The Climate Ocean and Sea Ice Model (COSIM) project
Computational and Theoretical Science Divisions

Gases in Sea Ice ^ and around

LANL: S. Elliott, E. Hunke, N. Jeffery, M. Maltrud
IARC: C. Deal, M. Jin
LBL: M. Reagan, G. Moridis
LLNL: P. Cameron Smith, D. Bergmann
Others: B. Loose, J. Stefels, M. Levasseur

U.S. DOE SciDAC for Earth System Modeling,
Plus Gas Hydrates and IMPACTS methane cycling

OUTLINE: Gases and Sea Ice

OPENING MONTAGE –volatiles on parade

ECOLOGY first but MINERALOGY close behind

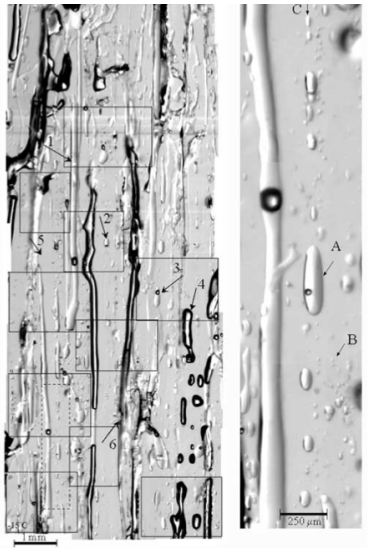
Extreme THERMO and C BUDGETS coming fast

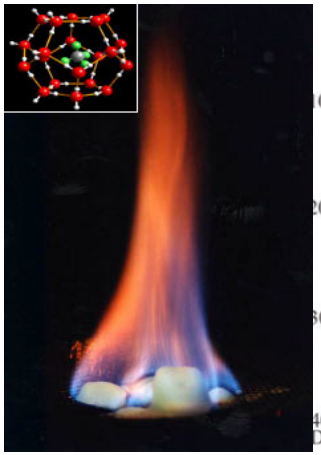
ORGANOSULFUR in ice and surroundings

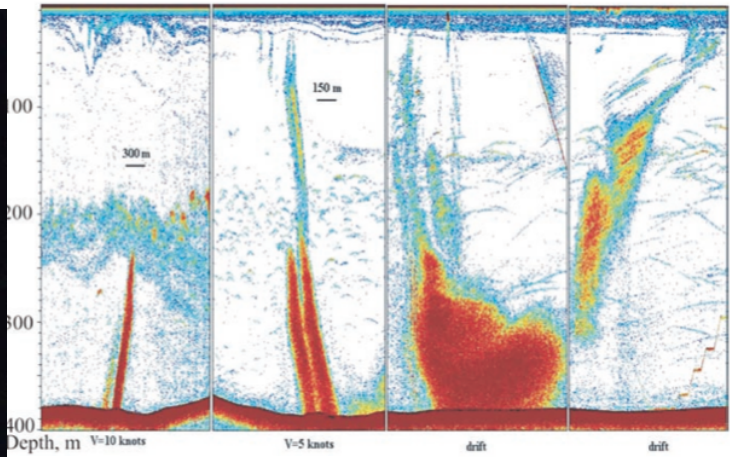
METHANE BUBBLES below, to, through pack

OTHER compounds including halogens

CO_2, DMS, O_2, CH_4…

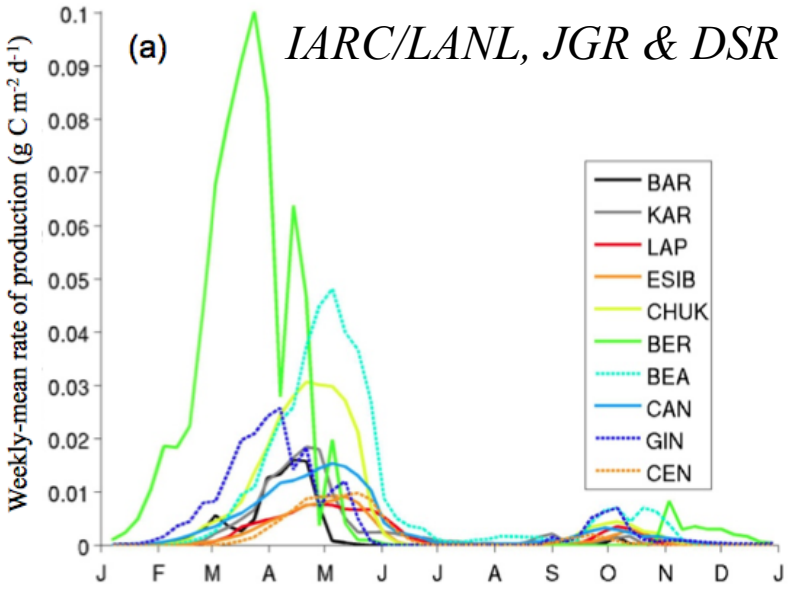


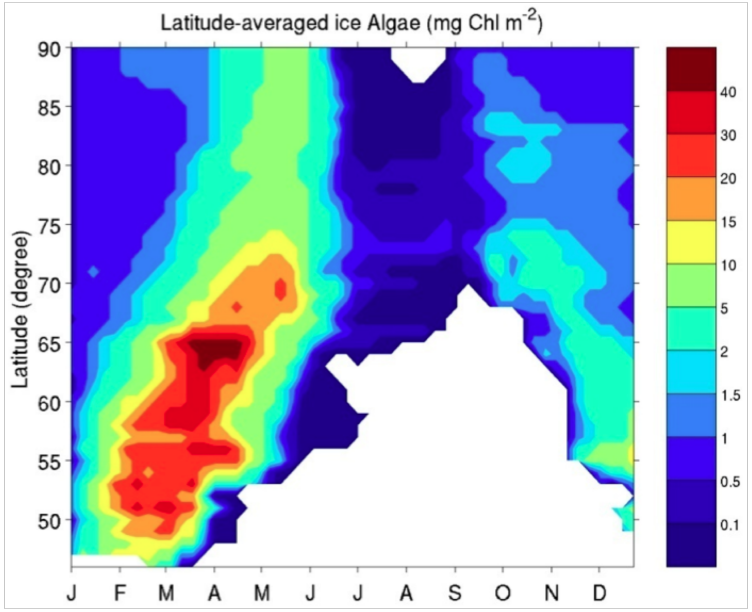


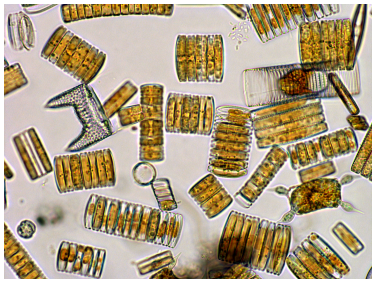


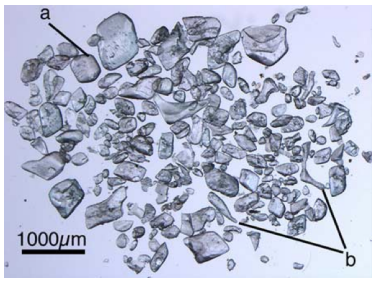
Loose et al. 2011
Deboer et al. 2011
Light et al. 2002
Obzhirov et al. 2004
Shakhova et al. 2009

All roads lead to ecodynamics, but…









N, Si, Fe drive:

$nCO_2 + nH_2O = (CH_2O)n + nO_2 + \Delta alkalinity$

$Ca_2^+ + CO_3^{2-} = ikaite + \Delta alkalinity$

$H_2O.CO_2 = H^+ + HCO_3^-$

$HCO_3^- = H^+ + CO_3^{2-}$

Vertical and ice-air transfer

All hypersaline: Pitzer eqs.

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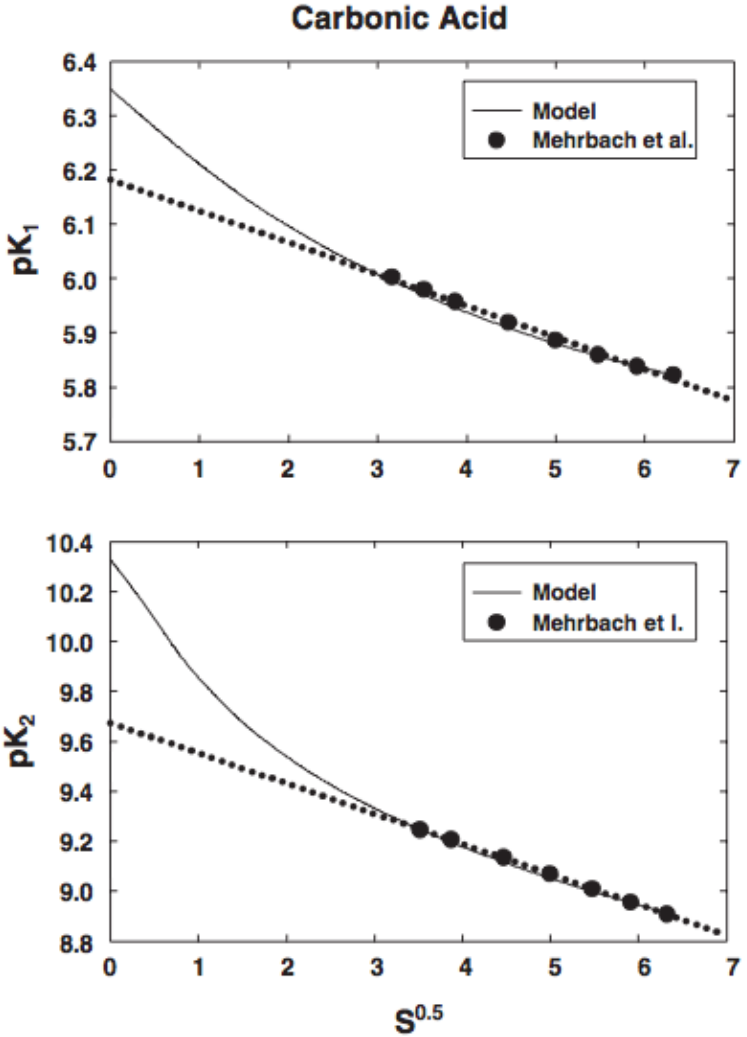
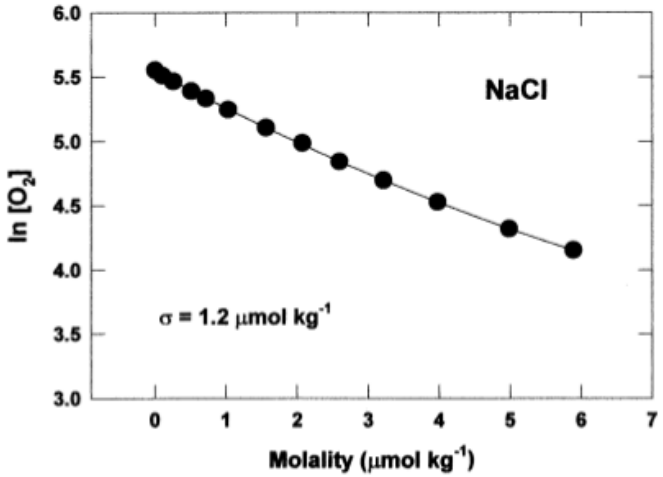
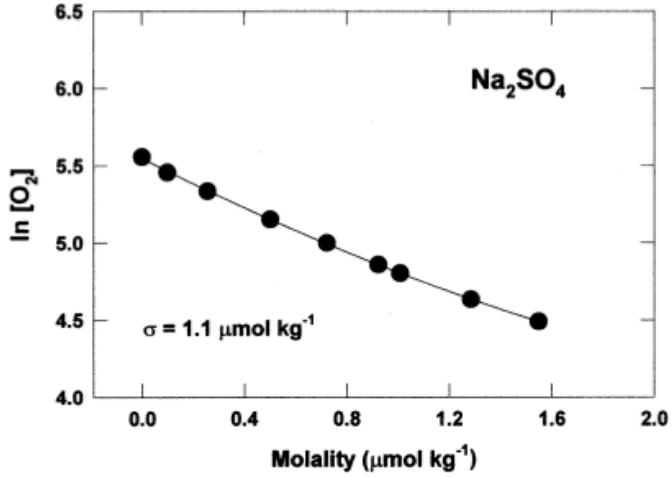
Extreme Thermochemistry





$$\ln\gamma_N = 2\Sigma_n\lambda_{Nn}m_n + 2\Sigma_c\lambda_{Nc}m_c + 2\Sigma_a\lambda_{Na}m_a + 3\Sigma_n\mu_{Nnn}m_n + 6\Sigma_n\Sigma n' m_n m_{n'}\mu_{Nnn'} + 6\Sigma_n m_N\mu_{NNn} + 6\Sigma_n\Sigma_c m_n m_c\mu_{Nnc} + 6\Sigma_n\Sigma_a m_n m_a\mu_{Nna} + 6\Sigma_c\Sigma_a m_c m_{ca}\zeta_{Nca} + \Sigma\Sigma_{c<c'} m_c m_{c'}\eta_{Ncc'} + \Sigma\Sigma_{a<a'} m_a m_{a'}\eta_{Naa'}$$

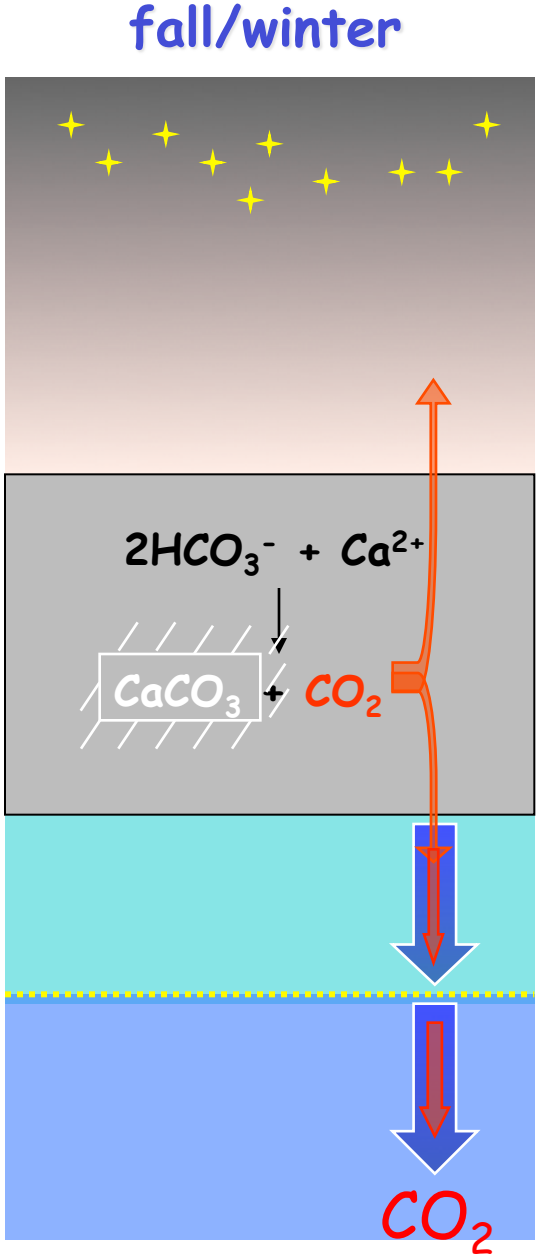


Millero et al., several ? No, CRREL as usual

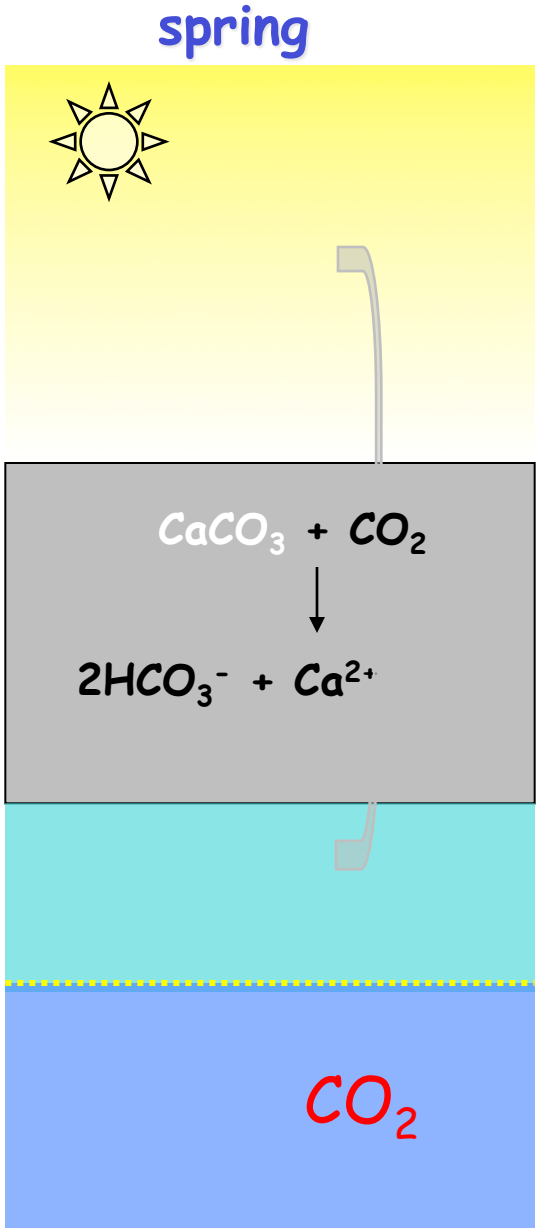
Pitzer equations -just Debye-Huckel on steroids

GAS COMPOSITION IN SEA ICE

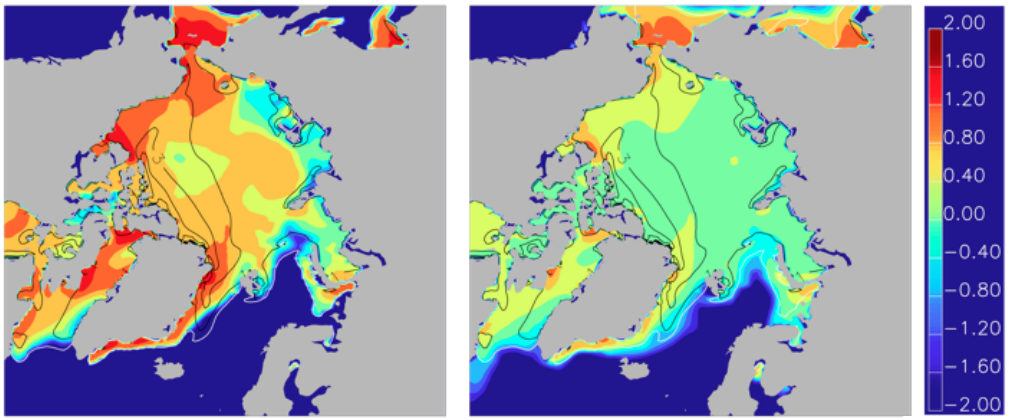
A potential abiotic $CaCO_3$ Carbon pump

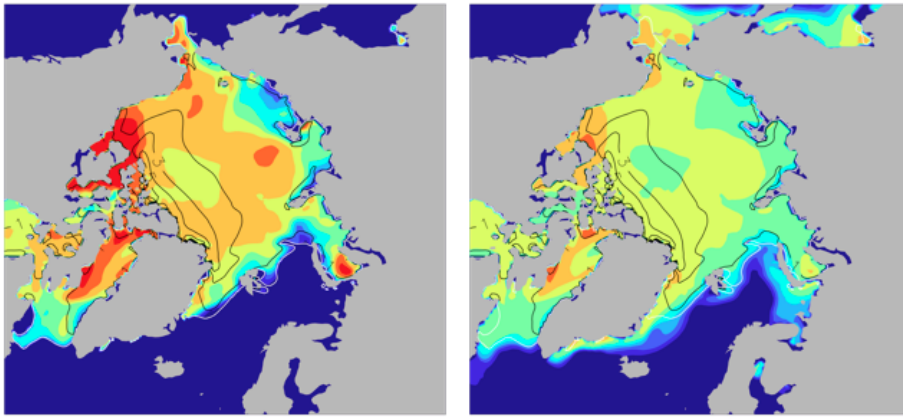


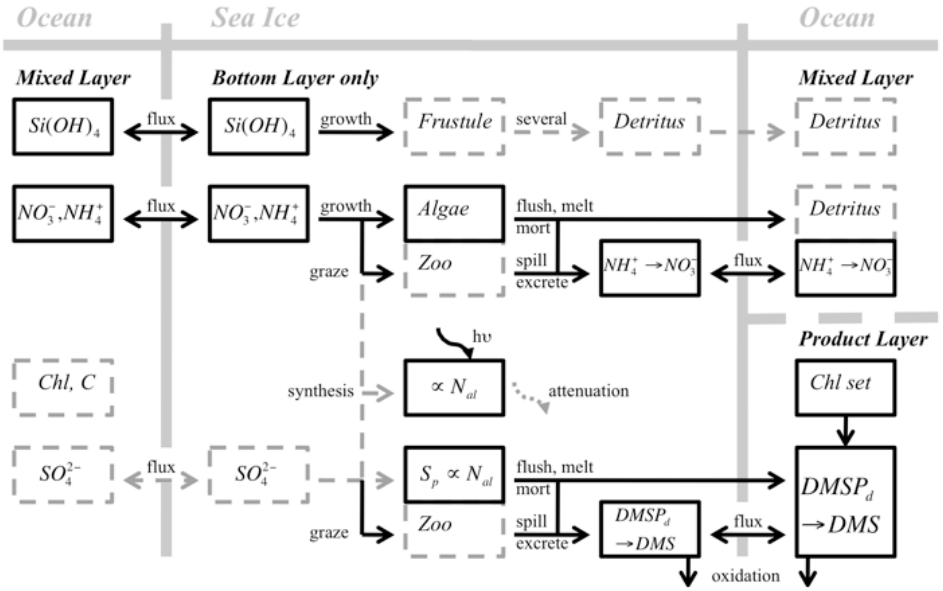
- In spring, $CaCO_3$ trapped within sea ice dissolves. This process consumes CO_2.
- Budget of winter and spring processes is a net sink of CO_2. It depends on:
  - ratio of $CaCO_3$ trapped vs CO_2 expelled (?)
  - quantity of CO_2 which pass below the pycnocline during the autumn-winter (?)



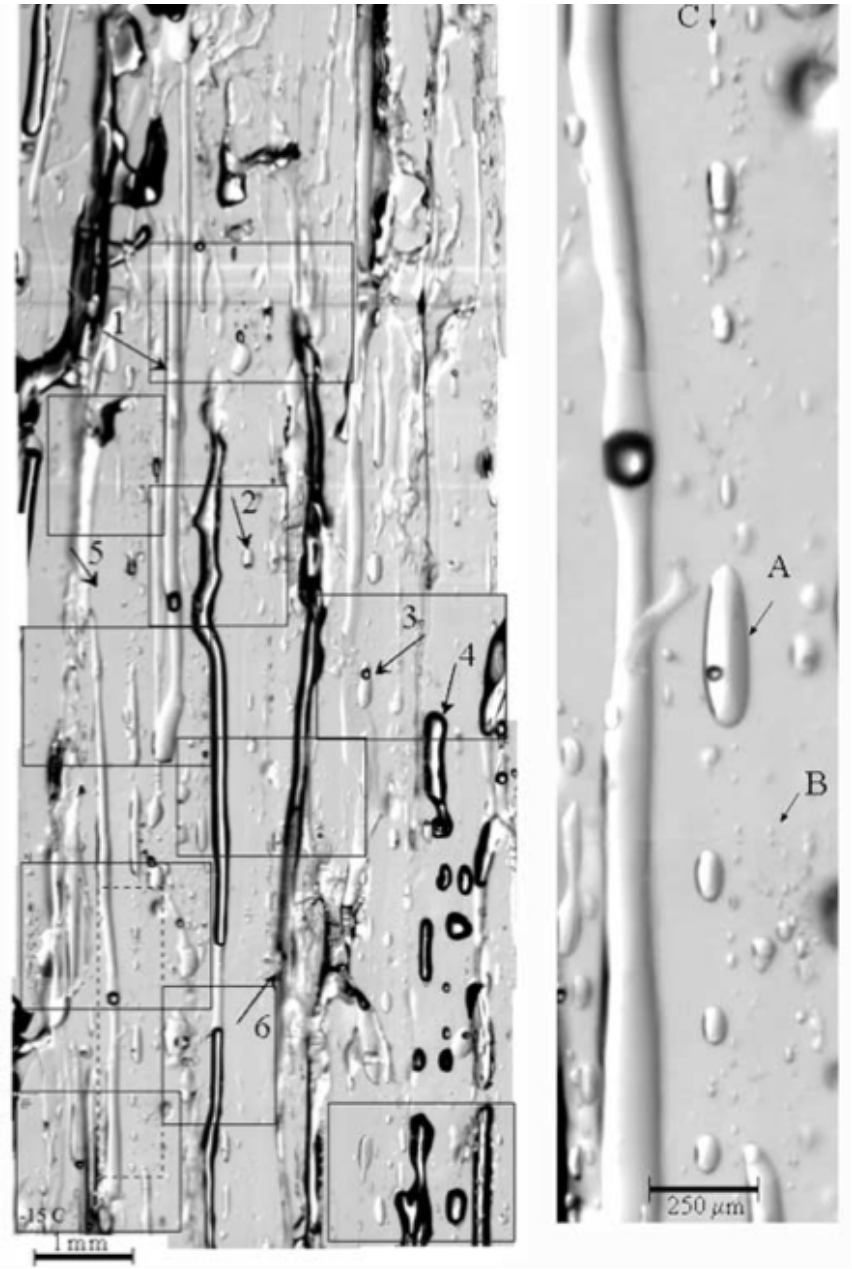
Rysgaard et al., 2007, Delille et al., in prep.







DMS in May: Sensitivities below CICE



Major Elements

O_2, photo-radical chemistry

-Biological stress

Nitrogen redox:

-de&nitrification, N_2O

(Which incidentally…

(Points to rest of N system…

(Reduced gases too, NH_3/NH_4+)

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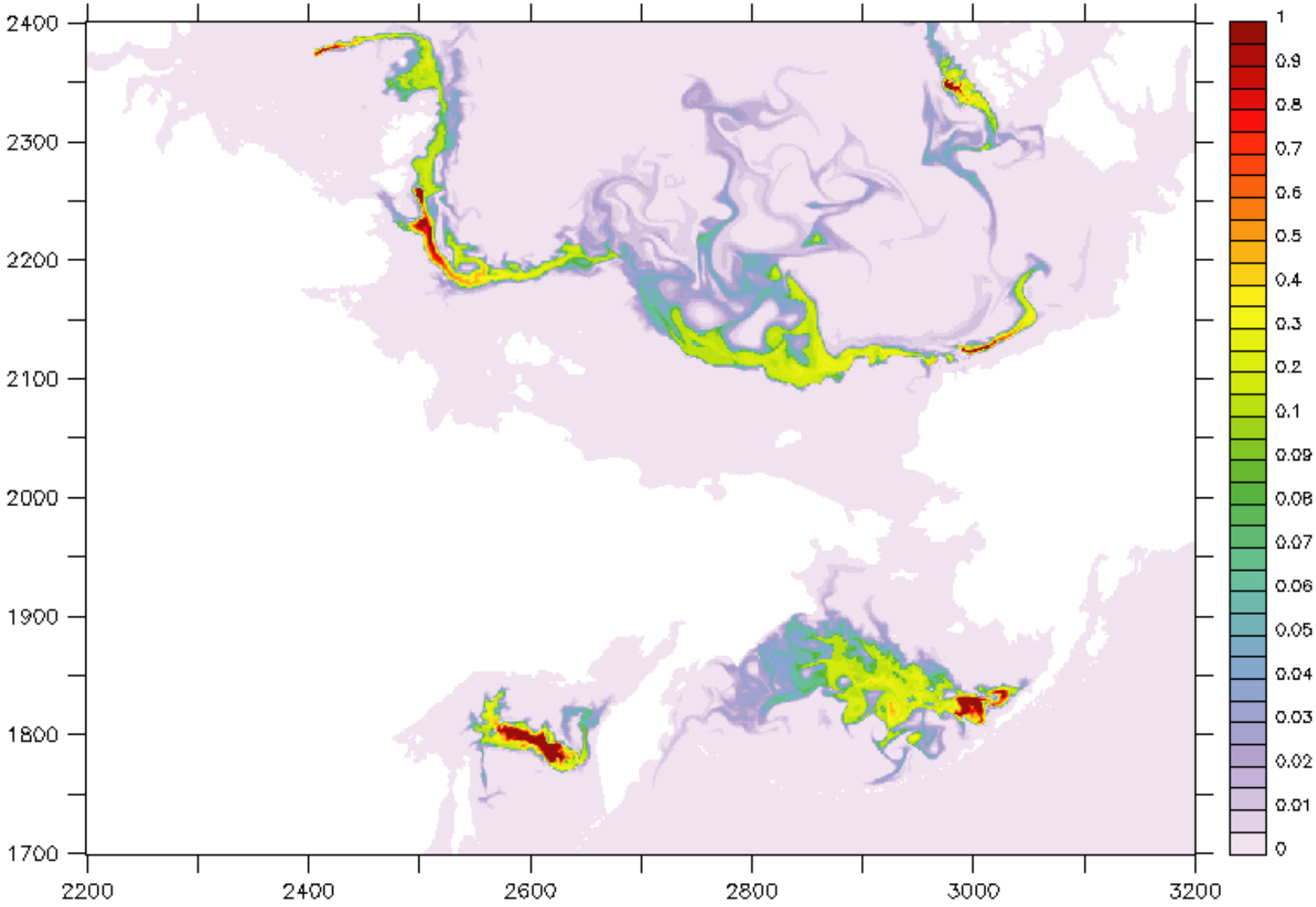
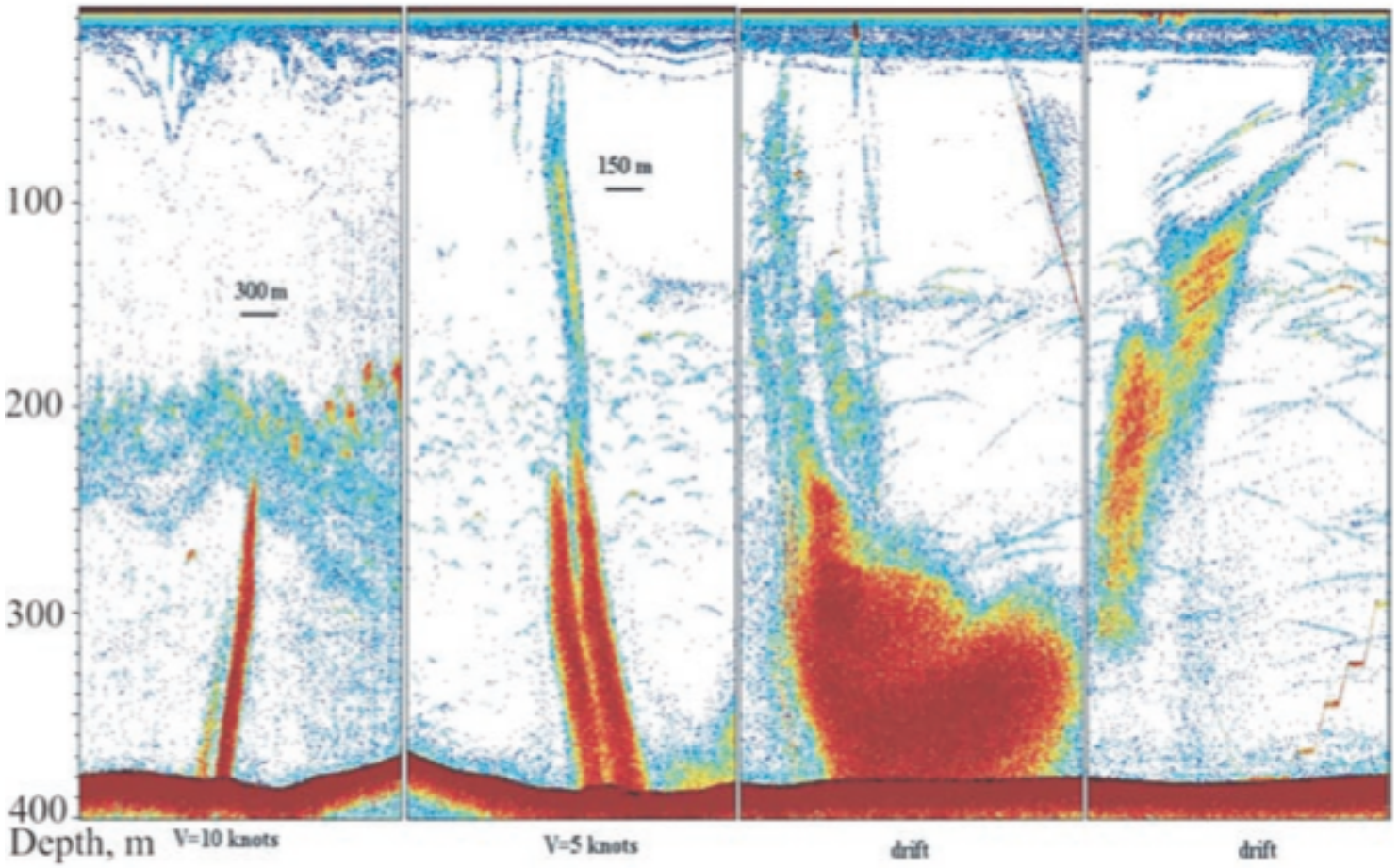
Clathrate destabilization for DOE Impacts and Fossil

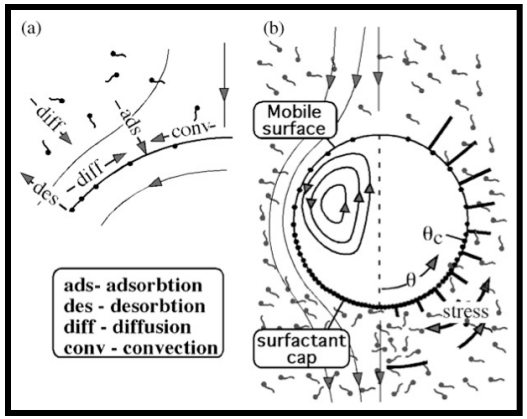


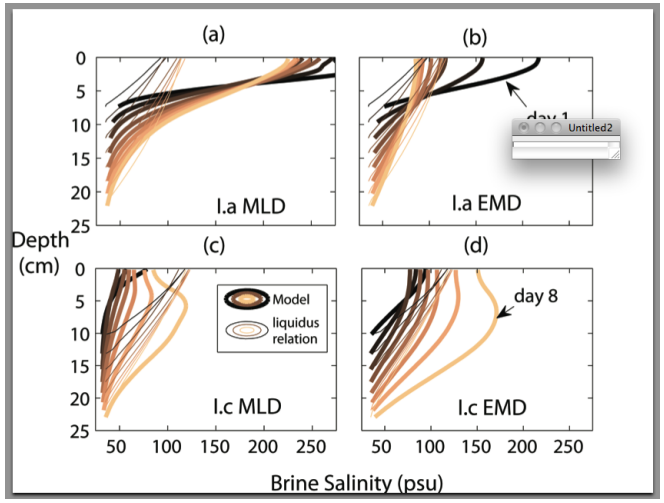
Obzhirov et al., Sea of Okhotsk off Sakhalin
CH_4 bubble flares

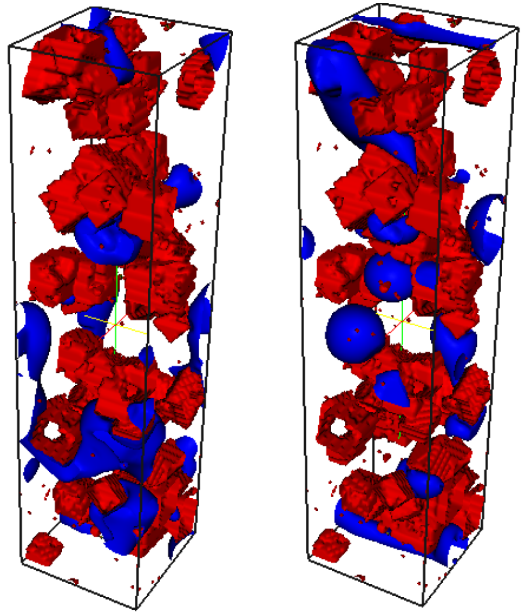


Bubbles and Futures

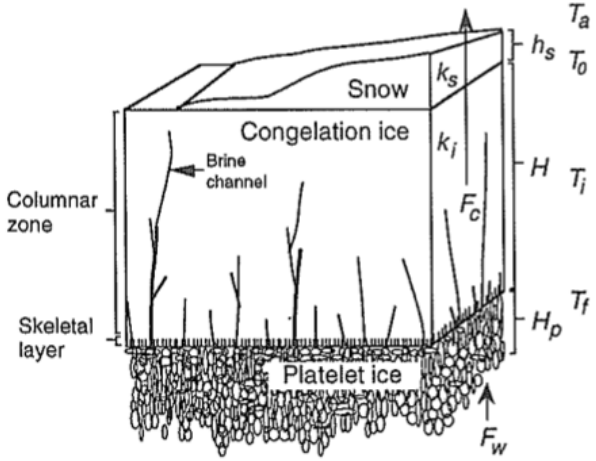
Percent CH_4, Atlantic Layer to Arctic Mixed Layer (conservative K_v)						
		Bubble Rise (vertical from destabilization at 350)				
		0 m	100 m	300 m (floor up)	300 m (Δ100)	>300 m
Circuit	**Biology**					
1,000 km	on	0	0	**0**	**0**	**100**
	off	0	0	**10**	**20**	**100**
10,000 km	on	0	0	**0**	**0**	**100**
	off	0	0	**20**	**40**	**100**
>10,000 km	on	0	0	**0**	**0**	**100**
(GIN mix)	off	100	100	**100**	**100**	**100**

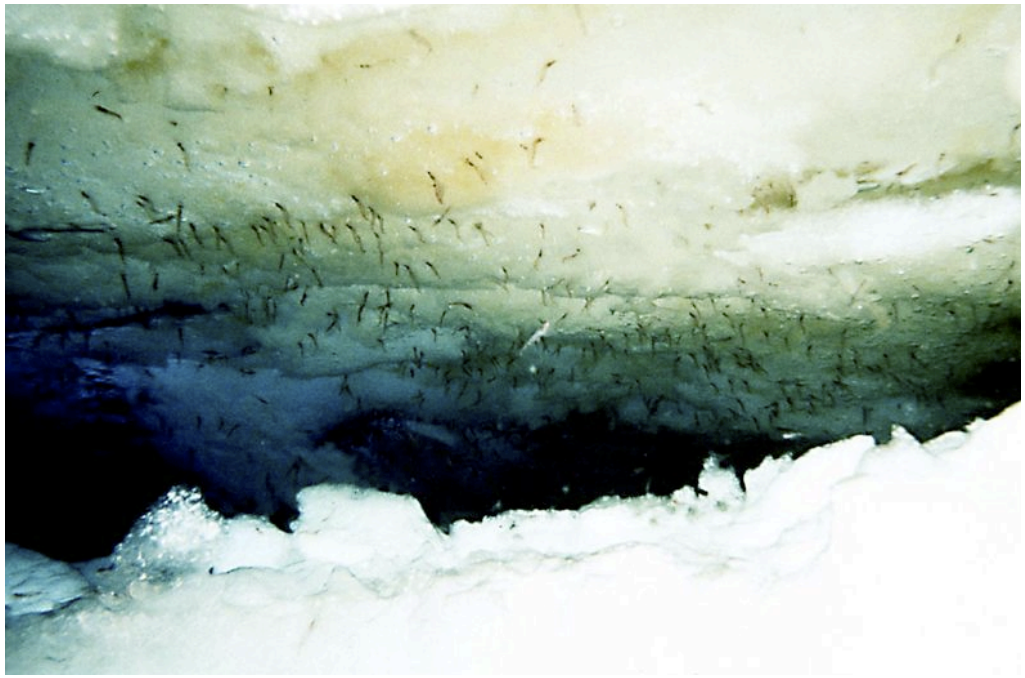


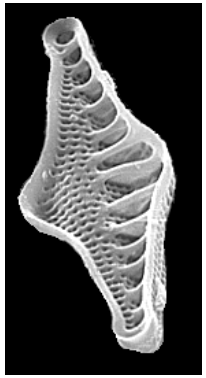


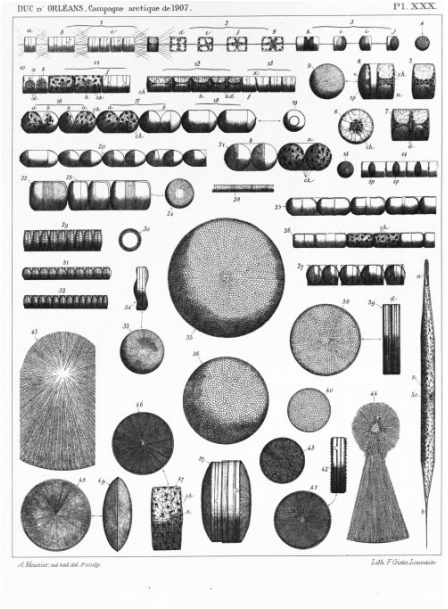


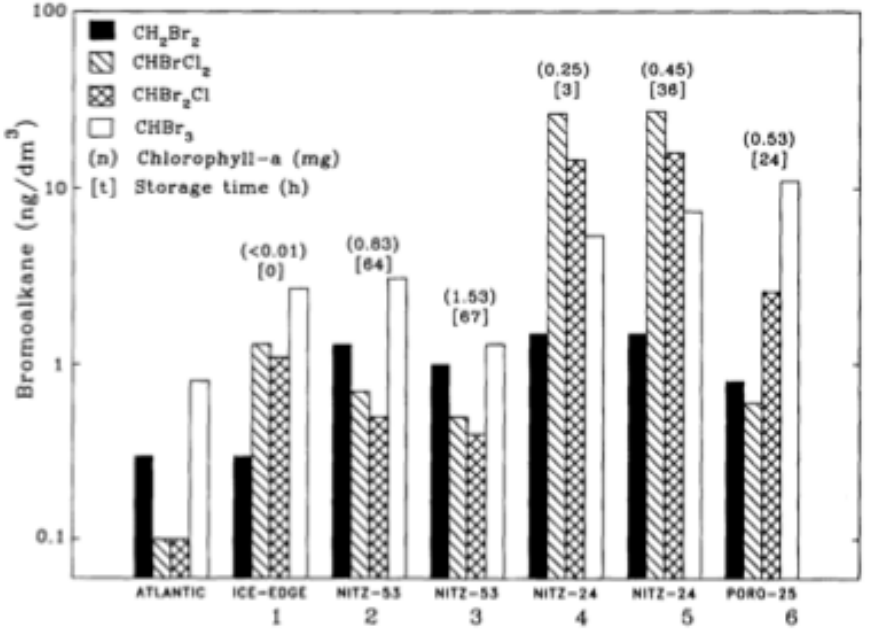
A Halogen Tale

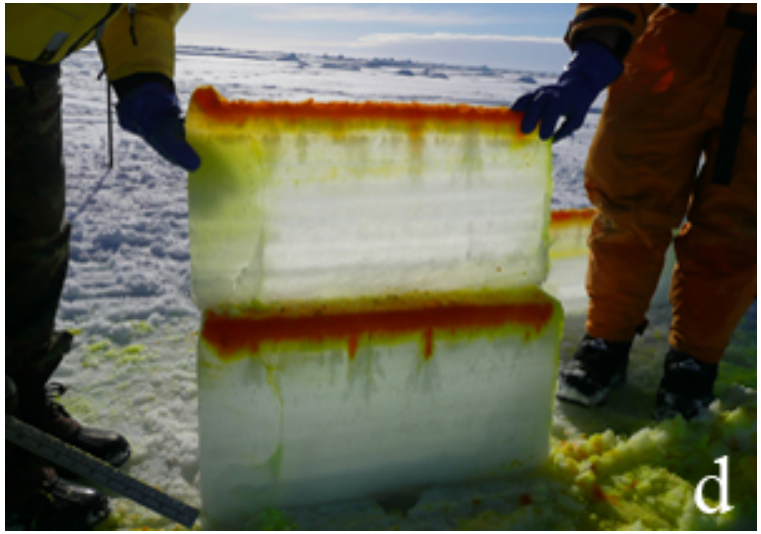




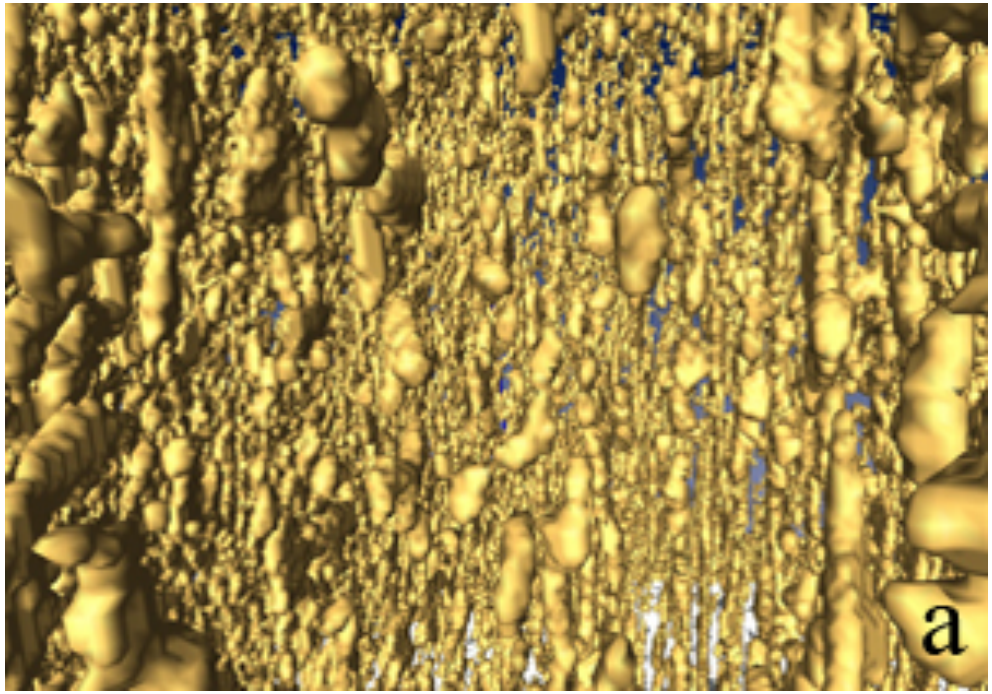






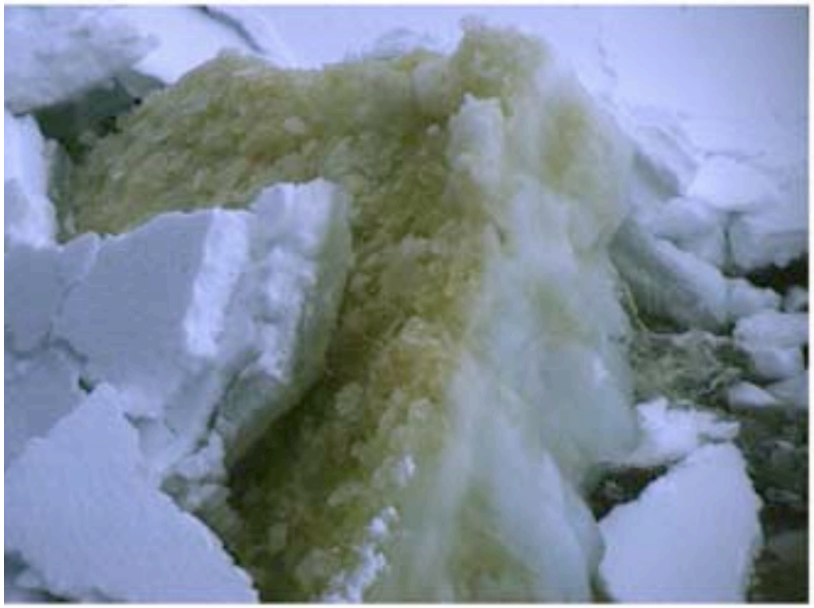


The Brine



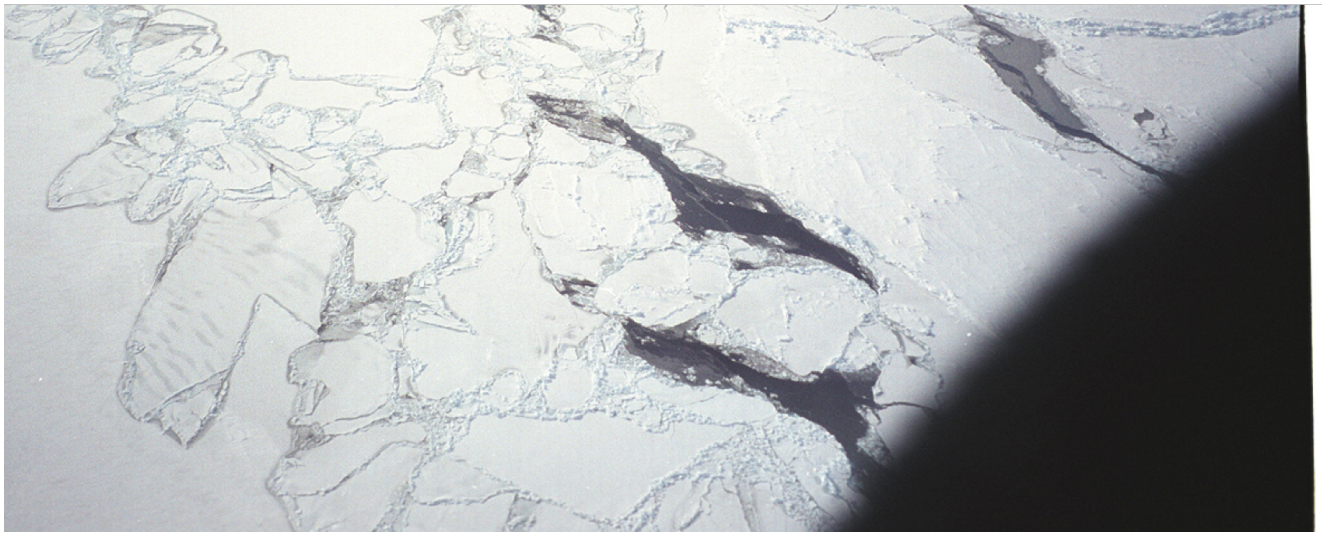
A complex salt dynamic
-salinities to 300 psu

Convection, flush, headspace
-then snow layers
-melt ponds

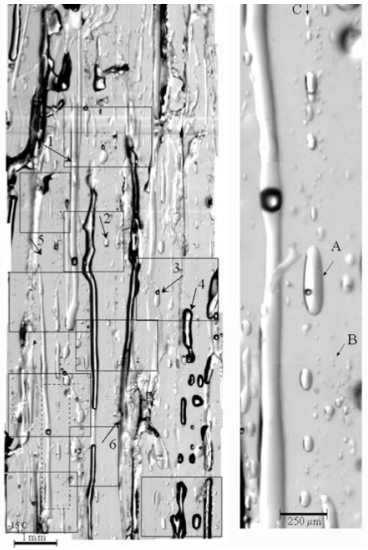


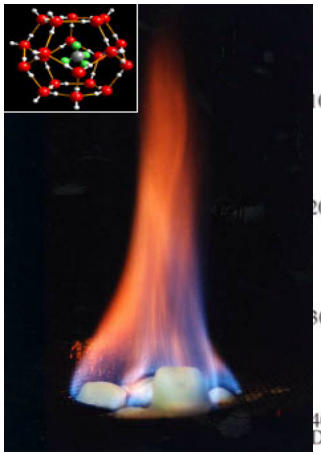
…and (ever) more

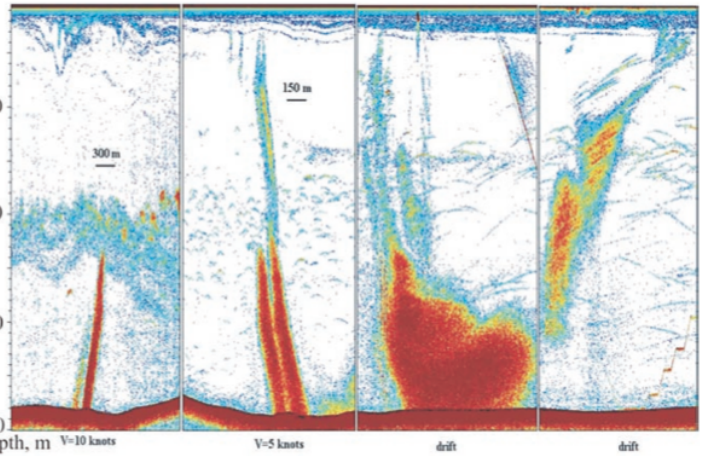
Organic surface chemistry
Transfer from leads
Aerosol/cloud systems



CO_2, DMS, O_2, CH_4…







Loose et al. 2011
Deboer et al. 2011
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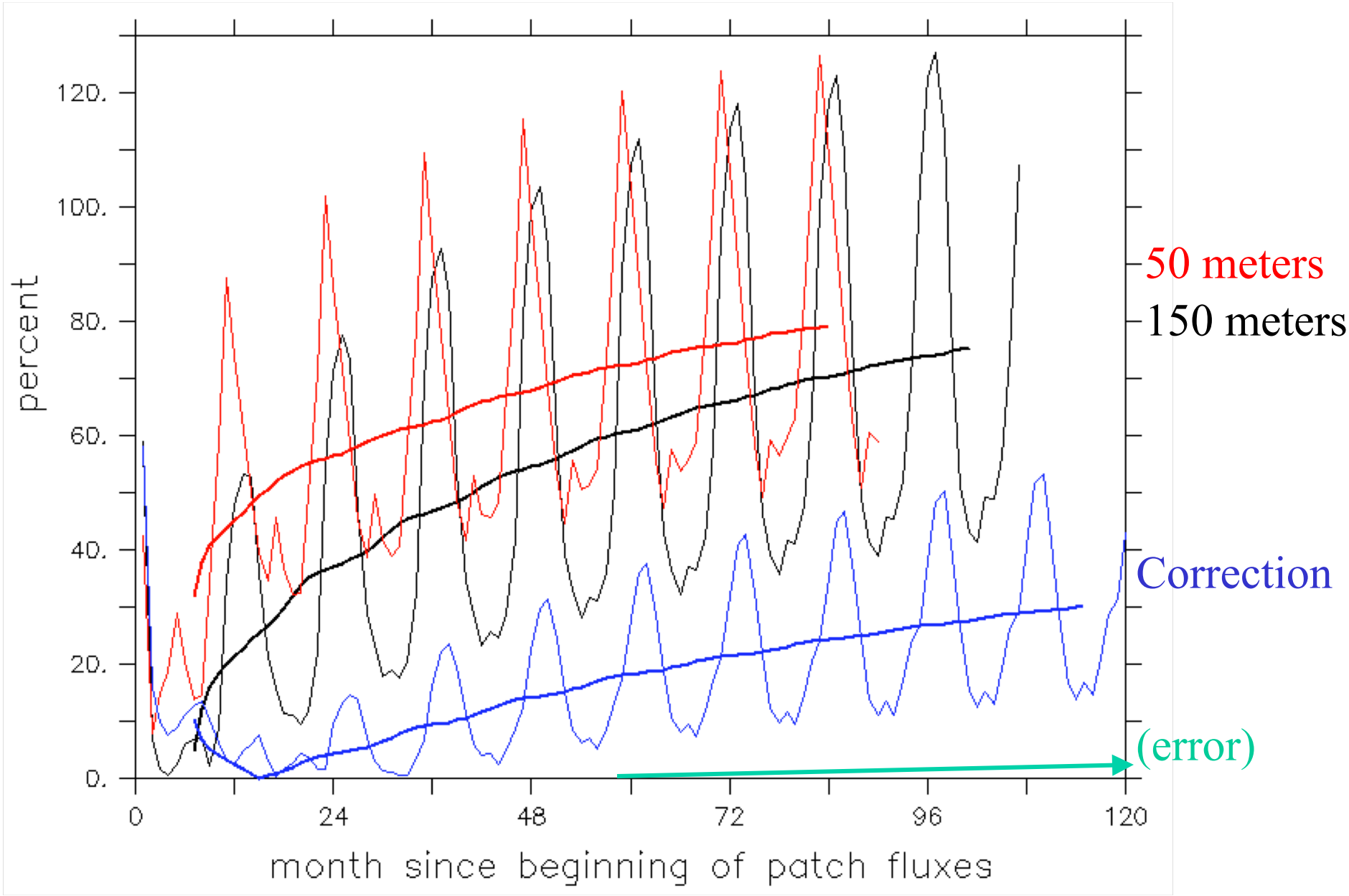
Integrated escape to Arctic atmosphere from JGR patches
Ten years, sea floor then injections, z = 150 and 50 meters



Scott--here they are on 1 plot. black is injection at 150m, red at 50m, blue is just flux from the bottom. the gaussians have a 50m width. all are inert. -mat