surface ocean solas lower atmosphere study

solas event report

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Online Workshop on Surface Ocean and Lower Atmosphere Study in Southeast Asia

23 August 2022
Online

The SOLAS Online Workshop on Surface Ocean and Lower Atmosphere Study in Southeast Asia was co-organised by Centre of IDEA and Ecosystem Marine Research Centre (EKOMAR), Universiti Kebangsaan Malaysia, Institute of Ocean and Earth Sciences (IOES), Universiti Malaya and Sun Yat-sen University. The workshop was held online on 23 August 2022.

Southeast Asia comprises eleven countries ranging from eastern India to China and is often separated into "mainland" and "island" zones. Myanmar, Thailand, Laos, Cambodia, and Vietnam comprise an extension of the Asian continent. Southeast Asia's island or marine region consists of Malaysia, Singapore, Indonesia and the Philippines and Brunei (Andaya 2015). The Southeast Asia region stretches 6,500 km east to west and 3,500 km north to south and borders the Gulf of Thailand, the Andaman Sea, the South China Sea, and the Pacific Ocean. Indonesia and the Philippines have nearly 24,000 islands, and 70% of Southeast Asia's population lives in coastal areas (Todd *et al.* 2010).

Due to the uniqueness of Southeast Asia's biodiversity, especially related to the coral reef,

In this report

Attendees research profiles

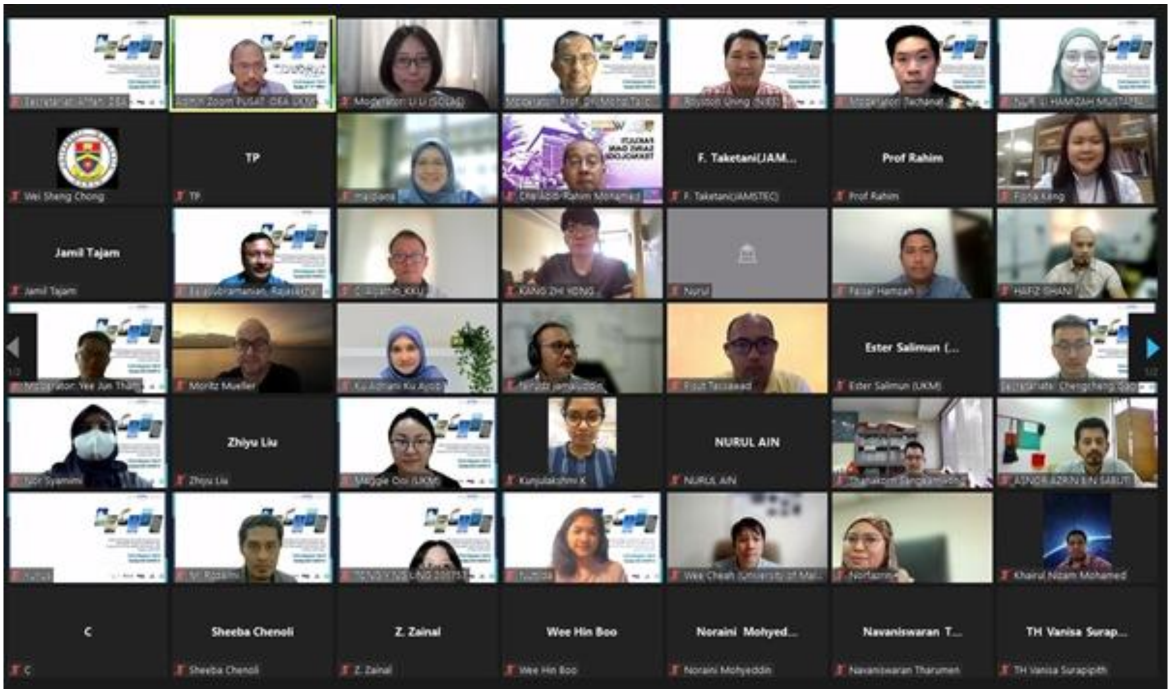

Figure 1: Online attendees of the workshop on surface ocean and lower atmosphere study in Southeast Asia

many studies are related to ocean biodiversity in this region. Nevertheless, there is limited knowledge of surface ocean lower atmosphere study in this region. Therefore, this workshop aims to highlight the previous and current studies on sea-atmosphere interaction by researchers from different countries in this region, and to introduce and discuss SOLAS's related research and activities among the Southeast Asian research communities. The online workshop was attended by more than 70 participants. Twelve presenters, from Malaysia, Thailand, Indonesia, Vietnam, Singapore, China, India and Spain, have presented their research outcomes at the workshop. The workshop has been officiated by Prof. Fredolin Tangang, the Head of the Department of Earth Sciences and Environment, Faculty of Science and Technology, Universiti Kebangsaan Malaysia. Prof. Tangang is a prominent professor of oceanography and climate change and currently leads the Southeast Asia Regional Climate Downscaling (SEACLID)/CORDEX Southeast Asia (http://www.ukm.edu.my/seaclid-cordex/).

The keynote of this workshop has been delivered by Prof. Zhiyu Liu from Xiamen University, China, entitled 'SOLAS Sciences: A Regional Perspective and Opportunity'. Prof. Liu, who represented SOLAS's co-chair Prof. Minhan Dai, has introduced SOLAS and SOLAS's research themes to all of the participants. Prof. Liu then discussed the research opportunity within the SOLAS's science community. He also discussed the importance of Southeast Asia based on the flow of circulation within this area, nutrient concentrations, biological productivity, marine biodiversity and the influence of this area on atmospheric circulation and world climate. All of these research topics are important for collaborative studies.

Six researchers have presented their works related to SOLAS's Theme 1, 3 and 4. The first presenter, Rajasekhar Balasubramanian, has discussed the issue of ocean acidification in tropical regions. Previous studies have investigated the impact of atmospheric deposition during haze and non-haze episodes on marine nutrient compositions. Ocean acidification is influenced by CO_2 absorption. The study on ocean acidification in the Southeast needs to consider various aspects including the understanding of the synergistic impacts of nutrient pollution and CO_2 atmosphere deposition. Ocean acidification studies are needed in tropical coastal areas such as Southeast Asia with a focus on seawater carbonate chemistry and reef calcification capacity for evaluation of good practices for ocean acidification management.

Faisal Hamzah from the National Research and Innovation Agency, Indonesia, has presented the dynamics of marine carbonate chemistry in the low latitude of the Indonesian Seas. He shared the profile distribution of the carbonate system e.g., dissolved inorganic carbon, total alkalinity, pH and aragonite saturation state, in the western Indonesian Sea which linked with the South China Sea and the Indian Ocean via the Karimata Strait and Sunda Strait. Another interest finding is the main route of the Indonesian Throughflow (ITF). He also diagnosed major control that affects DIC and TAlk. Along the main route of ITF, he identified mechanisms of transformation of the carbonate system and calculated carbon flux at the major inflow and outflow passages. The results of his study could be a baseline for future research since the region is strongly influenced by local climate (monsoonal system) and interannual variabilities such as (El Niño–Southern Oscillation) ENSO and Indian Ocean Dipole (IOD).

The third presenter, Che Rahim Mohamed has given a talk on the topic of Asian dust deposition into the Sunda Shelf Region: Natural radionuclides elucidates the monsoon effects. The presentation emphasizes the influence of dust and biomass burning during northeast and southwest monsoon, respectively to the ocean in Southeast Asia. Various isotopes from the mainland and deposition processes were found to be influenced by different sources. The speciation of ^{210}Pb and ^{210}Po in marine aerosol corresponds to transboundary haze; e.g., biomass burning especially forest fires and long-range air mass transport of terrestrial dust has enriched concentrations of particle mass in the local atmosphere. The difference of isotopes is also recorded from sources such as coal-fired power plants and the varieties influenced by different monsoons and meteorological factors.

Tran Manh Ha from Vietnam has discussed the preliminary results on the effects of ocean acidification on the growth of corals in the laboratory condition. Ha Long - Cat Ba Under Laboratory Experiments. The last two presentations were given by Iskhaq Iskandar and Ahmad Fairudz Jamaluddin, who have discussed the issues of ocean and greenhouse gases (GHGs) and their impact on climate change and the impact of the Indo-Pacific Climate Mode and their Impact on Forest Fire in Indonesia. The presentation by Iskhaq Iskandar has explained the five climate drivers that influence the climate in Indonesia, namely the diurnal cycle, Madden Julian Oscillation (MJO), monsoon, IOD and ENSO. Ahmad Fairudz Jamaluddin has discussed the concentration of GHGs recorded at the stations belonging to the Malaysian Meteorological Department. Methane was recorded higher in Malaysia compared to other international established stations. The northerly wind influenced the higher concentration of GHGs in Malaysia.

Five presenters have presented their work related to SOLAS Theme 4 and 5. Punyasloke Bhadury has presented his work on biogeochemical cycle of organics composition in coastal environment. Marine microorganisms have the ability to produce organic substances and atmospheric aerosols in the atmosphere. Qinyi Li has explained the sources of halogen from marine environments. WRF-Model has been used to estimate halogen and its impact. Fiona Keng has then shared her research at the University of Malaya on the emission of volatile halocarbons from tropical marine algae. The emissions of compounds such as $CHBr_3$ from marine algae are affected by changes in the environment such as irradiance and temperature. The preliminary investigation into economically-important seaweed species such as *Gracilaria manilaensis* and *Kapp*paphycus alvarezii showed that, besides the farming and post-harvest processing, the harvesting activity of the seaweed could have contributed to the release of a significant amount of bromine into the atmosphere. In the tropics, especially where large-scale seaweed farming occurs, there are currently insufficient investigations on algae-related trace gases.

Lim Po Teen from the University of Malaya has introduced the algal blooms of benthic marine dinoflagellate, *Ostreopsis cf.ovata* in Mediterranean Sea and increasing trend of human poisoning due to aerosol poisoning for the past two decades. He also shared seasonal and microhabitat preference of dinoflagellate Ostreopsis species from a study in Perhentian Island, Malaysia. To date, no human illness has been recorded in this region. He stressed the urgency to assess the potential risk and exposure to aerosol toxins of algal origin in the Southeast Asian region. Mohd Shahrul Mohd Nadzir from Universiti Kebangsaan Malaysia has presented on the topics of 'Halocarbon and its Potential Sources over Land and Maritime Region of Malaysia'. This topic explained the current status of halocarbons measurement and analysis over maritime and land areas in Sabah and Peninsula Malaysia. The presence of strong correlation of halocarbons mainly bromocarbons maybe implies that those gases emitted from the same sources such as marine seaweeds. These observations were proven by the strong correlation between halocarbons and Chl-a measurements. Strong correlations are also observed between bromocarbon in ambient air and seawater.

The panel discussion at the last session of this workshop has suggested that the researchers working on SOLAS related research could work together and establish the SOLAS Regional Panel for Southeast Asia.

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Faisal Hamzah got a bachelor in Marine Science from IPB University, Indonesia and PhD in Marine Chemistry from Xiamen University, Xiamen, China. His research focuses on marine biogeochemistry in marginal seas and estuary and biogeochemical in oligotrophic system i.e., carbon and nutrient in a low latitude of the Indonesian Seas.

Dynamics of the carbonate system in the western Indonesian Seas during the southeast monsoon

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The Indonesian Seas play an important role in global thermohaline circulation via the Indonesian throughflow (ITF) (Gordon 1986; Wyrtki, 1961). However, the general biogeochemistry of the Indonesian Seas and their roles in the global carbon cycle remain largely unknown, despite emerging research efforts across multiple fields. Previous studies reported that the western Indonesian Seas act as source of carbon dioxide (CO_2) to the atmosphere (Kartadikaria *et al.*, 2015). However, vertical and horizontal distributions and associated with the ITF remains uncertain.

Dynamics of the carbonate system in the western Indonesian Seas during the southeast monsoon were observed in the three regimes namely the Karimata Strait, western Java Sea and the Sunda Strait. In the Karimata Strait, the Kapuas River plume was observed, featuring low salinity, dissolved inorganic carbon (DIC), and total alkalinity (TAlk). In the western Java Sea, where waters were well mixed, we observed relatively homogeneous distributions of salinity, DIC, and TAlk. In the Sunda Strait, waters intruding from the Java Sea occupied the upper layer, and below was the Indian Ocean water with lower values of salinity, DIC, and TAlk. In its deep portion, depth profiles of normalized DIC and TAlk were very similar to those observed in the Indian Ocean. Physical processes and air-sea gas exchange exerted predominant controls on the carbonate system in the Karimata Strait and western Java Sea. While both processes play large roles in the Sunda Strait, a net DIC removal of 31 ± 23 μmol kg^{-1} in the surface mixed layer were revealed (Figure 2). The drawdown of DIC is consistent with an overall supersaturation of dissolved oxygen (102–107%), suggesting significant organic carbon production. In the subsurface-intermediate waters of the Sunda Strait mainly influenced by the advection of Indian Ocean water, a net DIC consumption of 54 ± 45 μmol kg^{-1} was distinct, likely stimulated by the nutrients supplied from the Indian Ocean.

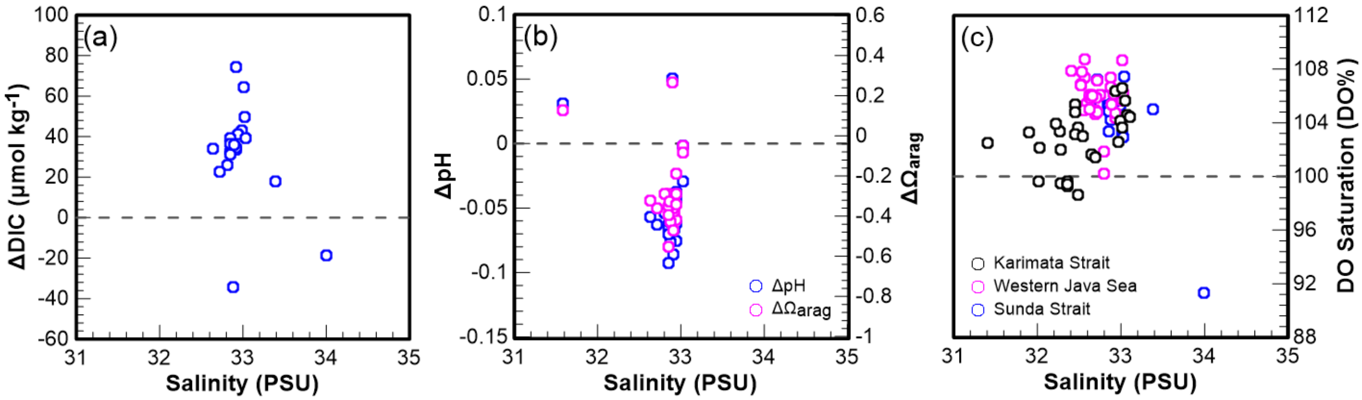

Figure 2: Biologically mediated dissolved inorganic carbon (DIC) variations represented by ΔDIC (ΔDIC = DICcons - DICmeas) (a) and ΔpH (ΔpH = pHcons - pHmeas) and ΔΩarag (ΔΩarag = Ωaragcons - Ωaragmeas) (b) in the surface mixed layer (upper 40 meters) of the Sunda Strait. (c) Dissolved oxygen saturation (DO%) in the upper 40 meters of the western Indonesian Seas during the southeast monsoon of June 2015. Grey dashed lines in panels (a) and (b) denote no net change in ΔDIC, ΔpH, and ΔΩarag due to equal amounts of addition and removal, and in panel (c) denotes DO% = 100% with equilibrium reached between the sea surface and the atmosphere.

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Fiona Seh-Lin Keng studied biotechnology at the University of Malaya in Kuala Lumpur before pursuing a master's degree and doctorate in algae trace gases at the Institute of Ocean and Earth Sciences (IOES), Malaysia. She is presently a lecturer at IOES, where she investigates biogenic sources of trace gas emissions, such as the influence of environmental change on tropical algae's emission of halocarbon.

Halocarbon emissions by tropical marine seaweeds

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Biogenic emissions of short-lived halocarbons affect the composition and chemistry of the atmosphere. Research has shown that marine seaweeds emits compounds such as bromoform ($CHBr_3$), dibromomethane (CH_2Br_2), diiodomethane (CH_2I_2) and dibromochloromethane ($CHBr_2Cl$) into the seawater and air. These chemicals are often formed during the metabolic processes of seaweeds, or they serve as antioxidants or defence molecules. The emission of these gases into the atmosphere may influence local weather patterns and contribute to the global halocarbon burden, resulting in a potential loss of stratospheric ozone. This is especially noticeable in the tropics due to the occurrence of vertical movement that might alter the global circulation of these atmospheric chemicals. At the University of Malaya, we have examined the some of the many environmental factors (Figure 3), such as irradiance and temperature, that might possibly affect the emission of volatile halocarbons by tropical seaweeds, but for which there are often insufficient data for modelling purposes. As a result of a lack of geographical and temporal data input from coastal and oceanic sources in this region where seaweeds such as *Kappaphycus alvarezii* are mass-cultivated, the projection of the present and future global halocarbon pool is frequently subject to enormous uncertainty.

Through our laboratory-based study, we found that changes in temperature (20–40 °C) and its exposure duration (4 and 28 hours) affected the emission of halocarbons by four selected wild and cultivated seaweeds, i.e., *Gracilaria manilaesis* (red), *Ulva reticulata* (green), *Kappaphycus alvarezii* (red), and *Turbinaria conoides* (brown).

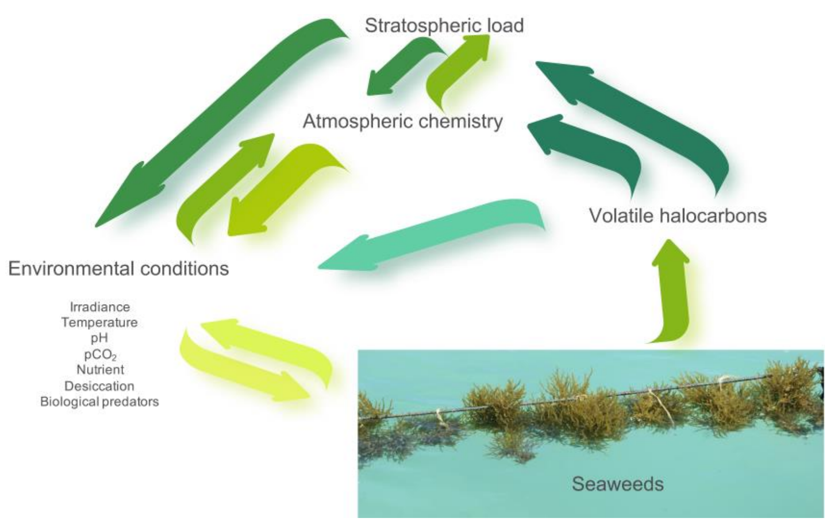

Figure 3: The interaction between the environmental conditions affecting halocarbon emissions by algae.

Longer exposure duration to higher temperatures was found to result in lower rates of halocarbon emissions by most of the seaweeds, which could be related to their lowered photosynthetic efficiency at the temperatures of 35 and 40°C (Keng *et al.*, 2021). When the combined effect of irradiance and temperature was tested on the commercially farmed *K. alvarezii*, lower emission rates were observed during dark treatment at most of the temperature tested while higher irradiance levels were found to increase the emissions of CH_3I, CH_2I_2, CH_2Br_2 and $CHBr_3$, while temperature was found to exert a stronger effect on the emission of the compounds compared to irradiance (Keng, 2021).

In order to provide a better representation of the emissions during seaweed farming, we have constructed three farming systems, namely the onshore tank system, the offshore platform, and the cage culture at a river mouth at Bachok, Kelantan, a small town along the East Coast of Peninsula Malaysia. *Gracilaria manilaensis*, a red seaweed, was grown in all three systems, while *K. alvarezii*, a commercially important seaweed, was grown on the onshore and offshore platforms. There was an exceptionally high emission of $CHBr_3$ from *G. manilaensis* cultivated at the river mouth, which could probably be due to the different environmental conditions i.e. nutrient content, temperature fluctuation, etc., in which it was cultivated. During the day, the cultivated seaweed was found to emit a higher amount of $CHBr_3$, $CHBr_2Cl$, and $CHBrCl_2$ than at night. On average, daytime *G. manilaensis* emissions were found to be 13 to 16 times greater than night time emissions, although *K. alvarezii* emissions were only three to six times higher during the day, which could probably be due to the decrease in photosynthesis-related activities. Another notable finding was the positive correlation between the transient changes in temperature and halocarbon emission rates, which was the opposite to that reported in the laboratory-based studies, possibly due to factors such as exposure duration and physiological state of the seaweed. As our measurement technique resembles that of the harvesting stage of farming, we were able to estimate the contribution of farmed Malaysian *Kappaphycus* during the harvesting process, which was up to 320 mol Br hr^{-1} (Keng *et al.*, in prep.) based on the biomass production by Food and Agriculture Organisation of the United Nations (2022).

Despite the fact that we conducted these studies on tropical seaweed, there are many unexplored areas in algae-halocarbon related studies, particularly in light of the impending climate change; from the physiology and mechanism of halocarbon production by tropical algae, to the fluxes, emissions, and environmental impact of the release, particularly in a region where seaweed farming is widely practiced.

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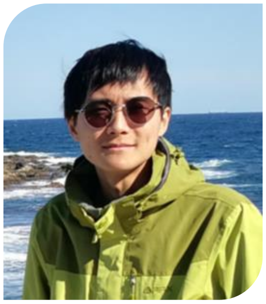

Qinyi Li obtained his PhD from The Hong Kong Polytechnic University (HKPolyU) in 2018. He worked as a postdoc in Spanish National Research Council from 2018 to 2022. He is currently a research fellow at HKPolyU. His research addresses the underlying causes of regional air pollution and global climate change with a focus on reactive halogen species, providing evidence-based recommendations for formulating mitigation policies.

Multiscale modelling of reactive halogen species and their connection to oxidation capacity, regional air quality, and global climate

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Halogen species, e.g., chlorofluorocarbon, have been recognized as being responsible for causing stratospheric ozone hole for several decades. Recently, elevated levels of reactive halogen species (RHS; inorganic and very short-lived organic chlorine, bromine, and iodine species with lifetime < 180 days), have also been detected in various environments in the troposphere (Saiz-Lopez and von Glasow, 2012). Field measurements of RHS suggest that halogens have the potential to induce perturbation in tropospheric chemistry, therefore affecting oxidation capacity, regional air quality, and global climate. The quantification of the RHS impacts on the atmospheric system calls for modelling studies on various spatial and temporal scales.

Tham *et al.* (2021) reported observation of inorganic iodine species at a remote marine boundary layer (MBL) site; the authors utilized a one-dimensional (1D) model to quantify the contribution of all possible processes to the observed level of iodine monobromide (IBr) and iodine monochloride (ICl); the authors found that much faster hypoiodous acid (HOI) uptake on sea-salt aerosol (SSA) was required. Li *et al.* (2022b) expanded the scope to global and implemented larger heterogeneous uptake coefficients in a three-dimensional (3D) global model, Community Atmosphere Model with Chemistry (CAM-Chem); their results suggested that the recycling process of iodine on SSA induced noticeable impacts on the level of oxidants, ozone (O_3, -7%), hydroxyl (OH, -2%), and hydroperoxyl radicals (HO_2, -4%), in the global MBL (Figure 4).

A series regional modelling studies in various environments were conducted to examine the impacts of RHS on regional air quality, e.g., nitryl chloride ($ClNO_2$) in coastal area (Li *et al.*, 2016), RHS in semi-polluted region (Li *et al.*, 2019), RHS in MBL (Li *et al.*, 2021a), and chlorine and bromine in polluted continental region (Li *et al.*, 2021b). These regional works highlight the competing role of halogens: the O_3-depletion effect of halogen atoms versus the volatile organic compound (VOC)-oxidation (O_3-production) effect of chlorine and bromine atoms. In polluted regions, the O_3-production effect prevails while in clean areas, the O_3-destruction effect dominates.

Li *et al.* (2022a) adopted an Earth system model,

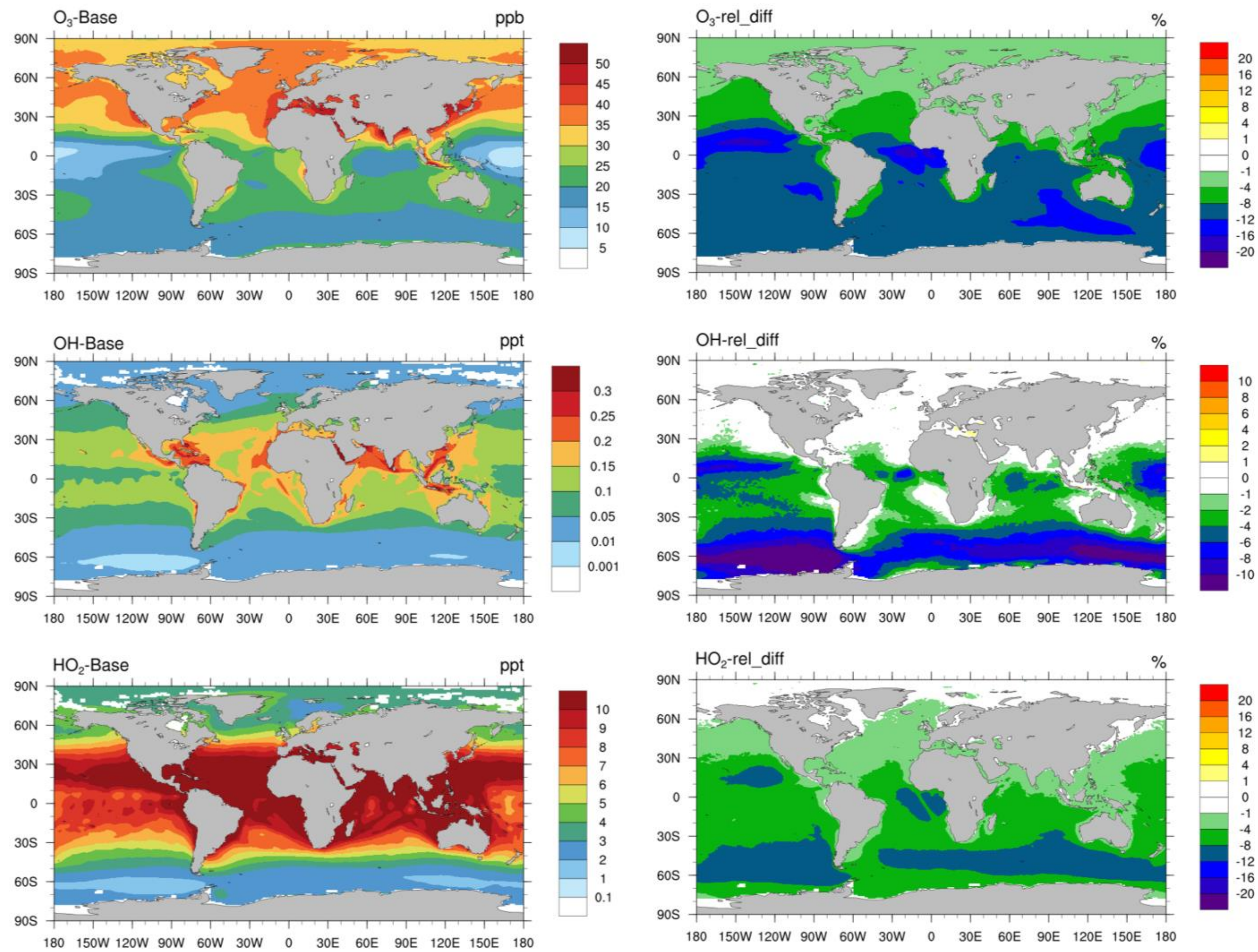

Figure 4: Simulated distribution of annual average ozone (O_3), hydroxyl (OH), and hydroperoxyl radicals (HO_2) mixing ratio in the marine boundary layer in the simulation without iodine recycling (left) and the relative change (%) due to iodine recycling (right).

Community Earth System Model (CESM) with comprehensive halogen chemistry, and further implemented latest findings, e.g., reactive chlorine sources. The authors then quantified the RHS impacts in the 21st century. The consideration of RHS has two consequences on methane (CH_4, the most abundant reactive greenhouse gas with two dominant losses through tropospheric OH radical and Cl atom): (1) to increase tropospheric Cl abundance, therefore increasing CH_4 loss rate, and (2) to reduce tropospheric OH burden, hence decreasing CH_4 loss rate. Globally speaking, the decreasing effect of RHS on CH_4 loss rate (via OH) fully compensated the increasing effect (through Cl), resulting in longer lifetime, larger burden, and more significant radiative forcing of CH_4.

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