surface ocean solas lower atmosphere study

Report for the year 2020 and future activities

SOLAS *'GERMANY'*
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This report has two parts:

***- Part 1:** reporting of activities in the period of January 2020 - Jan/Feb 2021*
***- Part 2:** reporting on planned activities for 2021 and 2022.*

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. ?
Facilitate better communication between researchers performing field and laboratory investigations. There is also a need for more communication **across** the many disciplines involved in SOLAS.

PART 1 - Activities from January 2020 to Jan/Feb 2021

1. Scientific highlight

*Describe one scientific highlight with a title, text (**max. 300 words**), a figure with legend and full references. Please focus on a result that would not have happened without SOLAS, and we are most interested in results of international collaborations. (If you wish to include more than one highlight, feel free to do so).*

Knowledge about the sea-air transfer of carbohydrates and subsequent secondary processes is still sparse, despite their oceanic and atmospheric importance. In order to unravel the relevant atmospheric mechanisms in a natural environment, we performed concerted measurements in bulk

seawater, sea surface microlayer (SML) and in size-resolved aerosol particles during a comprehensive field study conducted during the PI-ICE (Polar atmosphere ice-ocean Interactions: Impact on Climate and Ecology) field campaign in the coastal waters west of the Antarctic Peninsula. Free and combined carbohydrates were determined in all compartments. With the additional help of the concentrations of inorganic ions, meteorological data and back-trajectories, the ocean was confirmed as the primary source of carbohydrates in marine aerosol particles. Carbohydrate/sodium ratios were calculated in seawater, SML and aerosol particles in order to study the sea-air transport of these compounds. Furthermore, by studying the relative composition of the monosaccharides after hydrolysis, we found strong indications for subsequent secondary processes causing an aging of marine carbohydrates in atmospheric particles. Based on the results of this study, we propose that ambient carbohydrate concentrations in sea-spray-aerosols (SSA) could be modelled based on wind speed, sea surface temperature and Chlorophyll-a, while specific monosaccharide patterns might be strongly dependent on additional factors, such as regional bacteria communities in aerosol particles. However, it is still unclear, what amount of oceanic polysaccharides from primary emissions ultimately accounts for aerosolized polysaccharides and which contribution originates from secondary processes, such as bacterial metabolism and photochemistry. For this purpose, further laboratory experiments and concerted ambient measurements, ideally combined with in-situ mesocosm experiments for the production of fresh SSA, should elucidate the sea-air transport of marine carbohydrates and subsequent secondary processes in the atmosphere. **(SOLAS themes 2, 4, 5)**

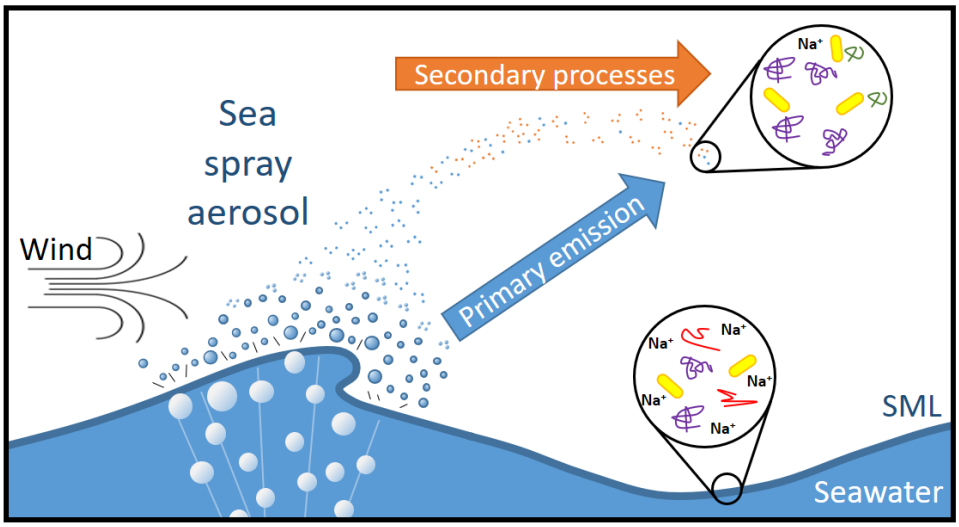

Figure: Conceptual overview of the primary oceanic emission of marine polysaccharides and the subsequent secondary processes.

Citation: Zeppenfeld, S., van Pinxteren, M., van Pinxteren, D., Wex, H., Berdalet, E., Vaqué, D., Dall'Osto, M., and Herrmann, H.: Aerosol Marine Primary Carbohydrates and Atmospheric Transformation in the Western Antarctic Peninsula, ACS Earth Space Chem., 10.1021/acsearthspacechem.0c00351, 2021.

2. Activities/main accomplishments in 2020 (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).

- As the Aeolotron could not be used during the Corona pandemic, the Jähne group in Heidelberg used the free time in 2020 to develop novel approaches for laboratory measurements of air-sea gas transfer with the goal to simulate the oceanic conditions in a much more realistic way. These activities resulted in a Reinhart Koselleck proposal, which we submitted to the German Science Foundation (DFG) end of June 2020. To our own surprise this proposal was fully funded already on December 14, 2020 for a period of five years starting in January 2021: https://www.uni-heidelberg.de/en/newsroom/climate-relevant-exchange-processes-between-atmosphere-and-ocean **(SOLAS theme 2)**

- The Wurl group (ICBM Oldenburg/Wilhelmshaven) explored the response of SML phytoplankton communities to contrasting conditions of light and nutrients. We collected communities from the SML and underlying bulkwater (as reference) at three different sites, the North Sea (open ocean) and in the Sognefjord (Norway). In incubation experiments, we adjusted light exposure, nitrogen (N) and phosphorus (P) supply to the communities and monitored growth rate until the stationary growth phase was reached. Overall, we concluded that both SML and bulk communities were N-limited as both communities responded significantly to N addition. We observed the highest biomass under the reduced light conditions and additional N and P supply, but growth rates were highest at non-reduced light condition and N supply. In addition, biomass yield was highest in the bulk communities. From the results we could further concluded that communities collected from the open ocean showed no response to light changes, but the communities from the fjord did. That is probably because the fjord communities experience light limitations due to higher turbidity and occasional shading. The study shows the distinct differences of communities' responses within the upper one meter of the ocean, and provides initial data of SML communities in terms of coastal darkening. **(SOLAS themes 1, 2, 4, 5)**

- Wurl group - Joint field campaign with Sanja Frka et al. in the Adriatic Sea (Croatian Coast) to understand the diel changes of the sea-surface microlayer, and secondly, the effect of dry deposition on the microlayer and near-surface layer **(SOLAS themes 2, 3)**

- Colleagues from GEOMAR (Achterberg group/Mark Hopwood) and Universidad Austral de Chile analyzed material from the 2015 Calbuco volcanic eruption to assess effects of the associated ash deposition on marine systems finding evidence of a fertilizing effect in the South Pacific shortly after the eruption OS - A mosaic of phytoplankton responses across Patagonia, the southeast Pacific and the southwest Atlantic to ash deposition and trace metal release from the Calbuco volcanic eruption in 2015 (copernicus.org) . **(SOLAS theme 3)**

- Marandino group (GEOMAR) – began incubation experiments as part of the international project ShipTRASE (funded by the Belmont Forum), seeking to investigate the influence of ship emissions on trace gas cycling in the surface ocean. Performed 2 sets of experiments using open loop and closed loop scrubber effluent diluted in Baltic Sea water samples. **(SOLAS theme 3 and Science and Society)**

- Invited keynote talk by C. Marandino - Atmospheric composition over the Indian Ocean for the SOLAS Indian Ocean Meeting, online – hosted in Pune, India. **(SOLAS theme 1, 3, 4, 5, and Integrated Studies of High Sensitivity Systems)**

- Herrmann group/Manuela van Pinxerten (TROPOS) - Amino acids are important contributors to marine organic matter. In order to elucidate their transfer from the ocean into the atmosphere, concerted measurements i.e., simultaneous measurements of seawater, size-segregated aerosol particles and cloud water were performed at the Cape Verde islands within the MarParCloud (Marine biological production, organic aerosol particles and marine clouds: a Process chain campaign) campaign. The amino acids were present in all investigated marine compartments and their similarity in the seawater, the SML and on the aerosol particle samples, indicated that a certain amino acid contribution, in particular the hydrophilic amino acids, was probably caused by sea spray and might be transferred up to cloud level. The neutral and hydrophobic amino acids were also present in all marine compartments, suggesting some interconnections. Stable amino acids like glycine are often reported as long-range tracers, but their abundance in seawater and marine air masses prevailing during the sampling period suggest an (additional) oceanic source. By distinguishing between submicron and supermicron aerosol particles, differences in the chemical composition of these aerosol particle size classes could be identified, which show a much higher complexity of the amino acid composition in the submicron aerosol particles. One striking finding was the high and varying amino acid cloud water concentration (11-490 ng m^{-3}) as well as high enrichments (enrichment factors of up to 10^4 compared to ocean water). Finally, the varying composition of the amino acids in the different matrices shows that their abundance and ocean-atmosphere transfer are influenced by additional biotic and abiotic formation and degradation processes. Simple physico-chemical parameters (e.g. surface activity) are not sufficient to describe the concentration and enrichments of the amino acids in the marine environment. For a precise representation in organic matter transfer models, further studies are needed to unravel their drivers and understand their

composition. Citation: N. Triesch, M. van Pinxteren, A. Engel, and H. Herrmann: Concerted measurements of free amino acids at the Cape Verde Islands: High enrichments in submicron sea spray aerosol particles and cloud droplets, *Atmos. Chem. Phys.*, 21: 163–81, 2021. **(SOLAS theme 4)**

3. Top 5 publications in 2020 (only PUBLISHED articles) and if any, weblinks to models, datasets, products, etc.

1. Jähne, B. (2020). What controls air-sea gas exchange at extreme wind speeds? Evidence from laboratory experiments. In Recent Advances in the Study of Oceanic Whitecaps. ed. By P. Vlahos and E. Monahan, Springer, 133-150, https://doi.org/10.1007/978-3-030-36371-0_10. **(SOLAS theme 2)**
2. Lennartz, S. T., Marandino, M., Von Hobe, M., Andreae, M. O., et al. (2020). Marine carbonyl sulfide (OCS) and carbon disulfide (CS_2): a compliation of measurements in seawater and the marine boundary layer. Earth System Science Data, 12(1), 591-609, https://doi.org/10.5194/essd-12-591-2020. **(SOLAS themes 1, 4, 5)**
3. Marandino, C., van Doorn, E., McDonald, N., Johnson, M., et al. (2020). From monodisciplinary via multidisciplinary to an interdisciplinary approach investigating air-sea interactions – A SOLAS Initiative. Coastal Management, 48(4), 238-256, https://doi.org/10.1080/08920753.2020.1773208. **(SOLAS Science and Society)**
4. Mustaffa, N. I. H., Ribas-Ribas, M., Banko-Kubis, H. M., & Wurl, O. (2020). Global reduction of in situ CO_2 transfer velocity by natural surfactants in the sea-surface microlayer. Proceedings of the Royal Society A, 476(2234), 20190763. **(SOLAS themes 1, 2)**
5. Stolle, C., Ribas-Ribas, M., Badewien, T. H., Barnes, J., Carpenter, L. J., Chance, R., ... & Wurl, O. (2020). The Milan Campaign: Studying the Sea Surface Microlayer. Bulletin of the American Meteorological Society, 101(4), 299-304. **(SOLAS theme 2)**

4. Did you engage any stakeholders/societal partners/external research users in order to co-produce knowledge in 2020? If yes, who? How did you engage?

During ShipTRASE, plans are being made to engage various actors in the shipping industry. This did not occur in 2020, but is planned for 2021 and 2022. **(SOLAS theme 3 and Science and Society)**

PART 2 - Planned activities for 2021 and 2022

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

- Balloon campaign in Ny Alesund: Oct/Nov. 2021 and March-May 2022, participants: TROPOS, University of Leipzig, AWI **(SOLAS theme 5)**
- CENBASE R/V EMB – Warnemünde to Warnemünde (June 2022), investigating air-sea exchange in the central Baltic, international collaboration between GEOMAR (Christa Marandino/Anja Engel), IOW (Gregor Rehder), and the University of Hawaii (David Ho) **(SOLAS theme 2)**
- VW-COS R/V Senckenburg - 4-8 October 2021 in the coastal North Sea area, investigating COS and CS_2 production from DOC and DOS, German-Israeli collaboration **(SOLAS themes 1, 4, 5)**
- CONNECT R/V SONNE – Dec 2021 – Jan 2022 from Las Palmas to Callao, investigating the biogeochemical connections between the eastern and western Atlantic Ocean, international participation (Chief Scientist - Birgit Quack/GEOMAR) **(all SOLAS themes)**
- REEBUS/MOSES Eddy Study III R/V Meteor, Mindelo – Ponta Delgada, 29 May -8 July 2021, Mauritanian upwelling, funded partly by REEBUS (see Part 2 – 3.) **(SOLAS theme 1)**
- DE-SOOP-Atlantic Sail – "Ship-of-Opportunity" line across North Atlantic between Europe and North America, operational station of European research infrastructure ICOS (Integrated Carbon Observation System), PI: Arne Körtzinger/GEOMAR, autonomous carbon and oxygen observations in surface waters, funded under C-SCOPE (see Part 2 –

3.) **(SOLAS theme 1)**

- Brazil-SOOP – new "Ship-of-Opportunity" line along Brazilian coast and 1500 m upstream Amazon river to Manaus PIs: Arne Körtzinger/GEOMAR, Leticia Cotrim da Cunha/UERJ Brazil, autonomous trace gas observations, funded under C-SCOPE **(SOLAS theme 1)**
- DE-SOOP-Finnmaid – "Ship-of-Opportunity" line across Baltic Sea between Germany and Finland, operational station of European research infrastructure ICOS (Integrated Carbon Observation System), PI: Gregor Rehder/IOW, autonomous trace gas observations in surface waters **(SOLAS theme 1)**
- DE-SOOP-Polarstern – "Ship-of-Opportunity" line in Atlantic, Arctic and Southern Ocean, operational station of European research infrastructure ICOS (Integrated Carbon Observation System), PI: Mario Hoppema/AWI, autonomous carbon and oxygen observations in surface waters **(SOLAS theme 1)**
- BETS - Boknis Eck Time Series Station, western Baltic Sea, PI: Hermann Bange/GEOMAR, monthly sampling, oceanography, biogeochemistry **(SOLAS theme 1, 4, 5 and Integrated Studies…)**
- ICOS-OTC pCO_2 inter-comparison – Flanders Marine Institute (VLIZ) in Oostende/Belgium, 28 June - 9 July 2021, international intercomparison of vast range of pCO_2 instruments and sensors (28 system of 19 different types) for various marine applications, lead-PI: Tobias Steinhoff, ICOS/GEOMAR **(SOLAS theme 1)**
- Wurl Group - Four field studies (24th April to 15th May 2022, 2 Oct to 23 Oct 2022 and two additional cruises confirmed in 2023) in the North Sea with the RV Heincke. In collaboration with European Space Agency (ESA) and SMOS Barcelona Expert Centre. Collecting in-situ sea surface data of essential climate variables to understand variability and cross-comparison with remote-sensed data. **(potentially all SOLAS themes)**
- Wurl Group - Field Study in the Western Antarctic Peninsula in collaboration with Dr. Juan Höfer, (Pontificia Universidad Católica de Valparaiso, Chile). Seasonal sampling starting end of 2021 with mooring, and field work for process study end of 2022. Further collaboration with Dr. Judith Piontek (IOW), Prof. Dr. Astrid Bracher (AWI), Dr. Frank Stratmann (TROPOS) and Prof. Dr. Carolin Löscher (Southern Denmark University). **(potentially all SOLAS themes)**

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

1. Forum and Panel Discussion – The apparent mismatch between science and policy at the air-sea interface, Sustainability Research & Innovation Congress, Brisbane, Australia June 2021, Erik van Doorn and Christa Marandino/Kiel University and GEOMAR – lead/co-conveners **(SOLAS Science and Society)**
2. UN Ocean Decade Predicted Ocean Laboratory OASIS Satellite Event (virtual, website - https://airseaobs.org/oasis-for-a-predicted), Christa Marandino/GEOMAR - co-organizer and plenary moderator **(potentially all SOLAS themes)**
3. UN Ocean Decade Clean Ocean Laboratory OASIS Satellite Event (virtual, proposed only) Christa Marandino/GEOMAR - lead organizer **(SOLAS theme 3 and Science and Society)**
4. Eddy Covariance Best Practice Workshops (Kickoff meeting), OBPS Workshop Series, 21 Sep 2021 Christa Marandino/GEOMAR - co-organizer **(SOLAS theme 2)**
5. B. Jähne (Flagship), C. Marandino (Keynote) - German speakers during the 8th Int. Symposium on Gas Transfer at Water Surfaces, Plymouth, 19 May 2021 (GTWS Bitesize) and 17 – 20 May 2022, http://www.pml.ac.uk/GTWS2020 **(SOLAS theme 2)**
6. Virtual SOLAS Summer School planned for 2022 – Christa Marandino Director, website - https://www.solas-int.org/news/events/summer-school-22-23/virtual-summer-school-22.html **(all SOLAS themes, including cross-cutting topics)**
7. SOLAS Shipping Workshop – planned for first half of 2022, discussion amongst all SOLAS sponsored and related projects, Christa Marandino/GEOMAR - co-organizer **(SOLAS theme 3 and Science and Society)**

3. Funded national and international projects/activities underway.

REEBUS – Role of Eddies in the Carbon Pump of Eastern Boundary Upwelling Systems – Demonstration Case Canary Current System, collaborative project funded by Federal Ministry of Education and Research, 2019-2022 (45 months), lead PI: Arne Körtzinger/GEOMAR, total funding: ~3 MEUR **(SOLAS theme 1 and Integrated Studies…)**

C-SCOPE – Towards Marine Carbon Observation 2.0: Socialization, Networking, Perfection and Extension, collaborative project funded by Federal Ministry of Education and Research, 2021-2023 (36 months), lead PI: Arne Körtzinger/GEOMAR, total funding: ~2.4 MEUR, DE-SOOP-Atlantic Sail, new Brazil-SOOP, combination BGC-Argo/SOCONET **(SOLAS theme 1 and Science and Society)**

ShipTRASE – Global shipping: Linking policy and economics to biogeochemical cycling and air-sea interaction, Belmont Forum CRA Transdisciplinary Research for Ocean Sustainability (German partners funded by the Federal Ministry of Education and Research), 2020-2023 (36 months), Lead German PI – Christa Marandino/GEOMAR, total German funding: ~300 KEUR (between GEOMAR and Kiel University) **(SOLAS theme 3 and Science and Society)**

VW-COS - A novel approach to quantify global ocean emissions of carbonyl sulphide, Lower Saxony-Israeli cooperation funding from Volkswagen Foundation, 2020-2023 (36 months), Lead PI – Sinikka Lennartz/Oldenburg University, total funding 300 KEUR **(SOLAS themes 1, 4, 5)**

Koselleck (German Science Foundation award to Bernd Jähne) - In the first stage of the project (2021-2022), a radically new approach will be taken to simulate oceanic conditions at low and medium wind speeds in the Heidelberg Aeolotron in an appropriately realistic way for the first time. Two advanced imaging techniques will be used to measure the gas and heat exchange rates locally within seconds under non-stationary conditions in the Heidelberg Aeolotron: Active thermography will be used to measure the heat exchange rate and a new opto-chemical technique will visualize the mass boundary layer at the water surface, which is only fractions of a millimeter thick, from which the local rate of gas exchange can be determined. By using these fast, new techniques, the processes controlling gas and heat transfer can be studied in the presence of growing and decaying wave fields for the first time. High wave ages, which have not been studied before in a wind-wave tank, will become accessible by using gases heavier than air as the Aeolotron's atmosphere. At low wind speeds, the important influence of surface-active materials on the gas transfer will also be studied in detail. With these measurements, a physically based description of the mechanisms of gas exchange under oceanic conditions finally will be possible.

In the second phase of the Koselleck project (2023-2024), a simple technique to measure gas and heat exchange on the ocean in less than a minute with meter-scale resolutions will be developed. The instrument consists just of a thermal imaging camera and determines the transfer rate and the dominant physical mechanisms from the spatio-temporal thermal patterns at the ocean surface. This will also enable to verify whether the prevoius laboratory measurements have included all mechanisms relevant to the ocean. The measurements on the ocean will be performed in cooperation with GEOMAR in Kiel and the Institute of Chemistry and Biology of the Sea at the University of Oldenburg. **(SOLAS theme 2)**

MATE – MAritime Traffic Emissions: A monitoring network (MarTerra/EU), Developing buoy platforms and towed vehicles for the monitoring of ship-based emissions entering and floating on the sea surface, including oil films, plastic debris and soot particles, Oliver Wurl/ICBM **(SOLAS theme 3 and Science and Society)**

NorthSat-X – The North Sea from space: Using explainable artificial intelligence to improve satellite observations of climate change (The Ministry for Science and Culture of the State of *Lower Saxony*), Understanding the variability of essential climate variables, primarily sea-surface temperature and salinity in the SML. The acquired knowledge will be used for the validation of satellite-derived data, Oliver Wurl/ICBM **(potentially all SOLAS themes)**

EWARP – Exchange fluxes of climate-relevant trace gases off the Western AntaRctic Peninsula (DFG). Understanding mechanisms for production and exchange fluxes of climate-relevant trace gases in coastal and open ocean waters off the Western Antarctic Peninsula with focus on primary

production, the sea-surface microlayer and near-surface hydrodynamics, Oliver Wurl/ICBM **(SOLAS themes 1, 4, 5)**

4. Plans / ideas for future national or international projects, programmes, proposals, etc. (please indicate the funding agencies and potential submission dates).

Atlantic Upwelling, new GEOMAR Integrated Research Focus, development of concept for year-long multi-platform, multi-parameter, multi-disciplinary intensive field campaign in coastal upwelling system off West Africa, planned time window: 2025-2027, lead-PI: Arne Körtzinger/GEOMAR **(potentially all SOLAS themes and Integrated Studies…)**

BASS – Biogeochemical processes and Air–sea exchange in the Sea-Surface microlayer (DFG Research group). Exploring the significance of the SML as a biogeochemical and photochemical reactor in an unprecedented comprehensive and interdisciplinary approach. Submitted on 19 July 2021, final evaluation on 2 November 2021. 24 PIs and co-PIs, 4.2 Million Euro requested. Anticipated duration: 2022-2025. Possibility of second phase, lead PIs: Oliver Wurl/ICBM and Hermann Bange/GEOMAR (includes many German institutions) **(potentially all SOLAS themes)**

Wurl Group - Proposal within the framework of the Federal Government's Strategy for the Internationalization of Science and Research Guidelines for the Promotion of Scientific and Technological Cooperation (STC) with Colombia. To continue established collaboration with Dr. Lennin Florez-Leiva (University of Antioquia, Colombia). **(SOLAS themes 1, 2, 5)**

5. Engagements with other international projects, organisations, programmes, etc.

- **SCOR** WG 162 Observing Air-Sea Interactions Strategy (OASIS) co-chaired by C. Marandino (GEOMAR)
- **UN Ocean Decade** – OASIS is a endorsed programme and is, thus, participating in all possible UN Ocean Decade events (e.g., satellite events of all Decade Labs)
- **Belmont Forum** sponsored project ShipTRASE (German PIs: C. Marandino-GEOMAR, N. Matz-Lück - CAU)

Comments

This report covers content provided by Oldenburg University, Heidelberg University, GEOMAR, and TROPOS only, but contains the work of other institutions, such as MPI Hamburg and Kiel University.

For further material on the Aeolotron, please see the zenodo "Small-Scale Air-Sea Interaction" Community https://zenodo.org/communities/asi