Frost flowers on sea ice - a multi-disciplinary research effort for the upcoming IPY

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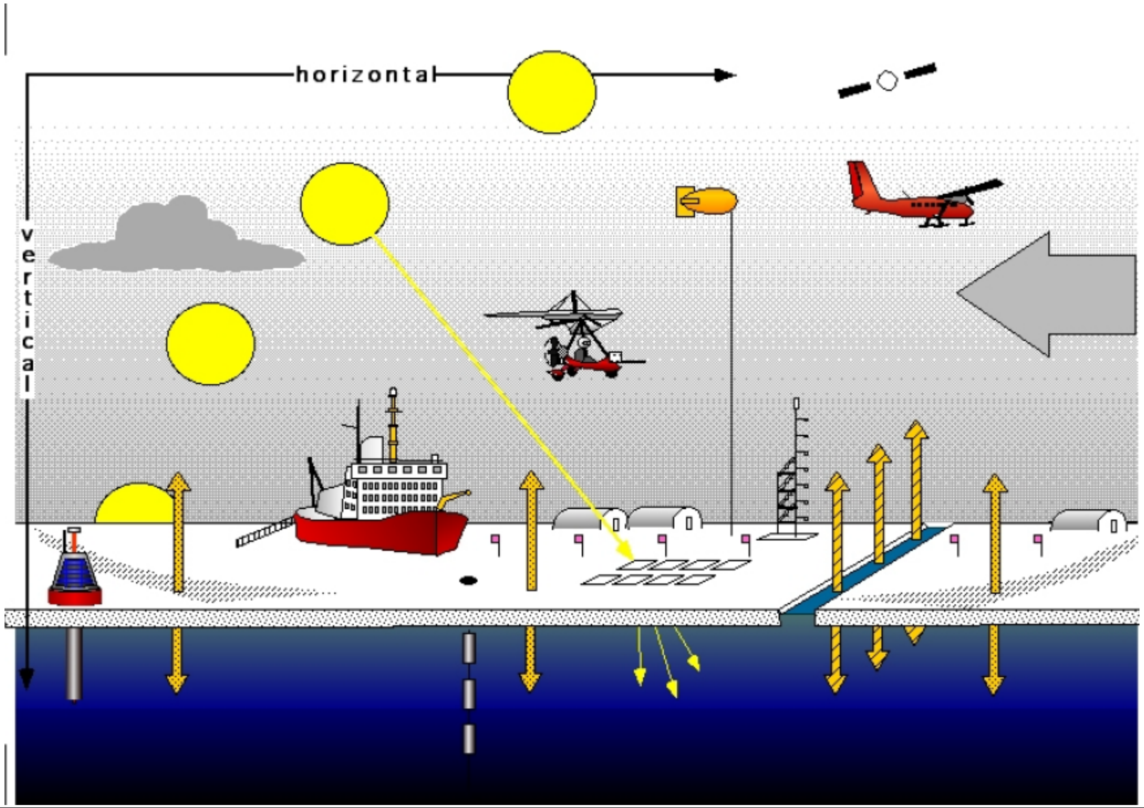
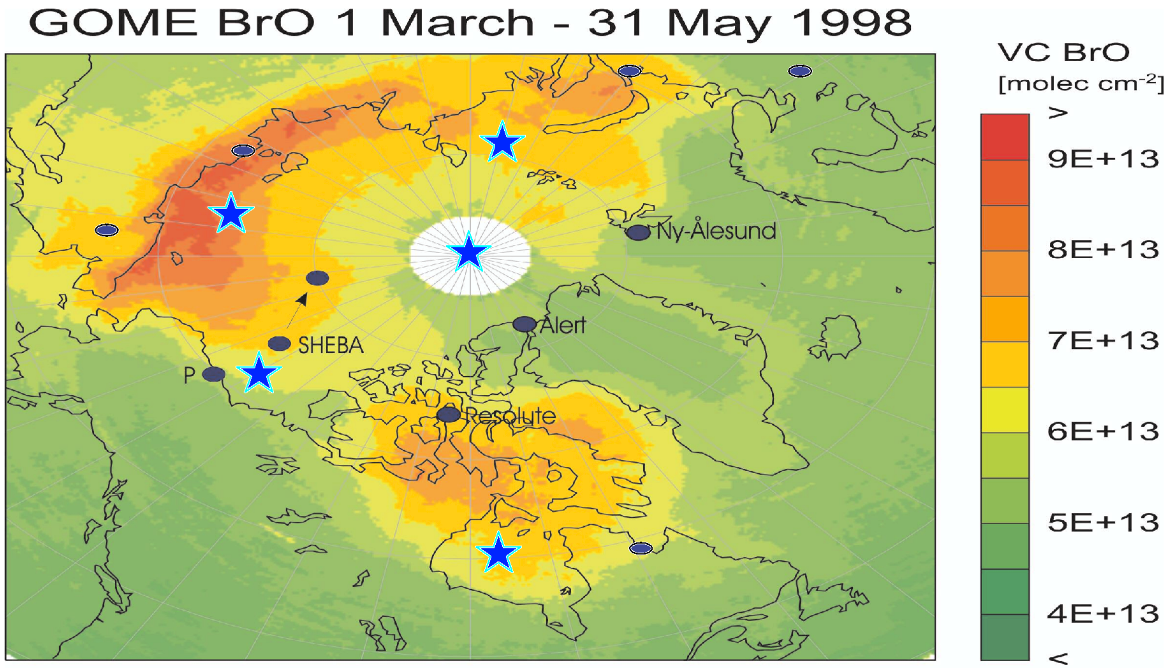
Ocean-Atmosphere-Sea-Ice-Snowpack-Projekt (OASIS)

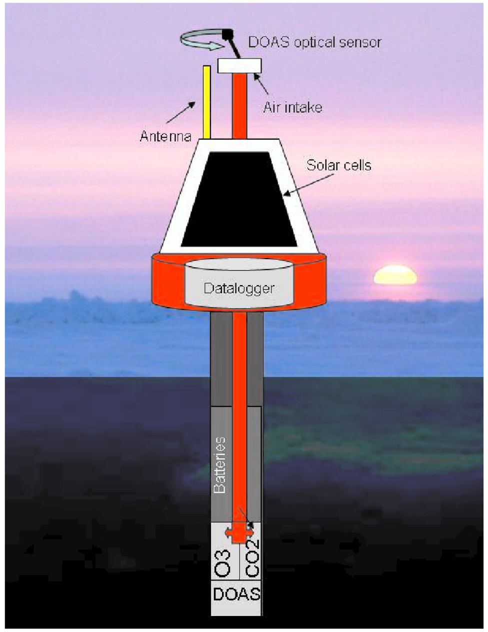
(OASIS ≈ “SHEBA 2” + Chemistry)



Conditionally endorsed IPY project - depends on funding

OASIS autonomous atmospheric chemistry buoy network

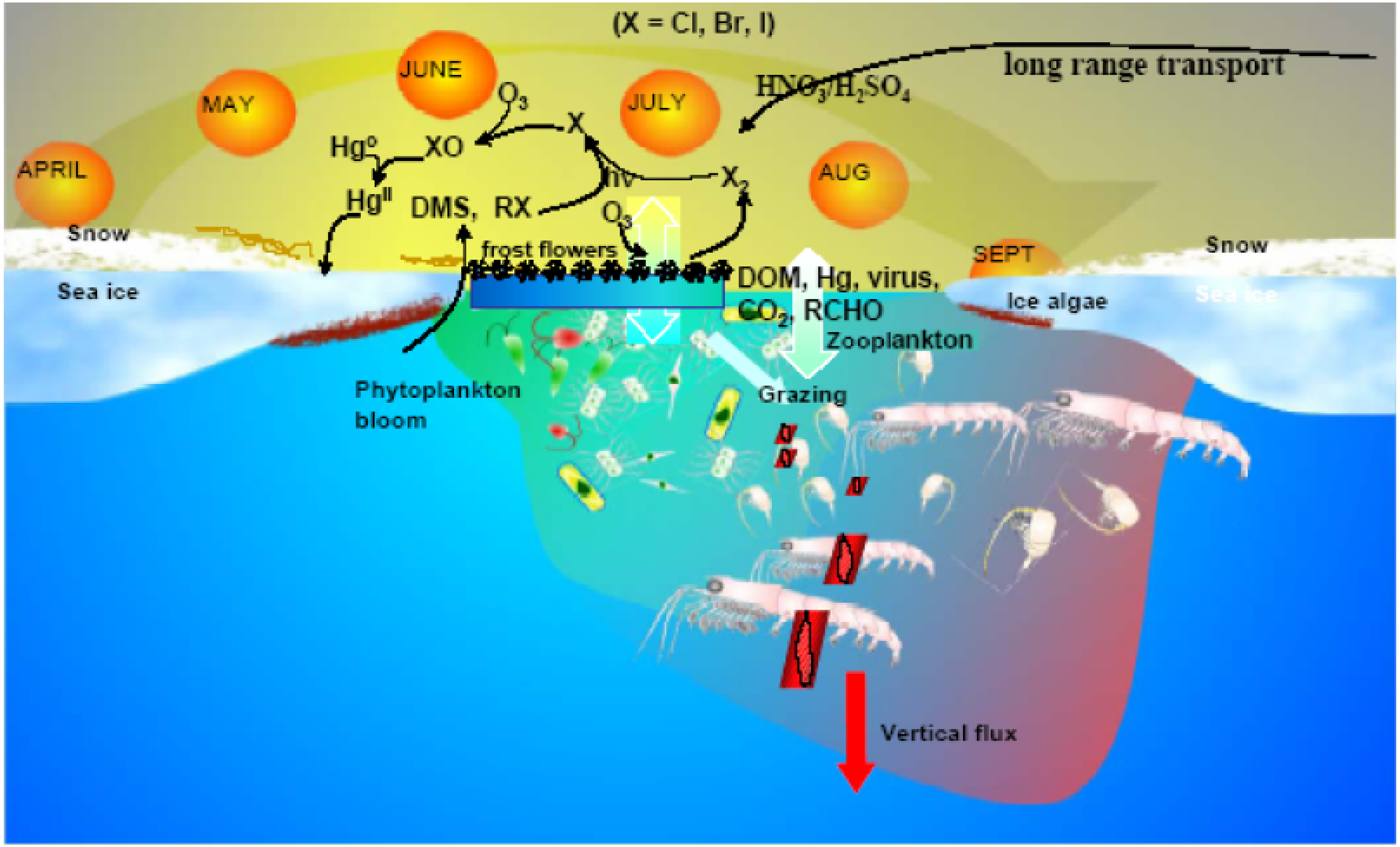




- ▶Enhanced BrO close to sea ice and polynyas
- ▶Airborne measurements will connect bouys, drifting icebreaker and stations

- ▶Surface ozone
- ▶BrO profiles
- ▶CO_2

OASIS Processes



A mechanism for halogen release from sea-salt aerosol

Vogt, Crutzen, Sander, *Nature 382*, 1996:

$HOBr + Br^- + H^+$	$\leftrightarrow$	$Br_2 + H_2O$	(1,-1)
$HOBr + Cl^- + H^+$	$\leftrightarrow$	$BrCl + H_2O$	(2,-2)
$BrCl + Br^-$	$\leftrightarrow$	Br_2Cl^-	(3,-3)
Br_2Cl^-	$\leftrightarrow$	$Br_2 + Cl^-$	(4,-4)
$Br_2 + h\nu$	$\rightarrow$	$2\,Br$	(5)
$2(Br+O_3)$	$\rightarrow$	$2(BrO + O_2)$	(6)
$2(BrO + HO_2)$	$\rightarrow$	$2(HOBr + O_2)$	(7)

$$\text{(net) } 2HO_2 + H^+ + 2O_3 + Br^- + h\nu \longrightarrow HOBr + 4O_2 + H_2O$$

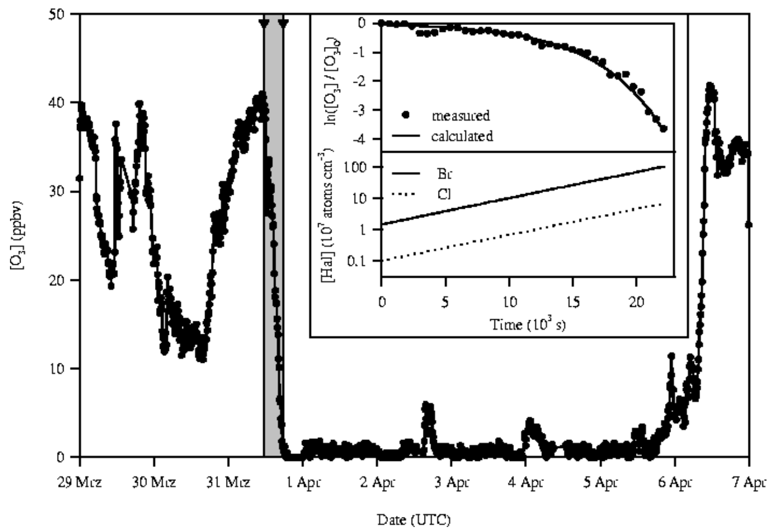
▶**Bromine explosion:** Every Br atom entering the liquid phase has the potential to release two Br atoms to the gas phase

Frost flowers are the reservoir for the bromine explosion

Courtesy of Stefan Kern (Univ. Hamburg)

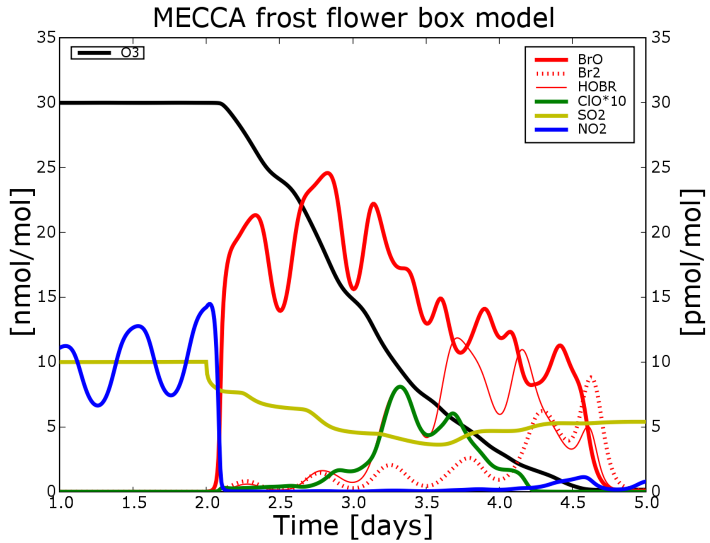
- Grow on thin ice at cold temperatures
- Very salty
- Large specific surface area
- Fragile crystals + wind $\rightarrow$ aerosol
- Sulfate fractionation
  Na_2SO_4 initially forms at $-8.2°$C
- Carbonate fractionation?
  $CaCO_3$ initially forms at $-2.2°$C

Observation of Ozone Depletion and Chemistry Model



Jacobi, Kaleschke, Richter, Rozanov & Burrows, subm.

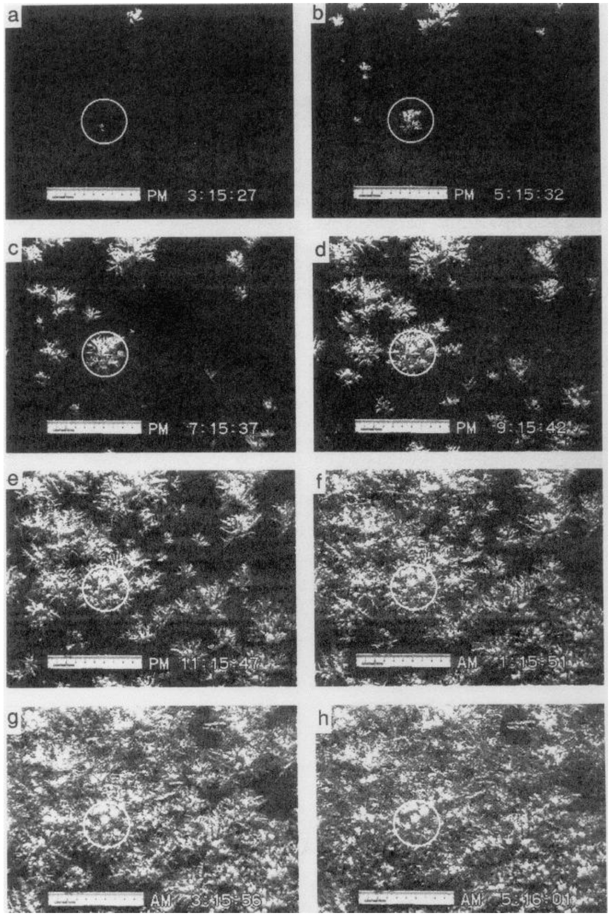
- ▶O_3 at Polarstern, spring 2003
- ▶ABL in the vicinity of frost flowers
- ▶Total ozone loss in less than 7h
- ▶Local chemistry, not transport



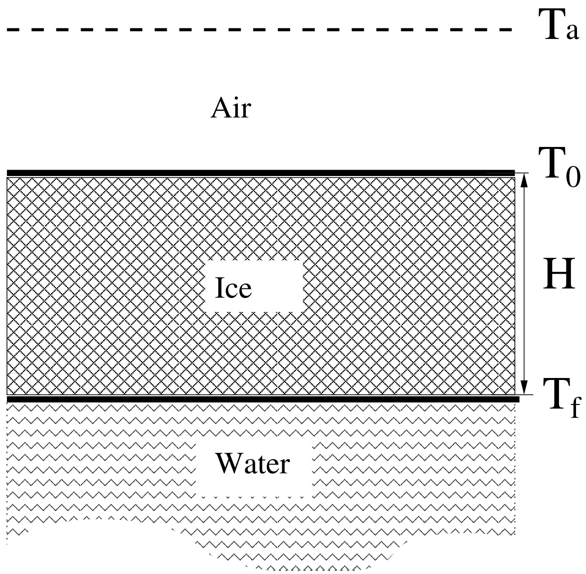
Sander, Kaleschke, Burrows, Cox, Glasow & Simpson, in prep.

- ▶Frost flower aerosol box model
- ▶HCO_3 removed
- ▶High sea salt concentration
- ▶Major change of oxidative capacity

Frost Flowers in the Laboratory



Martin *et al*, *JGR*, 1996



Area growth rate g depends on temperature gradient $\Delta T = T_0 - T_a$:

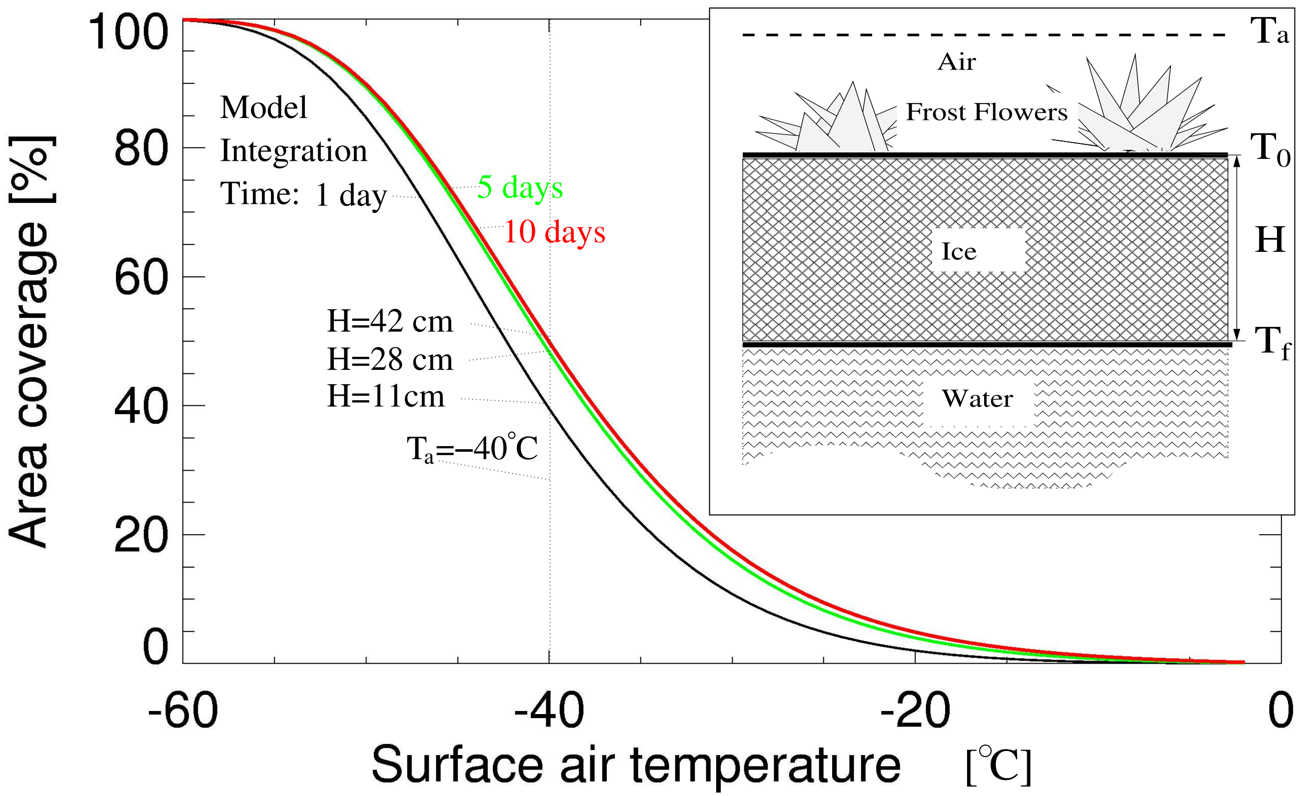
$$g = Be^{A\Delta T}$$

Frost Flower Model

- Input parameters
  - Open water area= 1 - sea ice concentration
  - Air temperature at the surface T_a
- Sea ice thickness $H(T_a)$
- Ice surface temperature $T_0(H, T_a)$
- Area growth rate $g = Be^{A(T_0 - T_a)}$
- Frost flower coverage

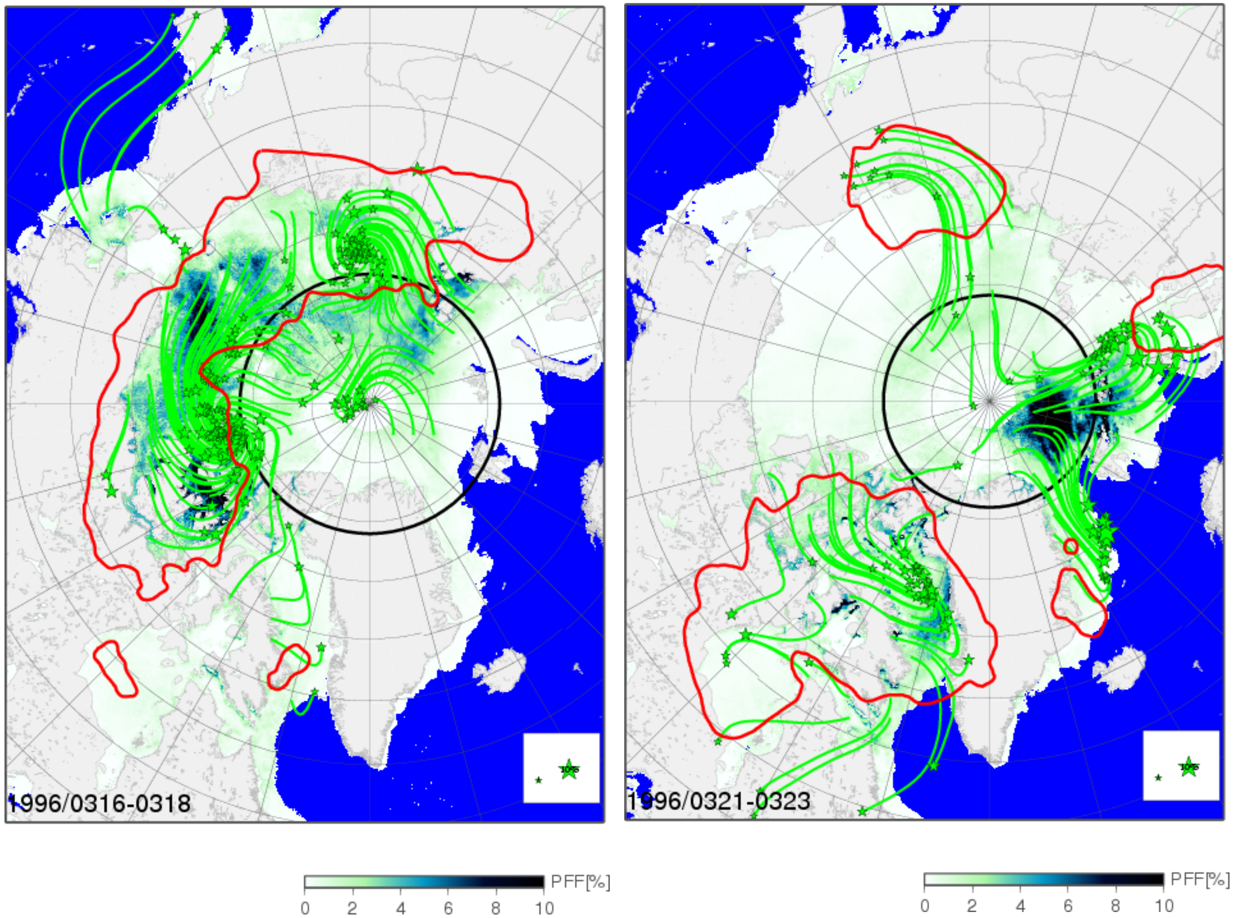
Kaleschke *et al., GRL*, 2004

Model Result



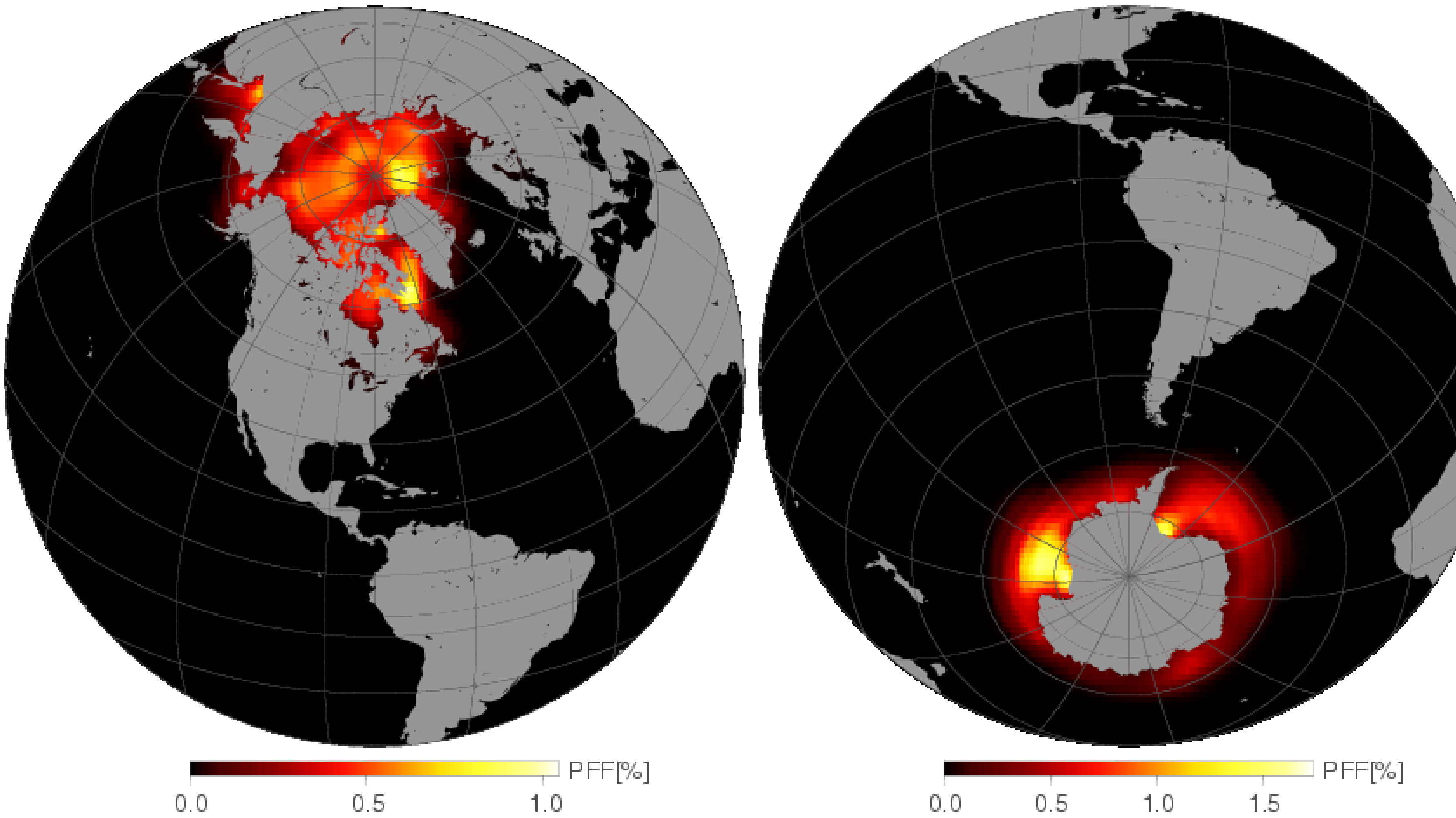
Upper limit (≈10 days): *Potential Frost Flower (PFF) coverage on new ice*

Comparison of FF model and BrO measurements

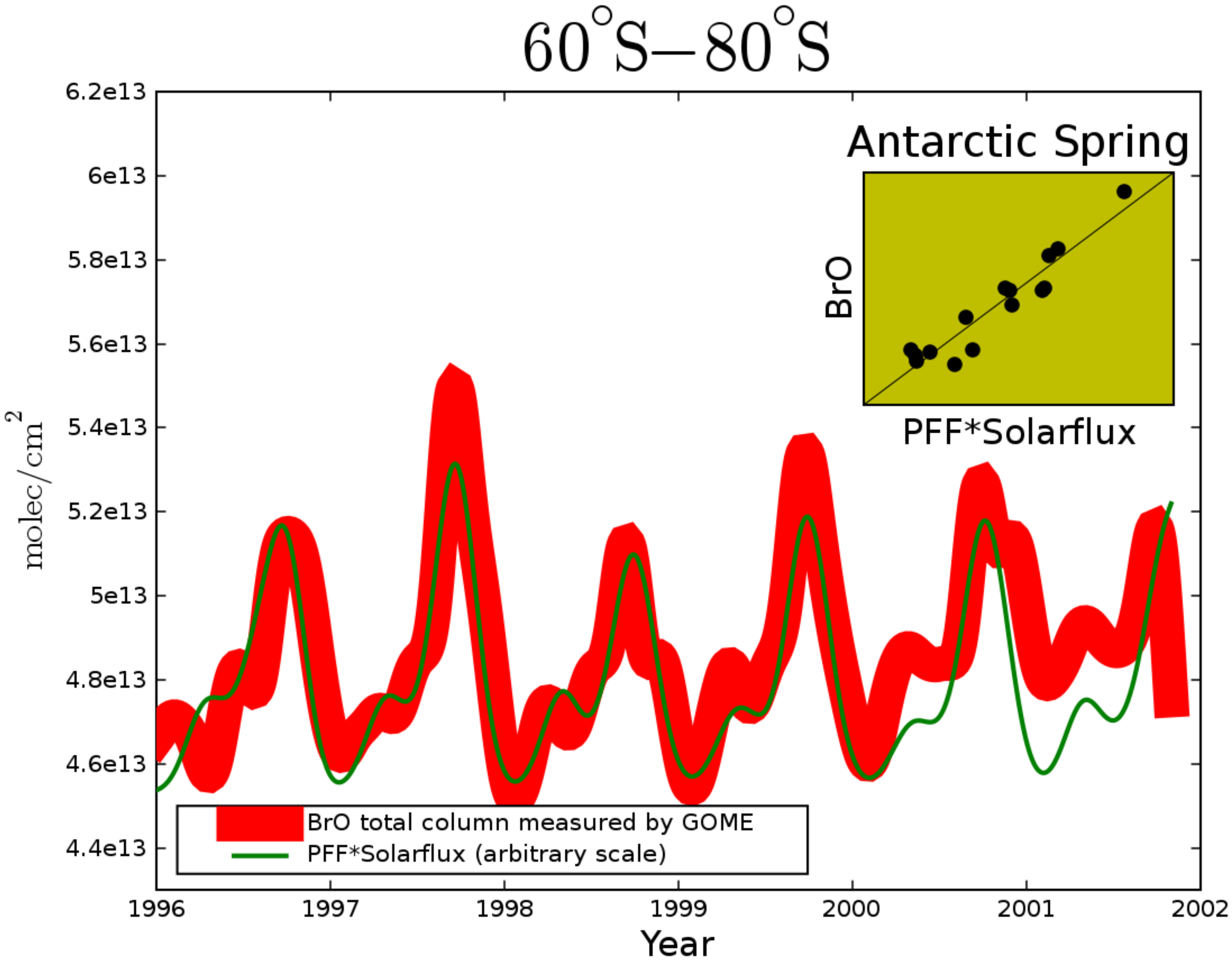


- Red isolines: enhanced BrO
- Green lines: air trajectories starting at high PFF values
- Green stars: traj. endpoints, size $\sim$ PFF
- Black circle: SZA $>$ 80° (almost dark)

Global Potential Frost Flower Distribution (1996-2001)



Potential Frost Flowers and BrO Measurements



Outlook

- Conduct OASIS IPY field campaign and lab experiments
- Improve techniques for remote sensing of frost flowers and develop parameterisation of sea salt aerosol production
- Integrate frost flower in climate and chemical transport models
  Univ. of Cambridge; MPI Mainz; York Univ. Toronto
- Paleoclimatic re-interpretation of ice core records
- Feedback effects?
  Declining sea ice $\rightarrow$ less trop. BrO $\rightarrow$ more trop. O_3 $\rightarrow$ warming

Thank you for your attention!

Arved Fuchs, Northern Searoute 2002