Impact of Arctic Clathrate Emissions

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DOE IMPACTS and SciDAC projects
Warming may release methane from large Arctic reservoirs

Stolaroff, et al., 2012
Onset of Clathrate emissions expected to be abrupt

Reagan, et al., 2011
Fraction of methane that passes through the ocean could be large because of bubbles.

Elliott, et al., 2010, 2011
Methane over Barents increasing faster than over land
Model CH$_4$ has similar annual means and variability to obs., but larger IH gradient.

OBS from CMDL network. Sites ordered by latitude.
Arctic clathrate methane emission produces non-uniform concentration increase.

- 20% increase in global emissions => 30-60% conc. increases.
- 200% increase in global emissions => 550-800% conc. increases.
Ozone increases most in polluted regions, worsening air-quality.

- Annual-mean surface ozone increase due to clathrate emission, vmr (std AE)

- Warning: super-fast mechanism not ideal for air pollution.
Ozone variability increases, which will cause more air-quality exceedances.

- Ozone variability over southern ocean is probably enhanced because methane is a larger fraction of the hydrocarbons, so its variability has a larger effect.
Effect on temperature of emitting in Arctic compared to globally is modest

Zonal-mean temperature response for UE10x and AE10x. Dashed lines show interannual standard error.

% regional temperature diffs (AE10x-UE10x) for Global, S.Pole, Low latitudes, N. Pole, and Equator to N. Pole diff. Bars show std error.
Long-timescale variability is also increased with clathrate emissions

Red Dots: Arctic Emission
Black Dots: Control
Lag-1 autocorrelation changes (T) over Southern Ocean for CH$_4$, but not CO$_2$
AE vs UE also changes precip, but only due to radiative forcing?

Increase in precip.

Arctic Emissions
Uniform Emissions
Methane emissions also changes precip variability, but only due to radiative forcing?
Forcing changes interannual T variability. CO$_2$ decreases more than CH$_4$?

AE10x  UE10x  UE10x(fixedCH$_4$)

10x scenarios

2xCO$_2$  4xCO$_2$CMIP
CMIP5 models (4xCO$_2$) do not agree on change to interannual variability.
Wavelet Spectra for long runs are interesting, but tricky to compare.
DMS in super-fast in CAM5 with MAM3. Decrease in surface solar due to DMS.

Global Mean = 3.5 W/m²
Conclusions

• Warming may release methane from large Arctic reservoirs.
• Clathrate methane emission scenario changes mean: methane, ozone, temperature, precip.
• Methane increase is non-uniform, but impact on temperature distribution is modest.
• Variability changes too.
• DMS has significant effect on $W/m^2$
Unused Slides
Testing CESM climate response to clathrate emission scenario

- **CESM with:**
  - Fast chemistry (CH$_4$ emissions, strat-chem),
  - Full ocean.

- **Steady-state simulations:**
  - 2000 control,
  - 2000 control + clathrate emissions in the arctic (AE),
  - 2000 control + clathrate emissions spread globally (UE),
  - Plus, AE and UE clathrate emissions increased 10x.

- Control has 629 Tg(CH$_4$)/yr (to give 1.79 ppm [CH$_4$]),
- Clathrate emissions add 139 Tg(CH$_4$)/yr (or 10x this).
Clathrate emissions increase methane lifetime and its variability.

Methane lifetime as a function of time for **Control** and **standard Arctic emission** case computed using three approximation methods.
Large increases in methane variability
Long-term variability increase in wavelet spectra too

Wavelet Power Spectrum of Global Mean Surface Temperature

Simulation year

Wavelet Period (years)
RCP4.5 predicts ocean floor warming that is also significant

Ocean bottom temperature change (RCP4.5 1855 to 2100)
CESM predicts minimal warming in clathrate locations in present-day.

Ocean bottom temperature change (1855 to 2005)
RCP8.5 predicts significant ocean floor warming by end of century

Ocean bottom temperature change (RCP8.5 1855 to 2100)
RCP8.5 predicted destabilization locations are mostly in Arctic.

Clathrate destabilization locations (RCP8.5).
Note: Changes larger than 3K tend to produce lots of bubbles.

Misses observed Svalbard coastal plumes due to insufficient resolution of ocean model.
Satellites show high methane over Barents

Western Arctic

Eastern Arctic

**IASI**

**AIRS**

Note: different color scales
AIRS matches Svalbard ground site (with offset)

Zeppelin NILU in situ data vs AIRS v6 for 78N–80N, 11E–13E

- in situ daily means
- in situ running 30-days average
- AIRS monthly 0–4 km mean
- AIRS minus bias 45.3 ppb

AIRS points are monthly means of 3°x3° around obs. site.