ACES4BGC

Applying Computationally Efficient Schemes for BioGeochemical Cycles

DMS-climate interactions

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Scientific Discovery through Advanced Computing (SciDAC-3)

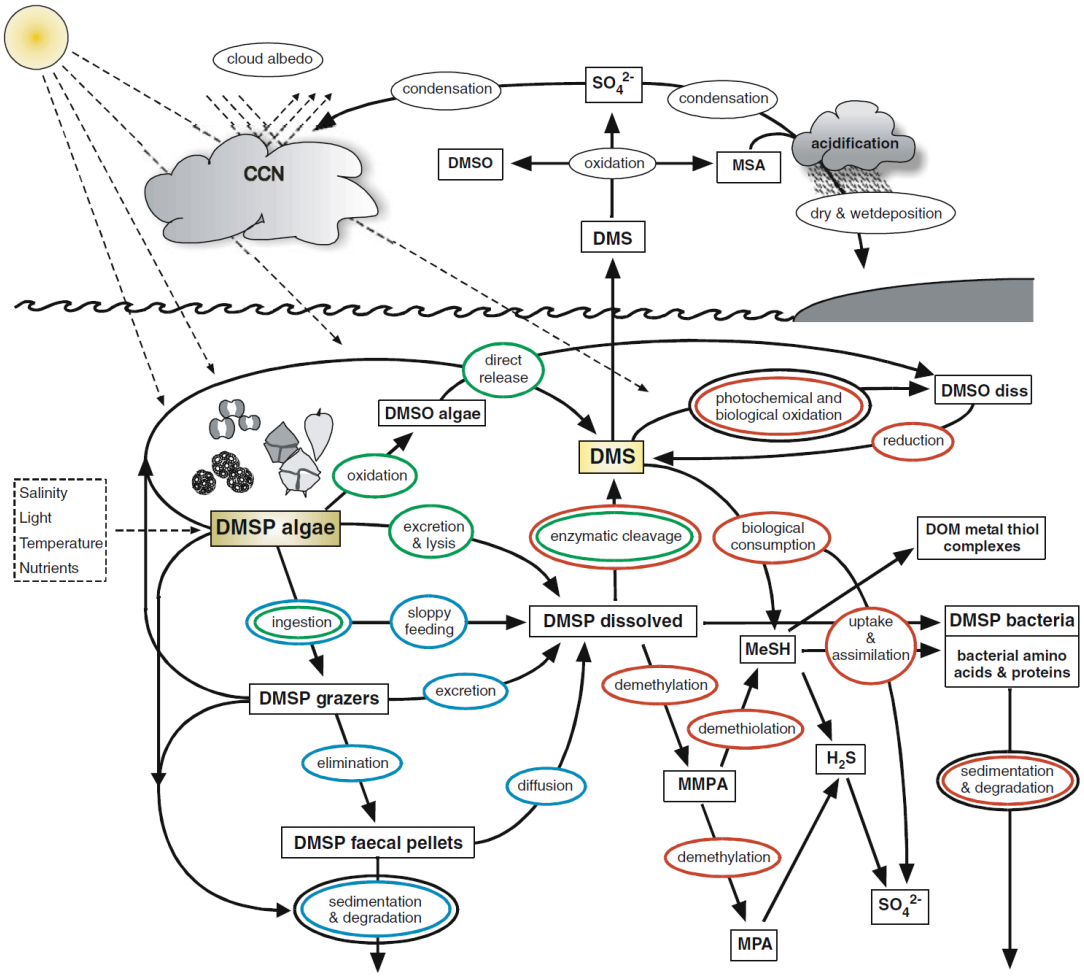
This work performed under the auspices of the U.S. Department of Energy by
Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

LLNL-PRES-667520

Overview

- DMS climate interactions.
- New advection scheme.
- Uncertainty quantification of reaction rate coefficients.

Ocean Sulfur Affects Climate



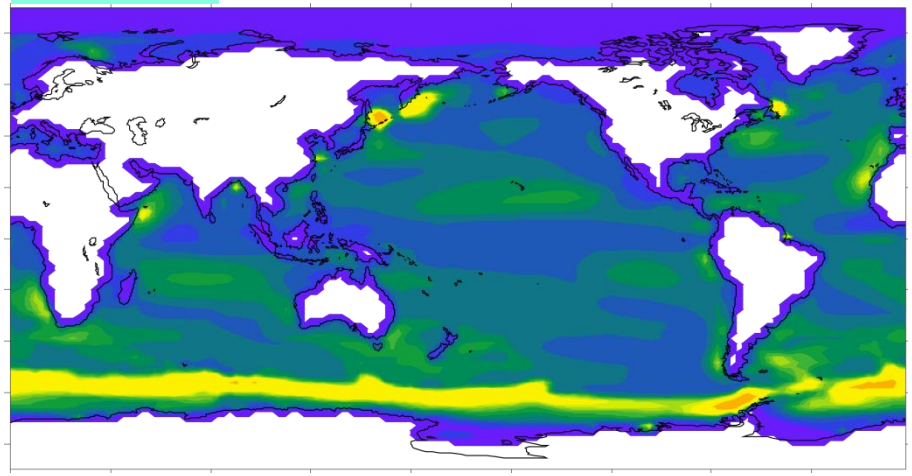
The many tracers in this diagram need to be repeated for multiple taxa.

Stefels, et al. (2007)

DMS emissions shift polewards with warming.

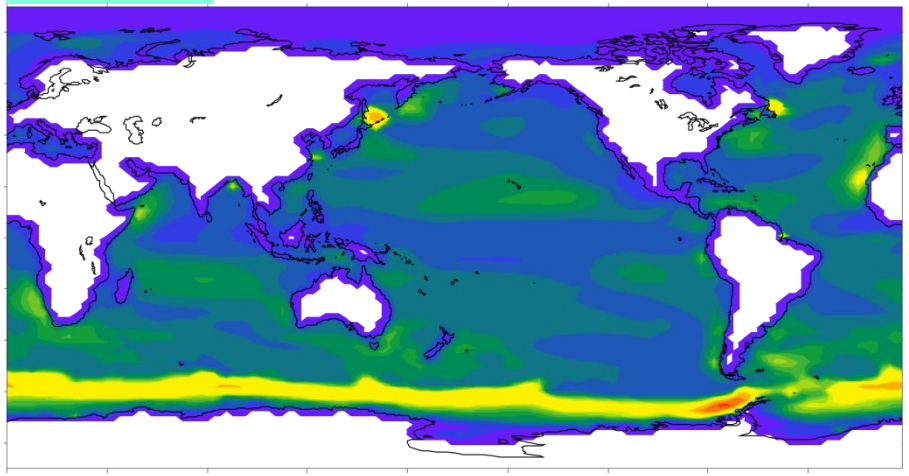
1850

mean = 2.65×10^{-12} kg/m^2/s

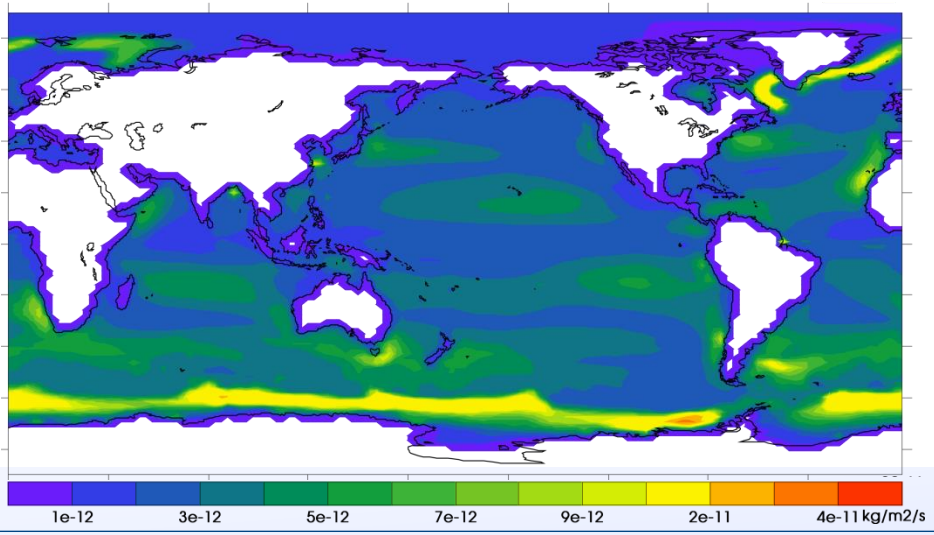


2000

mean = 2.59×10^{-12} kg/m^2/s

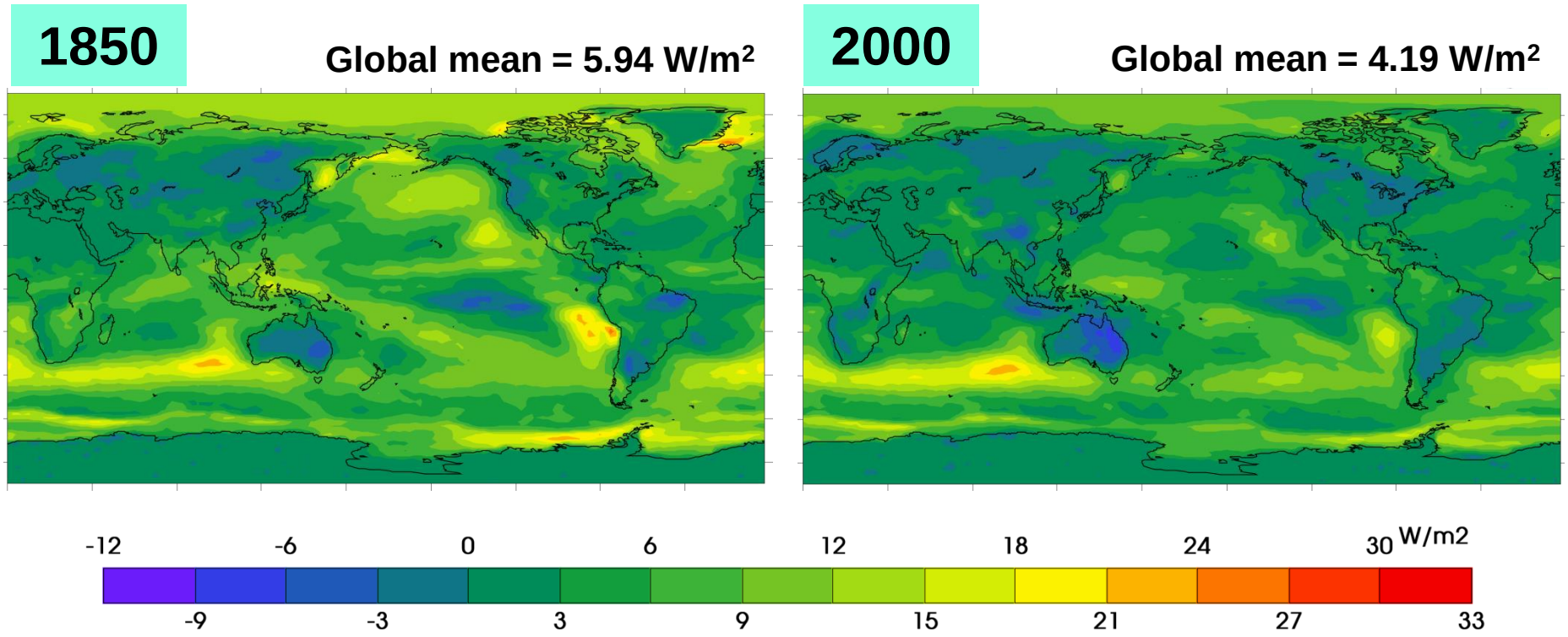


2100



mean = 2.41×10^{-12} kg/m^2/s

DMS has Large Effect on Reflected Shortwave

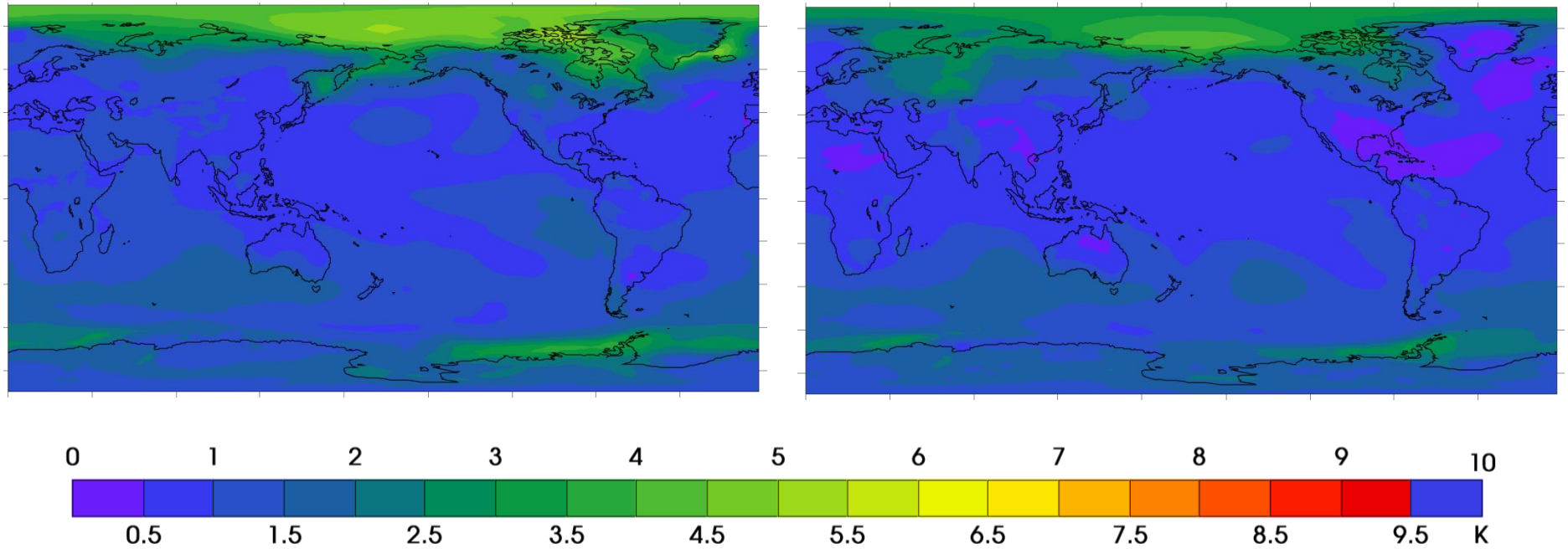


Reflected Shortwave shifts polewards, and decreases in magnitude to due competition with anthropogenic aerosols.

Arctic Amplification of DMS Cooling

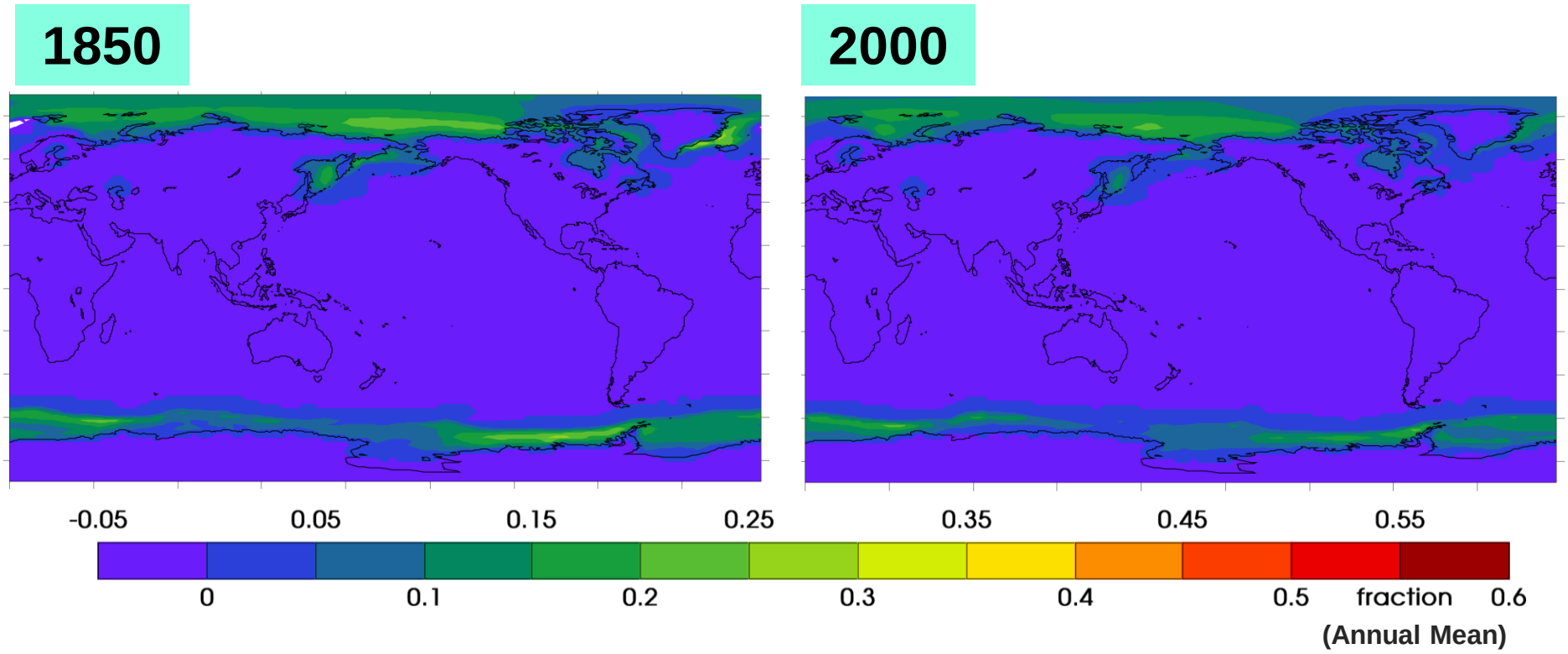
1850 Global mean = 1.28 K

2000 Global mean = 1.10 K



Ice albedo feedback works in both directions.

Sea-ice has negative feedback on DMS



Ice increases reduce the DMS emissions from phaeocystsis, and hence limit the DMS-climate feedback.

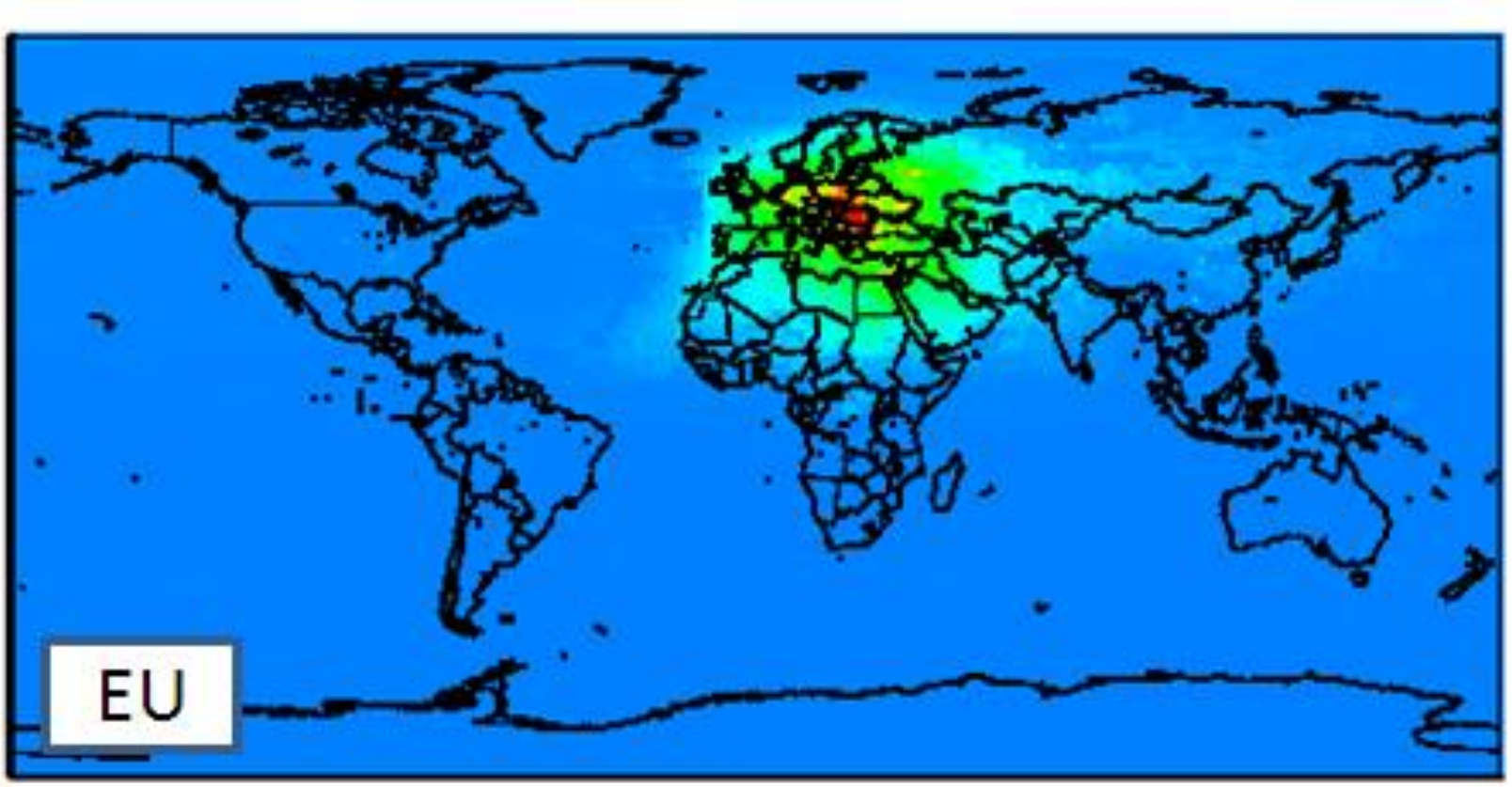
Climate model representations are currently heavily reduced.

Simplified volatility basis set (VBS) for current climate models.

Total of 8 tracers.

Shrivastava, et al. (GRL, 2013)

Tracers generate source-receptor Green's functions



Effect of PM2.5 from European emissions

Anenberg, et al (2014)

Cost of advected tracers is high.

Physics (ie processes on independent columns:

- scales as resolution^2,
- scales well to large numbers of CPUs.

Computational cost of *current* advection:

- scales as resolution^3,
- scales badly to large numbers of CPUs,
- scales linearly with number of tracers.

Cost of advected tracers is dropping

GPU parallelization:

- Parallelization over tracer #,

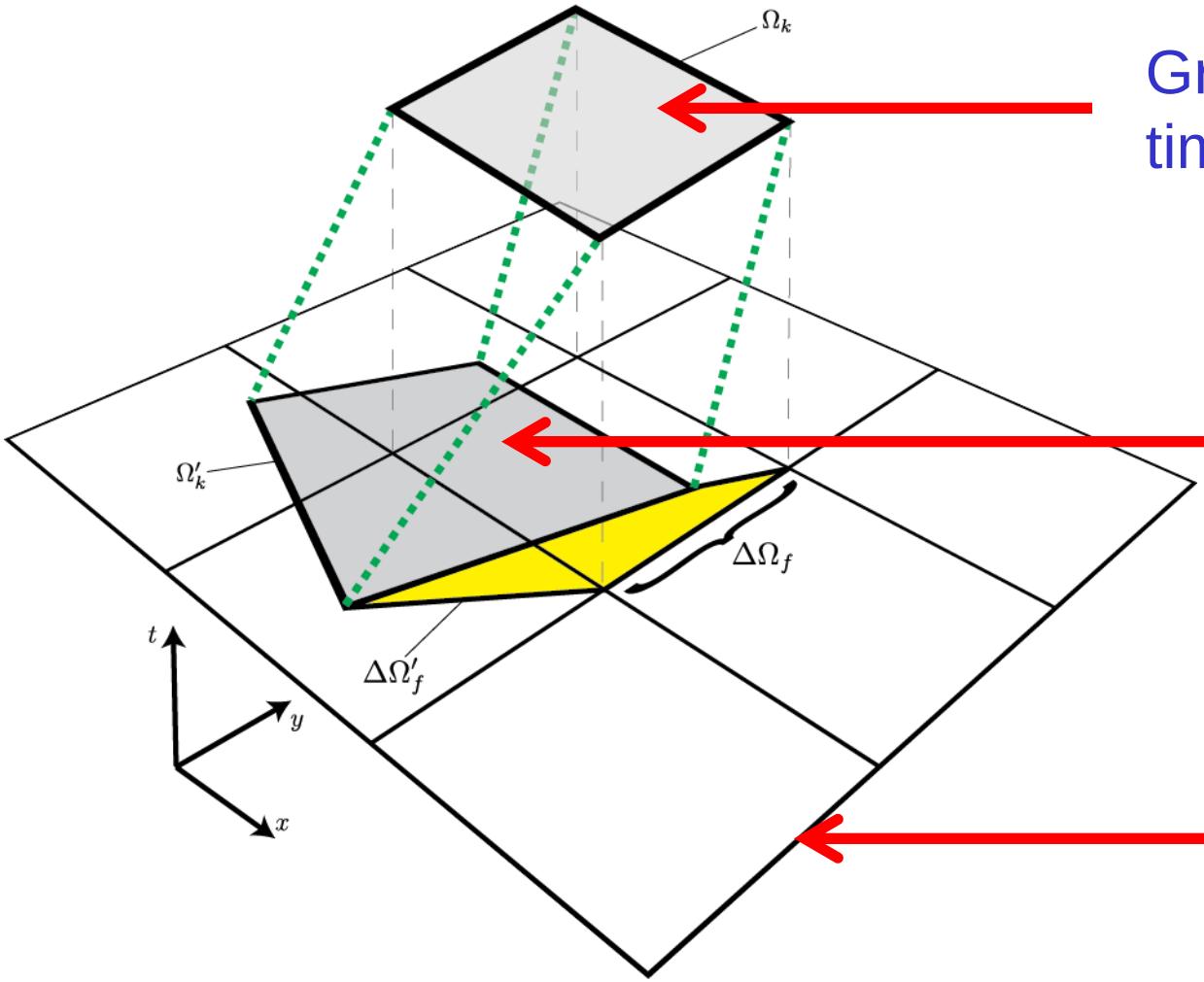
CSLAM:

- Pre-compute geometric mapping from start of advection timestep to the end [EXPENSIVE],
- Apply of mapping to each tracer [CHEAP].
- Limited to Courant # < 1

CSLAM-MOAB

- As CSLAM, but allows
  - Courant # >> 1
  - Arbitrary grids

Grid mapping is slow, but only done once

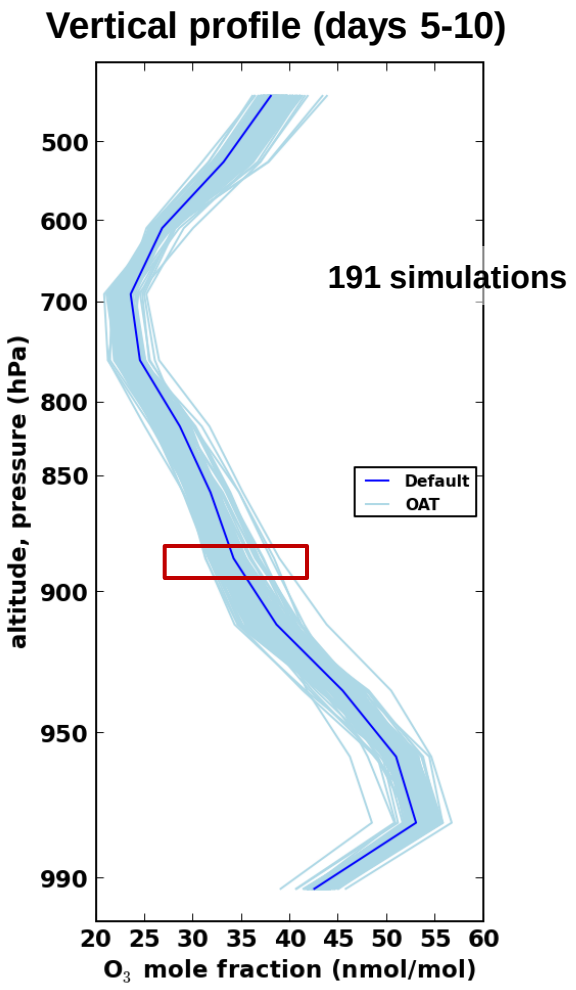


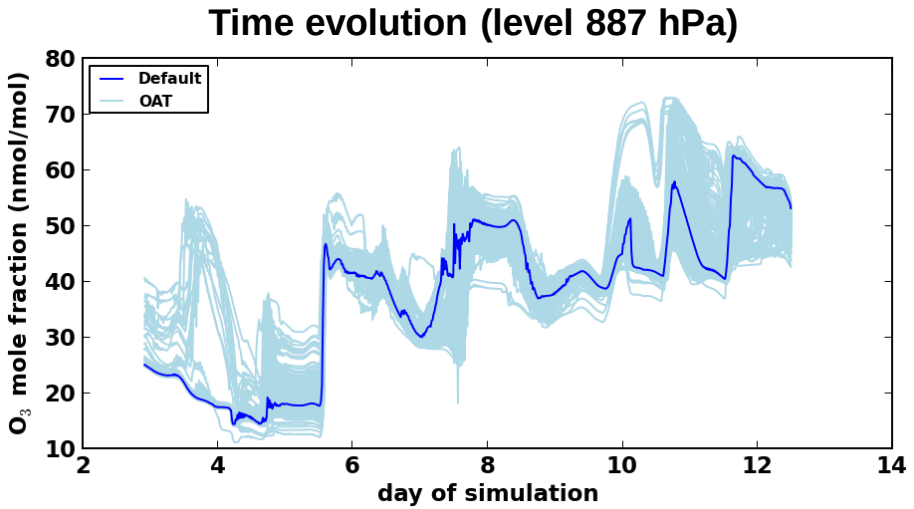
Gridcell at end of timestep

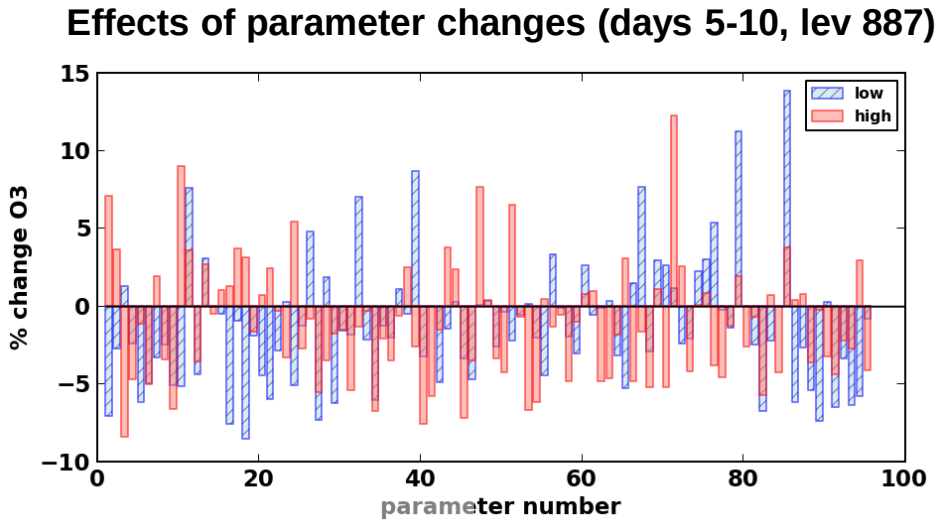
Lagrangian location of gridcell at start of timestep.

Eulerian grid at start of timestep

Uncertainty in laboratory measured rate constants causes uncertainty in ozone







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UQ with many tracers is cheaper and better than many simulations

MOZART Ozone Example

- Implemented PDFs for 100 photochemical parameters in the MOZART mechanism.
- Ran ~10^4 ensemble SCAM simulations using Latin hypercube sampling.
- Analyzing ensemble variance using new UQ methods in collaboration with QUEST.

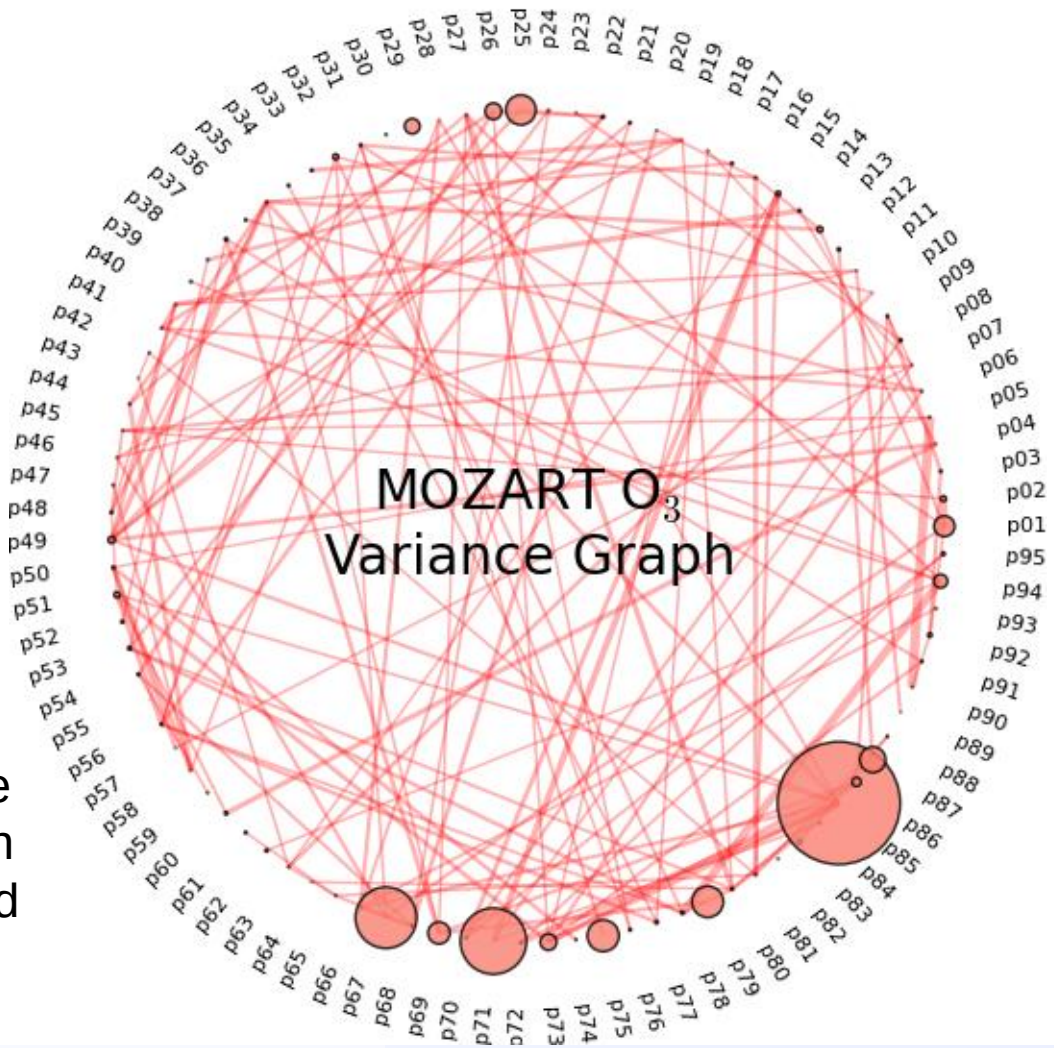

Figure: 2nd order decomposition of the variance of daily avg. O_3 concentration in the middle troposphere is dominated by about 10 parameters.

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Summary

- DMS has large effect on mean-state in CESM (v1.2.2)
- Reduced impact of DMS due to anthropogenic aerosols
- Interesting feedbacks in Arctic with sea-ice.
- New advection algorithms may be ‘cheap’:
  - Source-receptor Green’s functions,
  - Uncertainty quantification (including adjoints).
- Uncertainty quantification of reaction rate coefficients identifies a few as most important.