Overview of aerosol observations from the Marion Dufresne Atmospheric Program – Indian Ocean (MAP-IO) program

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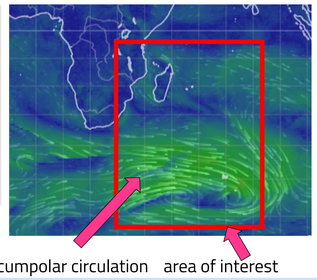
Introduction

The study of marine aerosols size distribution and cloud condensation nuclei (CCN) properties is of major interest as they influence clouds life and clouds radiative properties, particularly in the remote ocean which remains poorly documented. Several short campaigns focusing on specific regions as phytoplankton bloom regions, pristine regions or remote areas influenced by continental air masses took place to address this issue. However, long sampling periods targeting different in-situ conditions had not been realized.

In this context, the MAP-IO program was launched with the aim of providing a large new set of marine aerosol observations (size distribution from 10 nm to 10 µm and CCN properties) on different sea state and meteorological conditions. Thus, the Marion Dufresne vessel has been equipped with a set of various instruments described in Tulet et al. (in preparation) or on the website www.mapio.re. Two years after the launch of the program, we now have aerosol observations (about 200 days) over an area covering 50 ° of latitudes and extending from the Tropics to the upper Southern Ocean.

http://www.mapio.re/



Instruments and data

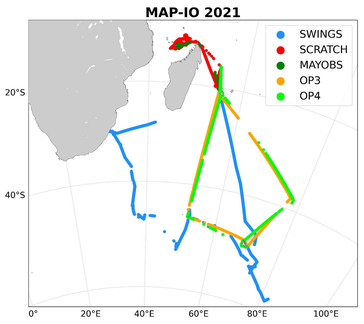
In this study, we focus on five campaigns carried out in the Indian Ocean and the Southern Ocean in 2021.

Instruments	Products	Size range
SMPS	Aerosol size distribution	3 – 995 nm
CCN100	Cloud condensation nuclei concentration	3 – 995 nm
POPS	Aerosol size distribution	120 nm – 3000 nm
OPC-N3	Aerosol size distribution	350 nm – 40000 nm
Vaisala station	Wind speed and direction	-
Picarro	CO, CO2 concentration	-

(Data and description available on www.aeris-data.fr)

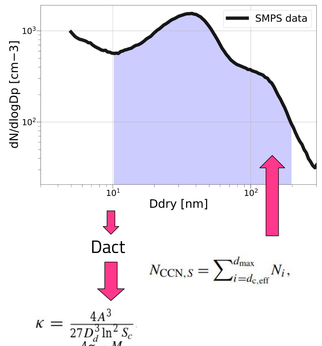
✚ filtering on wind criteria

Campaign	Dates
SWINGS	2021-01-13 - 2021-03-08
SCRATCH	2021-07-01 - 2021-07-22
MAYOBS	2021-09-13 - 2021-03-10
OP3	2021-10-28 - 2021-11-28
OP4	2021-11-28 - 2021-12-30



Methodology

- We investigated the behavior of cloud condensation nuclei concentrations according to wind speed (from 4 m s-1 to 33 m s-1)
- We analyzed the size distributions of aerosols according to the wind speed during a 5-day storm that occurred in the Southern Ocean
- 5-days back trajectories were simulated each hour using the FLEXPART model in order to link aerosol concentration collected onboard the Marion Dufresne to the air masses origin.
- The hygroscopicity parameter kappa was calculated according to Petters and Kreidenweis, 2007 at 0.2, 0.4, 0.6 and 0.8 supersaturation.



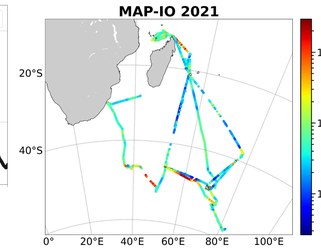
Dact

$$\kappa = \frac{4A^3}{27 D_d^3 \ln^2 S_c}$$

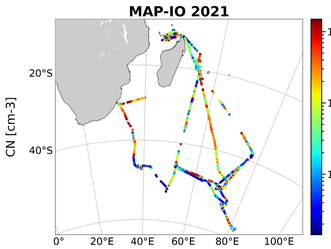
$$A = \frac{4\sigma_{s/a} M_w}{RT\rho_w}$$

$$N_{CCN,S} = \sum_{i=d_{c,eff}}^{d_{max}} N_i,$$

Petters and Kreidenweis, 2007

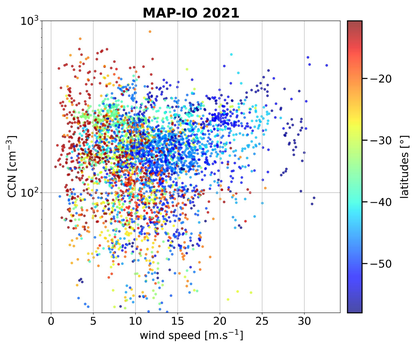


- Great variability of CN
- CN usually < 800 cm-3
- Concentration **picks south of 40° S** and **north of Madagascar** (CN > 5000 cm-3)

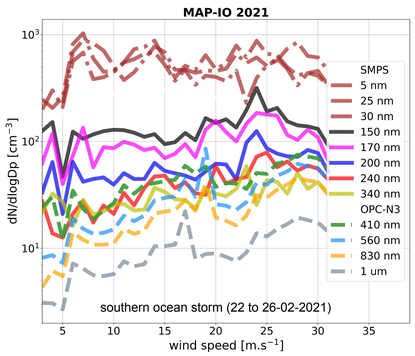


- Great variability of Kappa (**black carbon, organics, sea salts**)
- **CN picks** matches low kappa values (**kappa ~ 0**)

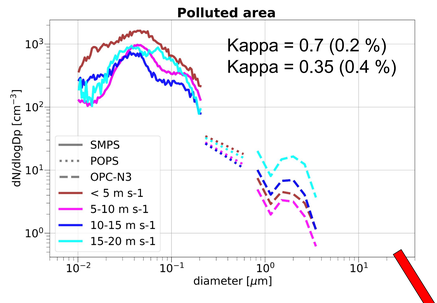
Results

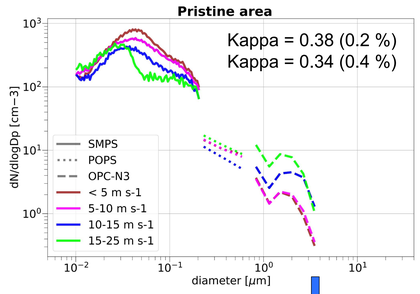


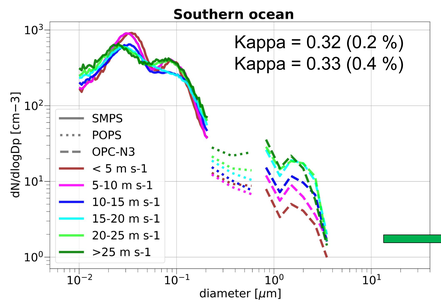
- **South of 50 °S**, the **minimum CCN concentration** tends to **increase when the wind speed exceeds** approximately **12 m s-1** (**sea salt emissions** mechanically driven by local conditions and tend to be **predominant from 10 m s-1**)
- **Below 10 m s-1** wind speed, **CCN concentration** is more **homogeneous according to wind speed** → mixture of **secondary and primary marine aerosols**

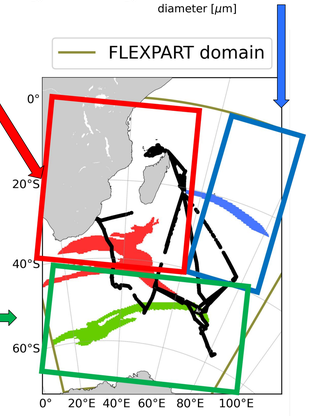


- The number of particles with a **diameter less than 400 nm** is **predominant** over the full range of wind speeds (4 to 33 m s-1)
- The number of aerosols with **diameter greater than 500 nm** remains **low under 10 m s-1** and **increases from 10 m s-1 to 33 m s-1**









- Three modes visible: **Aitken** (20 nm – 50 nm), **accumulation** (60 nm – 150 nm) and a **coarse** mode (1 µm - 3 µm)
- Number concentration of **coarse aerosols** increases with increasing **wind speed** (primary marine emission)
- **Aitken** and **accumulation modes** particularly remarkable when **wind speed exceeds 7 m s-1** in the **polluted** area, and **17 m s-1** in the **pristine** area, but noticeable for low **wind speed (< 5 m s-1)** in the **southern ocean** area
- Averaged **hygroscopicity** parameter **decreases** strongly **when supersaturation increases** in **polluted** area (mixture of **primary and secondary aerosols**)
- **Kappa ~ 0.3 (organics)** at 0.2 % and 0.4 % supersaturation in the **southern area** (**composition** of air masses **relatively homogeneous**)

Conclusion

- 5 campaigns were used to investigate **aerosol size distribution and CCN properties in the Indian and the Southern Ocean**
- Behavior of **CCN (size > 400 nm)** are in good agreement with the literature **when the wind speed exceeds 10 m s-1** (mechanically generated specifically in the Southern Ocean)
- **3 areas** determined according to air masses origin: **polluted, pristine and southern** area
- **Coarse mode** aerosols (size > 1 µm) show a **strong positive correlation to wind speed**
- **Aitken** and **accumulation modes** are more visible **when the wind speed increases in polluted and pristine areas**
- The hygroscopicity parameters calculated for the **polluted area** show the **variety of species** composing the air masses coming from this area

Acknowledgements

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