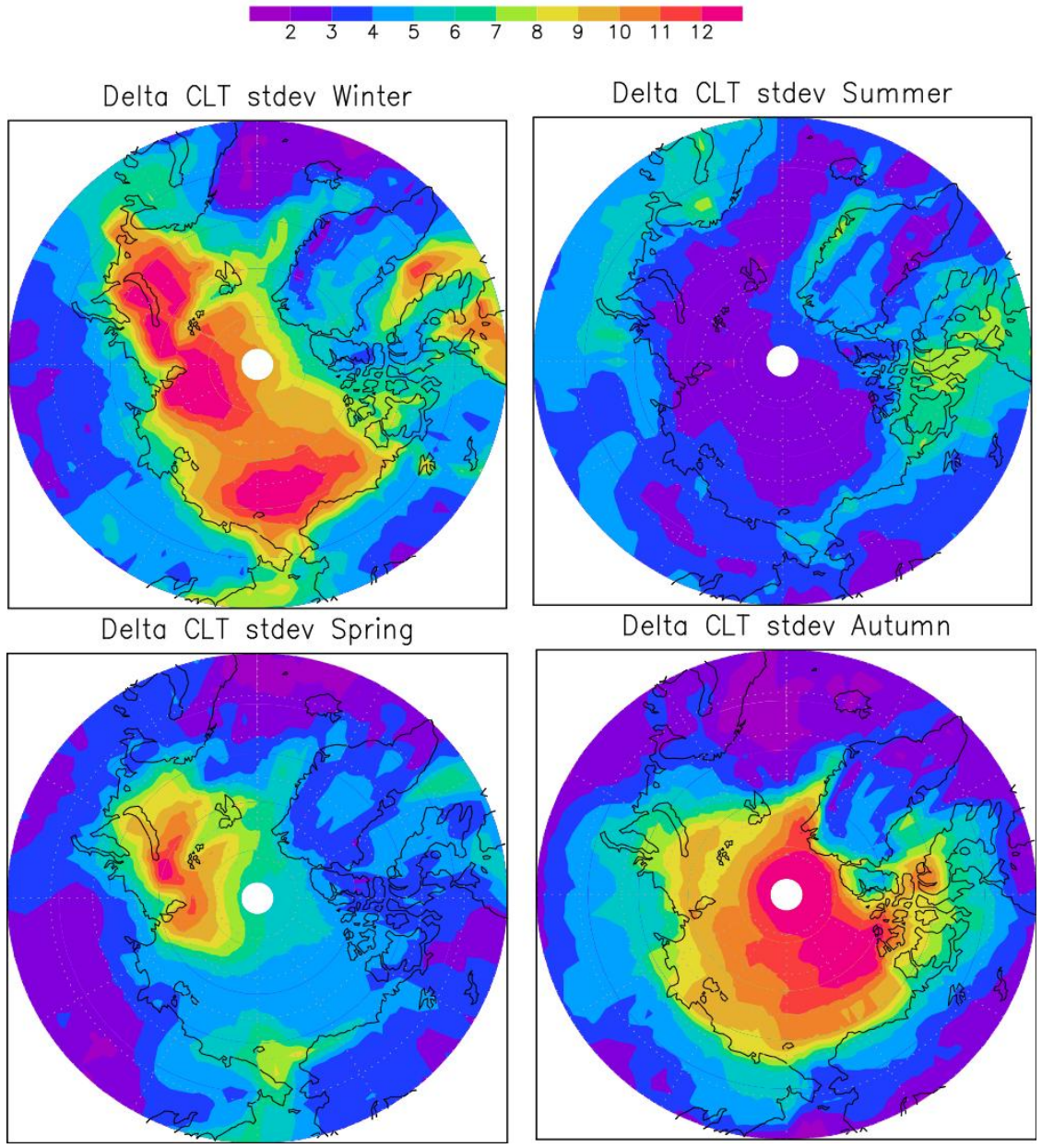
Polar
Low Cloud
Increase



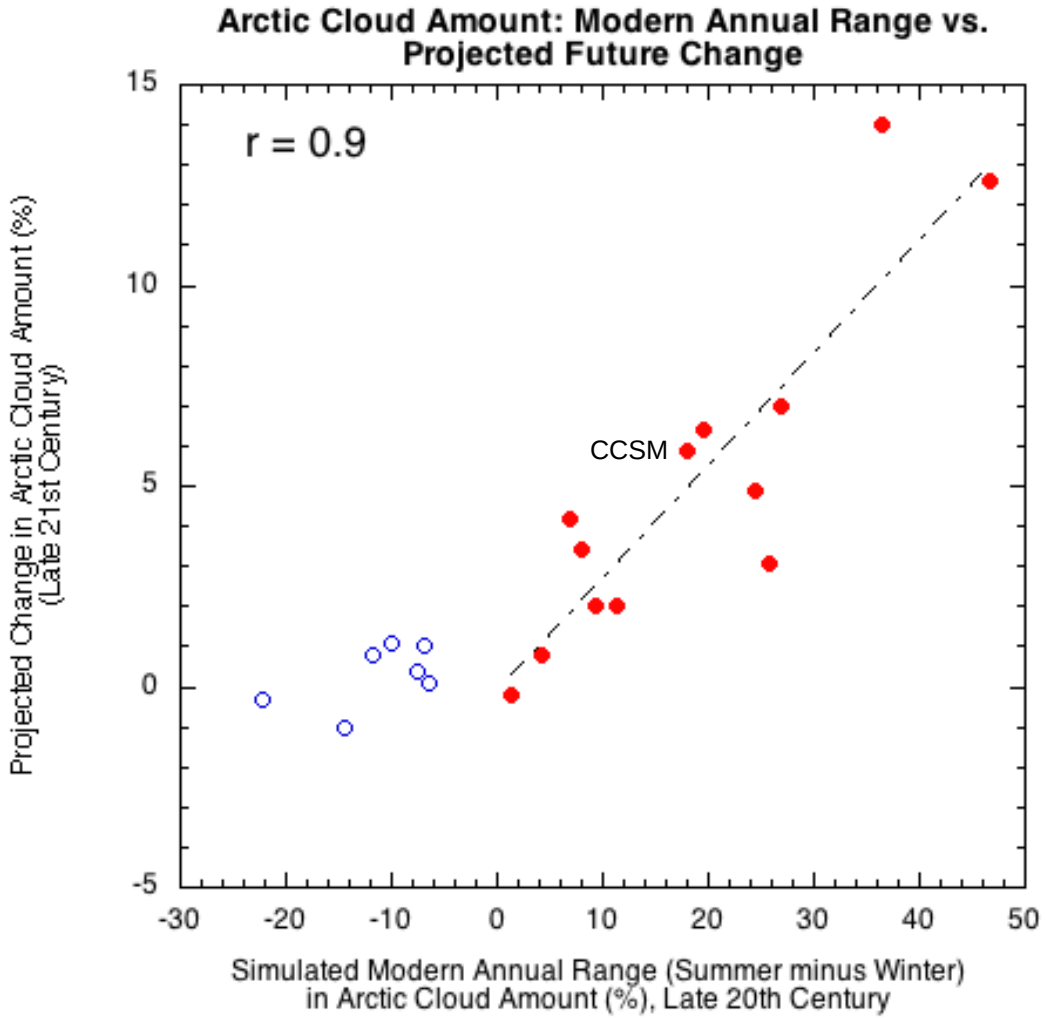
Late 21st century

Seasonal Changes in Cloud Amount (20 GCMs)



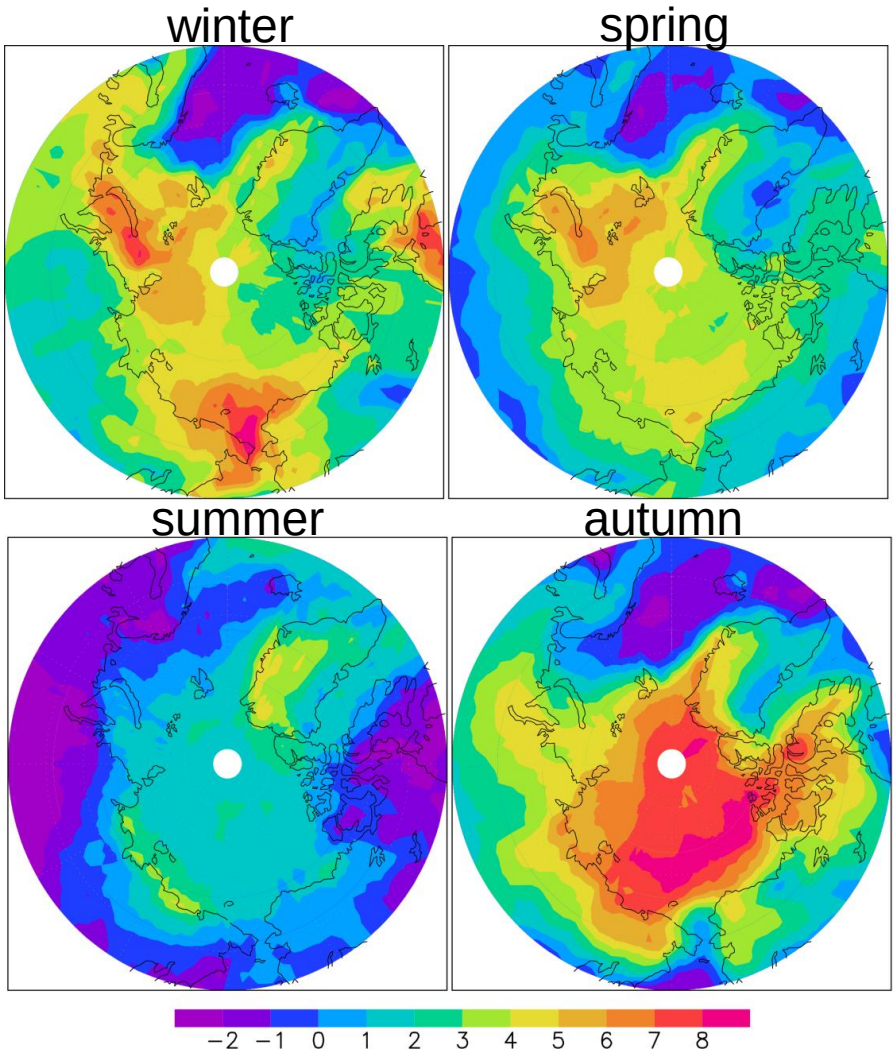

2 3 4 5 6 7 8 9 10 11 12
Delta CLT stdev Winter
Delta CLT stdev Summer
Delta CLT stdev Spring
Delta CLT stdev Autumn

Future

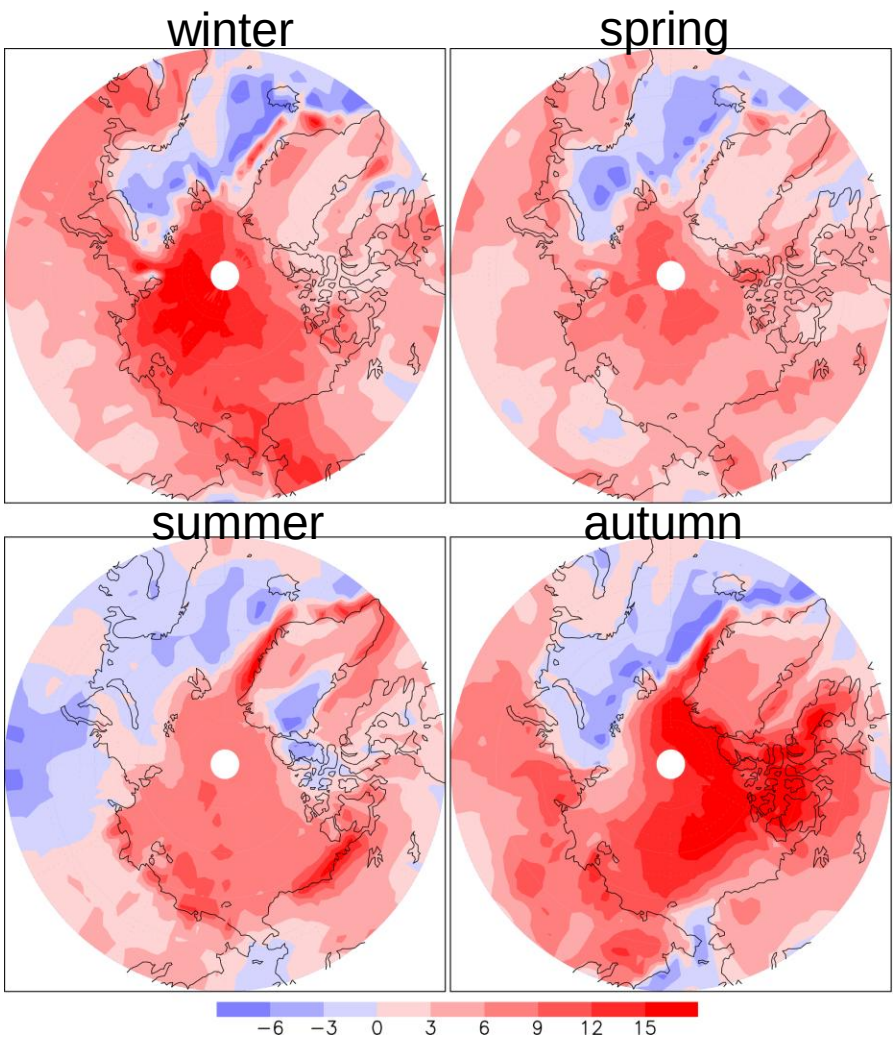


Present

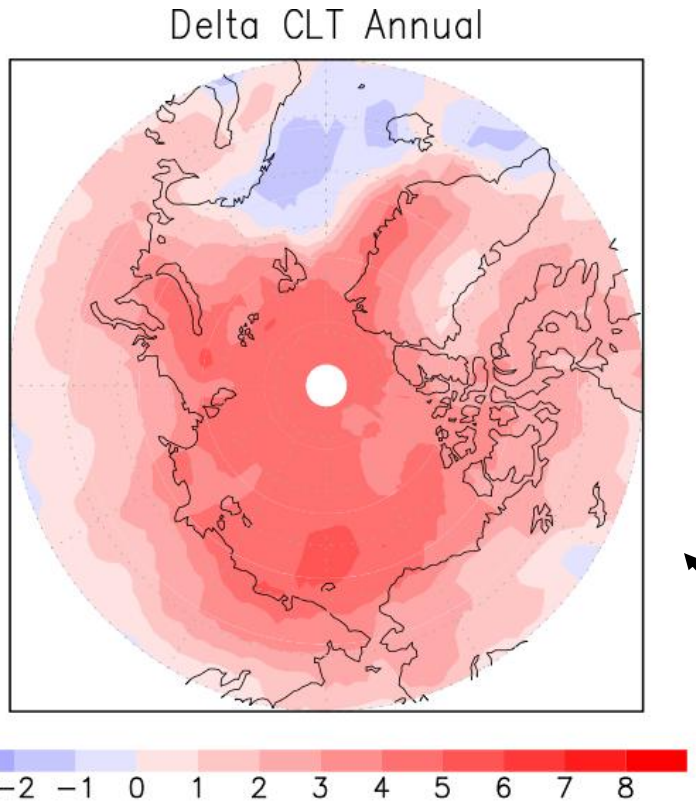
Seasonal Changes in Cloud Amount (20 GCMs)



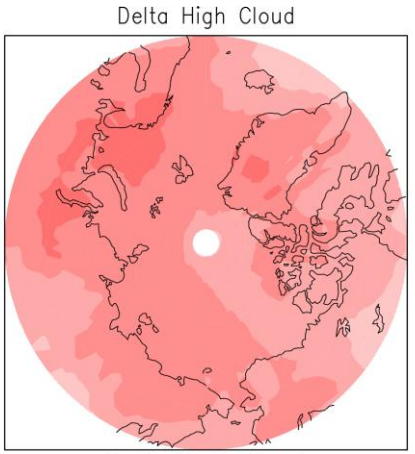
Seasonal Changes in Cloud Amount (CCSM)

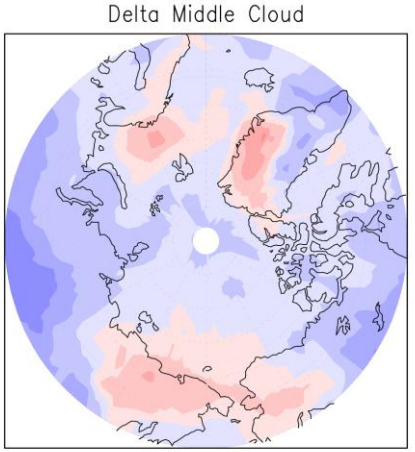


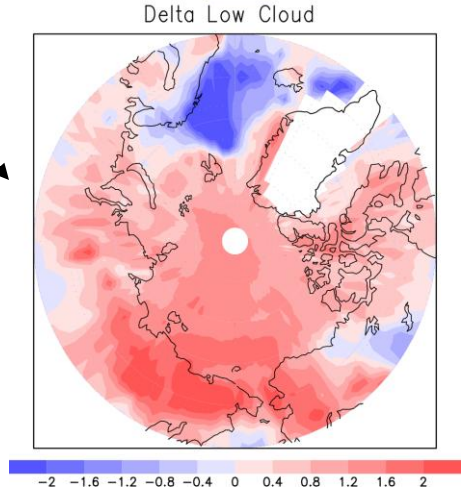
Change in Annual Cloud Amount (CMIP)



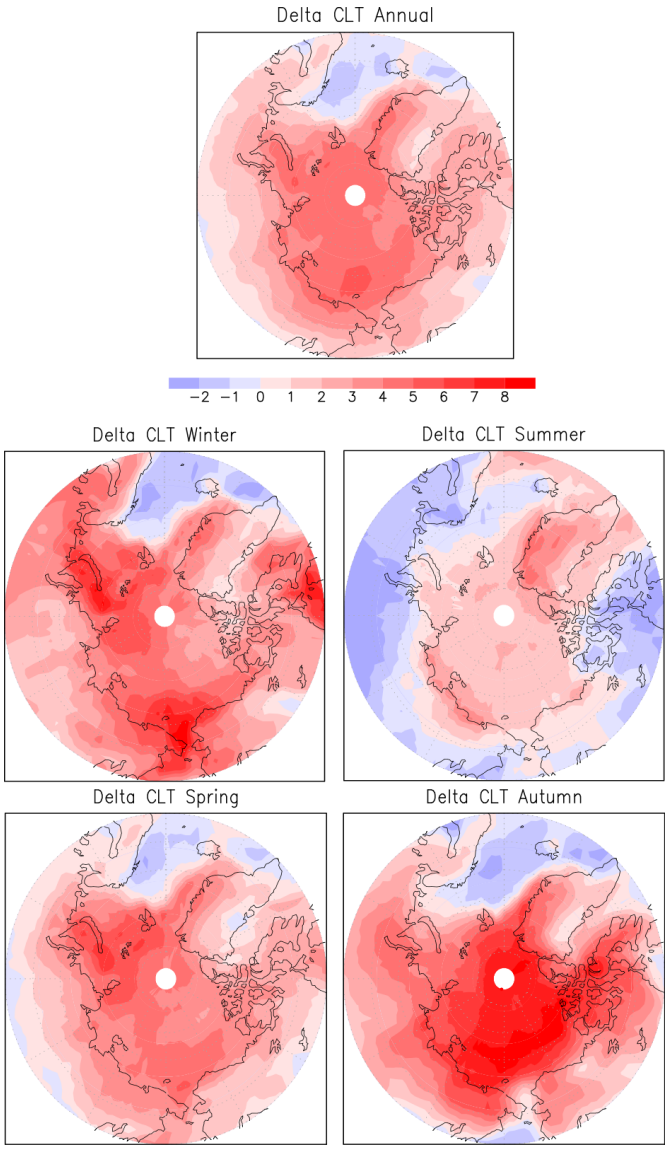
r =0.84



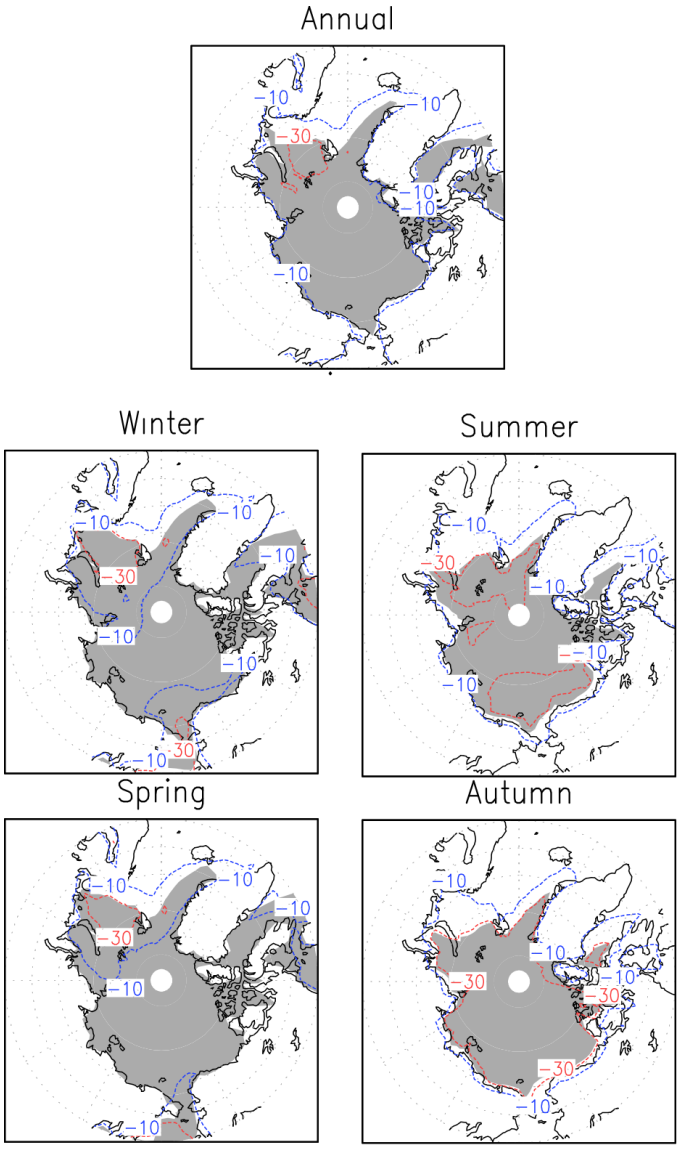


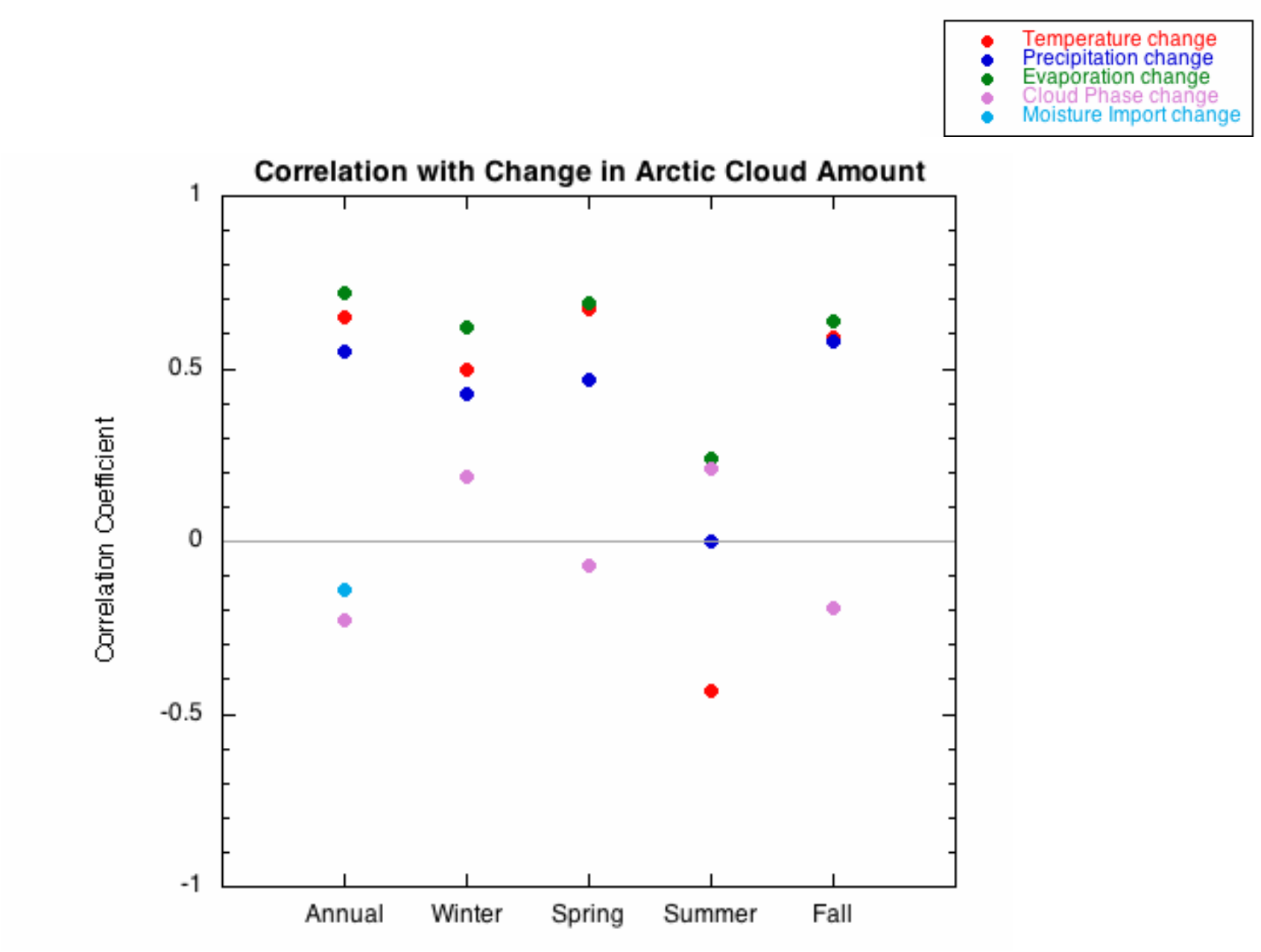


Change in Cloud Amount

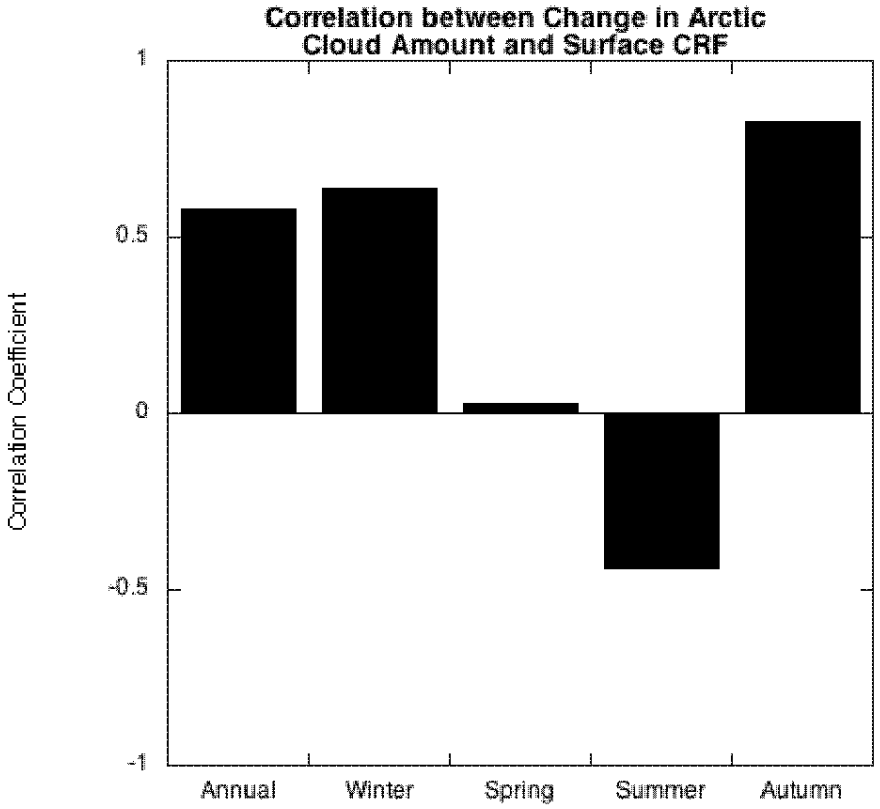


Sea Ice: 20th c and Change




Temperature change
Precipitation change
Evaporation change
Cloud Phase change
Moisture Import change
Correlation with Change in Arctic Cloud Amount
Correlation Coefficient
1
0.5
0
-0.5
-1
Annual
Winter
Spring
Summer
Fall

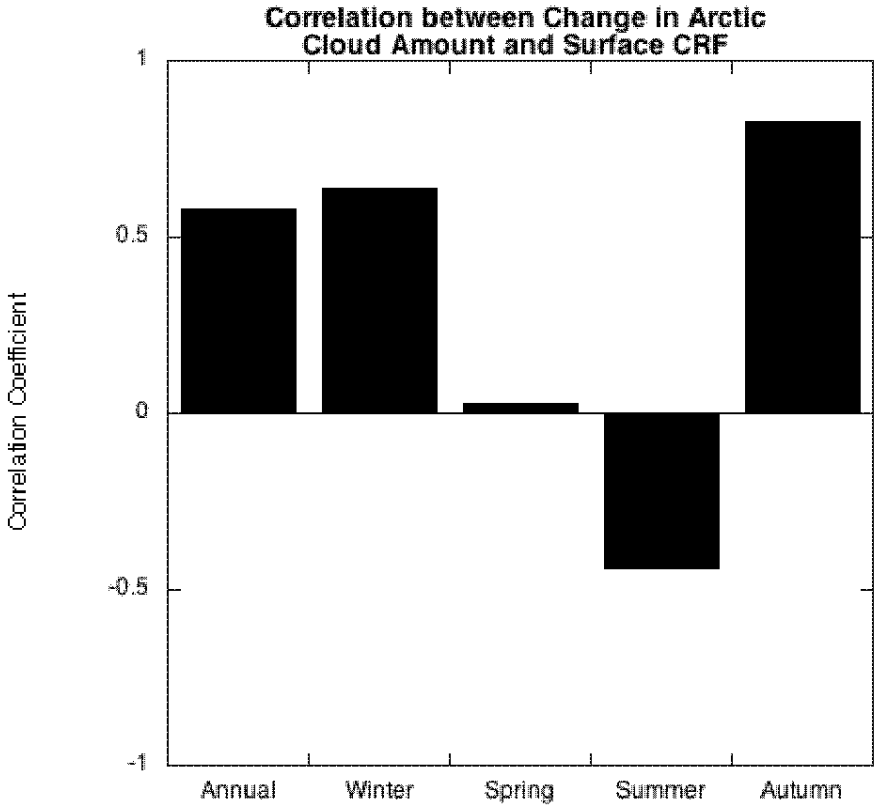
Cloud Feedback

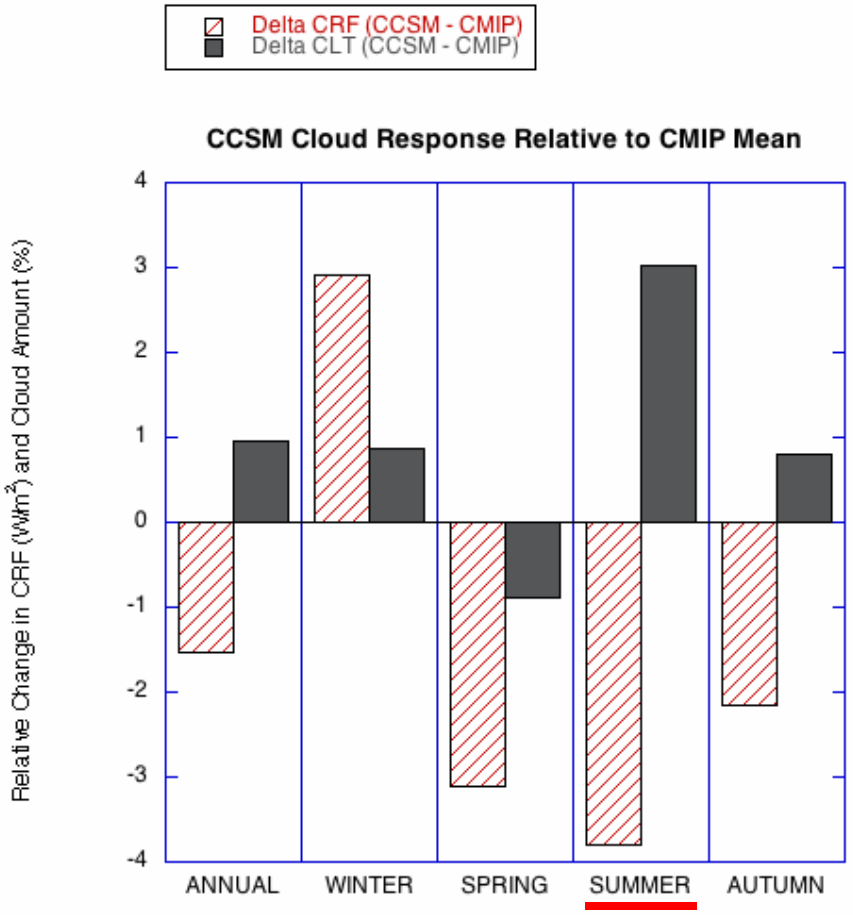


0.4 0.4 0.0 -1.6 0.6 $\Delta CRF/\Delta CLT$

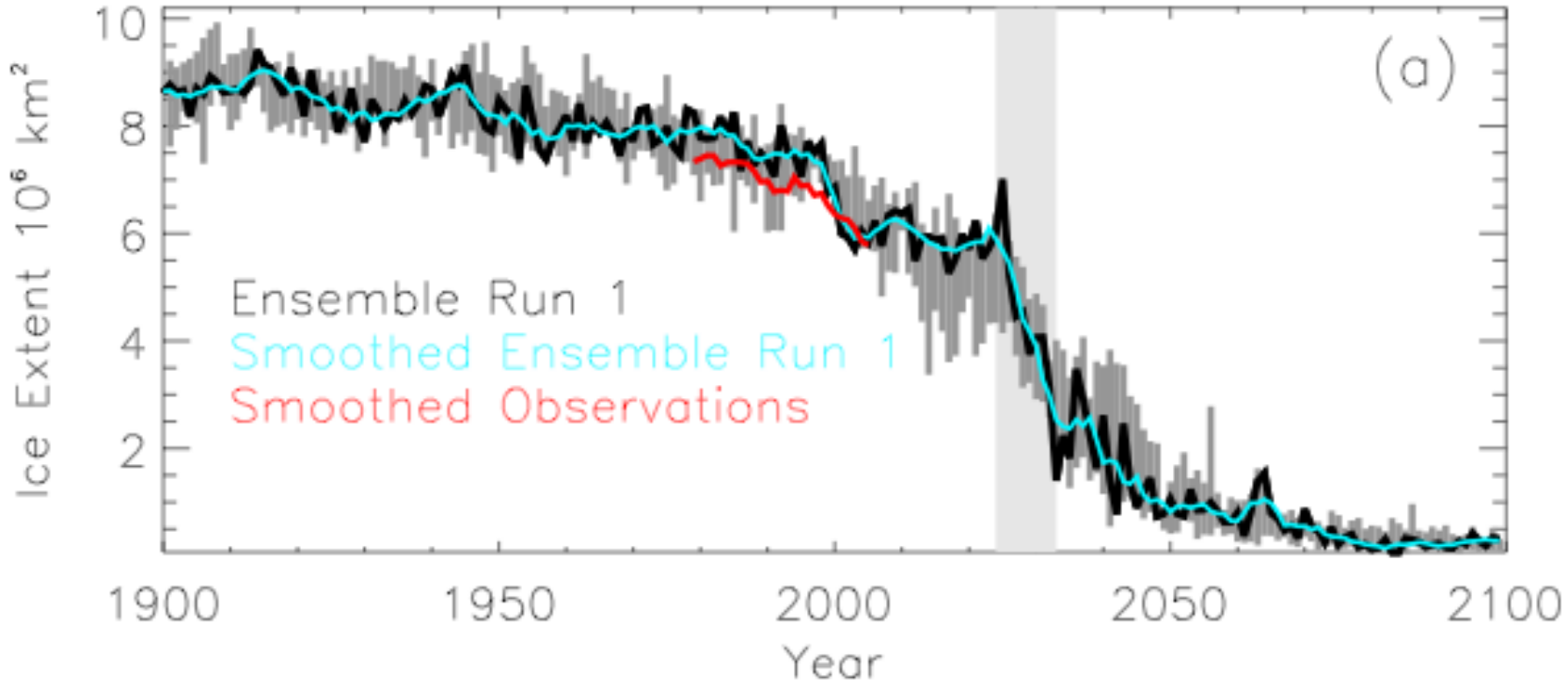
Observed: Arctic CRF = +25 W/m^2

Cloud Feedback



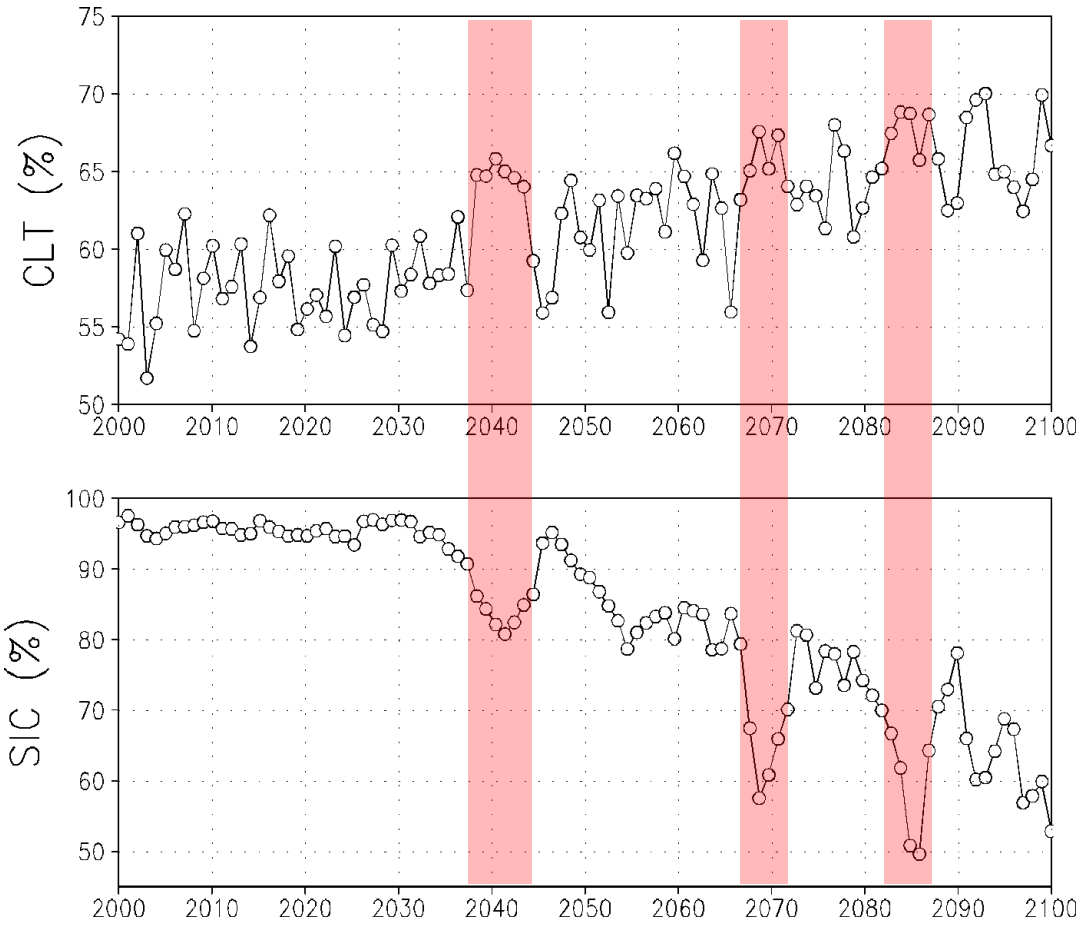


Rapid Changes in Central Arctic Sea Ice



Holland et al.,
GRL (2006)

Rapid Changes in Central Arctic Sea Ice and Clouds

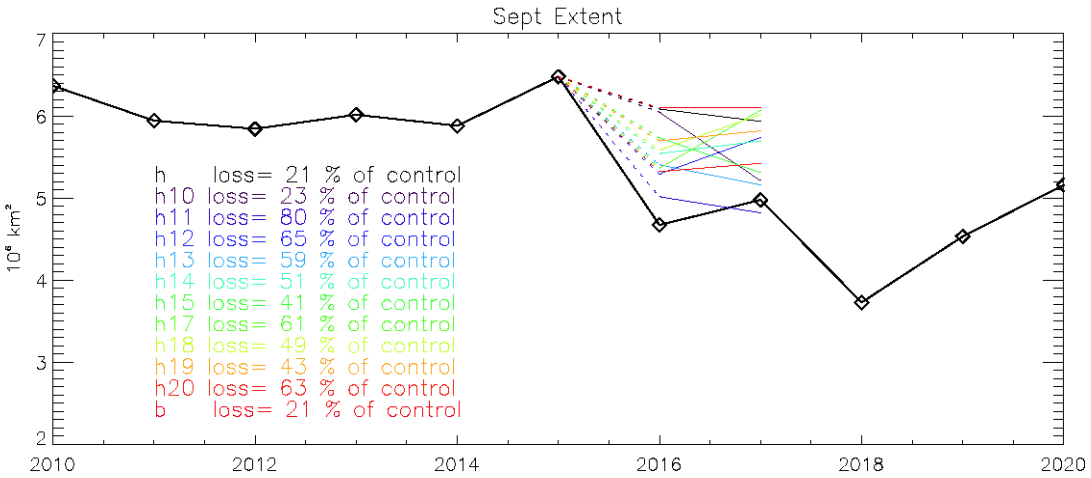


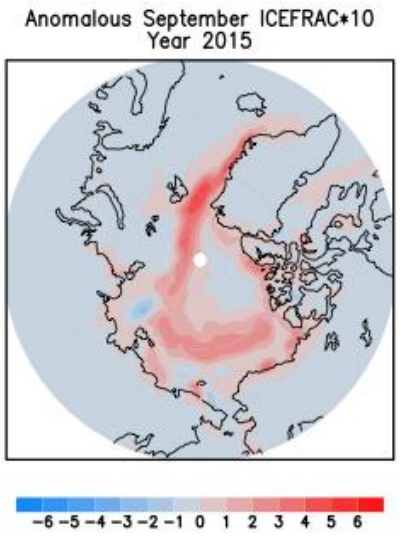
Cloud Amount

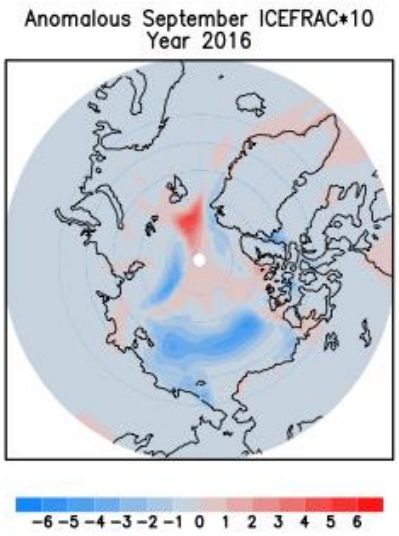
Ice Concentration

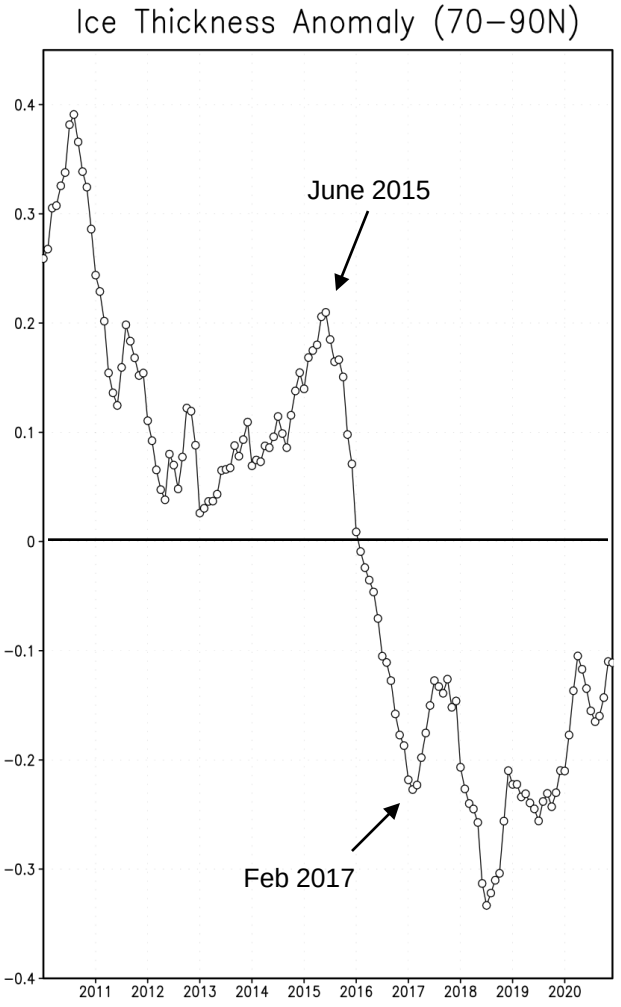
[Simulated by CCSM3 (80^{o}-90^{o}N), A1B emissions scenario]

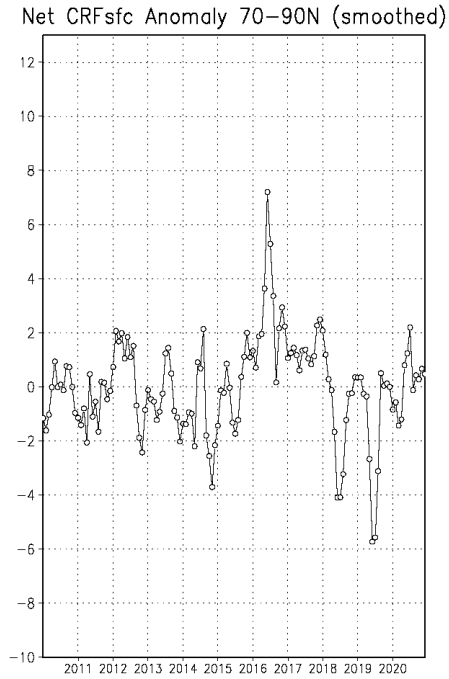
CCSM A1B Ensemble Simulations

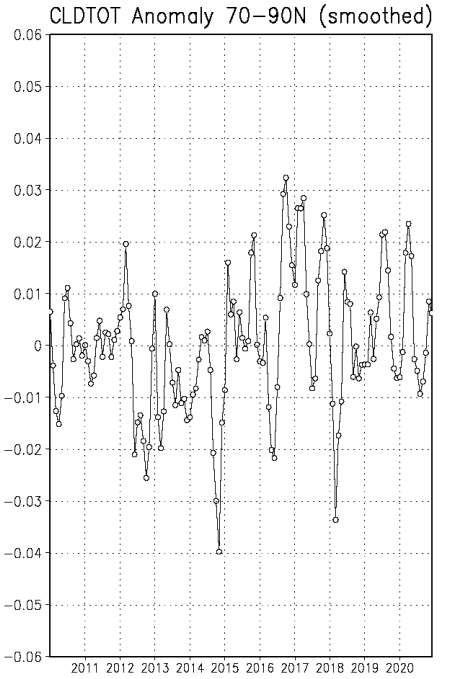


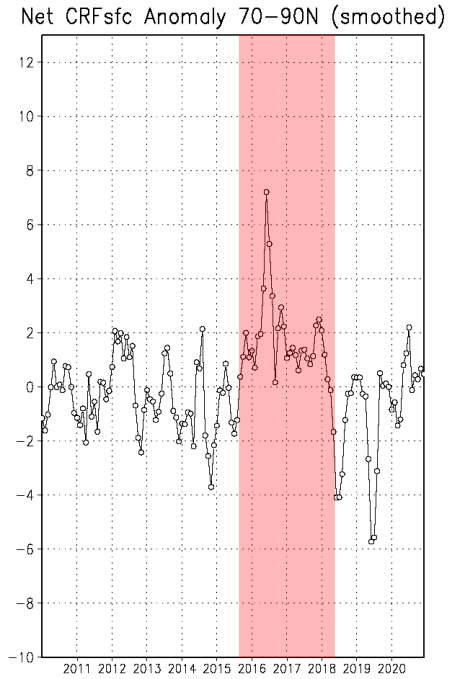


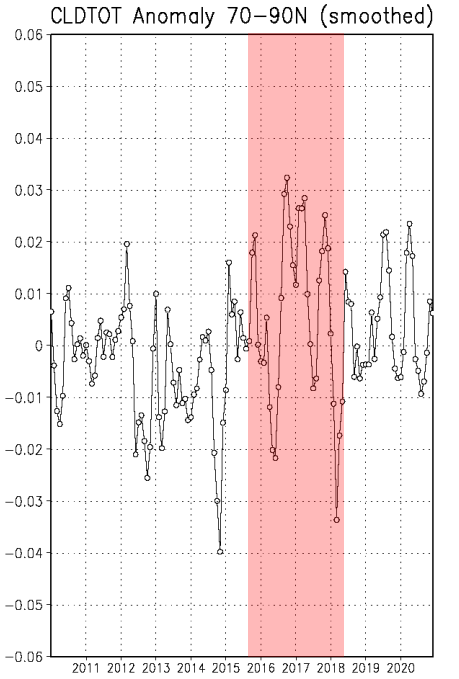




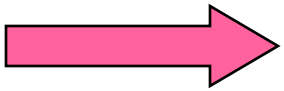

Net CRFsfc Anomaly 70–90N (smoothed)
12
10
8
6
4
2
0
−2
−4
−6
−8
−10
2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

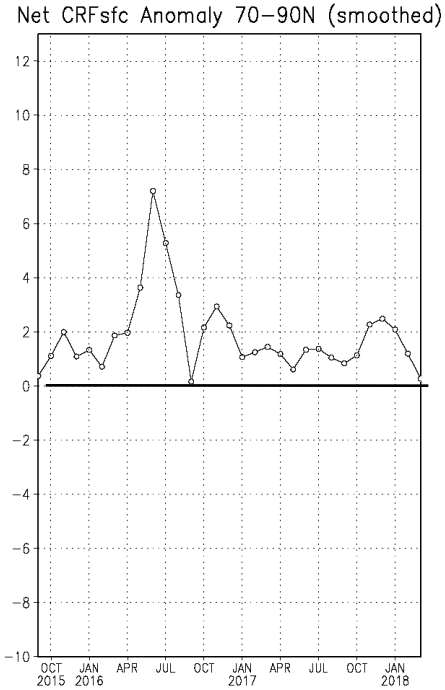

CLDTOT Anomaly 70–90N (smoothed)
0.06
0.05
0.04
0.03
0.02
0.01
0
−0.01
−0.02
−0.03
−0.04
−0.05
−0.06
2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

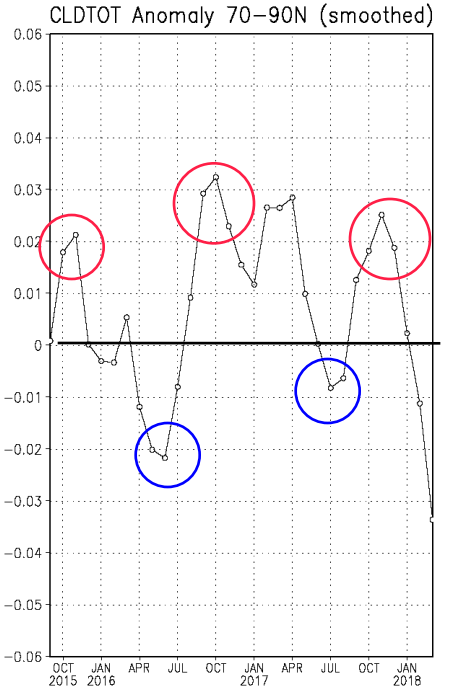


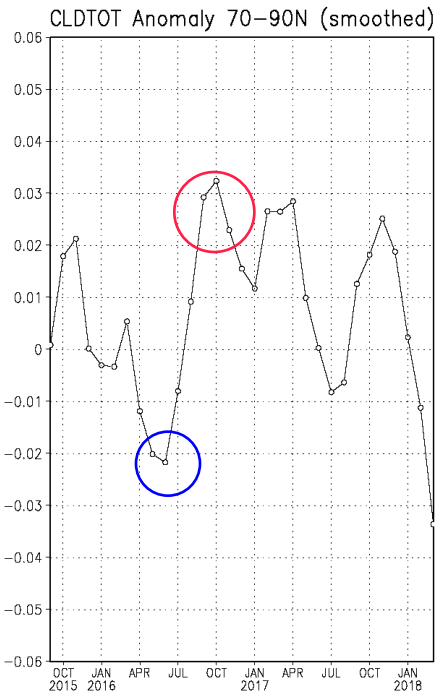


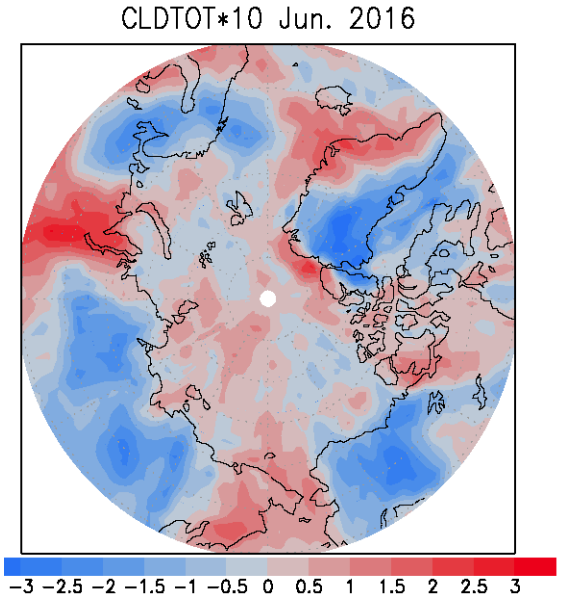
Sept. 2015 -
Feb. 2018

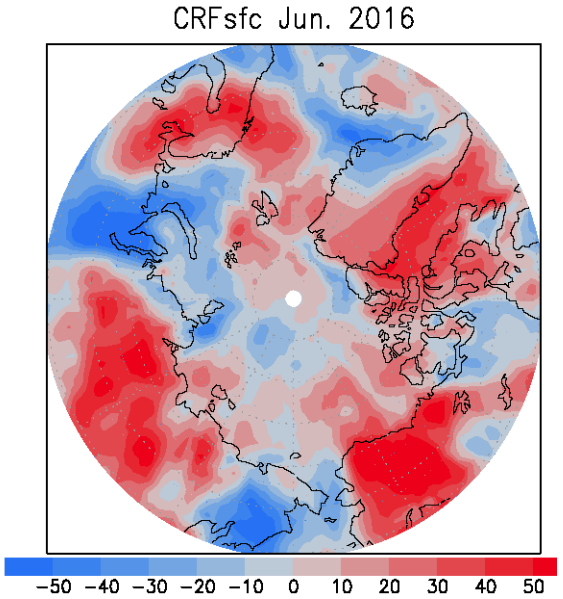


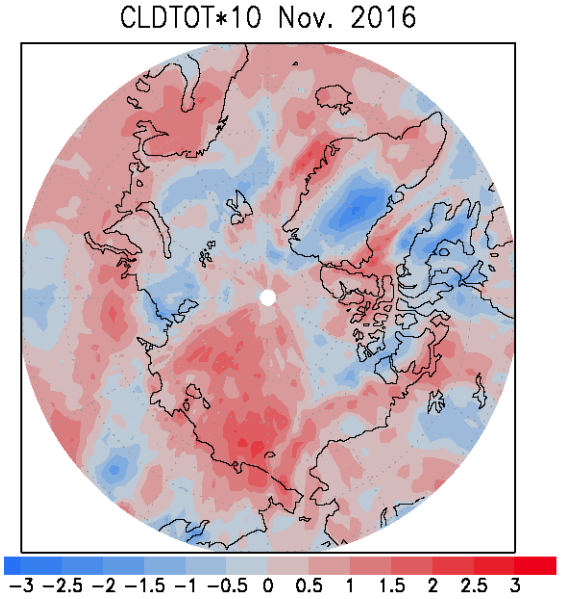


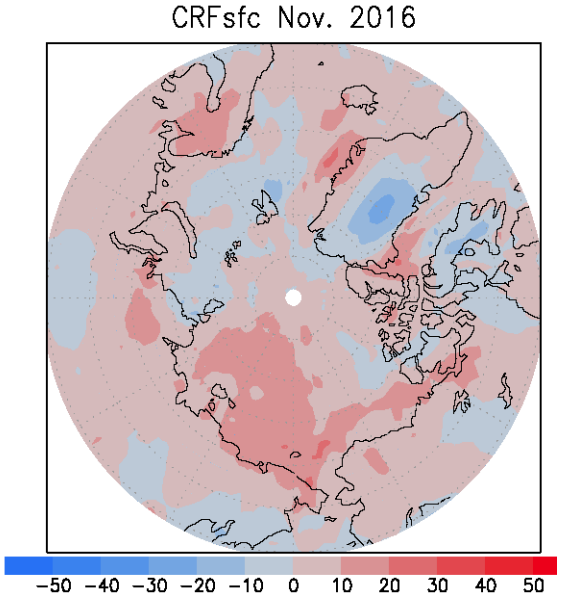



CLDTOT Anomaly 70–90N (smoothed)
0.06
0.05
0.04
0.03
0.02
0.01
0
−0.01
−0.02
−0.03
−0.04
−0.05
−0.06
OCT 2015
JAN 2016
APR
JUL
OCT
JAN 2017
APR
JUL
OCT
JAN 2018


CLDTOT*10 Jun. 2016
−3 −2.5 −2 −1.5 −1 −0.5 0 0.5 1 1.5 2 2.5 3


CRFsfc Jun. 2016
−50 −40 −30 −20 −10 0 10 20 30 40 50


CLDTOT*10 Nov. 2016
−3 −2.5 −2 −1.5 −1 −0.5 0 0.5 1 1.5 2 2.5 3


CRFsfc Nov. 2016
−50 −40 −30 −20 −10 0 10 20 30 40 50

Conclusions

- Warming favors polar cloud increases, especially low and high
- Projected cloud increases are strongly associated with sea ice
- Cloud increase probably driven by enhanced local evaporation
- Cloud gain appears to be a positive feedback (autumn, winter)
- Clouds seem to contribute to abrupt ice-loss events