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Influence of oceanic DMS emissions on CCN concentrations over the Southern Ocean: A global model study

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Funding from QUEST and SOLAS programmes

Objectives

- Observations have established a link between DMS and CCN, but the mechanism is not clear
- Global model studies have simulated aerosol mass, but have not included the microphysical processes that control CCN specifically
- We aim to understand the seasonal changes in CCN in terms of the controlling processes of aerosol and precursor gas emissions, atmospheric transport, aerosol formation, growth, coagulation, cloud processing, removal, etc.
- Use the model to quantify the sensitivity of CCN to changes in DMS

Global Model of Aerosol Processes (GLOMAP)
http://researchpages.net/glomap

First global study using a detailed aerosol microphysics model

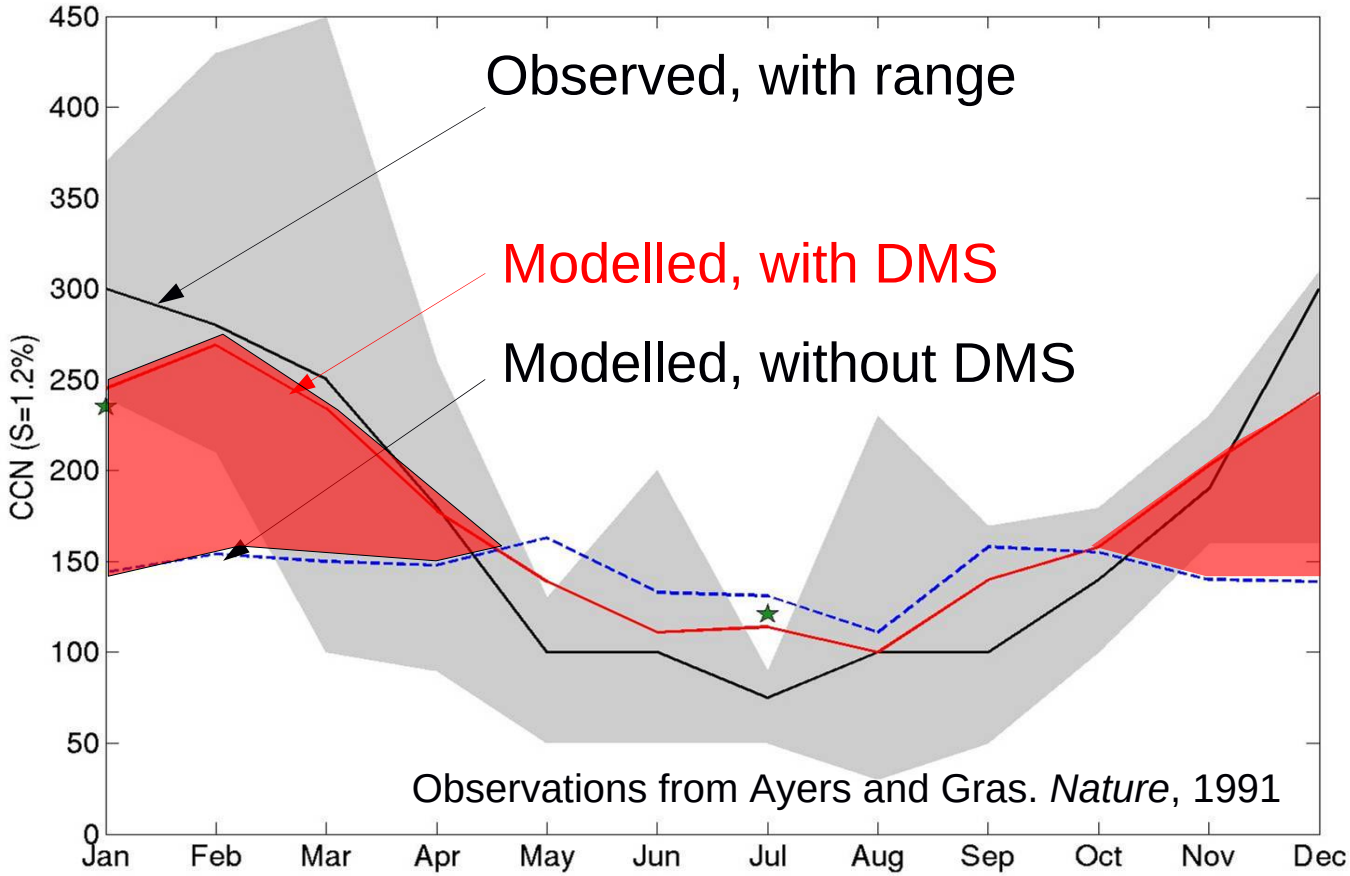
- Global offline CTM forced by 6-hourly ECMWF winds
- T42 (2.8^ox2.8^o) resolution
- Convective and frontal precipitation

- Sectional aerosol scheme with 20 bins, 3 nm – 20 μm
- Gaseous emissions of DMS, SO_2, biogenic compounds
- Primary emissions of sea spray
- Nucleation via binary homogeneous nucleation of H_2SO4-H_2O+ boundary layer mechanism
- Aerosol transport, microphysics, wet/dry deposition, cloud processing, etc.

- Typically 3-month spin-up

Spracklen et al. (ACP, 2005a,b, 2006, 2007), Korhonen et al., 2007

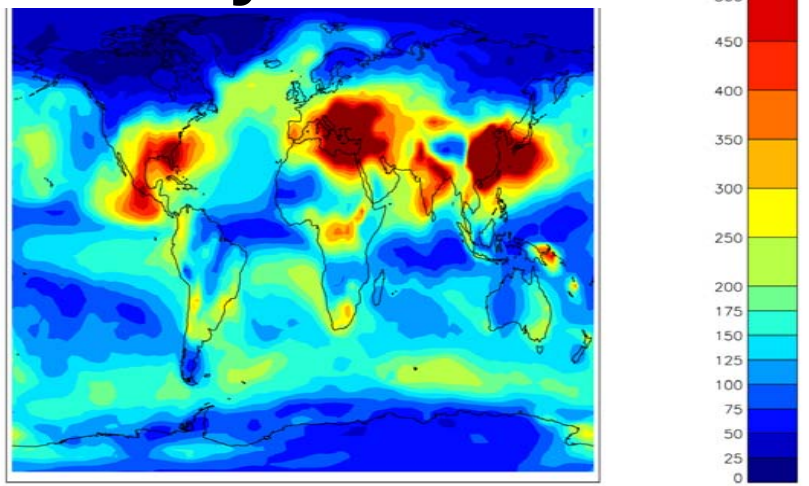
CCN seasonal cycle at Cape Grim, Tasmania



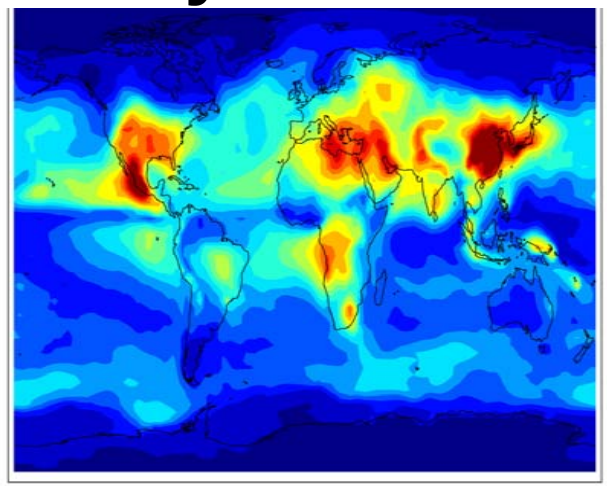
DMS contribution to CCN

CCN and change due to DMS

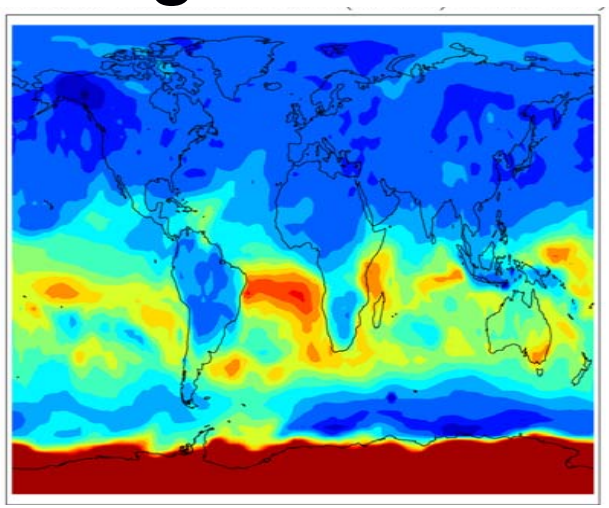
January CCN(0.23%)

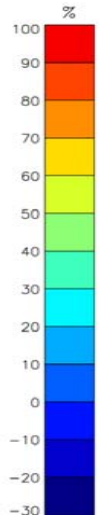


July CCN(0.23%)

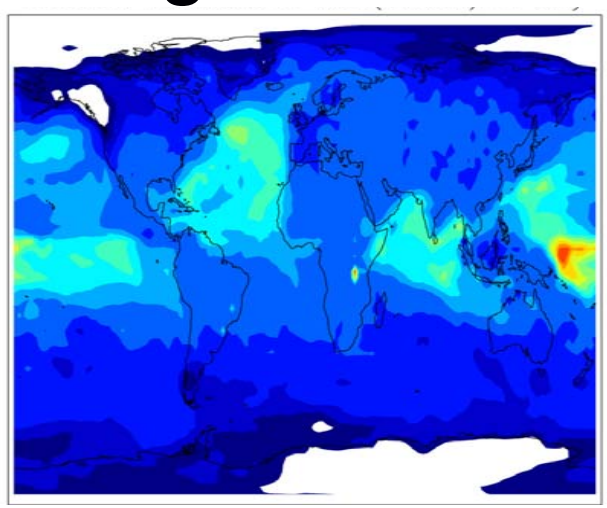


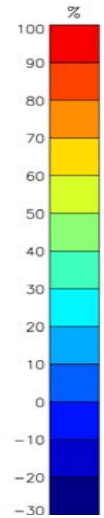
Change due to DMS



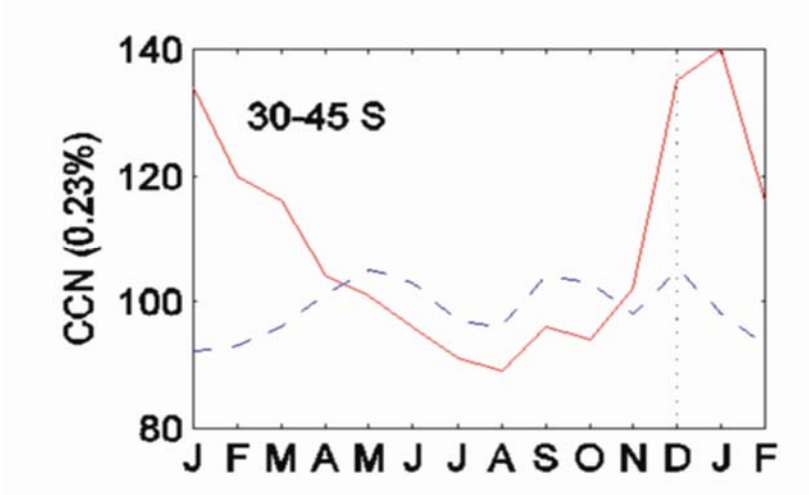


Change due to DMS

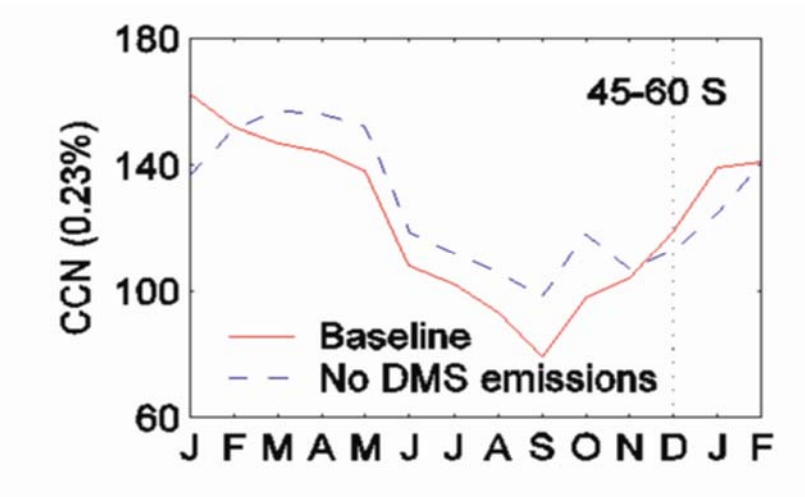


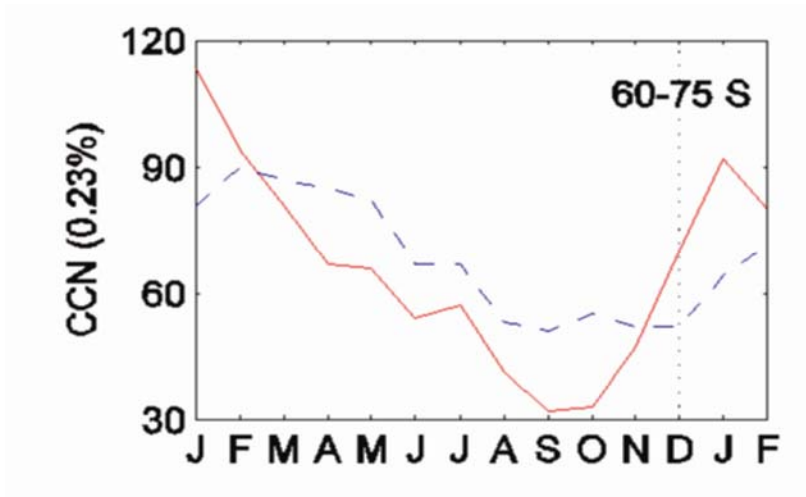


CCN cycle with and without DMS

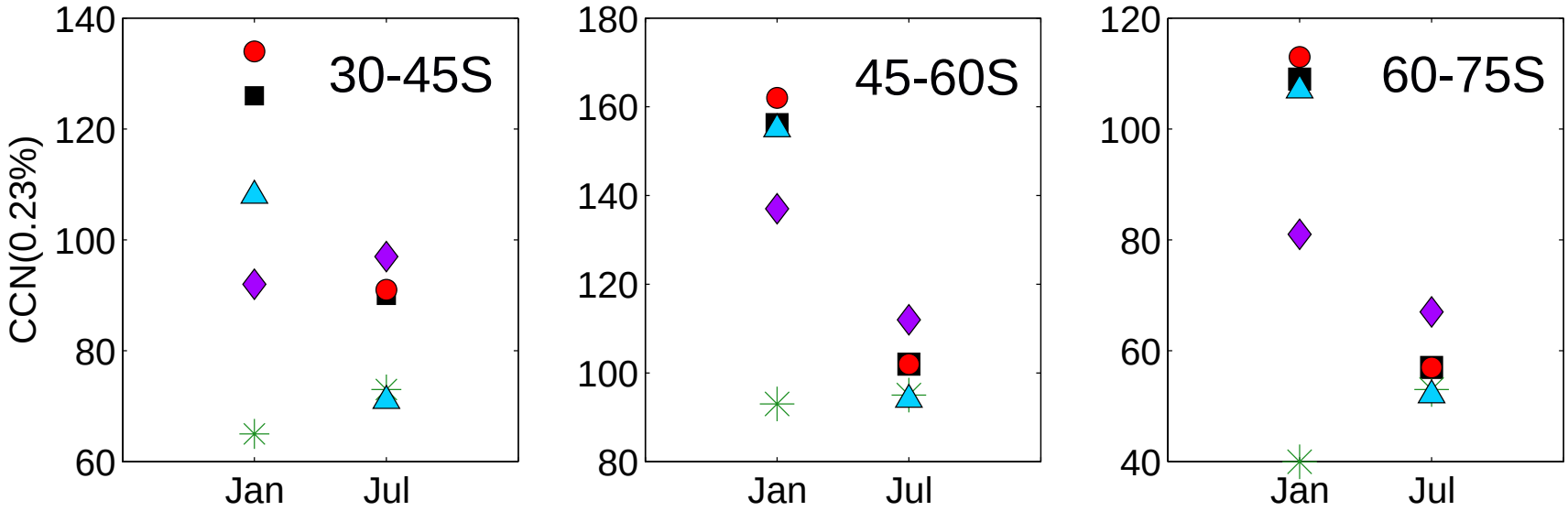


Note the strong seasonal cycle >45ºS even without DMS (blue lines)





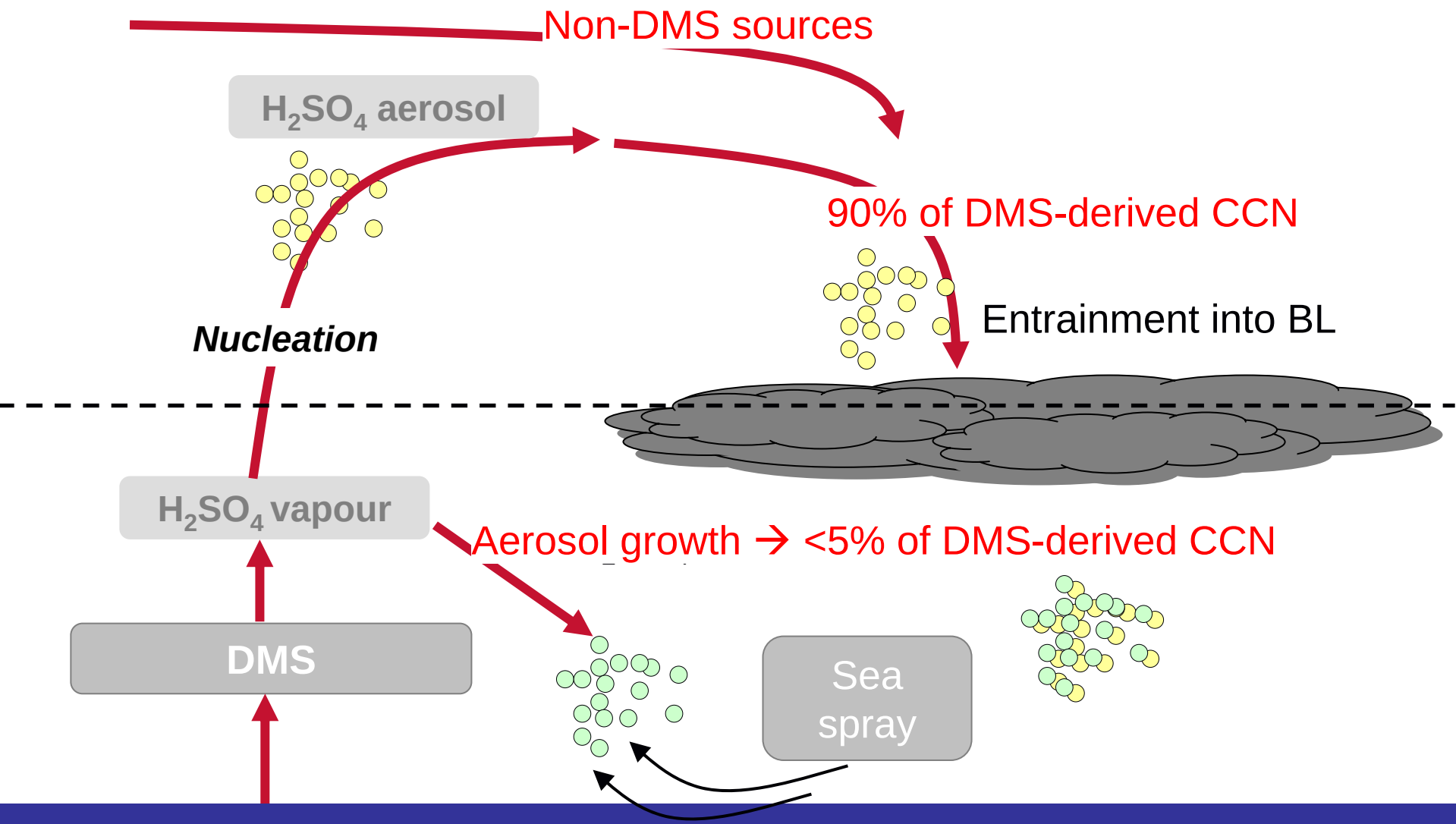
Change in CCN due to various emissions and processes



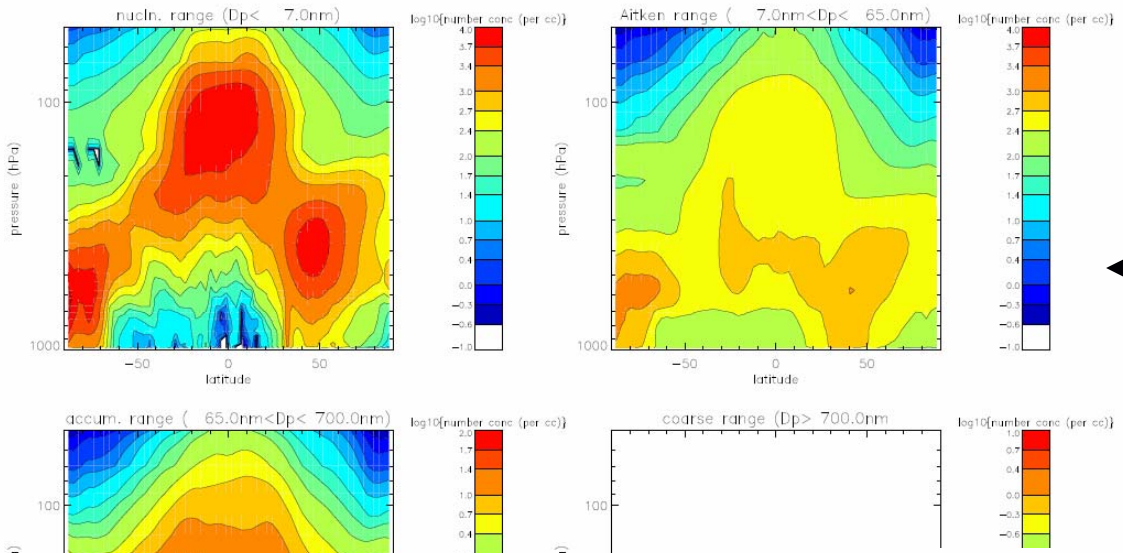
Key:

- Baseline run with all S emissions and processes
- Without DMS emissions
- Without condensation of H_2SO_4 vapour in boundary layer
- Without nucleation of particles in free troposphere

Important processes driving DMS-CCN link

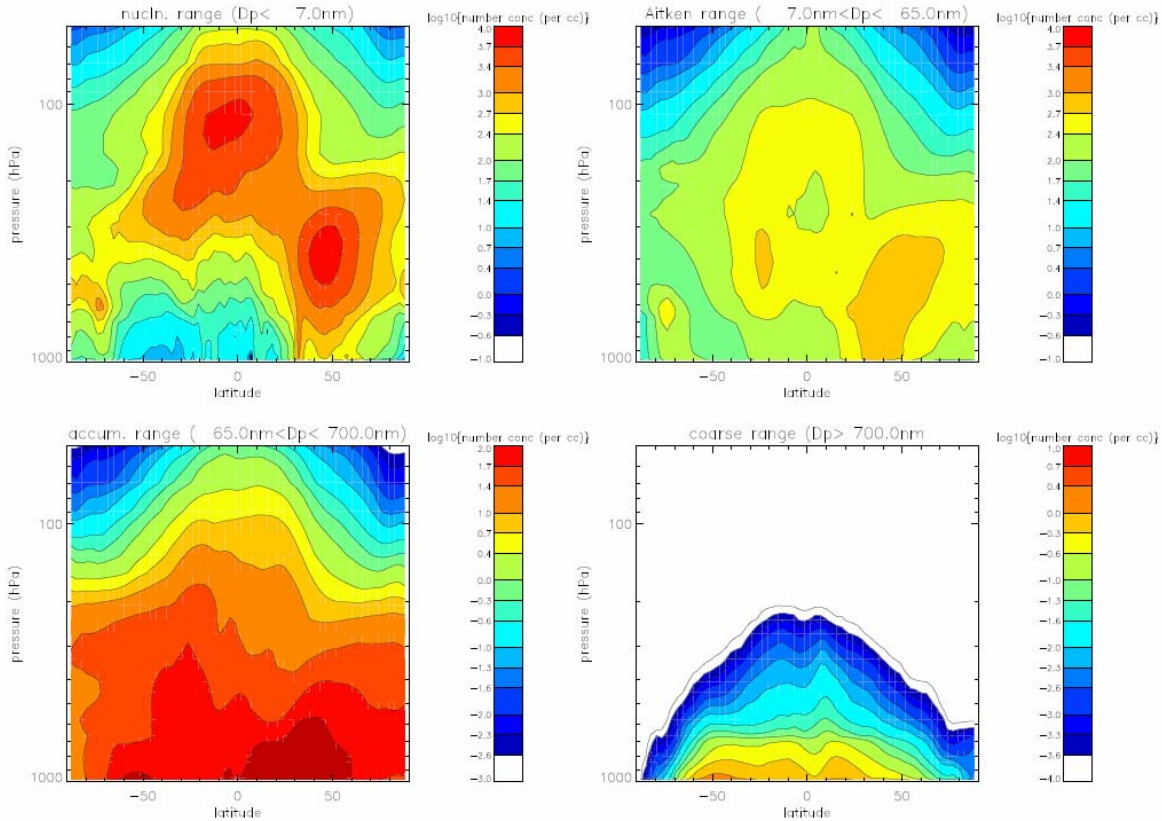


Aerosol profiles with and without DMS



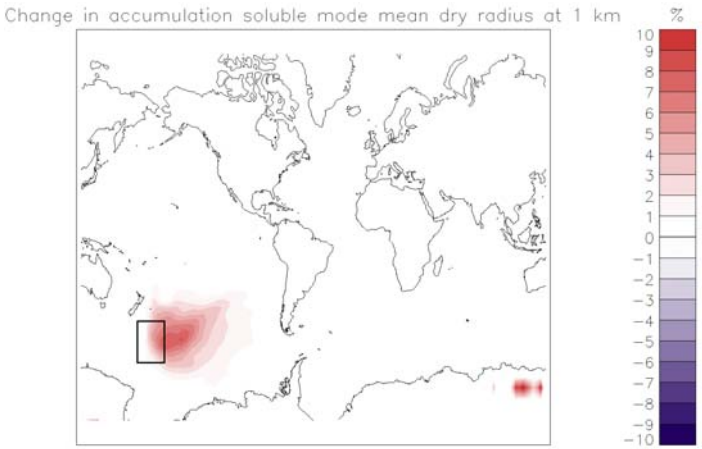
With DMS. Notice the huge abundance of aerosol in the FT that contributes to MBL CCN

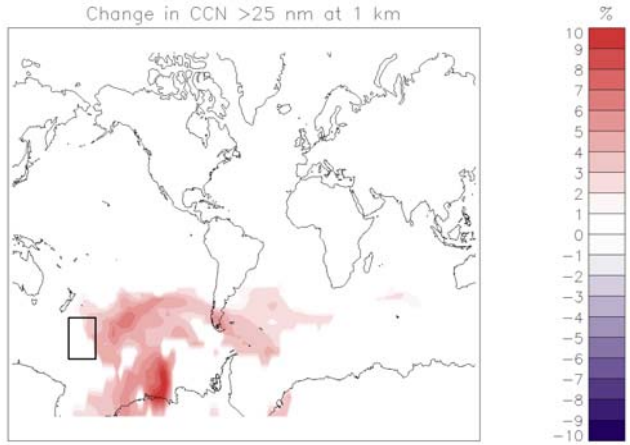
Without DMS. Notice the large change in nucleation mode over the SH, but the remaining large aerosol input to the MBL from the FT, originating from continental sources

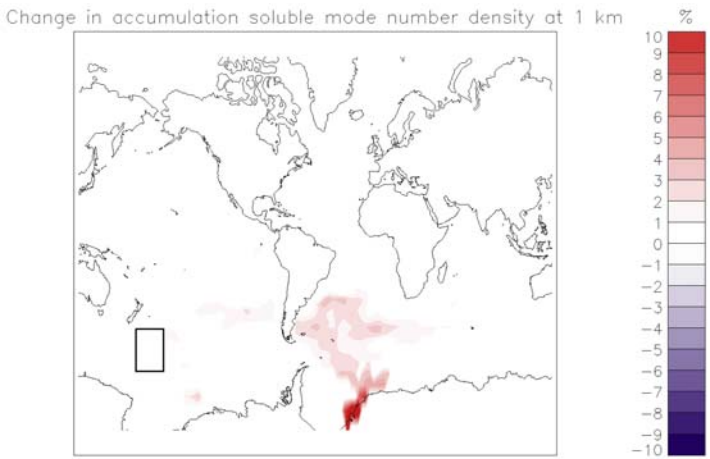


DMS “patch” experiment

After Wingenter (2007) we have quantified CCN changes due to a 1-month emission of DMS from a patch of the Southern Ocean. Changes in CCN are much smaller than he estimated (1.29% versus 8%)







Mean changes over Southern Ocean

	Wingenter et al., 2007	Model 5x patch	Model 20x patch
DMS flux change	+20 %	+8.0 %	+38.0 %
CCN (> 25 nm) change	+10 %	+1.29 %	+15.15 %
CCN (> 35 nm) change	-	+ 0.04 %	+8.91 %

Conclusions

- DMS contribution to CCN in summer SO is 46% (30-45 ^{o}S), 18% (45-60 ^{o}S), 40% (60-75 ^{o}S)
- These estimates are less than derived from satellite data (Vallina et al., 2006) – about 80%
- When DMS is removed, a large fraction of CCN still comes from continental SO_2 emissions, due to efficient nucleation in the free troposphere, and explains the different result
- The response of CCN to atmospheric sulfur is non-linear
- >90% of DMS-derived CCN arise from nucleation in the FT
- We calculate <1.3% change in SO CCN for 5x DMS emission in a small ocean patch, much smaller than estimated by Wingenter (2007)