Satellite Observations of Organizational Regimes in Low-Level Mixed-Phase Clouds over the Southern Ocean

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Introduction

Low-level clouds cover between 40% to 60% of the ocean surface in the Southern Ocean (SO) and exert a substantial radiative cooling. Marine stratocumulus typically self-organize into two types of mesoscale-cellular convective (MCC) regimes:

- Open MCC
- Closed MCC

which are associated with different cloud albedos and cloud radiative effect *(McCoy et al 2017)*.

Many of MCC clouds in the SO are not pure liquid but contain a mixture of liquid and ice.

▶ **Does the ice formation within mixed-phase clouds influence MCC organization?**

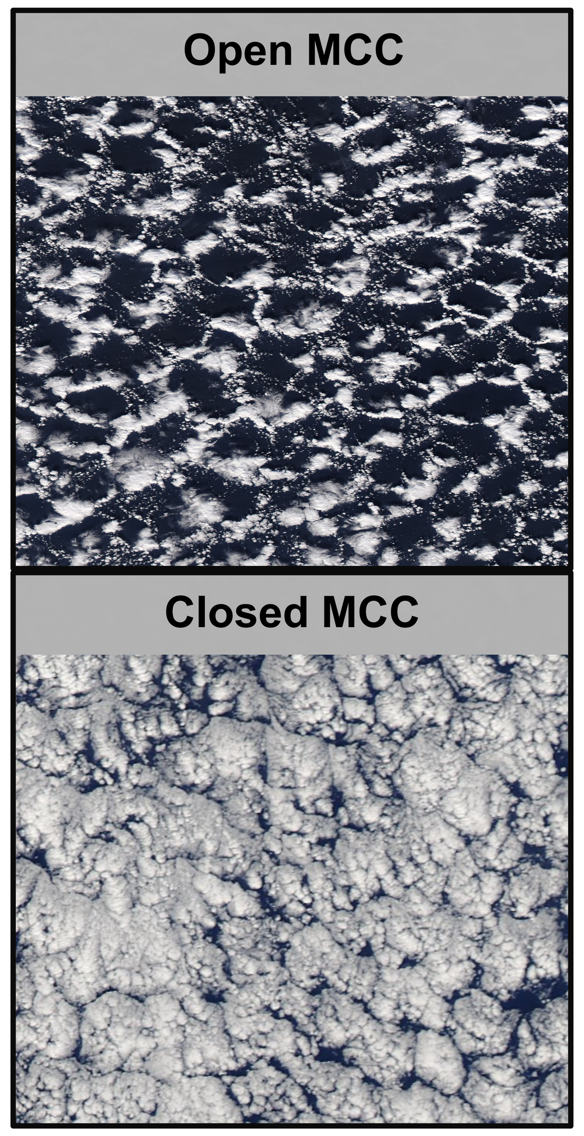

Fig. 1: Two cellular organizational regimes in low-level clouds identified by visual inspection. Example cloud scenes were taken on Jan. 30th 2020 by MODIS Aqua (provided by: https://earthdata.nasa.gov).

DARDAR and MODIS

DARDAR v1 product and MODIS cloud product on the CALIPSO track (res: 5km)

- Time period: 2007 - 2010
- SO: 40°S to 65°S
- Low-level: ≤ 3km

Cloud phase of DARDAR is vertically resolved into:

- Ice (Ice)
- Mixed (Mix)
- Liquid warm (Liq)
- Supercooled (Sup)

Reduction of vertical cloud phase to non-vertical cloud phase (Liquid, Mixed and Ice) by vertical distribution (see Fig. 2)

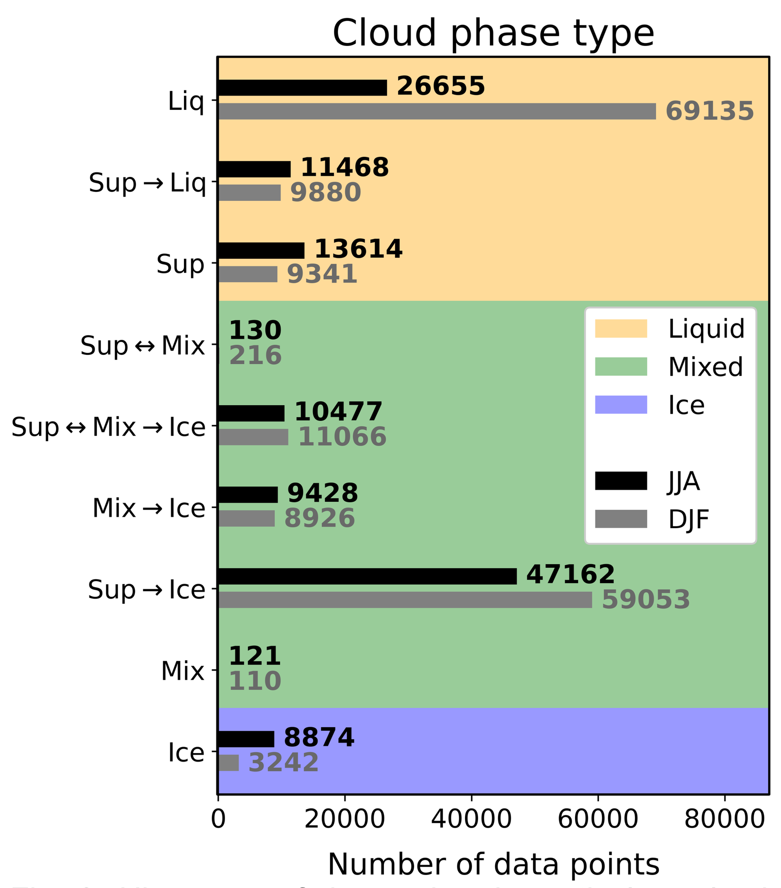

Fig. 2: Histogram of data points in vertical resolved cloud phase categories dived into liquid, mixed and ice clouds for JJA and DJF in 2008. → indicates layer on top of next. ↔ indicates interchangeable layers.

MCC Classification

MCC regimes identified by a neural network algorithm based on the power density function and power spectrum of liquid water path (Wood and Hartmann 2006).

- MODIS scenes
  - 256 km x 256 km
  - Three organizational regimes
    - Open MCC
    - Closed MCC
    - Cellular but disorganized

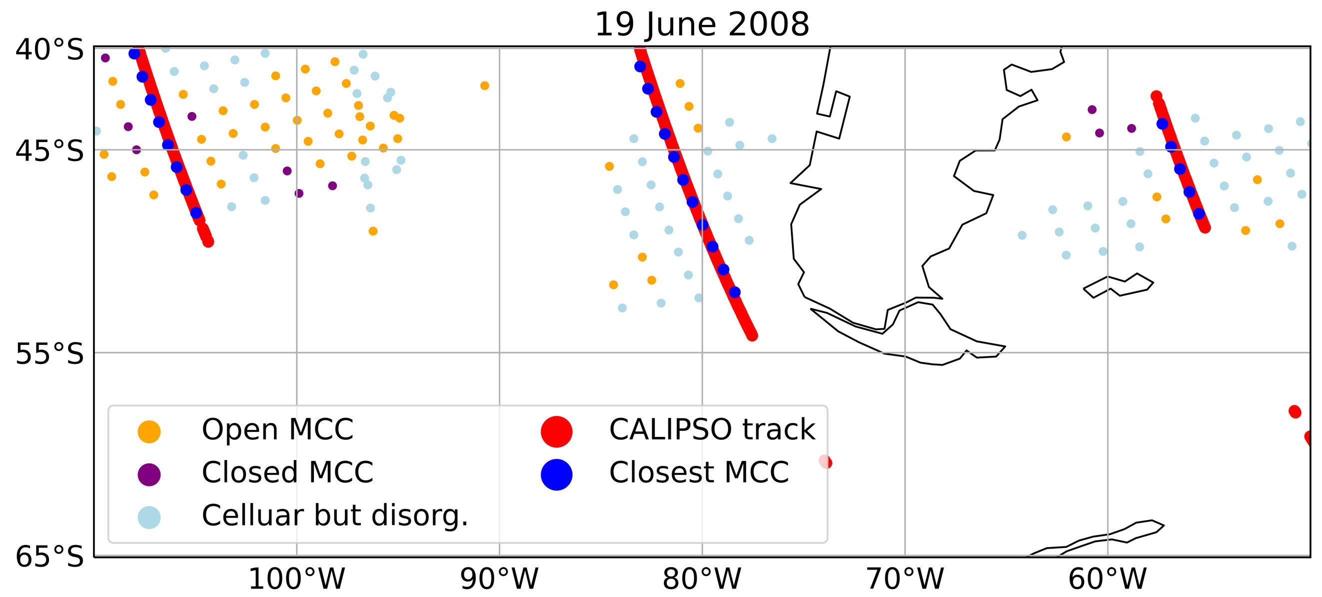

Fig. 3: Map of combined CALIPSO track from DARDAR (red dots) with MCC classification data set (yellow, purple, grey) on June 19th 2008. The blue dots indicate the closest MCC points to the CALIPSO track.

Preliminary Results - Cloud Phase

JJA (Winter)

- Open MCC: More often mixed-phase than liquid phase
- Closed MCC: No phase tendency

DJF (Summer)

- Open and closed MCC: More often mixed than liquid phase

Tab.1: Number of data points of open and closed MCC regimes with cloud top temperatures (CTT) from -10 to 0 °C divided into three cloud phases in JJA and DJF.

	Liquid		Mixed		Ice	
JJA						
Open MCC	6 393	(26.8%)	15 683	(65.6%)	1 849	(7.7%)
Closed MCC	5 204	(49.5%)	5 214	(49.6%)	93	(0.9%)
DJF						
Open MCC	4 354	(19.0%)	17 978	(78.3%)	609	(2.7%)
Closed MCC	20 438	(33.9%)	39 577	(65.6%)	328	(0.5%)

Preliminary Results - CTT

Open MCC (Fig. 4 left)

- Shift to higher percentage of mixed in DJF (Tab. 1) due to:
  - More mixed clouds with CTT from -8°C to -3°C
  - Less liquid clouds with CTT above -3°C
- More ice clouds at higher CTT than lower CTT

Closed MCC (Fig. 4 right)

- Increase of mixed clouds in DJF especially strong at CTT below -3°C
- Nearly no ice clouds

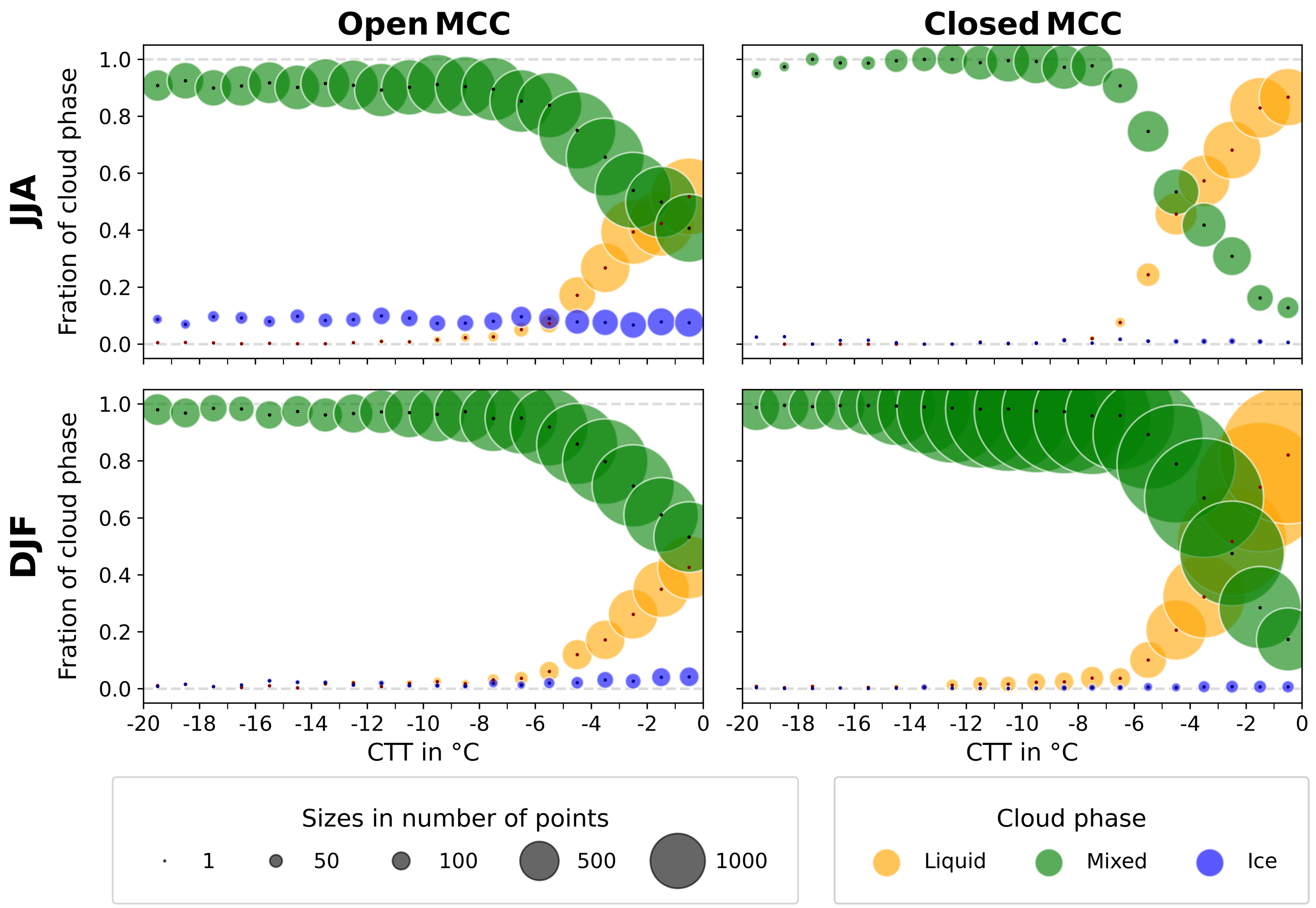

Fig. 4: Liqud, mixed and ice fraction binned by cloud top temperature (CTT) from -20°C to 0°C with a bin width of 1°C. Circle size indicates number of data points in bin for each cloud phase. Data from 2007 to 2010 (top) JJA and (bottom) DJF with (left) open MCC and (right) closed MCC regime.

Preliminary Conclusions

▶ Cloud morphology is impacted by ice for CTT above -3°C

▶ Sensitivity of cloud phase on CTT is different for open and closed MCC organization

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