surface ocean solas lower atmosphere study

# Report for the year 2021 and future activities

## SOLAS *FRANCE*
## *compiled by: Rémi Losno (losno@ipgp.fr)*

*This report has two parts:*

***- Part 1:** reporting of activities in the period of January 2021 - Jan/Feb 2022*
***- Part 2:** reporting on planned activities for 2022 and 2023.*

*The information provided will be used for reporting, fundraising, networking, strategic development and updating of the live web-based implementation plan. As much as possible, please indicate the specific SOLAS 2015-2025 Science Plan Themes addressed by each activity* **or specify an overlap between Themes or Cross-Cutting Themes.**

1 Greenhouse gases and the oceans;
2 Air-sea interfaces and fluxes of mass and energy;
3 Atmospheric deposition and ocean biogeochemistry;
4 Interconnections between aerosols, clouds, and marine ecosystems;
5 Ocean biogeochemical control on atmospheric chemistry;
Integrated studies of high sensitivity systems;
Environmental impacts of geoengineering;
Science and society**.**

***IMPORTANT**: This report should reflect the efforts of the SOLAS community in the **entire country** you are representing (all universities, institutes, lab, units, groups, cities).*

| **First things first…Please tell us what the IPO may do to help you in your current and future SOLAS activities. ?** |
|---|
| This is well done by SOLAS webinar organization |

## PART 1 - Activities from January 2021 to Jan/Feb 2022

### 1. Scientific highlight

*Carla Geisen (carla.geisen@locean.ipsl.fr), Céline Ridame and Damien Cardinal.*

**Southern Ocean diatoms benefit from nutrients provided by desert dust and volcanic ash. A phytoplankton response triggered by a representative deposition event of natural aerosols in the Indian sector of the Southern Ocean.**

An experimental study focusing on marine biogeochemistry has been carried out as part of the OISO program (French Océan Indien Service d'Observations) during an oceanographic campaign in January-February 2019 in the Indian sector of the Southern Ocean aboard the R/V Marion

Dufresne. Incubations (Figure 1) show that a representative deposition of natural aerosols triggers a phytoplankton response in different regions of the Southern Ocean, while modifying the structure of the planktonic community to the benefit of diatoms. This study, conducted mainly by researchers from LOCEAN-IPSL and LISA-IPSL, has just been published in open access in the journal Limnology and Oceanography (Geisen et al. 2022).

*Figure 1. Photograph of the incubators on board the R/V Marion Dufresne, equipped with light filters and supplied by surface seawater to maintain representative radiance and temperature of the surface ocean*

Within the South Indian and Southern Oceans, contrasting concentrations of macro- and micronutrients induce different nutrient limitations for phytoplankton. microalgae communities are thus locally limited by different nutrients, which is reflected in a variable biomass (expressed as Chlorophyll-a concentration, Figure 2). Nutrients can be supplied to the sea surface via deeper waters during winter mixing, as well as episodically via ocean interfaces such as aerosols. Only limited amounts of atmospheric dust reach currently the remote areas of the Southern Ocean, but aerosol deposition nevertheless constitutes one of the major sources of new nutrients during the stratified period of the Austral summer. Moreover, considerably larger depositions have been recorded in this area during glacial times and/or volcanic eruption events. After deposition on the sea surface, the desert dust and volcanic ash particles release nutrients such as iron and silicon to the seawater, which might temporally boost algal development. To assess this response within distinct biogeochemical areas, we conducted microcosm experiments at different stations. A dry or wet deposition of dust from Patagonia or ash from the Icelandic volcano Eyjafjallajökull or dissolved nutrients (Si, Fe, N and/or P) was added to clean surface seawater incubations.

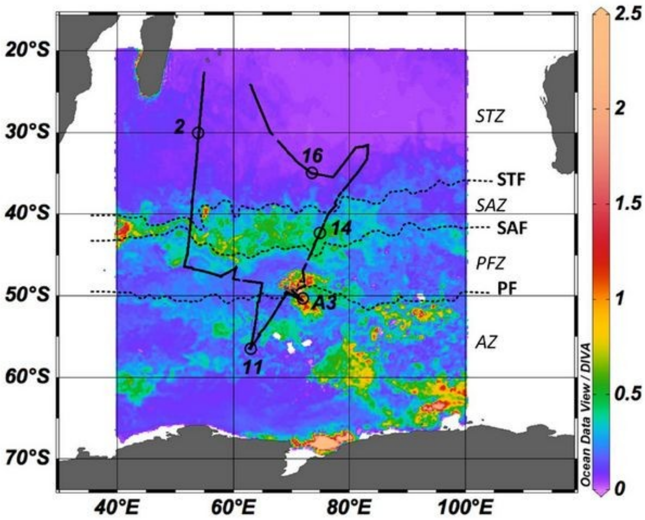



*Figure 2. OISO-29 cruise transect showing the locations of the five stations (LNLC-2, HNLC-11, Kerguelen-A3, HN-LSi-LC-14 and LNLC-16) where the bioassay experiments were performed, and satellite-derived chlorophyll-a concentration (µg.L-1) averaged over January 2019 (MODIS). The position of major fronts was determined from satellite-derived temperature data (January 2019, MODIS): STF: subtropical front (18 °C), SAF:*

*Subantarctic front (13 °C) and PF: polar front (5 °C). Fronts delimit the STZ: subtropical zone, SAZ: Subantarctic zone, PFZ: polar front zone and AZ: Antarctic zone.*

In this study, we show that a realistic deposition of desert or volcanic aerosols is an important source of nutrients to the ocean surface, triggering a significant increase in the photosynthetic activity of phytoplankton ($CO_2$ fixation) in different regions of the Indian Southern Ocean (Figure 3). Both aerosol types mitigated iron deficiency occurring in the Southern Ocean during the Austral summer and caused a 24 to 110% increase in primary production, depending on the station. The release of dissolved silica potentially also contributed to this response, although to a lesser extent. Some algae groups such as diatoms benefit more from the new nutrients (40 to 100% of the biomass increase in the responding stations), thereby modifying the structure of the planktonic community. On the other hand, the same deposition had no effect in the subtropical part of the South Indian Ocean, as the local nitrogen limitation was not relieved by the aerosols.

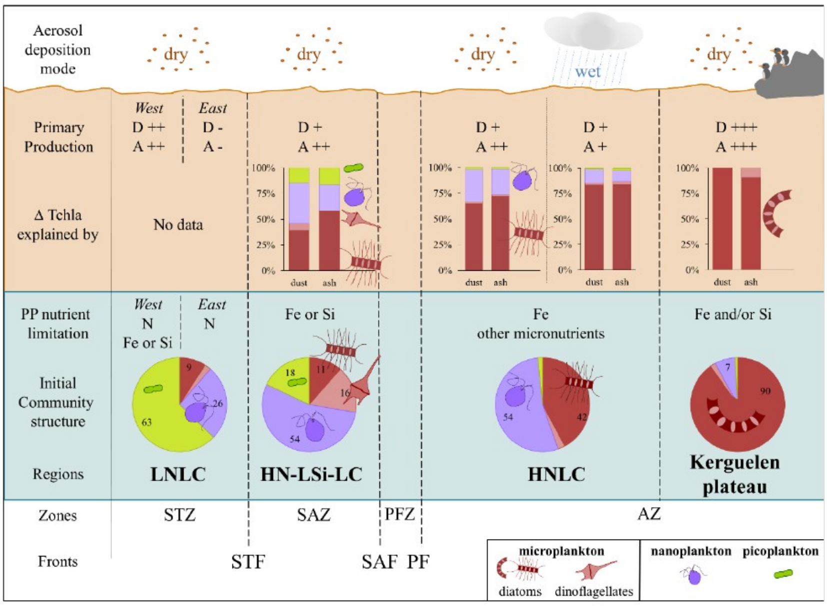



***Figure 3.*** *Schematic representation of the biological response of phytoplankton communities after dry or wet dust (D) or ash (A) deposition to the sea sur- face within different biogeochemical regions of the South Indian Ocean and Southern Ocean. The top part of the figure (orange box) shows the phytoplankton response to aerosol deposition (PP and ΔTchla), while the bottom part (blue box) represents the initial conditions prior to deposition (nutrient limitation and phytoplankton structure). Primary production is expressed in relative change (%), as follows: +++ above 100%; ++ above 50%; + below 50%;–no significant change compared to control. ΔTchla shows the contribution (%) of different phytoplankton classes explaining the global increase in Tchla. The community composition (initial and final) is based on the pigment signature, with red: microplankton (dark: diatoms and light: dinoflagellates), purple: nanoplankton, and green: picoplankton. The graphic concerns solely the surface layer and response after 48 h, regardless of depth and particle sinking. Zones and fronts (from North to South): Subtropical Zone and Front (STZ and STF); Subantarctic Zone and Front (SAZ and SAF); Polar Front Zone and Polar Front (PFZ and PF); and Antarctic Zone (AZ).*

**Reference**


Geisen, Ridame, Journet, Delmelle, Marie, Lo Monaco, Metzl, Ammar, Kombo, Cardinal (2022). Phytoplanktonic Response to simulated Volcanic and Desert Dust Deposition Events in the South Indian and Southern Oceans. Limnol. Oceanogr. doi : 10.1002/lno.12100

Karine Sellegri (k.sellegri@opgc.univ-bpclermont.fr)

**Sea2Cloud**

***Highlight 1:*** *Oceanic phytoplankton are a potentially important source of benzenoids to the remote marine atmosphere*

Benzene, toluene, ethylbenzene and xylenes can contribute to hydroxyl reactivity and secondary aerosol formation in the atmosphere. These aromatic hydrocarbons are typically classified as anthropogenic air pollutants, but there is growing evidence of biogenic sources, such as emissions from plants and phytoplankton. Here we use a series of shipborne measurements of the remote marine atmosphere, seawater mesocosm incubation experiments and phytoplankton laboratory cultures to investigate potential marine biogenic sources of these compounds in the oceanic atmosphere. Laboratory culture experiments confirmed marine phytoplankton are a source of benzene, toluene, ethylbenzene, xylenes and in mesocosm experiments their sea-air fluxes varied between seawater samples containing differing phytoplankton communities. These fluxes were of a similar magnitude or greater than the fluxes of dimethyl sulfide, which is considered to be the key reactive organic species in the marine atmosphere. Benzene, toluene, ethylbenzene, xylenes fluxes were observed to increase under elevated headspace ozone concentration in the mesocosm incubation experiments, indicating that phytoplankton produce these compounds in response to oxidative stress. Our findings suggest that biogenic sources of these gases may be sufficiently strong to influence atmospheric chemistry in some remote ocean regions.

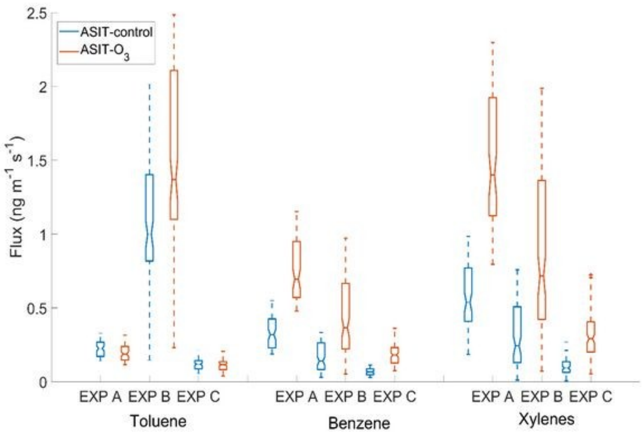



***Figure 4:*** *Influence of 10 ppb ozone concentration increase on seawater phytoplankton-derived BTEX fluxes. Comparison of toluene, benzene and xylenes fluxes (ng m-1 s-1) over the three experiments performed in ship-borne Air-Sea Interface Tanks (ASIT). Bottom and top of each box are the 25th and 75th percentile, line in the middle of each box is the median and whiskers are the maximum and minimum values*.

***Highlight 2****: New particle formation at Baring Head in coastal New Zealand*

Even though oceans cover the majority of the Earth, most aerosol measurements are from continental sites. We measured aerosol particle number size distribution at Baring Head, in coastal New Zealand, over a total period of 10 months to study aerosol properties and new particle formation, with a special focus on aerosol formation in open ocean air masses. Particle concentrations were higher in land-influenced air compared to clean marine air in all size classes from sub-10 nm to cloud condensation nuclei sizes. When classifying the particle number size distributions with traditional methods designed for continental sites, new particle formation was observed at the station throughout the year with an average event frequency of 23%. While most of these traditional event days had some land-influence, we also observed particle growth starting from nucleation mode during 16% of the data in clean marine air and at least part of this growth was connected to nucleation in the marine boundary layer. Sub-10 nm particles accounted for 29% of the total aerosol number concentration of particles larger than 1 nm in marine air during the spring. This shows that nucleation in marine air is frequent enough to influence the total particle concentration. Particle formation in land-influenced air was more intense and had on average higher growth rates than what was found for marine air. Particle formation and primary emissions increased particle number concentrations as a function of time spent over land during the first 1-2 days spent over land. After this, nucleation seems to start getting suppressed by the pre-existing particle population, but accumulation mode particle concentration keeps increasing, likely due to primary particle emissions. Further work showed that traditional NPF events were favoured by sunny conditions with low relative humidity and wind speeds. In marine air, formation of sub-10 nm particle concentrations was favoured by low temperatures and wind speeds and could happen even during the night. This study sheds light on both new particle formation in open ocean air masses coming from the Southern Ocean and local aerosol properties in New Zealand.

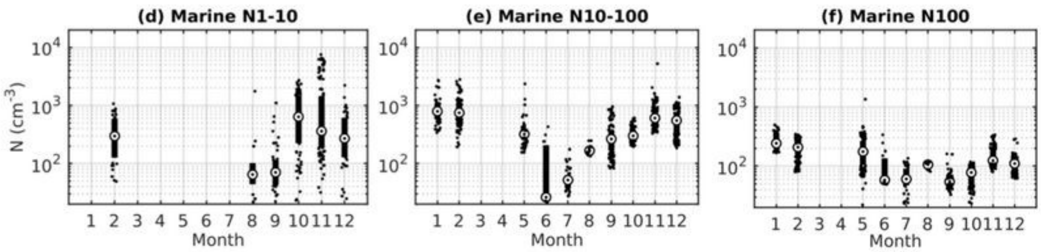



*Figure 5. Seasonal cycles of particle number concentrations in 1-10 nm, 10-100 nm and above 100 nm marine (d-f) land masses. The circles are the median concentrations for each month, black boxes mark 25th and 75th percentiles and rest of the point are outside this range.*

**References**


Peltola, M., Rose, C., Trueblood, J. V., Gray, S., Harvey, M., and Sellegri, K.: New particle formation in coastal New Zealand with a focus on open ocean air masses, Atmos. Chem. Phys. Discuss. [preprint], https://doi.org/10.5194/acp-2021-819, 2022.

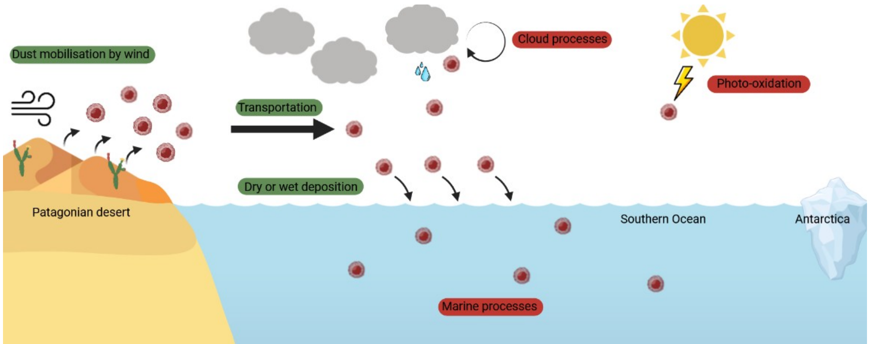
Manon Rocco, Erin Dunne, Maija Peltola, Neill Barr, Jonathan Williams, Aurélie Colomb, Karl Safi, Alexia Saint-Macary, Andrew Marriner, Stacy Deppeler, James Harnwell, Cliff Law and Karine Sellegri, Oceanic phytoplankton are a potentially important source of benzenoids to the remote marine atmosphere, Nature Communications Earth & Environment volume 2, Article number: 175 (2021).


**2. Activities/main accomplishments in 2021 (e.g., projects; field campaigns; workshops and conferences; model and data intercomparisons; capacity building; international collaborations; contributions to int. assessments such as IPCC; collaborations with social sciences, humanities, medicine, economics and/or arts; interactions with policy makers, companies, and/or journalists and media).**

**SOLAS-France** zoom meeting, march $29^{th}$, 2021, about 20 attendees. Three presentations: Cécile Guieu: PEACETIMES, Clément Demasy, solubility of patagonian dust in an acidification context,Yangjunjie Xu-Yang, Atmospheric Deposition over Guadeloupe, see: http://solas.ipgp.fr/2021/

Clément Demasy, demasy@ipgp.fr, Marie Boyé

**Solubility and bioavaibility of patagonian dust in the future Southern Ocean**




The next decades is well-known as the fast global warming. Climate studies are commonly investigated about the impact on the life and the human activities. Since the industrial revolution, humans have been generating large amounts of $CO_2$ and these greenhouse gases are the main source of the global warming. In this regard, trace metals such as iron (Fe) are present at very low concentrations in the open ocean (~fmol.kg$^{-1}$ to nmol.kg$^{-1}$) and therefore play an essential role for the growth of microalgae. The Southern Ocean (SO), which is the largest HNLC area, represents the most important oceanic biological carbon pump in the world ocean. In this perspective, it is crucial to investigate micronutrient inputs but also their behavior in seawater. Atmospheric inputs are one of the main sources of metals in the SO and inputs from the Patagonian desert account for half of aerosol deposition. This source should intensify in the future SO, along with acidification and warming of the surface waters. However, the solubility of Patagonian dust in the future SO that supplies micronutrients available for the phytoplankton, is not known yet. The impact of future anthropogenic changes on the efficiency of the biological carbon pump is thus poorly constrained.

In turn, the SAGAS project (Solubility of Patagonian dust in the future Southern Ocean, funded by the IDEX-Université de Paris Cité in 2020 and coordinated by M. Boye at IPGP) aimed to diagnose the effects of increased dust deposition and other predicted changes on the solubility of Fe and other trace metals contained in Patagonian dust. It relies on abiotic experiments that were conducted under the actual and future controlled conditions using Patagonian dust and filtered seawater sampled during the OISO-30 cruise. The solubility kinetics of dust were established using ICP-MS, SEM and synchrotron light analytical methods at different time and space scales (hour to week, nano- to micro- scale). They provided a better understanding of the dissolution and bioavailability of Patagonian dust in the context of climate change, constituting an essential step to more accurately predict the evolution of the biological carbon pump in the future SO.

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Marie Boye, boye@ipgp.fr, Clément Demasy and Ambroise Delisée.

**Responses of phytoplankton to Patagonian dust input and anthropogenic changes in the future Southern Ocean**

Dust inputs to the Southern Ocean (SO) have the potential to alter future global climate by supplying iron and other critical limiting micronutrients to Antarctic diatoms, thus stimulating the biological $CO_2$ pump as suggested in the Last Glacial Maximum. Future projections indicate an intensification of these depositions in areas of the polar front due to the intensification of winds and an increase in the frequency and magnitude of storms. They also indicate acidification and warming of the waters, but the cumulative effect of these anthropogenic changes on phytoplankton and on the biological carbon pump is not yet known. The SO-dust project (Responses of phytoplankton to Patagonian dust input and anthropogenic changes in the future

Southern Ocean) supported by the LEFE-CYBER program of INSU-CNRS and led by Marie Boye at the globe physics institute of Paris (IPGP), aims to diagnose the net effect of these multifaceted changes on phytoplankton communities, assessing their individual and interactive effects.

We conducted on board incubations aboard R.V. Marion Dufresne II between January and March 2022 as part of the OBS Austral program and the OISO-32 cruise to test the effects of those changes projected at the 2100 horizon on the natural phytoplankton community, following a reduced factorial experimental plan with 4 scenarios (current conditions, future conditions and 2 intermediate conditions). The experiments were conducted in two contrasting zones of the SO, the Polar Front Zone and the High-Nutrients Low-Chlorophyll area where iron is the first limiting micro-nutrient. Different biogeochemical and biological parameters have been sampled and are being analyzed. The results will allow us to diagnose the combined effect of the intensification of dust inputs, acidification and warming of the waters projected for the 2100 horizon on southern phytoplankton communities and on the efficiency of biological carbon pumping. They will be presented at SOLAS-Open Science Conference in Cape Town in September 2022.

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Yangjunjie Xu-Yang (yxu@ipgp.fr), Rémi Losno, Céline Dessert

**Atmospheric deposition over the Caribbean region**

Dust emitted from North Africa is transported over long distances and has a strong impact on large areas over the North Tropical Atlantic Ocean. Sea salt emitted by the sea surface is the second source of essential elements transported in the atmosphere and plays a major role in the cycles of alkaline-earth metals in the ecosystems of tropical North Atlantic Islands. The total atmospheric deposition fluxes were continuously sampled on a weekly basis in Guadeloupe, Lesser Antilles, from March 2015 to August 2018 (41 months). Elemental deposition fluxes including Al, Ca, K, Mg, Fe, Na, P, S, and Zn were measured for all samples in order to provide the first long time series of atmospheric elemental deposition fluxes over the Lesser Antilles region. It is shown that: *(i)* the three sources of atmospheric deposits in Guadeloupe for the presented elements are sea salt (for K, Ca, Mg, Na, S), long-range transported Saharan dust (for Al, Ca, K, Fe), and biogenic particles (for P and Zn); *(ii)* the average deposition mass fluxes of sea salt and Saharan dust are 16.7 $g.m^{-2}.year^{-1}$ and 10.6 $g.m^{-2}.year^{-1}$, respectively, without noticeable inter-annual variations; *(iii)* a pronounced seasonality is found for the Saharan dust deposition, for which maximum flux values are observed between June and July each year and 85% of the annual deposition flux occurs between April and September; *(iv)* the deposition flux of sea salt is strongly correlated to local wind speed, without seasonality.

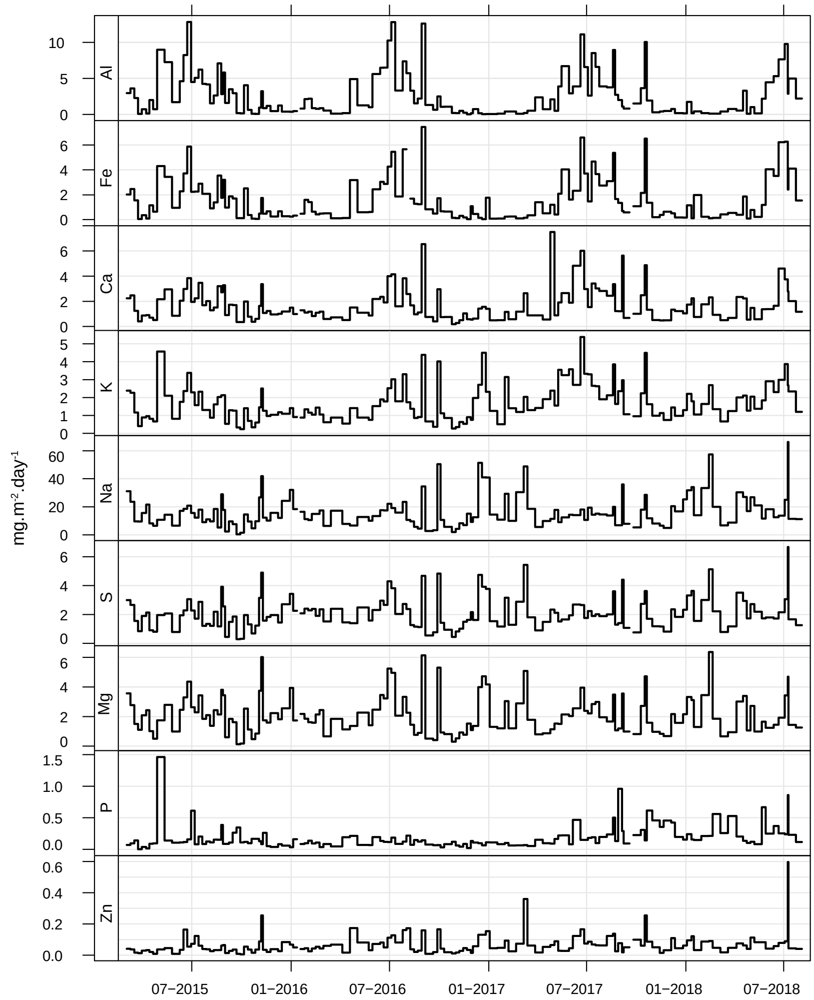


***Figure 6.*** *Total deposition flux of elements on the Guadeloupe Island. A strong seasonality is noticed for iron which is brought by Saharan dust transportation events. Phosphorous and zinc are suspected to have a strong local biogenic origin.*

**Reference**

Y. Xu-Yang et al., Atmospheric deposition over the Caribbean region: sea salt and Saharan dust are sources of essential elements on the island of Guadeloupe, submitted to JGR.

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Patrick Augustin, Weidong Chen (Weidong.Chen@univ-littoral.fr)

**Coastal investigations for Air Sea Exchange at Wissant (Hauts de France)**

In the context of better understanding the atmosphere/sea interaction, a measurement campaign was carried out recently on June 16 & 17, 2022, in the Bay of Wissant near the Strait of Pas-de-Calais. The purpose of the measurements is to better study the marine boundary layer influenced by sea breezes and their impacts on marine and anthropogenic aerosols. This study involves all the study of the atmospheric dynamics in a coastal interface zone by carrying out measurements of the concentration of aerosols (including concentration fluxes) via synchronous or quasi-synchronous multi-sensor measurements. The deployment of the Atmospheric Mobile Unit (UMA), its masts, associated lidars as well as the drone flights took place on June 16. The two sea breezes (in connection with the morphology of the site studied) were indeed observed by the scanning wind lidar. These breezes were able to transport atmospheric pollutants from maritime traffic emissions as well as marine aerosols present above the sea, to the study site (detected by our pollutant analyzers located on the roof of the UMA, taken by a cascade impactor and whose lung cells, located in an experimental device at UMA, were exposed to it). These measurements were supplemented by the drone which carried aerosol sensors and gas sensors ($NO_2$/$SO_2$). Data are still under processing.

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Philippe Goloub (*philippe.goloub@univ-lille.fr*), *L. Blarel, G. Dubois, B. Torres, O. Pujol, F. Ducos, Gest L., N. Marquestaut, et al.*

**Monitoring of Aerosol Properties in the Indian Ocean**

Networks of ground-based stationary sun/sky-photometers like AERONET (AERosol RObotic NETwork, Holben et al., 1998, https://aeronet.gsfc.nasa.gov/) are quite fundamental aerosol observing systems for providing knowledge on aerosol properties, for satellite cal/val activities and model evaluation/assimilation. Looking at the AERONET global map (figure 1a), which is the most dense worldwide network (~21 millions of quality assured AOD accumulated from 2007 to 2021), still a limited amount of data is available over oceanic regions (~ 2%), areas which are currently manually operated within the Maritime Aerosol Network (MAN) branch of AERONET (Smirnov et al., 2002). Figure 7 is showing the accumulation of quality assured aerosol optical depth (AOD) data over the world from 2007 to 2021 thanks to operators onboard various research/commercial vessels.

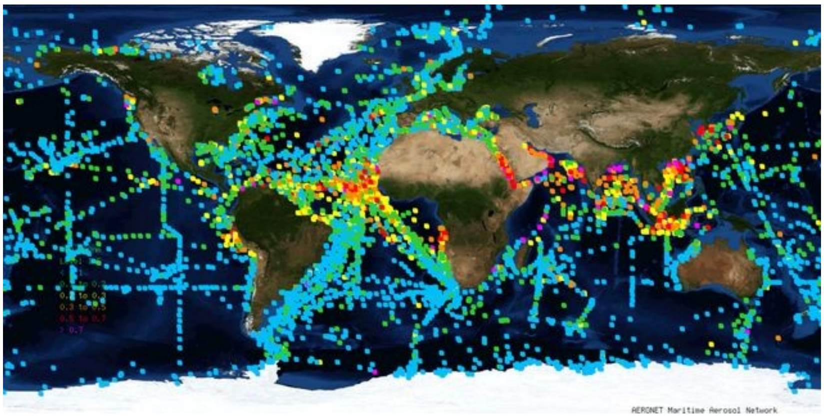


***Figure 7****. Map of worldwide quality assured MAN AOD accumulated during campaigns between 2007 and 2021 (~ 380 000 AOD records)*

Efforts are currently made in the framework of several projects such as Quality Assurance for the Earth Observation (QA4EO, https://qa4eo.org/) programme from ESA, labex CaPPA (https://www.labex-cappa.fr), in collaboration with AERONET NASA to enlarge the ground-based observation system over the ocean. A first automatic shipborne CIMEL CE318T photometer was permanently installed early January 2021 aboard the French research vessel Marion Dufresne in the frame of the MAP-IO (Marion Dufresne Atmospheric Program - Indian Ocean, https://lacy.univ-reunion.fr/map-io) research programme (Tulet et al., 2019, Figure 8). The shipborne instrument was developed at Laboratoire d'Optique Atmosphérique (LOA), Lille (France), in the frame of the joint LOA/CIMEL laboratory (AGORA-Lab, https://www.agora-lab.fr/), to enable measurement of atmospheric aerosols from mobile platforms and to expand and AErosol RObotic NETwork (AERONET) coverage to the vast ocean (Sirmov et al., 2022, 2009). This instrument is engaged in the Southern Hemisphere/Indian Ocean to primarily provide routine Aerosol Optical Depth (AOD), Ångström Exponent (AE), columnar water vapor content and downward atmospheric spectral radiance. This new observation capacity is expected to contribute to fill the gap of frequent ground-based observation in the Indian Ocean, to thus enhance the maritime manual component of AERONET (MAN) as well as the scheduled ACTRIS (https://www.actris.eu/) and worldwide mobile exploratory platforms.


*__Figure 8:__ Photometer system in permanent operation onboard Marion Dufresne; set up on Marion Dufresne.*

Few periods without observation can be noticed which correspond to cloudy conditions and Marion Dufresne maintenance or stop at La Réunion port. This high frequency dataset is quite relevant for satellite validation purposes but, as the "instrument" is moving the spatial distribution of the measurement has also to be addressed to reveal the 3 dimensional variability of these properties over the whole considered period (figure 9).

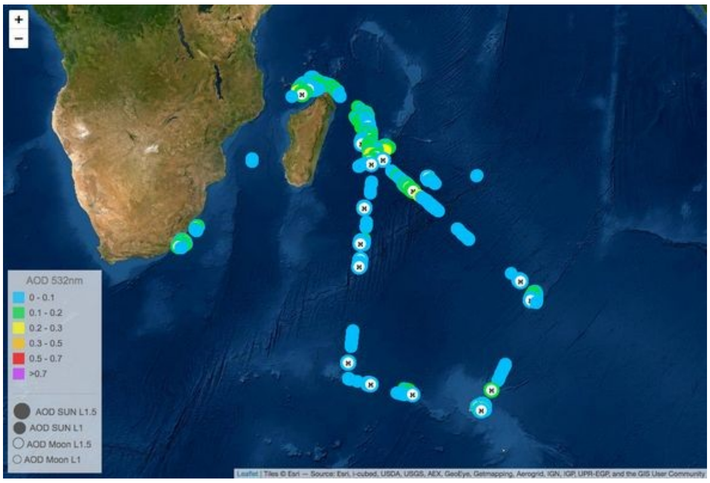


*__Figure 9:__ Spatial distribution of version 3 level 1.5 AOD data recorded during day and night on the MD during the period 01 July 2021 to 30 April 2022*

Almost one year of automatic sun/moon/sky-photometer observation onboard the Marion Dufresne. show clearly the ability of the shipborne photometer to perform high frequency and high quality AOD measurements which enable aerosol properties and spatial distribution analysis over the Indian ocean. In the following sections we present our main conclusions and perspectives at instrument, data processing, synergy and applications levels. This automatic ship-borne CE318T photometer is a good candidate to contribute to satellite Cal/Val activity of current and coming earth observation missions. It is now foreseen that several research or commercial vessels could be equipped with this system and continuously measuring and monitoring aerosol properties over the Oceans.

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**Access to data:** AOD level 1.5 files are available at AERIS/ICARE, file name is : AERONET_ACTRIS-AOD-L15_YYYY-MM-DD_Marion-Dufresne-1273_V1-00.txt, where YYYY-MM-DD is indicating the corresponding date.

**Access to visualization**: a real time visualization tool of recorded AOD, AE , $H_2O$ by Marion Dufresne is available at LOA at: http://loaphotons.univ-lille1.fr/photons/planning/scp/mob/map-phmob-2021.php?fph=1273&fns=Marion-Dufresne&fddc=2021-06-30&fdfc=2022-12-31&origin=NASA&cp=2022/21-Mar-Duf

**3. List SOLAS-related publications published in 2021 (only PUBLISHED articles). If any, please also list weblinks to models, datasets, products, etc.**


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**4. Did you engage any stakeholders/societal partners/external research users in order to co-produce knowledge in 2021? If yes, who? How did you engage?**

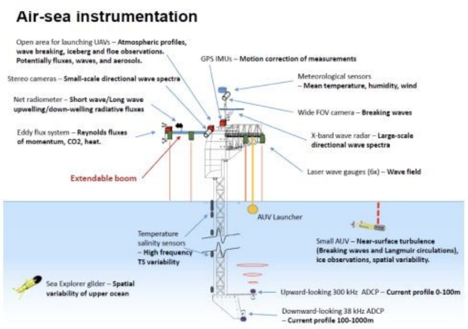
## PART 2 - Planned activities for 2022 and 2023

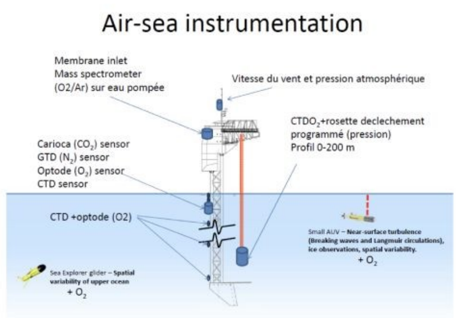
**1. Planned major national and international field studies and collaborative laboratory and modelling studies (incl. all information possible, dates, locations, teams, work, etc.).**

David Antoine (david.antoine@curtin.edu.au), Peter Sutherland, Karine Leblanc, Cédric Cotte, Rémi Losno.

**Polar-Pod program** really starts after a decade of preparation. See: https://www.polarpod.fr/

More than 100 researchers of 43 worldwide research institutions are involved in the Polar POD scientific program. It will be an essential contribution to the program of the United Nations Decade of Ocean Science for Sustainable Development (2021-2030). All data will be available to the entire scientific community as well as the general public.




**2. Events like conferences, workshops, meetings, summer schools, capacity building etc. (incl. all information possible).**

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| **3. Funded national and international projects/activities underway.** |
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| **4. Plans / ideas for future national or international projects, programmes, proposals, etc. (please indicate the funding agencies and potential submission dates).** |
| |
| **5. Engagements with other international projects, organisations, programmes, etc.** |
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| **Comments** |
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