Impact of Arctic Clathrate Emissions

P. Cameron-Smith, S. Bhattacharyya, D. Bergmann (LLNL)
M. Reagan, G. Moridis (LBNL)
S. Elliott (LANL)
L. Yurganov (UMBC)

DOE IMPACTS and SciDAC projects

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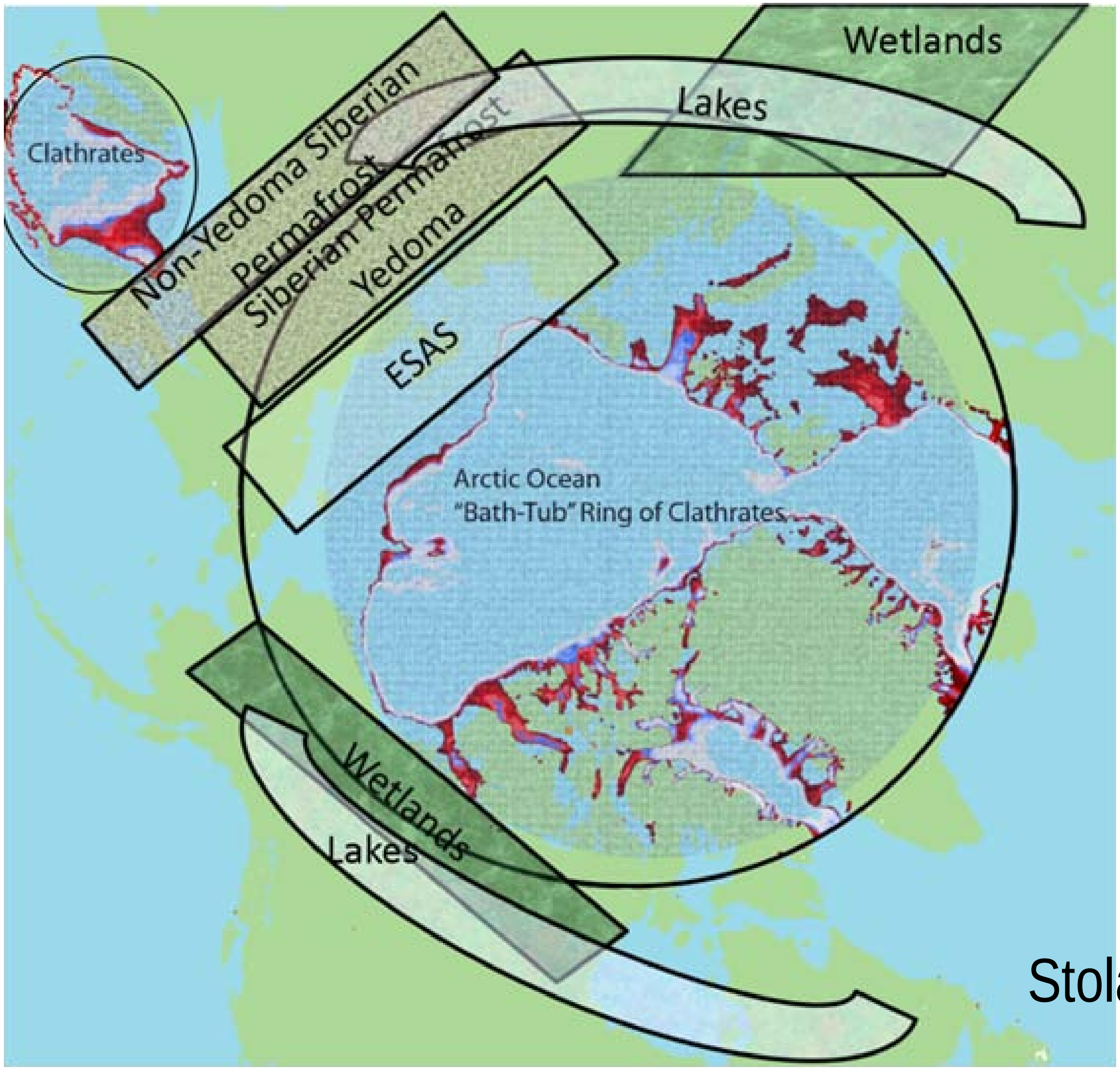
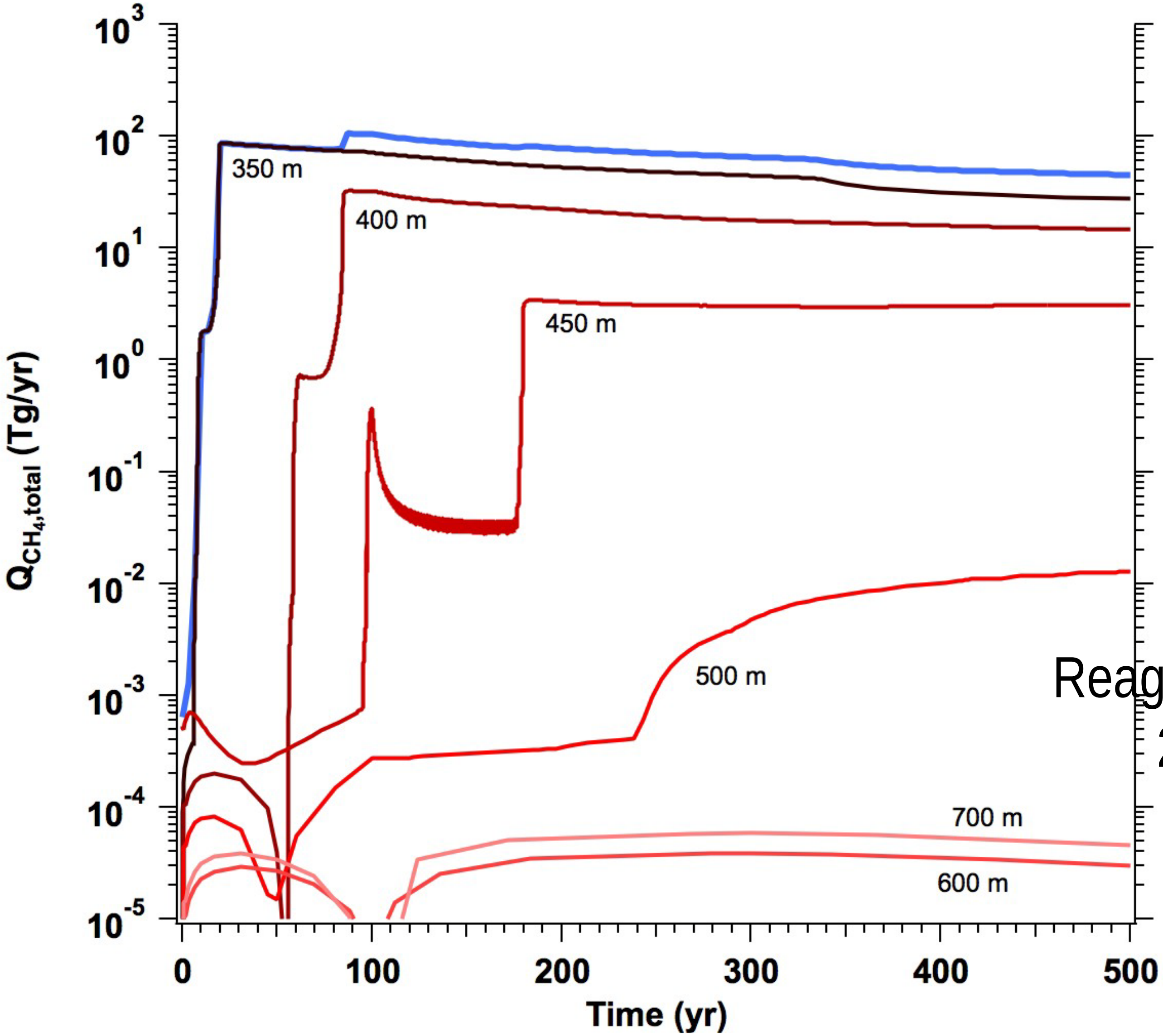
Warming may release methane from large Arctic reservoirs



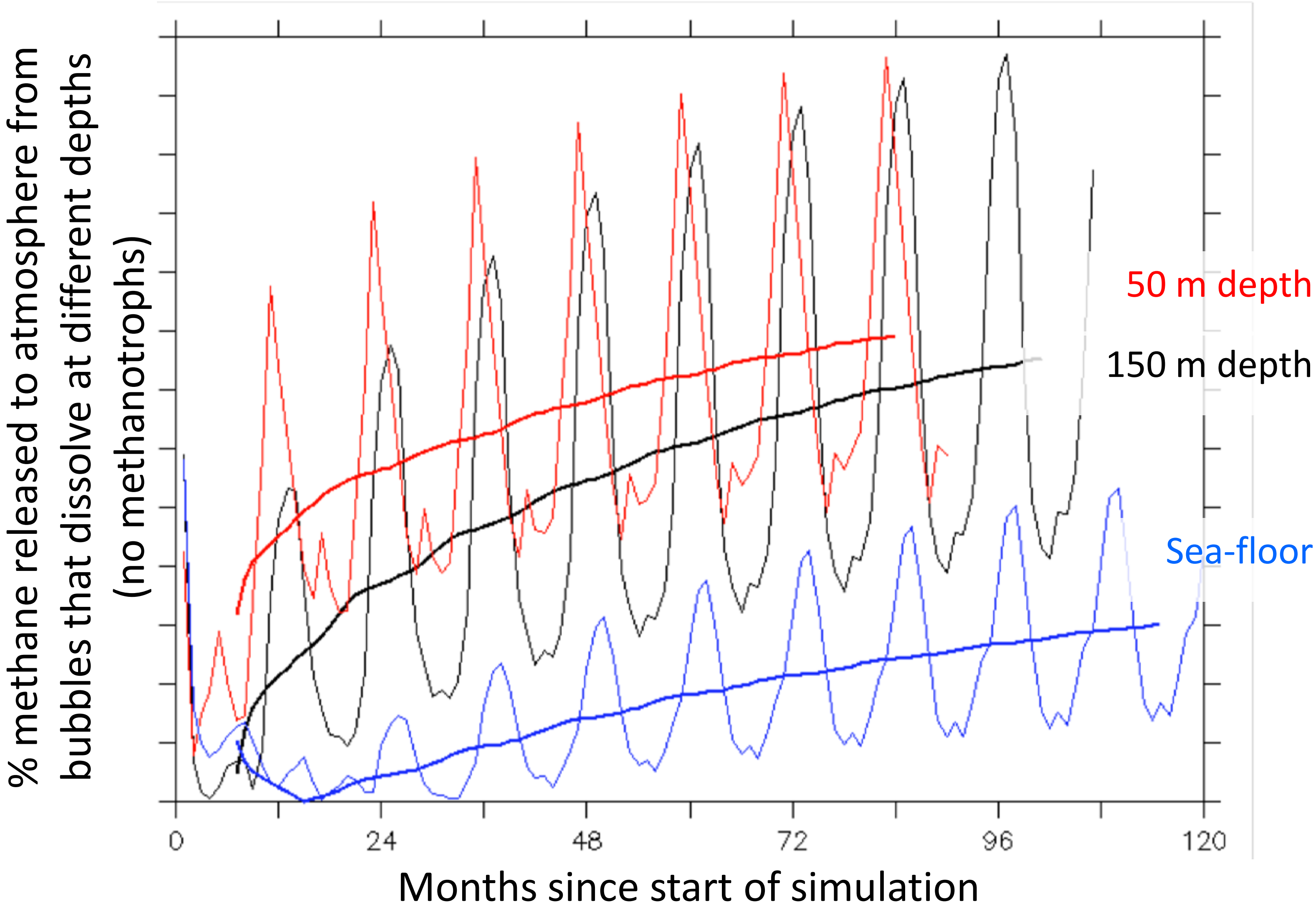
Stolaroff, et al., 2012

Onset of Clathrate emissions expected to be abrupt



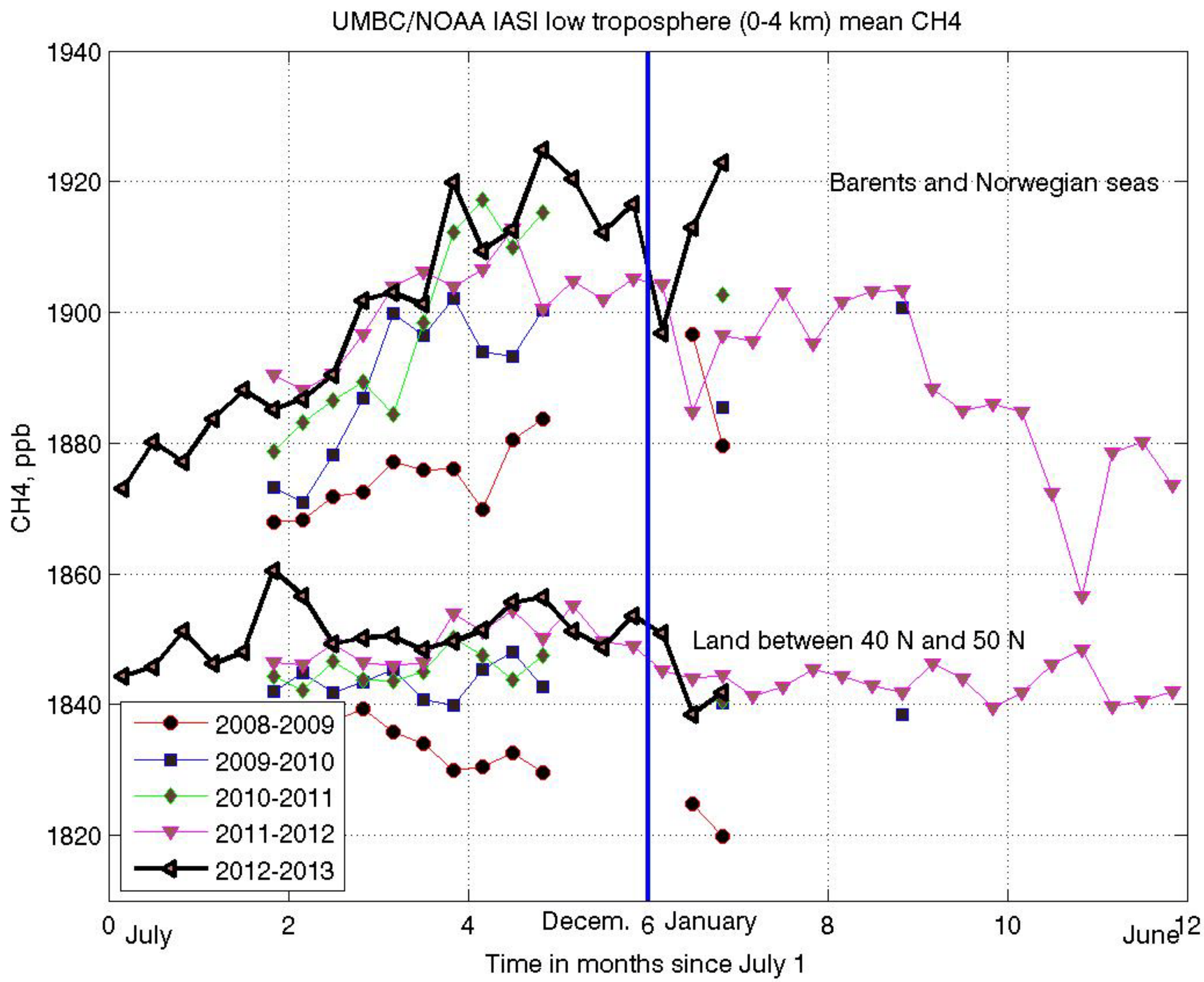
Reagan, et al., 2011

Fraction of methane that passes through the ocean could be large because of bubbles

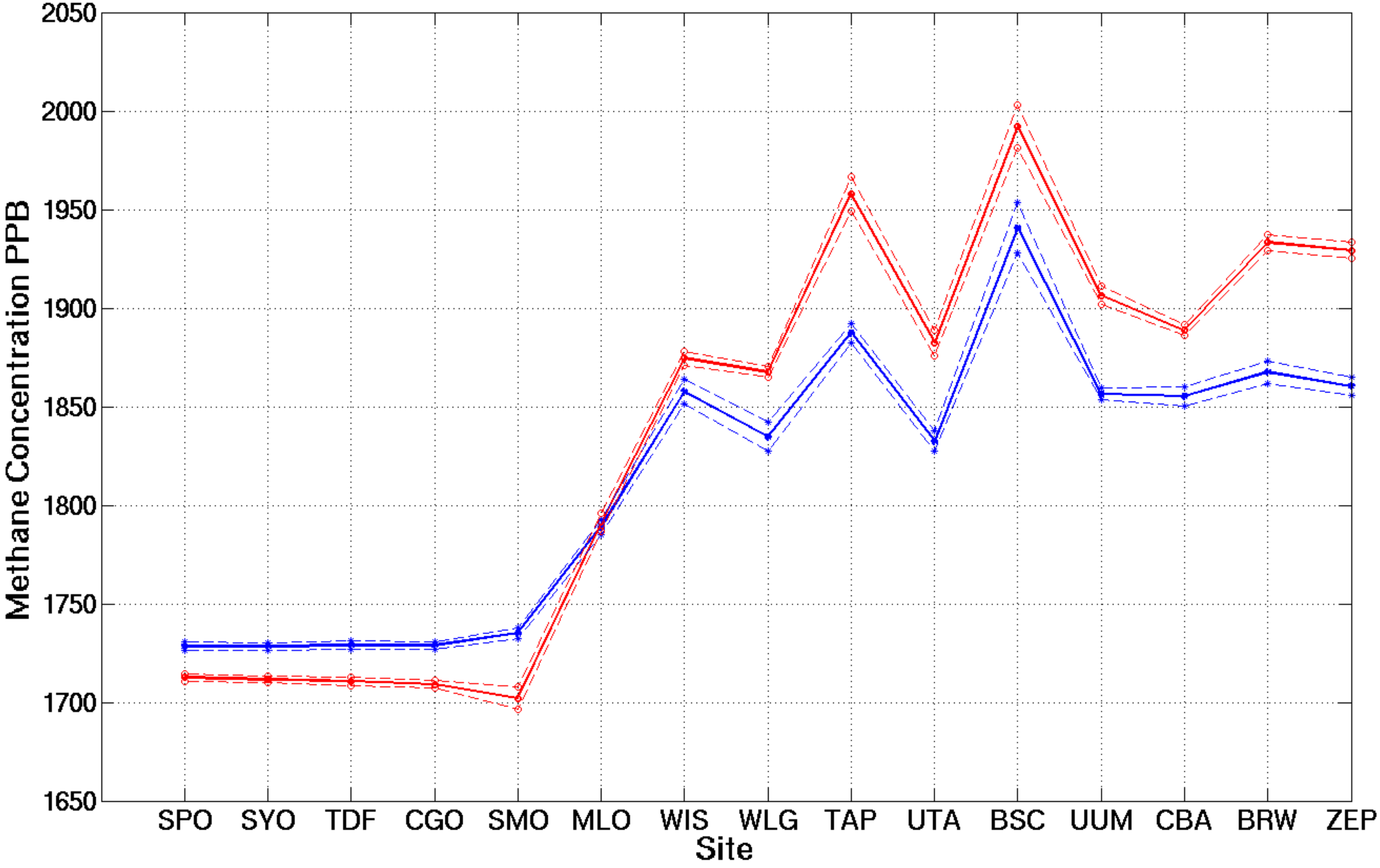


Elliott, et al., 2010, 2011

Methane over Barents increasing faster than over land

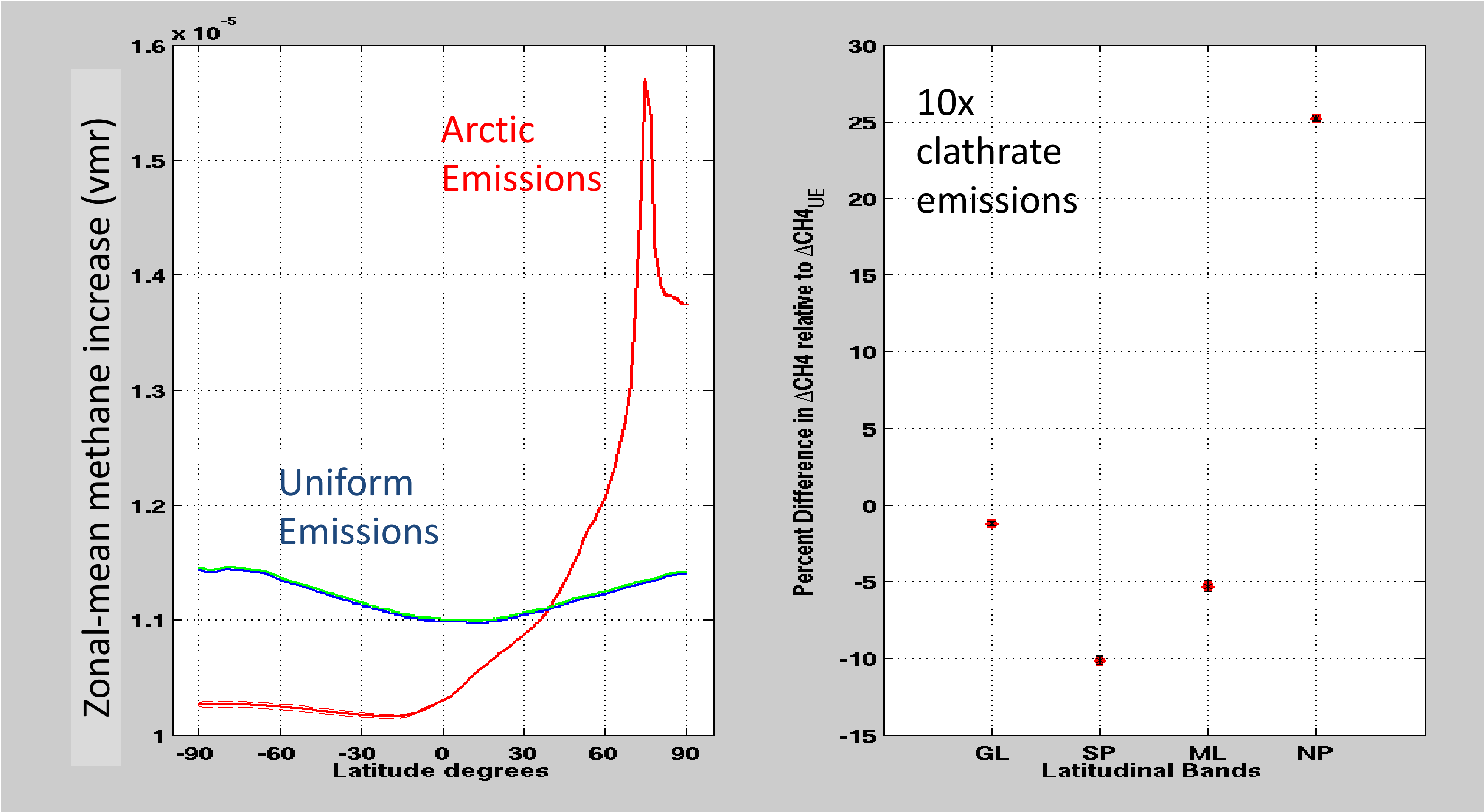


Model CH_4 has similar annual means and variability to obs., but larger IH gradient



OBS from CMDL network. Sites ordered by latitude.

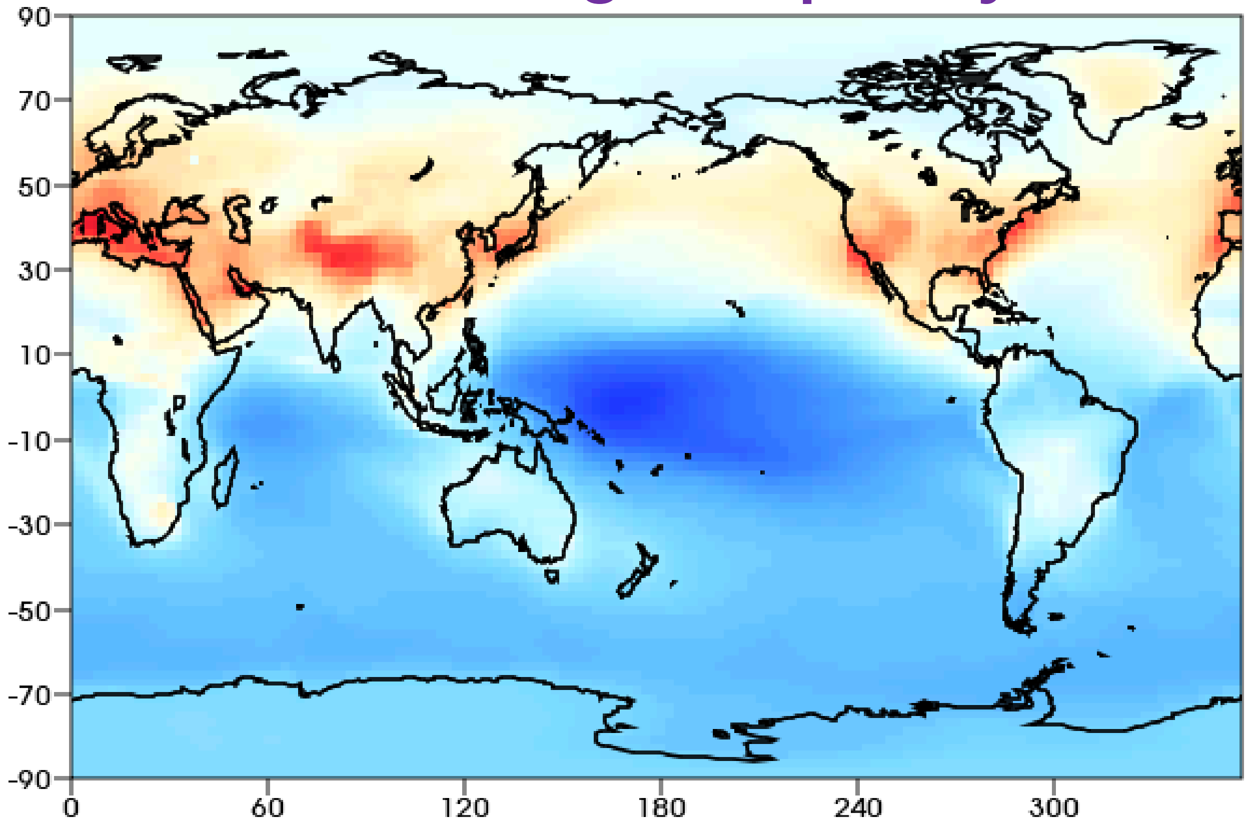
Arctic clathrate methane emission produces non-uniform concentration increase



- ❖ 20% increase in global emissions => 30-60% conc. increases.
- ❖ 200% increase in global emiss => 550-800% conc. increases.

Ozone increases most in polluted regions, worsening air-quality.

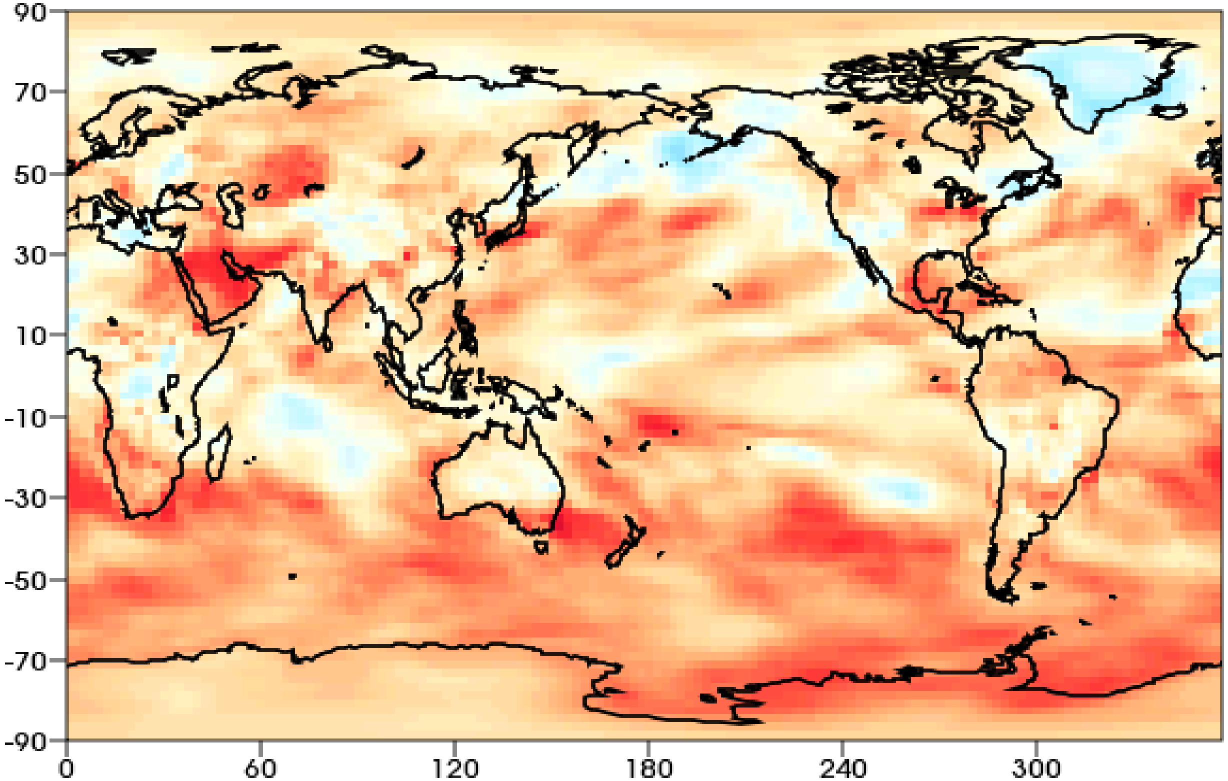
1x clathrate emissions



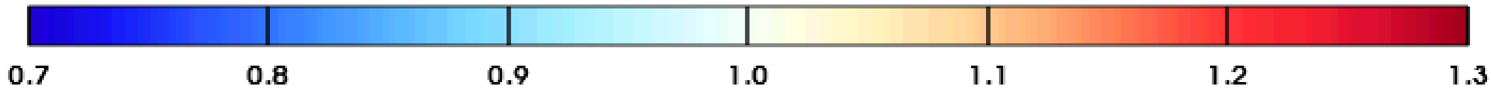
Annual-mean surface ozone increase due to clathrate emission, vmr (std AE)

❖ Warning: super-fast mechanism not ideal for air pollution.

Ozone variability increases, which will cause more air-quality exceedances

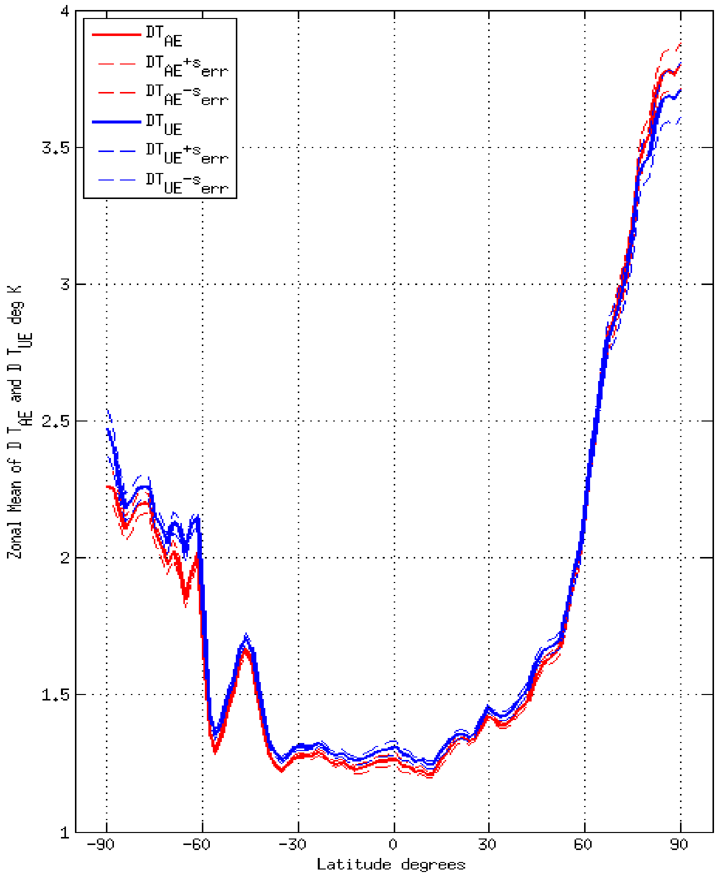


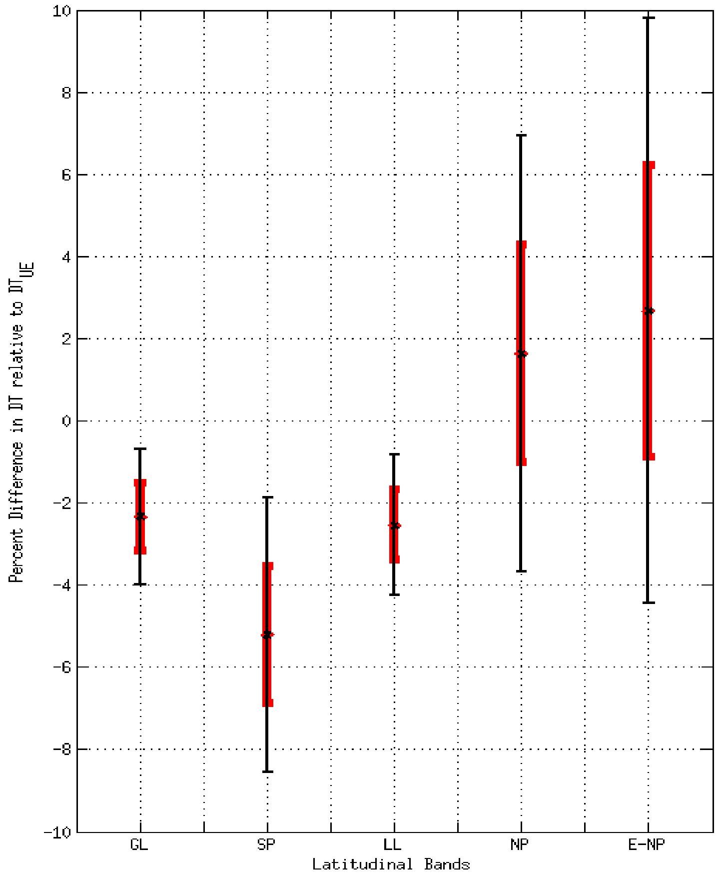
Ratio of interannual variability of surface ozone concentration (std AE)



- 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

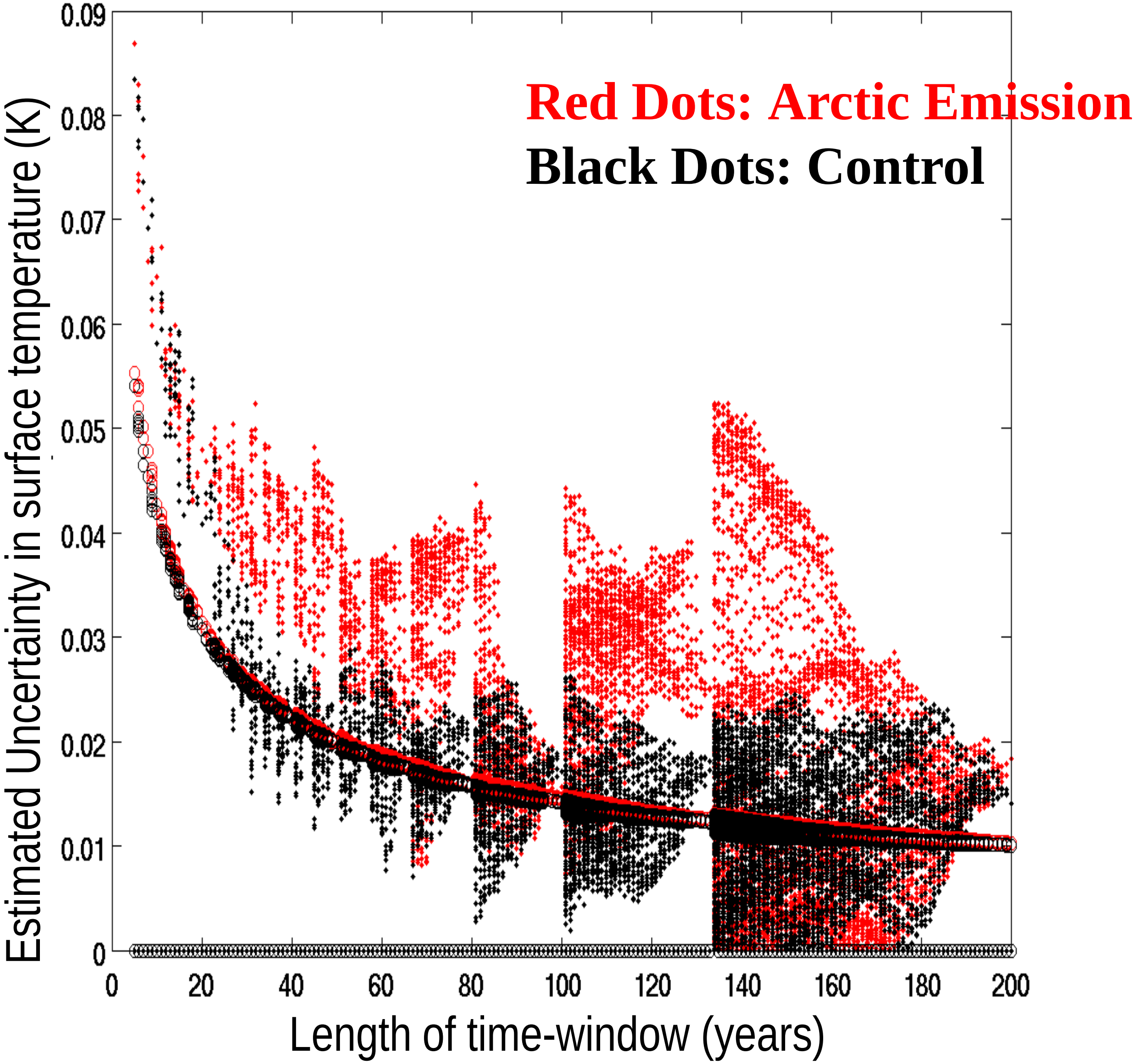




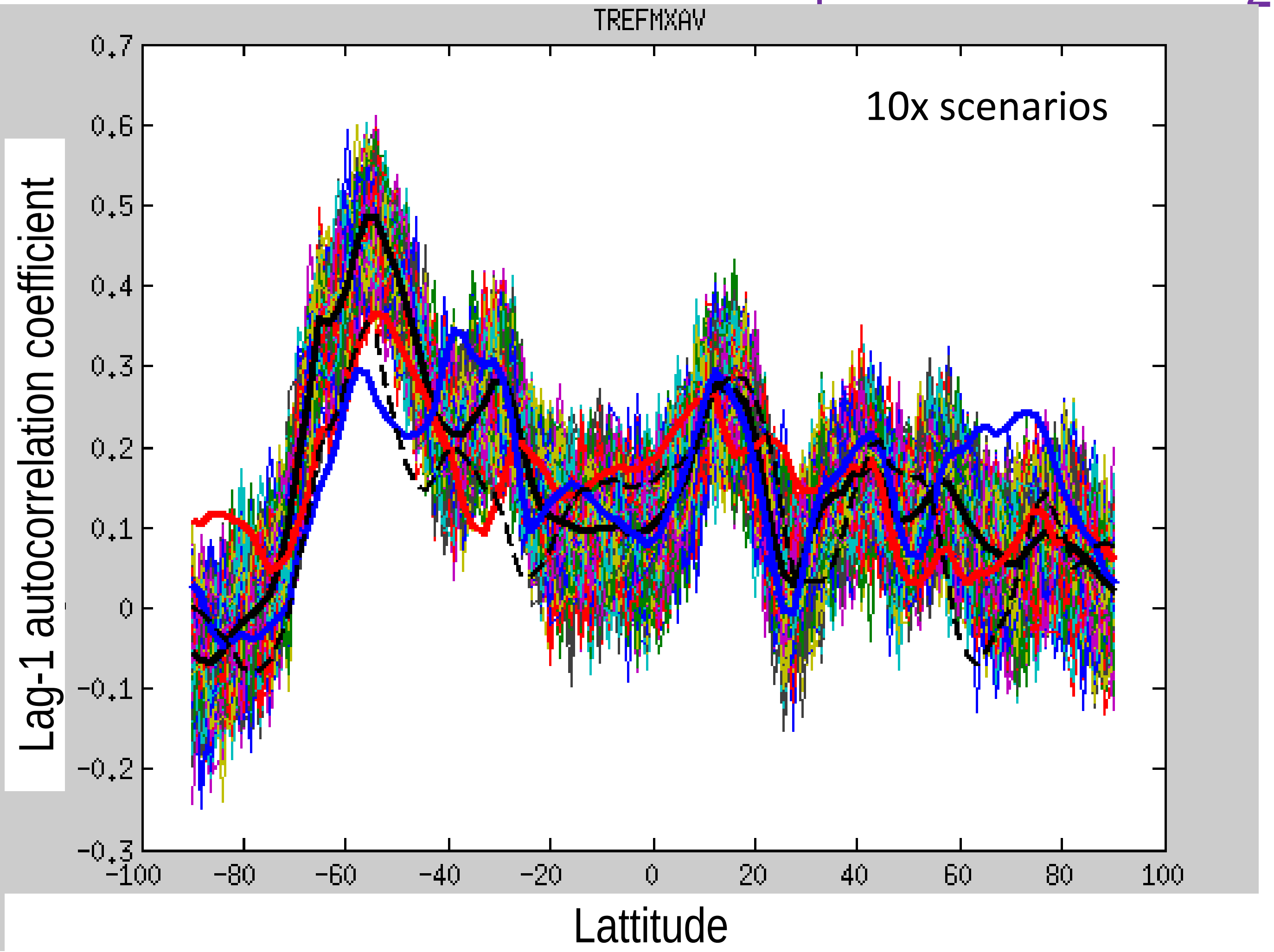
Zonal-mean temperature response for UE10x and AE10x. Dashed lines show interannual standard error.

% regional temperature diffs (AE10x-UE10x) for Global, S.Pole, Low latitudes, N. Pole, and Equator to N. Pole diff. Bars show std error.

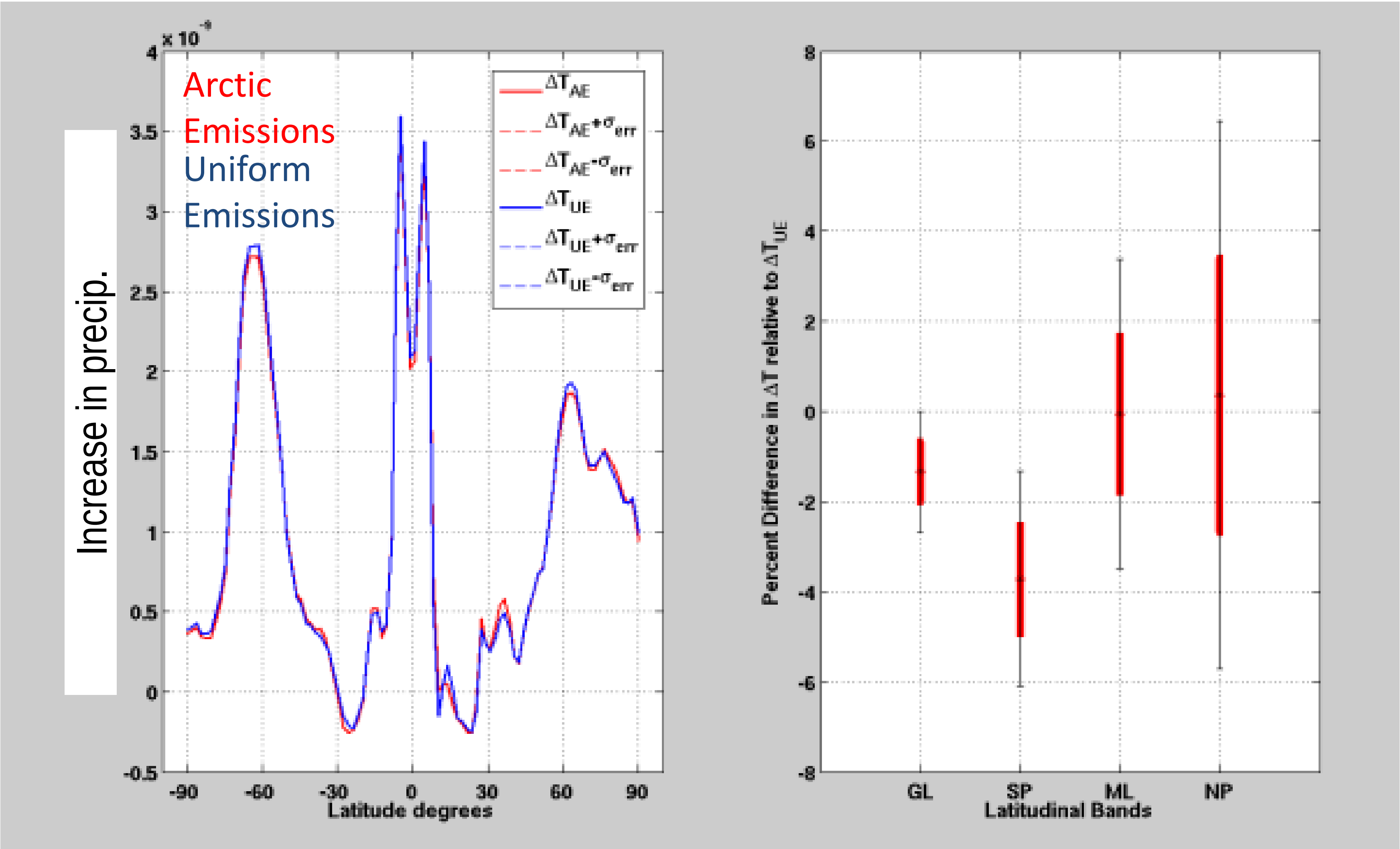
Long-timescale variability is also increased with clathrate emissions



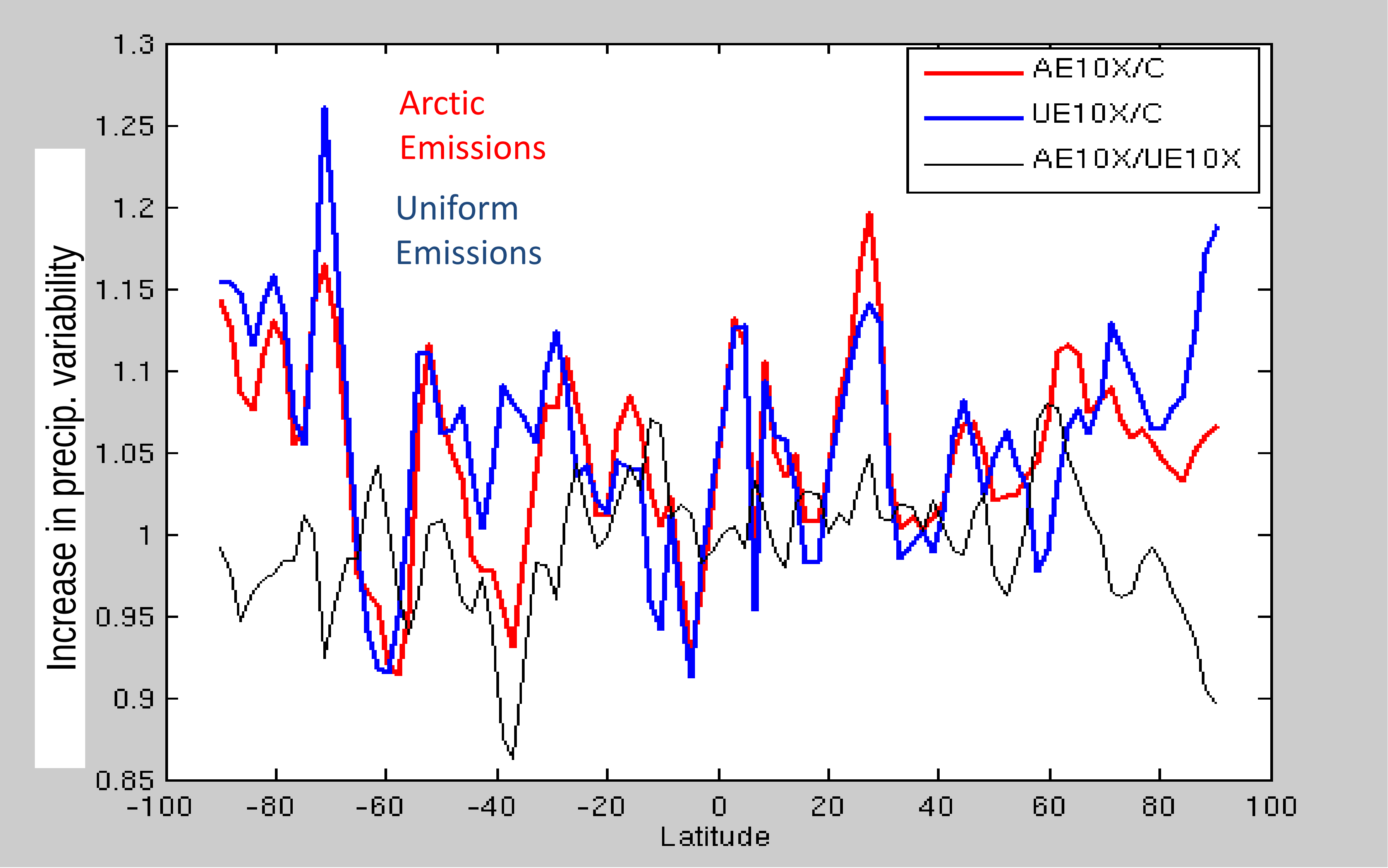
Lag-1 autocorrelation changes (T) over Southern Ocean for CH_4, but not CO_2



AE vs UE also changes precip, but only due to radiative forcing?

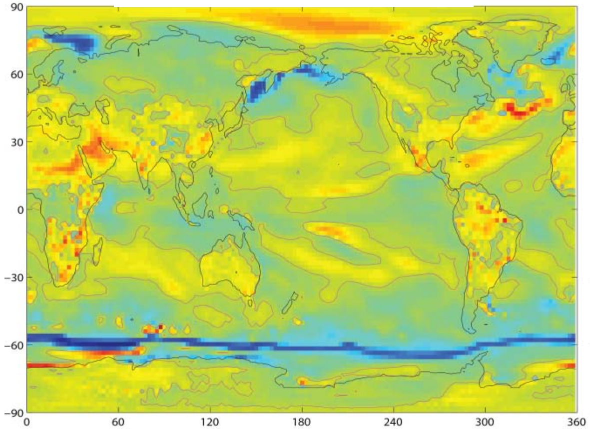


Methane emissions also changes precip variability, but only due to radiative forcing?

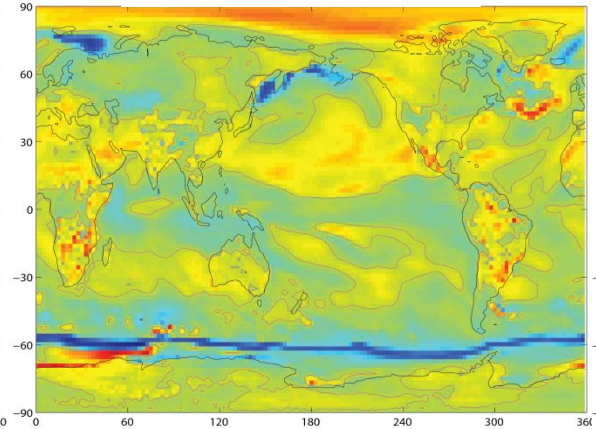


Forcing changes interannual T variability. CO_2 decreases more than CH_4?

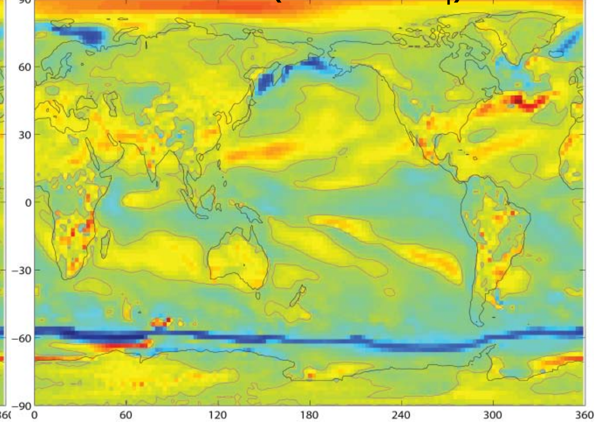
AE10x



UE10x

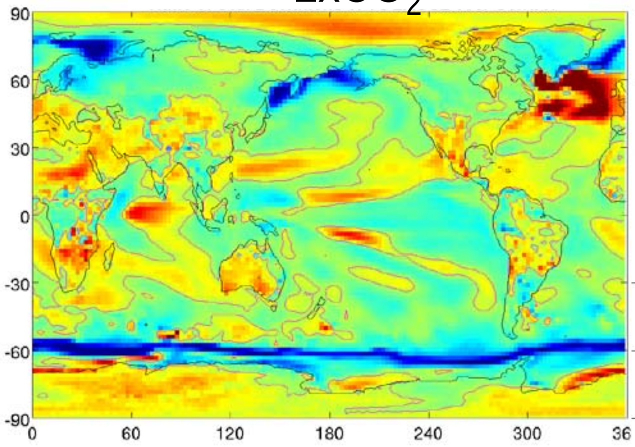


UE10x(fixedCH_4)

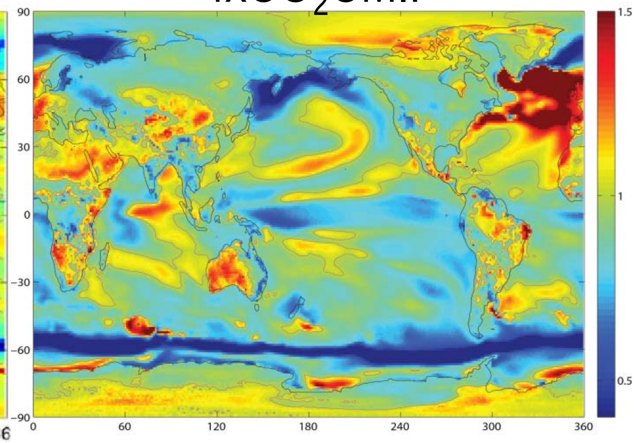


10x scenarios

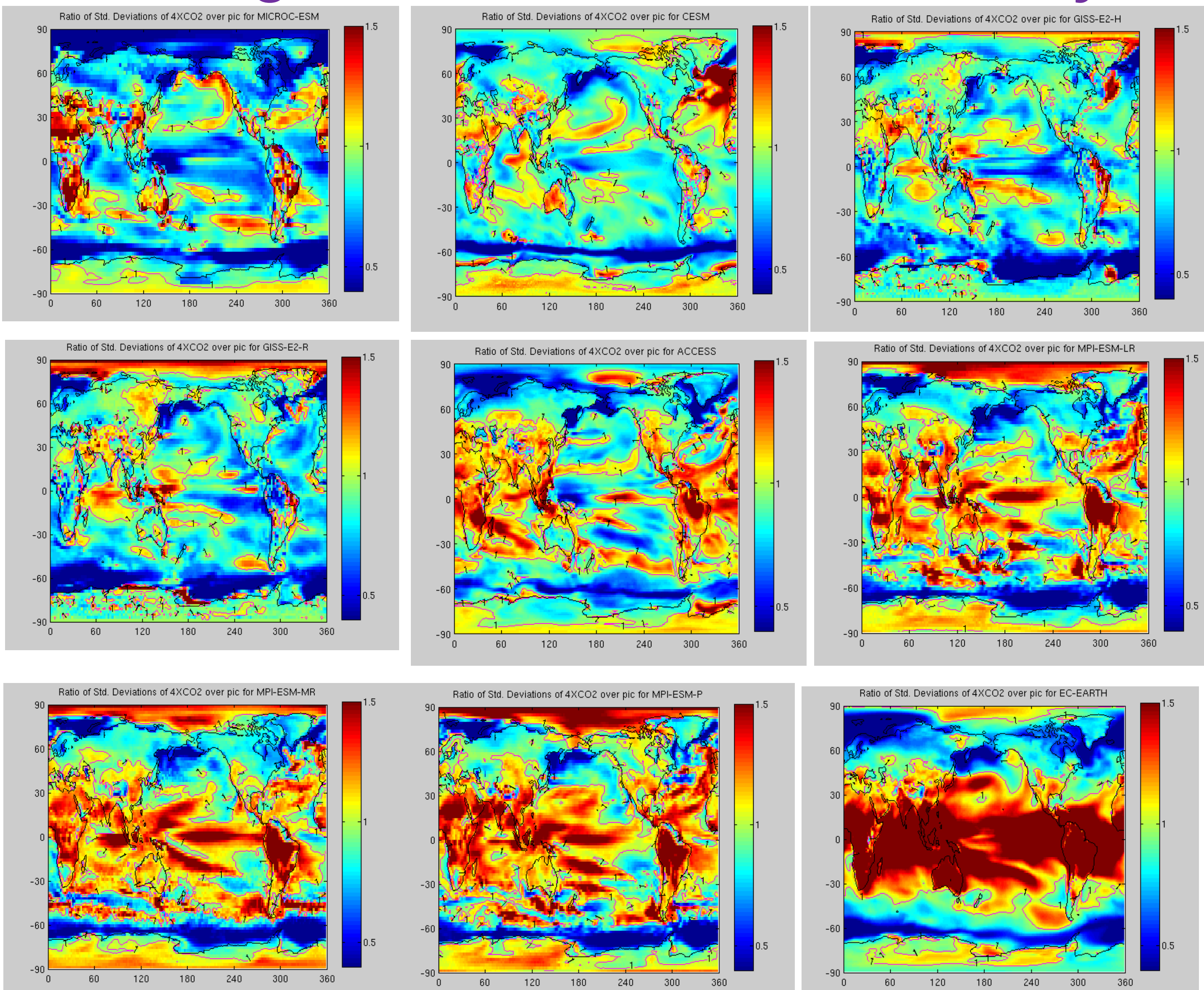
$2xCO_2$



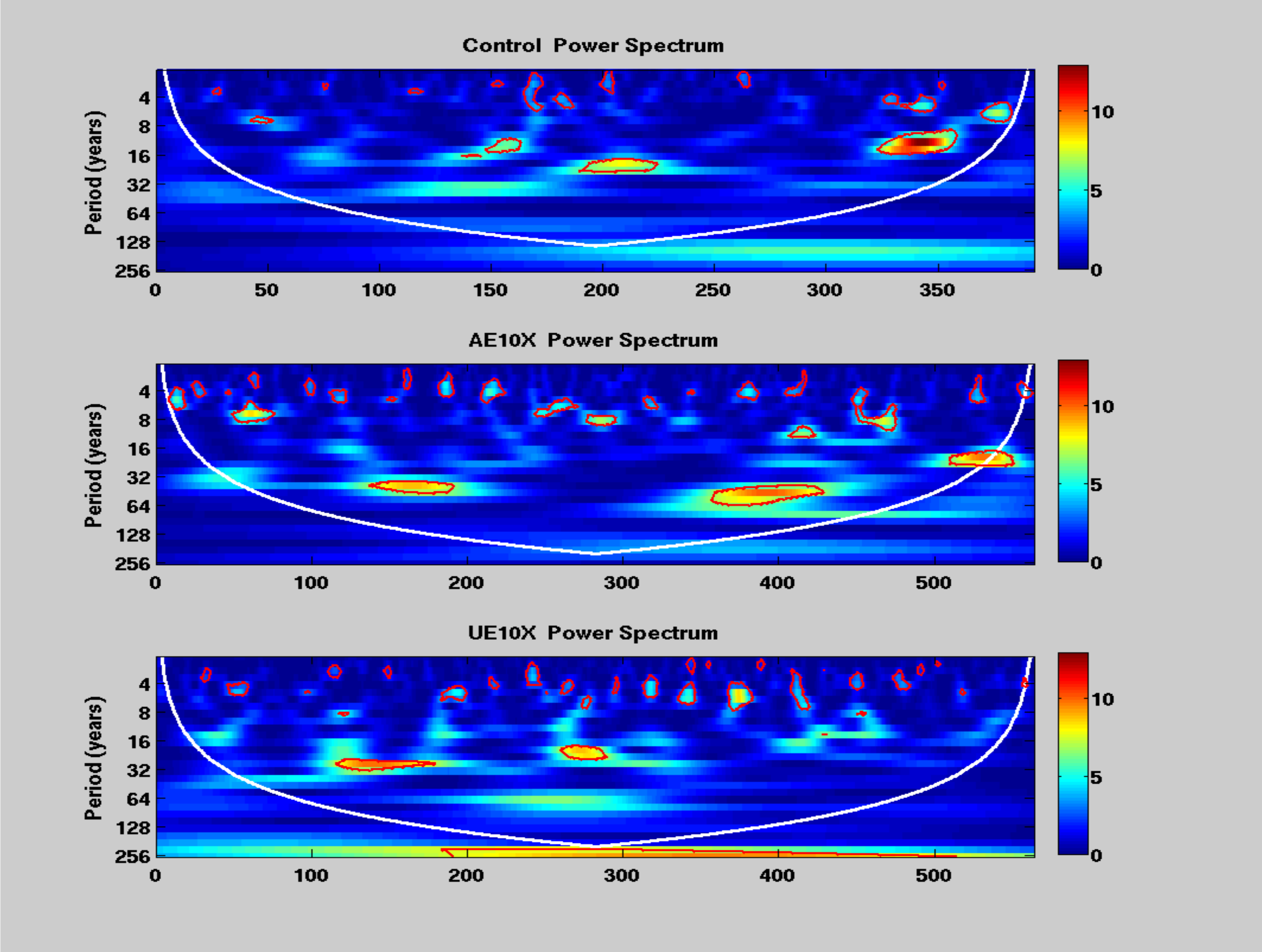
$4xCO_2$CMIP



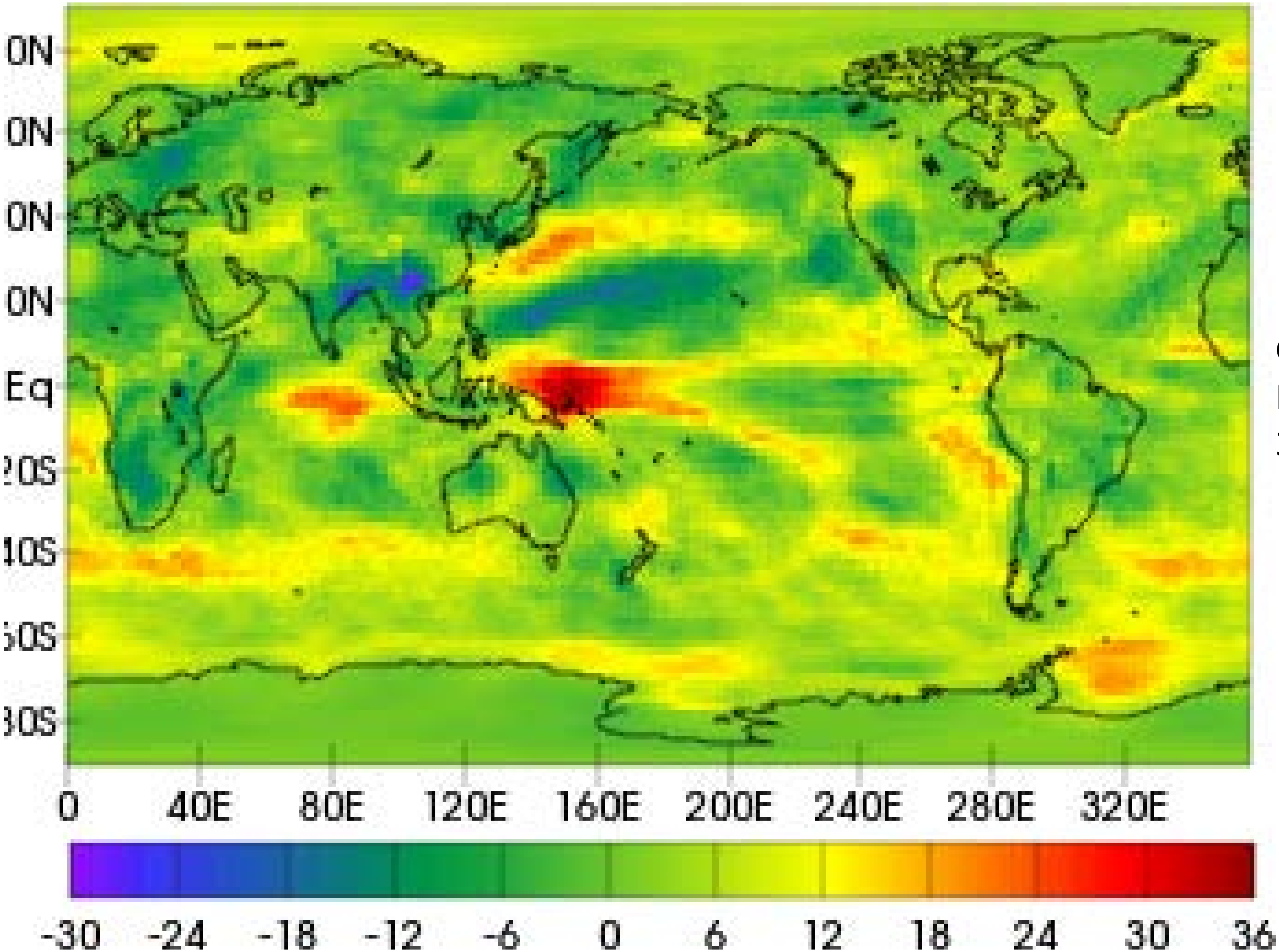
CMIP5 models (4xCO_2) do not agree on change to interannual variability.



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/m^2

Conclusions

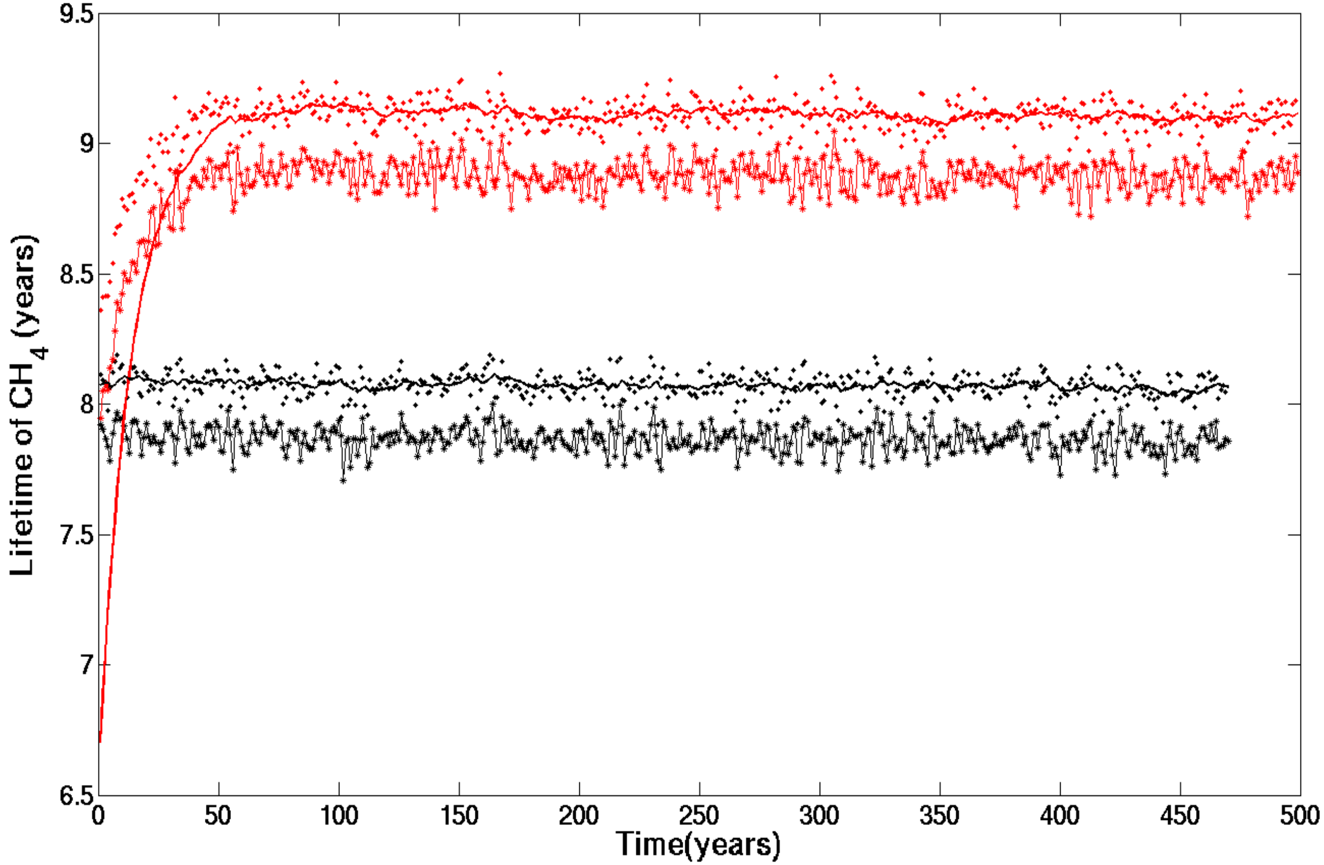
- Warming may release methane from large Arctic reservoirs.
- Clathrate methane emission scenario changes mean: methane, ozone, temperature, precip.
- Methane increase is non-uniform, but impact on temperature distribution is modest.
- Variability changes too.
- DMS has significant effect on W/m^2

Unused Slides

Testing CESM climate response to clathrate emission scenario

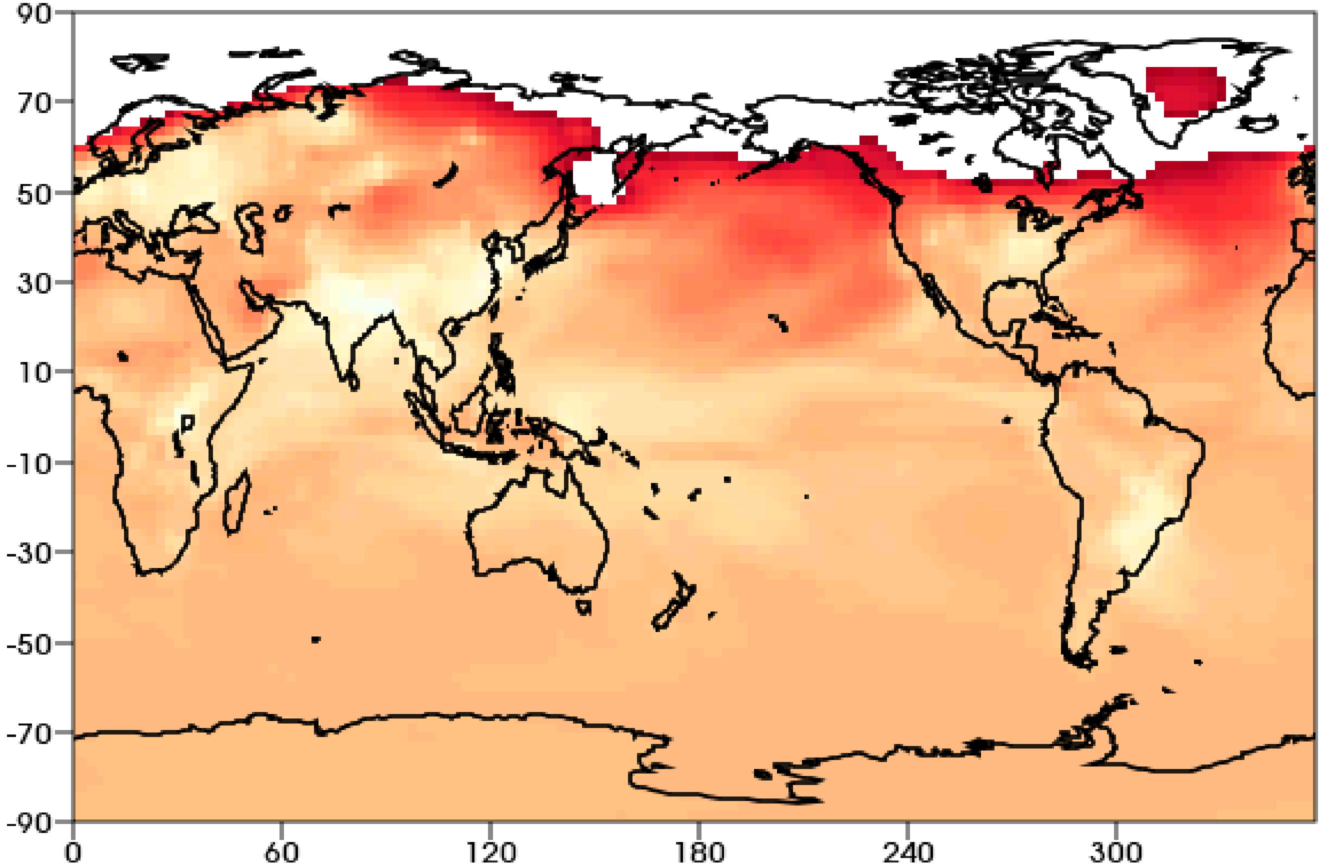
- CESM with:
  - Fast chemistry (CH_4 emissions, strat-chem),
  - Full ocean.
- Steady-state simulations:
  - 2000 control,
  - 2000 control + clathrate emissions in the arctic (AE),
  - 2000 control + clathrate emissions spread globally (UE),
  - Plus, AE and UE clathrate emissions increased 10x.
- 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

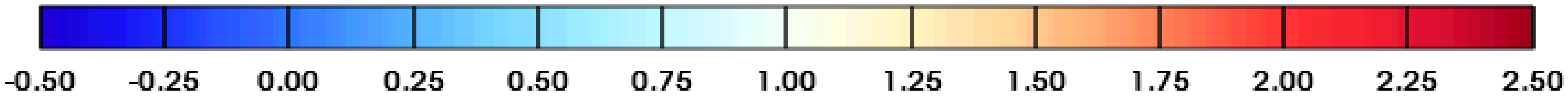


Methane lifetime as a function of time for **Control** and standard Arctic emission case computed using three approximation methods

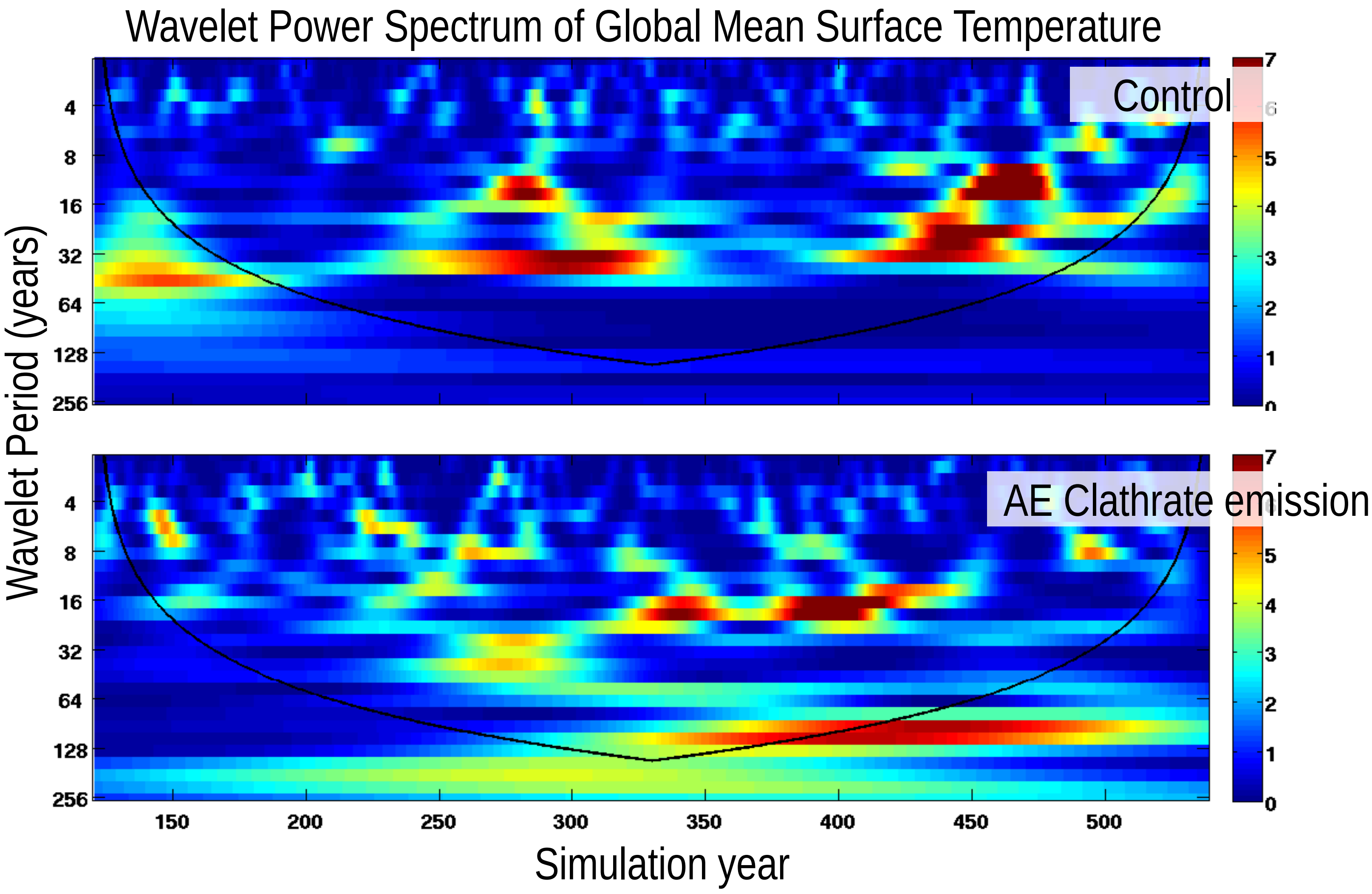
Large increases in methane variability



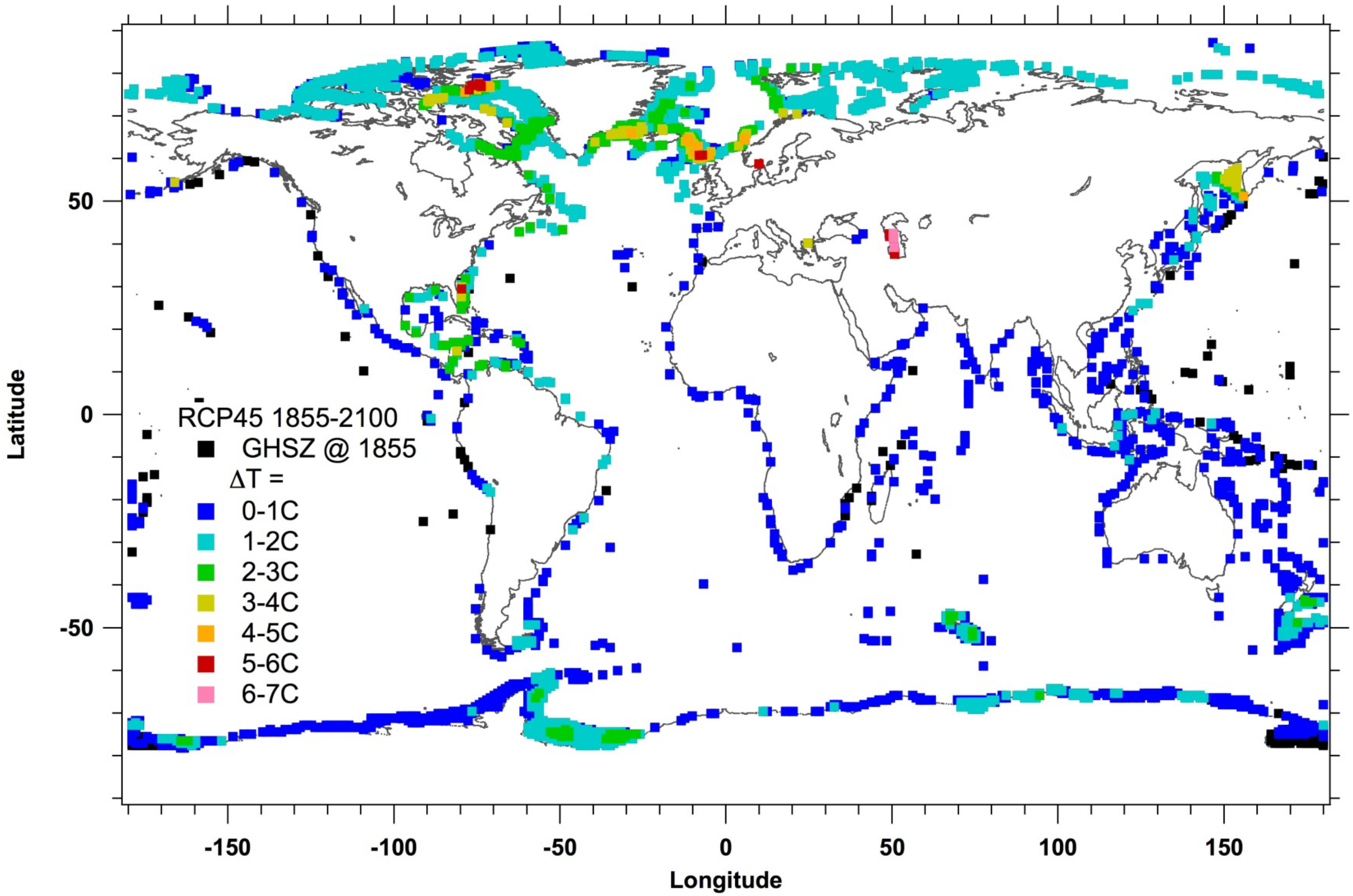
Ratio of interannual variability of surface methane concentration



Long-term variability increase in wavelet spectra too

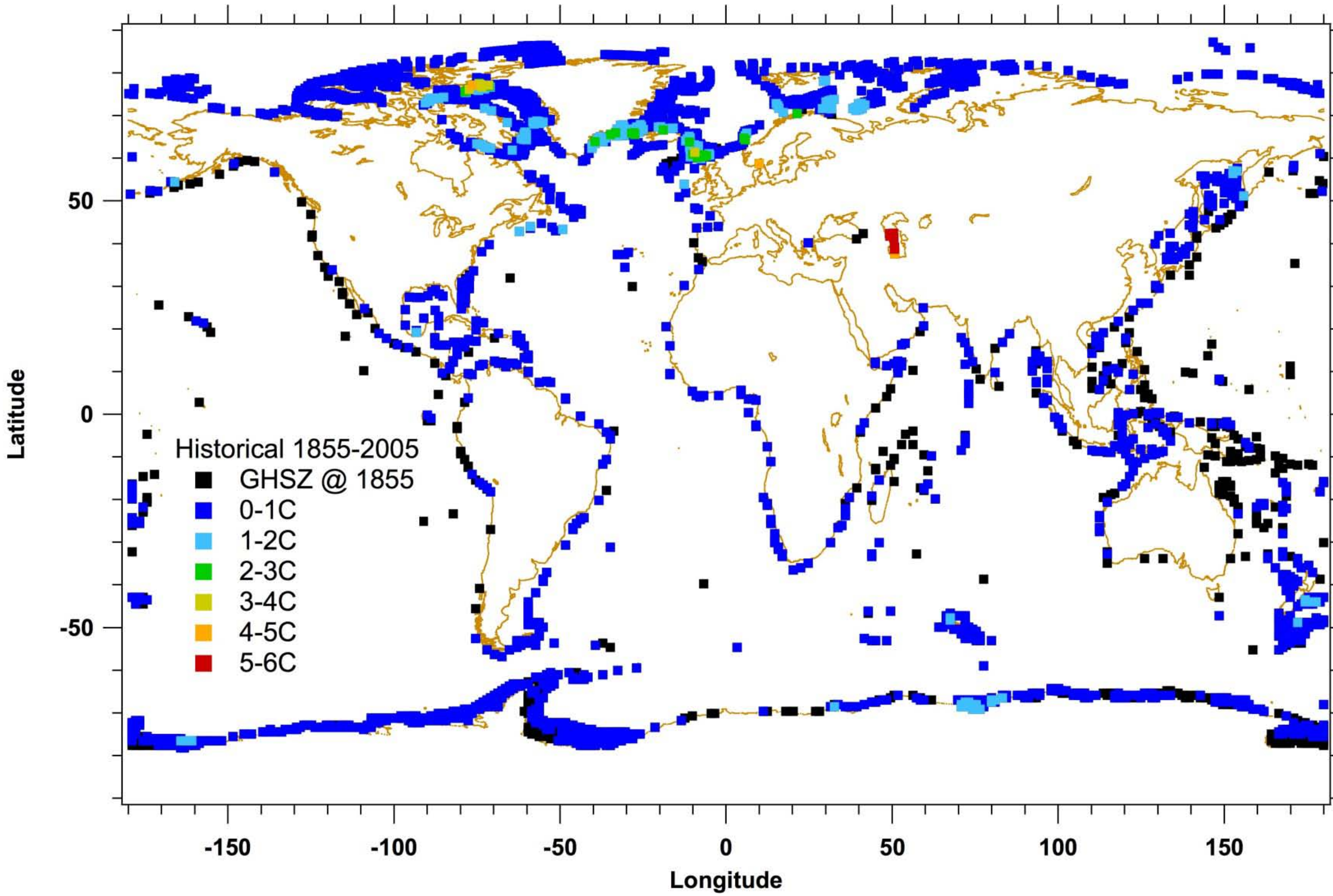


RCP4.5 predicts ocean floor warming that is also significant



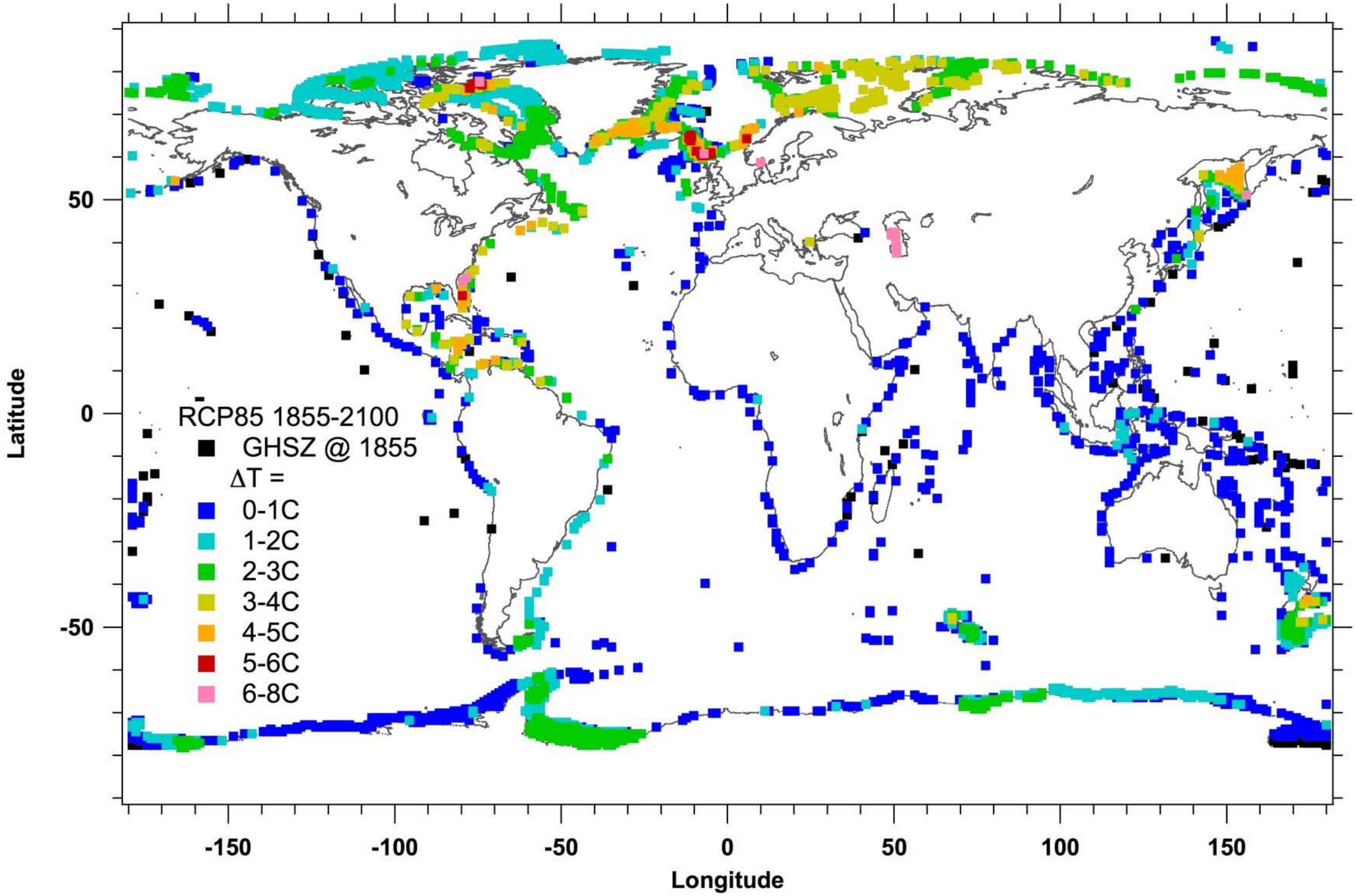
Ocean bottom temperature change (RCP4.5 1855 to 2100)

CESM predicts minimal warming in clathrate locations in present-day



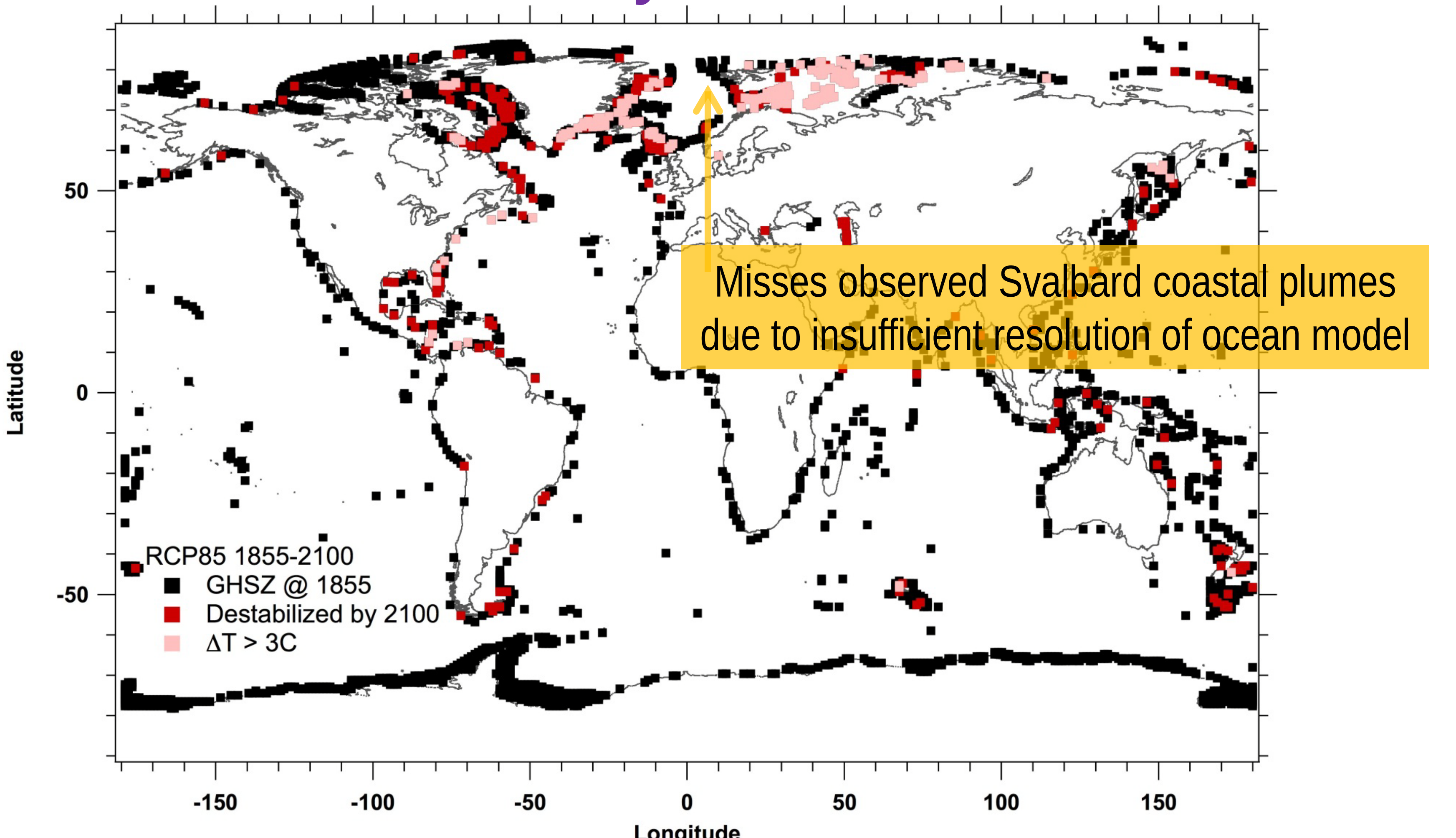
Ocean bottom temperature change (1855 to 2005)

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.

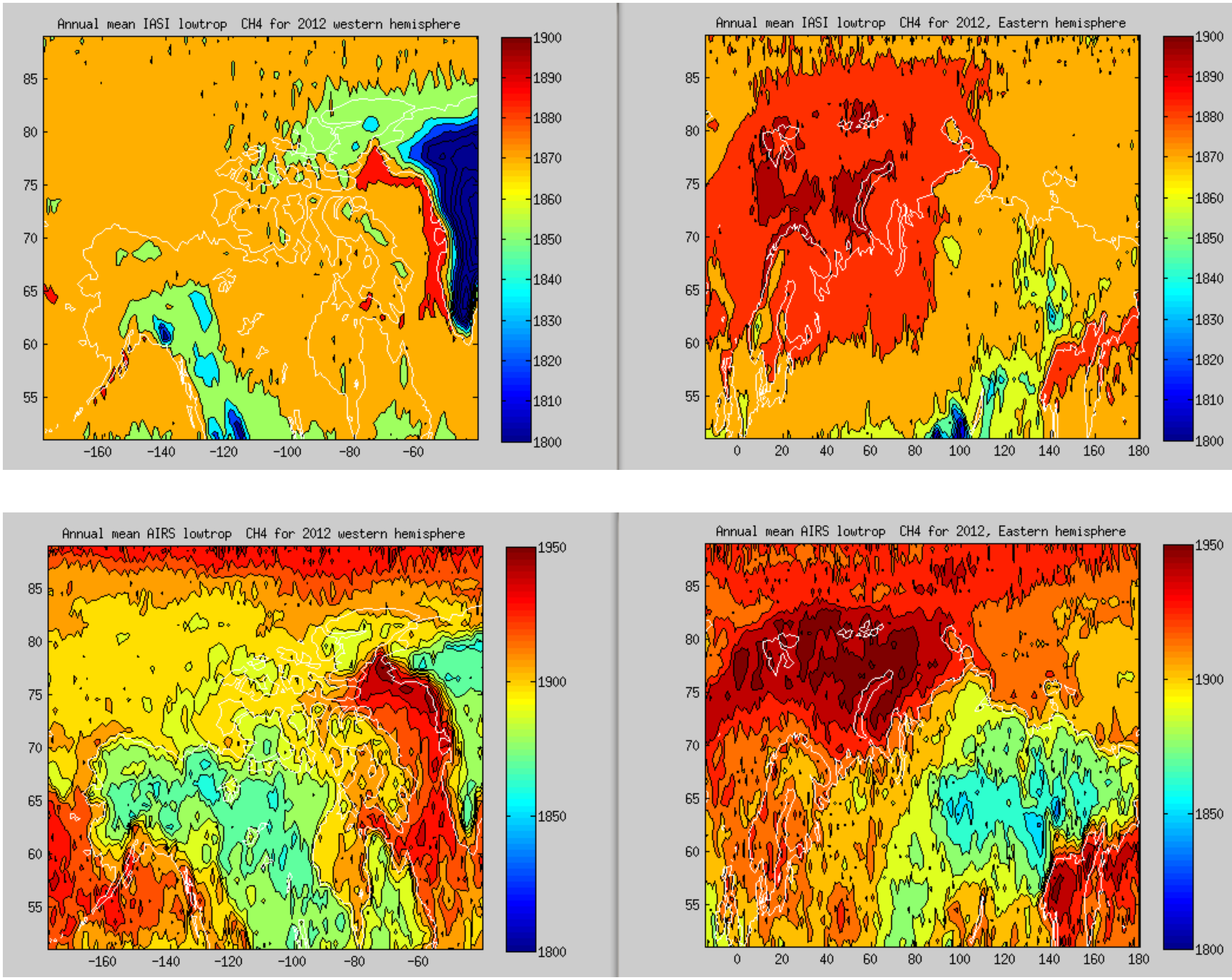
Satellites show high methane over Barents

Western Arctic

Eastern Arctic

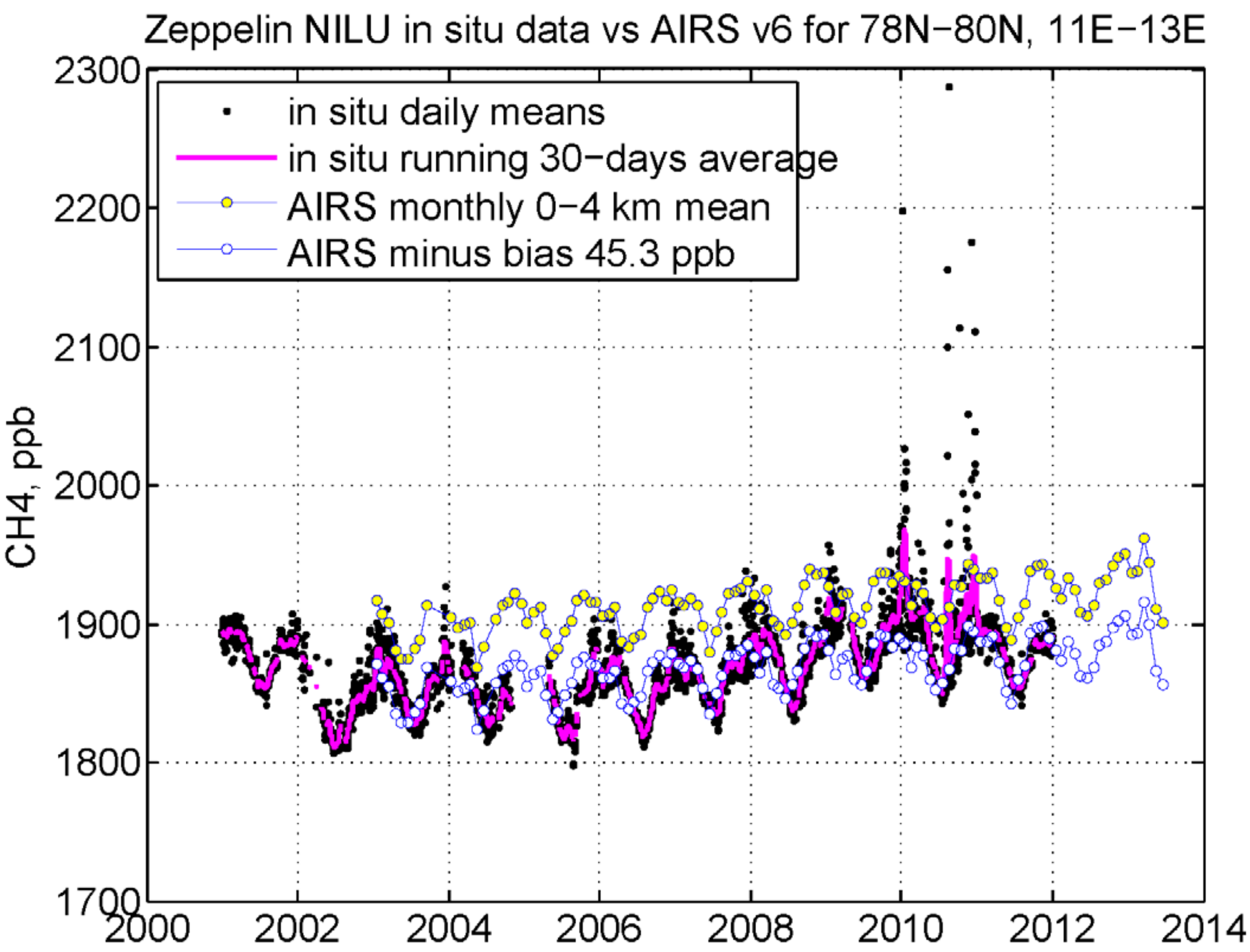
IASI

AIRS



Note: different color scales

AIRS matches Svalbard ground site (with offset)



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