The complex response of Arctic cloud condensation nuclei to sea-ice retreat

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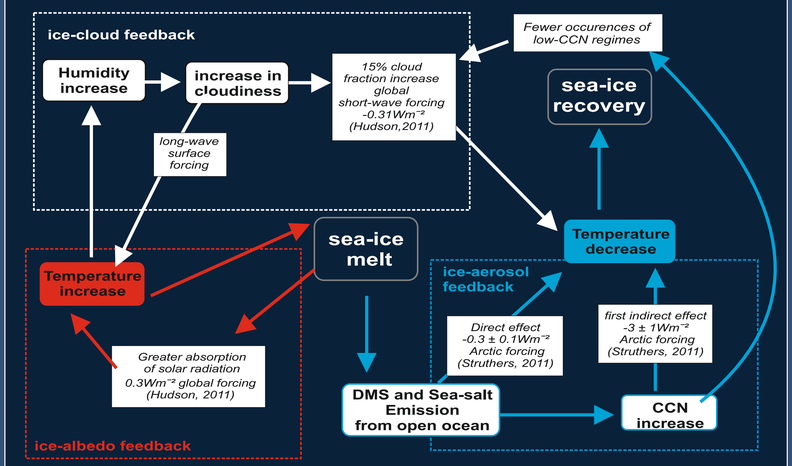
The complex coupling of sea-ice, cloud and Arctic aerosol

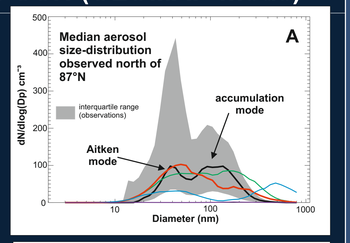


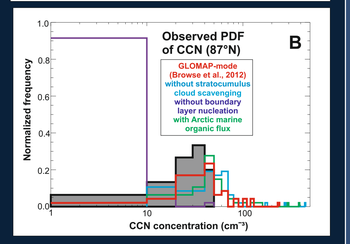
Schematic showing response of Arctic surface temperatures to the ice-albedo, ice-aerosol and ice-cloud feedbacks

Modelling present day Arctic CCN (GLOMAP-mode)

A Global Model of Aerosol Processes (GLOMAP-mode)

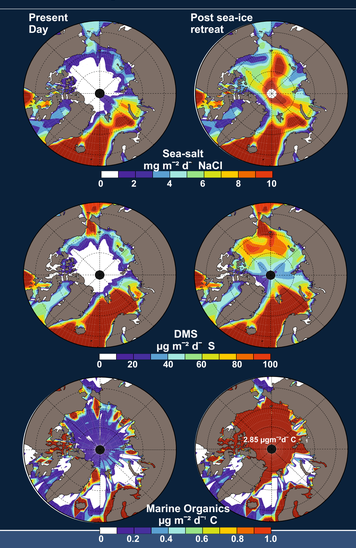
- GLOMAP is a global microphysics model capable of simulating aerosol mass and number in multiple lognormal modes (Mann et al., 2010).
- After recent improvements to the treatment of scavenging GLOMAP has been shown to reproduce observed sulphate and BC aerosol mass between 71° - 81°N well (Browse et al.,2012)
- Further evaluation of GLOMAP against observed high-latitude (87°N) CCN and aerosol size spectra from the 2008 Arctic summer cloud ocean study (ASCOS) (Martin et al., 2011) show good agreement with measurements (A,B)
- Modelled Arctic CCN are shown in GLOMAP to originate primarily from boundary layer nucleation of H2SO4 (B)
- However, observations suggest that primary organic material from the ocean surface is a significant source of boundary layer Arctic CCN (Orellana et al., 2011). Thus, we include a constant open water OC flux north of 60°N, which has improved the models reproduction of the observed accumulation mode (A)





Comparison of the model (GLOMAP-mode) with observations from the summertime ASCOS campaign in 2008 (Martin et al.,2011)

Response of local emissions to sea-ice retreat



Arctic Sea-salt Emissions x10

Dimethyl Sulphide emissions x15

Marine organic emissions x4

Experimental set-up:

1) Present day: run with 2000 sea ice

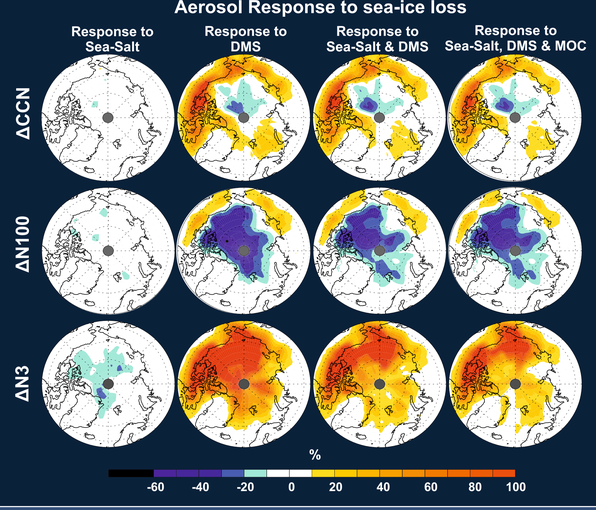
2) no-ice: same as present day but with sea-ice fraction set to zero from Jul-Sep

3) no-ice-SS:where the removal of sea-ice affects only sea salt emissions

4) no-ice-DMS: where the removal of sea-ce affects only DMS emissions

All runs had identical
meteorology
emission inventories (BC,SO2)
DMS sea-water concentrations
precipitation rates

Response of cloud condensation nuclei to sea-ice retreat



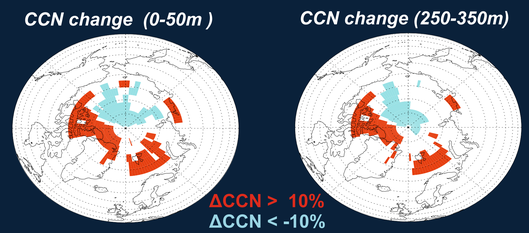
sea-salt emissions alone suppress nucleation flux by 50%

DMS emissions alone enhance nucleation flux by 350%

Sea-Salt emissions suppress nucleation increase by a factor of ~6 in an ice-free Arctic

Majority of S mass converted from SO2 to H2SO4 via in-cloud processing (adding mass not number)

Explaining the CCN response



Grid-boxes where ΔCCN <-10%	Present day (ngm⁻³d⁻¹)		ΔPresent day (%)					
			no-ice		no-ice-SS		no-ice-DMS	
Altitude (m)	0-50	250-350	0-50	250-350	0-50	250-350	0-50	250-350
Nucleation flux	0.001	0.0001	60	180	-50	-60	390	350
Condensation flux	0.02	0.005	350	220	30	-8	240	260
Aq. phase ox. flux	0.25	5.4	120	240	0	0	120	240
Ageing flux	0.001	0.0004	180	320	-20	-1	250	330
	(ngm⁻²d⁻¹)							
Ait. wet dep	0.04		120		-5		200	
acc. wet dep	1625.4		150		10		140	

How can higher emissions decrease BL CCN?

Condensation vs Nucleation

- More sea-salt aerosol alone reduces CCN because it acts to suppress boundary layer nucleation (-50%) and is strongly scavenged
- More DMS alone can cause a reduction in CCN because the increase in H2SO4 grows all particles to sizes where they can be scavenged more easily
- A combination of DMS, OC and Sea-Salt accelerates the growth of primary particles (increasing the scavenging rate) while simultaneously suppressing nucleation.
- Away from the sea salt source this response is more than compensated for by the enhanced supply of CCN from boundary layer nucleation

Conclusions

Sea-ice retreat significantly increases local fluxes of primary aerosol and pre-cursor gas DMS

The response of boundary layer CCN to sea-ice retreat is spatially non-uniform ranging from -26% to +62%

The modelled CCN change is the result of enhanced aerosol growth and nucleation processes competing in a strongly scavenging environment

Our study highlights the significant uncertainties that remain in trying to quantify aerosol-cloud processes in the poorly understood Arctic system

paper: www.atmos-chem-phys-discuss.net/13/17087/2013/doi:10.5194/acpd-13-17087-2013
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