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Impact of decreasing sea ice cover and warming Arctic surface temperature on the energy budget and on the large-scale circulation

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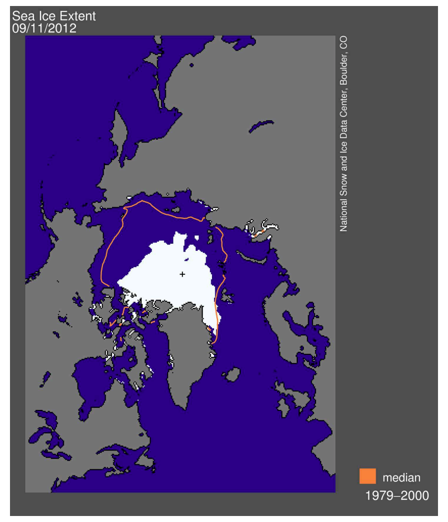
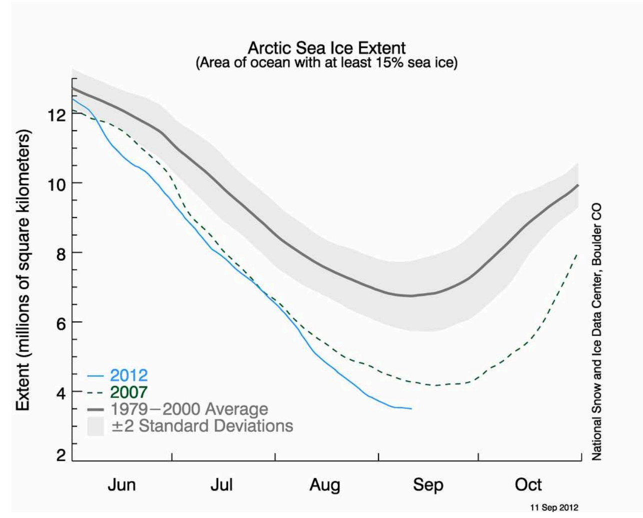
Motivation

Arctic sea ice declining faster than predicted by climate models – what is the sole influence of declining Arctic sea ice on the Northern mid-latitudes climate as opposed to multiple influences in coupled simulations?





Method

Idealized sensitivity experiments

T255L62 (79 km)

One with reduced sea ice concentration (SIC) plus increased sea ice surface temperature (SIST) (referred to as **IR**):

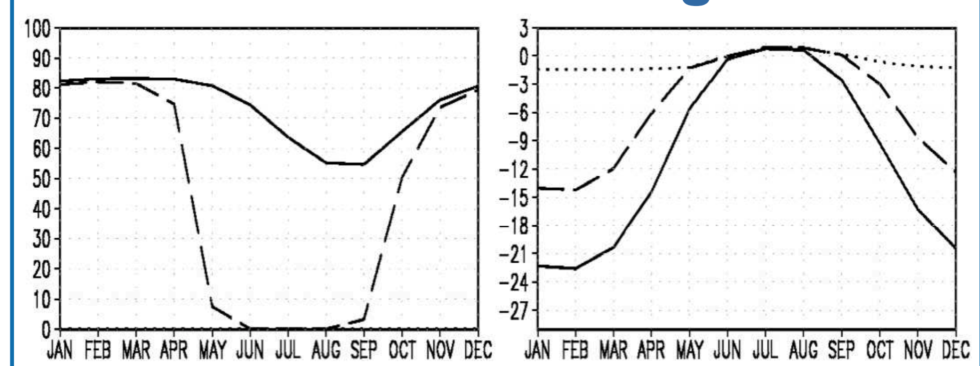
SIST ≤ Tfreeze – 10 °C → SIST = SIST + 10 °C, SIC = SIC
SIST > Tfreeze – 10 °C → SST = Max(Tfreeze,SIST), SIC = 0

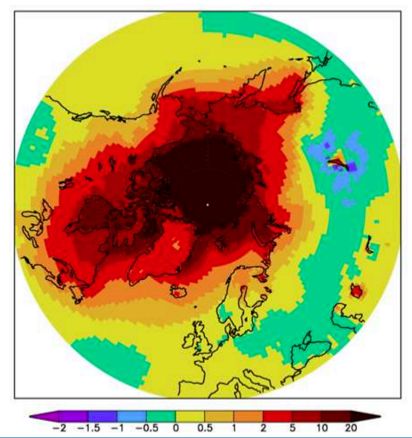
One with ice-free Arctic throughout the year (referred to as **IF**)

atmosphere-only

SST unchanged

Surface forcing





Above: Prescribed sea ice concentration [%] and surface temperature [°C] averaged over Arctic sea grid points north of 70 °N as climatological monthly means from 1960 to 2000. Solid line: REF, dashed line: IR, dotted line: IF. Right: 2 m temperature difference [°C] IF minus reference for winter 1960-2000

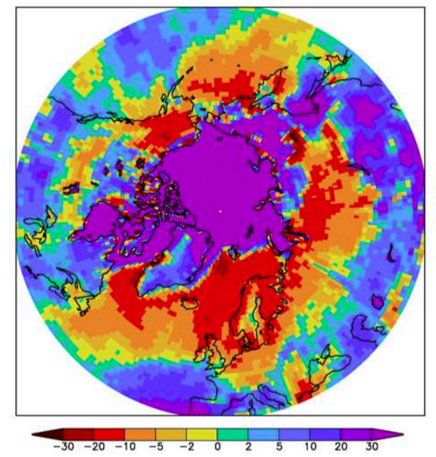
Energy budget

	Net shortwave radiation	Net longwave radiation	Sensible heat flux	Latent heat flux	Budget
Year	38 54 59	-38 -42 -51	-2 -5 -9	-12 -14 -21	-14 -7 -22
Winter	1 0 1	-44 -49 -67	-2 -8 -19	-11 -14 -31	-56 -71 -116
Spring	45 70 89	-42 -48 -57	-1 -5 -6	-10 -15 -19	-8 2 7
Summer	98 135 135	-28 -29 -29	-1 -2 -2	-12 -11 -12	57 93 92
Autumn	10 13 13	-37 -43 -50	-4 -6 -8	-13 -17 -21	-44 -53 -66

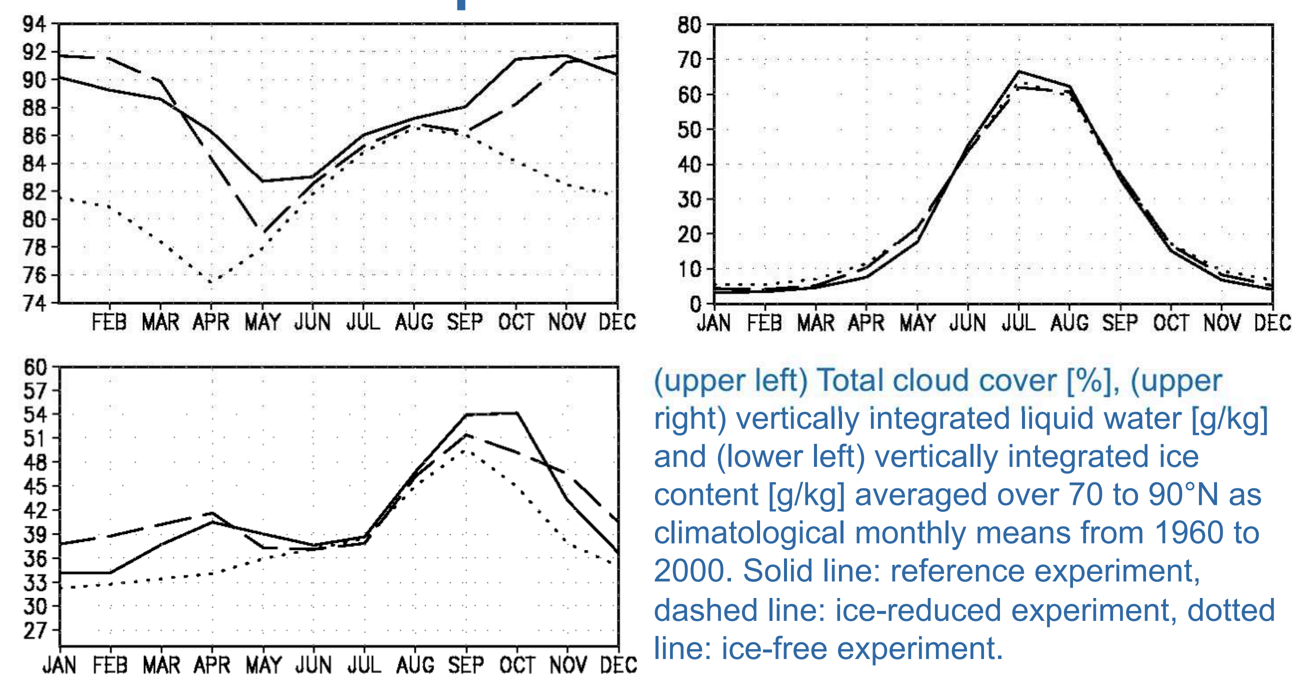
	Net shortwave radiation	Net longwave radiation	Budget
Year	83 98 103	-197 -201 -207	-114 -103 -104
Winter	2 2 2	-173 -180 -193	-171 -178 -191
Spring	104 128 145	-196 -201 -208	-92 -73 -63
Summer	202 235 235	-224 -224 -224	-22 11 11
Autumn	26 28 8	-195 -199 -202	-169 -171 -174

Components of the surface energy budget (above) and the top of the atmosphere energy budget (below) averaged over the area north of 70° N. In each cell the first value corresponds to REF, the second to IR and the third to IF. All values are given in W/m2 as climatological mean values for 1960-2000, positive downward, negative upward.

Precipitation and clouds

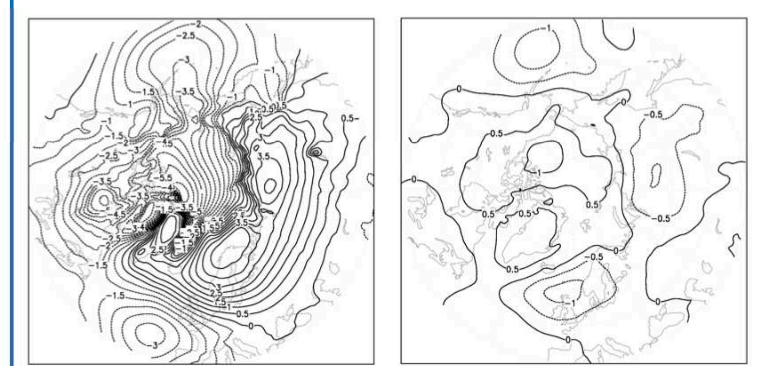


Precipitation difference [%] IF versus REF over the Arctic and the Northern mid-latitudes as climatological seasonal means for winter 1960-2000

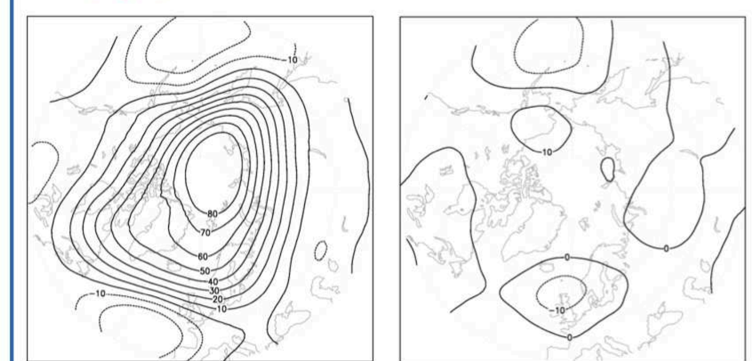


(upper left) Total cloud cover [%], (upper right) vertically integrated liquid water [g/kg] and (lower left) vertically integrated ice content [g/kg] averaged over 70 to 90°N as climatological monthly means from 1960 to 2000. Solid line: reference experiment, dashed line: ice-reduced experiment, dotted line: ice-free experiment.

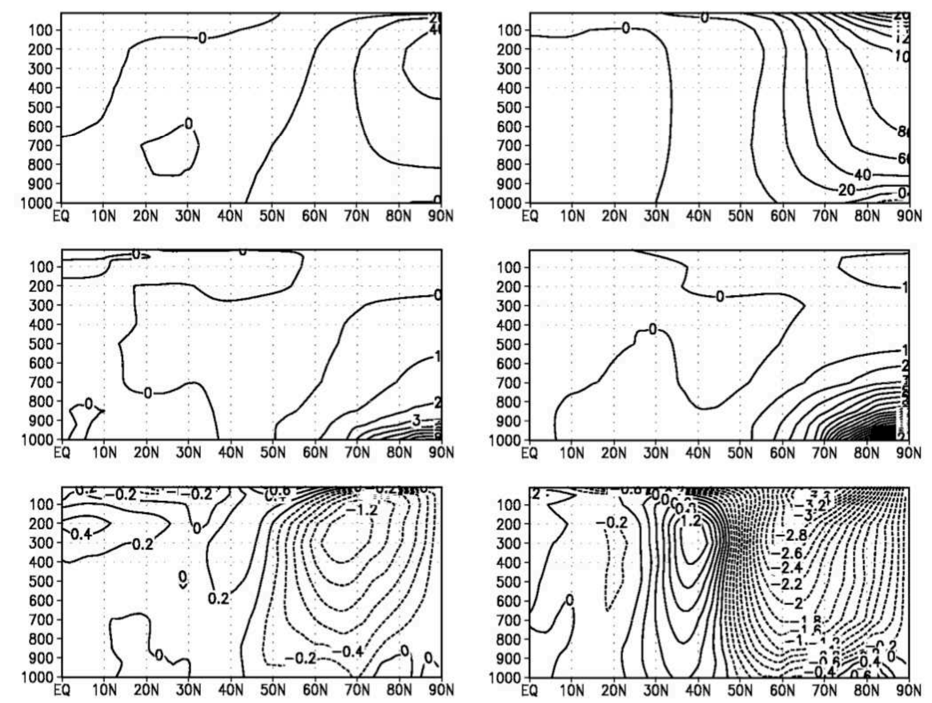
Large-scale circulation



Mean sea level pressure difference [hPa] IF versus REF over the Arctic and the Northern mid-latitudes as climatological seasonal means for (left) winter and (right) summer 1960-2000



Same as above but difference in 500 hPa geopotential [m]



Zonally averaged cross sections of differences in geopotential height [m] for (upper left) IR minus REF and (upper right) IF minus REF as climatological means for winter 1960-2000. Middle row same as upper row but for temperature [K], lower row same as upper row but for zonal wind [m/s].

Summary and conclusions

- In spring and summer more than 30 W/m2 increase in TOA and net surface energy budget if sea ice loss occurs
- Similarly to our sensitivity studies it has been observed in 2007 that the impact of lost sea ice is amplified by a reduction in cloud cover and/or liquid water content. Large uncertainty in cloud observations / simulations but clouds are hugely important for radiation balance and speed of Arctic sea ice melting!
- Energy gain in spring and summer outweighing increased outgoing longwave radiation in autumn and winter
- Circulation cells, especially the polar cell, weakened due to decreased poleward heat transport

More results in: Semmler, T., McGrath, R., and Wang, S. (2012): The impact of Arctic sea ice on the Arctic energy budget and on the climate of the Northern mid-latitudes. Climate Dynamics (EC-Earth Special Issue), DOI 10.1007/s00382-012-1353-9

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