The Cryosphere Discuss., 9, C2370–C2375, 2015
www.the-cryosphere-discuss.net/9/C2370/2015/

Interactive comment on "Halogen-based reconstruction of Russian Arctic sea ice area from the Akademii Nauk ice core (Severnaya Zemlya)" *by* A. Spolaor et al.

A. Spolaor et al.

andrea.spolaor@unive.it

Received and published: 25 November 2015

Anonymous Referee #2 Received and published: 14 October 2015 General Comments:

The submitted manuscript presents results demonstrating both the connection between ice-core Br(exc) and spring sea ice in the Laptev Sea and the connection between iodine concentration and summer sea ice area as found in the Akademii Nauk ice core record. In a well-written and concise manuscript, the authors do an excellent job of demonstrating the statistically significant correlations and explaining the significance of the findings. The manuscript is relevant and of interest to the readership of The

Cryosphere and I recommend for publication after some minor revisions.

Specific Comments:

pg 4411, lines 20-22: Some studies have also found Br depleted in the snowpack relative to Cl or Na, while others have found constant concentrations. It is more complex than simply stating there is enrichment of Br due to the bromine explosion and this should be discussed.

We agree with the referee and we improve the text in the manuscript (line 103-108). We also agree with the referee that it is possible to detect areas where Br is depleted in the snow compared to Na or Cl. However in all the sites where we measured Br (e.g. NEEM, Svalbard, Severnaya Zemlya, Law Dome, Talos Dome) we always detect an excess of Br (during interglacial samples, the aim of the paper is not to investigate the glacial transition). Depleted samples have been found by the authors in Antarctic samples collected very close to the coast. A recent paper from (Pratt, Custard et al. 2013) suggests that the BrO are mainly produced in sea ice area and Tundra. However, consider the results obtain in Svalbard (Spolaor, Gabrieli et al. 2013) we don't consider tundra regions as the main source for the excess of Br in Severnaya Zemlya.

pg 4413, section 2.1: Changes of the bromine and iodine concentrations in the snowpack over time needs to be more fully discussed. What about processes/reactions that may change the concentrations post-deposition? Although there is some reference to the effect of movement due to meltwater percolation, is it possible to get an estimate on the expected error?

It is not possible to have a precise estimation of how much Br and I can be re-allocated in the ice core. These questions have been already discussed in a previous paper published by the authors. Briefly we determined that Br is stable after deposition as well as later in ice while iodine could be remobilized inside the annual snow layer due to photolitic activities but the general annual climate signal seems to be maintained (more details are provided in (Spolaor, Vallelonga et al. 2014) - Seasonality of halogens deposition in polar snow and ice). The text has been improved (line 161-163).

pg 4415, lines 4-6: Why was HYSPLIT run for a different number of days for spring (three) vs summer (six)?

The different lengths of the calculated summer and spring backward trajectory (BT) periods are given by the different processes and elements we are evaluating. During springtime Br is involved in the main reactions and processes. For Bromine and considering the relatively fast deposition velocity of gas phase bromine (HBr), it is likely that the enrichment of bromine is more regionally influenced than for iodine. There are no references directly available for this proposition but it is supported by the findings of (Simpson, Alvarez-Aviles et al. 2005). They detected Br enrichments in snow in Alaska up to 300 km inland and our approach was to calculate BTs for an area of 300 km around the island, however some long-range transport could influence the deposition. For iodine, considering the atmospheric lifetime of some organic iodine compounds (CH_3I) in the order of 2 – 6 days (Carpenter 2003, Simpson, Brown et al. 2015) and possible re-cycling processes that can occur, we extended our BT calculation to 6 days for the summer period. We used the vertical motion mode and added this to the manuscript as well as the reason for the different calculated periods. The text has been modified accordingly (line 196-1969 and 203-206).

pg 4416, line 17: To me, it looks like there is a greater minimum than 44% for the period 1996-2000

For the period 1996-2000 the minimum is given by the sum of the two back-trajectories calculated. Both BT suggest a source of the air masses from the east with respect to Severnaya Zemlya, and likely Laptev sea. The sum of both is 49%. However to be more precise we use a cluster of 5 BT that suggest a minimum of 44% for that period. To be consistent in the figure we still continue to use the three cluster mean BT.

pg 417, lines 6-8: States that "seasonal changes in Kara Sea ice area are comparable but smaller than those calculated for the Laptev Sea." This is because the Laptev Sea

is a larger area than the Kara Sea. If you normalized by sea area, the changes would be more comparable.

We agree with the referee and we modify the sentence. The changes in Kara and Laptev seas are similar however the rate of production of seasonal sea ice is higher in Laptev Sea (line 247-249).

pg 4418, lines 10-11: The authors state that the results "confirm the finding that Br(exc) is correlated with Laptev and kara Sea ice." However, the findings of the spring sea ice showed only correlation with Laptev ice and not Kara spring ice. This differs from the finding of the summer ice results with the Polyakov anomalies.

Thanks to the referee to note this typesetting errors. There is no correlation between Kara Sea spring sea ice and Br exc. We corrected the sentence.

pg 4429, Table 1: Why was the Br(exc) not compared to the summer sea ice areas? Presumably this was due to negative Br(exc) values. However, it would be important to still present negative Br(exc) values and see how the trend varied with sea ice extent. Perhaps it would be better to use Br(enr) values for statistical correlations instead. If not, then a scaling of the Br(exc) would be required to take logarithms. - Although it is helpful to see the raw Br and Na concentrations in the supplement, it would be helpful to have a plot showing these trends in the manuscript as well.

From previous results we detect that the excess of Bromine is caused by the Bromine explosion. Bromine explosion happens in springtime, so if there is a connection it must be within spring seasonal sea ice. The correlation between Brexc and summer sea ice is still positive however we do not have any thorough explanation to connect summer sea ice and Br excess. Na and total Br concentrations show a very similar trend (R^2=0.65) and the authors do not think it can help in the data interpretation. In any case we add the raw Na signal in Figure 5. The main finding and object of the paper is to describe the behaviour of Brexc and Iodine with regard to sea ice. Regarding scaling the Br exc we agree with the reviewer. In fact, the statistical correlations reported in the paper are computed with the log-transformed Br(exc), as shown in Table 1. In order to avoid any source of misunderstanding, we have amended the text in a few places in order to emphasize that we took the logarithm of Br(exc).

pg 4421, lines 10-11: Why would the Svalbard record have less clear seasonal variability and be more susceptible to influences of summer melting and iodine re-emission when the climate conditions are similar?

Though Svalbard and Severnaya Zemlya are almost at the same latitude the climate is not the same. We need to keep in mind that Svalbard archipelago is influenced by the warm ocean currents coming from south. In summer time in Svalbard temperatures can rise up to 15°C. In addition during winter time the Svalbard archipelago presents sea ice only in the north eastern side while Severnaya Zemlya is surrounded. In Svalbard rain events can be present also during winter and spring time, for e.g. in 2015 three rain events has occured between December and April. Severnaya Zemlya climate is not strongly affected by the warm ocean current coming from south. Just to have an indication the average annual temperature in Svalbard is around -6.5°C while in SZ is close to -15°C.

Technical Corrections:

pg 4431, Figure 2: It would be helpful to crop all of the back trajectory images to show the same geographical region (i.e. enlarge images to have the same boundaries).

Thanks for the suggestion however the aim of the figure is show from which areas the air mass are most likely be originate and we prefer to be focused on the length of the BT. Re-scaling can under-estimate the local source.

Be consistent in use of either paleoclimate and palaeoclimate (e.g., pg 4410, line 22 vs pg 4413, line 13)

Thanks to the referee to note this. We adopt paleoclimate.

pg 4412, line 23: missing "the" before "last 50 years" - pg 4418, line 12: missing "to"

before "iodine"

Thanks to the referee to note this.

REFERENCES

Carpenter, L. J. (2003). "Iodine in the Marine Boundary Layer,." Chem. Rev. 103: 4953–4962. Pratt, K. A., K. D. Custard, P. B. Shepson, T. A. Douglas, D. Pohler, S. General, J. Zielcke, W. R. Simpson, U. Platt, D. J. Tanner, L. Gregory Huey, M. Carlsen and B. H. Stirm (2013). "Photochemical production of molecular bromine in Arctic surface snowpacks." Nature Geosci. 6: 351-356. Simpson, W. R., L. Alvarez-Aviles, T. A. Douglas, M. Sturm and F. Domine (2005). "Halogens in the coastal snow pack near Barrow, Alaska: Evidence for active bromine air-snow chemistry during springtime." Geophys. Res. Lett. 32(4): L04811. Simpson, W. R., S. S. Brown, A. Saiz-Lopez, J. A. Thornton and R. v. Glasow (2015). "Tropospheric Halogen Chemistry: Sources, Cycling, and Impacts." Chemical Reviews 115(10): 4035-4062. Spolaor, A., J. Gabrieli, T. Martma, J. Kohler, M. B. Björkman, E. Isaksson, C. Varin, P. Vallelonga, J. M. C. Plane and C. Barbante (2013). "Sea ice dynamics influence halogen deposition to Svalbard." The Cryosphere 7(5): 1645-1658. Spolaor, A., P. Vallelonga, J. Gabrieli, T. Martma, M. P. BjoÌĹrkman, E. Isaksson, G. Cozzi, C. Turetta, H. A. Kjær, M. A. J. Curran, A. D. Moy, A. SchoÌĹnhardt, A. M. Blechschmidt, J. P. Burrows, J. M. C. Plane and C. Barbante (2014). "Seasonality of halogen deposition in polar snow and ice." Atmos. Chem. Phys. 14: 9613-9622.

Interactive comment on The Cryosphere Discuss., 9, 4407, 2015.