Low-level clouds and large-scale conditions in the southern oceans

A review of the processes

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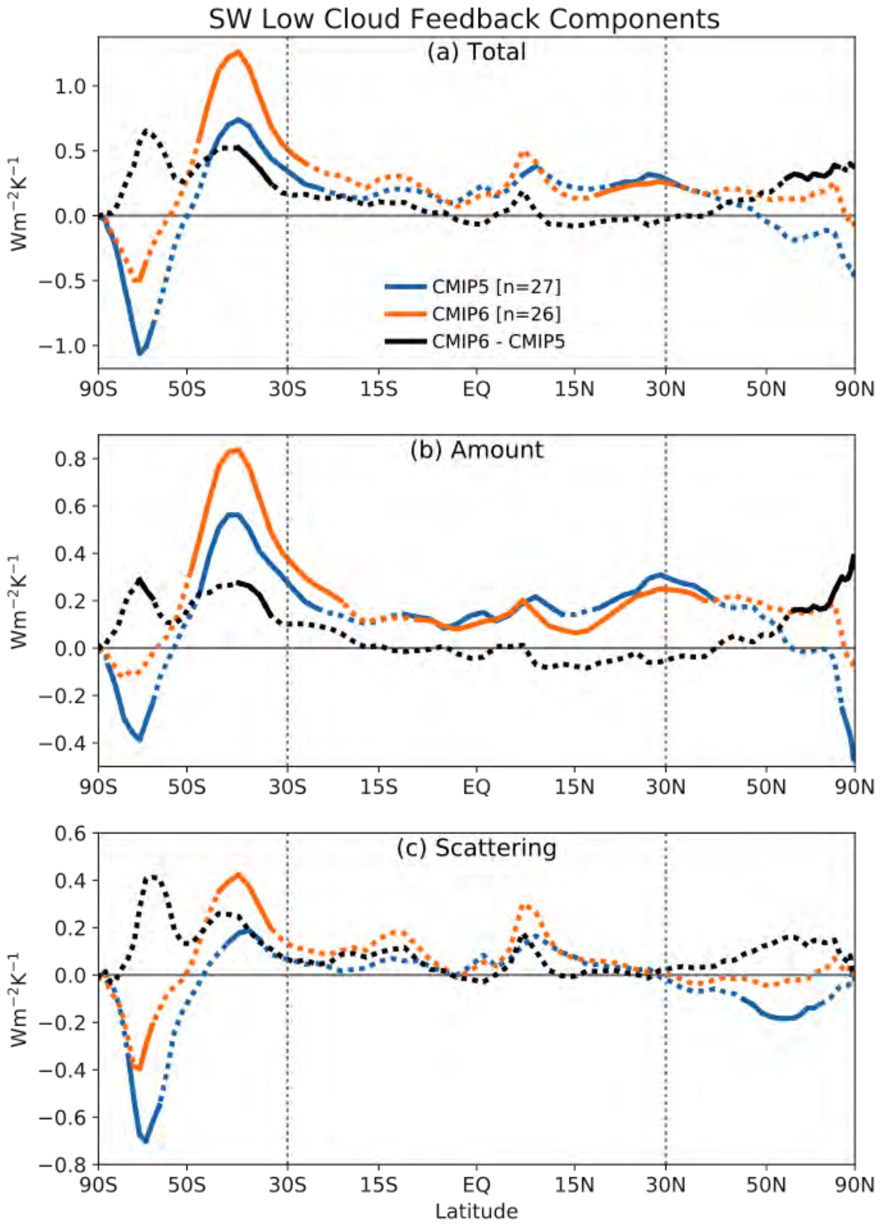
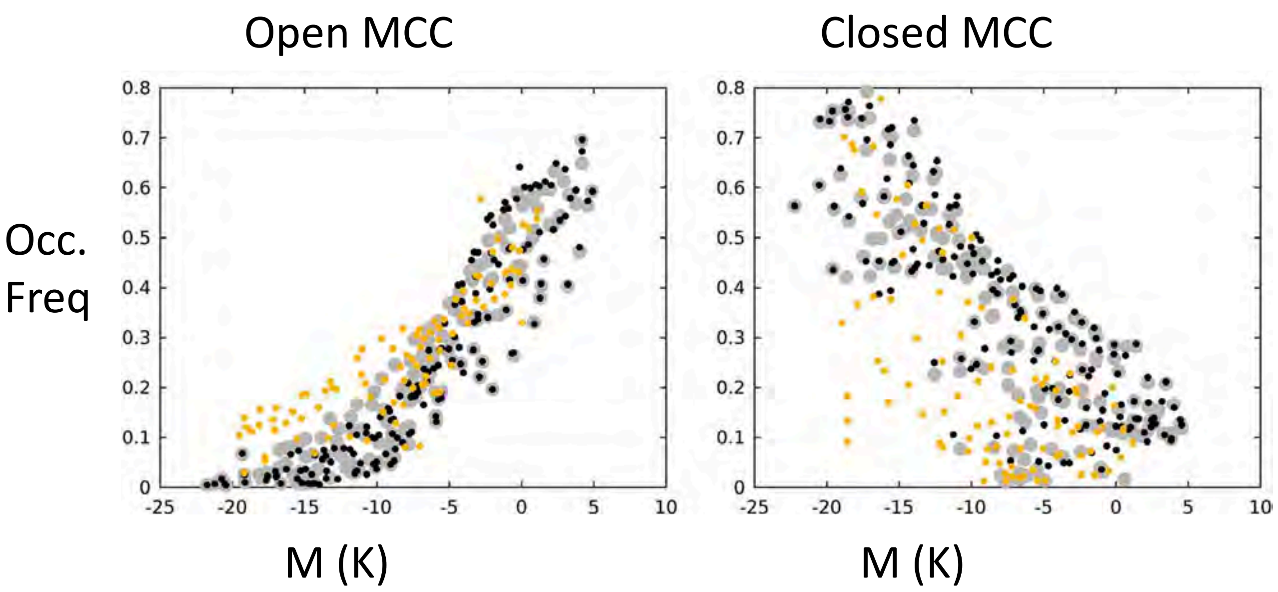
Context

- Clouds in the southern oceans: majority at low level (Mace JGR 2010, Haynes et al JCLI 2011; McCoy et al JCLI 2014,...)
- From Zelinka et al (GRL 2020):
  SW low cloud feedback large in southern oceans, and experienced significant changes between CMIP5 (blue) and CMIP6 (orange) models.
- Amongst models, noticeable differences in sensitivity of cloud properties to changes in **cloud controlling factors**: e.g. EIS, SST, Tadv, RH-lower free troposphere, omega Klein et al. (2017 Sur. Geophys.) show their importance for tropics/subtropics
- How about for mid to high latitudes low level clouds?



Zelinka et al., GRL 2020

Cloud controlling factors: midlatitude Mesoscale Convective Clouds organization



Grey: global
Black: midlatitude
Gold: tropical

McCoy et al. (JGR 2017)

Examined open vs closed cellular convection globally and find strong correlation in midlatitude of Freq. occurrence with EIS, sea-air temperature contrast and M (Fletcher et al 2016):

$M = \Theta_{surf} - \Theta_{800hPa}$

M better predictor for midlatitude than tropics

ARM observations for oceans: continuum through latitudes

Tropics/subtropics
e.g. MAGIC (north) or LASIC (south)

Mid to high latitude oceans
e.g. ENA (north) and **MARCUS&MICRE** (south)

High latitudes
e.g. NSA/Oliktok, MOSAIC/**COMBLE** (north)
MARCUS/AWARE (south)

Cloud Controlling Factors

- Stability:
  LTS ($=\boldsymbol{\theta}_{700}-\boldsymbol{\theta}_{near\text{-}surf}$; Klein and Hartmann 1993)
  EIS ($=LTS-\boldsymbol{\Gamma}_{850}^{M}(Z_{700}-LCL)$; Wood and Bretherton (2006)
  M ($= \boldsymbol{\theta}_{skin}-\boldsymbol{\theta}_{800}$; Fletcher et al., 2016)
- Dynamics: $\boldsymbol{\omega}_{700}$ (or 500hPa)
  surface winds
- Thermodynamics: T/q advection
  $RH_{near\text{-}surf}$
  PW
- Surface forcing: SST
  latent/sensible heat fluxes

Processes

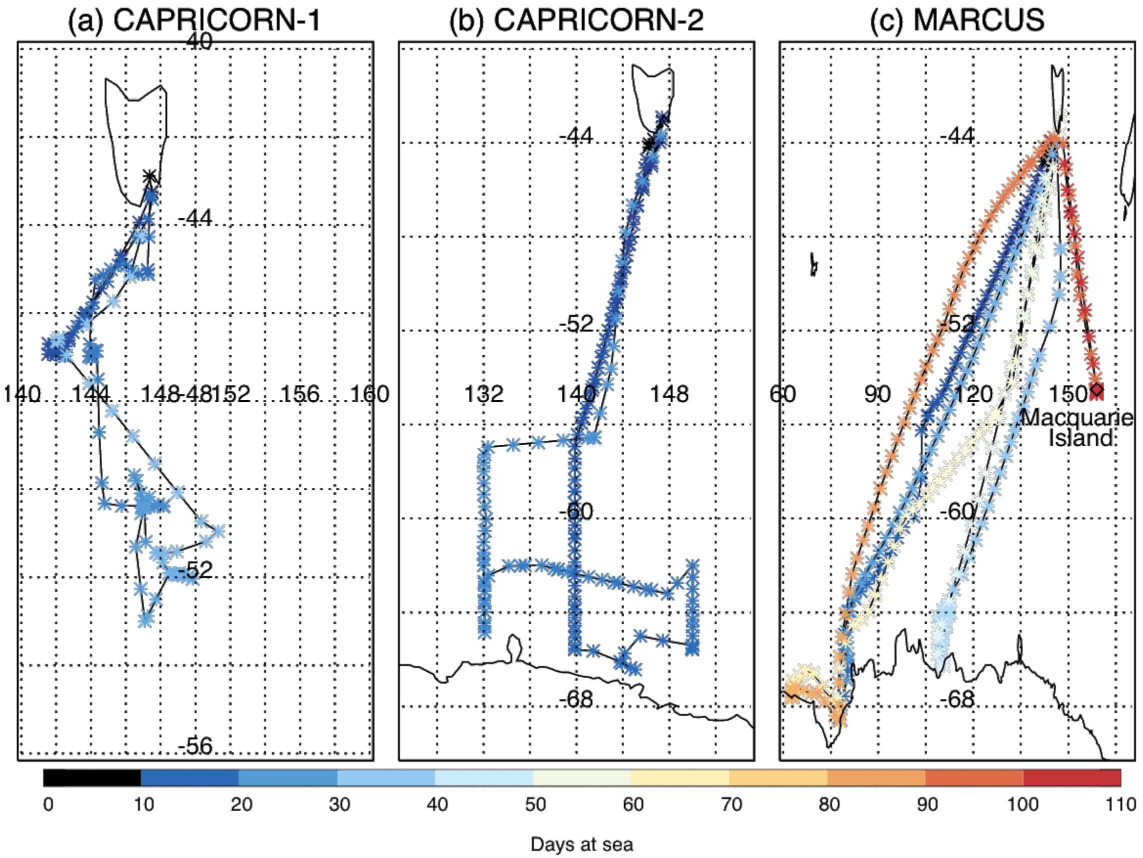
- PBL (stratification/mixing /turbulence...)
- Shallow convection
- Microphysical processes (aerosol-cloud interaction, precipitation...)

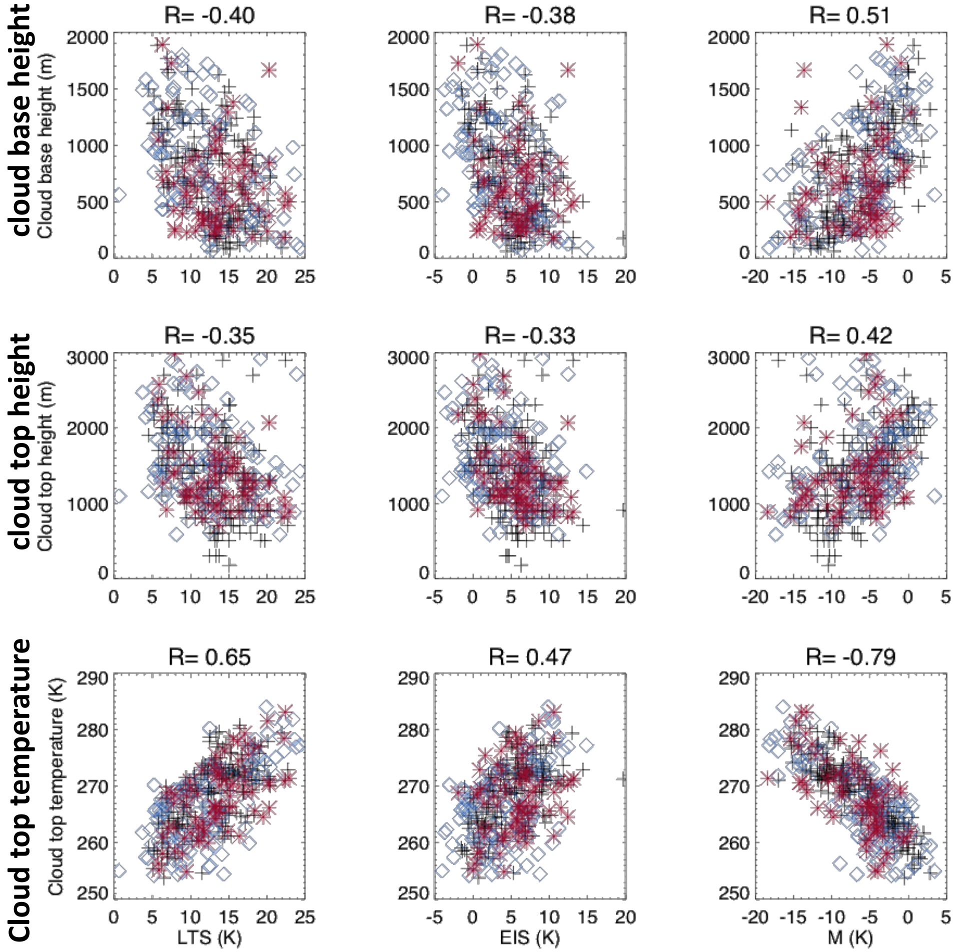
Cloud properties

- Cloud amount
- Cloud organization
- Cloud top height/temperature
- Cloud phase
- decoupling

Low clouds in the southern oceans

Map of voyages of MARCUS/CAPRICORN/SOCRATES + MICRE SO campaigns to study clouds vs CCF





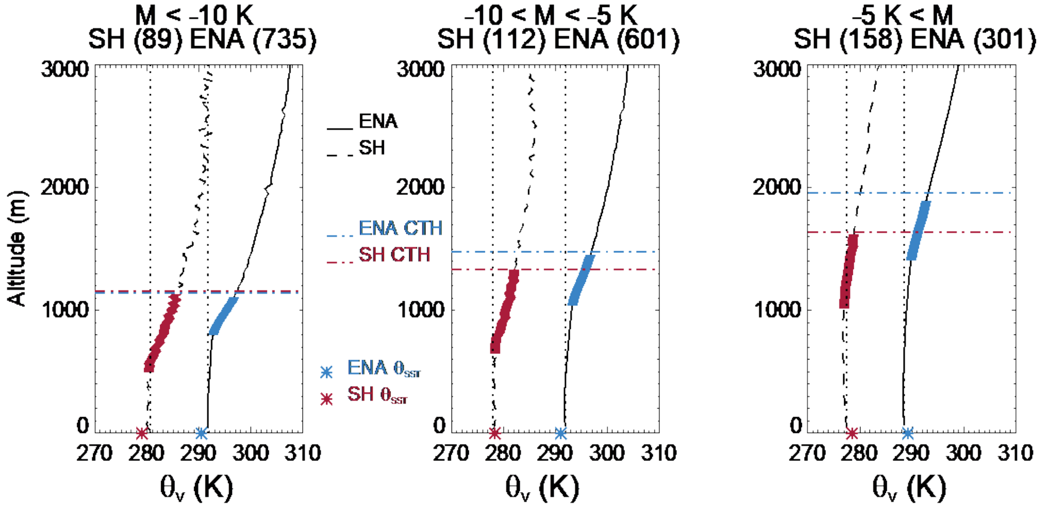
LTS (K) EIS (K) M (K)

Correlation of stability metrics with cloud top/base heights stronger when using M

Naud et al. 2020

Stability vs. cloud base/top heights

Comparison of changes in PBL structure with M between ENA (blue/solid) and SO (red/dashed):



Evolution of mean virtual potential profiles as a function of M (decreasing stability from left to right)

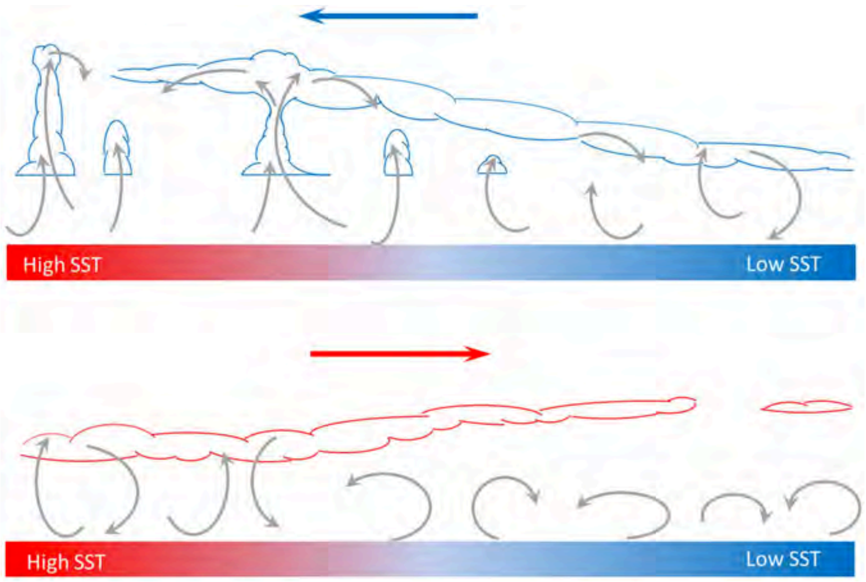
Despite imposing similar stability conditions, the two locations display clear differences in the vertical structure of the lower atmosphere as well as in the cloud depth

Conditions of subsidence with clouds below 3km:
Cloud base and top height sensitive to changes in M in both locations: clouds higher as M increases
Suggests transition from stratocumulus to cumulus

But vertical structure of PBL different in SO vs ENA
And SLP SO << SLP ENA + SST SO << SST ENA

⇒ Impact of surface fluxes (sensible and latent heat fluxes)?
⇒ Impact of temperature and moisture advection?

Thermal advection vs decoupling



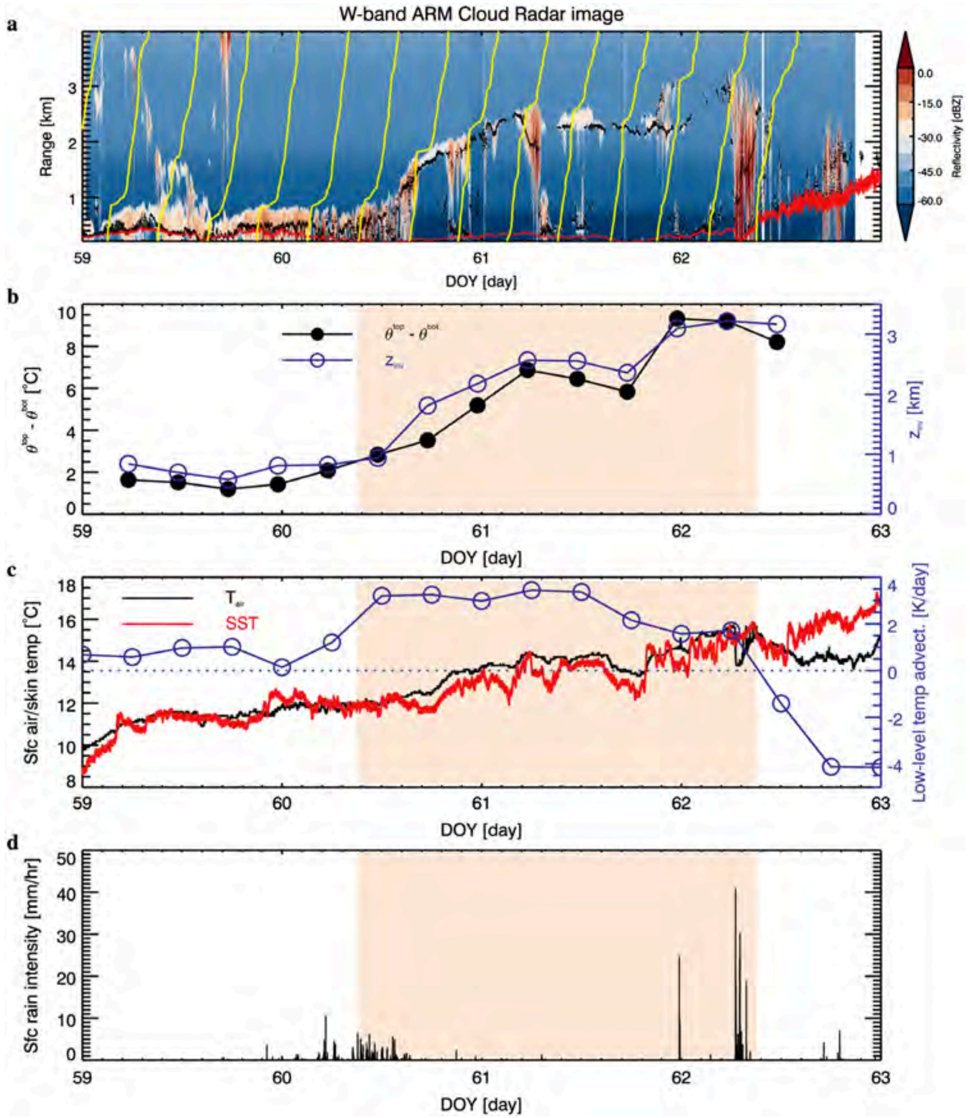
Cold air advection

(typical of low latitudes)

Warm air advection

(e.g. warm sectors of extratropical cyclones)

Warm air over cold surface: deepening of PBL, cloud transition from thin low-level continuous layer to broken, convective and deeper



Zheng et al 2018 and **Zheng and Li (2019)**: work on the response of MBL coupling state to thermal advection

Use MARCUS data

+ Zheng et al. (2020): larger impact of warm vs cold advection at all latitudes

Discussion

- Subtropics vs extratropics: relative role of dynamics?
- How are clouds observed during COMBLE (and other high latitude campaigns) related to CCF vs. lower latitudes?
- Proximity to land/ice surfaces?
- Contrast microphysics and large scale forcing: role of aerosols?
- Cloud phase? Supercooled vs mixed clouds (e.g. Mace et al GRL 2020)