Characteristics of sulfur-containing aerosols and organic carbon in the Amundsen Sea, Antarctica

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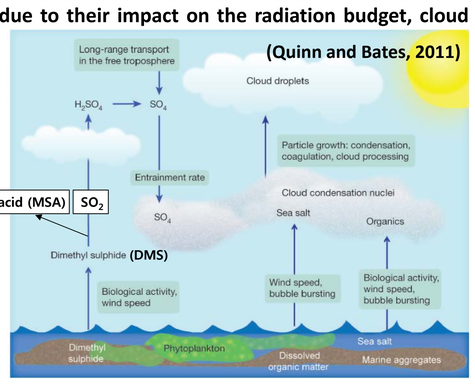
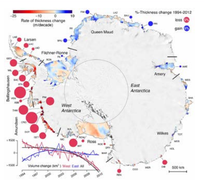
1. Introduction

- Marine aerosols have been recognized to play an essential role in global climate due to their impact on the radiation budget, cloud microphysics and acting as cloud condensation nuclei (CCN).
- The conversion of dimethylsulfide (DMS) into non-sea-salt sulfate (nss-SO_4^{2-}) aerosols is an important process because of their role on cloud microphysics which could result in a negative climate feedback mechanism.
- Ocean surface waters are enriched with small particulate organic materials including phytoplankton, bacteria, fragments of larger organisms and organic detritus as well as dissolved organic matter released or exuded by phytoplankton during growth, predation by grazing organisms and viral lysis.
- The organic fraction in surface waters can be broadly characterized as lipids, amino and fatty acids, mono- and polysaccharides and humic substances, which can be emitted into the marine atmosphere with sea-salt particles through bubble bursting processes.

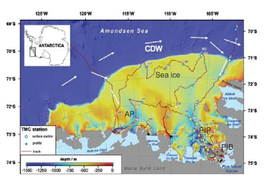


- Because of the difficulty in conducting a field observation, the sources and evolution of aerosols over the Antarctic are still a subject of many open questions. It is, therefore, necessary to fill the data gap in the knowledge of biogenically-derived aerosols in the Antarctic to improve understanding of the effect of ocean ecosystem on the marine aerosol-cloud-climate system.

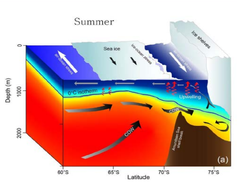
2. The Amundsen Sea



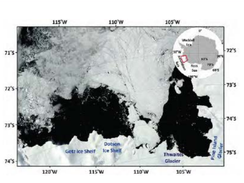
(Paolo et al., 2015)

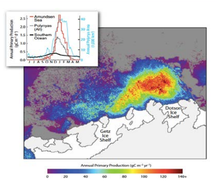


(Alderkamp et al., 2012)



(Kim et al., 2017)

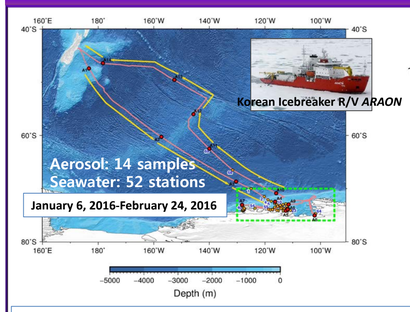


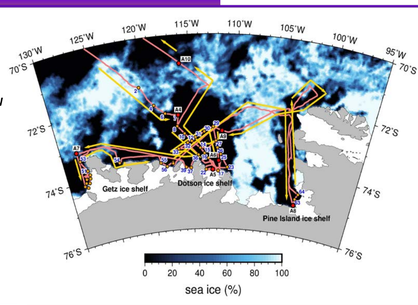


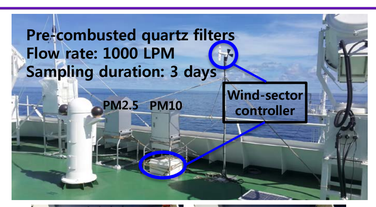
(Yager et al., 2012)

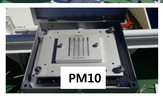
- The Amundsen Sea Polynya (ASP) is the most productive polynya (per unit area) among 37 identified coastal polynya systems in the Antarctic due to the combined effects of the enhanced light condition, the abundance of macronutrients, supply of iron (Fe) from melting sea ice and/or glaciers and continental shelf sediments resulted from the intrusion of relatively warm, salty, and nutrient-rich Circumpolar Deep Water (CDW).
- The Amundsen Sea is an ideal place to monitor a direct link between biological production and local emissions of sulfur compounds and organics, not only because of its remoteness from anthropogenic activity but also because it is an area of exceptionally high seasonal primary production.

3. Cruise track and methods





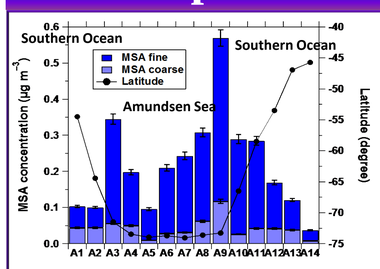




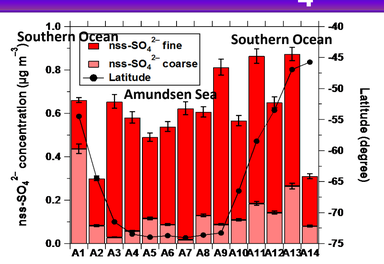
Analysis of aerosol samples
- Ionic species
- Water-soluble organic carbon (WSOC)
- Water-insoluble organic carbon (WIOC)
- Fluorescence properties of WSOC

Analysis of seawater samples
- Phytoplankton taxonomic composition
- Chlorophyll-a
- Dissolved organic carbon (DOC)
- Particulate organic carbon (POC)

4. Atmospheric MSA and nss-SO_4^{2-}



Southern Ocean: 0.16 ± 0.096 μg m^{-3}
Amundsen Sea: 0.28 ± 0.15 μg m^{-3}

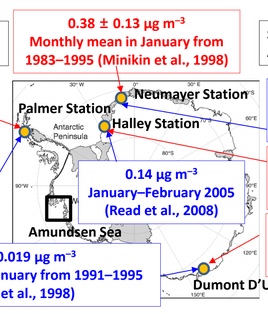


Southern Ocean: 0.60 ± 0.23 μg m^{-3}
Amundsen Sea: 0.62 ± 0.10 μg m^{-3}

0.38 ± 0.13 μg m^{-3}
Monthly mean in January from 1983–1995 (Minikin et al., 1998)

0.24 ± 0.16 μg m^{-3}
December 1990–March 1991
(Savoie et al., 1993)

0.122 ± 0.127 μg m^{-3}
December 1990–March 1991
(Savoie et al., 1993)



0.14 μg m^{-3}
January–February 2005
(Read et al., 2008)

0.063 ± 0.019 μg m^{-3}
Monthly mean in January from 1991–1995
(Minikin et al., 1998)

0.154 ± 0.077 μg m^{-3}
Monthly mean in January from 1983–1995
(Minikin et al., 1998)

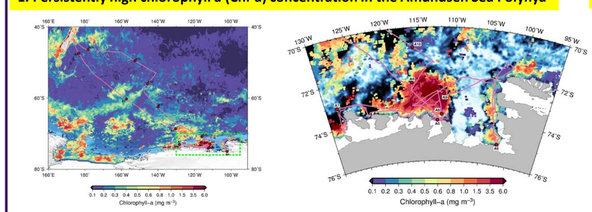
0.14 ± 0.017 μg m^{-3}
Monthly mean in January from 1991–1993
(Legrand and Pasteur, 1998)

0.34 ± 0.039 μg m^{-3}
Monthly mean in January from 1991–1995
(Minikin et al., 1998)

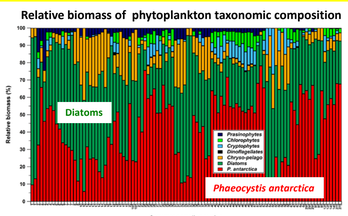
- Over the Southern Ocean (43°S–70°S, samples A1–A2), the MSA concentration was relatively low (mean: 0.10 ± 0.002 μg m^{-3}), whereas its concentration over the Amundsen Sea (70°S–75°S, samples A3–A9) increased sharply up to 0.35 μg m^{-3} and showed high spatial variability (range: 0.096–0.57 μg m^{-3}, mean: 0.28 ± 0.15 μg m^{-3}), with the highest value observed in the ASP.
- Over the Southern Ocean, the nss-SO_4^{2-} concentration ranged from 0.30–0.87 μg m^{-3} (mean: 0.60 ± 0.23 μg m^{-3}), whereas its concentration over the Amundsen Sea varied from 0.49–0.81 μg m^{-3} (mean: 0.62 ± 0.10 μg m^{-3}). Unlike MSA, the mean nss-SO_4^{2-} concentration in the Amundsen Sea was comparable to that in the Southern Ocean, although the variation trend of nss-SO_4^{2-} in the Amundsen Sea was similar to that of MSA, suggesting that nss-SO_4^{2-} was affected by both marine and anthropogenic sources.

5. Factors influencing atmospheric MSA over the Amundsen Sea

1. Persistently high chlorophyll a (Chl-a) concentration in the Amundsen Sea Polynya

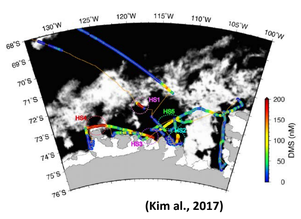


2. The Dominance of *Phaeocystis Antarctica*, a DMS producer, in the Amundsen Sea

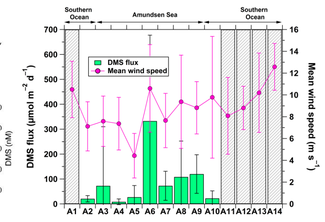


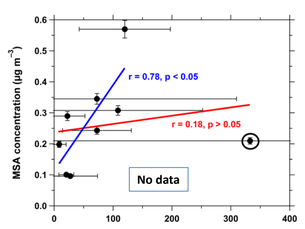
- *Phaeocystis antarctica* known as a DMS producer, was dominant phytoplankton species in the upper 50 m, accounting for 42 ± 19% of phytoplankton biomass (Chl-a), with lesser abundances of diatoms (39 ± 17%) found throughout the polynya and sea ice zone.
- Atmospheric MSA concentration showed no significant relationship with sea surface Chl-a concentration ($r = 0.029$, $p > 0.05$) or with the relative biomass of *P. antarctica* ($r = 0.30$, $p > 0.05$), suggesting that Chl-a concentration and phytoplankton taxomonic composition are not direct factors determining atmospheric MSA concentration in the Amundsen Sea.

3. High dimethylsulfide (DMS) concentration in sea surface water over the Amundsen Sea



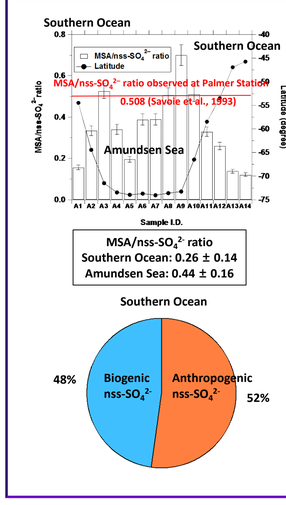
(Kim et al., 2017)



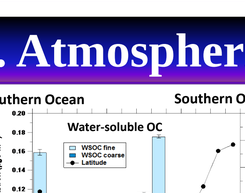


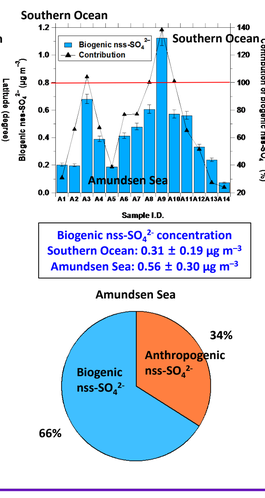
- DMS flux (data from Kim et al., 2017) averaged for the duration of each aerosol sampling showed a somewhat similar variation trend to that of atmospheric MSA concentration, but the correlation between atmospheric MSA and DMS flux was weak ($r = 0.18$, $p > 0.05$, Fig. 4b); however, if the single outlying point is excluded, the correlation coefficient (r) between atmospheric MSA concentration and DMS flux increases to 0.78 ($p < 0.05$).

6. Contribution of biogenically-derived nss-SO_4^{2-} to total nss-SO_4^{2-}

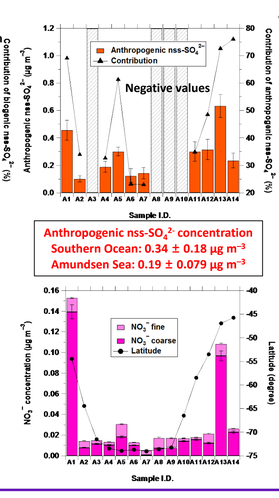


MSA/nss-SO_4^{2-} ratio
Southern Ocean: 0.26 ± 0.14
Amundsen Sea: 0.44 ± 0.16





Biogenic nss-SO_4^{2-} concentration
Southern Ocean: 0.31 ± 0.19 μg m^{-3}
Amundsen Sea: 0.56 ± 0.30 μg m^{-3}

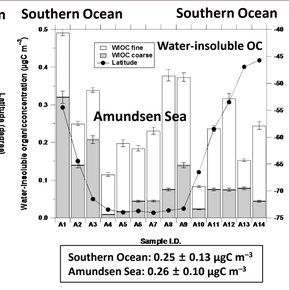


Anthropogenic nss-SO_4^{2-} concentration
Southern Ocean: 0.34 ± 0.18 μg m^{-3}
Amundsen Sea: 0.19 ± 0.079 μg m^{-3}

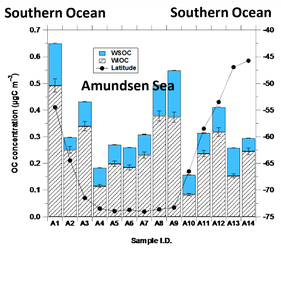
- Based on the MSA/nss-SO_4^{2-} ratio observed during the austral summer through long-term monitoring at Palmer Station (Savoie et al., 1993), mean concentrations of biogenically-derived nss-SO_4^{2-} over the Southern Ocean and the Amundsen Sea were estimated to be 0.31 ± 0.19 μg m^{-3} (range: 0.074–0.57 μg m^{-3}) and 0.56 ± 0.30 μg m^{-3} (range: 0.19–1.1 μg m^{-3}), accounting for 52 ± 28% (range: 24–101%) and 86 ± 32% (range: 39–138%) of total nss-SO_4^{2-}, respectively. However, when the MSA/nss-SO_4^{2-} ratio by Savoie et al. (1993) was used in this study, the concentration and contribution of biogenically-derived nss-SO_4^{2-} for samples, where the MSA/nss-SO_4^{2-} ratios were higher than 0.508 (i.e., samples A3, A8–A10), were somewhat overestimated, so that anthropogenic nss-SO_4^{2-} concentrations in those samples were underestimated, showing negative values. Nevertheless, anthropogenic nss-SO_4^{2-} in the other samples showed a similar variation trend to that of nitrate (NO_3^-, an indicator of anthropogenic contribution) (Savoie et al., 2002), varying from 0.10–0.63 μg m^{-3} (mean: 0.34 ± 0.18 μg m^{-3}) in the Southern Ocean, and 0.13–0.30 μg m^{-3} (mean: 0.19 ± 0.079 μg m^{-3}) in the Amundsen Sea.

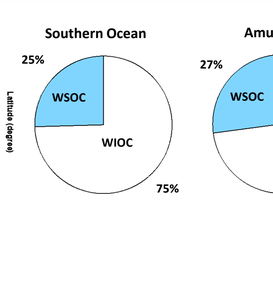
7. Atmospheric WSOC and WIOC

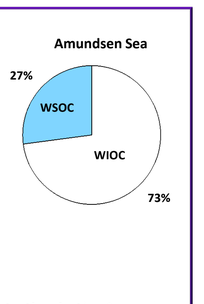
Southern Ocean: 0.087 ± 0.038 μgC m^{-3}
Amundsen Sea: 0.097 ± 0.038 μgC m^{-3}



Southern Ocean: 0.25 ± 0.13 μgC m^{-3}
Amundsen Sea: 0.26 ± 0.10 μgC m^{-3}

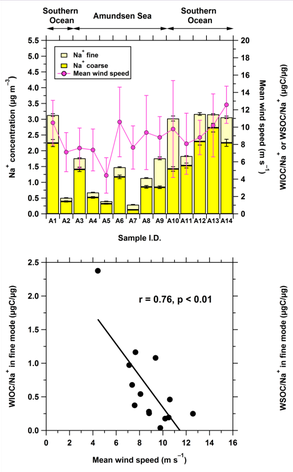


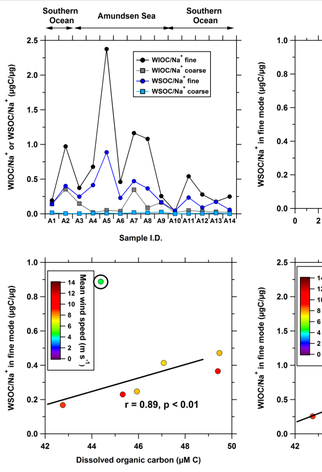


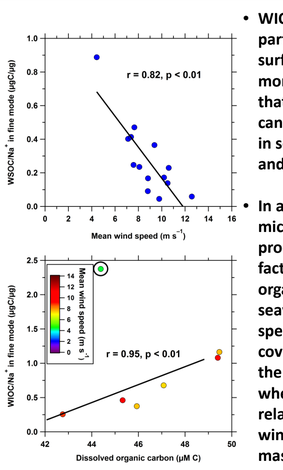


- We expected much higher WSOC and WIOC concentrations in the Amundsen Sea than the Southern Ocean because of extremely high Chl-a concentration in the Amundsen Sea. However, no significant differences of mean WSOC and WIOC concentrations were found between the Southern Ocean and the Amundsen Sea, suggesting that Chl-a concentration is not a direct factor controlling atmospheric OC concentration in our study area.

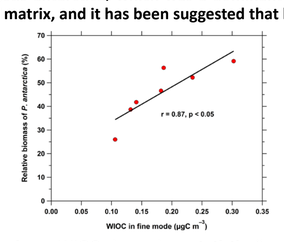
8. Factors influencing atmospheric WIOC and WSOC

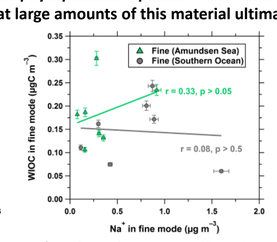


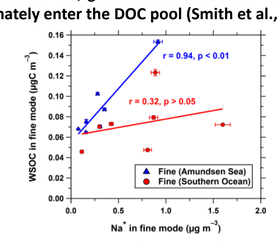




- WIOC was much more enriched in the fine mode sea spray particles than WSOC, suggesting that bubble bursting at the ocean surface is a major source of atmospheric WIOC and that WIOC is more accumulated in the sea surface water. These results show that the higher marine biological activities in the Amundsen Sea can be a significant factor leading to the higher enrichment of OC in sea spray aerosols, indicating a linkage between OC emission and biological activities.
- In addition to marine biological activities, the sea surface microlayer (SML) coverage, which directly couples biological processes to atmosphere-ocean exchange, could be an important factor influencing organic mass fraction of sea spray aerosol since organic matter is concentrated in the SML relative to the bulk seawater. According to Gantt et al. (2011), an increase in wind speed above 3–4 m s^{-1} causes a rapid decrease in the SML coverage, and the wave breaking thoroughly mixes the SML with the underlying water resulting in the homogeneous water column when the wind speeds exceed 8 m s^{-1}. Therefore, the inverse relationships between WSOC/Na^+, WIOC/Na^+ ratios and the mean wind speed suggest that the SML coverage affected the organic mass fractions of sea spray aerosols in our study region.
- Both the WSOC/Na^+ and the WIOC/Na^+ ratios showed strong positive relationships with sea surface DOC concentrations measured in the Amundsen Sea when the mean wind speed exceeded 7 m s^{-1}; however, when the mean wind speed was lowest (i.e., aerosol sample A5), both the WSOC/Na^+ and the WIOC/Na^+ ratios sharply increased, although sea surface DOC concentration was low. These results indicate that both biological activity and the SML coverage are crucial factors influencing the organic mass fraction of sea spray aerosol.
- *Phaeocystis antarctica*, which was a dominant phytoplankton species in the Amundsen Sea, generates a substantial amount of extracellular polysaccharide mucus in its colonial matrix, and it has been suggested that large amounts of this material ultimately enter the DOC pool (Smith et al., 1998).







- The submicron WIOC showed no statistically significant relationships with submicron Na^+ over the Southern Ocean and the Amundsen Sea, although WIOC was highly enriched in the fine mode sea spray particles. This insignificant relationship between WIOC and Na^+ in the fine modes could result from the differences in local wind speeds and local biological activities, such as sea surface DOC concentration, because wind speed, a key factor determining sea spray aerosols, controls the local flux rather than local concentration of marine particles.
- The strong correlations between WSOC, Na^+ and MSA in the Amundsen Sea implies that the Amundsen Sea that has the most productive polynya in the Antarctic is a strong source region of BVOCs, and that WSOC was formed by the condensation of BVOCs released from sea surface onto preexisting submicron sea spray aerosols through gas-to-particle conversion due to a higher surface-to-volume ratio of submicron aerosols

9. Fluorescence properties of WSOC

- The spectral features of component 1 (C1, Ex/Em: 300/344 nm) was similar to the component previously identified in coastal and oceanic waters as well as the polar ocean and was thought to be phytoplankton-derived (or ice algae-derived) protein-like component. Component 2 (C2, Ex/Em: 276/326 nm) was assigned as a tryptophan-like fluorophore, which has been considered to be a labile component produced as a result of biological production in marine environments. Component 3 (C3, Ex/Em: <260/458 nm) spectra were characterized as representing terrestrial humic-like fluorophores.
- Among the three components, the protein-like C1 was the dominant fluorescence component in our marine aerosol samples, accounting for 31–73% of the total intensity, and the relative contributions of tryptophan-like C2 and terrestrial humic-like C3 were found to represent 17–50% and 8–31%, respectively. In our marine aerosol samples, protein-like components (i.e., C1 and C2) represented 69–91% of the total intensity.
- Despite the extremely high Chl-a concentration in the Amundsen Sea, we found no significant difference of the average values of protein-like C1 and tryptophan-like C2 fluorescence intensity between the Amundsen Sea and the Southern Ocean. However, relatively much higher values of C1 and C2 fluorescence intensity were observed when the ship approached the Amundsen Sea (i.e., samples A3 and A4), passing through the sea ice zone. The C1 and C2 fluorescence intensity values sharply decreased and remained relatively low in the Amundsen Sea, and then gradually increased from the Amundsen Sea to the Southern Ocean.
- Interestingly, fluorescence intensity of C1 showed a significant positive relationship with the relative biomass of diatoms ($r = 0.89$, $p < 0.01$); however, it was negatively correlated with the relative biomass of *P. antarctica* ($r = 0.79$, $p < 0.05$). Similar results were found between fluorescence intensity of C2 and the relative biomass of diatoms and *P. antarctica*. Phytoplankton can emit several types of BVOCs, such as isoprene, monoterpenes, and amines that have the potential to form secondary organic aerosol. Sabolis (2010) reported that diatoms were the largest emitters of most of the observed BVOC (including isoprene, monoterpenes, chloroform, and iodomethane) and that the other phytoplankton species (e.g., dinoflagellates, haptophytes, and Prochlorococcus) showed variable production rates for different BVOC, showing a strong dependence on phytoplankton speciation for BVOC production. Consequently, our results suggest that protein-like components are most likely produced as a result of biological processes of diatoms, which play a key role in forming the submicron WSOC observed over the Southern Ocean and the Amundsen Sea, and that phytoplankton community structure is a significant factor affecting atmospheric OC species since the submicron WIOC was quite related to the relative biomass of *P. antarctica*.

Jung, J., Hong, S.-B., Chen, M., Hur, J., Jiao, L., Lee, Y., Park, K., Hahm, D., Choi, J.-O., Yang, E. J., Park, J., Kim, T.-W., Lee, S. Characteristics of biogenically-derived aerosols over the Amundsen Sea, Antarctica, *Atmos. Chem. Phys. Discuss.* 2019, https://doi.org/10.5194/acp-2019-133 (under review).

SOLAS OSC 2019 program

Time	Sunday, 21 April	Time	Monday, 22 April	Time	Tuesday, 23 April	Time	Wednesday, 24 April	Time	Thursday, 25 April
09:00	Early Career Scientists Day	08:30	Conference opening Welcome & SOLAS introduction	08:30	**Geoengineering / Science and Society** Introduction by sessions chairs: **P. Boyd and E. van Doorn**	08:30	**Theme 1: Greenhouse gases and the oceans** Introduction by session chairs: **A. Koertzinger and G. Zhang**	08:50	**Integrated topics II** Introduction by session chairs: **K. Altieri and S. Kameyama**
			Integrated topics I Session chairs: **T. M. Latif and A. Mahajan**						
		08:50	**M. Cornejo**: The dynamic of the nitrous oxide in the Humboldt Current System	08:40	**A. Lenton**: Geoengineering, the Ocean and SOLAS	08:40	**S. Lauvset**: The Carbon Cycle: The role of oceans and humans	09:00	**S. Landwehr**: Investigation of sea spray source functions with aerosol size spectra measurements from the Antarctic Circumnavigation Experiment
	Geoengineering workshop	09:20	**M. Dai**: Air-Sea CO2 fluxes, diapycnal nutrient fluxes and export productivity in oligotrophic ocean	09:10	**S. Tegtmeier**: Impact of large-scale macroalgae production on the ozone layer	09:10	**O. Bui**: Dissolved methane distribution and its controlling factors in the Arctic Ocean in 2016 summer	09:20	**L. Gutierrez-Loza**: Air-sea CH4 fluxes from eddy covariance measurements in the Baltic Sea
		09:40	**E. Saltzman**: Air/sea transfer of highly soluble gases over coastal waters	09:30	**K. Mengerik**: Marine Spatial Planning as a Tool to Advance Science-Based Decision-Making	09:30	**Y. Eddebbar**: Volcanic Modulation of Ocean Ventilation: Implications for Air-sea Carbon and Oxygen Exchange	09:40	**P. Wongpan**: Using under-ice spectra to determine land-fast ice algal biomass in Lake Saroma, Japan
		10:00	**J. Kim/K. Lee**: Biological production reduces the net impacts of coastal acidification in the northwestern Pacific Ocean	10:00	**S. Sarker**: Taking the science to community: An approach of multi-stakeholders integration for sustainable Blue Economy development in Bangladesh	09:50	**L. Keppler**: Regional Wind Variability Modulates the Southern Ocean Carbon Sink	10:00	**M. Frey**: Sea salt aerosol from blowing snow above sea ice - a new particle source
						10:10	Group picture		
10:20	Coffee break	10:20	Coffee break	10:20	Coffee break	10:20	Coffee break	10:20	Coffee break
10:50	Early Career Scientists Day	10:50	**Theme 4: Interconnections between aerosols, clouds and ecosystems** Introduction by session chairs: **M. Levasseur and Y. Iwamoto**	10:50	**Theme 2: Air-sea interface and fluxes of mass and energy** Introduction by session chairs: **P. Minnett and A. Rutgersson**	10:50	**Theme 5: Ocean biogeochemical control on atmospheric chemistry** Introduction by session chairs: **J. Ovadnevaite and Y. Miyazaki**	10:50	**Theme 3: Atmospheric deposition and ocean biogeochemistry** Introduction by session chairs: **L. Gallardo and P. Suntharalingam**
		11:00	**J. Abbatt**: Connecting the ocean to aerosols and clouds in the summertime Canadian Arctic	11:00	**D. Nomura**: Gas exchange process in the ice covered oceans	11:00	**A. Mahajan**: Oceanic Regulation of Atmospheric Chemistry: Past, Present and Future	11:00	**Y. Chen**: Atmospheric deposition of nitrogen and trace metals affects marine phytoplankton and their feedback to aerosols
	Geoengineering workshop	11:30	**A. Baccarini**: Is new particle formation an aerosol source over the Southern Ocean?	11:30	**K. Krall**: Air-sea gas transfer at hurricane wind speeds	11:30	**S. Smith**: Modelling of ammonia/um across the air-sea interface in the Atlantic sector of the Southern Ocean	11:30	**W. Landing**: Atmospheric Deposition to the Oceans Controls Biological Productivity
		11:50	**P. Rodríguez-Ros**: Ecological modeling of marine biogenic isoprene emissions in the Southern Ocean	11:50	**P. Markuszewski:** Sea spray fluxes: interconnections between ambient noise of bubbles and wave age	11:50	**K. Hamasaki**: Microbial community dynamics in sea surface microlayer and sea spray aerosols observed in coastal inlets of Japan	11:50	**R. Mukherjee**: Limitation of iron on N2 fixation in the Arabian Sea
		12:10	**P. Zieger**: Revising the hygroscopicity of inorganic sea salt particles	12:10	**R. Stanley**: Relating air-sea gas fluxes to bubble distributions at high wind speeds: insights from the sustain wind-wave tank	12:10	**J. Maas**: Simulating halocarbon concentration in ocean and atmosphere from industrial water treatment	12:10	**C. White**: Impact of atmospheric nitrogen deposition to nitrogen limited marine surface waters in the temperate and subtropical North Atlantic Ocean
12:30	Lunch	12:30	Lunch	12:30	Lunch	12:30	Lunch	12:30	Conference closing
14:30	Early Career Scientists Day	14:30	**Discussion sessions** **C. Marandino, A. Koertzinger, T. Bell, J. Jeong**: Can long term observatories be used to study the processes controlling air-sea exchange? **S. Royer, D. Deheyn**: Impacts of ocean plastic and microfibers on air quality and climate	14:30	**Discussion sessions** **E. van Doorn, C. Marandino:** SOLAS Science & Society: achievements, present status & future possibilities **P. Hwang, T. Toyota**: Enhanced air-sea interaction in the emerging Marginal Ice Zone	14:30	**Discussion sessions** **M. Uematsu, A. Zivian, K. Slavik**: WHAT IS Ocean KAN? **A. Ito, W. Landing, D. Hamilton**: Atmospheric deposition of iron, ocean biogeochemistry and marine emission of biological aerosols		
	Geoengineering workshop		**M. Frey, P. Zieger, D. Nomura, J. Thomas, N. Steiner**: The coupling of ocean, sea ice and atmospheric chemistry & biogeochemistry - a cross-disciplinary research challenge		**C. Chen, E. Achterberg**: The High Resolution Measurement for the Ocean-Atmosphere Interfacial Layers		**P. Suntharalingam, G. Zhang, A. Koertzinger**: Oceanic greenhouse gases: The present situation and future initiatives		
15:00	Coffee break	16:00	Coffee break (during poster session)	16:00	Coffee break (during poster session)	16:00	Coffee break (during poster session)		
15:30	Early Career Scientists Day	16:30-18:00	**Poster sessions** **Theme 3**: Atmospheric deposition and ocean biogeochemistry **Integrated topics**	16:30-18:00	**Poster sessions** **Theme 5**: Ocean biogeochemical control on atmospheric chemistry **Geoengineering**	16:30-18:00	**Poster sessions** **Theme 2**: Air-sea interface and fluxes of mass and energy		
	Geoengineering workshop	17:30-19:00	**Theme 4**: Interconnections between aerosols, clouds and ecosystems	17:30-19:00	**Theme 1**: Greenhouse gases and the oceans **Science & Society**				
18:00	Welcome reception	19:30	National representatives dinner (invitation only)			19:30	Conference banquet		

SOLAS

Open Science Conference 2019

21 - 25 April

Sapporo - Japan

surface ocean solas lower atmosphere study

www.solas-int.org

Table of contents

Welcome to Sapporo for the 2019 SOLAS Open Science Conference!

We have an exciting and interesting program lined up for our 7th installment of the SOLAS open science conferences, set in this cosmopolitan city at the wild end of Japan. During the coming week, you have the opportunity to explore the full range of SOLAS science, from the core themes of the science plan during plenary lectures, to emerging issues in discussion sessions, to the future wave during the Early Career Scientists' Day.

SOLAS is a bottom-up organization, in which the scientific community sets the agenda, and the Open Science Conferences play a key role in that process. The first SOLAS Open Science Conference, held in Damp, Germany in 2000, generated the ideas that formed the first SOLAS Science Plan, and that tradition continues, as we hope this week will also identify new frontiers for our community to explore.

Hokkaido provides a perfect backdrop to our discussions this week, located at a nexus of air-sea exchange research of both global and local significance. The northern coast of Hokkaido is the lowest latitude at which sea ice forms. It also borders the Sea of Okhotsk, the primary ventilation site for the North Pacific Ocean. To the west, lies a temperate marginal sea that has been a site of extensive SOLAS research into how the human system interacts with air-sea exchange processes. And of course, to the east, the North Pacific Ocean, itself, where High Nitrate-Low Chlorophyll waters meet atmospheric dust and nutrient deposition, with periodic perturbation by typhoons.

We want to thank all the sponsors and funders of this conference, as well as the sponsors of the International SOLAS program (SCOR, Future Earth, iCACGP, and WCRP) for all their support over the years. We also thank the SOLAS International Project Office and the Local Organizing Committee for their hard work and dedication in assuring that we have a fun and comfortable meeting this week. Finally, we thank you, the SOLAS community, for making SOLAS the productive, exciting, and important organization that it is.

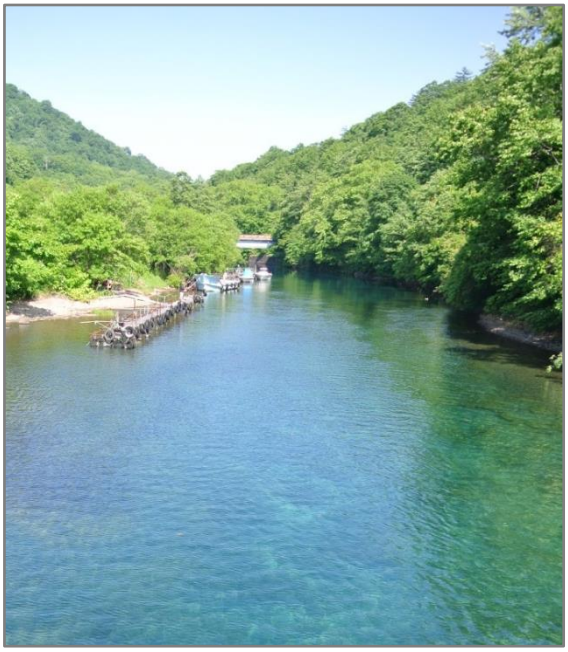
Enjoy!

Lisa A. Miller
Chair, SOLAS Scientific Steering Committee

Jun Nishioka
Chair, SOLAS 2019 Local Organizing Committee

Scientific Organising Committee (SOC)

Katye Altieri (South Africa)
Phil Boyd (Australia)
Erik van Doorn (Germany)
Cristina Facchini (Italy)
Laura Gallardo (Chile)
Veronique Garcon (France)
Santiago Gassó (USA)
Ilan Koren (Israel)
Arne Körtzinger (Germany)
Mohd Talib Latif (Malaysia)
Maurice Levasseur (Canada)
Anoop Mahajan (India)
Lisa Miller (SOC chair, Canada)
Peter Minnett (USA)
Jun Nishioka (LOC chair, Japan)
Jurgita Ovadnevaite (Ireland)
Anna Rutgersson (Sweden)
Alfonso Saiz-Lopez (Spain)
Parvadha Suntharalingam (UK)
Guiling Zhang (China)



Local Organising Committee (LOC) at Hokkaido University

Masahiko Fujii
Sohiko Kameyama
Yuzo Miyazaki
Jun Nishioka (LOC chair)
Yutaka Watanabe
Takeshi Yoshimura

Early Career Scientist Day Committee (ESDC)

Martine Lizotte (Canada)
Yoko Iwamoto (Japan)
Sohiko Kameyama (Japan)

SOLAS International Project Office

Jessica Gier, Germany
Li Li, China
Esther Rickert, Germany

In memory of Ron

Picture credit: David Kieber

A dearly beloved colleague and friend in the SOLAS community, Ronald Peter Kiene, died unexpectly on January 19, 2019. Ron was an incredibly active scientist, a leader in his field, and one who delved deeply into everything that interested him. This included topics ranging from religion and social mores, woodworking, fishing, sports and politics to research on climate change and the marine organosulfur cycle, all topics that he was passionate about. Ron organized and hosted the first and highly successful international DMSP symposium. He played a pivotal role in developing techniques and stimulating ideas that propelled the marine organosulfur field from its early days of discovery to the complex, multifaceted study area of today ranging from molecular to global scales. He was the quintessential SOLAS scientist, interested in interfacial processes at the ocean-atmosphere boundary spanning the globe from ice-impact polar waters to the up-welling region in the equatorial Pacific. His research was not only focused on the oceanic organosulfur cycle and DMS, but also included other volatile compounds such as methane and other environments, including boreal bogs and Spartina-dominated salt marshes. Ron was creative and inquisitive, but was also analytical questioning everything – every number, every technique, every experiment, every hypothesis – and this made him an invaluable colleague and an outstanding scientist.

Perhaps more important than his contributions to science, and what Ron may be best remembered for, is that he was a trusted colleague and mentor to many in the field, students and scientists alike. He treated everyone with dignity and respect. He spent countless hours nearly every day corresponding to colleagues and friends, and he made everyone feel special and valued. What an exceptional personal and scientific legacy he gifted to us. I think that we can all smile knowing that a part of Ron, his carbon and sulfur, now flows freely through oceans and atmosphere.

David Kieber

Professor, Department of Chemistry
College of Environmental Science and Forestry
State University of New York, Syracuse

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www.icacgp.org

Scientific Committee on Oceanic Research
www.scor-int.org

World Climate Research Programme
www.wcrp-climate.org

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GEOMAR Helmholtz Centre for Ocean Research Kiel
www.geomar.de

State Key Laboratory of Marine Environmental Science Xiamen University, Xiamen, China

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KIMOTO ELECTRIC CO.,LTD.
www.kimoto-electric.co.jp/english/

Metrohm / www.metrohm.com

North Pacific Marine Science Organization (PICES)
meetings.pices.int

Ocean Mixing Processes Impact on Biogeochemistry, Climate and Ecosystem
omix.aori.u-tokyo.ac.jp/en/

Science Council of Japan
www.scj.go.jp/en/

Scientific Committee on Oceanic Research (SCOR)
scor-int.org

subCtech
subctech.com

TOKYO DYLEC CORP.
www.t-dylec.net

3S Ocean Network Ltd.
http://www.3s-ocean.co.jp/

Open Science Conference Programme

Times	Monday, 22 April	Time	Tuesday, 23 April
08:30	**Conference opening** **Welcome & SOLAS introduction**	08:30	**Geoengineering / Science and Society**
	Integrated topics I Session chairs: **T. M. Latif** and **A. Mahajan**		Introduction by sessions chairs: **P. Boyd** and **E. van Doorn**
08:50	**M. Cornejo**: The dynamic of the nitrous oxide in the Humboldt Current System	08:40	**A. Lenton**: Geoengineering, the Ocean and SOLAS
09:20	**M. Dai**: Air-Sea CO2 fluxes, diapycnal nutrient fluxes and export productivity in oligotrophic ocean	09:10	**S. Tegtmeier**: Impact of large-scale macroalgae production on the ozone layer
09:40	**E. Saltzman**: Air/sea transfer of highly soluble gases over coastal waters	09:30	**K. Mengerink**: Marine Spatial Planning as a Tool to Advance Science-Based Decision-Making
10:00	**J. Kim/K. Lee**: Biological production reduces the net impacts of coastal acidification in the northwestern Pacific Ocean	10:00	**S. Sarker**: Taking the science to community: An approach of multi-stakeholders integration for sustainable Blue Economy development in Bangladesh
10:20	Coffee break	10:20	Coffee break
10:50	**Theme 4: Interconnections between aerosols, clouds and ecosystems** Introduction by session chairs: **M. Levasseur** and **Y. Iwamoto**	10:50	**Theme 2: Air-sea interface and fluxes of mass and energy** Introduction by session chairs: **A. Rutgersson** and **P. Minnett**
11:00	**J. Abbatt**: Connecting the ocean to aerosols and clouds in the summertime Canadian Arctic	11:00	**D. Nomura**: Gas exchange process in the ice covered oceans
11:30	**A. Baccarini**: Is new particle formation an aerosol source over the Southern Ocean?	11:30	**K. Krall**: Air-sea gas transfer at hurricane wind speeds
11:50	**P. Rodríguez-Ros**: Ecological modeling of marine biogenic isoprene emissions in the Southern Ocean	11:50	**P. Markuszewski:** Sea spray fluxes: interconnections between ambient noise of bubbles and wave age
12:10	**P. Zieger**: Revising the hygroscopicity of inorganic sea salt particles	12:10	**R. Stanley**: Relating air-sea gas fluxes to bubble distributions at high wind speeds: insights from the sustain wind-wave tank
12:30	Lunch	12:30	Lunch
14:30	**Discussion sessions** (in parallel) C. Marandino, A. Koertzinger, T. Bell, J. Jeong: **Can long term observatories be used to study the processes controlling air-sea exchange?** S. Royer, D. Deheyn: **Impacts of ocean plastic and microfibers on air quality and climate** M. Frey, P. Zieger, D. Nomura, J. Thomas, N. Steiner: **The coupling of ocean, sea ice and atmospheric chemistry & biogeochemistry - a cross-disciplinary research challenge**	14:30	**Discussion sessions** (in parallel) E. van Doorn, C. Marandino: **SOLAS Science & Society: achievements, present status & future possibilities** P. Hwang, T. Toyota**: Enhanced air-sea interaction in the emerging Marginal Ice Zone** C. Chen, E. Achterberg: **The High Resolution Measurement for the Ocean-Atmosphere Interfacial Layers**
16:00	Coffee break (during poster session)	16:00	Coffee break (during poster session)
16:30 - 18:00	**Poster sessions** (in parallel) **Theme 3**: Atmospheric deposition and ocean biogeochemistry **Integrated topics**	16:30 - 18:00	**Poster sessions** (in parallel) **Theme 5**: Ocean biogeochemical control on atmospheric chemistry **Geoengineering**
17:30- 19:00	**Theme 4**: Interconnections between aerosols, clouds and ecosystems	17:30 - 19:00	**Theme 1**: Greenhouse gases and the oceans
19:30	**National representatives dinner** (invitation only)		

Open Science Conference Programme

Time	Wednesday, 24 April	Time	Thursday, 25 April
08:30	**Theme 1: Greenhouse gases and the oceans** Introduction by session chairs: **A. Koertzinger** and **G. Zhang**	08:50	**Integrated topics II** Introduction by session chairs: **K. Altieri** and **S. Kameyama**
08:40	**S. Lauvset**: The Carbon Cycle: The role of oceans and humans	09:00	**S. Landwehr**: Investigation of sea spray source functions with aerosol size spectra measurements from the Antarctic Circumnavigation Experiment
09:10	**O. Bui**: Dissolved methane distribution and its controlling factors in the Arctic Ocean in 2016 summer	09:20	**L. Gutierrez-Loza**: Air-sea CH4 fluxes from eddy covariance measurements in the Baltic Sea
09:30	**Y. Eddebbar**: Volcanic Modulation of Ocean Ventilation: Implications for Air-sea Carbon and Oxygen Exchange	09:40	**P. Wongpan**: Using under-ice spectra to determine land-fast ice algal biomass in Lake Saroma, Japan
09:50	**L. Keppler**: Regional Wind Variability Modulates the Southern Ocean Carbon Sink	10:00	**M. Frey**: Sea salt aerosol from blowing snow above sea ice - a new particle source
10:10	**Group picture**		
10:20	Coffee break	10:20	Coffee break
10:50	**Theme 5: Ocean biogeochemical control on atmospheric chemistry** Introduction by session chairs: **J. Ovadnevaite and Y. Miyazaki**	10:50	**Theme 3: Atmospheric deposition and ocean biogeochemistry** Introduction by session chairs: **L. Gallardo** and **P. Suntharalingam**
11:00	**A. Mahajan**: Oceanic Regulation of Atmospheric Chemistry: Past, Present and Future	11:00	**Y. Chen**: Atmospheric deposition of nitrogen and trace metals affects marine phytoplankton and their feedback to aerosols
11:30	**S. Smith**: Modelling of ammonia/um across the air-sea interface in the Atlantic sector of the Southern Ocean	11:30	**W. Landing**: Atmospheric Deposition to the Oceans Controls Biological Productivity
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12:30	Lunch	12:30	**Conference closing**
14:30	**Discussion sessions** M. Uematsu, A. Zivian, K. Slavik: **WHAT IS Ocean KAN?** A. Ito, W. Landing, D. Hamilton: **Atmospheric deposition of iron, ocean biogeochemistry and marine emission of biological aerosols** P. Suntharalingam, G. Zhang, A. Koertzinger: **Oceanic greenhouse gases: The present situation and future initiatives**		
16:00	Coffee break (during poster session)		
16:30-18:00	**Poster session** **Theme 2**: Air-sea interface and fluxes of mass and energy		
19:30	**Conference banquet**		

Follow us on twitter
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Conference venue

The SOLAS Open Science Conference will be held on Hokkaido, in Sapporo at the Hokkaido University Conference Hall.
The campus is easily accessible by foot (10 min from the JR Sapporo station) and (20 min from downtown Sapporo).

Address:
Hokkaido, Sapporo, Kita, Kita 8 Jonishi, 7 Chome

Conference Hall, Hokkaido University

Registration/information desk

If you require any assistance, please visit the registration desk.
The registration desk will be open at 9:00 am on Sunday and at 8:00 am on Monday to Thursday.
There will be also a registration desk open at the Ice Breaker event (Sunday) from 5:30 pm to 9:00 pm.

Please regularly check the information board next to the desk, which will inform about conference details, programme changes, and other announcements.

Mobile phones

Please assure that yourself that your phone is turned off or put on silent mode during presentations.

Internet

Your personal WiFi password is printed on your name tag. Please use this WiFi password to connect to the internet.

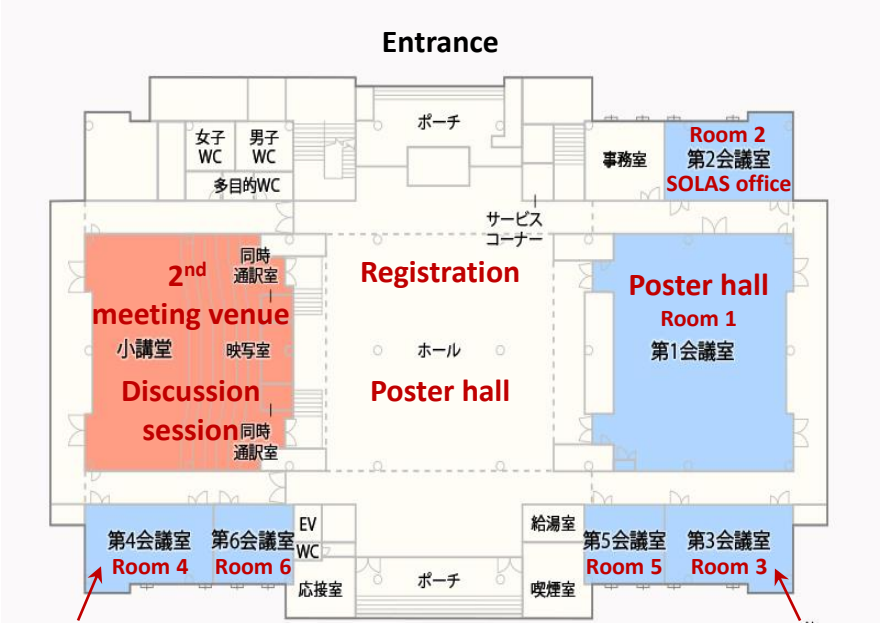
Join the SOLAS community

Join the mailing list to stay apprised of the most current news on SOLAS, conferences, events, publications and more.

www.solas-int.org/community/join.html

Conference venue overview map

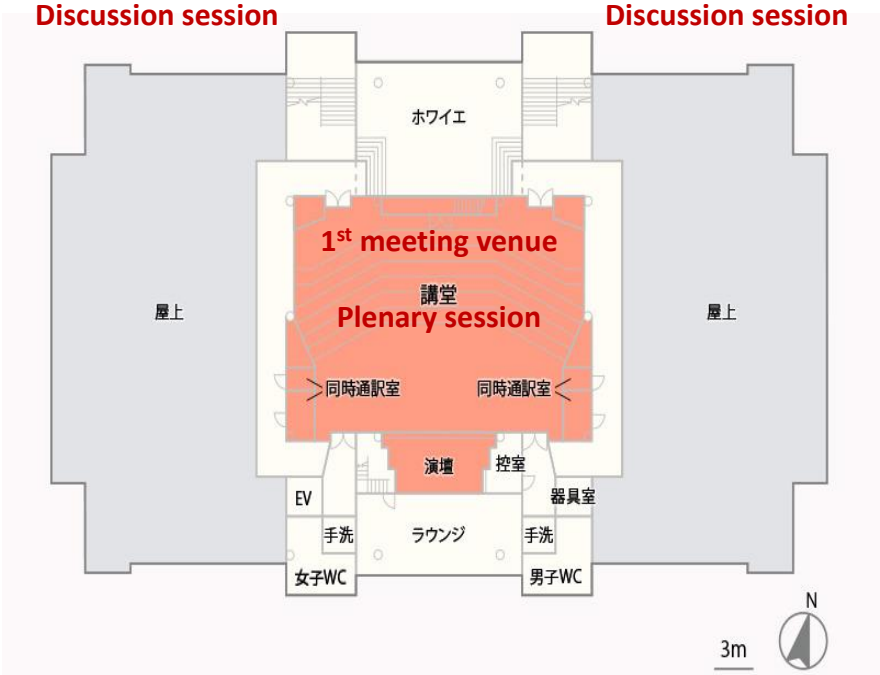
1st Floor



Early Career Scientist Day
Discussion session

Geoengineering workshop
Discussion session

2nd Floor



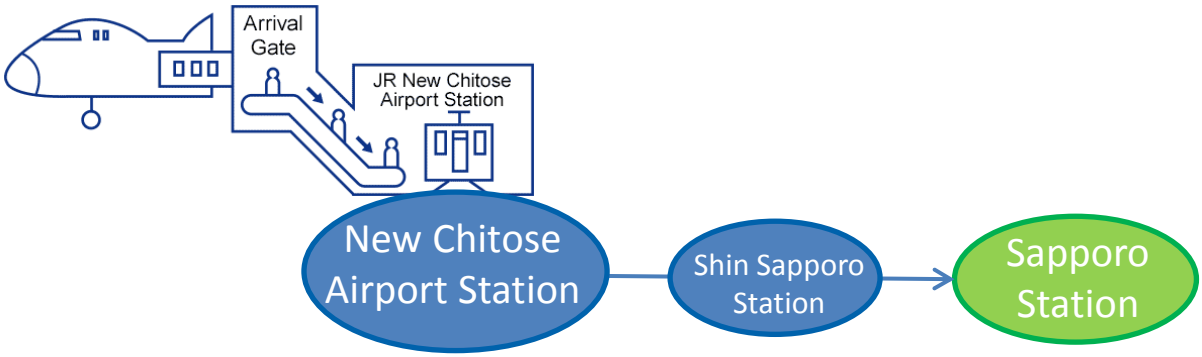
New Chitose airport - Sapporo

New Chitose airport connects Hokkaido with the rest of Japan. The airport is approx. 50 km (30 miles) from downtown Sapporo.

Train – JR rapid airport line

JR rapid airport line is the fastest way to travel between the New Chitose airport and Sapporo city. It takes only **40 minutes** from New Chitose airport to Sapporo station. The JR rapid airport line runs every 15 minutes. The JR rapid airport line is directly connected to the underground floor of the domestic terminal of New Chitose airport and departures only 10 minutes by walking from the international arrival gate. Ticket sales are shortly before the station in the airport.

Fare: adult 1,070 JPY, child 530 JPY



NOTE! JR Sapporo Station is not JR Shin Sapporo Station, which will come up after 30 minutes. Stay on the train until just about everyone prepares to get off; that will be Sapporo Station.

Further information: http://www2.jrhokkaido.co.jp/global/english/travel/airport.html
Image source: www2.jrhokkaido.co.jp/global/english/travel/airport.html

Express bus

The express busses **Chuo bus** and **Hokuto Kotsu bus** departs from New Chitose Airport to Sapporo station. One ride from Chitose Airport to Sapporo station takes approx. 70 minutes.
Fare: adult 1,030 JPY, child 520 JPY

Taxi

A taxi ride from New Chitose airport to Sapporo downtown takes approx. 90 minutes. To share a taxi with several other people is recommended.
Fare: 15,000 JPY (New Chitose airport - Sapporo downtown)

Further Information

http://www.new-chitose-airport.jp/en/access/
http://www.new-chitose-airport.jp/en/access/jr/timejr/

JR Sapporo station

The Sapporo station is a massive transport hub connecting different transportations such as trains, subways, busses, and taxies. In addition, the station hosts an enormous variety of shops, kiosks, drugstores, eateries as well as ATMs, a post office and a tourism information center. The tourist information, is located at the northwest corner of the station at the **JR Information Desk** and the **Hokkaido-Sapporo Tourist Food and Tourism Information Center** (see highlighted red boxes in the map below).

Sapporo Station has two exits to the outside: North and South. Take the **North Exit** to walk to the campus of **Hokkaido University** (see highlighted red box in the map below).

Map downloaded from www.sapporostation.com/sapporo-station-layout-and-facilities/

SAPICA cards in Sapporo

SAPICA is a prepaid card which can be used on Sapporo's three subway lines, city buses (JR Hokkaido Bus, Jotetsu and Hokkaido Chuo Bus) and tram. SAPICA cannot be used on JR trains or outside of the Greater Sapporo area. Purchase locations: Subway stations, commuter pass sales offices, bus terminals, office counters

Price: ¥2,000 (¥1,500 can be used for fare, while ¥500 is the deposit. Source: www.sapporo.travel/

Taxi in Sapporo

Taxi stands are located all over central Sapporo, JR Sapporo station, at some hotels and you can also find many taxis running on the major roads. Credit cards are accepted in most of the taxis. In addition, there are sightseeing taxis that visit tourist attractions inside Sapporo City, with a wide range of plans for different courses and schedules. The drivers also serve as guides. Source: www.sapporo.travel/

If you want to get a taxi in the streets raise your hand to stop it.

Japan connected-free Wi-Fi App

The "Japan Connected-free Wi-Fi" smartphone app is a free app that allows you to search for free Wi-Fi hotspots and connect to free Wi-Fi with a single tap. It allows you to bypass the registration procedures necessary to use Wi-Fi at each hotspot. It can be used to connect to many free Wi-Fi hotspots around Japan such as those in airports, train stations and commercial facilities. The app is available in 11 languages.
Visit the"Japan Connected-free Wi-Fi" website for further details. Source: www.sapporo.travel/

Free Wi-Fi in Sapporo

Free Wi-Fi offered at around 2,400 locations across Sapporo. This Wi-Fi service can be accessed by visitors with a Wi-Fi enabled device such as a smartphone. This service is available regardless of your mobile carrier or mobile phone manufacturer. For details, check out **NTT East's "Hikari Station Service Contents**." Source: www.sapporo.travel/

Free Wi-Fi is also available at convenience stores and shopping centers with this mark. Ask the staff at the store for details.

7 Spot　FamilyMart

ATM service in Sapporo
Seven Bank and Japan Post Bank

Many ATMs in Japan do not accept cards that are issued outside of Japan.
Exception are **ATMs at Seven Bank** (セブン銀行) **convenience stores**, and the **cashing service in Japan Post Bank** (ゆうちょ銀行).

Seven Bank ATMs, mainly located inside 7-Eleven convenience stores (see map below for 7-Eleven store location or use the QR code to find the next ATM).

ATMs **No. 1 - 4** (indicated in the map) are open from **Mo-Sun, 7:00 am - 10:00 pm.**
all other 7-Eleven convenience stores indicated at the map are open form Mo-Sun, 24 hours.

For details, please see the website:
https://www.sevenbank.co.jp/intlcard/card2.html

Searching for the nearest Seven Bank ATMs, use this website:
http://inbound.standard.navitime.biz/sevenbank-english/Index.act

Search via mobile ATM location.

Subway transportation in Sapporo

Sapporo's subway system has three lines: Namboku line (green) running north-south, Tozai line (orange) running east-west, and Toho line (blue) connecting suburbs in between. The subway hub, with all lines pass through, is the Odori Station. Odori Station is located below the downtown center and Odori Park.

A **one-day ticket** is the money-saving alternative that allows you **unlimited subway rides for the whole day**. Single ticket price is approx. 200 – 360 yen.
One-day pass for adults: approx. 830 yen
Sales points: subway ticket-vending machines, and commuter pass sales offices .

It's worth a ride!

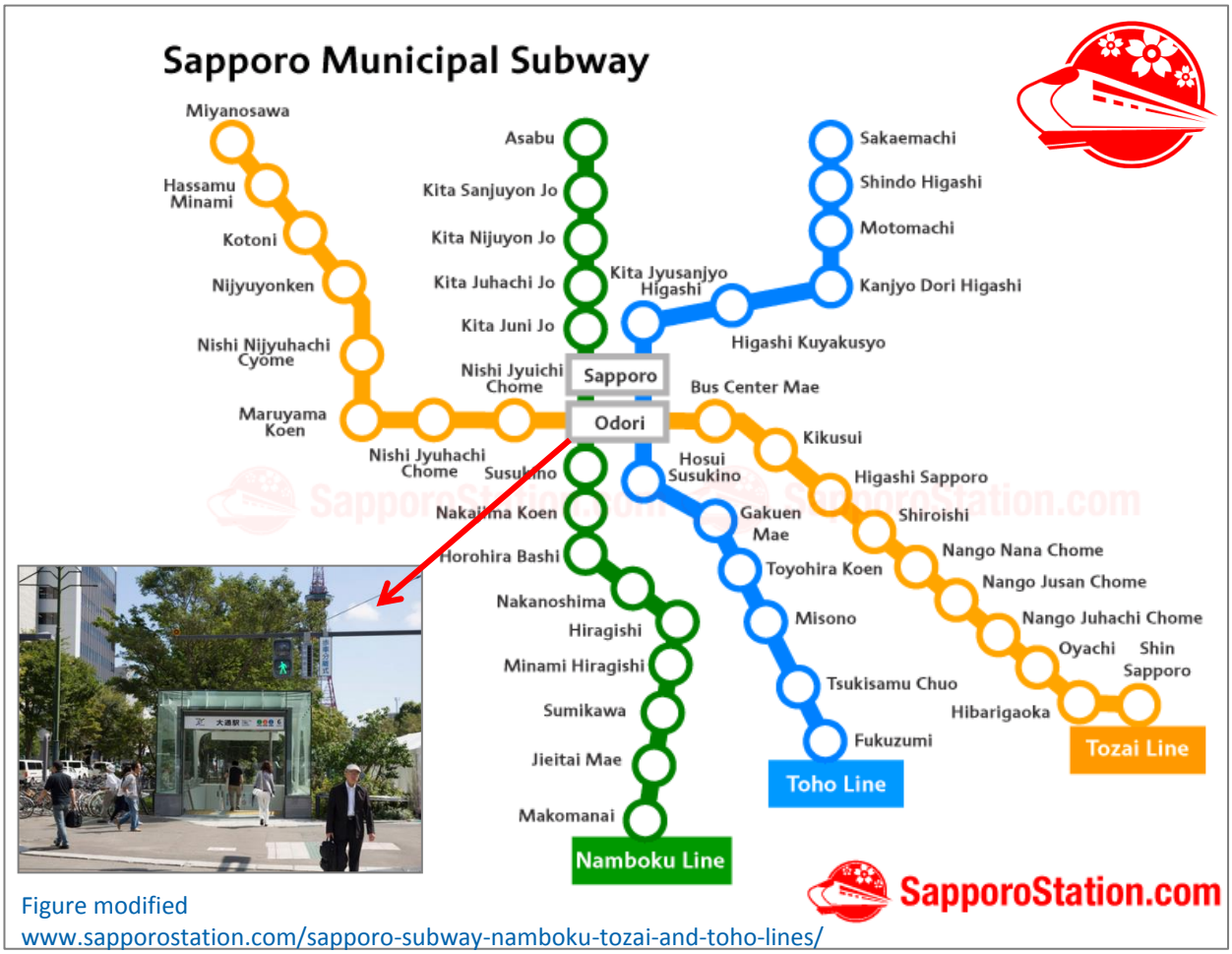
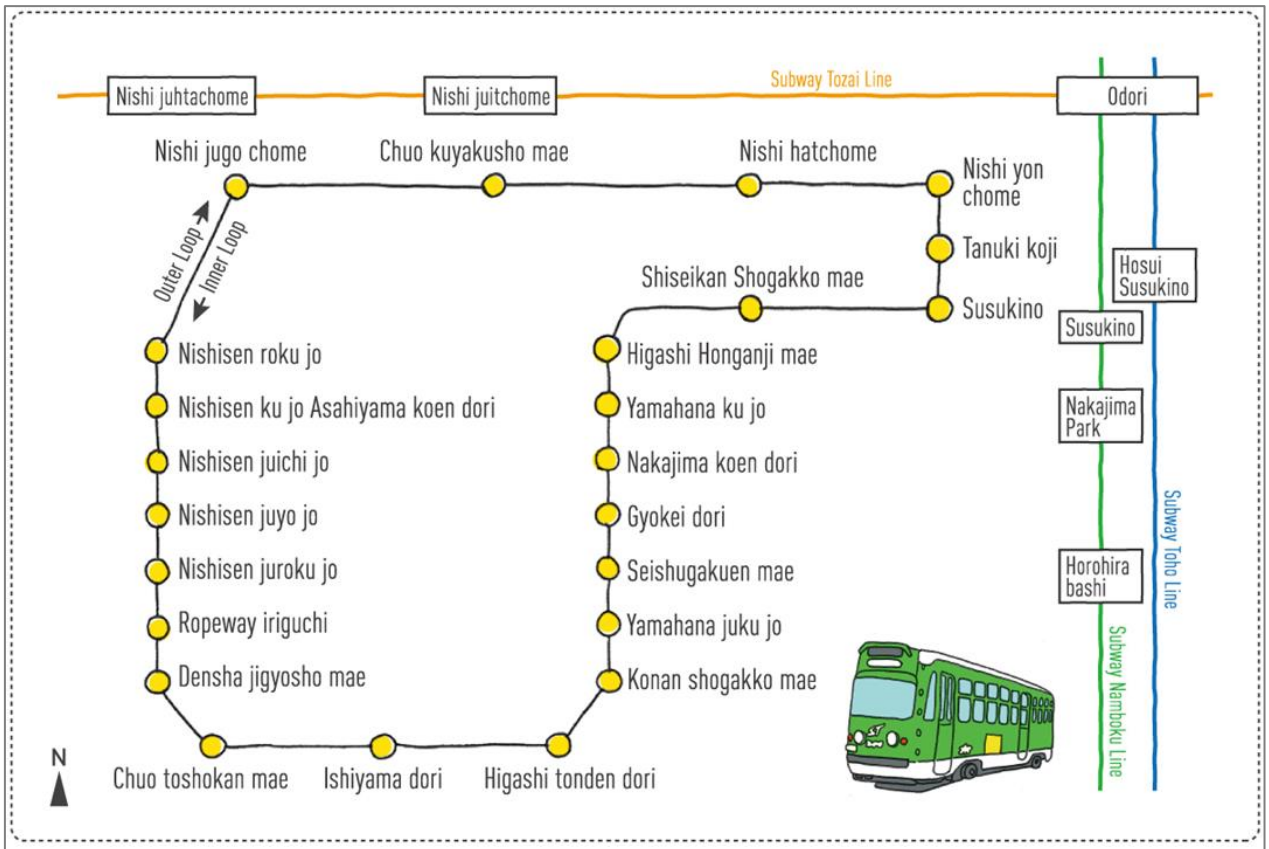


Figure modified
www.sapporostation.com/sapporo-subway-namboku-tozai-and-toho-lines/

Tram transportation

The slowly moving Sapporo Streetcars (*Sapporo shiden)* run in a loop from central Sapporo to mainly the western area. Most stops are located in the middle of the street. Choose to hop on the inner loop (counter-clockwise) or the outer loop (clockwise) depending on which direction is closer to your destination. Be sure to stand clear as the train arrives at the station. The fare for one ride on the shiden is ¥200 for adults, and ¥100 for children, per person. The SAPICA card can be used.



Source and further information:
www.sapporo.travel/choose/keywords/sapporo-streetcar-sightseeing-how-to-ride/?lang=en

Bus transportation

There are bus terminals in various locations in Sapporo City, including those directly connected to subway stations. Extensive regular-route buses link different locations in the city and are operated by three companies: **Hokkaido Chuo Bus**, **JR Hokkaido Bus**, and **Jotetsu Bus**.

City bus tickets can be paid in cash or with SAPICA cards.

Ice breaker location with direction maps

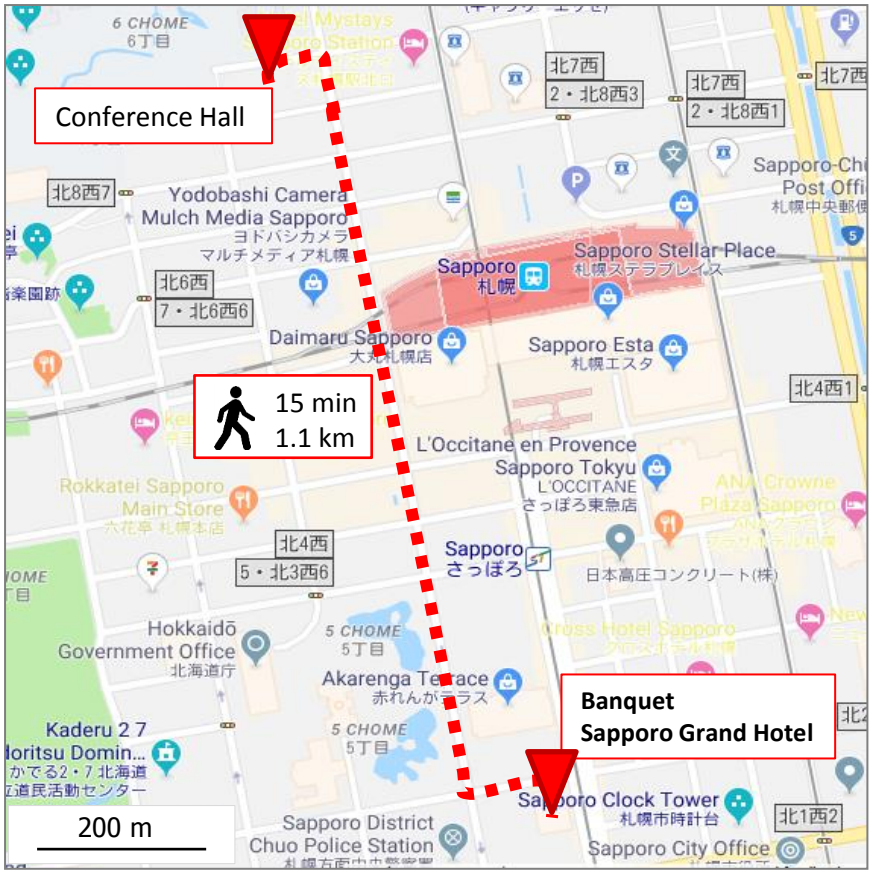
The OSC Ice breaker event will take place on Sunday 21 April from 6.00 to 9.00 pm at the Beer Keller Sapporo Bureau of Development. The Beer Keller is located in a brick building of the Sapporo Factory (1F) / North 2, East 4, Chuo-ku, Sapporo.

By walking the Beer Keller is approx. 25 min away from the conference hall or rather approx. 10 min by walking from the Sapporo TV tower.

Banquet location with direction maps

The OSC banquet event will take place on Wednesday 24 April from 7.30 to 10.30 pm at the Sapporo Grand Hotel (2F). The Sapporo Grand Hotel is located at North 1, West 4, Chuo-ku, Sapporo.

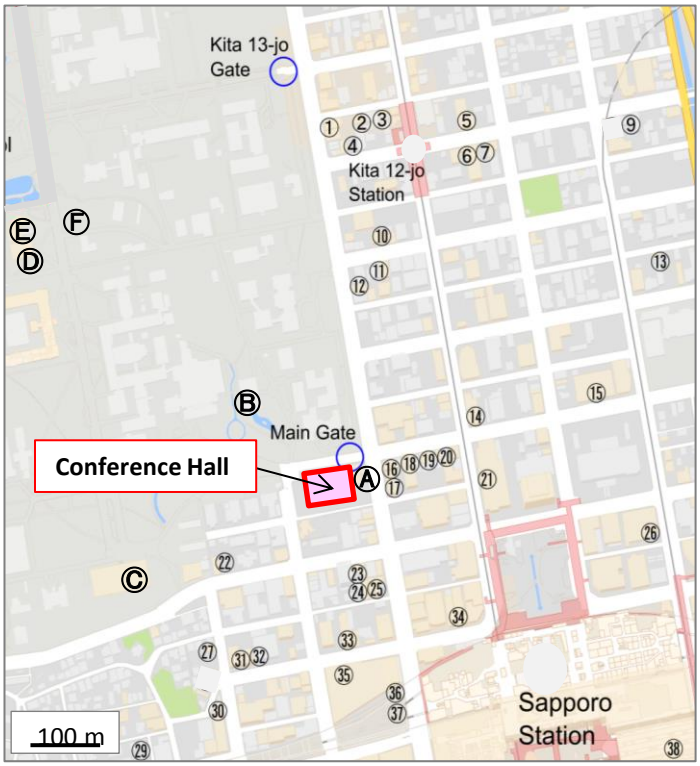
By walking the Sapporo Grand Hotel is approx. 15 min away from the conference hall.



Dinning out in Sapporo

Restaurants with lunch menus in Sapporo

No	Name	Category
A	Elm no Mori	Cafeteria (light meal)
B	Hokudai Marche	Restaurant
C	Clark Cafeteria *	Cafeteria
D	Chuo Cafeteria *	Cafeteria
E	Elm Restaurant	Restaurant
F	Seicomart	Store & Restaurant
1	Clark-Tei	Restaurant
2	Hashimaya	Ramen
3	THE KEBAP'S	Turkish food restaurant
4	Maru	Ramen
5	Go Bee	Chinese food restaurant
6	Suriyothai	Thai food restaurant
7	Dejeuner Campanula	Restaurant
9	Jack in the box	Soup curry
10	Marutaka Ramen	Ramen
11	Kitchen taft B	Restaurant
12	Chinman	Chinese food restaurant
13	Hirose Shoten	Ramen
14	Mos Burger	Hamburger restaurant
15	Osteria EST EST EST	Italian food restaurant
16	Shun	Japanese food restaurant
17	CoCo ichibanya	Curry
18	Kuromugi	Buckwheat noodles
19	Yunron	Chinese food restaurant
20	Kogane	Japanese food restaurant
21	Yamawasabi	Buckwheat noodles
22	Mizuki	Buckwheat noodles
23	ROGA	Curry
24	Erimo-Tei	Japanese food restaurant
25	Fukagawa	Japanese food restaurant
26	Ushinoya	BBQ house
27	Kofuku	Chinese food restaurant
29	Ramen Jiro	Jiro Ramen
30	Tsukimiken	Ramen
31	Sopracciglia	Italian food restaurant
32	Ichizen	Buckwheat noodles
33	Mia Bocca	Italian food restaurant
34	175° DENO	Ramen
35	McDonald's	Hamburger restaurant
36	Barikiya	Ramen
37	Saint Marc cafe	Cafe
38	The Republic of Ramen	Ramen street



***Please note!** – Hokkaido University's cafeterias (C and D) might be overcrowded during lunch time.*

Dinning out in Sapporo

Local Cuisine

Nemuro Hanamaru JR Tower Stellar Place
$$ - $$$, Japanese, Seafood, Sushi
Certificate of Excellence2015 - 2018 Winner
2 Kitagojonishi, Chuo-ku | 6F Stella Place, Chuo, Sapporo 060-0005, Hokkaido

Suage Honten
$$ - $$$, Asian, Soups, Vegetarian Friendly - Certificate of Excellence2015 - 2018 Winner
5-chome Minami 4jo Nishi, Chuo-ku | 2nd Floor, Chuo, Sapporo 064-0804, Hokkaido

Jingisukan Daruma
$$ - $$$, Japanese, Barbecue
Minami 4 jo Nishi 4, Sapporo 064-0804, Hokkaido

Cheap Cuisine

Refined Tavern Aiyo
$, Japanese, Seafood
Kita 3 Jo Nishi 2 cho-me, Chuo-ku, Sapporo, Hokkaido

Ramen Sapporo Akaboshi
$, Japanese
7-7 Minami 3 Jo Nishi, Chuo-ku | Tanukikoji Market, Sapporo 060-0063, Hokkaido

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Bars and Pubs

Sky Lounge ANA Hotel Sapporo
$$ - $$$, Bar
1-2-9 Kita 3 Jo Nishi, Chuo-ku | Ana Crowne Plaza Sapporo 26F, Chuo, Sapporo 060-0003, Hokkaido

Brooklyn Parlor Sapporo
$$ - $$$, Pub, Gastropub
4-1 Kita 2-jo Nishi, Chuo-ku | 2F Aka Red Terrace, Sapporo 060-0002, Hokkaido

Source and for further restaurant information see:

www.tripadvisor.com/Restaurant_Review-g14126710-d1588319-Reviews-Suage_Honten-Chuo_Sapporo_Hokkaido.html

Early Career Scientist Day (ECSD)

The SOLAS Early Career Scientist Day (ECSD) is an international event that brings together around 30 early career scientists and world-leading international scientists for a day of lectures and practical sessions. In addition, we will do a tour to the beautiful Lake Shikotsu which is surrounded by volcanoes. No registration fee is required to attend the ECSD. The selected 30 participants will have coffee breaks, lunch, and transportation to and from Lake Shikotsu paid for. Participants are responsible for airfare and registration for the SOLAS conference.

ECSD Programme – Sunday, 21 April 2019

08:30 - 09:00	Registration at the conference venue at Hokkaido University
09:00 - 09:10	Opening remarks by the ECSD organizing committee
09:10 - 09:50	Lecture by Anoop Mahajan, Scientist at the Indian Institute of Tropical Meteorology, India *(Title tbd).*
09:50 - 10:20	Lecture by Naoki Namba, International Public Relations Senior Academic Specialist Global Relations Office, Institute for International Collaboration, Hokkaido University, Japan (“Writing about your research for a non academic audience")
10:20 - 10:50	*Break (coffee, snacks, refreshments etc)*
10:50 - 13:00	Presentation contest by the ECSD participants (max 1 slide, 3 min & Q&A, 2 min)
13:30	Departure from Hokkaido University by bus (*bento box lunches in the bus*)
14:50	Arrival at Lake Shikotsu
15:00 - 17:30	Lake Shikotsu walk/visit
17:30	Departure from Lake Shikotsu
18:50	Arrival at Sapporo factory for the ice breaker

Geoengineering Workshop

This one-day workshop will assess how SOLAS science can contribute to the debate around negative CO2 emission technologies (NETs) and geoengineering, by bringing together observationalists, modellers, and legal experts working on the interactions between the ocean and the atmosphere. In addition to considering different NET approaches and how SOLAS science can add rigour to their assessment, the workshop will examine international frameworks, with the aim of developing strategies on how scientific organisations such as SOLAS can help coordinate governance and guidelines for NETs-related research.

Geoengineering Workshop Programm – Sunday, 21 April 2019

09:00	Registration at the venue
09:15	Welcome, introduction, and aims
09:30	SOLAS & Geoengineering - Setting the scene: What has been achieved?
10:00	Looking forward: Geoengineering techniques and SOLAS
10:30	*Coffee break*
11:00	Breakout session 1 / Four groups based upon SOLAS Themes: How can each SOLAS theme contribute to the understanding of Geoengineering? What are the questions, opportunities, and roadblocks?
12:00	Regroup (5-minute summary from rapporteurs)
12:20	Discussion
12:30	*Lunch*
13:30	Modelling Geoengineering (Andrew Lenton, Commonwealth Scientific and Industrial Research Organisation, Australia)
14:00	Societal issues of Geoengineering relating to SOLAS (Erik van Doorn, Kiel University, Germany)
14:30	Breakout session 2 / Four groups focusing on: a) Modelling and societal aspects of SOLAS Themes; b) Process modelling, earth system modelling, public perceptions, and policy frameworks
15:30	*Coffee break*
16:00	Regroup (5-minute summary from rapporteurs)
16:20	Brief discussion
16:30	The way forward - identify meeting outputs and next steps
17:00	Meeting End
18:00	Ice breaker

Times	Monday, 22 April
08:30	**Conference opening - Welcome & SOLAS introduction**
	Integrated topics I Session chairs: **T. M. Latif** and **A. Mahajan**
08:50	**M. Cornejo**: The dynamic of the nitrous oxide in the Humboldt Current System
09:20	**M. Dai**: Air-Sea CO_2 fluxes, diapycnal nutrient fluxes and export productivity in oligotrophic ocean
09:40	**E. Saltzman**: Air/sea transfer of highly soluble gases over coastal waters
10:00	**J. Kim/K. Lee**: Biological production reduces the net impacts of coastal acidification in the northwestern Pacific Ocean
10:20	Coffee break
10:50	**Theme 4: Interconnections between aerosols, clouds and ecosystems** Introduction by session chairs: **M. Levasseur** and **Y. Iwamoto**
11:00	**J. Abbatt**: Connecting the ocean to aerosols and clouds in the summertime Canadian Arctic
11:30	**A. Baccarini**: Is new particle formation an aerosol source over the Southern Ocean?
11:50	**P. Rodríguez-Ros**: Ecological modeling of marine biogenic isoprene emissions in the Southern Ocean
12:10	**P. Zieger**: Revising the hygroscopicity of inorganic sea salt particles
12:30	Lunch
14:30	**Discussion sessions (in parallel)** C. Marandino, A. Koertzinger, T. Bell, J. Jeong: **Can long term observatories be used to study the processes controlling air-sea exchange?** S. Royer, D. Deheyn: **Impacts of ocean plastic and microfibers on air quality and climate** M. Frey, P. Zieger, D. Nomura, J. Thomas, N. Steiner: **The coupling of ocean, sea ice and atmospheric chemistry & biogeochemistry - a cross-disciplinary research challenge**
16:00	Coffee break (during poster session)
16:30 -18:00	**Poster sessions** **Theme 3**: Atmospheric deposition and ocean biogeochemistry / **Integrated topics**
17:30 -19:00	**Theme 4**: Interconnections between aerosols, clouds and ecosystems
19:30	**National representatives dinner (invitation only)**

Plenary session
Integrated topics I

Session chairs: M. T. Latif and A. Mahajan

Keynote speaker: Marcela Cornejo

Marcela Cornejo was born in Santiago de Chile. Her undergraduate studies were in Oceanography, at the Pontifical Catholic University of Valparaíso, where she began research on the nitrogen cycle in sediments and water column in central Chile subjected to the oxygen minimum zone. Next, she moved to Concepción, where she completed her postgraduate studies in Oceanography, working with the carbon and nitrogen cycle focused on the ocean-atmosphere exchange of greenhouse gases, along the South Eastern Pacific Ocean. Currently, she is an academic at the Pontificia Universidad Católica de Valparaíso, where she promoted the biogeochemical line of greenhouse gases. Her research covers, among others, regions such as the mesoscale eddies generation zone, the coastal upwelling zone, the Chilean fjords and channels, and that Australian Ocean.

The dynamic of the nitrous oxide in the Humboldt Current System

Nitrous oxide is a potent greenhouse gas in the troposphere, and it is involved in the ozone destruction in the stratosphere. The Global Ocean is a source of atmospheric nitrous oxide with a high spatial, seasonal and temporal variability. A critical ecosystem in the marine nitrous oxide dynamic contribution is the Humboldt Current System in the eastern South Pacific, which acts as a net source to the atmosphere, but sink regions are also present. The magnitude of this contribution is subject to the occurrence of different physical and biogeochemical processes. Thus, the presence of coastal upwelling events, upwelling fronts, El Niño, mesoscale eddies, the variability of the oxygen minimum zone, contributions of fluvial waters, among others, determine a large part of the temporal and spatial dynamics of the coastal region in both subsurface and surface layer. Additionally, the oxycline variability is influencing the gas diffusion from the subsurface layer. In situ biogeochemical processes are also affecting the sub or over saturation of nitrous oxide in the surface layer through the presence of the aerobic (e.g., nitrification, nitrous oxide fixation) and anaerobic (by denitrification) processes. These processes have been measured in experiments with seawater and with particles, such as a faecal pellet, showing an important contribution to the surface nitrous oxide budget. Additionally, there are some efforts to establish the nitrous oxide cycling in microorganisms living associated with the surface microplastic, known as plastisphere. These results allow to estimate a direct impact of the plastic pollution in the ocean on the surface nitrous oxide inventories.

Minhan Dai is a Chair Professor of Marine Chemistry at Xiamen University. He has published over 150 papers in leading international journals. Minhan Dai has served on many national and international committees. He was elected as an Academician of the Chinese Academy of Sciences in 2017.

Air-Sea CO_2 fluxes, diapycnal nutrient fluxes and export productivity in oligotrophic ocean

M. Dai, C Du, Z. Liu, W. Yang, Z. Yuan, Y. Ma, K. Zhou, Y. Xu, X. Guo and Z. Cao

The oligotrophic ocean is conventionally known to be characterized by permanent stratification, nutrient depletion and extremely low net biological production, and hence, contributes little to carbon export from surface to deep waters or net sequestration of atmospheric CO_2. Based on simultaneous turbulence microstructure and high-resolution chemical measurements during two cruises conducted in the oligotrophic South China Sea, we quantified diapycnal fluxes of dissolved inorganic nitrogen (DIN) and other nutrients. These diapycnal fluxes are then compared with the export and CO_2 fluxes. We show extremely low diapycnal fluxes of DIN in the nutrient depleted layer (NDL), where other nutrient supplies sustain the export production. Below the NDL across the nutricline to the base of euphotic zone, termed as nutrient replete layer (NRL), the DIN flux is 1-3 orders of magnitude larger and sufficient in supporting the export production therein. Considering these new observations, we attempt to propose an improved framework of nutrient-determined and biologically mediated carbon export and their coupling or decoupling with CO_2 fluxes in the oligotrophic ocean.

Eric Saltzman is an atmospheric chemist who studies the atmospheric cycling of trace gases, the exchange of chemicals between the ocean and atmosphere, and the atmospheric histories of climate-active trace gases.

Air/Sea transfer of highly soluble gases over coastal waters

J. G. Porter, W. DeBruyn, S. D. Miller, and E. S. Saltzman

The physical processes governing soluble trace gas deposition to the sea surface are not well studied, due to a lack of direct flux measurements carried out under field conditions. Unlike less soluble gases, the air-sea exchange of these substances are controlled by physical processes on the air-side of the interface. In this study simultaneous eddy covariance flux measurements of water vapor, sulfur dioxide (SO_2), and momentum were made from coastal piers in the Pacific and Atlantic oceans. The gas transfer velocities were compared with each other and with gas transfer theory and previously published parameterizations. Transfer velocities were lower for sulfur dioxide than for the other quantitites, reflecting the influence of diffusion in the interfacial layer as a source of resistance to gas transfer. These are the first field observations quantifying differences in air-side resistance due to differences molecular diffusivity.

Ja-Myung Kim is a research scientist at POSTECH. Her research has focused on impacts of the ocean acidification on marine phytoplankton. She investigated the CO2-induced changes in growth of natural phytoplankton assemblage, biological C pump efficiency and the bioavailability of trace metals (the role of weak ligands in metal uptake process).

Biological production reduces the net impacts of coastal acidification in the northwestern Pacific Ocean

J.-M. Kim, K. Lee, I.-S. Han

The seasonal and interannual dynamics of primary production and carbonate chemistry were investigated in coastal waters of Korea (the Yellow Sea, East China Sea, and East Sea (Sea of Japan) using time series data collected from 2015 to 2018 (April, August and October). Analysis of carbonate data revealed that organic carbon production (photosynthesis) dominates over inorganic carbon production (calcification) in the study area. The changes in surface pH and pCO_2 (calculated at a constant temperature from TA and DIC) via photosynthesis of phytoplankton were comparable to a magnitude of the alterations due to temperature variation, indicating that net impacts of ocean acidification and global warming can be mitigated by biological activity in the coastal marine ecosystem.

Plenary session
Theme 4: Interconnections between aerosols, clouds and ecosystems

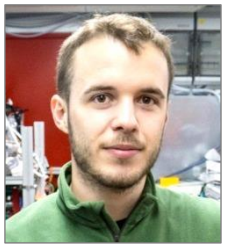
Session chairs: M. Levasseur and Y. Iwamoto

Keynote speaker: Jonathan Abbatt

Jon Abbatt is an atmospheric chemist interested in multiphase processes that occur between gases, aerosol particles, and environmental surfaces. He has a longstanding interest in polar chemistry, starting with halogen activation processes in both the stratosphere and troposphere. Most recently he has been the principal investigator of a large Canadian project (NETCARE) that has endeavored to assess the connections between the ocean, aerosol particles, and climate in remote environments, such as in the Canadian Arctic Archipelago.

Connecting the ocean to aerosols and clouds in the summertime Canadian Arctic

The Arctic is warming at twice the global average rate and the extent of summertime sea ice is diminishing. How will the atmosphere respond to the increased levels of Open Ocean? In this talk, observational results from the NETCARE research consortium will be presented for icebreaker and aircraft field campaigns conducted in the Canadian Arctic in 2014. It was observed that the ocean is productive, releasing high levels of DMS and oxygenated VOCs. As well, ultrafine particles are frequently observed in marine boundary layer environments, with occasional growth to CCN sizes. The impacts of these particles on low-level cloud properties will be presented. These observations will be placed in the context of other high latitude measurements that together illustrate the tight coupling that exists in the summertime Arctic between sea ice extent and the chemical state of the atmosphere.



Andrea Baccarini is a PhD student in the Laboratory of Atmospheric Chemistry at Paul Scherrer Institute. Andrea is interested in the investigation of aerosol processes in polar regions and chamber studies. He participated in the Antarctic Circumnavigation Expedition, in the ArcticOcean18 expedition and in several CLOUD campaigns at CERN.

Is new particle formation an aerosol source over the Southern Ocean?

A. Baccarini, S. Henning, K. Lehtipalo, M. Hartmann, F. Tummon, A. Welti, F. Aemisegger, C. Bolas, K. Carslaw, N. Harris, L. Regayre, F. Stratmann, I. Thurnherr, H. Wernli, U. Baltensperger, M. Gysel , J. Dommen and J. Schmale

Models estimate that about 38 - 66 % of the cloud condensation nuclei (CCN) in the atmosphere originate from new particle formation (NPF) events driven by nucleation of vapors (in contrast to direct particulate emissions). However, field and laboratory experiments are required to confirm the validity of these predictions. With this contribution we will present the first comprehensive investigation of NPF in the Southern Ocean. Concentration of gaseous precursors (like sulfuric and iodic acid), chemical composition of small nucleating clusters and size distribution of ions and neutral particles were measured during the Antarctic Circumnavigation Expedition. We will show that, despite of the generally low temperatures and small condensational sink, NPF in the Southern Ocean rarely happen due to the small amount of condensable vapors. Our observations suggest that the few NPF events observed are sulfuric acid driven. Finally, we will discuss the relevance of NPF in the Southern Ocean as source of CCN.

Pablo Rodríguez-Ros is a graduate researcher doing a PhD in marine sciences at the Institute of Marine Sciences in Barcelona. His research focus on marine trace gases in the Southern Ocean, for which I use different ecological-biogeochemical modelling approaches. I have also participated in a couple of oceanographic cruises along many of the Earth's oceans. Passionate about science outreaching and social communication of scientific research.

Ecological modeling of marine biogenic isoprene emissions in the Southern Ocean

P. Rodríguez-Ros, C. Nissen, P. Cortés, N. Gruber, R. Simó, S. Vallina, M. Vogt

Marine isoprene (C_5H_8) is a volatile organic compound produced eminently by phytoplankton, which acts as a precursor of secondary organic aerosol upon emission to the atmosphere . However, there is still a huge uncertainty on its global marine emission estimates (0.1-11.6 Tg C year-1). We implemented lab- and in situ-derived, chlorophyll-specific isoprene production rates of three phytoplankton functional types (diatoms, coccolithophores and others), into a high-resolution set-up of the marine ecosystem model ROMS-BEC for the Southern Ocean (SO). Modeled isoprene emission peaks within the latitude band 40-60° S during austral summer, associated with high chlorophyll-a concentrations of diatoms and coccolithophores. The annual flux of isoprene in the SO (< 40° S) accounts for 0.027 Tg C year-1, which represents 0.2 - 27 % of global marine isoprene emission estimates. Model sensitivity analyses show that better constraints on phytoplankton isoprene production rates and sinks are needed if we aim to project emission changes under global warming.

Paul Zieger is an assistant professor in atmospheric sciences at Stockholm University, Sweden. His research focuses around atmospheric aerosols and clouds using field and laboratory based experiments. In particular, he is interested in aerosol hygroscopicity (e.g. of sea spray particles) and aerosol optical properties. One major focus as the Arctic.

Revising the hygroscopicity of inorganic sea salt particles

P. Zieger, O. Väisänen, J.C. Corbin, D. G. Partridge, S. Bastelberger, M. Mousavi-Fard, B. Rosati, M. Gysel, U. K. Krieger, C. Leck, A. Nenes, I. Riipinen, A. Virtanen and M. E. Salter

Sea spray is one of the largest natural aerosol sources and plays an important role in the Earth's radiative budget. These particles are inherently hygroscopic, that is, they take-up moisture from the air, which affects the extent to which they interact with solar radiation. In this work, we demonstrate that the hygroscopic growth of inorganic sea salt is 8 - 15 % lower than pure sodium chloride, most likely due to the presence of hydrates. We observe an increase in hygroscopic growth with decreasing particle size (for particle diameters below 150 nm) that is independent of the particle generation method. We vary the hygroscopic growth of the inorganic sea salt within a general circulation model and show that a reduced hygroscopicity leads to a reduction in aerosol-radiation interactions, manifested by a latitudinal-dependent reduction of the aerosol optical depth by up to 15 %, while cloud-related parameters are unaffected.

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Parallel discussion sessions

Can long term observatories be used to study the processes controlling air-sea exchange?

Co-conveners: C. Marandino, A. Koertzinger, T. Bell, and J. Jeong
Room: 3

The boundary between the ocean and atmosphere is one of the Earth's most important interfaces. Despite the importance of this interface, the controls upon fluxes of mass and energy are not fully understood and quantified. Researchers from GEOMAR, Plymouth Marine Laboratory, the Korea Institute of Ocean Science and Technology, and the ENEA Station for Climate Observation Roberto Sarao have varying levels of experience running integrated air-sea exchange observatories. During this discussion session, we will identify the benefits and challenges associated with the data collected at these and similar sites around the world. The goal of the workshop is to publicize ongoing activity and to encourage community interest and participation at these sites.

Impacts of ocean plastic and microfibers on air quality and climate

Co-conveners: S. Royer and D. Deheyn
Room: 4

Plastic pollution has been a growing concern recently as it is found everywhere, impacting all forms of life, including humans. While many studies have investigated the extent of plastic pollution in aquatic environments and wildlife, very few studies have looked at the interplay between plastics and the atmosphere. It was recently proven that greenhouse gases are emitted from plastic degradation, which may potentially affect the global budget of methane, and thus link plastics to climate change. Similarly, synthetic microfibers are ubiquitous in the environment, including in the oceans and the atmosphere. Microfibers are invisible to the naked eye given their small size, and thus we breathe, eat and drink them without being aware of it. There is clearly an urgent need for increasing our knowledge regarding plastics and synthetic microfibers in the ocean and their transfer to the atmosphere, especially in the wake of environmental and human health issues already increased by climate change.

The coupling of ocean, sea ice and atmospheric chemistry & biogeochemistry – a cross-disciplinary research challenge

Co-conveners: M. Frey, P. Zieger, J. Thomas, D. Nomura, and N. Steiner
Room: 2nd meeting venue

The ocean areas covered by sea ice are undergoing significant climate change. Yet many underlying chemical, biological, and physical processes and feedbacks are still poorly understood strongly motivating continued research on the ocean-sea ice-atmosphere system. CATCH is an emerging activity sponsored by IGAC and SOLAS, whereas BEPSII is an initiative supported by SOLAS and CliC. Both facilitate interdisciplinary and international research on atmospheric chemistry and biogeochemistry with a focus on interactions between snow, ice, ocean, aerosols, and clouds in cold regions.
The session aim is to identify uncertainties in our understanding of the coupled ocean-sea ice-atmosphere system and discuss potential SOLAS/CATCH/BEPSII collaboration strategies. Topics include: ocean-sea ice-atmosphere interactions and their impacts on atmospheric and ocean biogeochemistry; feedbacks between climate change and atmospheric chemistry mediated by changes in sea ice; production and processing of aerosol and cloud precursors above and within sea ice/polar ocean and climate impacts; modelling challenges.

Poster sessions - Monday

These sessions features the posters from the following topics:

- 16:30 - 18:00
  - Theme 3: Atmospheric deposition and ocean biogeochemistry
  - Integrated topics
- 17:30 - 19:00
  - Theme 4: Interconnections between aerosols, clouds and ecosystems

Author	Title	No.
Theme 3: Atmospheric deposition and ocean biogeochemistry		
Gao, Huiwang	Changes in phytoplankton community due to dust addition in eutrophication, LNLC and HNLC seawaters in the Northwest Pacific	301
Gong, Xiang	Spatial variation of subsurface chlorophyll maximum in relation to temperature in northern South China Sea	302
Guo, Wei	Modelling the effects of atmospheric nitrogen deposition on primary production in the Yellow Sea and East China Sea	303
Guo, Zhigang	Atmospheric deposition and air? Sea gas exchange of polycyclic aromatic hydrocarbons over the Yangtze River Estuary, East China Sea	304
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08:30	**Geoengineering / Science and Society** Introduction by sessions chairs: **P. Boyd** and **E. van Doorn**
08:40	**A. Lenton:** Geoengineering, the Ocean and SOLAS
09:10	**S. Tegtmeier**: Impact of large-scale macroalgae production on the ozone layer
09:30	**K. Mengerink**: Marine spatial planning as a tool to advance science-based decision-making
10:00	**S. Sarker**: Taking the science to community: An approach of multi-stakeholders integration for sustainable Blue Economy development in Bangladesh
10:20	Coffee break
10:50	**Theme 2: Air-sea interface and fluxes of mass and energy** Introduction by session chairs: **A. Rutgersson** and **P. Minnett**
11:00	**D. Nomura**: Gas exchange process in the ice covered oceans
11:30	**K. Krall**: Air-sea gas transfer at hurricane wind speeds
11:50	**P. Markuszewski**: Sea spray fluxes: interconnections between ambient noise of bubbles and wave age
12:10	**R. Stanley**: Relating air-sea gas fluxes to bubble distributions at high wind speeds: insights from the sustain wind-wave tank
12:30	Lunch
14:30	**Discussion sessions** (in parallel) E. van Doorn, C. Marandino: **SOLAS Science & Society: achievements, present status & future possibilities** P. Hwang, T. Toyota**: Enhanced air-sea interaction in the emerging Marginal Ice Zone** C. Chen, E. Achterberg: **The high-resolution measurement for the ocean-atmosphere interfacial layers**
16:00	Coffee break (during poster session)
16:30 -18:00	**Poster sessions** **Theme 5:** Ocean biogeochemical control on atmospheric chemistry **Geoengineering**
17:30 -19:00	**Theme 1**: Greenhouse gases and the oceans

Plenary session
Geoengineering

Session chairs: P. Boyd and E. van Doorn

Keynote speaker: Andrew Lenton

Andrew Lenton is an ocean carbon cycle and earth system modeler with Commonwealth Scientific and Industrial Research Organisation's (CSIRO's) Climate Science Centre, the Antarctic Climate and Ecosystems CRC, and the Centre for Southern Hemisphere Oceans Research, based in Tasmania, Australia. His research focuses on key three key impact areas: (i) Quantifying the past, present and future role of the of the global carbon cycle focusing primarily on the ocean; (ii) Exploring and understanding the impact of the carbon cycle and feedbacks changes on both climate and the marine environment; (iii) The potential role of geoengineering in ameliorating or reducing climate change, both globally and locally. He initiated and now leads the Carbon Dioxide Removal Model Intercomparison Project (CDRMIP) and continues to be part of the Geoengineering Model Intercomparison Project (GeoMIP), as well as serving on the international Working Group on Marine Geoengineering (GESAMP WG41).

Geoengineering, the Ocean and SOLAS

At present even rapid decarbonization through emissions reduction is unlikely to be sufficient to stabilise climate at the global temperature thresholds of the Paris Agreement. Consequently, keeping warming to well-below 2 degrees will almost certainly require some form(s) of climate geoengineering, either through solar radiation/reflection management (SRM) and/or negative emissions technologies (NETs). Despite the potential of geoengineering to limit warming, and its inclusion in many IPCC low-emissions pathways, the efficacy and potential impacts on the ocean, and the ecosystem services that it provides remains poorly known.

Therefore it is urgent that we fully understand the degree to which geoengineering could help mitigate climate change, and what may be the associated potential positive and negative impacts at the global and regional scale. This knowledge is needed if we are to weigh up the risks between the deployment of climate scale geoengineering and the projected impacts of climate change.

In this talk, I will discuss the current proposed SRM, and oceanic NETs approaches, how they differ, the domain and time-scales over which they act, and the ongoing challenges associated with geoengineering research. I will conclude by highlighting the potential role SOLAS, and its associated research community could play in geoengineering research.

Susann Tegtmeier (GEOMAR Helmholtz Centre for Ocean Research Kiel) is working in the field of atmospheric chemistry-climate interactions. Her research interests include oceanic halogen and sulfur emissions and their impact on atmospheric processes. Currently she is investigating if anthropogenic very short-lived halocarbons can pose a new threat to the ozone layer.

Impact of large-scale macroalgae production on the ozone layer

S. Tegtmeier, Y. Jia, D. Keller, B. Quack, J. Wu

Large-scale industrial production of marine macroalgae is currently discussed as an opportunity to mitigate and adapt to climate change. Among other climate benefits, macroalgae aquaculture can remove CO_2 from the atmosphere. Some of this carbon may be buried in sediments or exported to the deep sea, leading to long-term sequestration. There have also been initiatives to create biochar and bioenergy from macroalgal biomass with the goal of sequestering carbon via technical means.
In addition to the currently discussed benefits and limitations of macroalgae aquaculture, substantial production and emissions of very-short lived halocarbons (VSLHs) such as bromoform can be expected. Since VSLH contribute significantly to current ozone depletion, higher emissions in the future might install a new and so-far unrecognized threat to the ozone layer. Here, we simulate the bromoform production rates for future scenarios of industrial macroalgae production and highlight the implications for atmospheric ozone chemistry.

Plenary session
Science and Society

Session chairs: P. Boyd and E. van Doorn

Keynote speaker: Kathryn Mengerink

Kathryn Mengerink is Executive Director at the Waitt Institute, a U.S. nonprofit that partners with governments to support sustainable ocean management. In particular, her work focuses on operationalizing science-based decision making through marine spatial planning, marine protected area development and fisheries management. In this position, she leads a team of ocean experts through a process of assessment, legal and policy development and management implementation.

From 2006 -2016 Kathryn founded and directed the Ocean Program at the Environmental Law Institute. Under her leadership, the Ocean Program launched law and policy projects related to regional ocean management, coastal zoning, fisheries management and enforcement, aquaculture, ocean and coastal restoration, offshore energy development, marine protection, Alaska Natives rights and ocean management, environmental DNA, deep seabed mining and more. From 2007-2016, she also served as a lecturer for Scripps Institution of Oceanography (SIO), where she taught ocean law and policy and served as an advisor to the Center for Marine Biodiversity and Conservation. She holds a B.S. in Zoology (Texas A&M University), Ph.D. in Marine Biology from SIO (UC San Diego) and a J.D. with a certificate of specialization in environmental law (UC Berkeley).

Marine spatial planning as a tool to advance science-based decision-making

Policymakers must make decisions about all aspects of society, economy and environment—decisions that sometimes align across these topics and other time conflict. In this framework, policymakers struggle with decisions related to ocean health, biodiversity, climate change, and how to achieve long-term sustainability. Clearly science is a core part of decision-making, but it is not the only issue under consideration. There are many competing interests. So how does science inform decision-making? This talk will explore the interface between science and society, focusing particularly on marine spatial planning (MSP). MSP is a science-based and participatory process that results in ocean plans that determine how the ocean will be used. MSP considers existing uses, as well as proposals for future uses such as deep seabed mining and geoengineering experiments. This talk with highlight existing work in South Pacific and the Caribbean where marine spatial planning efforts are underway.

Subrata Sarker is serving as an assistant professor of oceanography at the Shahjalal University of Science and Technology, Bangladesh. Here he is involved in teaching and research. His research interests are stochastic and nonlinear modelling of marine ecosystem, aquatic biodiversity, and coastal and marine resource management.

Taking the science to community: An approach of multi-stakeholders integration for sustainable Blue Economy development in Bangladesh

S. Sarker, M. M. Rahman, S. C. Basak and M. M. Islam

Utilization of marine resources towards achieving the sustainable economic development has got worldwide attention. This study aims to identify the Blue Economy (BE) potentials, challenges and develop a management framework for Bangladesh integrating multi-stakeholders. To collect data, consultations with different stakeholders were conducted. Secondary data were collected from the review of policy documents and articles. Marine resources, trades and commerce related to sea, and protections from the disasters are identified as the components of BE of Bangladesh. Conversely, climate-driven extreme events, pollutions, human interferences and limited law enforcement are identified as the challenges for the BE. To achieve sustainable BE in Bangladesh, a strategic planning is required which should focus on potential sectors related to BE, research and governance. The study argue that enhancing BE and achieving Sustainable Development Goals must go together to ensure that balance does not swing too far towards BE at the expense of environmental sustainability.

Plenary session
Theme 2: Air-sea interface and fluxes of mass and energy

Introduction by session chairs: P. Minnett and A. Rutgersson

Keynote speaker: Daiki Nomura

Daiki Nomura's research focuses on the carbon cycle within the ocean-atmosphere system, especially in the polar oceans. He has studied sea ice in the Southern Ocean, the Arctic Ocean, and the Sea of Okhotsk, in addition to conducing laboratory experiments on sea-ice freezing processes.

Gas exchange process in the ice covered oceans

Sea ice has until now rarely been considered in estimates of global biogeochemical cycles, especially gas exchanges, because of the assumption that, in ice-covered oceans, sea-ice acts as a barrier for atmosphere–ocean exchange. In order to understand the effects of sea-ice growth and decay processes on the biogeochemical cycles in the polar oceans, field observations in the Arctic, Antarctic, and Sea of Okhotsk as well as laboratory experiments were carried out. Observations over recent decades suggest that sea ice plays a significant role in global biogeochemical cycles, providing an active biogeochemical interface at the ocean-atmosphere boundary.

Kerstin Krall is a postdoctoral researcher at the Institute of Environmental Physics at Heidelberg University, Germany, and the head of the Aeolotron wind-wave tank laboratory. Her research interest is to untangle the physical mechanisms driving air-sea gas exchange. She has worked in wind-wave flumes throughout the world.

Air-sea gas transfer at hurricane wind speeds

K. Krall, S. Friman, B. Jähne, N. Takagaki, S. Komori, A. Smith, B. Haus, D. Sergeev, A. Kandaurov, Y. Troitskaya

The gas transfer velocities of many tracers (including He, SF6, and DMS) spanning a wide range of solubilities and Schmidt numbers were measured in the Kyoto High-Speed Wind-Wave-Tank and the Miami SUSTAIN wind-wave-tank at wind speeds up to 76 m/s. Gas transfer velocities were measured with fresh and sea water.

A new regime starting at a wind speed of around 35 m/s was found, in which the gas transfer velocity increases stronger than the friction velocity cubed. In fresh water (sea water), bubble-mediated transfer contributes at most one third (two thirds) to the total gas transfer velocity, even for the gases with the lowest solubilities. For moderately soluble gases with negligible bubble contribution, the same steep increase was found. Therefore, this strong increase is not caused by bubble-induced gas transfer. For gases with solubilities larger than one, bubble contribution was found to be not dominant.

Piotr Markuszewski is a scientist from the Institute of Oceanology PAS, Poland. He received his PhD in 2018. His research interests include *in situ* observations of marine aerosols: fluxes, vertical and horizontal composition and transport. He performs his work in the Baltic Sea and North Atlantic region on board R/V Oceania.

Sea spray fluxes: interconnections between ambient noise of bubbles and wave age

P. Markuszewski, T. Petelski, Z. Klusek, E. D. Nilsson, P. Makuch, J. Piskozub, I. Wróbel, V. Drozdowska, K. Dziembor

We present results of nine years of sea spray emission measurements on-board the R/V Oceania ship (Petelski, 2003; Markuszewski et al., 2017). Scientific cruises were conducted in the so-called European Arctic (Norwegian Sea, Greenland Sea, Spitsbergen's fiords) and in the southern Baltic Sea region.
Based on a long range of measurements we found a strong relationship between the sea spray flux and parameters such as a wave age and a wind history. A wave age is the parameter combining a wind speed with a wave phase velocity. Our findings shows the flux even one order of magnitude higher for young waves than for old ones. We combined the sea spray flux measurements with recordings of an ambient noise of bubbles. The acoustic system, with the bandwidth of the tract reduced to the frequency range from 80 Hz to 12.5 kHz, was oriented towards registration of wind/rain components of an underwater noise.

Rachel Stanley is an assistant professor in the chemistry department at Wellesley College. Her research focuses on using dissolves gases as tracers of air-sea gas exchange and upper-ocean productivity. She is the United States national representative to SOLAS and the chair of the OCB Ocean-Atmosphere Interaction Committee.

Relating air-sea gas fluxes to bubble distributions at high wind speeds: insights from the sustain wind-wave tank

R. H. R. Stanley, L. Kinjo, H. Alt, E. Kopp, D. Aldrett, A. W. Smith and B. K. Haus

Despite much progress, air-sea gas exchange parameterizations differ from each other widely at high wind speeds. In addition, the gas flux due to bubbles, which become increasingly important as wind speed increases, is not explicitly represented in many commonly-used air-sea gas exchange parameterizations. In order to improve understanding of gas exchange at high wind speeds, in July 2018 we measured the gas flux of five noble gases (He, Ne, Ar, Kr and Xe) and oxygen at wind speeds of 20 to 50 m s-1 in the SUSTAIN salt-water wind-wave tank. Concurrent shadowgraph measurements, which provide bubble size distributions, and polarimetric images of the water surface, which provide surface wave slopes and short wave spectra, enable the noble gas and oxygen fluxes to be linked to the physical environment. In this presentation, we will discuss results from this study, focusing on the linkages between bubble size distribution and air-sea gas fluxes.

Parallel discussion sessions

SOLAS Science & Society: achievements, present status & future possibilities

Co-conveners: E. van Doorn and C. Marandino

Room: 3

SOLAS has grown in recent years to include more disciplines as well as a diversity of stakeholders. It has recognised that greater efforts are needed to increase interaction between natural scientists and social scientists – especially in the light of anthropogenic influence on the ocean-atmosphere system. At the last Open Science Conference, we organised a discussion session to probe the interest in this topic. Multiple workshops have followed, focusing on bridging the gap between SOLAS science and the societal realm. SOLAS' current Science Plan contains a cross-cutting theme on science and society. Three main topics are currently being worked on under this umbrella: valuing carbon in the ocean, air-sea interaction and policy, and ship emissions. In this discussion session, we would like to outline how SOLAS scientists can participate in deepening and widening this range of topics.

Enhanced air-sea interaction in the emerging Marginal Ice Zone

Co-conveners: P. Hwang and T. Toyota

Room: 4

Multi-decadal observations have shown significant reductions in the extent and thickness of Arctic sea ice. Thinner sea ice promotes less snow accumulation on sea ice due to the loss of thicker multiyear ice and later freeze-up dates. Declining sea ice extent promotes more dynamic sea ice conditions in the emerging Marginal Ice Zone (MIZ). The expanding MIZ allows an intensification of the momentum and heat exchange between atmosphere and ocean, generates stronger ocean surface waves and enhances solar warming in the upper ocean. By contrast, intense sea ice melt in the MIZ forms a fresher surface layer and subdues the exchanges of momentum and heat between the ocean surface and the deep ocean. How do these contrasting factors affect air-sea interactions in the future Arctic Ocean?

The high-resolution measurement for the ocean-atmosphere interfacial layers

Co-conveners: C. Chen and E. Achterberg

Room: 2nd meeting venue

Ocean-atmosphere interactions (OAIs) form a dynamic and continuous natural material exchange process, and play an important role in the functioning of our earth system. Many of the mechanism of OAIs are not well understood. OAIs involve molecular activities, but the present in-situ measurements can only provide data at cm to m resolution, and cannot meet the need for OAI studies. It is necessary to improve the observation resolution for OAI layers. The temperature observation at the OAI layers with 0.6mm resolution (using the Buoyant Equipment for Skin Temperature-BEST) show that there is a strong OAI thermocline, which is just several centimeters thick on the top of ocean with up to 5k temperature difference. The strong temperature difference in the OAI thermocline will influence exchange processes and likely impact on microbial ecosystems and their functioning. This discussion session will provide a forum for scientists and technique experts to exchange ideas on promoting the high resolution measurement for the OAI layers, including new instrument development, high resolution measurement of physical, chemical and biological parameters, and data analysis

Poster sessions - Tuesday

These sessions features the posters from the following topics:

- 16:30 - 18:00
  - Theme 5: Ocean biogeochemical control on atmospheric chemistry
  - Geoengineering
- 17:30 - 19:00
  - Theme 1: Greenhouse gases and the oceans

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Conte, Ludivine	Modeling the oceanic cycle of isoprene at the global scale	504
Deschaseaux, Elisabeth	Dimethylsulfide (DMS) fluxes from permeable coral reef carbonate sediments	505
Du, Lin	Surface reactions of marine aerosols	506
Fujii, Masahiko	First long-term continuous monitoring and modeling of ocean acidification properties in the subarctic coast of Hokkaido, Japan	507
He, Xucheng	Nucleation and growth of iodic particles in the CERN CLOUD experiment	508
Hepach, Helmke	Linking marine phytoplankton and atmospheric chemistry – biogenic iodate reduction and potential impacts on tropospheric iodine	509
Jia, Yue	The impact of oceanic emissions of bromoform on the remote atmosphere	510
Jung, Jinyoung	Characteristics of sulfur-containing aerosols and organic carbon in the Amundsen Sea, Antarctica	511
Kameyama, Sohiko	Development of measurement system for marine and atmospheric isoprene and dimethyl sulfide using Curie-Point Pyrolyzer (CPP)	512
Kanaya, Yugo	Comprehensive over-ocean atmospheric ozone measurements on R/V Mirai from 67 °S to 75 °N during 2012 – 2017: missing sink linked to iodine chemistry in low latitudes	513
Kieber, David	Photochemical production and biological turnover of acrylate in a coral reef ecosystem in Mo'orea, French Polynesia	514

Latif, Mohd Talib	Surfactants in the sea surface microlayer, subsurface water and fine marine aerosols in coastal areas around Malaysian Peninsula	515
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Liu, Chun-Ying	Effects of *Ulva prolifera* blooms on the carbonate system in the southern Yellow Sea	517
Manville, George	High-resolution spatial variability length scales of surface ocean dimethylsulfide (DMS) concentrations	518
Masdeu Navarro, Marta	Day/night VOC's cycling in open ocean and coral reef ecosystems of the French Polynesia	519
Nishikawa, Hatsumi	High-resolution modeling of iron and phosphate transport in the subarctic North Pacific	520
Omori, Yuko	Quantification of microbial and photochemical production of oxygenated volatile organic compounds in coastal seawater	521
Ooki, Atsushi	Isoprene productions in seawater of the Funka Bay, Hokkaido, Japan	522
Schneider, Stephanie	Formation of secondary organic aerosol from the oxidation of *T. pseudonana* cultures	523
Sellegri, Karine	Biological influences on atmospheric new particle formation during a mesocosm experiment in New Zealand coastal waters	524
Simó, Rafel	Sources and sinks of DMS, isoprene and halomethanes in a coral reef ecosystem of the French Polynesia	525
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Tjiputra, Jerry	Amplification of future warming through changes in marine DMS emissions	528
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Yao, Xiaohong	Mapping concentrations of ammonia in the marine atmosphere along the long coastline in China	532

Yu, Juan	Effects of nitrate and salinity on DMSP production and antioxidant systems of *Emiliania huxleyi* (Prymnesiophyceae)	533
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Zhang, Guiling	Distribution of concentration and stable isotopic composition of N_2O in the shelf and slope of the northern South China Sea: Implications for production and emission	114
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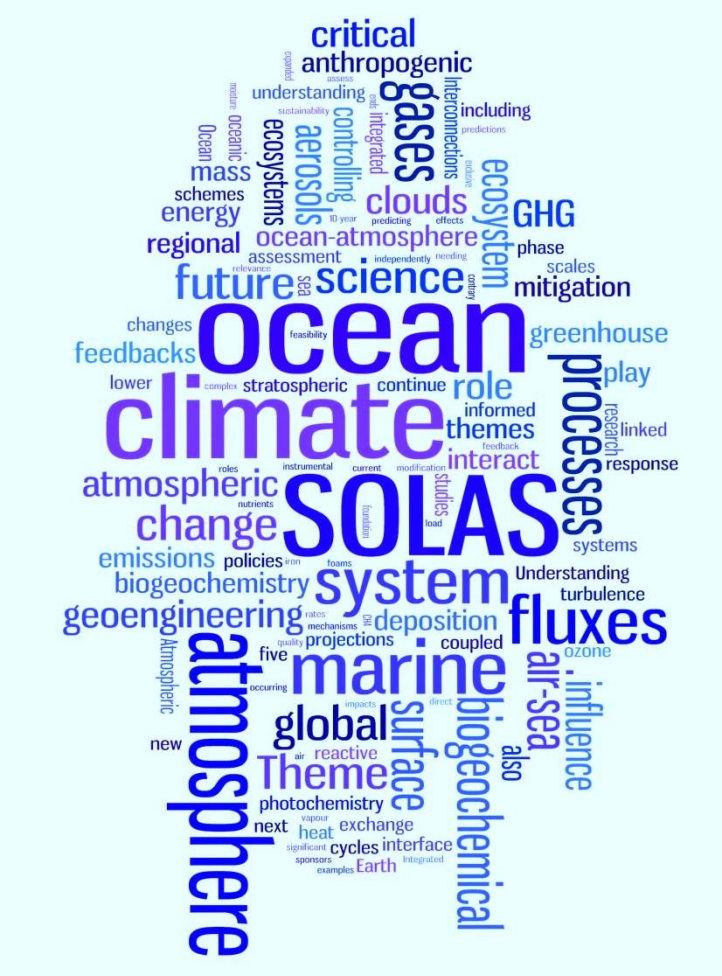

Times	Wednesday, 24 April
08:30	**Theme 1: Greenhouse gases and the oceans** Introduction by sessions chairs: **A. Koertzinger** and **G. Zhang**
08:40	**S. Lauvset**: The Carbon Cycle: The role of oceans and humans
09:10	**O. Bui**: Dissolved methane distribution and its controlling factors in the Arctic Ocean in 2016 summer
09:30	**Y. Eddebbar**: Volcanic modulation of ocean ventilation: implications for air-sea carbon and oxygen exchange
09:50	**L. Keppler**: Regional wind variability modulates the Southern Ocean carbon sink
10:10	**Group picture**
10:20	Coffee break
10:50	**Theme 5: Ocean biogeochemical control on atmospheric chemistry** Introduction by session chairs: **J. Ovadnevaite** and **Y. Miyazaki**
11:00	**A. Mahajan**: Oceanic regulation of atmospheric chemistry: past, present and future
11:30	**S. Smith**: Modelling of ammonia/um across the air-sea interface in the Atlantic sector of the Southern Ocean
11:50	**K. Hamasaki**: Microbial community dynamics in sea surface microlayer and sea spray aerosols observed in coastal inlets of Japan
12:10	**J. Maas**: Simulating halocarbon concentration in ocean and atmosphere from industrial water treatment
12:30	Lunch
14:30	**Discussion sessions** M. Uematsu, A. Zivian, K. Slavik: **WHAT IS Ocean KAN?** A. Ito, W. Landing, D. Hamilton: **Atmospheric deposition of iron, ocean biogeochemistry and marine emission of biological aerosols** P. Suntharalingam, G. Zhang, A. Koertzinger: **Oceanic greenhouse gases: The present situation and future initiatives**
16:00	Coffee break (during poster session)
16:30 -18:00	**Poster session** **Theme 2:** Air-sea interface and fluxes of mass and energy
19:30	**Conference banquet**

Plenary session
Theme 1: Greenhouse gases and the oceans

Session chairs: A. Koertzinger and G. Zhang

Keynote speaker: Siv Kari Lauvset

Siv Kari Lauvset is interested in increasing the overall understanding we have of the carbon cycle in the ocean and how human perturbations to the atmosphere affects the ocean. She focuses especially on carbon cycle changes in recent decades, but also how this may change in a future with or without emission mitigation efforts. While she focuses mostly on observational studies she finds Earth System models a useful and valuable tool. It is very important that we have good observational data and she is engaged in global data syntheses and quality control of large datasets such as GLODAP and SOCAT. She is currently coordinating the Norwegian node of the European distributed research infrastructure ICOS, and on the steering committee for the Norwegian BGC-Argo network. She started her career by focusing on the waters around Norway, but in recent years has worked more and more with global issues.

The Carbon Cycle: The role of oceans and humans

One of the fundamental unanswered questions in climate science is: where does the carbon go? Humans are perturbing the natural carbon cycle by burning fossil fuels and we need to be able to quantify the movement of anthropogenic carbon in nature in order to verify the self-reporting of emission reductions pledged under the Paris Agreement. Quantifying the magnitude of these carbon fluxes is non-trivial, and identifying where carbon goes is further complicated by the large internal variability in Earth's carbon cycle. The ocean currently remove ~25 % of anthropogenic CO_2 emissions, and the ocean carbon sink has considerably less variability than the terrestrial carbon sink. Nevertheless, recent research has shown that fully accounting for the interannual and multidecadal variations in the ocean carbon sink significantly reduce the estimated cumulative ocean uptake. The ocean carbon sink is a key element in understanding future climate change because the retention time of carbon in the ocean is vastly longer than that in the terrestrial sink, making the ocean the only long-term removal option for anthropogenic carbon. To properly quantify this removal large amounts of data with high spatial and temporal coverage is necessary. This is beginning to become available through networks such as ICOS, SOCONET, and BGC-Argo and already a transformation in our understanding of both the magnitude and dynamics of the ocean carbon sink is taking place. This presentation will focus on the role of oceans and humans in Earth's carbon cycle, including how these roles might influence the future ocean and the future climate.

Bùi Thị Ngọc Oanh studied in Earth Science and received her PhD from Hokkaido University (Japan) in 2018. After graduation, Oanh started lecturer position in the field of Oceanology in University of Science (VNU-HCMC, Vietnam). Her research interests are sea-air interaction of methane in the polar regions, biogeochemical cycles.

Dissolved methane distribution and its controlling factors in the Artic Ocean in 2016 summer

O. T. N. Bui, S. Kameyama, U. Tsunogai, J. Jung, E. J. Yang and S.-H. Kang

Methane (CH_4) is a potent greenhouse gas and plays significant roles in both tropospheric and stratospheric chemistry. In the Arctic Ocean, a massive CH_4 hydrates from marine sediments release and/or biogenic CH_4 producing in anaerobic environment and then diffusion into water column was examined. Due to global warming sea ice extent is decreasing, it directly affects sea-air exchange of CH_4. During the cruise of IBRV ARAON (ARAON-07B) on August 2016, we investigated CH_4 distribution in the Arctic Ocean under two conditions: in the shelf water and sea ice covered region in order to evaluate the influence of sea ice coverage on CH_4 emission. High dissolved CH_4 concentration was found at the Chukchi shelf slope and was detected at surface seawater where was consistent with high sea ice concentration. This investigation allows us to gain some insights into the role of the sea ice on CH_4 concentration and the flux.

Yassir Eddebbar is a postdoctoral scholar at the Scripps Institution of Oceanography. He received his PhD in Oceanography working with Dr. Ralph Keeling on understanding the natural variability of the oceanic oxygen cycle using models and observations. Currently, he is focused on understanding how mesoscale phenomena impact ocean biogeochemical dynamics.

Volcanic modulation of ocean ventilation: implications for air-sea carbon and oxygen exchange

Y. Eddebbar and K. Rodgers

Volcanic eruptions have a major influence on global and regional climate. Their impacts on the oceanic oxygen (O_2) and carbon cycle however remain poorly understood. We evaluate here Large Ensemble CESM and GFDL model simulations of recent eruptions including Agung, El Chichon, and Pinatubo on ocean physics and biogeochemistry. Models indicate a substantial volcanic modulation of ocean ventilation at higher latitudes and ENSO phase in the tropical Pacific driving significant changes in air-sea O_2 and carbon exchange. The high latitude ventilation response is associated with significant upper ocean heat loss, deepening of mixed layer, and enhanced mode and intermediate water mass formation, driving significant changes in air-sea O_2 and carbon exchanges. This acts to significantly halt the advance of ocean deoxygenation during the 20th century and drives substantial interannual-to-decadal variability in the oceanic carbon sink, and must thus be taken into account in attribution studies.

Lydia Keppler did a MSc in climate science at the University of the South Pacific in Fiji. Currently Lydia is doing her PhD at the Max-Planck-Institute for Meteorology in Hamburg, Germany. Combining various observation-based estimates, her research focus is on the carbon uptake in the Southern Ocean and the physical drivers behind its variability.

Regional wind variability modulates the Southern Ocean carbon sink

L. Keppler and P. Landschützer

The Southern Ocean (SO) accounts for ~50 % of the annual oceanic carbon uptake, substantially mitigating the effect of anthropogenic carbon dioxide (CO_2) emissions. The intensity of this globally important carbon sink varies substantially, but the drivers of this variability are still debated. Analyzing observation-based air-sea CO_2 fluxes, we find that the overall carbon sink south of 35 °S has weakened since ~2011, reversing the trend of the reinvigoration period of the 2000s. Although there is a strong regional correspondence between the SO carbon uptake and the Southern Annular Mode (SAM) over the past 35 years, the overall effect of the SAM on the SO carbon sink variability is approximately zero, due to the opposing effects of enhanced outgassing in upwelling regions and enhanced uptake elsewhere. Instead, regional shifts in sea level pressure and surface wind patterns substantially contribute to the inter-annual to decadal variability of the SO carbon sink.

Plenary session
Theme 5: Ocean biogeochemical control on atmospheric chemistry

Introduction by session chairs: J. Ovadnevaite and Y. Miyazaki

Keynote speaker: Anoop Mahajan

Anoop S. Mahajan received his PhD in atmospheric chemistry at the University of Leeds, UK and after working as a postdoctoral researcher at the Department of Atmospheric Chemistry and Climate, CSIC, Spain, he has been working at the Indian Institute of Tropical Meteorology since 2012. His research group focuses on the measurement and modelling of trace gases in the atmosphere. Most of his work has been on the emissions of halogens and volatile organic compounds from the ocean surface and the impact they have on the atmosphere in terms of changing the oxidising capacity and affecting the radiation budget through aerosol formation. He has co-authored more than 50 papers on halogen, dimethyl suphide and volatile organic carbon chemistry.

Oceanic regulation of atmospheric chemistry: past, present and future

It has been more than three decades since the CLAW hypothesis, which suggested that ocean biogeochemistry could directly affect atmospheric chemistry and hence climate, was proposed. In this intervening period, significant research has investigated the links between different biogeochemical processes and their effect on the lower and upper atmosphere. We now know that the hypothesized processes are more complex than first proposed but it has also become clear that ocean biogeochemistry does significantly affect atmospheric chemistry. This happens through a range of processes such as changing the aerosol concentrations and hence cloud properties, as in the case of dimethyl sulfide or non-methane volatile organic compounds (NMVOCs); affecting oxidation chemistry and the ozone and hydroxyl radical budget, as in the case of halogens and NMVOCs such as acetone and isoprene; or impacting reactive chemistry in the troposphere and stratosphere, as in the case of halocarbons. Indeed, these processes can also have a feedback with changes in atmospheric concentrations affecting oceanic biogeochemistry and emissions. Proxies from ice cores have thrown new light on the extent of changes that have occurred in the past and the trends that can be expected in the future. New observations indicate that the impacts of ocean biogeochemistry on the atmosphere are not only important on climatic scales but that some of these processes are important on short timescales and need to be included in air quality models. This talk summarizes the major achievements, current state-of-the-art and new questions that need attention on this front, with a focus on oceanic emissions and its impact on atmospheric trace gas chemistry.

Shantelle Smith is an oceanography student at the University of Cape Town. Her thesis uses an observational and modeling approach to study the exchange of ammonia/um across the air-sea interface in the Southern Ocean.

Modelling of ammonia/um across the air-sea interface in the Atlantic sector of the Southern Ocean

S. Smith, M. Vichi, and K. E. Altieri

Investigating the anthropogenic effect on the nitrogen cycle requires distinguishing between natural and anthropogenic sources. However, the largest natural source, the surface ocean, has been difficult to study due to the dominance of continental sources and inaccessibility of remote regions. We investigated ammonia/um cycling between the surface ocean and lower atmosphere at 15 stations across the Southern Ocean during 2017. We used the Biogeochemical Flux Model, initialised with cruise observations, to calculate the concentrations and isotopic compositions of atmospheric ammonia gas and ammonium aerosols. The model was forced with environmental conditions from atmospheric and oceanic reanalyses, extracted at selected stations. Predicted concentrations and isotopic compositions varied between Southern Ocean Zones. The main drivers of atmospheric ammonia/um variability are seawater ammonium concentrations and isotopic compositions, sea surface temperatures, and wind speeds. The relationship between environmental conditions and atmospheric ammonia/um suggests a regionally varying isotopic signature of the natural marine ammonia source.

Koji Hamasaki is professor of the laboratory of marine microbiology. He has been interested in microbial diversity and functions in surface ocean ecosystems and their roles in biogeochemical cycles. Many work of his group is based on sample and data collections during sea-going oceanographic research.

Microbial community dynamics in sea surface microlayer and sea spray aerosols observed in coastal inlets of Japan

K. Hamasaki, S. K. Wong, Y. Iwamoto, A. Iwata, M. Furuya, A. Matsuki and M. Uematsu

Organic matter and microbes in the sea surface microlayer (SML) are sources of bioaerosols in the ocean and determines physicochemical characteristics of sea spray aerosols (SSA) such as cloud condensation nuclei (CCN) activity and ice nuclei (IN) activity. They are important to understand interacting mechanisms between marine biota and physicochemical atmospheric processes. We investigated the prokaryotic diversity and functions in the SML and their roles in SSA as a source of CCN and IN activities. Community structure analyses of bacterial and archaeal 16S rRNA gene sequencing revealed large differences between the SML and UW. The difference was also found in functional potential of microbial community genomes analyzed by an environmental gene microarray, GeoChip 5.0M. Furthermore, field campaigns have been done to study the relationship between microbial community diversity in the SML and CCN/IN activity of the SSA.

Josefine Maas is a PhD candidate at GEOMAR in Kiel, Germany. Her research focuses on the increase of very short-lived halocarbons from oxidative water treatment in industry and shipping. With high-resolution models she simulates anthropogenic species in the ocean and their emission to the atmosphere. Her aim is to estimate anthropogenic halocarbon concentration against natural sources.

Simulating halocarbon concentrations in ocean and atmosphere from industrial water treatment

J. Maas, Y. Jia, A. Biastoch, B. Quack, S. Tegtmeier

Large volumes of seawater are used in different industrial sectors such as power plants and ships. Chemical disinfection of this seawater prevents bio-fouling, but also produces halogenated disinfection by-products (DBPs). One major DBP is bromoform whose anthropogenic input to the environment is highly uncertain. Halocarbons such as bromoform impact the oxidation of trace gases and ozone chemistry in the atmosphere.

We quantify the contribution of DBPs from industrial waste water to oceanic halocarbon concentrations and their impact on atmospheric chemistry. Based on industrial water discharge and DBP estimates, we simulate oceanic pathways of halocarbons along NEMO-ORCA12 driven Lagrangian trajectories. Anthropogenic halocarbon concentration are strongly enhanced along the coasts in Southeast Asia, but also allow for transport into the open ocean. We highlight bromoform showing that its anthropogenic sources can explain much of observed shelf water concentrations. We show how anthropogenic marine bromine impacts tropospheric and stratospheric ozone chemistry compared to natural background emissions.

Parallel discussion sessions

WHAT IS Ocean KAN?

Co-conveners: M. Uematsu, A. Zivian, and K. Slavik

Room: 4

The importance of protecting the ocean is recognized in Sustainable Development Goal (SDG) 14, "Conserve and sustainably use the oceans, seas and marine resources (LIFE BELOW WATER)", proclaimed by the United Nations. The goal recognizes several threats to the ocean including climate change, acidification, deoxygenation, and pollution, which are closely related to SOLAS research topics. In addition, SOLAS, as a Global Research Project under Future Earth, will play a critical role in the upcoming United Nations Decade of Ocean Science for Sustainable Development (2021–2030). The Ocean Knowledge-Action Network (KAN), co-sponsored by Future Earth, WCRP, SCOR, and IOC, is a network of networks. Its mission is to bridge disciplines and draw experts together to seek action-focused solutions for challenges that require a multi-sectoral approach, international cooperation and transdisciplinary research. In that role, it can work with SOLAS to contribute directly to global sustainability efforts, in particular the SDGs, the UNFCCC, and the Decade of Ocean Science. This session will explore and outline ways that SOLAS and the Ocean KAN can work together to amplify SOLAS's work and to connect it to the broader ocean, climate, and sustainable development communities to improve the knowledge, governance, and action needed to ensure healthy, functional oceans.

Atmospheric deposition of iron, ocean biogeochemistry and marine emission of biological aerosols

Co-conveners: A. Ito, W. Landing, and D. Hamilton

Room: 2nd meeting venue

Atmospheric deposition of aerosols to the ocean has been suggested to modulate marine primary productivity. Marine organic material has been shown to be an important source of ice-nucleating particles (INP) in high-latitude environments, and hence impacts the atmospheric energy balance. Significant progress has been made in our understanding of atmospheric inputs of labile iron (Fe) from natural and anthropogenic sources to the surface oceans. However, there are still large uncertainties regarding the relative importance of different sources of aerosols, the effects of atmospheric aerosol deposition on bioavailable Fe concentrations in the ocean and on the marine organic material and its role as INP. The discussion in this session focuses on problems and challenges in laboratory experiments and field measurements to improve the representations of trace metal biogeochemistry in atmosphere and ocean models, in particular, the two-way movement of aerosol material across the boundary between the atmosphere and ocean.

Oceanic greenhouse gases: The present situation and future initiatives

Co-conveners: P. Suntharalingam, G. Zhang, and A. Koertzinger

Room: 3

Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the most significant long lived greenhouse gases (GHGs) after water vapour. Physical and biogeochemical processes in the surface ocean play an important role in controlling the fluxes of these gases between the ocean and atmosphere. This session aims to encourage discussions about pertinent and unresolved issues relating to oceanic GHGs. For example, what are the sensitivities of the governing source and sink processes to climate and environmental change? How will GHG cycling and air-sea fluxes be influenced by factors such as increasing seawater temperatures, decreasing oxygen concentrations, ocean acidification and increasing nutrient loading? How reliably can we predict future oceanic fluxes of GHGs in in a changing earth system? We will also highlight the work of ongoing GHG related programs and initiatives such as the Global Carbon Project's GHG Budget syntheses, and the newly formed Intergovernmental Oceanographic Commission Integrated Ocean Carbon Research Working Group. This session aims to provide an overview of ongoing GHG-related activities, to highlight directions for future relevant research, and to encourage the development of new initiatives and collaborations. Participants are encouraged to contribute to this session by providing the organisers with short summaries (e.g., 1 slide) of their ongoing and planned GHG research activities.

Poster session - Wednesday

These session features the posters from the following topic:

- 16:30 - 18:00
  - Theme 2: Air-sea interface and fluxes of mass and energy

Author	Title	No.
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Barbot, Simon	Internal tidal waves impact over the surface elevation and their seasonal variability	201
Dai, Hanjing	Surface oil film effects on hydrodynamic properties of short wind-generated waves	202
Du, Ling	Costal vulnerability connected with sea level rise and storm surge in the Northwest Pacific Ocean	203
Esters, Leonie	Evaluation of a turbulence-based description of the air-water gas transfer velocity	204
Friman, Sonja	Investigations of SO_2 transfer across the air-water interface	205
Giostra, Umberto	Influence of sub-mesoscale motions on dispersion in marine boundary layer	206
Guo, Tianfeng	Seasonal deposition to and gas exchange of PBDEs at the air-water interface over a strongly human influenced large river estuary: role of atmospheric transport and riverine runoff	207
Horowitz, Hannah	Blowing snow sea salt aerosol emissions and radiative effects in present and future climates	208
Kameyama, Kohei	Typhoon-induced vertical mixing measured by the Kuroshio Extension Observatory buoy	209
Kang, Sok Kuh	Air-sea interaction around the warm and cold eddies in low wind conditions within the eddy-rich zone of the Northwestern Pacific	210
Kieber, David	Oceanic efflux of ancient marine dissolved organic carbon in primary marine aerosol	211
Kinjo, Lumi	Measuring noble gas fluxes at high wind speeds in the sustain wind-wave tank	212
Komatsu, Kosei	Measuring the air-sea interface using a bird-attached logger	213
Li, Bofeng	Quasi-real-time and high-resolution spatiotemporal distribution of anthropogenic CO_2 in the subarctic North Pacific Ocean	214
Li, Yangchun	The relationship between the NAO and North Atlantic CO_2 flux on different timescales	215
Marandino, Christa	Baltic Sea Gas Exchange Experiment (Baltic GasEx)	216

Times	Thurdsday, 25 April
08:50	**Integrated topics II** Introduction by session chairs: **K. Altieri** and **S. Kameyama**
09:00	**S. Landwehr**: Investigation of sea spray source functions with aerosol size spectra measurements from the Antarctic Circumnavigation Experiment
09:20	**L. Gutierrez-Loza**: Air-sea CH_4 fluxes from eddy covariance measurements in the Baltic Sea
09:40	**P. Wongpan**: Using under-ice spectra to determine land-fast ice algal biomass in Lake Saroma, Japan
10:00	**M. Frey**: Sea salt aerosol from blowing snow above sea ice - a new particle source
10:20	Coffee break
10:50	**Theme 3: Atmospheric deposition and ocean biogeochemistry** Introduction by session chairs: **L. Gallardo** and **P. Suntharalingam**
11:00	**Y. Chen**: Atmospheric deposition of nitrogen and trace metals affects marine phytoplankton and their feedback to aerosols
11:30	**W. Landing**: Atmospheric deposition to the oceans controls biological productivity
11:50	**R. Mukherjee**: Limitation of iron on N_2 fixation in the Arabian Sea
12:10	**C. White**: Impact of atmospheric nitrogen deposition to nitrogen limited marine surface waters in the temperate and subtropical North Atlantic Ocean
12:30	**Conference closing**

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Sebastian Landwehr studies air-sea interaction processes. Whether he is investigating CO_2 piston-velocity via ship-borne Eddy Covariance or harmonising multidisciplinary data sets of the ACE Expedition in the Antarctic, he is convinced that advances in theory require close observation of measurement data. He currently works at Paul Scherrer Institute, Switzerland.

Investigation of sea spray source functions with aerosol size spectra measurements from the Antarctic Circumnavigation Experiment

S. Landwehr, R. Modini, M. Volpi, F. P. Cruz, A. Toffoli, I. Thurnherr, F. Aemisegger, H. Wernli and J. Schmale

Sea spray aerosols affect the Earth's radiation balance. They directly scatter solar radiation, and act as cloud condensation nuclei, thereby modifying the reflectivity and lifetime of clouds. This may be especially important over remote, heavily undersampled, ocean regions, which are far from continental and anthropogenic sources of particles. The scarcity of data limits our ability to constrain sea spray aerosol flux parameterisations and to accurately model the natural aerosol burden of the atmosphere. Here we present aerosol size spectra measurements from the Antarctic Circumnavigation Expedition (ACE) December 2016 to March 2017, which covered a wide range of regions (some previously unsampled) and weather conditions. We isolate the sea spray component using a lognormal-mode-fitting procedure and relate it to in situ measurements of wind speed and sea state. Using air parcel backward trajectories we also evaluate commonly used sea spray source function parameterisations against the measured number size distributions.

Lucia Gutierrez Loza did her master studies in physical oceanography in México on air-sea interaction processes. Currently, she does her PhD at the Uppsala University on air-sea exchange processes with the focus on the direct flux estimation of energy, water vapor, and greenhouse gases in the Baltic Sea.

Air-sea CH_4 fluxes from eddy covariance measurements in the Baltic Sea

L. Gutierrez Loza, A. Rutgersson, M. Wallin, E. Sahlée and E. Nilsson

The potential of micrometeorological methods has been poorly exploited for the estimation of CH_4 fluxes (FCH_4) in marine environments. The use of these techniques (e.g. eddy covariance (EC)) can be useful for constraining the regional and global estimates of oceanic CH_4 contributions to the atmosphere, as well as, to improve our understanding about air-sea exchange processes.
We investigate the viability and quality of EC measurements to estimate FCH_4 from a land-based station in the Baltic Sea. We use one year of continuous measurements to analyze the annual cycle of CH_4 concentrations and FCH_4. We observe positive FCH_4 throughout the year. Both the air-water concentration gradient and the physical conditions (i.e. wind speed) are crucial parameters controlling the flux. The results are in well agreement with other CH_4 measurements in the Baltic Sea (MEMENTO database) suggesting that the EC technique is a useful tool for improving the understanding of air-sea FCH_4.

Pat Wongpan was born in Thailand. He obtained his PhD from University of Otago, New Zealand, and was a David Crighton fellow at University of Cambridge. He is a JSPS Postdoctoral fellow at ILTS, Hokkaido, Japan. He is interested in sea ice-ice shelf-ocean interaction and its consequences on ecosystem.

Using under-ice spectra to determine land-fast ice algal biomass in Lake Saroma, Japan

P. Wongpan, T. Toyota, T. Tanikawa, D. Nomura, T. Hirawake, A. Ooki, and S. Aoki

Land-fast ice is a key component of coastal ecosystems in polar regions, providing a habitat for ice algal communities. To date the estimation of algal biomass by satellites has only applied to the unfrozen ocean. This study examines the relationships between the normalized difference indices (NDI) calculated from under-ice hyperspectral measurements and ice algal biomass for land-fast ice in Lake Saroma, Japan. We analyze physical properties of snow and ice supporting our paired in situ optical and biological measurements along transect lines. Our new observation-based algorithms can be applied to non-invasively estimate land-fast ice algal biomass which will fill the gap of monitoring algal biomass under the ice cover during winter and winter-spring transition. Together with the Ocean Color, our algorithms will help improve the understanding of the temporal and spatial variability of algal biomass using moorings and underwater vehicles and its impact on the local aquaculture of Japanese scallops.

Markus M. Frey is an atmospheric and ice chemist at the British Antarctic Survey and co-chair of the IGAC activity CATCH (Cryosphere & Atmospheric Chemistry). His research is about physical and chemical air-snow exchange to understand better polar air chemistry and the chemical record preserved in ice cores.

Sea salt aerosol from blowing snow above sea ice – a new particle source

M. M. Frey, S. J. Norris, I. M. Brooks, K. Nishimura, P. S. Anderson, S. P. Palm, A. E. Jones, X. Yang, E. W. Wolff

Atmospheric particles in the polar regions consist mostly of sea salt aerosol (SSA). SSA plays an important role in the regional radiation balance and therefore climate, either directly or indirectly via clouds. SSA irradiated by sunlight also releases halogen radicals, which control concentrations of ozone, a pollutant and greenhouse gas. Recent observations above sea ice confirm that blowing salty snow, which undergoes sublimation, is a significant but so far neglected source of SSA especially during winter and spring, rivalling that of the open ocean. Based on observations from two polar sea ice cruises, one in the Weddell Sea / Antarctica and the other in the Arctic Ocean, we critically evaluate source mechanism and existing model parameterisations. In particular, we discuss the impact of chemical and physical sea ice properties on the magnitude of the SSA source as well as implications for model predictions of regional climate change and air quality.

Plenary session
Theme 3: Atmospheric deposition and ocean biogeochemistry

Introduction by session chairs: L. Gallardo and P. Suntharalingam

Keynote speaker: Ying Chen

Ying Chen's research focuses on marine aerosols and its biogeochemical and climatic effects. Specifically, her group does long-term or cruise observations on physiochemical and optical properties of aerosols as well as abundance and community structure of airborne microbes over the marginal seas and the western North Pacific. They do source apportionment and study the effects of anthropogenic emissions and Asian dust on chemical composition, microbial structure and light extinction ability of marine aerosols. The contribution of marine biogenic sources to the aerosol components and microbes is also of interest. Her working group estimates the atmospheric deposition fluxes of nutrients and trace elements to the ocean using the dry deposition velocities corrected by the size distribution of each component. The effects of aerosol deposition on phytoplankton growth and community structure is explored through microcosm experiments and analysis of observational and remote sensing data.

Atmospheric deposition of nitrogen and trace metals affects marine phytoplankton and their feedback to aerosols

Atmospheric deposition is an important source of nutrients and trace metals to the surface ocean, which may affect the efficiency of biological carbon pump and the emission of marine biogenic gases and aerosols through changing the phytoplankton biomass and community structure. Marine aerosols influenced by dust storms and polluting air masses have very different chemical composition, size distribution, elemental solubility, etc., and thereby their impacts on phytoplankton growth are also distinct. Atmospheric deposition contains much more nitrogen relative to phosphorus, and increased anthropogenic emissions exacerbate this ratio. Affluent nitrogen may enhance the primary productivity in oligotrophic oceans, but atmospheric deposition may not be able to promote the phytoplankton growth in eutrophic coastal areas if phosphorus is in shortage. Iron in dust deposition can stimulate phytoplankton growth in high nutrient low chlorophyll oceans, whilst high copper deposition may show a toxic effect and induce the change of phytoplankton community structure. Its toxic threshold may vary under different nutrient conditions and trace metal concentrations such as iron and zinc. Nitrogen, iron and copper are probably the most important elements in the atmospheric deposition affecting marine phytoplankton. The change of phytoplankton biomass and community structure in turn can influence the composition and characters of marine aerosols by contributing to MSA, amines, ammonium, etc.

William Landing is a professor in the Department of Earth, Ocean, and Atmospheric Science at Florida State University. His research interests include the biogeochemistry of trace elements in marine and fresh waters, the chemistry and deposition of atmospheric aerosols, and mercury cycling in the atmospheric and in aquatic environments.

Atmospheric deposition to the oceans controls biological productivity

W. M. Landing

The atmospheric flux of trace elements and isotopes (TEIs) to the oceans is extremely important in marine biogeochemical cycles, especially for bioactive trace elements such as Mn, Fe, Co, Ni, Cu, Zn, and Cd. However, converting aerosol TEI concentrations into atmospheric deposition fluxes is problematic. We use an aerosol tracer, berylium-7, whose atmospheric deposition flux can be calculated from its upper ocean inventory. By measuring upper ocean inventories and aerosol concentrations of Be-7, we derive "bulk deposition" velocities that account for both wet and dry deposition. These can then be applied to any other aerosol species to calculate its flux, such as the soluble fraction of aerosol TEIs. This is especially useful for estimating the impact of atmospheric deposition of bioactive TEIs on biological productivity. We will present results from field campaigns in the Sargasso Sea (Bermuda) and the Arctic Ocean to test this approach.

Rupa Mukherjee is a early career scientist working as an assistant professor at the Rajendra College, Bihar, India. Rupa completed her M.Sc from IIT Roorkee and her PhD work at the Physical Research Laboratory, India with major research focus on N and C biogeochemistry of aquatic ecosystems in India.

Limitation of iron on N_2 fixation in the Arabian Sea

R. Mukherjee, A. Singh, A. Patel, P. K. Kumar, N. Rastogi, S. Kumar

The Arabian Sea is one of the major upwelling driven eutrophic regions of the world oceans. However, there are reports that high nutrient low chlorophyll (HNLC) condition prevails in some part of the Arabian Sea due to iron (Fe) limitation. Dust being the major supplier of Fe in the ocean has potential to enhance N_2 fixation rates. Here, we conducted thirteen dust (~ 1.45 nM dissolved Fe) addition onboard deck incubations to understand the role of Fe on N_2 fixation rates in the central and eastern Arabian Sea during spring 2017. Average surface N_2 fixation rates for dust and controlled experiments were ~ 0.14 ± 0.26 and 0.13 ± 0.25 nmol N L^{-1} h^{-1}, respectively, whereas, average column integrated rates for the same were ~ 114.63 ± 85.15 and 127.45 ± 157.15 µmol N d^{-1} m^{-2}, respectively. These findings suggest that Fe is not a limiting nutrient in this region.

Caroline White is a third year PhD candidate from the University of Plymouth. Her research focuses on the cycling of reactive nitrogen aerosols in the atmosphere and, has conducted this research at Penlee Point Atmospheric Observatory in the United Kingdom and Tudor Hill Atmospheric Observatory in Bermuda.

Impact of atmospheric nitrogen deposition to nitrogen limited marine surface waters in the temperate and subtropical North Atlantic Ocean

C. White, S. Ussher, T. Bell, M. Fitzsimons, A. Peters, S. Atkinson, M. Yang

Nitrogen cycling is a vital process in global biogeochemistry but recent anthropogenic activities have altered the global nitrogen cycle, by creating new and enhanced sources of fixed reactive nitrogen. Atmospheric reactive nitrogen is transported long distances from emission sources, spanning entire continents and ocean basins, which results in nutrient limited ecosystems receiving significant pulses of reactive nitrogen.

Seasonal observations of atmospheric nitrogen species in soluble aerosols and rainwater have been compared from two marine sites (2017-2018). Tudor Hill Atmospheric Observatory, (Bermuda) is uniquely situated in the remote North Atlantic Ocean, whereas Penlee Point Atmospheric Observatory, (UK) monitors marine and continental urban air masses. Both sites are systematically relevant to two well-established marine time series, Bermuda Atlantic Time series and Western Channel Observatory, respectively. Using atmospheric and sea surface measurements, important estimates of nitrogen deposition to stratified nitrogen limited waters have shown deposition can temporarily relieve nitrogen limitation and affect primary production.

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