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
CO₂, DMS, O₂, CH₄…

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:
\[ n\text{CO}_2 + n\text{H}_2\text{O} = (\text{CH}_2\text{O})_n + n\text{O}_2 + \Delta\text{alkalinity} \]
\[ \text{Ca}^2+ + \text{CO}_3^{2-} = \text{ikaite} + \Delta\text{alkalinity} \]
\[ \text{H}_2\text{O} \cdot \text{CO}_2 = \text{H}^+ + \text{HCO}_3^- \]
\[ \text{HCO}_3^- = \text{H}^+ + \text{CO}_3^{2-} \]
Vertical and ice-air transfer
All hypersaline: Pitzer eqs.
**Extreme Thermochemistry**

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

Pitzer equations - just Debye-Hückel on steroids
In spring, CaCO₃ trapped within sea ice dissolves. This process consumes CO₂.

Budget of winter and spring processes is a net sink of CO₂. It depends on:
- ratio of CaCO₃ trapped vs CO₂ expelled (?)
- quantity of CO₂ 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$_2$O
(Which incidentally…
(Points to rest of N system…
(Reduced gases too, NH$_3$/NH$_4^+$))
Clathrate destabilization for DOE Impacts and Fossil
Obzhirov et al., Sea of Okhotsk off Sakhalin

$\text{CH}_4$ bubble flares
# Bubbles and Futures

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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
CO₂, DMS, O₂, CH₄…

Loose et al. 2011
Deboer et al. 2011
Light et al. 2002
Obzhirov et al. 2004
Shakhova et al. 2009
Integrated escape to Arctic atmosphere from JGR patches
Ten years, sea floor then injections, \( z = 150 \) and 50 meters

Correction

(error)

50 meters
150 meters