ECAS 2016

Impacts of Organic Sources on the Ozone Depletion Events in Arctic Spring

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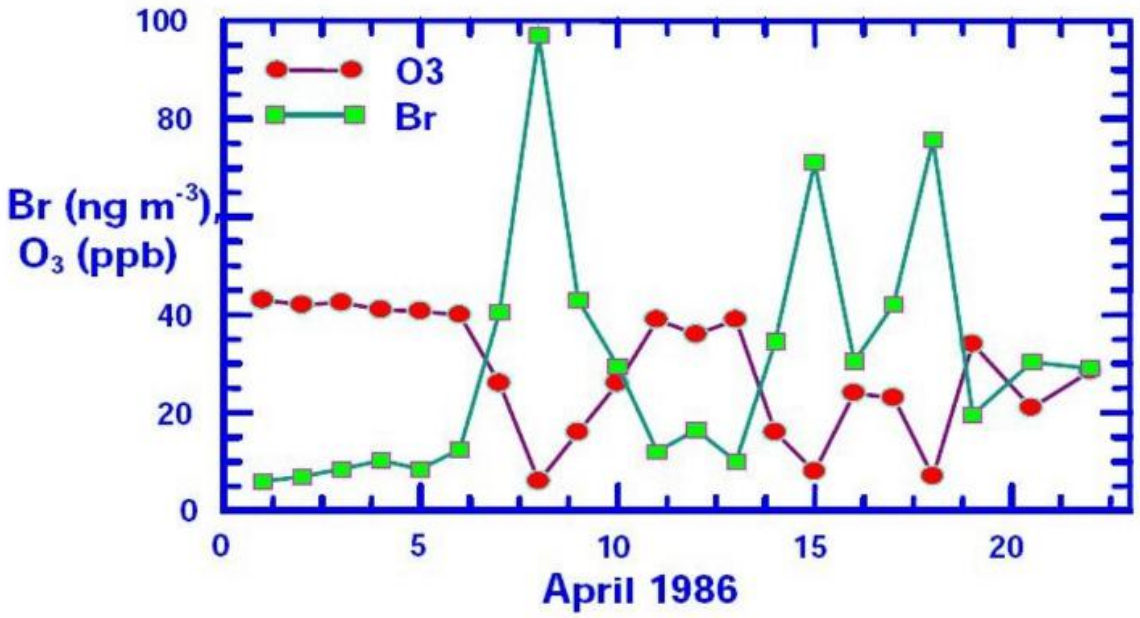
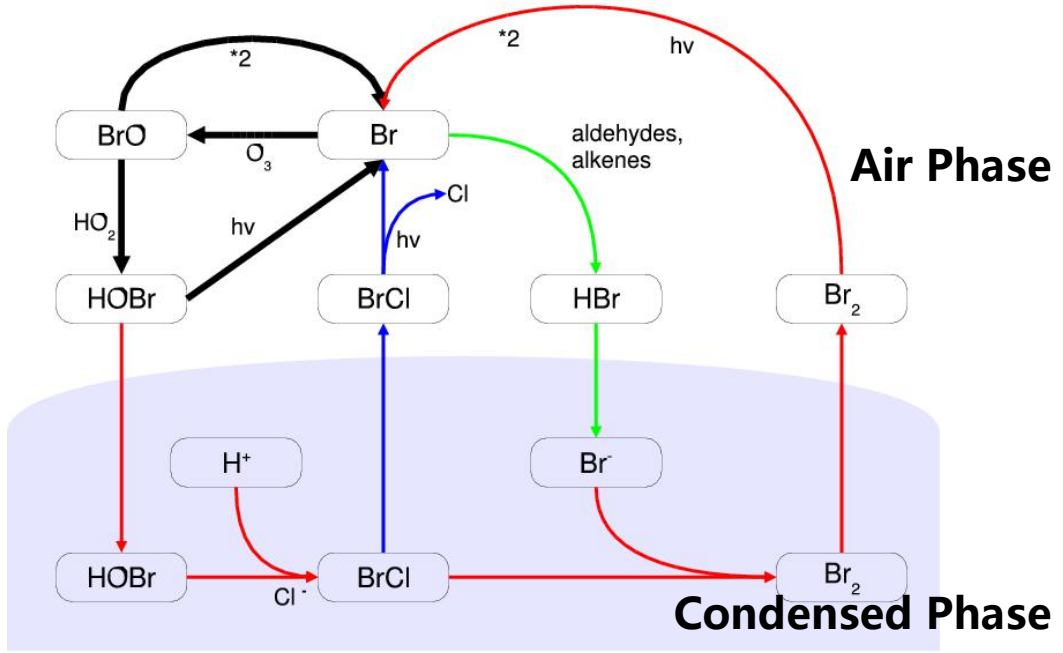
Part 1

Introduction

Bromine Explosion



Alert, Canada (Bottenheim et al., 1986)



HOBr-BrO-Br Reaction Cycle (Simpson et al., 2007)

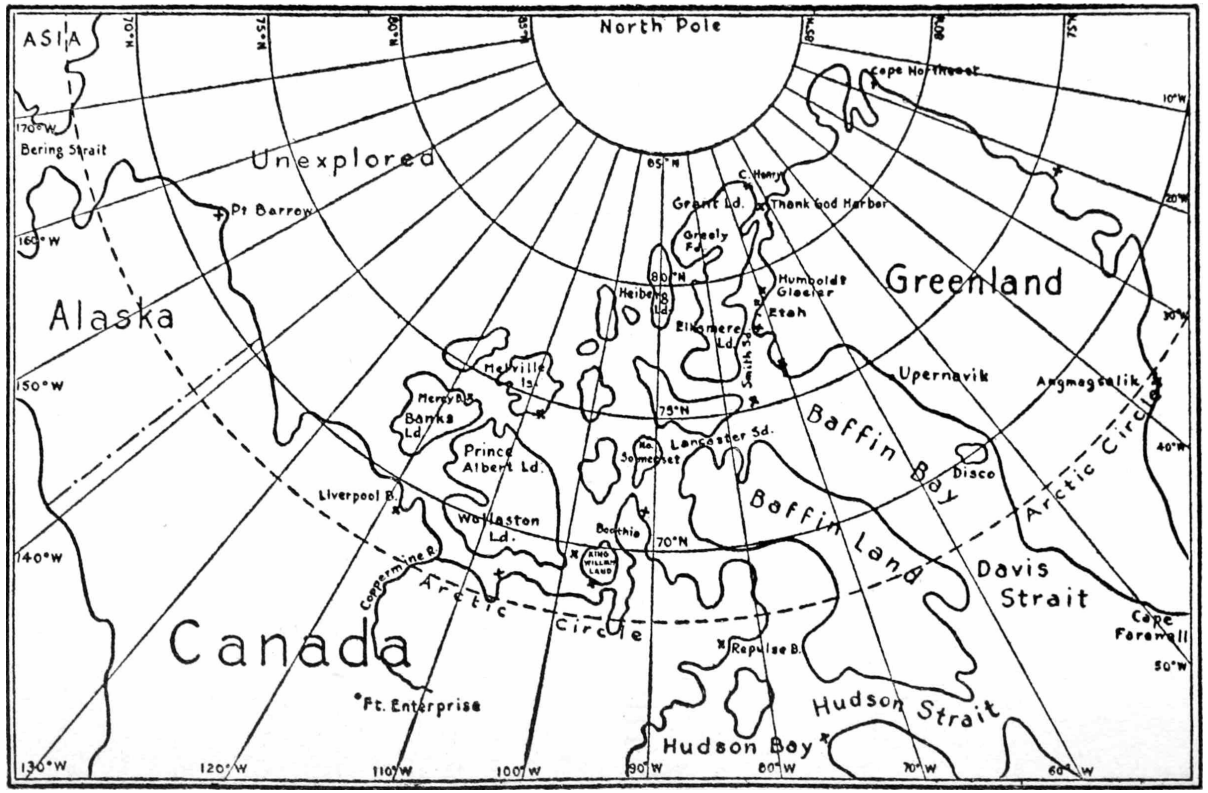
Ozone is consumed through a catalytic cycle.

Inorganic Sources

Flux rates of organic sources. (Cao et al., 2014)

Species	Flux Rates [molec./(cm^2·s)]	Major Origin
H_2O_2	1.0×10^8	Ice/Snow
HCHO	6.0×10^7	Sea
NO	1.6×10^7	Ice/Snow
NO_2	1.6×10^7	Ice/Snow
HONO	1.6×10^7	Sea

Organic Bromine Sources



Natural Sources

- **Plants**
- Animals & Microbes

Marine

- **Macro-Algaes**
  - Sea Weeds

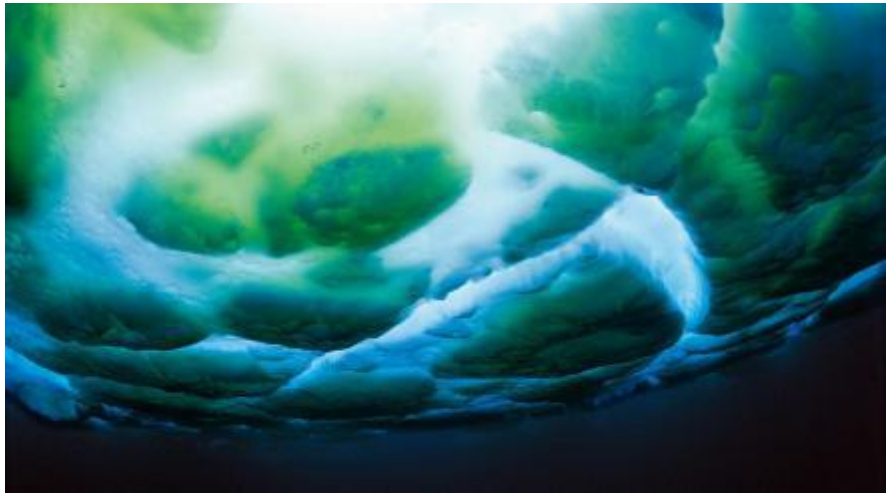
Terestrail

- **Mosses**
- **Lichens**
- Grasses
- Shrubs

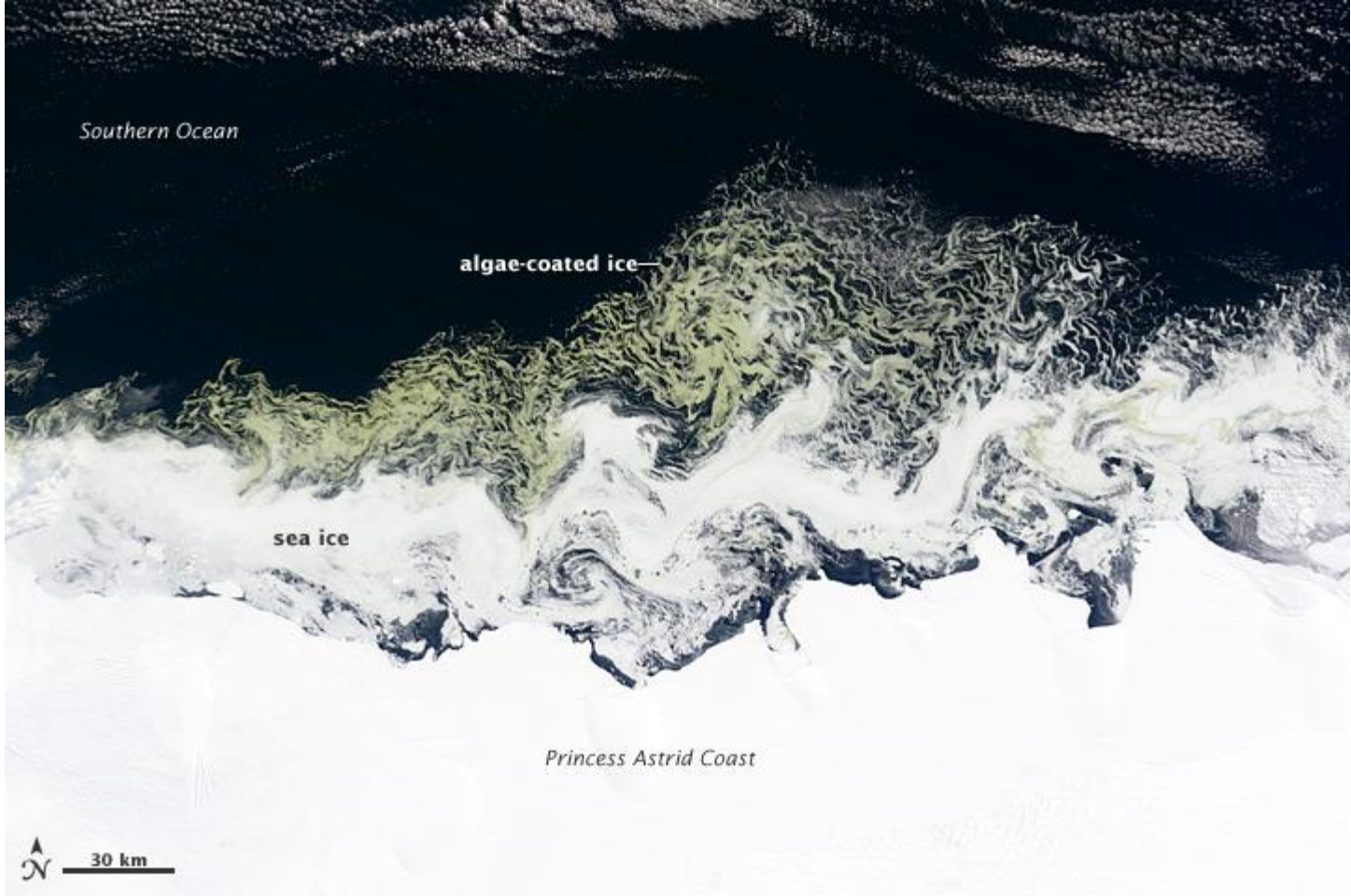
Artificial Sources

- Shipping Traffic
- Biomass Burning
- Fire Retrdants
- Driling Fluid

Macro-Algaes



Chukchi Sea, (Kevin et al., 2012)



Antarctica, Feb 2012 (NASA)

Eisenia arborea
Egregia menziesii

Marine Species

Nitzschia stellata
Porosora pseudodenticalata

Terrestrial Species

KINAL

$$\frac{d\mathbf{c}}{dt} = f(\mathbf{c},\mathbf{k}) + \mathbf{F}$$

$$\mathbf{c}|_{t=0} = \mathbf{c}_0$$

$\mathbf{k}$, $\mathbf{F}$

$$\frac{d\mathbf{c}}{dt} \longrightarrow \frac{\delta\mathbf{c}}{\delta t}$$

4_{th} **Order** **Runge-Kutta Method**

Differential Equation (1)

c: Concentration

k: Reaction rate

F: Flux

Solution: $\mathbf{c}_t$

Part 2

Bromine Model

Algal Emission

Estimation Based on Observation (Carpenter et al., 2000)

$CHBr_3$	1.7×10^2
CH_2Br_2	2.8
CH_3Br	0.1
	(Gg/yr)

Macro-algaes produce 70% of world's bromoform.

5.3×10^7 molec. Br/($cm^2\cdot s$)

Laboratory Research (Cota et al., 1997)

124~5434ng $CHBr_3$/(g dry weight·h)

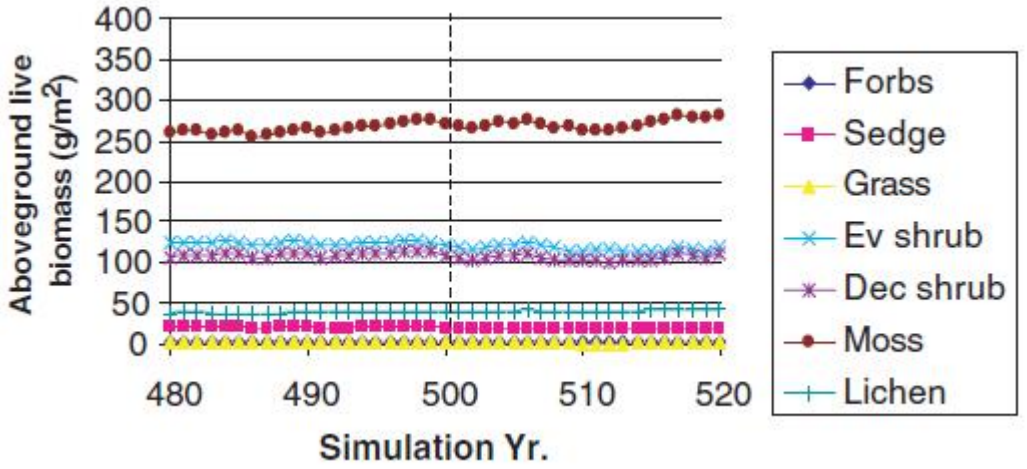
Observation (Pihl et al., 1996)

Biomass density is under 300g dry weight/m^2 in early spring.

Tundra Plants Emission

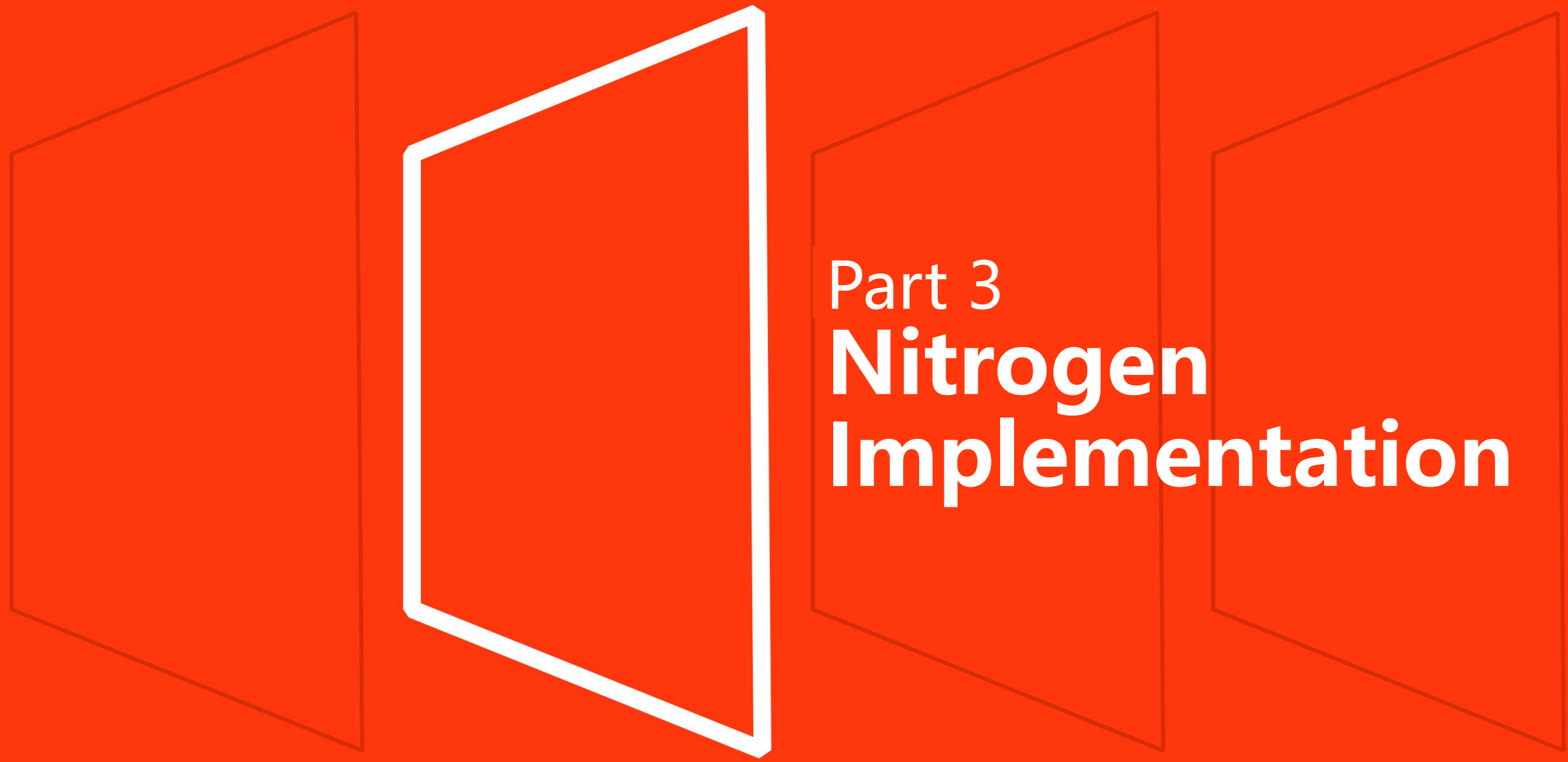
Moss+Lichen=350g dwt/m²

(Almost same productivity as algaes)



Simulated temporal evolution of tundra biomass (Chapin et al., 1995)

Total bromine flux=**6.3×10^{7} molec. Br/($cm^2\cdot s$)** after spatial mean.



Part 3

Nitrogen Implementation

Nitrogen Emission

NO

0.5~1 nmol/(mg chlorophyll·h) (Tischner et al., 2004)

chlorophyll density=6~18 mg/m^2 (Cota et al., 1997)

N_2O

i.e.

NO=5×10^7~3×10^8 molec. /(cm^2·s)

Assumption:

NO Flux=**1×10^8 molec. /(cm^2·s)**

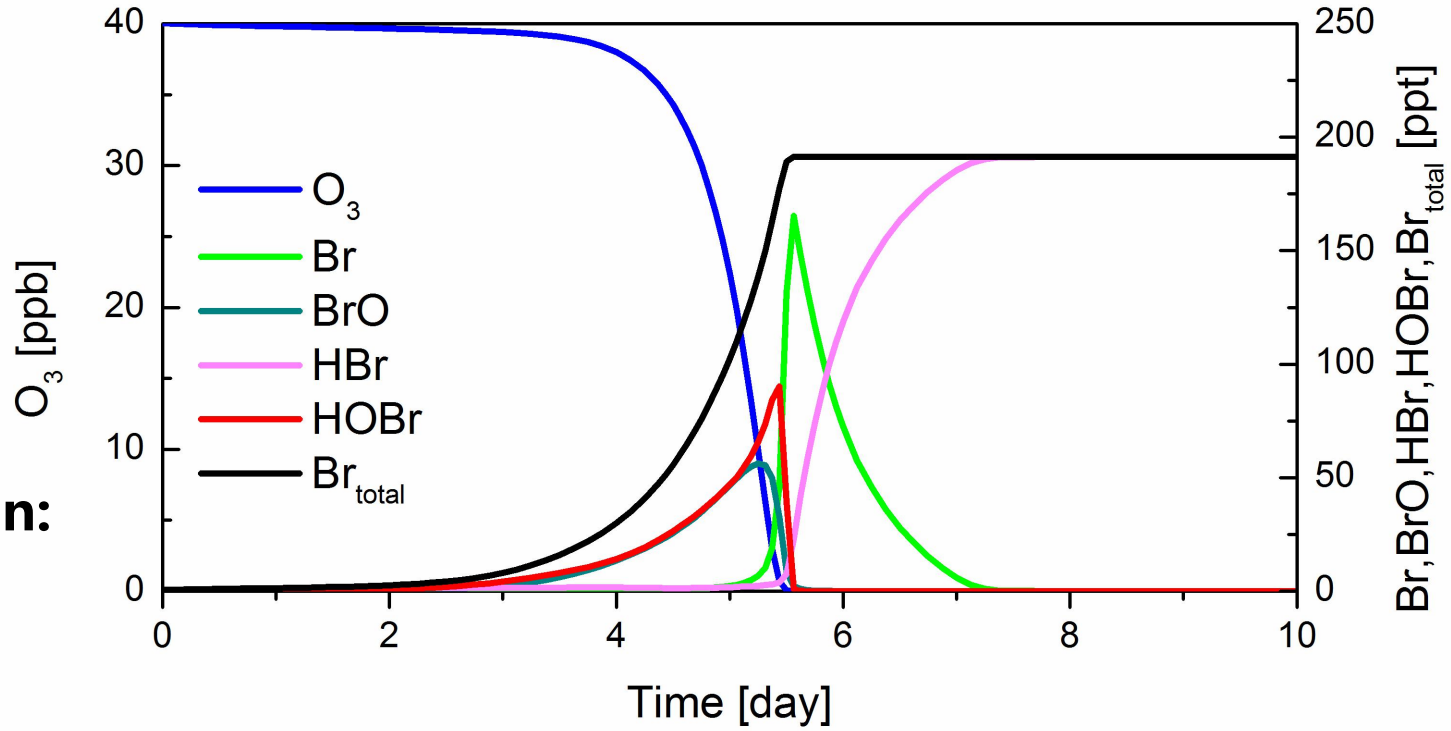
Part 4

Results & Discussions

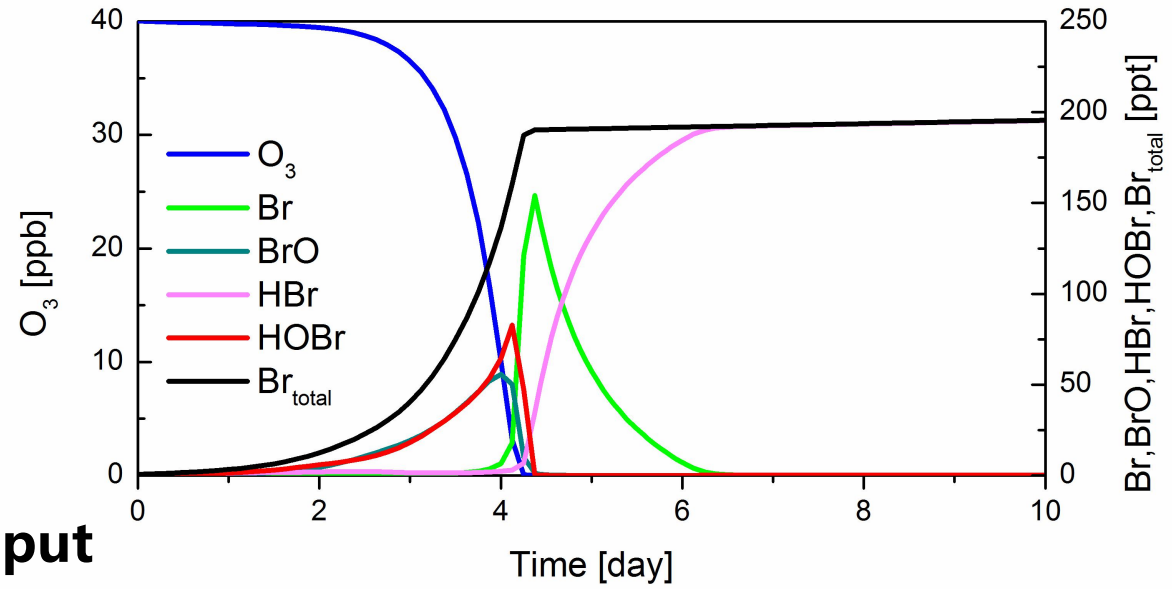
Inorganic Only

complete ozone depletion:

5.4 days



Organic Bromine

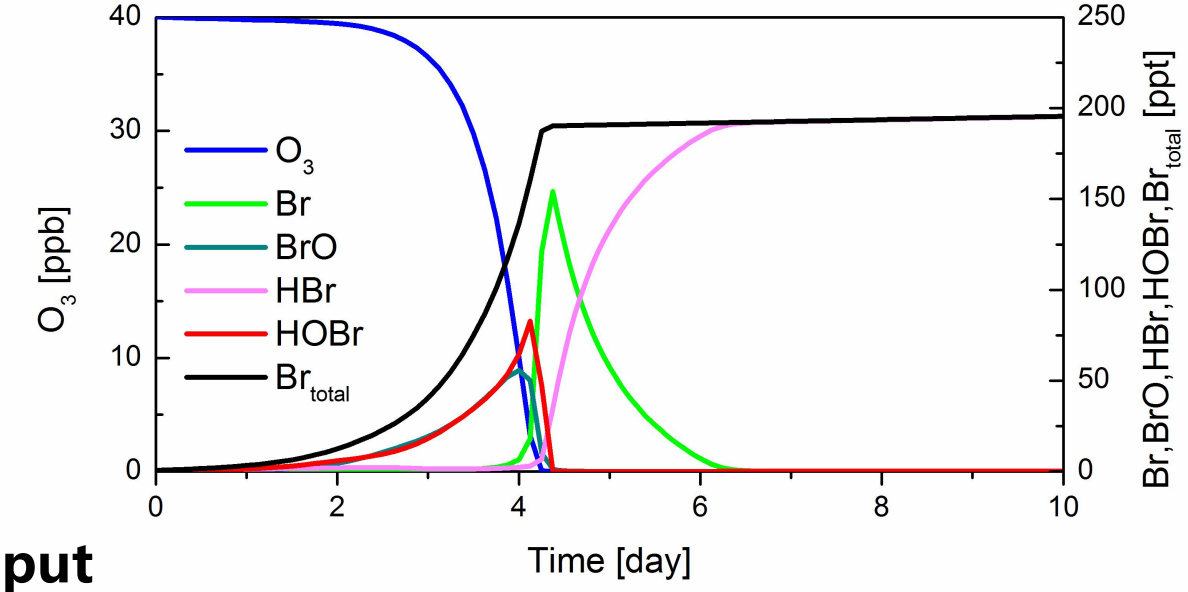


HOBr Input

Organic $HOBr/Br_2$ Input

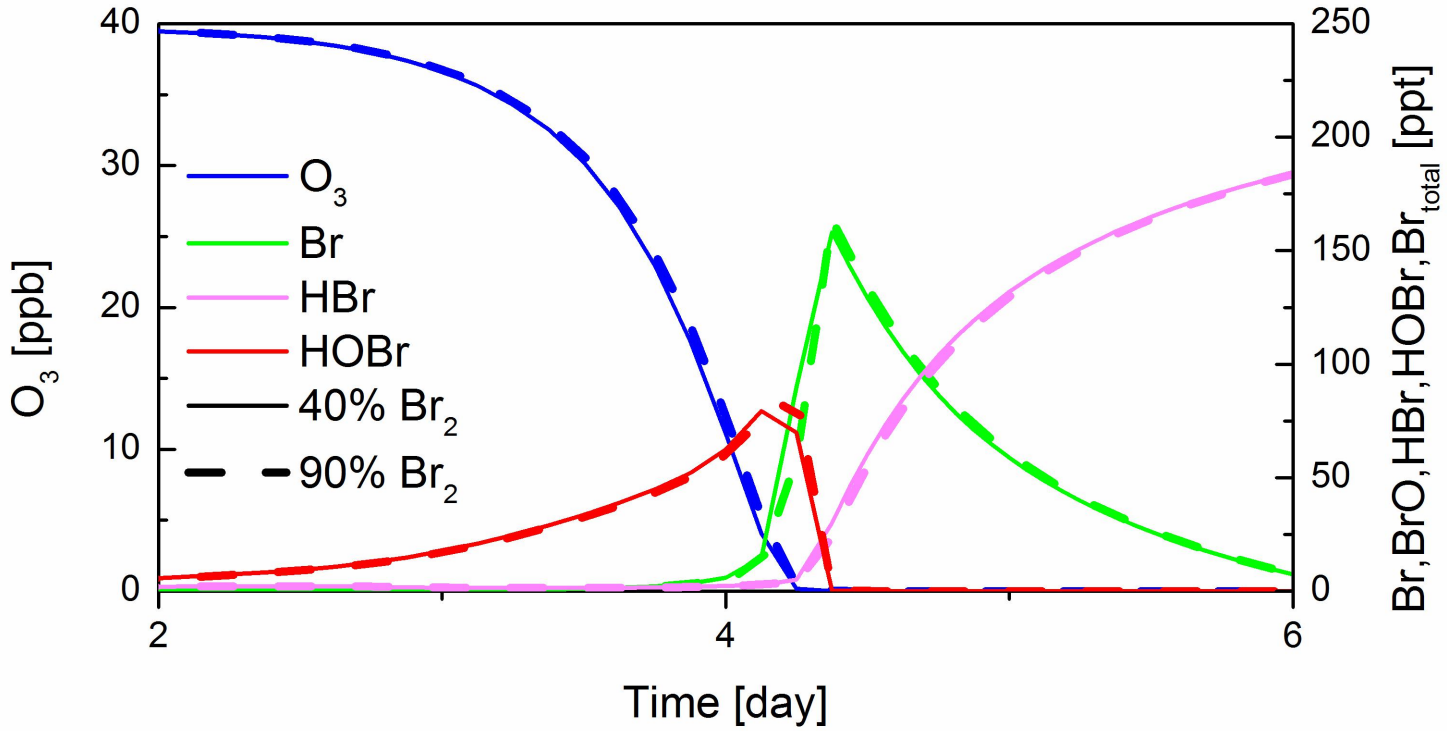
complete ozone depletion:

4.2 days



Br_2 Input

$HOBr–Br_2$



Portion of Br_2 does not make much importance.

s.t. Take assumption: $HOBr/Br_2$=6/2 (6/4 in bromine count)

Role of Br

$HOBr + h\nu \rightarrow Br + OH$	photolysis	$1 \rightarrow 1$
$HOBr + HBr \rightarrow Br_2 + H_2O$	heterogeneous	$1 \rightarrow 2$
$HOBr + H^+ + Br^- \rightarrow Br_2 + H_2O$	heterogeneous	$1 \rightarrow 2$

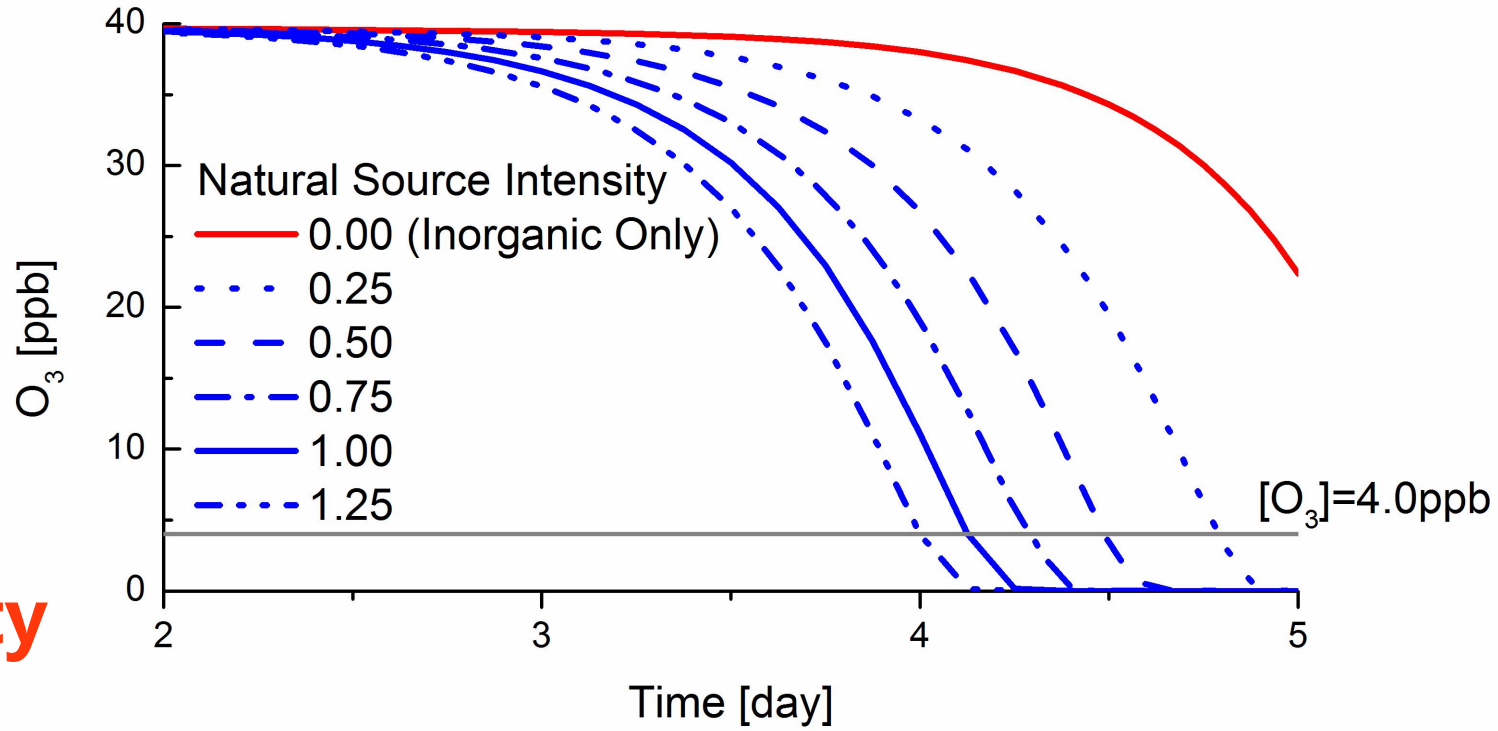
The photolysis process is the principal bromine reaction in the induction stage.

Impact of Br Input

Peak time and values of gaseous species, and stage beginning time under average level of organic source input.

	Peak Time [day]			Peak Value [ppt]			Depletion	End Stage
	HOBr	Br	BrO	HOBr	Br	BrO	Stage [day]	[day]
Inorganic Only	5.4	5.6	5.3	90	165	55	4.4	5.4
Algal [HOBr]	4.1	4.4	4.0	83	154	56	3.2	4.1
Algal [BR_2]	4.2	4.4	4.1	87	165	54	3.2	4.2

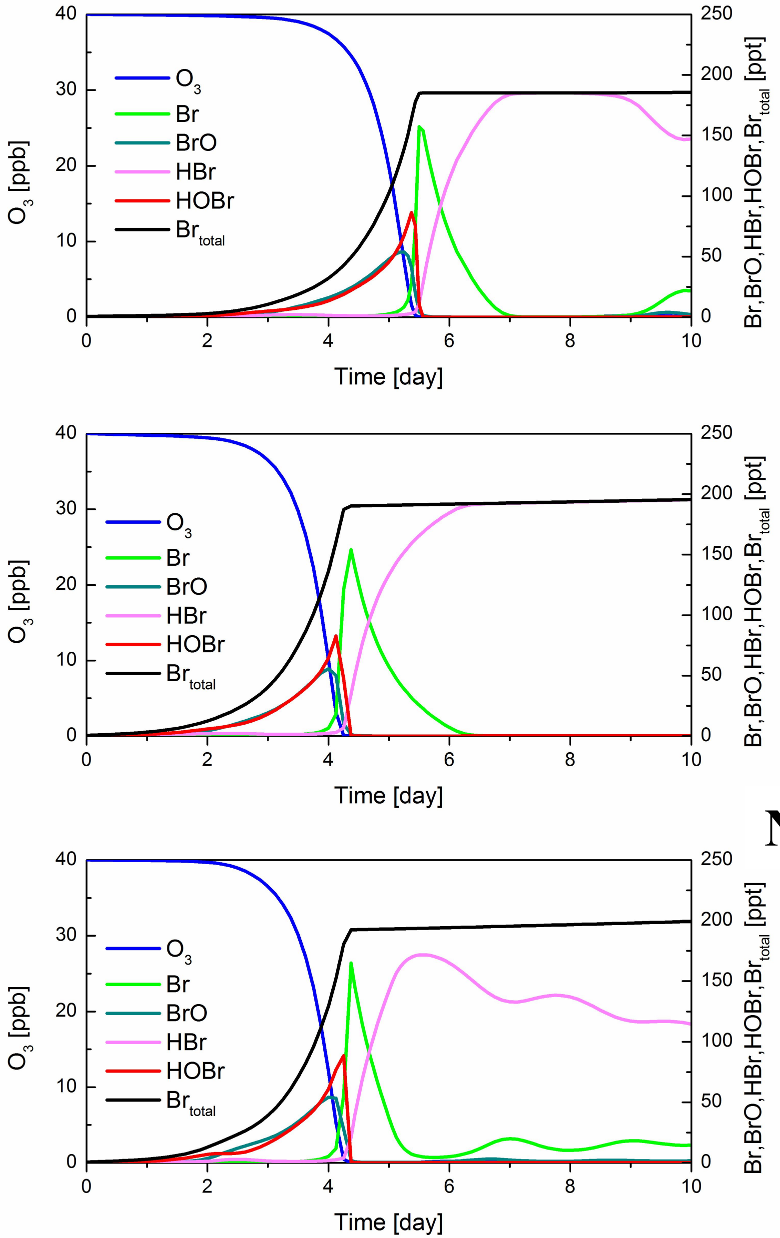
The induction stage is shortened for ~1.2 days, while the other stages are not significantly influenced.



Br Source Intensity

There is a limit to the induction stage reduction.

Impact of N



Peak time and values of specific events under different organic source input, as the organic source consists of average level of Br and N input at the same time.

		Br Peak	HOBr Peak	Br_{total} stability
Time [day]	Br Only	4.6	4.4	4.6
	Br and N	4.4	4.2	4.4
Value [ppt]	Br Only	158	85	185
	Br and N	164	88	192

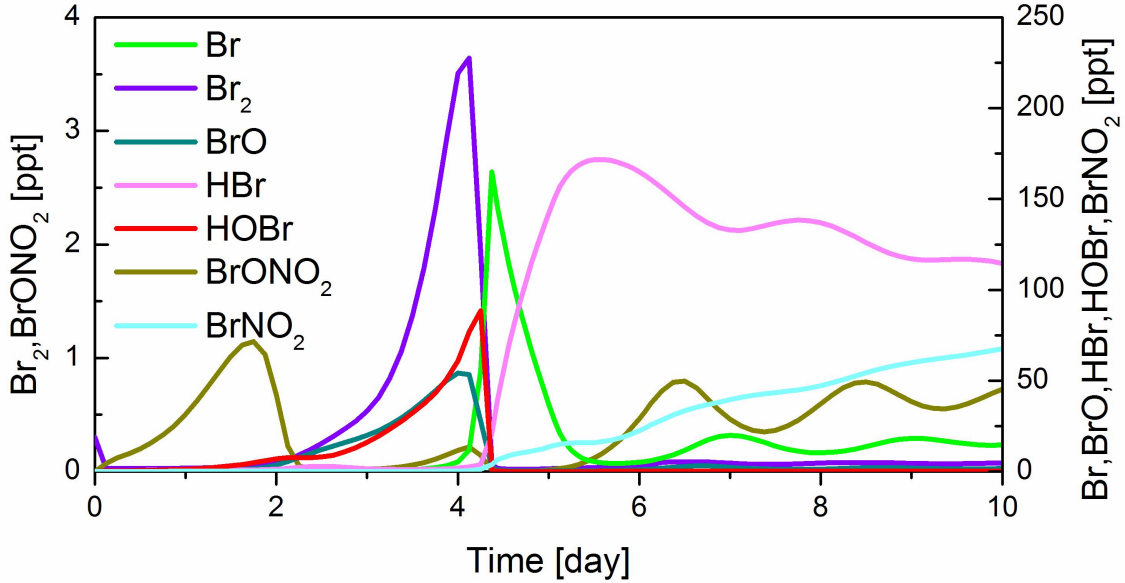
N input addresses minor influence on the atmospheric ozone.

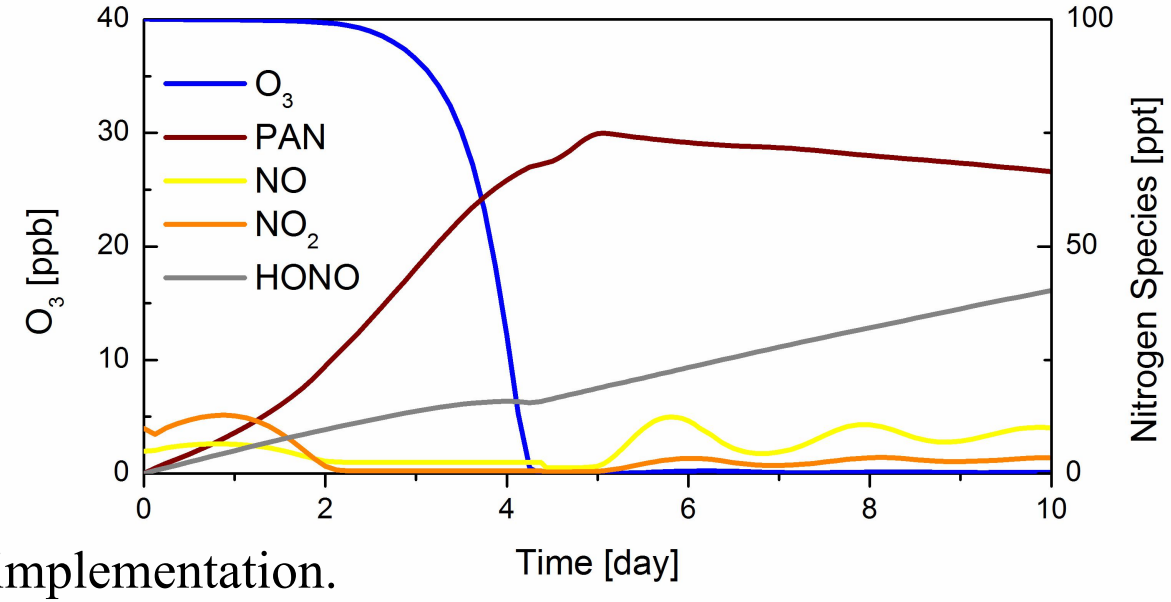
Simulated temporal volution of specific species under
(top) Inorganic Sources Only,
(mid) Inorganic and Br Sources, and
(bott) Inorganic and complete organic sources.

Impact of N

PAN (CH_3COONO_3) is the principal N sink.

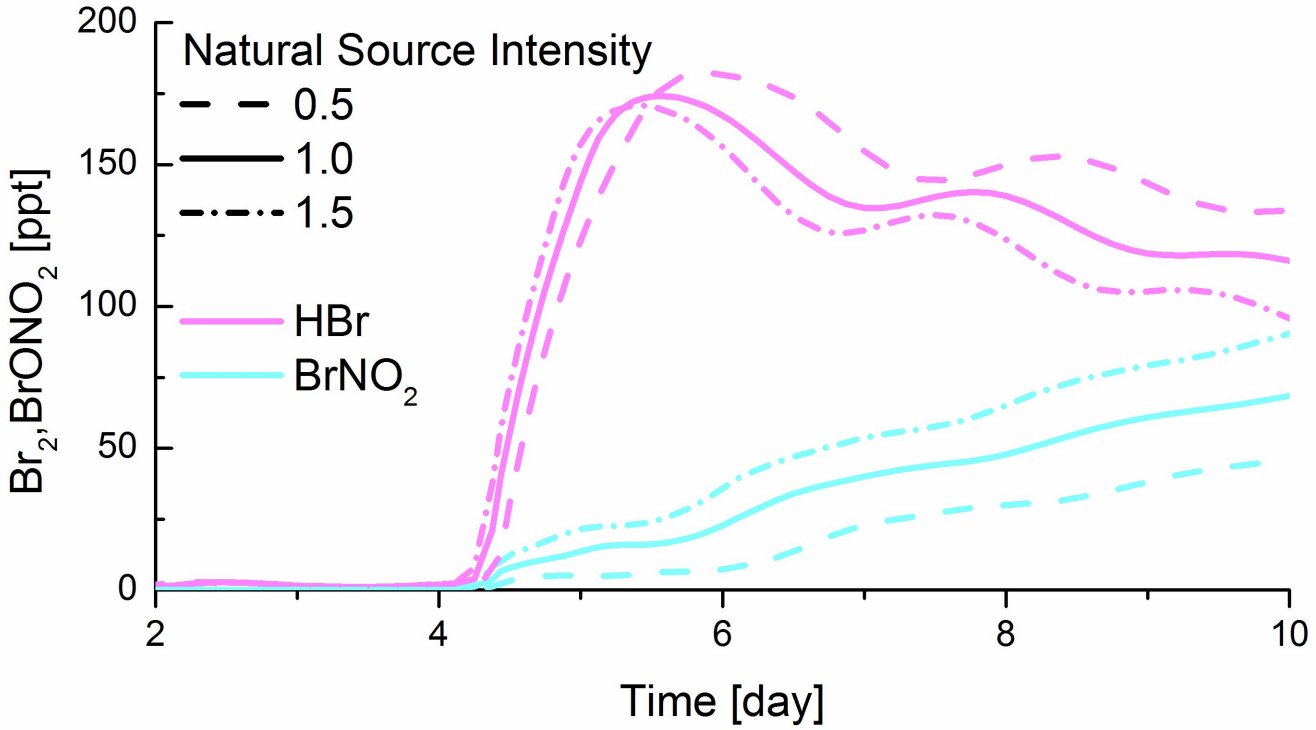
N input modifies the Br chemistry, transforming HBr to $BrNO_2$.





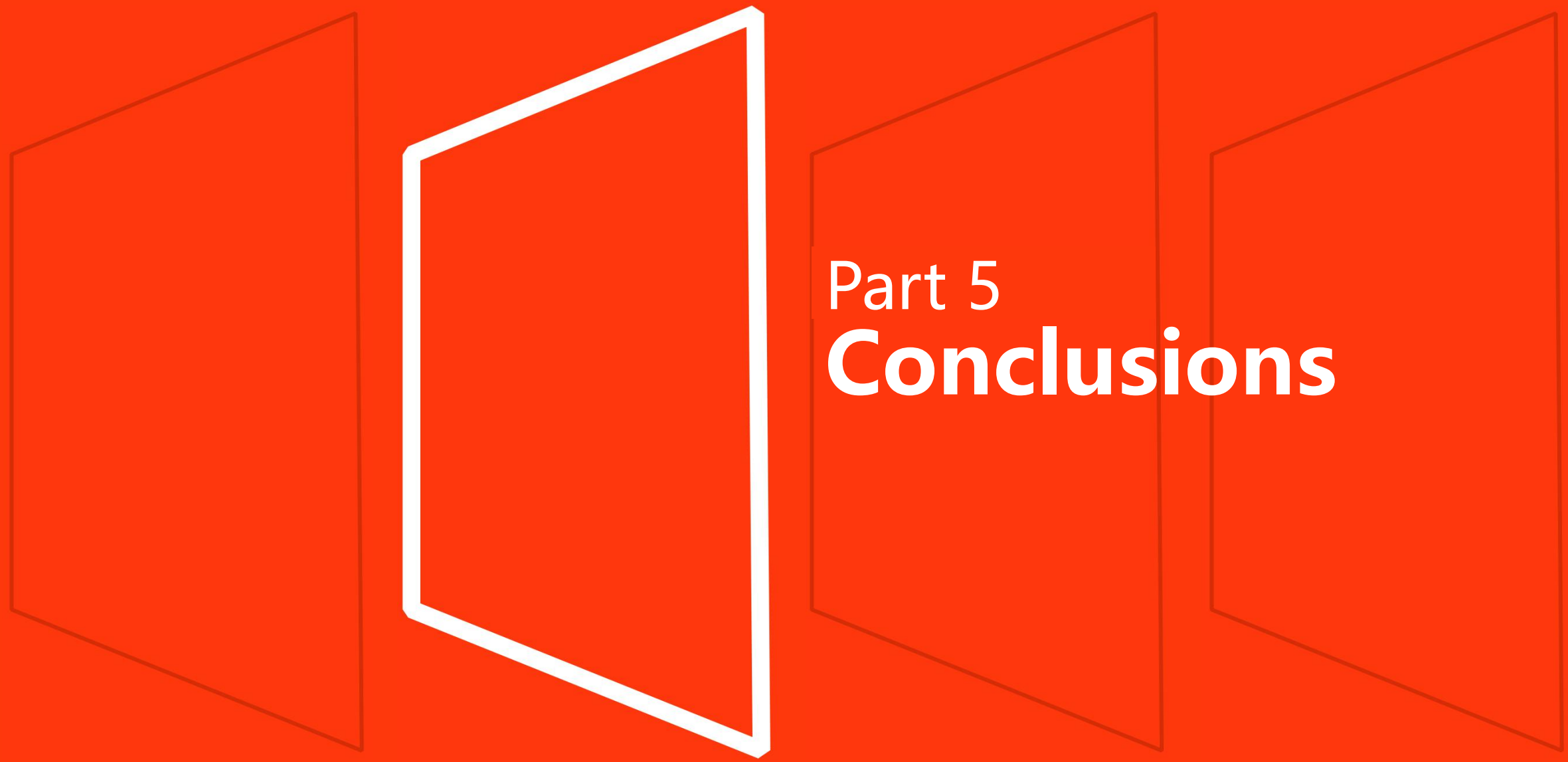
Simulated temporal evolution of
(top) bromine species, and
(bott) nitrogen species after nitrogen implementation.

Br Source Intensity



Prediction:

For NO input>1.5×10^8 molec. /($cm^2\cdot s$),$BrNO_2$ becomes the major atmospheric bromine.



Part 5
Conclusions

Conclusions

The natural organic source involved in the KINAL simulation consists Br and N input.

Br input is a mixing emission of HOBr and Br_2. An average level of Br input causes a 1.2 days antedate to the induction stage of the ODE, which lasts 4.4 days under inorganic sources only. The depletion and end stages are not obviously influenced.

N input is the NO emitted by various plants. Other than the negligible enhancement on the ozone depletion, NO input modifies the bromine chemistry to a great extent.


Q&A