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

Gases in 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 of the Ice Domain

OPENING MONTAGE –volatiles on parade

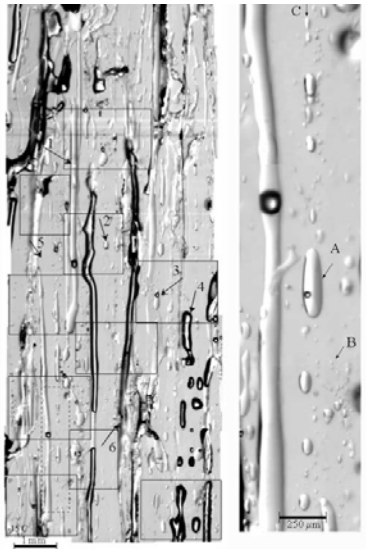
ECOLOGY first but MINERALOGY close behind

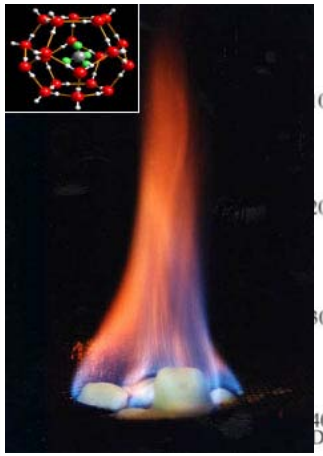
Extreme THERMO and C BUDGETS coming fast

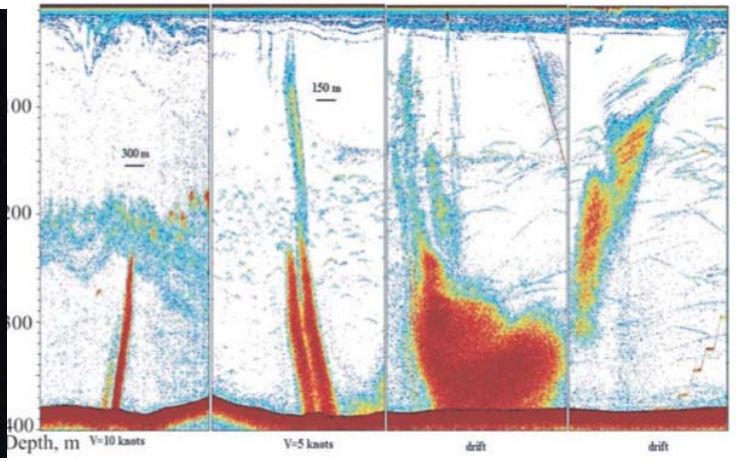
ORGANOSULFUR in ice and surroundings

METHANE BUBBLES below and to the pack

OTHER compounds, issues



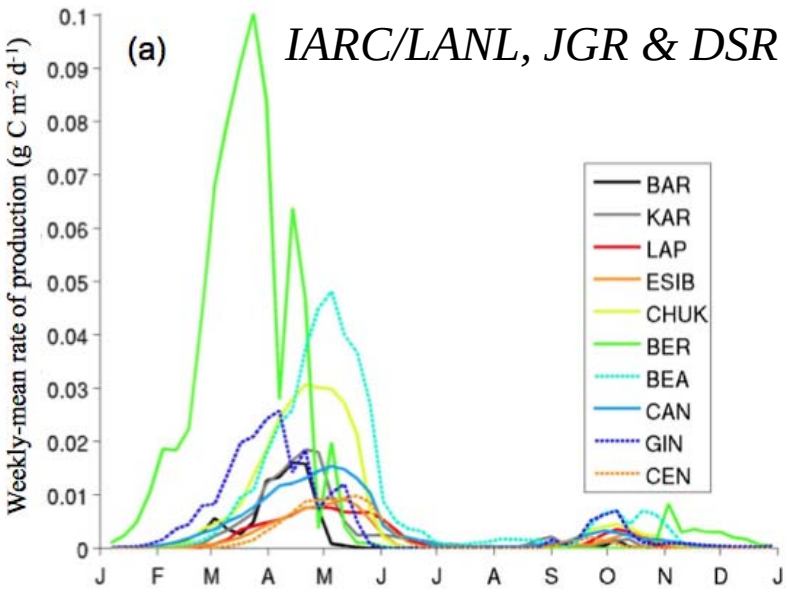


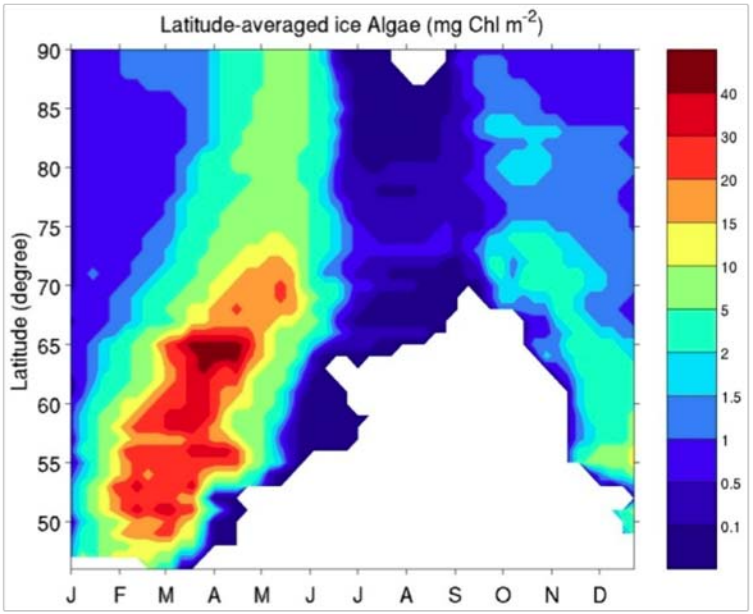


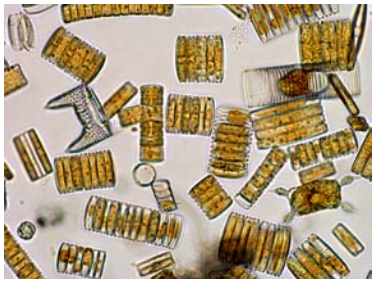
CO_2, DMS, O_2, CH_4

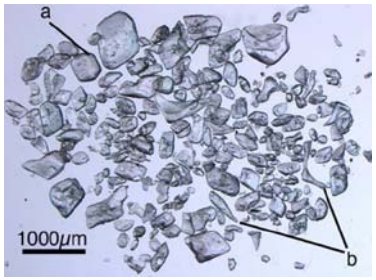
Loose et al. 2011
Deboer et al. 2011
Light et al. 2002
Obzhirov et al. 2004
Shakhova et al. 2009

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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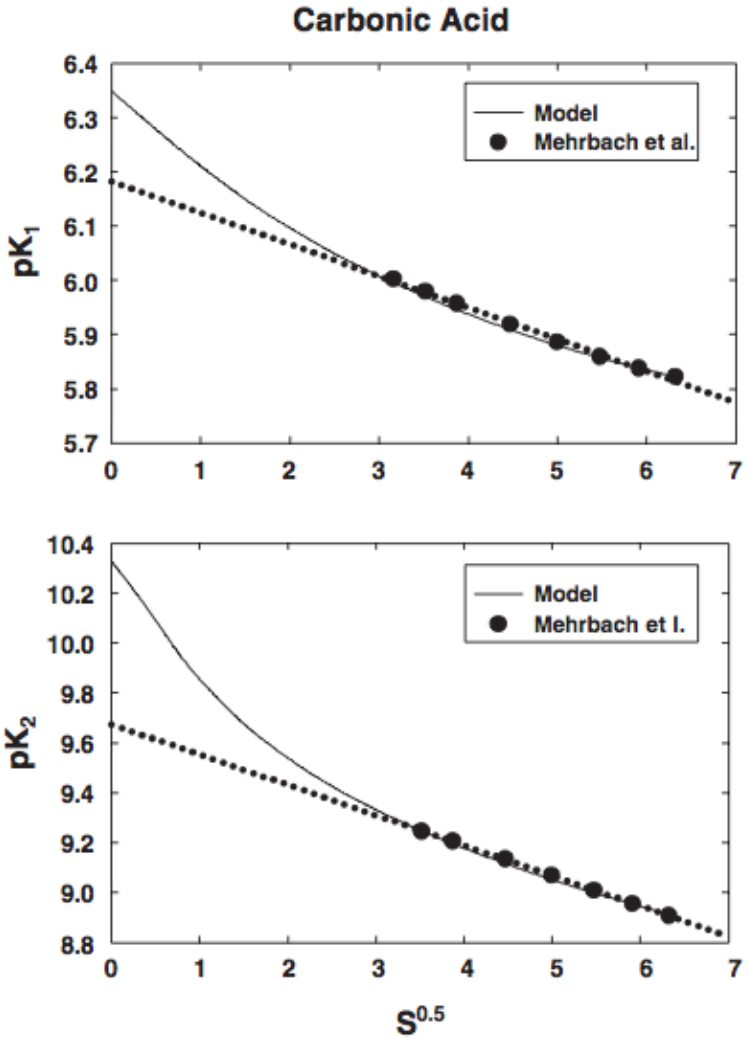
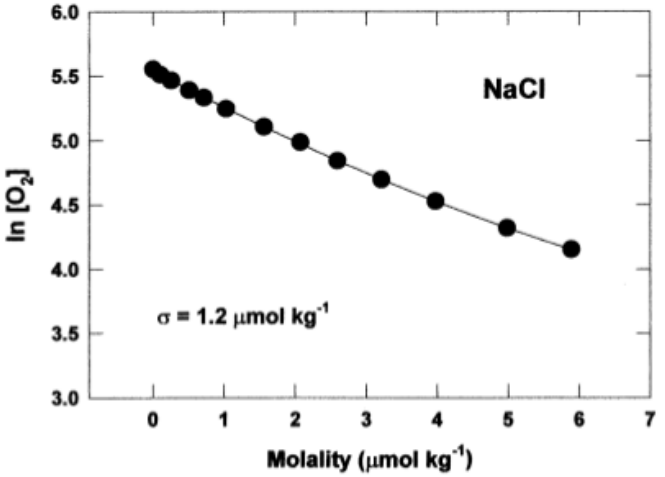
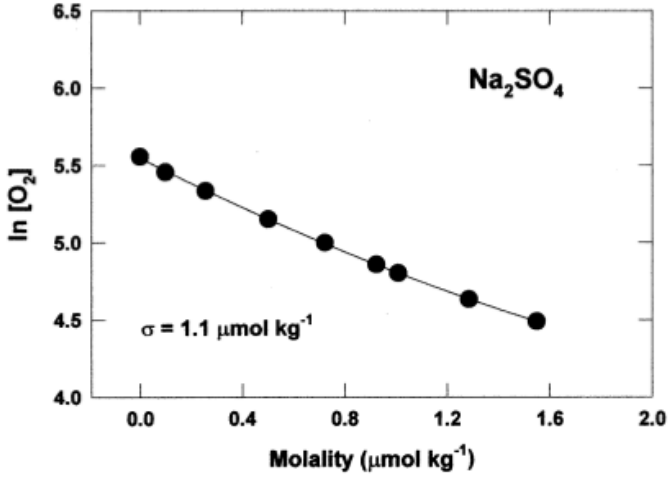
Extreme Thermochemistry





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



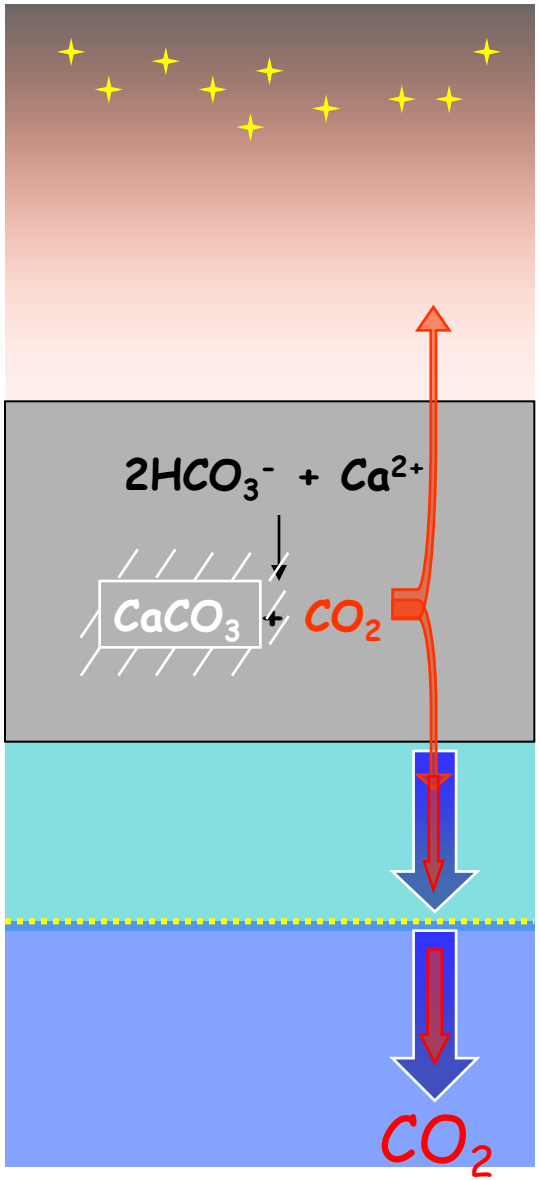
Millero et al., several ? No, CRREL as usual

Pitzer equations -just Debye-Huckel on steroids

GAS COMPOSITION IN SEA ICE

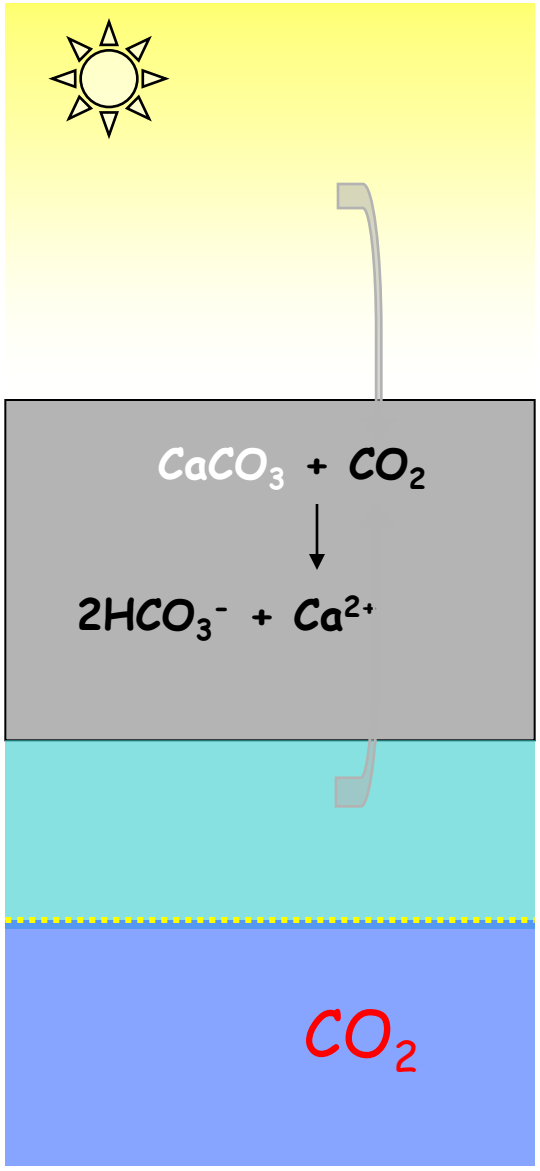
A potential abiotic $CaCO_3$ Carbon pump

fall/winter

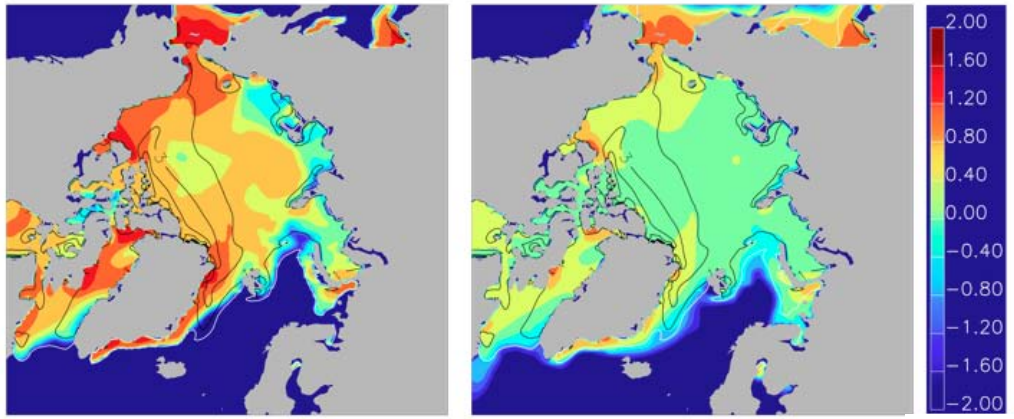


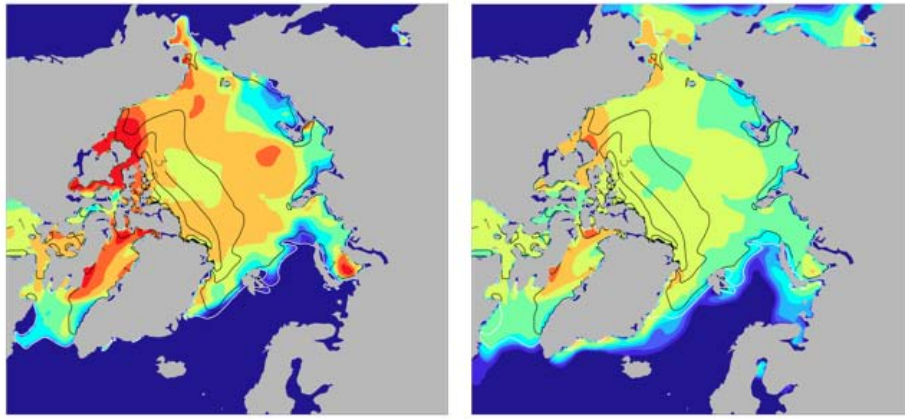
- In spring, $CaCO_3$ trapped within sea ice dissolves. This process consumes CO_2.
- Budget of winter and spring processes is a net sink of CO_2. It depends on:
  - ratio of $CaCO_3$ trapped vs CO_2 expelled (?)
  - quantity of CO_2 which pass below the pycnocline during the autumn-winter (?)

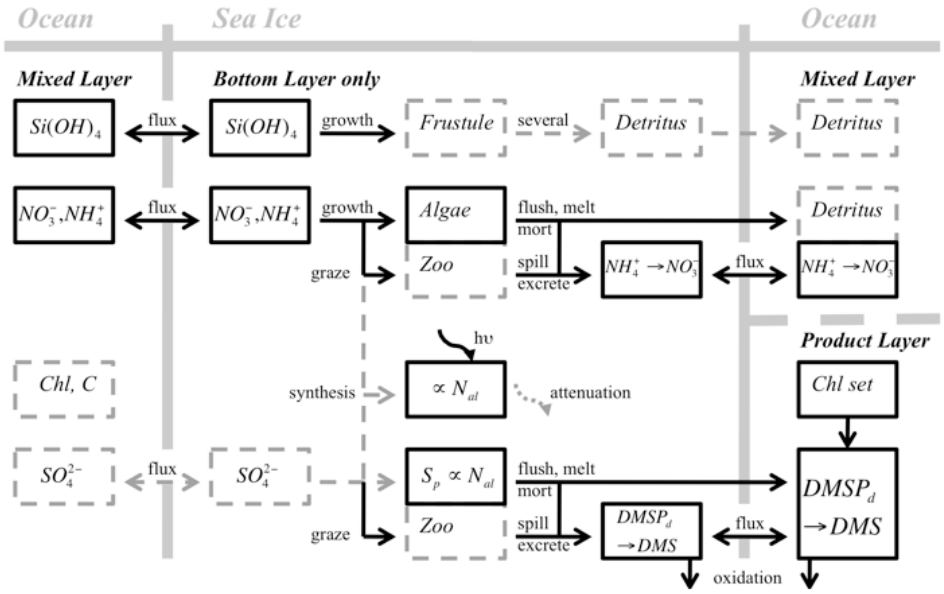
spring



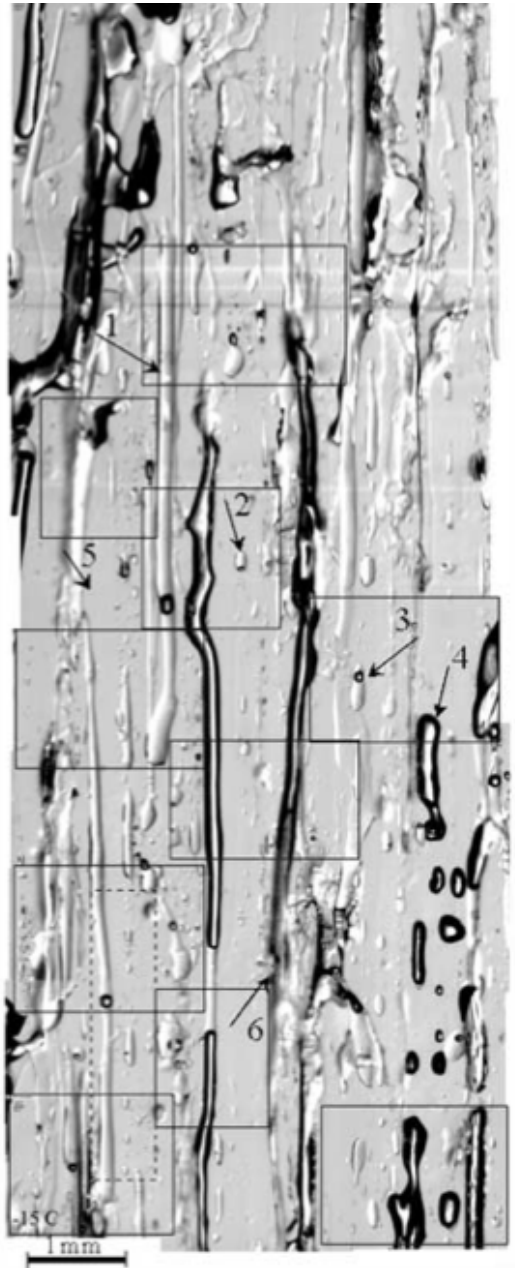
Rysgaard et al., 2007, Delille et al., in prep.

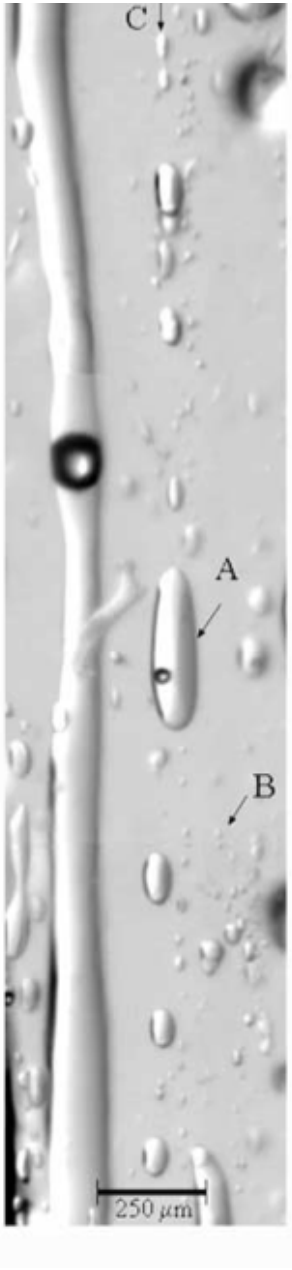






DMS via CICE: beneath, residual





Major Constituents

O_2, photo-radical chemistry

-Biological stress

Nitrogen redox:

-Nitrification, N_2O

(Which incidentally…

(Points to rest of N system…

(Reduced gases too, NH_3/NH_4+)

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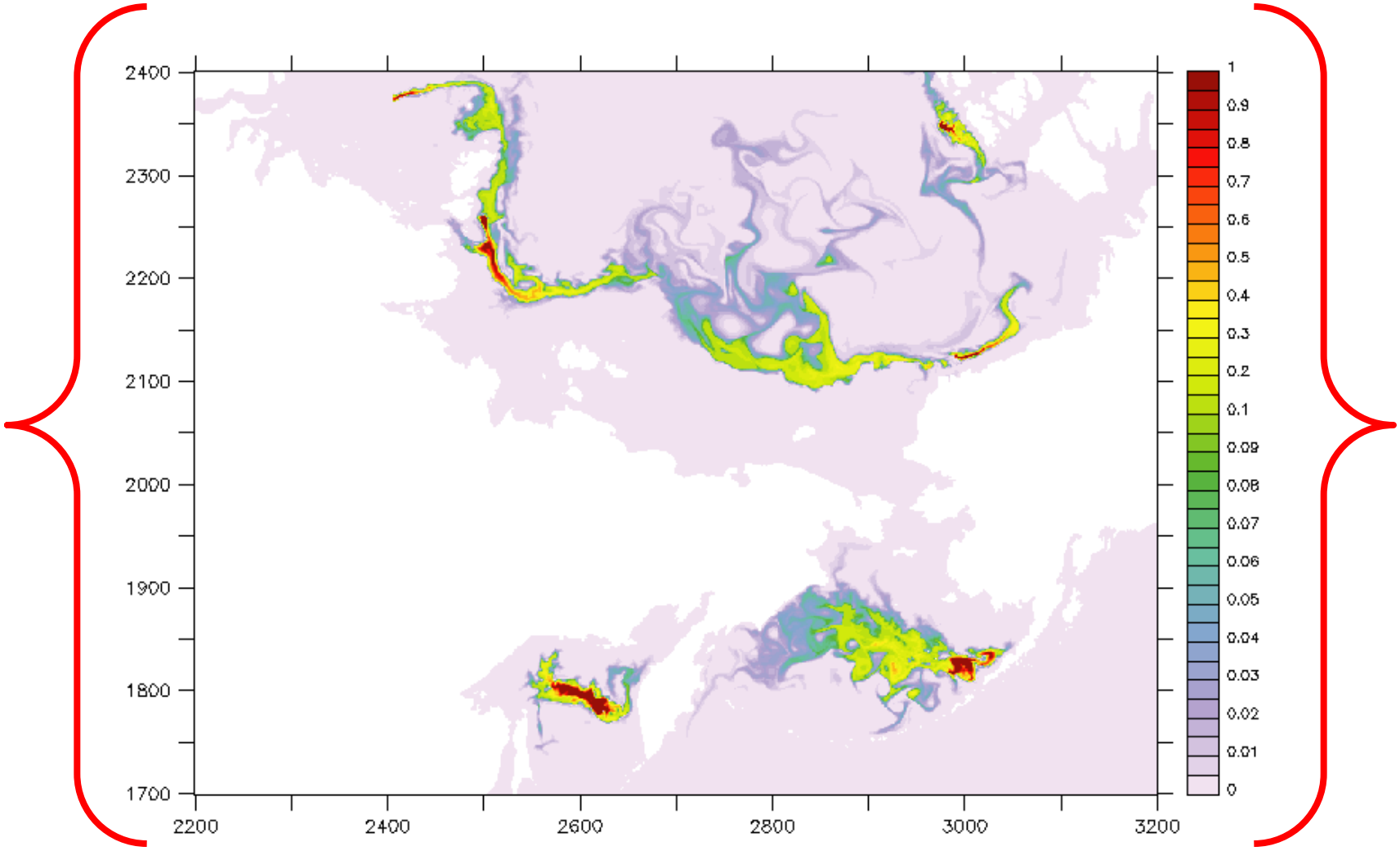
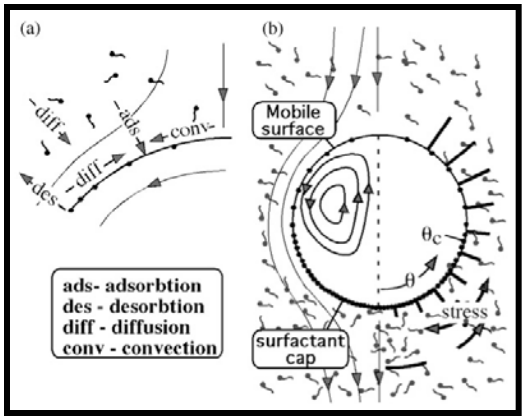
Bubble rise for DOE Impacts and Gas Hydrates

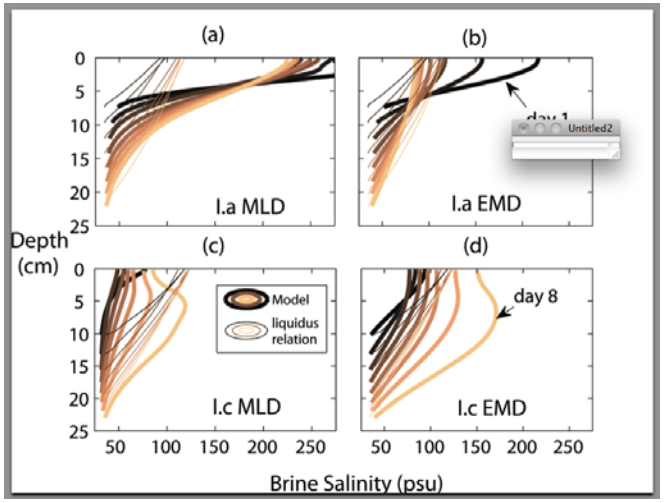


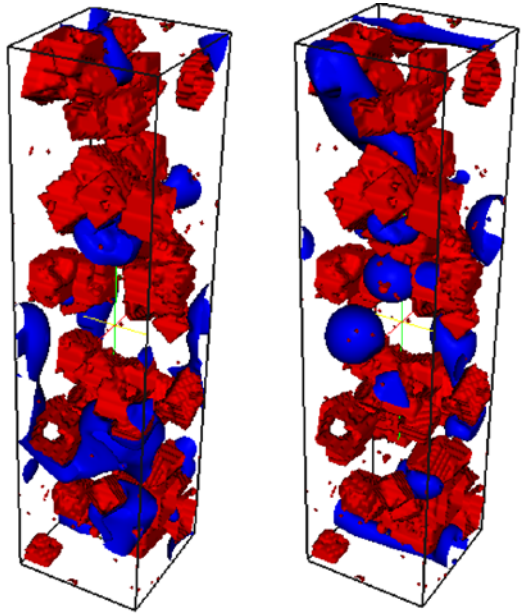
{Swap in latest runs, methane trapped below ice…}

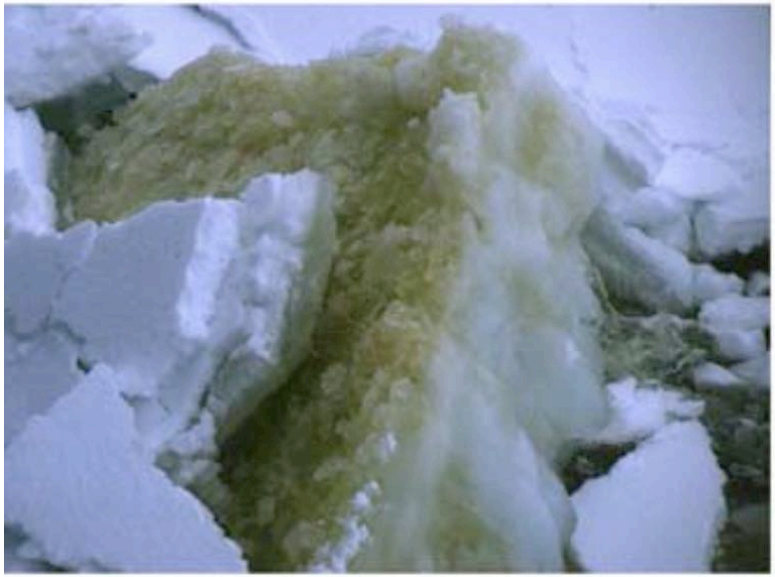
Bubbles and Futures

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	JF 0	0	**0**	**0**	**100**
	off	0	0	**10**	**20**	**100**
10,000 km	on	0	0	**0**	**0**	**100**
	off	0	0	AJ **20**	**40**	**100**
>10,000 km	on	0	0	**0**	**0**	**100**
(GIN mix)	off	100	100	**100**	**100**	**100**



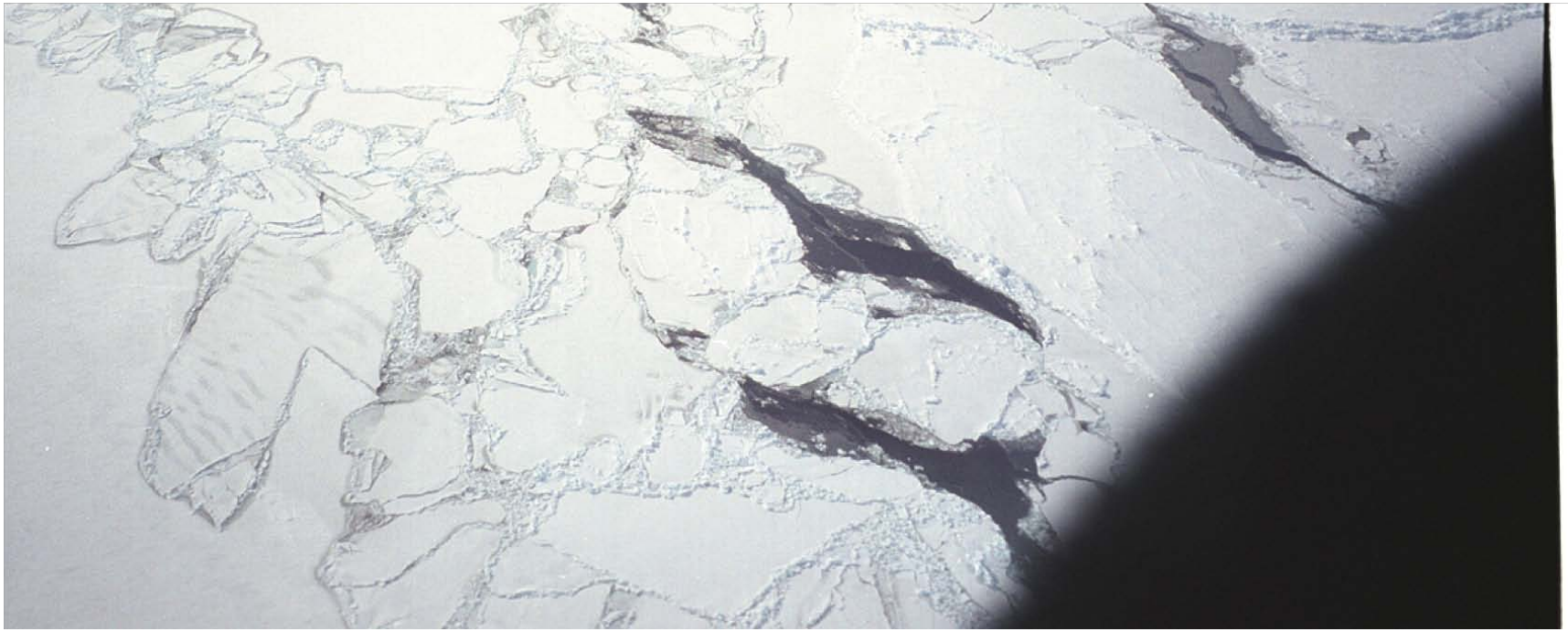


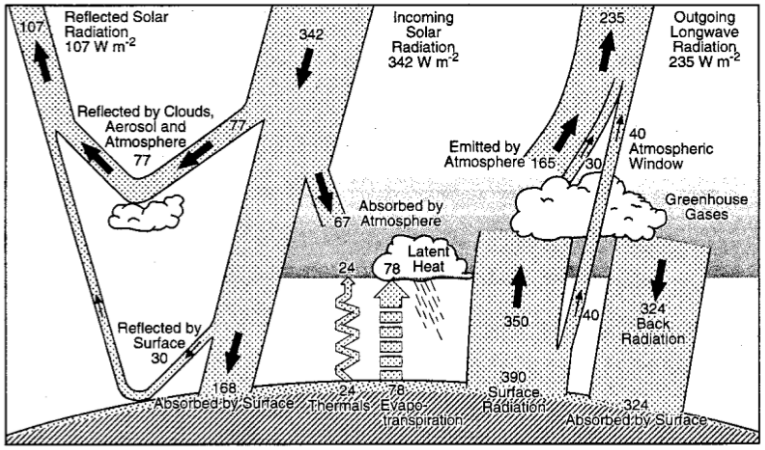




…and (ever) more

Organic surface chemistry
Transfer from leads
Halogenates, I_2




Reflected Solar Radiation 107 W m-2
107
342
Incoming Solar Radiation 342 W m-2
235
Outgoing Longwave Radiation 235 W m-2
Reflected by Clouds, Aerosol and Atmosphere
77
77
Emitted by Atmosphere 165
30
40 Atmospheric Window
Absorbed by Atmosphere
67
Greenhouse Gases
Latent Heat
24
78
Reflected by Surface
30
350
40
324 Back Radiation
168
Absorbed by Surface
24
Thermals
78
Evapo-transpiration
390 Surface Radiation
324
Absorbed by Surface


Slinky
Slinky

The envelope please…

By these criteria, rank order for high latitude cycles:

-Ice chlorophyll (surface darkening)
-DMS
-Organics tweak sea-air transfer
-CH_4
-Organics tweak aerosol
-Seeding tweaks sea-air transfer
-Open, brine, skeletal C cycles
-Aerosol/ice iron cycle
-Ice nitrogen ($NH_3/_4^+$, N_2O)
-O_2 and radical photochemistry

Note: Order 10^2 characters –IPCC does same job in 10^6

The envelope please…

By these criteria, rank order for high latitude cycles:

CO_2, O_2

- -Ice chlorophyll (surface darkening)
- -DMS
- -Organics tweak sea-air transfer — All
- -CH_4
- -Organics tweak aerosol
- -Seeding tweaks sea-air transfer
- -Open, brine, skeletal C cycles — CO_2
- -Aerosol/ice iron cycle
- -Ice nitrogen ($NH_3/_4^+$, N_2O)
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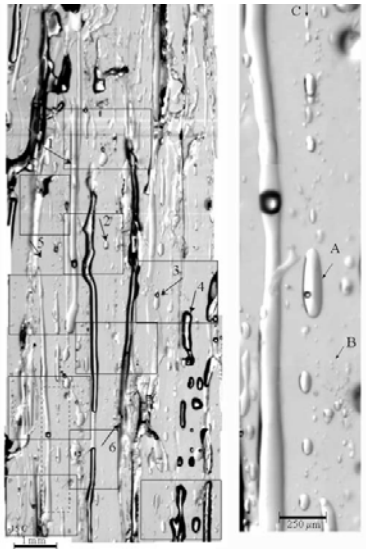
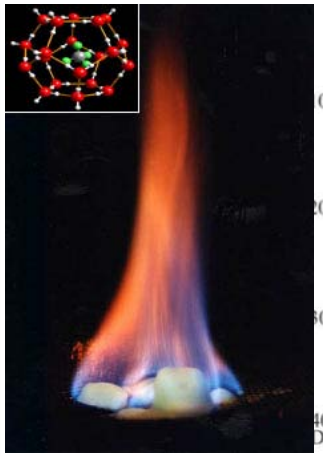
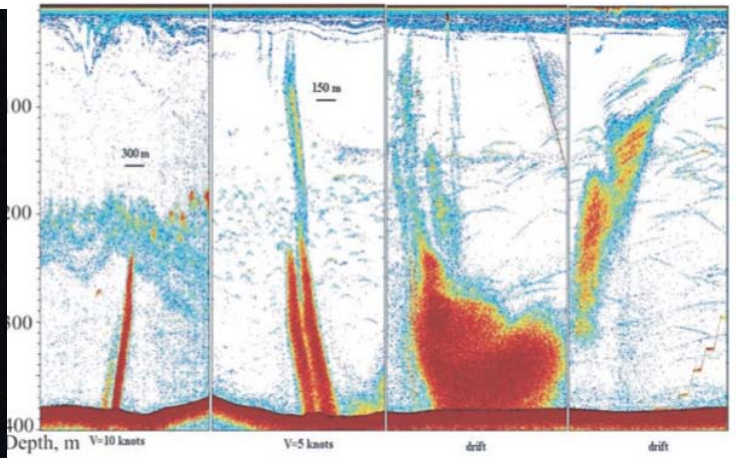
Note: Order 10^2 characters –IPCC does same job in 10^6







CO_2, DMS, O_2, CH_4

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