FINAL REPORT PROGRAM LEFE

Program LEFE - CHAT	**Project Title:** **Investigating winter- and spring-time sources and cycling of Bromine in the Arctic using 1D and 3D regional modeling (Brom-Arc)**	**Years 2019 – 2021**

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Other Participating Laboratories : LATMOS, Paris

Contribution to :

CATCH: The Cryosphere and Atmospheric Chemistry

Other funding sources :

- EU H2020 Grant agreement no. 689443 via project iCUPE
- EU H2020 Grant agreement No 101003826 via project CRiceS
- Shaddy Ahmed's PhD grant from the STEP ED

Context :

Elevated concentrations of atmospheric bromine are known to cause ozone depletion in the Arctic, which is most frequently observed during springtime. Two processes are studied/modeled that could be responsible for halogen activation, thus leading to tropospheric ozone depletion: (1) the heterogeneous chemistry on surface snow on sea ice, triggered by ozone deposition to snow and (2) the heterogeneous reactions on sea salt aerosols emitted through the sublimation of lofted blowing snow.

Objectives / scientific questions:

The main objective was to implement both sources into a chemistry-transport model (WRF-Chem), to address the main scientific questions: what are the origins of Arctic bromine and of ozone depletion events? What is the relative contribution of surface snow and blowing snow to this phenomenon?

Main results :

- Halogen activation and its role in Arctic surface ozone depletion events (ODEs) is modeled using WRF-Chem by representing two halogen activation mechanisms (1) surface snow and (2) blowing snow
- Comparisons to observations (Utqiaġvik, Alaska) do show better results when including these processes.
- A spring 2012 case study indicates that both mechanisms can trigger near-surface ODEs, but that surface snow dominates

Figure 1 from Marelle et al., 2021

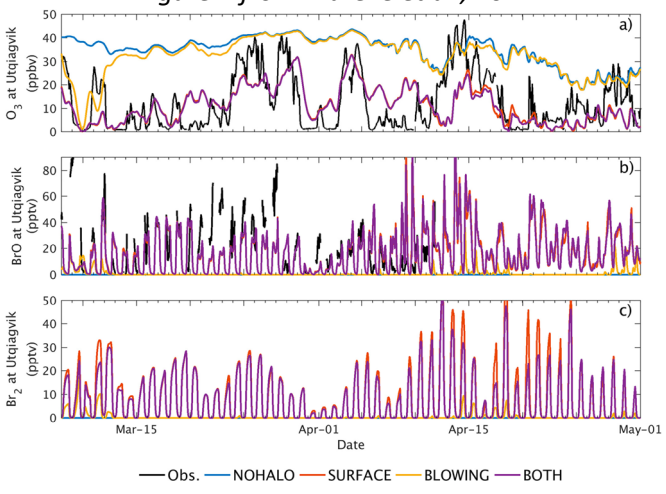

Figure 2 from Marelle et al., 2021

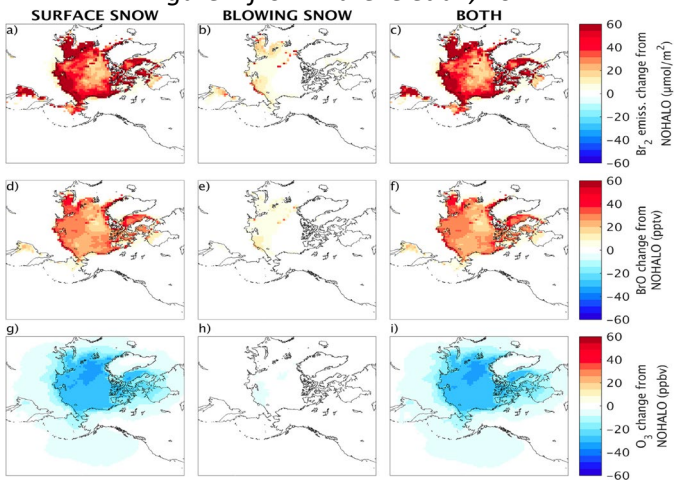

Figure 1: O_3 observed (black) at Utqiaġvik (Alaska) and simulated by WRF-Chem without halogen chemistry (blue), with surface chemistry (orange), with blowing aerosol chemistry (yellow), and with both (purple). (Middle) BrO observed by MAX-DOAS and simulated by WRF-Chem. (Bottom) Br_2 simulated by WRF-Chem. It shows, for a measurement station in Alaska, that (i) a representation of halogen chemistry in the model is needed to reproduce observations and (ii) the developments can significantly improve the representation of ozone depletion events at this location.

Figure 2: shows how the newly implemented processes affect surface concentrations of BrO and O_3 at the pan-Arctic scale, and that surface snow processes are the main contributor to Br_2 emissions and O_3 depletion in sea-ice regions.

Future of the project:

This project resulted in a model version with a much better representation of halogen chemistry (Chlorine and Bromine) in the Arctic. This significant improvement will be built upon in ongoing and future model developments aiming to obtain the best possible holistic representation of polar atmospheric chemistry. In addition, this project revealed the need for a model intercomparison of BrO chemistry, which is currently undertaken by PIs of Brom-Arc.

Number of publications, communications and theses

2 peer-reviewed articles

Marelle, L., Thomas, J. L., Ahmed, S., Tuite, K., Stutz, J., Dommergue, A., et al. (2021). Implementation and impacts of surface and blowing snow sources of Arctic bromine activation within WRF-Chem 4.1.1. Journal of Advances in Modeling Earth Systems, 13, e2020MS002391. https://doi.org/10.1029/2020MS002391

Ahmed, S., et al. (accepted). Modelling the coupled mercury-halogen-ozone cycle in the central Arctic during spring. Elementa: Science of the Anthropocene.

1 PhD thesis

Ahmed, S., *Modeling reactive atmospheric chemistry in the Arctic region*, 2022

2 presentations in conferences

Thomas, J. L., *Regional modeling of bromine activation and ozone depletion during two Arctic spring seasons using WRF-Chem*, SOLAS openscience conference, Cape Town, 2022

Marelle, L., *Impacts of Surface Snow and Blowing Snow Sources of Arctic Bromine Activation on surface ozone depletion*, CATCH open science workshop, online 2022

Data availability

The codes developed in this project are available on Zenodo as

- Marelle et al. (2021) https://doi.org/10.5281/zenodo.4607934
- Ahmed et al. (2022). Regional-Modeling-LATMOS-IGE/WRF-Chem-Polar: WRF-Chem 4.3.3 including mercury chemistry (v1.0). Zenodo. https://doi.org/10.5281/zenodo.7137482
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