

Probabilistic Forecast for 21st Century Climate Changes in High Latitudes of Northern Hemisphere.

Andrei Sokolov, Mort Webster, Chris Forest and Marcus Sarofim

MIT Joint Program on the Science and Policy of Global Change

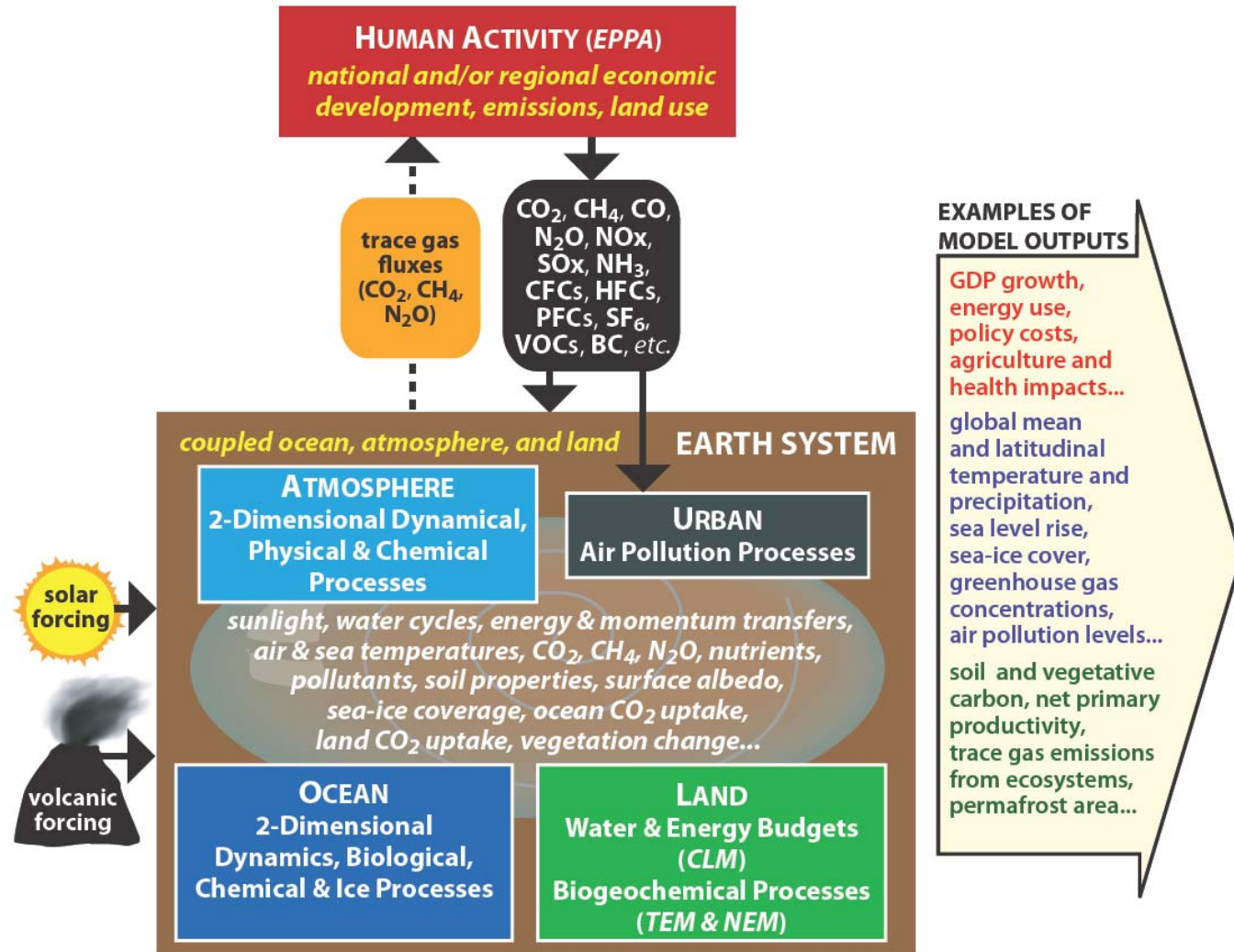
Sokolov, A.P., P.H. Stone, C.E. Forest, R. Prinn, M.C. Sarofim, M. Webster, S. Paltsev, C.A. Schlosser, D. Kicklighter, S. Dutkiewicz, J. Reilly, C. Wang, B. Felzer, H.D. Jacoby, 2009: Probabilistic Forecast for 21st Century Climate Based on Uncertainties in Emissions (without Policy) and Climate Parameters. *J. Climate* in review.

Webster, M., C. Forest, H. Jacoby, S. Paltsev, R. Prinn, J. Reilly, M. Sarofim, A. Schlosser, A. Sokolov, P. Stone, 2009: Long-term greenhouse gas stabilization and the risks of dangerous impacts. (in preparation).

R. Prinn. Probabilistic Forecast for 21st Century Climate Based on Uncertainties in Emissions. CL52, Room 28, Thu, 23 Apr. 13:30–13:45,

M. Webster, S. Paltsev, J. Reilly, and A. Sokolov

GHG Emissions and mitigation cost uncertainty. CL52, Halls X/Y, Thu, 23 Apr 17:30–19:00



MIT Integrated Global System Model version 2.2

Main sources of uncertainties.

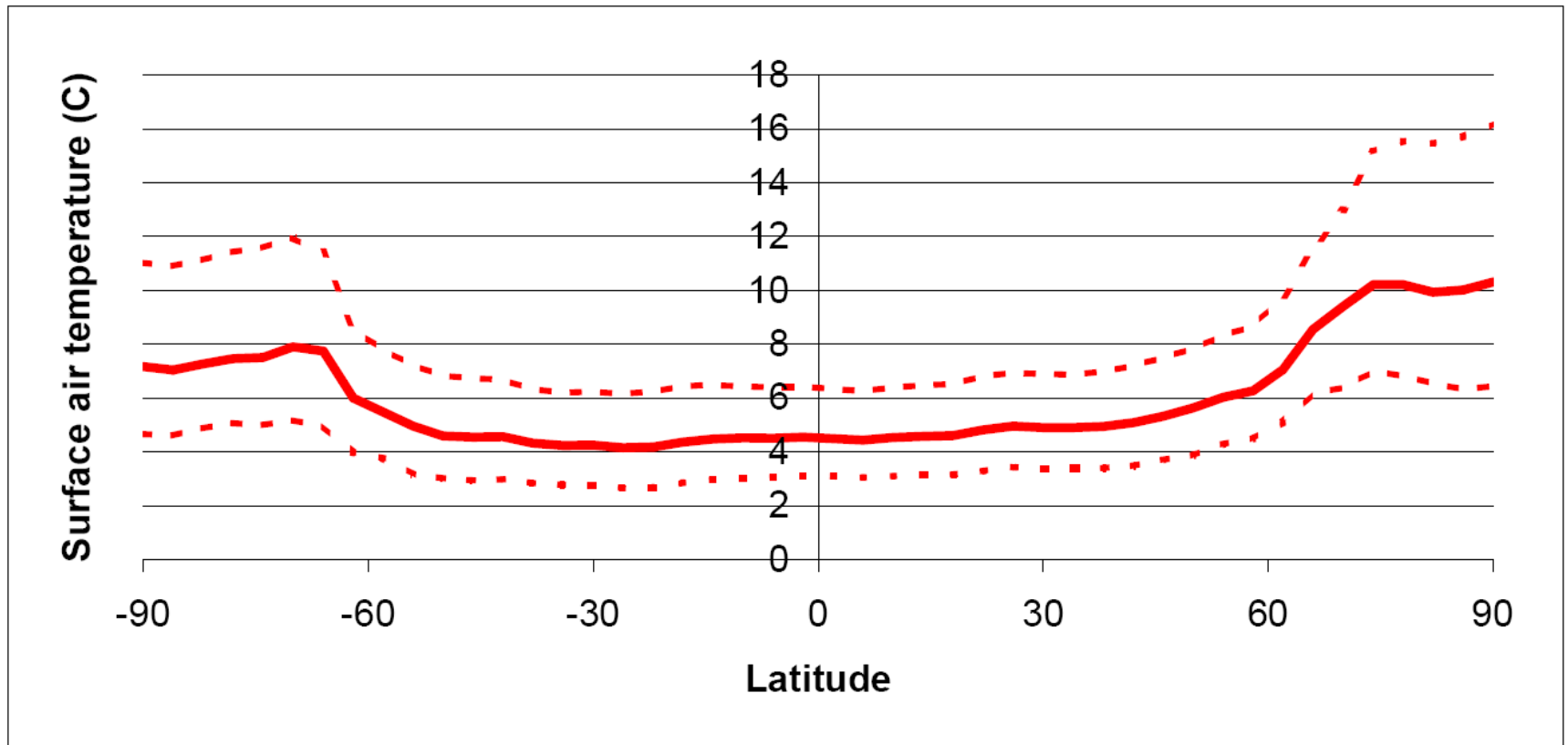
Economics.

Uncertainties in labor productivity, resource availability, population growth, and cost and availability of new technologies.

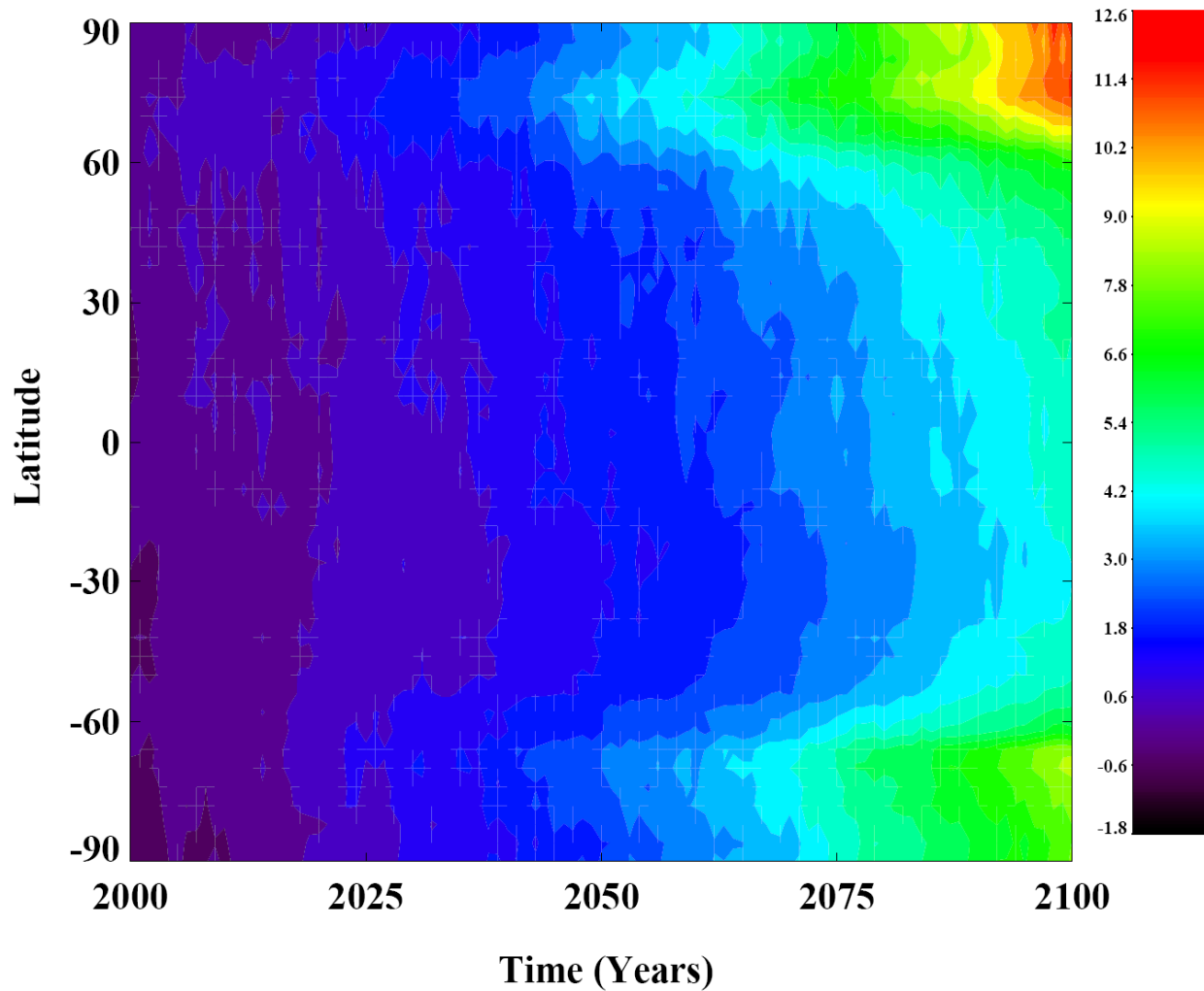
Climate.

Climate sensitivity, rate of the heat uptake by the deep ocean, strength of the sulfate aerosol forcing, and uncertainty in carbon uptake by the ocean and terrestrial ecosystem.

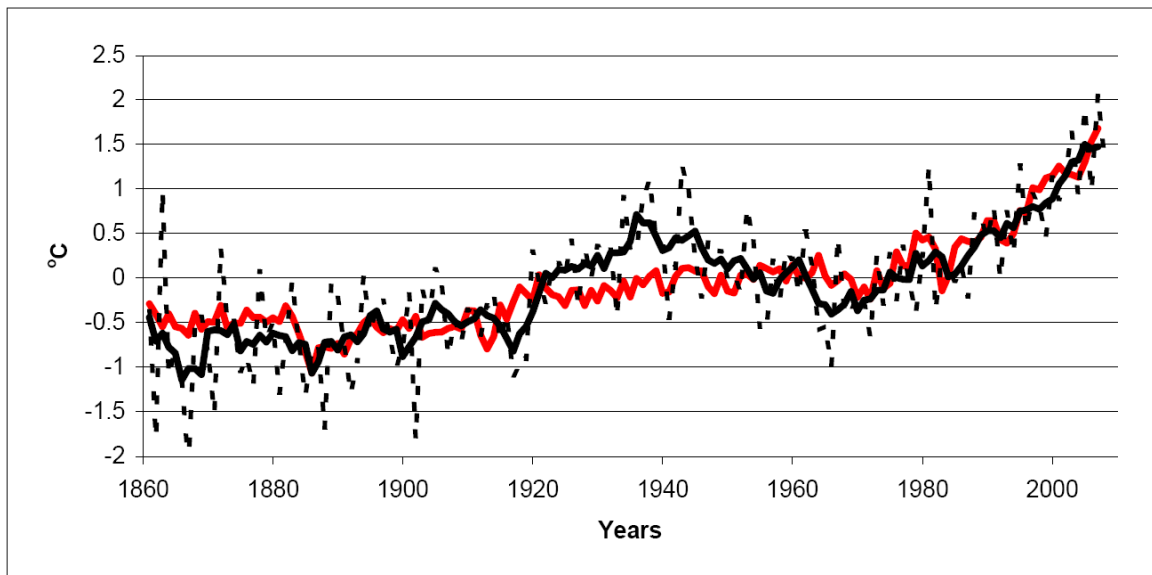
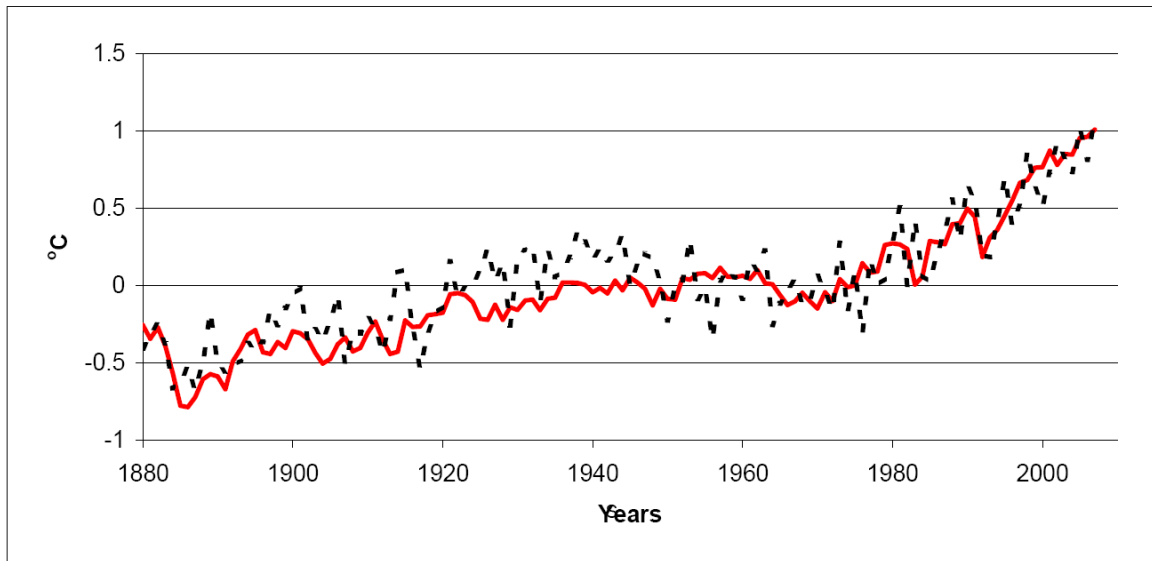
Probability distributions for models' parameters are defined based on data for economic development and climate change over second half of 20th century



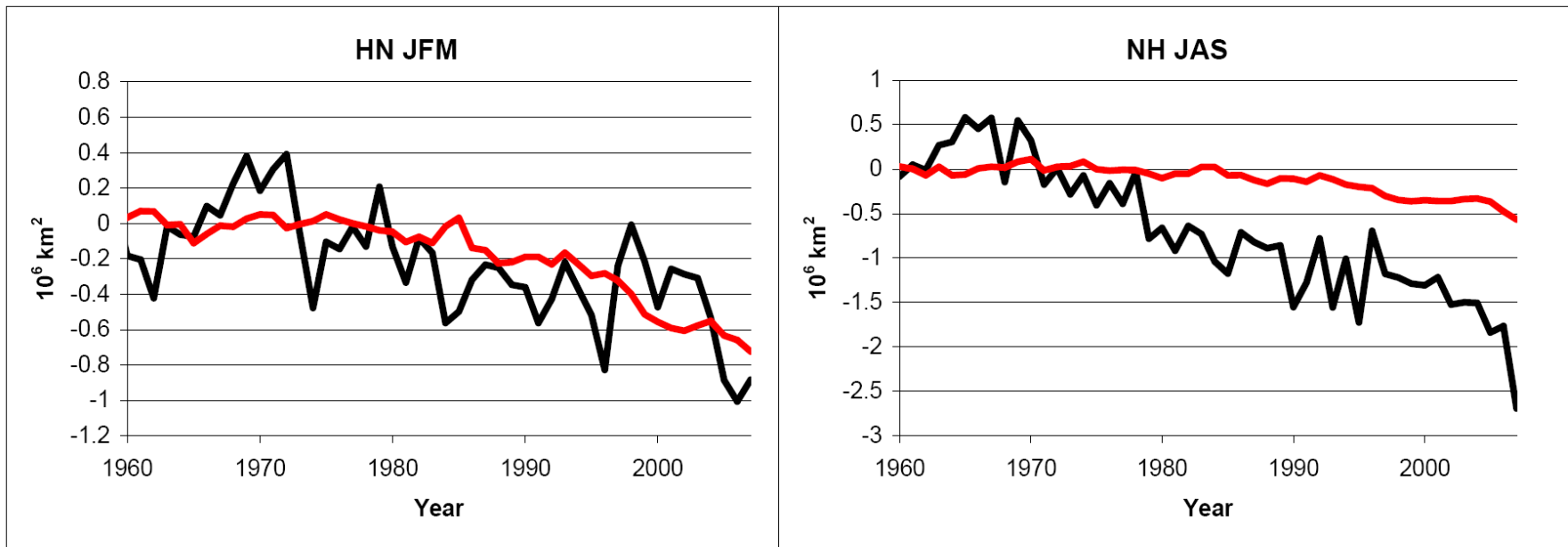
Latitudinal distribution of changes in SAT in the last decade of 21st century relative to 1981-2000 in simulations without climate policy. Solid line is median, dashed lines are 5% and 95% percentiles.



Transient change in surface air temperature in simulation with median values of climate parameters and reference GHG emissions.

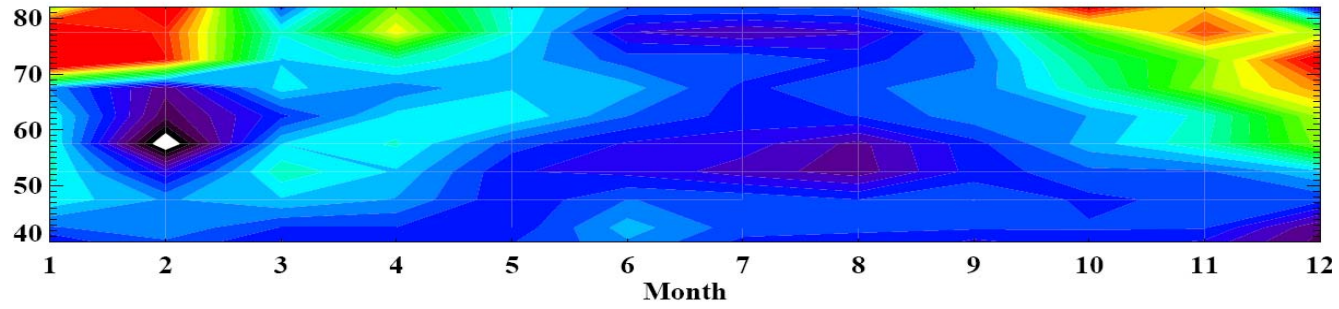


Surface air temperature over land area: global (top) and north from 60°N (bottom).
Black - observed: dashed line - annual data, solid line - 5 year running mean
Red - in simulation with median values of climate parameters and observed forcing

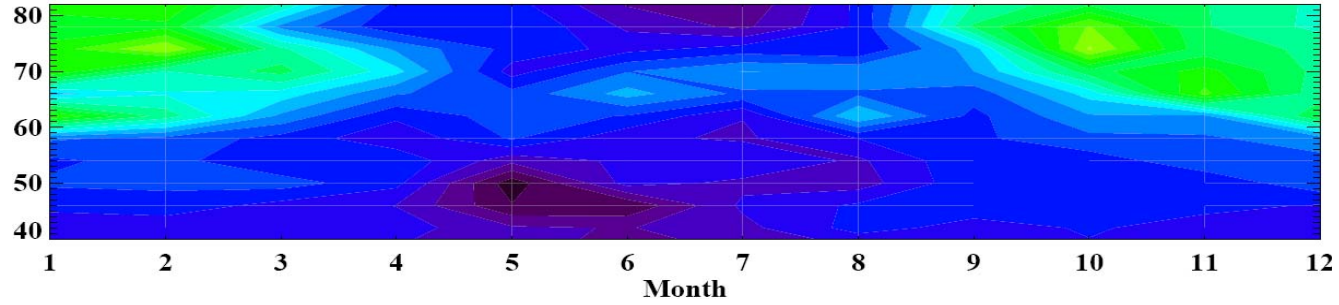


Changes in Atlantic sea ice area during winter (left) and summer (right).
Red lines - simulated by the MIT IGSM with prescribed forcing. Black lines - observed

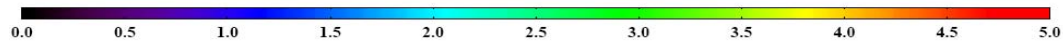
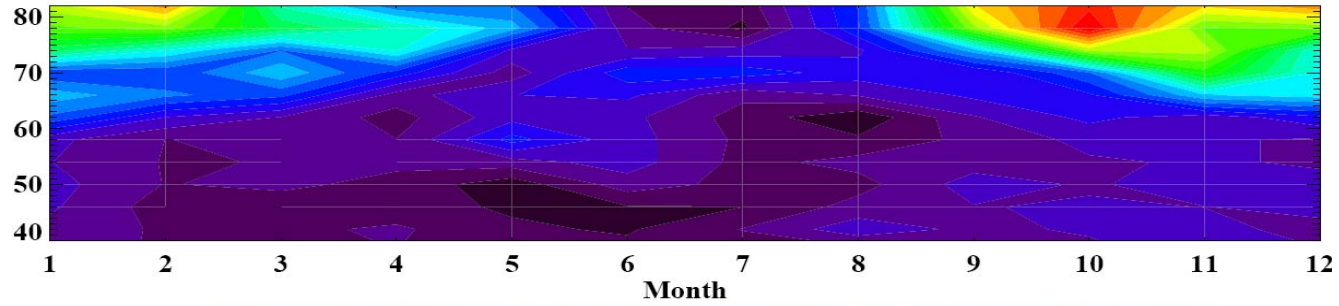
Observed

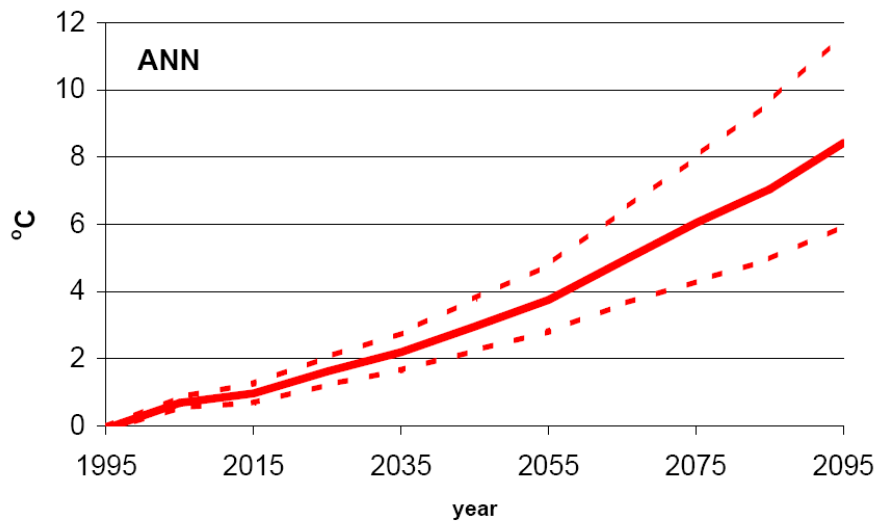


Simulated

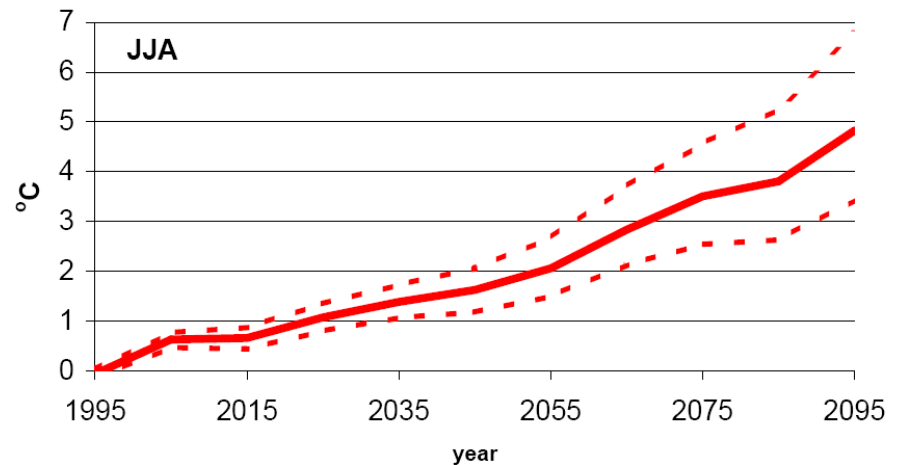
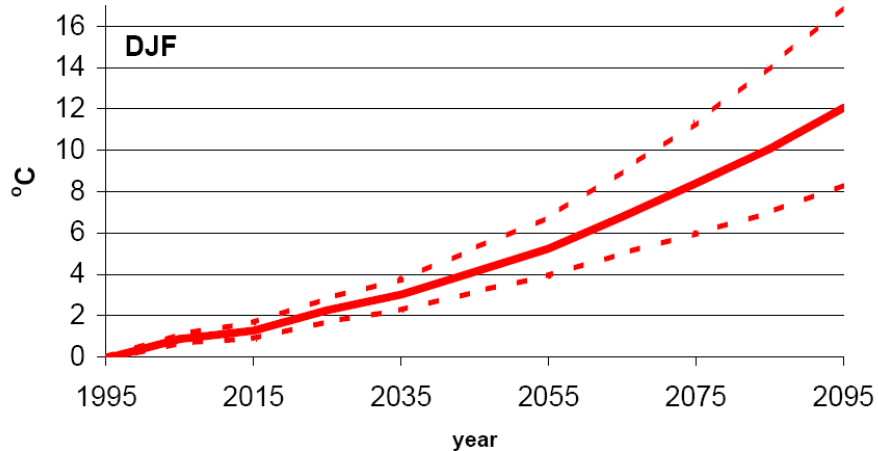


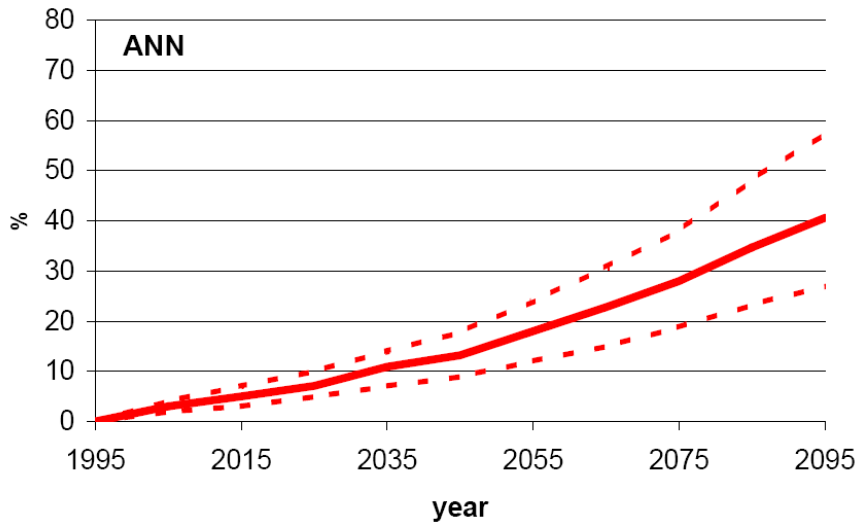
Simulated with prescribed changes in SST and sea ice



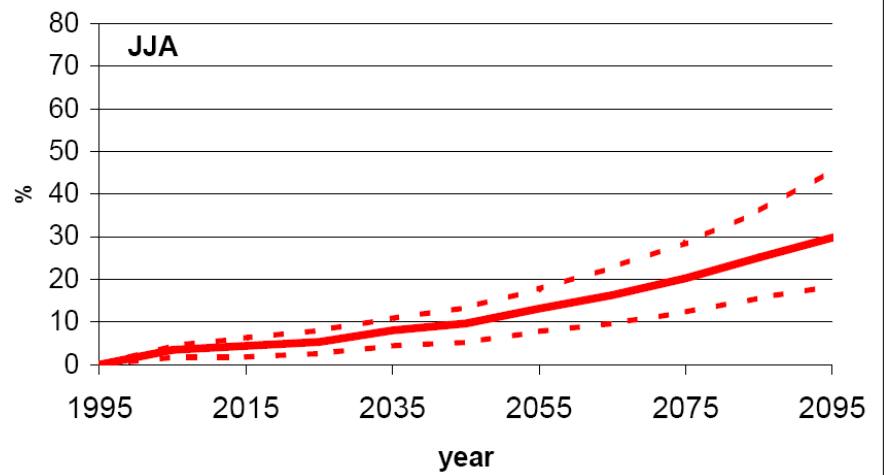
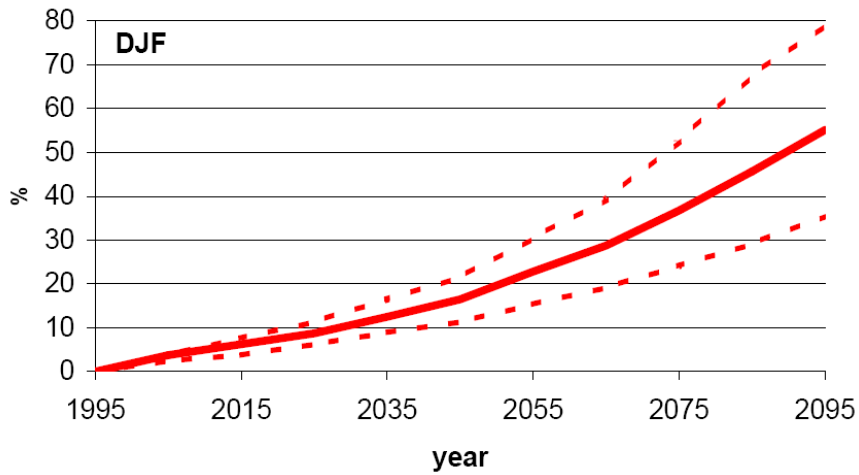


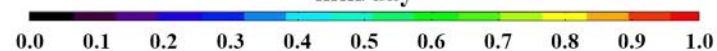
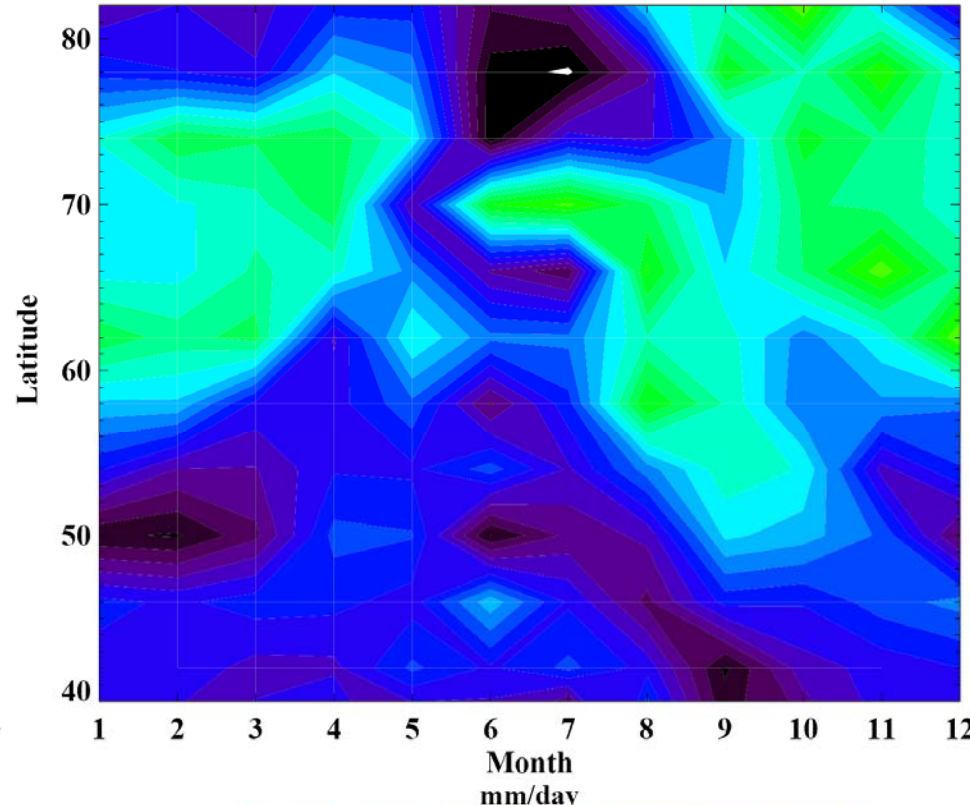
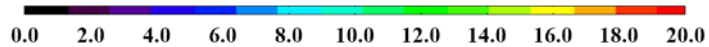
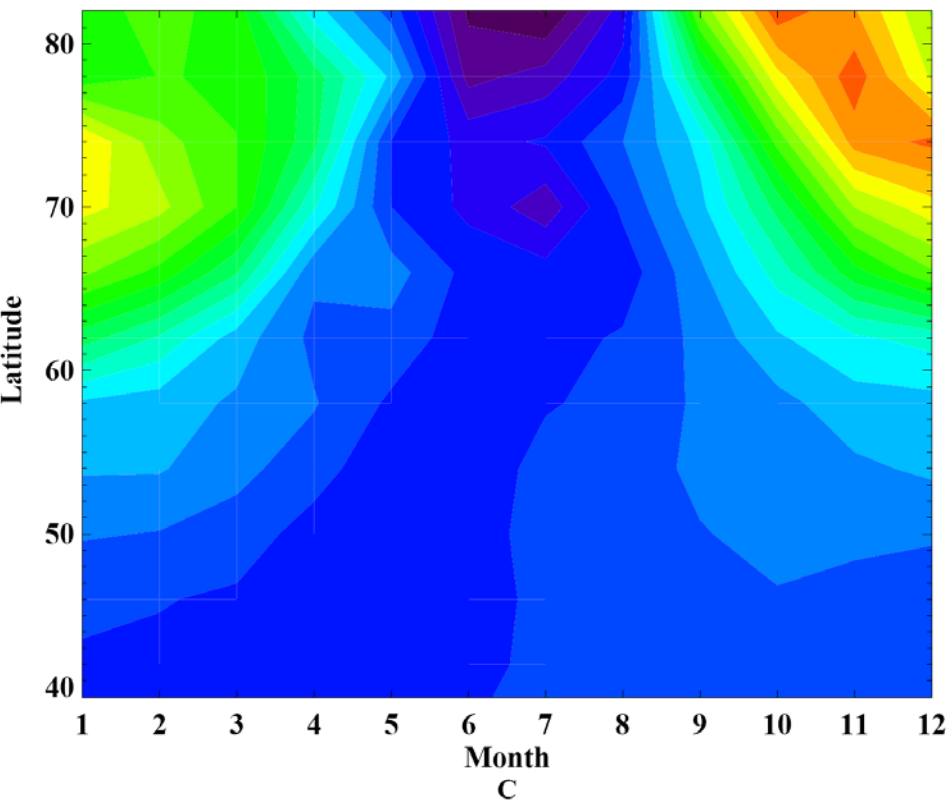
Projected changes in decadal mean surface air temperature over land area north from 60N
Solid line - median,
dashed lines - 5% and 95% percentiles



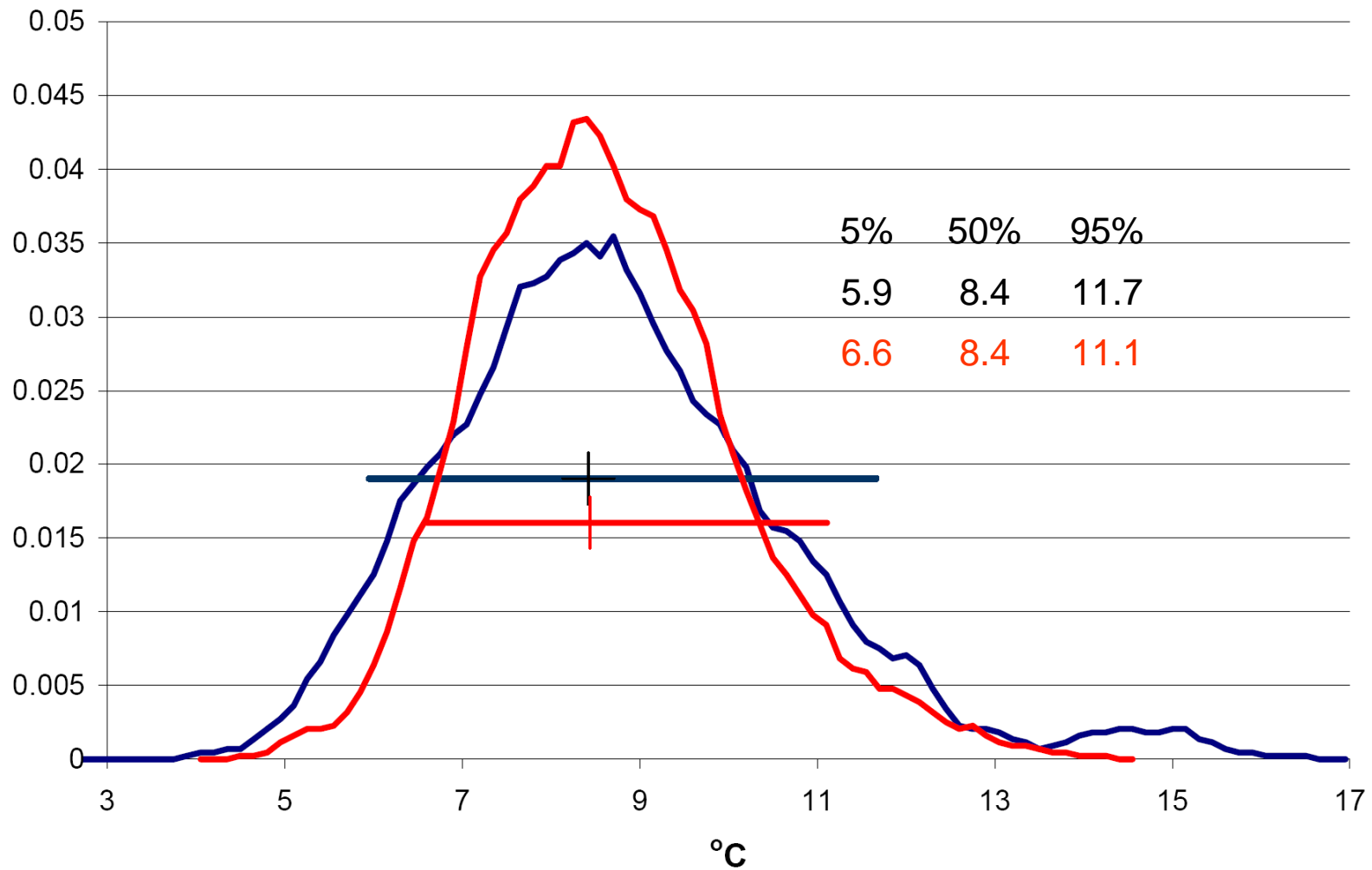


Projected changes in decadal mean precipitation (as % of 1981-2000 value) over land area north from 60N
 Solid line - median,
 dashed lines - 5% and 95% percentiles





Change in surface air temperature and precipitation over land in simulation with median values of climate parameters and reference GHG emissions. Average for 2091-2100 minus average for 1981-2000

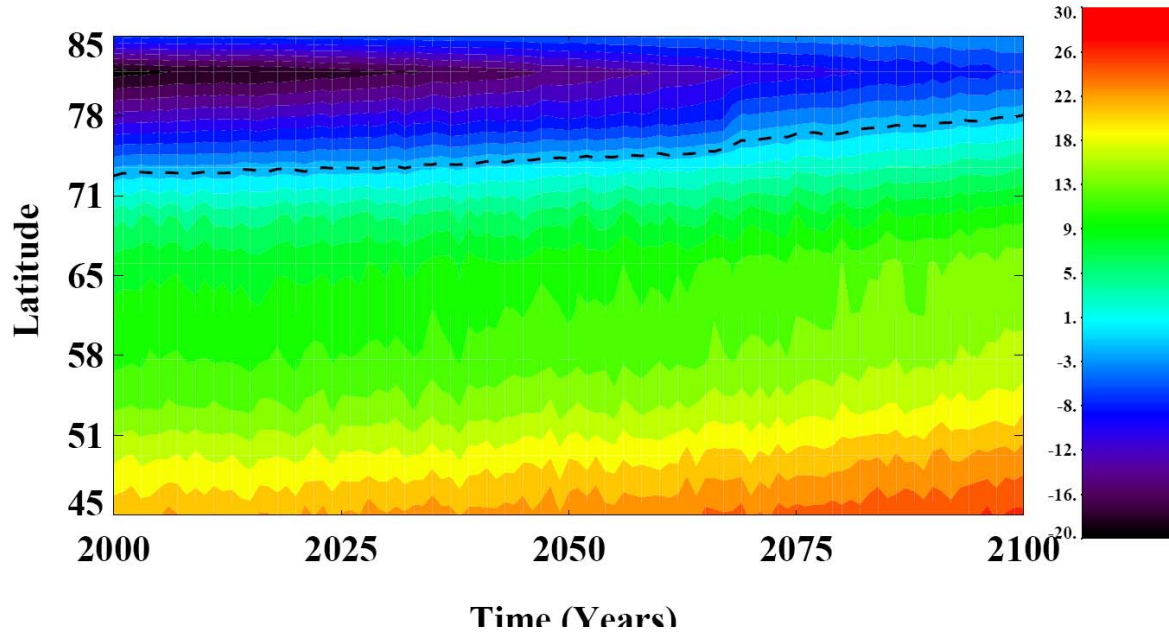


Frequency distributions for SAT increase over land north from 60N
in 2091 to 2100 relative to the 1981 to 2000 average.

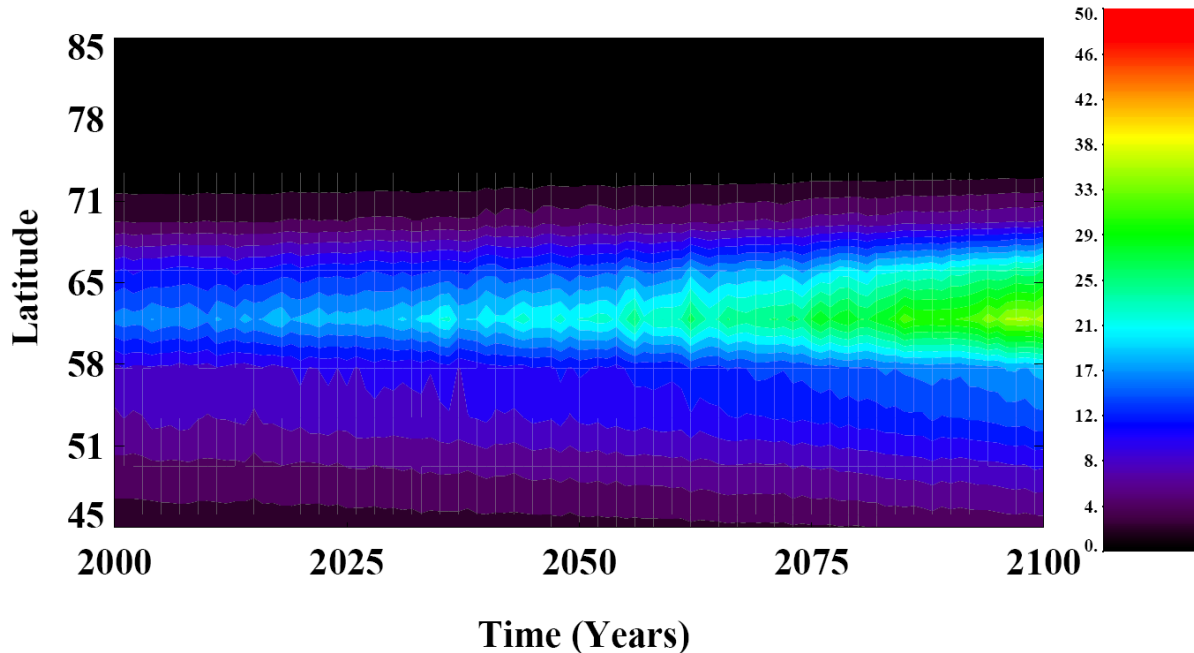
Red – climate uncertainty only, black – full uncertainty.

Horizontal bars – 5%-90% ranges

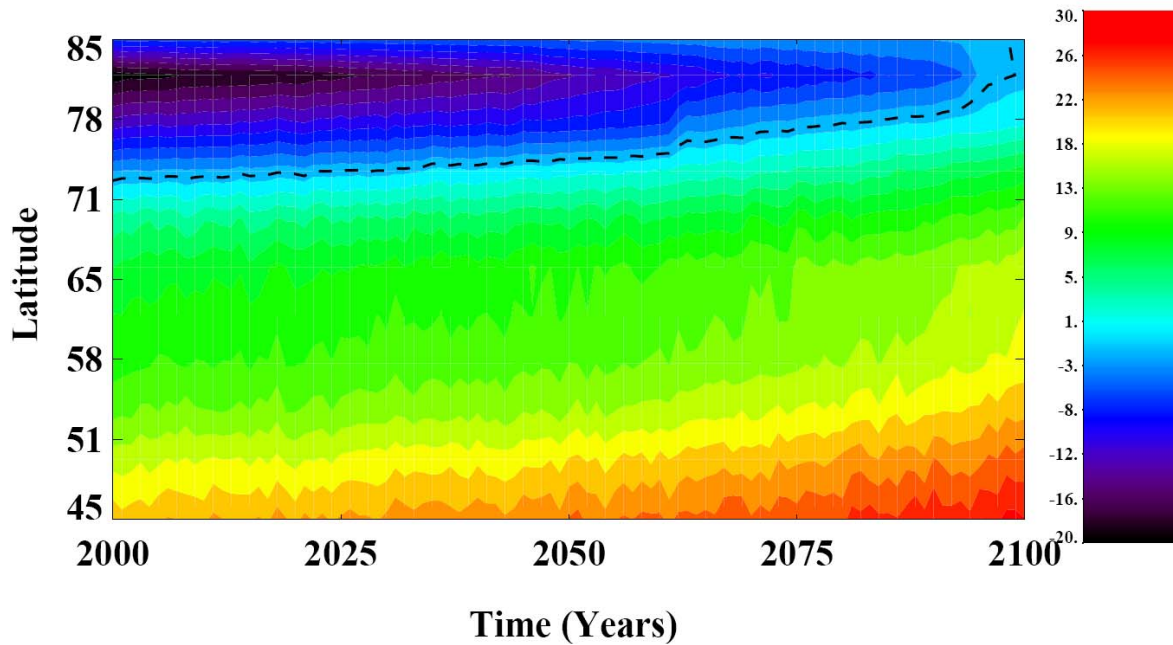
Vertical bars - medians



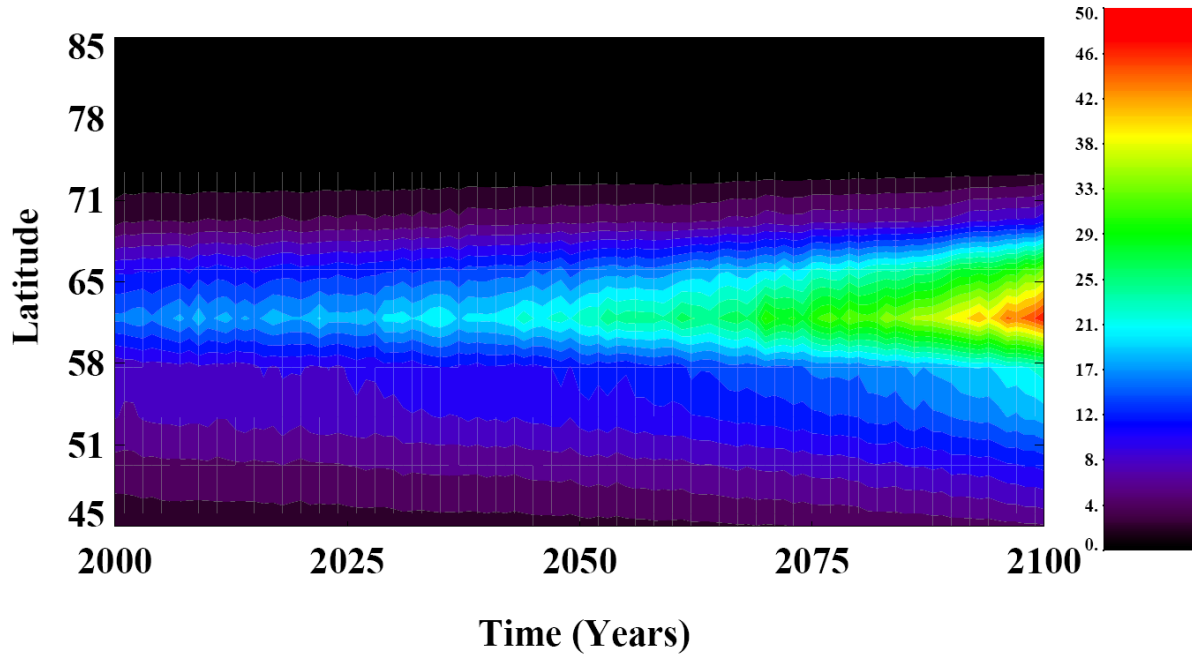
Summer (JJA) soil temperature averaged from 0 to 1 m in simulation with median values of climate parameters and reference GHG emissions.
Dashed line - 0°C



Natural methane emissions (Mt CH₄/year) in simulation with median values of climate parameters and reference GHG emissions.

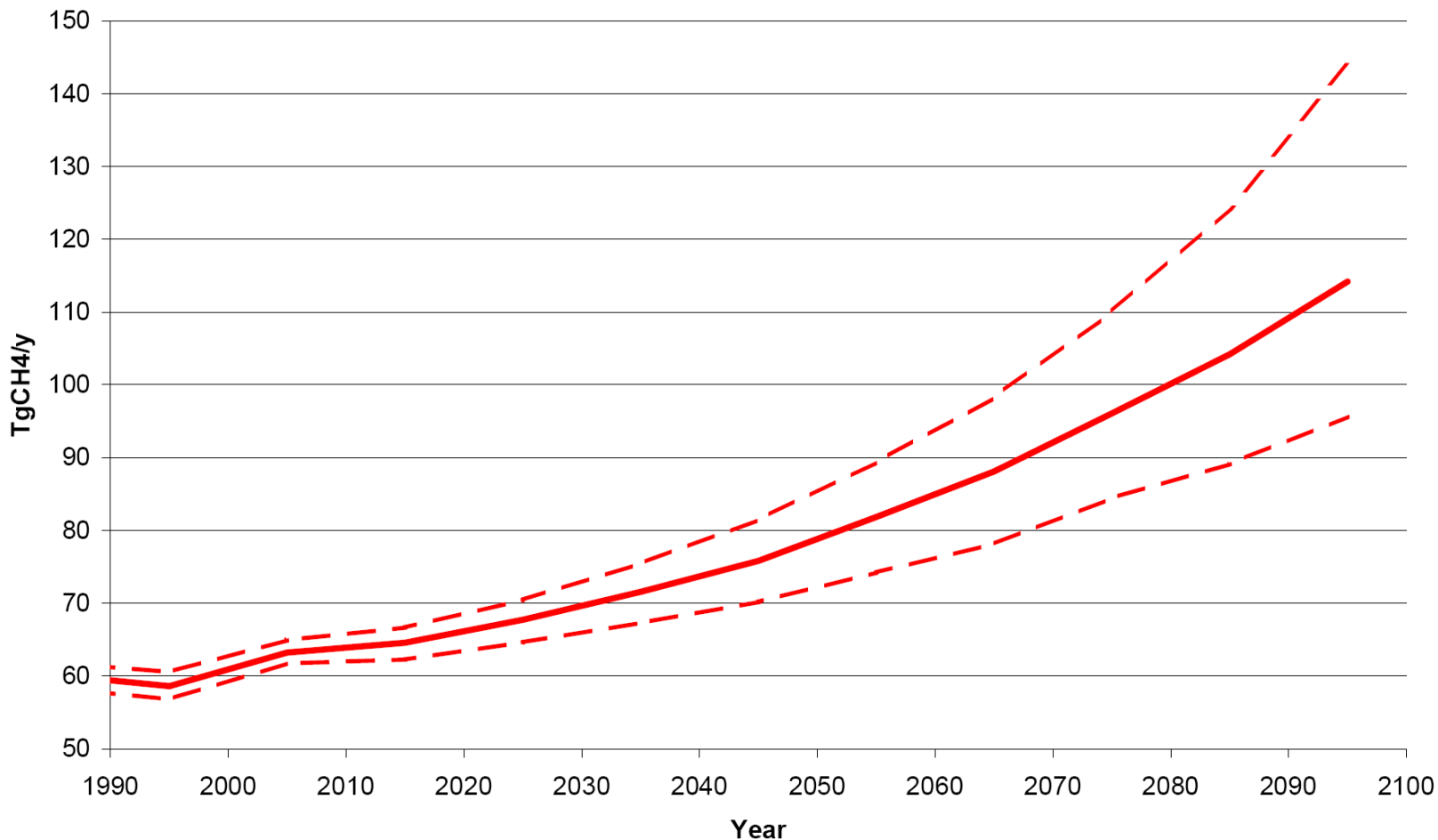


Summer (JJA) soil temperature averaged from 0 to 1 m in simulation with SAT increase of 12°C in 2095. Dashed line - 0°C



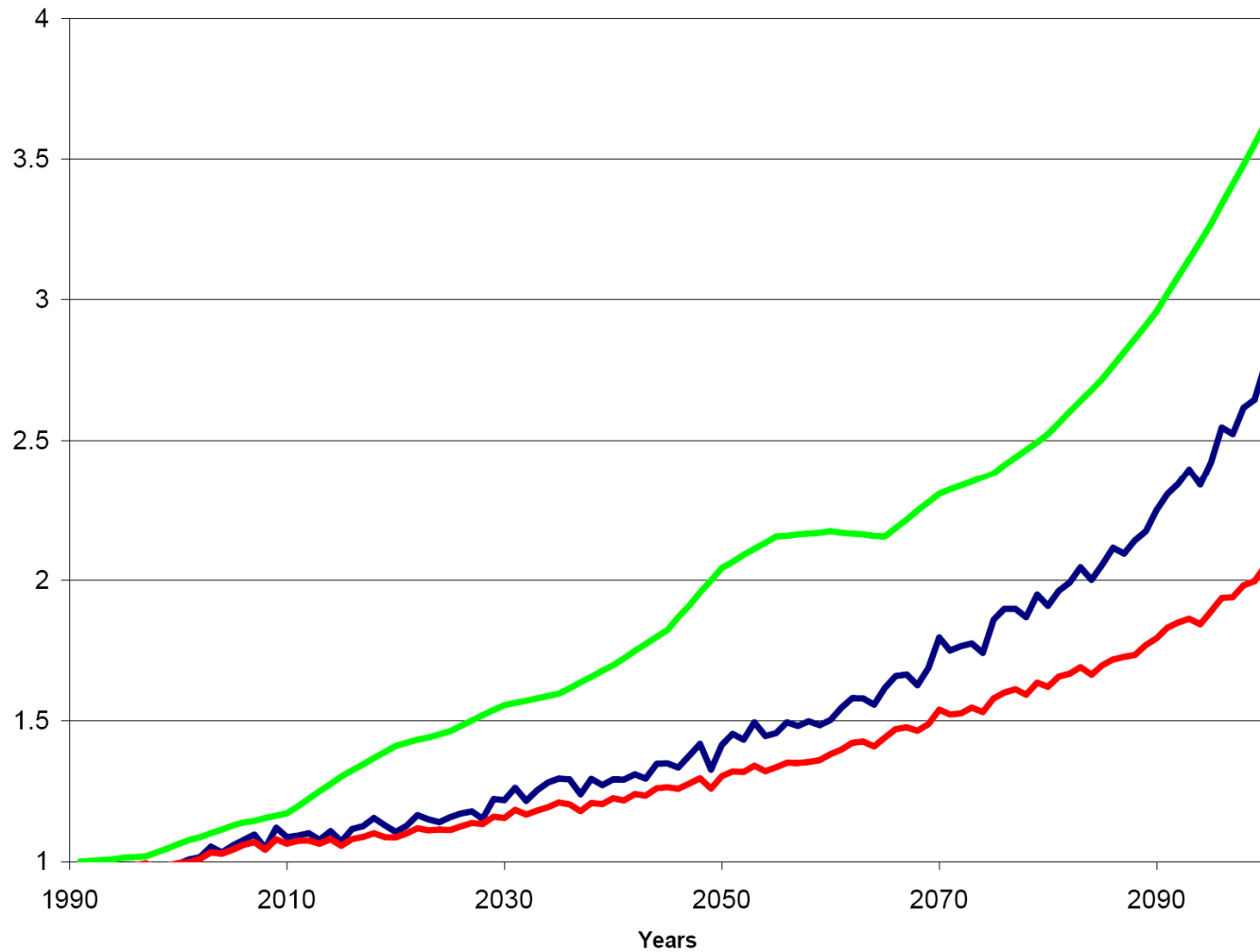
Natural methane emissions (Mt CH₄/year) in simulation with SAT increase of 12°C in 2095.

Natural CH₄ emissions north from 40N

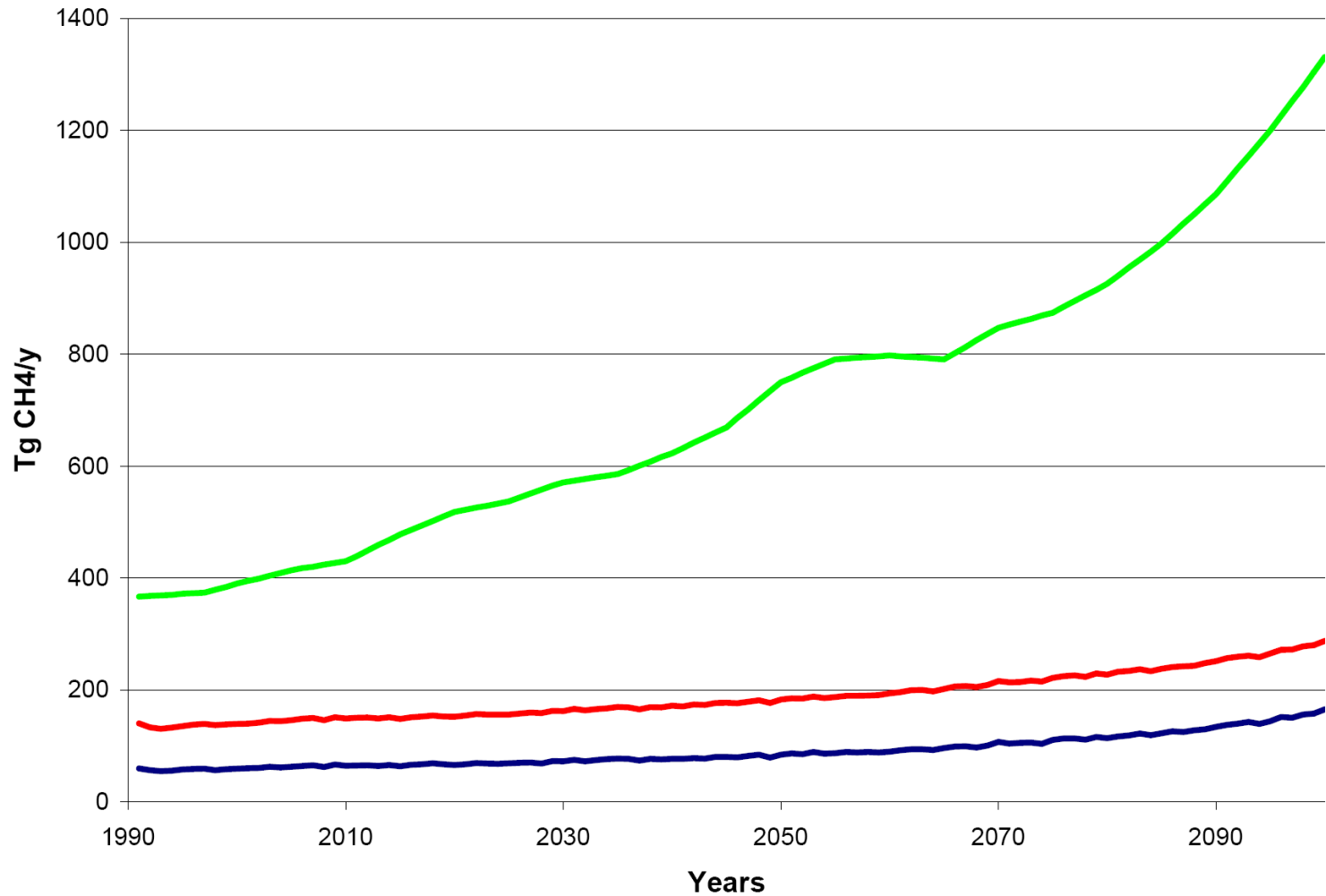


Projected changes in decadal mean natural CH₄ emissions north from 40°N

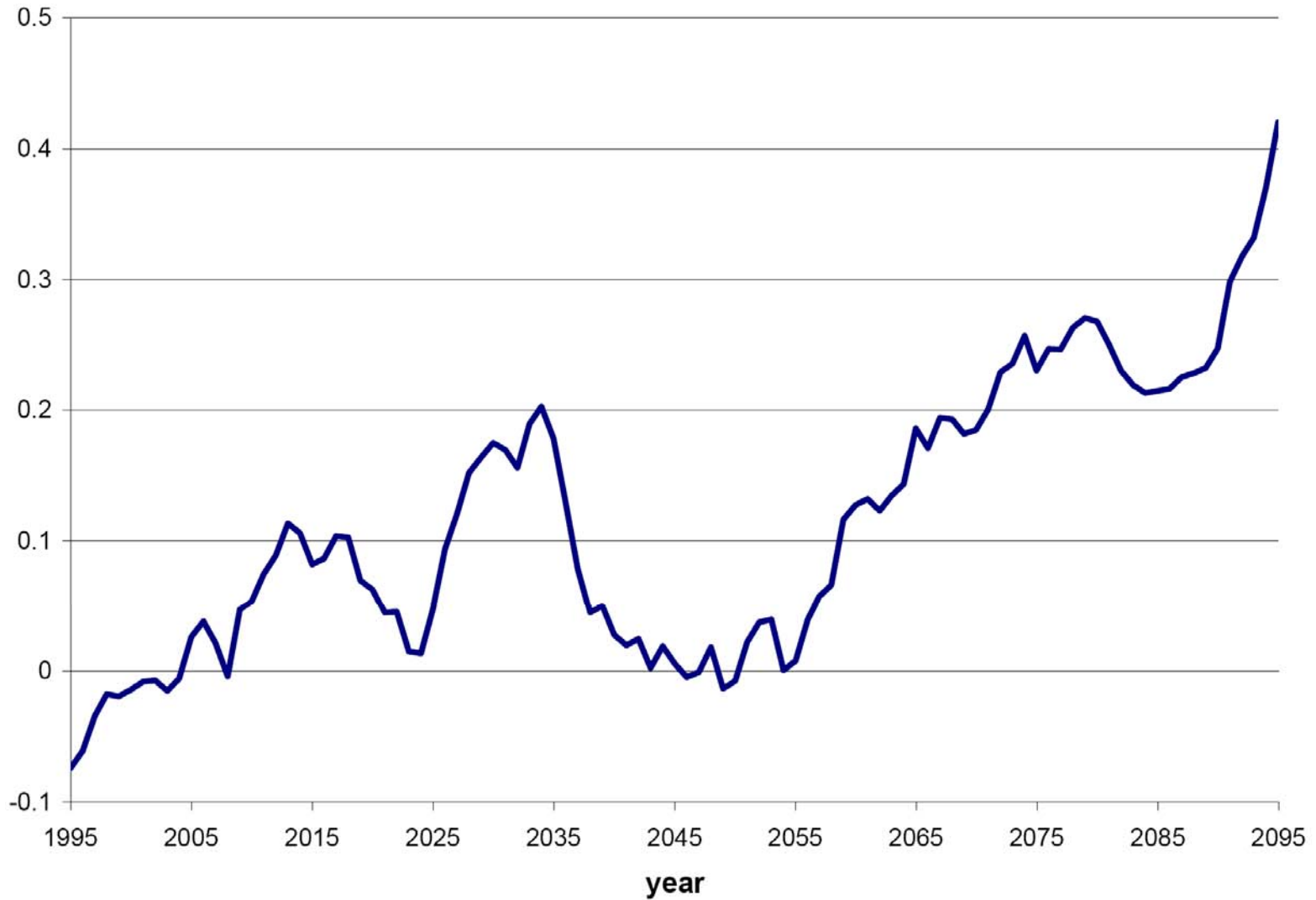
Solid line - median, dashed lines - 5% and 95% percentiles



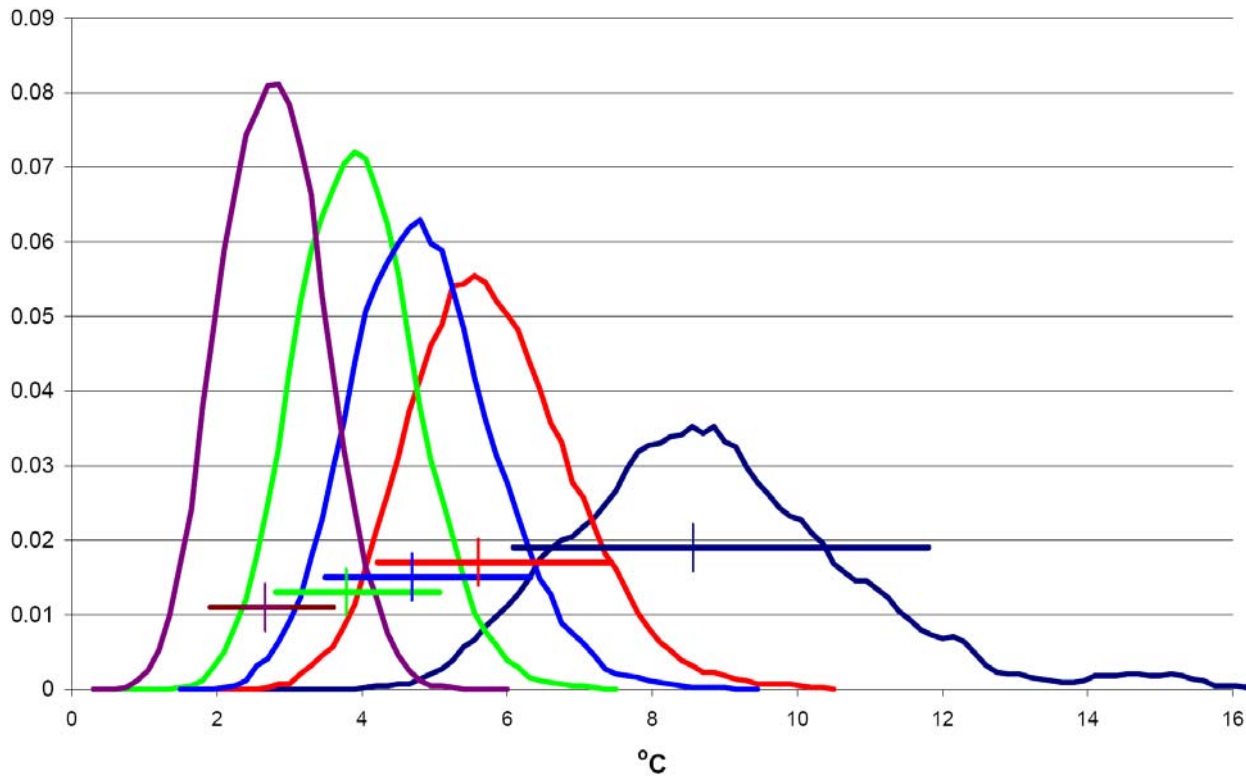
CH₄ emission in simulation with 12°C warming
Green – anthropogenic, red – natural, blue – natural north from 40°N



CH₄ emission in simulation with 12°C warming
Green – anthropogenic, red – natural, blue – natural north from 40°N



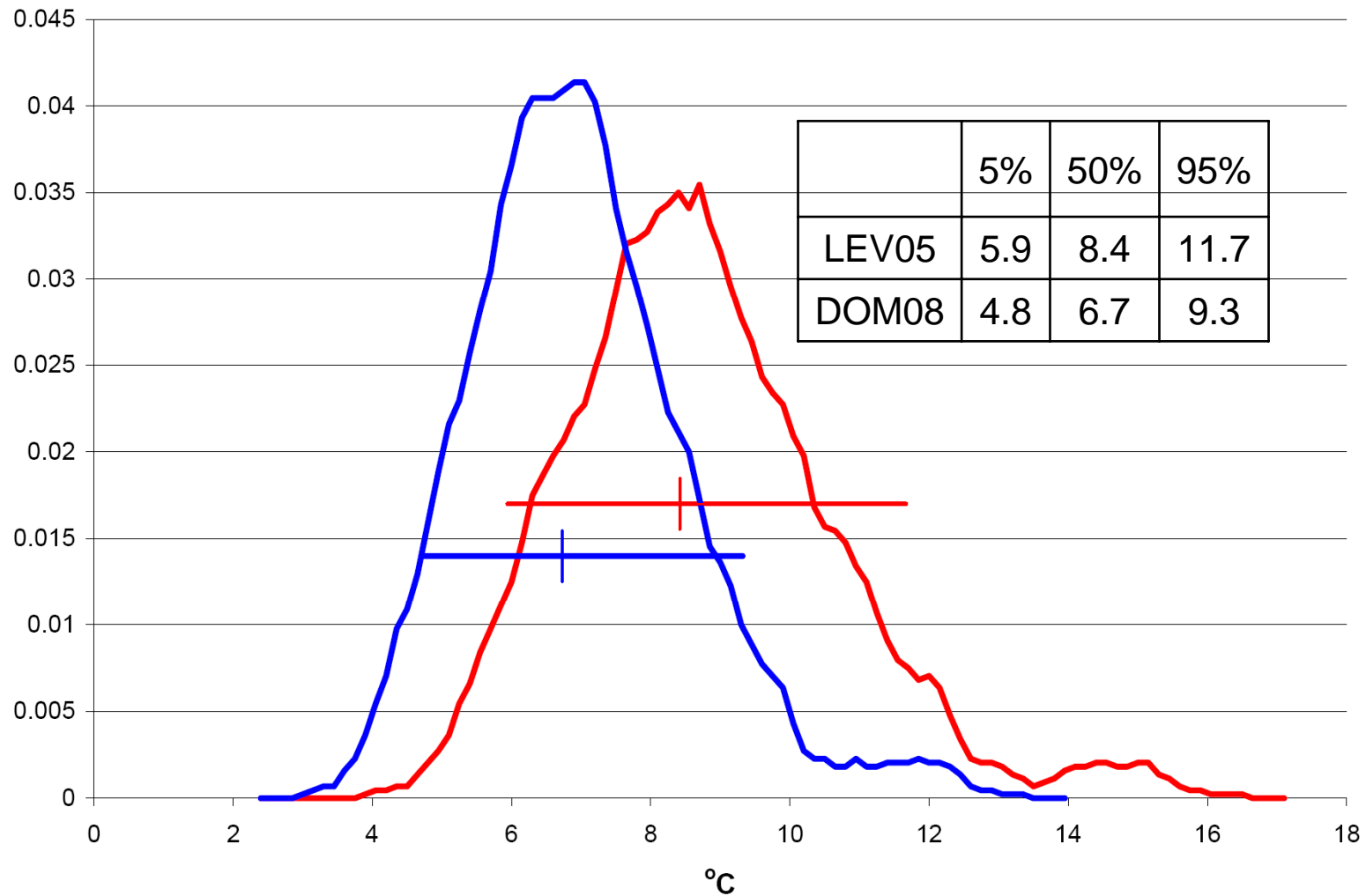
Change in SAT over land north from 60°N due to an increase in natural CH₄ emissions north from 40°N



Frequency distributions for SAT increase over land north from 60°N in 2091 to 2100 relative to the 1981 to 2000 average.

Equivalent CO ₂	5.0%	16.7%	50.0%	83.3%	95.0%
1400	5.94	6.88	8.42	10.33	11.66
900	4.21	4.76	5.60	6.72	7.43
790	3.50	3.98	4.69	5.58	6.32
660	2.81	3.26	3.78	4.51	5.06
550	1.91	2.21	2.66	3.18	3.60

Equivalent CO₂ for 2005 is 440 ppm



Frequency distributions for SAT increase over land north from 60N in 2091 to 2100 relative to the 1981 to 2000 average without climate policy. In simulations using input climate parameters based on ocean heat content estimates by Levitus et al. 2005 – red and Domingues et al. 2008 – blue.

Conclusions.

- Updated projections of climate changes show that in the absence of any climate policy by the end of the 21st century global averaged annual mean surface air temperature will be increase by 3.5°C - 7.4°C (90% probability range) relative to 1981-2000, with the median value of 5.2°C.
- Over the same period temperature over land area north for 60°N will rise between 6°C and 11.7°C, with warming being significantly larger during winter than during summer 8.3°C to 16.9°C compare to 3.4°C to 6.8°C. Corresponding median values are 8.4°C, 12.1°C and 4.8°C, respectively.
- Natural methane emissions from wetlands north from 40°N will increase by 38 to 83 (Mg CH₄)/year or 1.7-2.4 times relative to present. However even in simulations with very high warming (near upper bound of 90% range) methane emission from northern wetland are only about 10-15% of anthropogenic emissions. As a result an effect of the increase in natural emissions on surface temperature is very small.
- Even under rather stringent climate policy there is about 95% probability of surface warming over land area north from 60°N exceeding 2°C.
- Future climate change projections are sensitive to the estimates of changes in ocean heat content over 20th century.

Thank you