The history of Holocene atmospheric iodine over the North Atlantic

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Corella et al., 2019: Holocene atmospheric iodine evolution over the North Atlantic. *Clim. Past, 15, 2019–2030, 2019*. https://doi.org/10.5194/cp-15-2019-2019

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Introduction

Atmospheric iodine chemistry has a large influence on the oxidizing capacity and associated radiative impacts on the troposphere.

Direct instrumental measurements of atmospheric iodine are restricted to the last decades, preventing us from understanding the long term biogeochemical cycle of iodine and further environmental and climatic implications. Ice core records partially overcome these limitations since these natural archives sensitively record continuous atmospheric iodine levels in polar regions.

In this study we report (from the Greenland-ReCAP ice core record) the first and continuous reconstruction of iodine levels (i.e. iodine concentration [I] and iodine depositional fluxes (I_{flux})) in the Northern Hemisphere since the onset of the Holocene (last 11 700 years). This exceptional natural archive, provide us with an analytical framework to investigate, for the first time, the evolution of atmospheric iodine in the Arctic since the Holocene.

The global 3D chemistry-climate model CAM-Chem, is used to study how the ozone-driven emissions of iodine (HOI and I_2) may have controlled the variability of atmospheric iodine during the 1950-2010 time period.

This study also provides a unique insight into the environmental drivers controlling the long term atmospheric iodine biogeochemical cycle in the Arctic

The ReCAP (Renland Ice Cap) ice-core

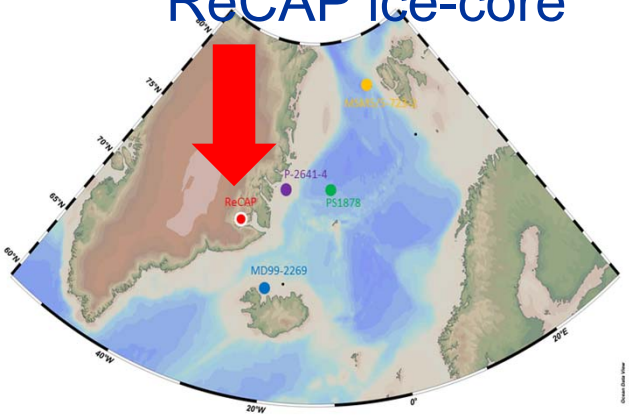
Drilled at 71,30ºN, 26,72ºW, 2315 m asl.

584 m ice drilled to bedrock by the **Centre for Ice and Climate of the University of Copenhagen** in 2015

Here we report **Iodine** and **Sodium** in a depth-range spanning the Holocene period (last 11.7 kyr BP) from the upper 535 m of the ice-core.

Measurements of ^{127}I and ^{23}Na carried out at the **Environmental Analytical Chemistry Laboratory of the IDPA-CNR**, **University Ca'Foscari** in Venice (Italy), using an Inductively Collision Reaction Cell Inductively Coupled Plasma Mass Spectrometry (CRC-ICP-MS) and an Inductively Coupled Plasma Sector Field Mass Spectroscopy (ICP-SFMS) Iodine (^{127}I) was determined at low mass resolution with stability of instrumental signal evaluated by the continuous monitoring of ^{129}Xe

ReCAP ice-core



The CAM-Chem model

3D **chemistry-climate** model within the CESM framework (Community Earth System Model) (*Lamarque et al., 2012*)

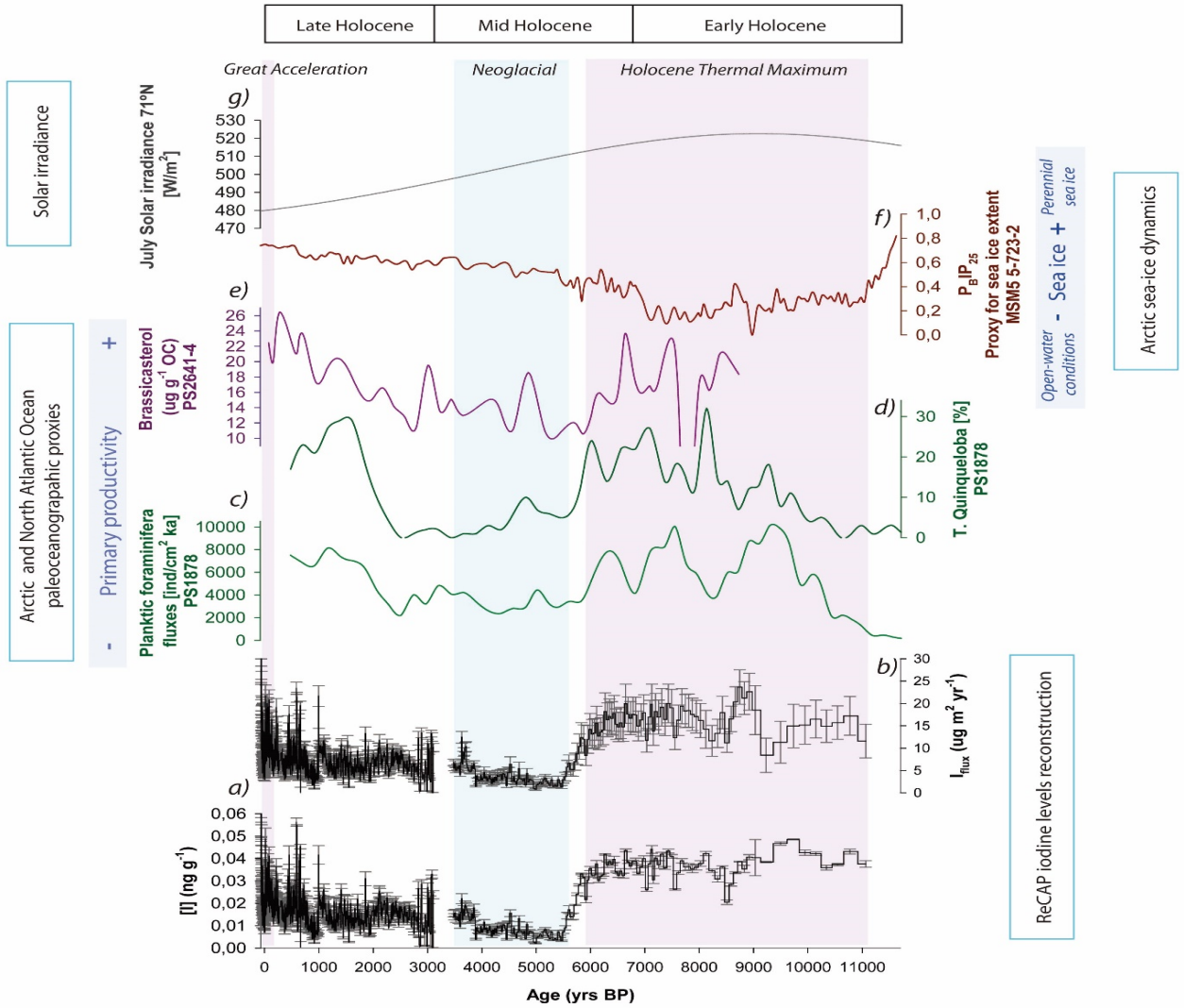
Model setup based on **CCMI-REFC1** experiment

Updated chemistry scheme for halogens (chlorine, bromine and iodine) (*Ordóñez et al., 2012, Fernandez et al. 2017, Saiz-lopez et al., 2014, 2015*)

Includes an **explicit state-of-the-art scheme of iodine emissions** (both organic and inorganic) and **photochemistry** (both gas and particle phase), which account for **chemical transformation during transport** from the ocean source to deposition in the Renland region

1.9° latitude × 2.5° longitude spatial resolution and 26 vertical levels (0-40 km)

The model was run in **free-running mode** considering prescribed **sea surface temperatures** and **sea ice distributions** from 1950 to 2010 (MERRA reanalysis dataset)



Holocene iodine concentrations and fluxes evolution from the ReCAP ice core and primary productivity and sea-ice cover proxies from the Nordic seas (Figure 2)

From bottom to top:

a) Iodine concentrations (1σ, experimental uncertainties; (Iodine detection limits are within 0.005 and 0.002 ppb)

b) Iodine fluxes (1σ, propagated from the concentration and accumulation rate uncertainties) (N=1050);

c) and d) Planktic foraminifera and T. quinqueloba (core PS1878) (M Telesiński et al., 2015)

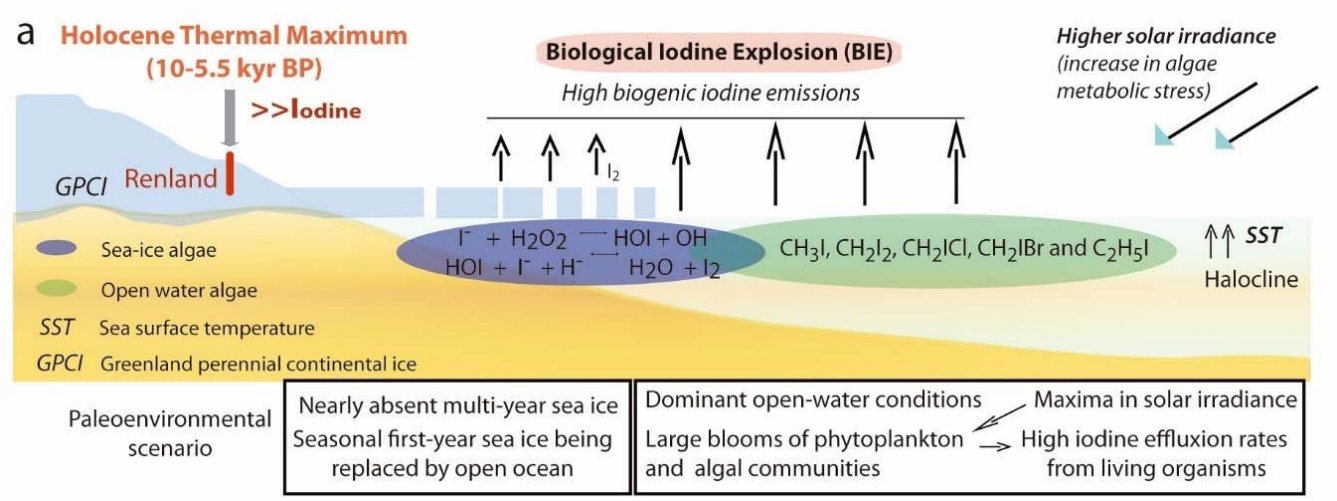
e) Brassicasterol (core PS2641-4) (Müller et al., 2012)

f) Sea-ice cover (core MSM5 5/723-2) (Werner et al., 2013; Werner et al., 2016)

g) 71ºN July solar irradiance

Color boxes indicate the Holocene main climatic periods mentioned in the text; pink boxes indicate warmer phases while blue boxes indicate colder intervals.

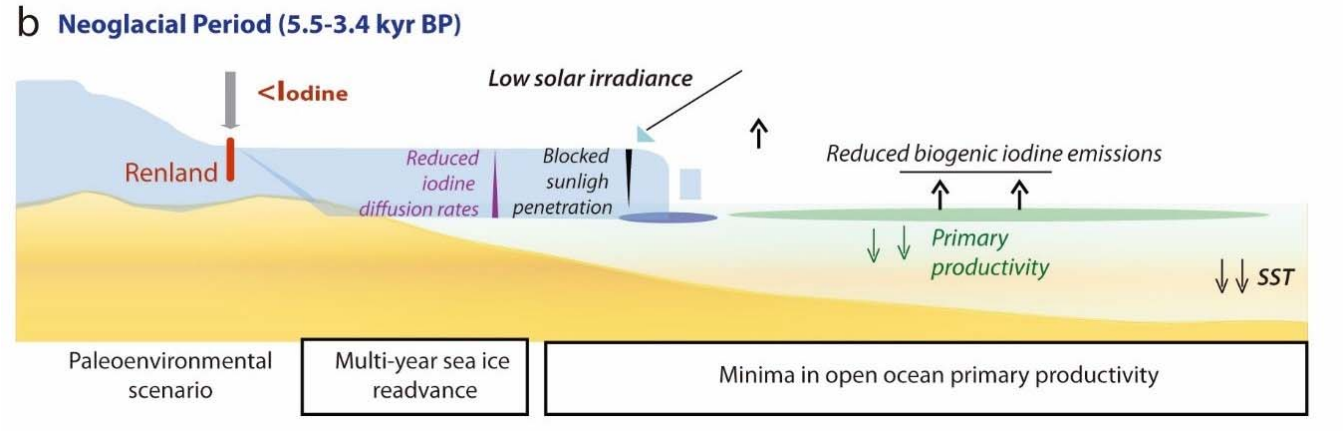
Atmospheric iodine evolution during the Holocene



Maximum organic iodine emissions were recorded during this period (fig 2a in previous slide). The rise of atmospheric iodine levels at the onset of this warm period was due to a **Biological Iodine Explosions (BIEs).** BIE resulted from the interplay of different factors:

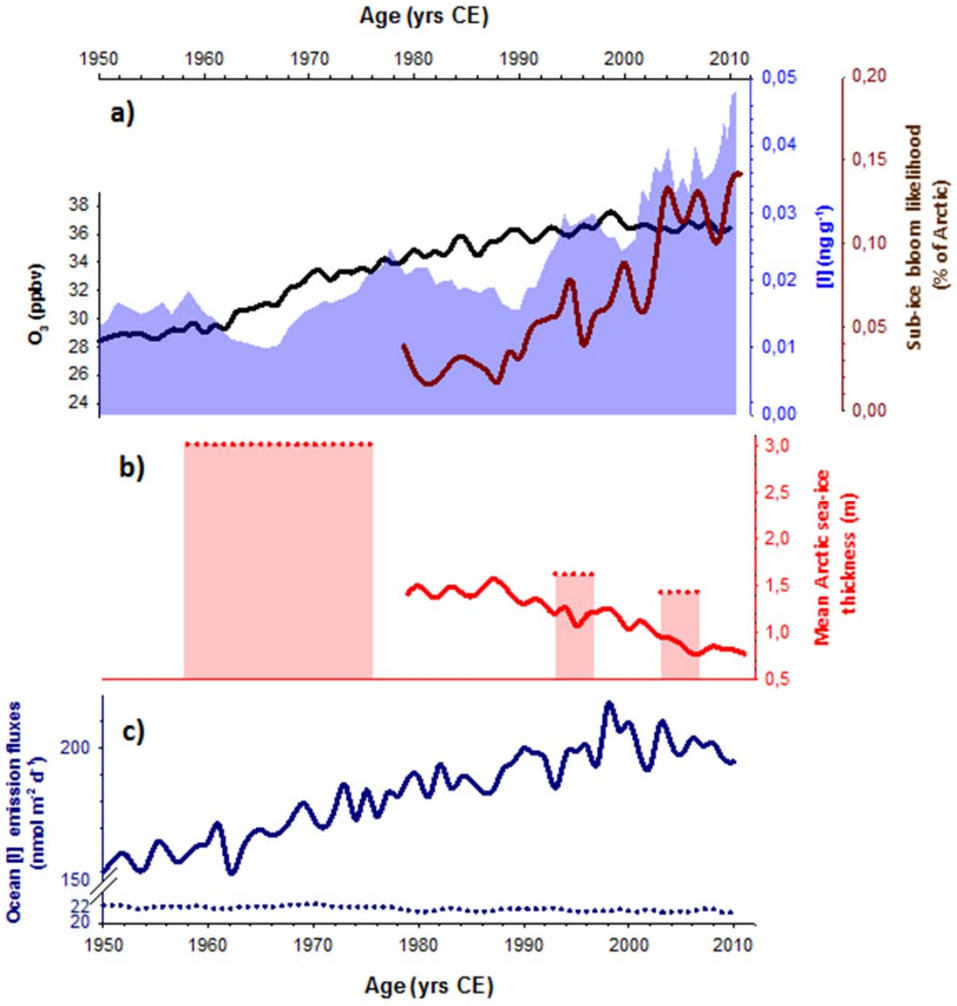
- Enhanced ocean primary productivity and dominant open water conditions in the Arctic ocean, leading to massive emissions of iodine from the oceans to the atmosphere
- Maxima in solar irradiance in the Arctic increased the algae oxidative stress, leading to an enhancement of the biological iodine production in the ocean and subsequent release to the atmosphere
- Higher sea surface temperatures (SST), favoring the sea air phase transfer of iodine compounds produced in the ocean surface

Neoglacial Period (5.5 3.4 krys BP)



Iodine values were significantly reduced during this period Three factors controlled the atmospheric iodine levels drop

- Sunlight could not penetrate through the densely packed ice impeding sea ice diatoms blooms.
- Thicker sea ice reduced the iodine diffusion rates
- The reduction in solar insolation diminished algae metabolic activity and hence iodine production in the open ocean



Iodine concentration evolution and forcing mechanisms for the period 1950-2011 (figure 5)

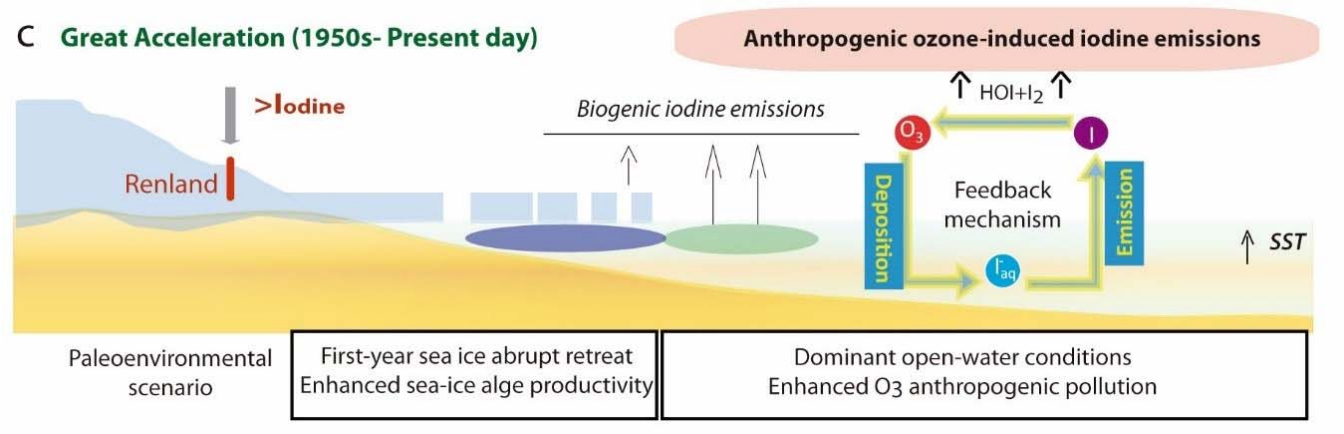
From top to bottom:

a) iodine concentration (blue area); ozone annually averaged over the North Atlantic region (latitude: 20N-70N, longitude=75W-0) (dark line) and evolution of the pan-Arctic likelihood of sub-ice blooms in late spring and early summer (May-June-July) over time (Horvat et al., 2017) (read line)

b) mean Arctic sea ice thickness, red line from Horvat et al. 2017 and red dots from Kwok et al. 2009

c) CAM-Chem modelled ocean emission fluxes of iodine with (solid line) and without (dotted line) the implementation of the ozone-induced iodine emission mechanism.

Great Acceleration (1950s Present dayAtmospheric iodine evolution during the Holocene



Iodine levels doubled since the beginning of the Industrial Period and **tripled since 1950** (Figs 5 in previous slide). This increase is **driven by anthropogenic ozone pollution and enhanced sub ice phytoplankton production** associated with the recent thinning of Arctic sea ice. The global 3D chemistry-climate model CAM-Chem, also shows that increasing atmospheric iodine has accelerated ozone loss and considerably increased iodine transport and deposition to the Northern hemisphere continents since 1950

Atmospheric implications

• The abrupt **long term fluctuations in atmospheric iodine levels** most likely had a significant **impact on the Northern Hemisphere (paleo) atmosphere** by decreasing ozone radiative forcing and promoting aerosol nucleation through ocean biology, iodine chemistry and climate feedback mechanisms

• The transport of marine iodine and its deposition to the North American and European continents have increased by 38% and 25% respectively, during the past 50 years The **enhancement of iodine deposition over continents** and the subsequent adsorption onto soil and vegetation is important since it is estimated that 2 billion people worldwide still have insufficient iodine intake.

• The **sustained growth in iodine concentrations in the Arctic during the last decades**, most likely due to human influences on tropospheric ozone and recent climate change, **will accelerate tropospheric ozone loss affecting the oxidative capacity of the atmosphere and the ozone radiative forcing.** Future climate and anthropogenic forcing may continue to amplify oceanic iodine emissions, with **potentially significant health and environmental impacts at a global scale.**

• **Iodine levels evolution during past warmer phases** with near ice free conditions in the Arctic may be used as an **analog to predict iodine trends in future warmer scenarios**

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