The Impact of a Proposed Geo-engineering Scheme on Troposphere and Stratosphere using WACCM

(Stratospheric Aerosol Approach)

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The Impact of a Geo-engineered Sulfate Aerosols on Troposphere and Stratosphere

Overview

- Temperature Response of Volcanic Aerosols in WACCM319
- Geo-engineering Model Simulation: WACCM319
- Impact of Geo-engineering on Temperatures, Chemistry (Ozone) and Dynamics
- Polar Temperatures and Ozone Loss in WACCM3548

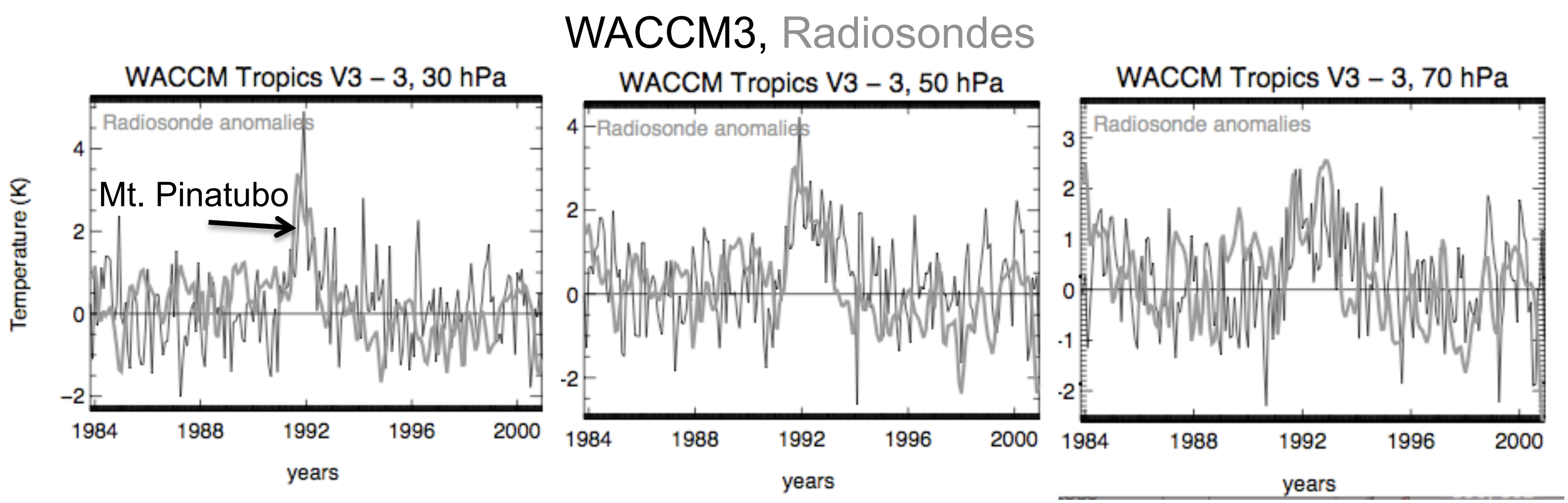
Whole Atmosphere Community Climate Model (WACCM3)

MODEL Framework	Dynamics	Tracer Advection	Resolution	Chemistry	Other Processes
Extension of the NCAR Community Atmospheric Model version 3 (CAM3)	Finite Volume Dynamical Core (Lin, 2004) Fully-interactive	Flux Form Finite Volume (Lin, 2004)	Horizontal: 1.9° x 2.5° Vertical: 66 levels 0-150km	Middle Atmosphere Mechanism 57 Species Includes Het. Chemistry on LBS, STS, NAT, ICE	Slab Ocean flux scheme (assuming a steady ocean circulation) Volcanic Aerosol Heating Scheme

WACCM3

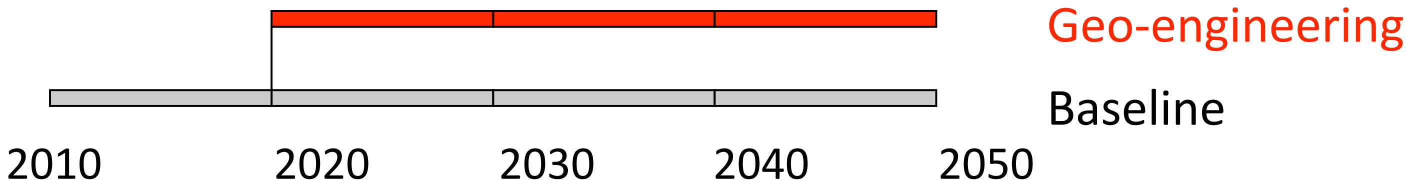
WACCM3 test simulation for a volcanic period (around Mt. Pinatubo eruption)

Difference: (WACCM + Aerosol Heating) – (WACCM without Aerosol Heating)
in comparison to
Temperature anomaly from the mean: radio-sonde data (*Randel et al., 2007*)



WACCM3 heating scheme produces realistic temperature response after the Mt. Pinatubo volcanic eruption.

Setup of the Future Geo-engineering Model Simulation: 2010-2050



Baseline Run:

- IPCC scenario A1b 2010-2050
- Secular increase of greenhouse gases (CO_2)
- Changing halogen loading
- Background SAD from SAGE aerosols

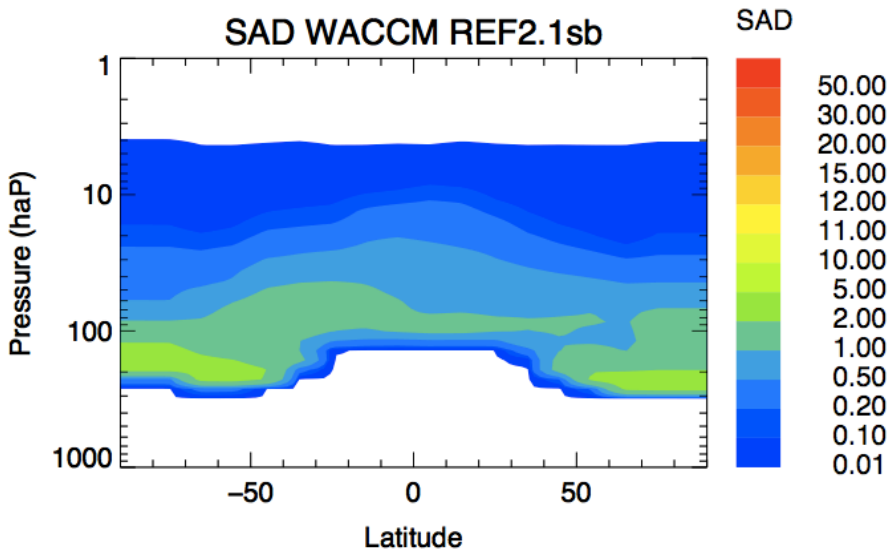
Geo-engineering using Volcanic Sized Aerosols:

- As baseline run 2020-2050 but with geo-engineered aerosols
- Prescribed fixed SAD resulting from the injection of 2Tg S/yr, assuming volcanic-sized aerosols (simulated using CAM: *Rasch et al., 2007*)

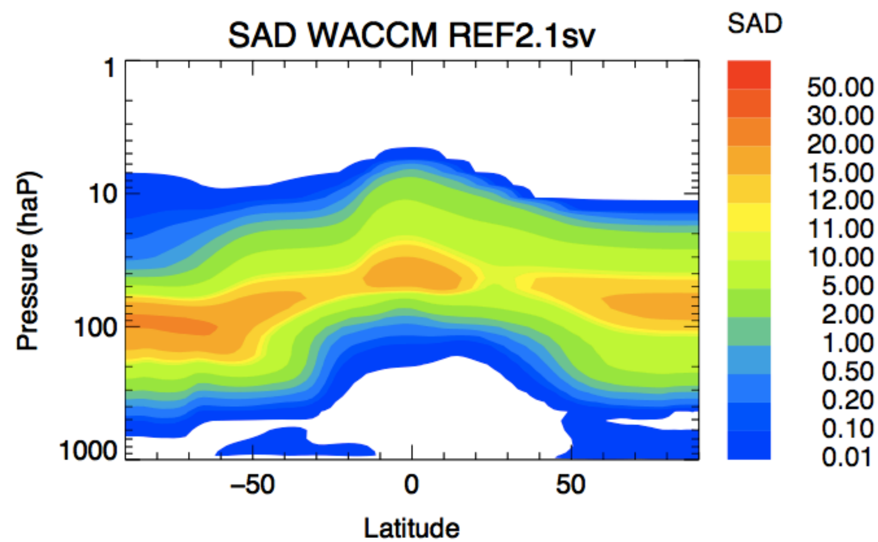
Aerosol Distribution: Basic Run and Volcanic Run

Surface Area Density for Sulfate Aerosol Particles SAD ($\mu m^2/cm^3$)

Baseline Run

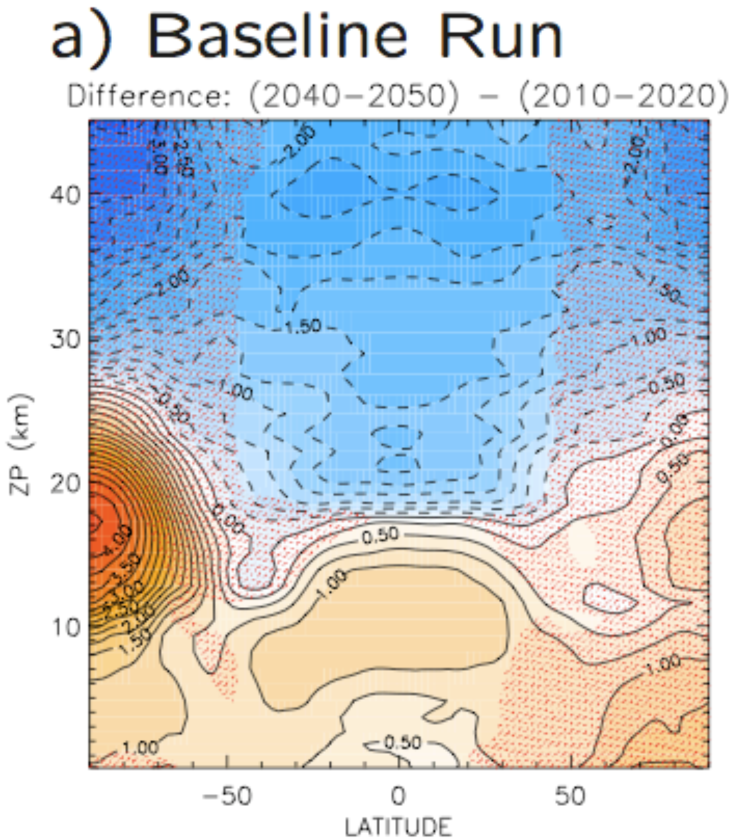


Geo-engineering Run



Prescribed Surface Area Density using a distribution derived by a CAM Geo-engineering Experiment (Rasch et al., GRL 2007) for present day conditions

Global Annually Averaged Temperature Response Between 2010-2020 and 2040-2050



Hatched areas are not significant at 95% level

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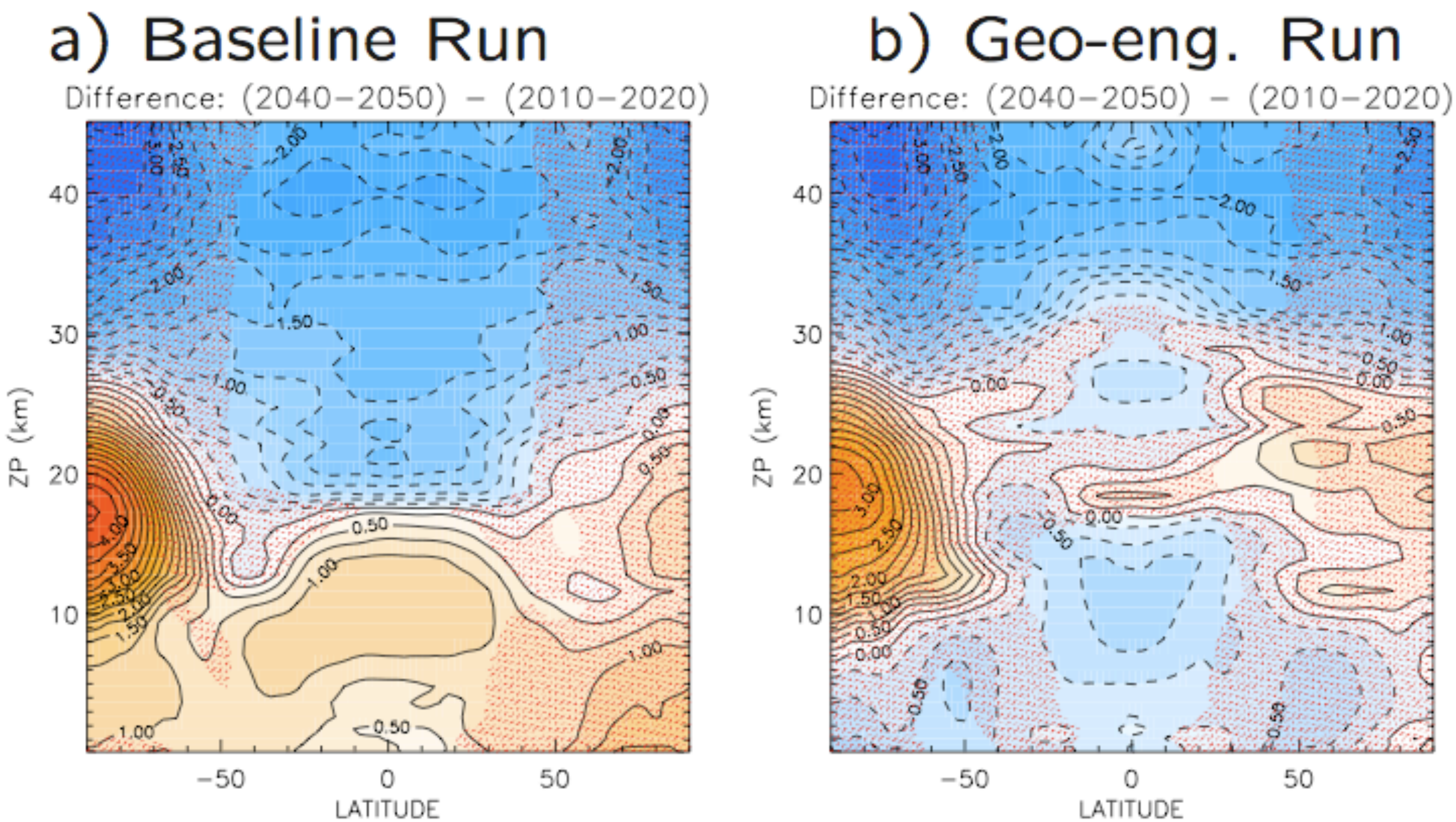

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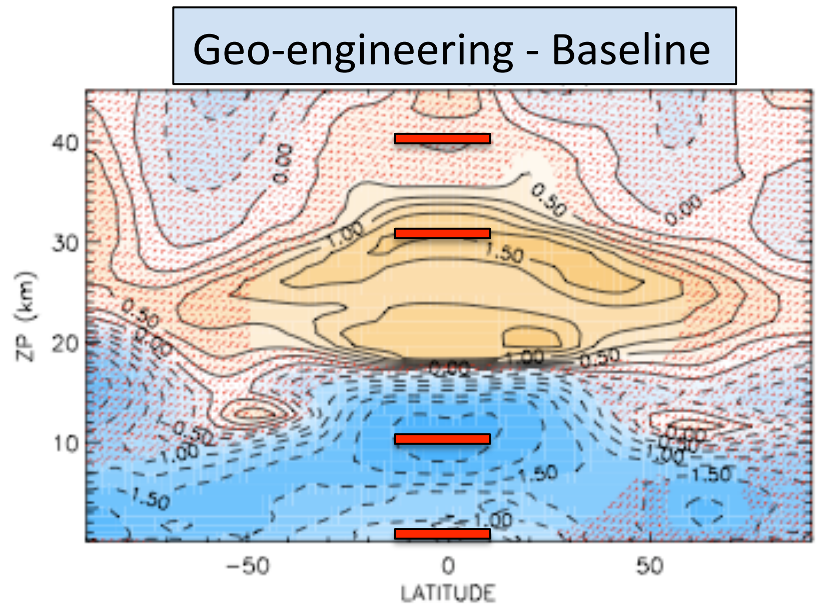
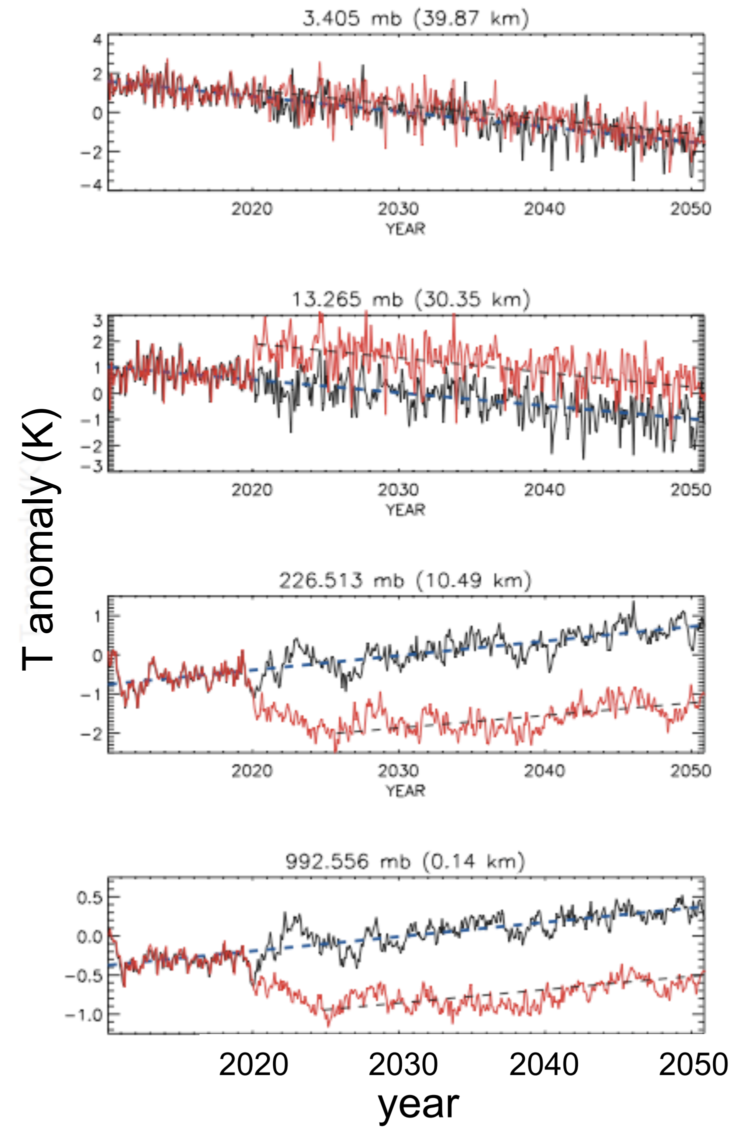
Global Annually Averaged Temperature Response Between Geo-eng. and Baseline Runs 2040-2050





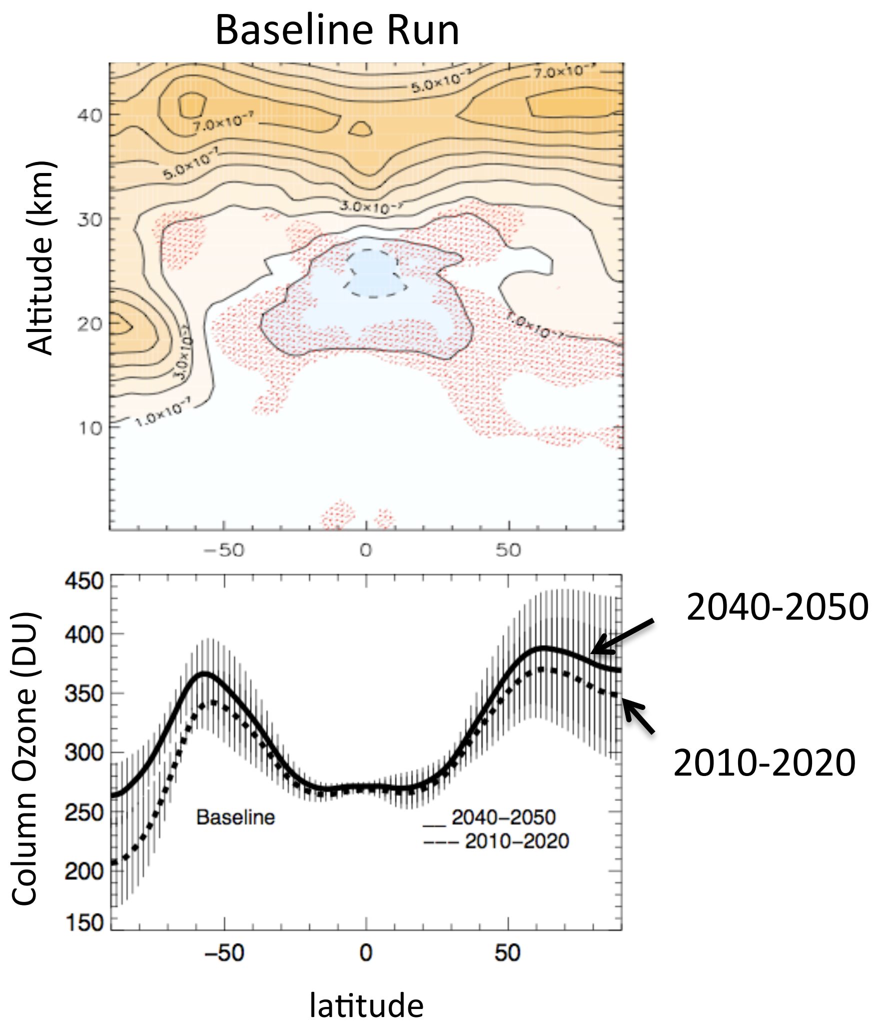
- ~5 year adjustment of temperatures
- Constant temperature offset
- The fixed amount of sulfur cools the Earth's surface by ~0.9 K,

-> Delay of global warming by ~ 40 years

-> Still climate change

Ozone Changes With Increasing Greenhouse Gases and Geo-Engineered Sulfate Aerosol Particles

Ozone changes (2040-2050) – (2010-2020)



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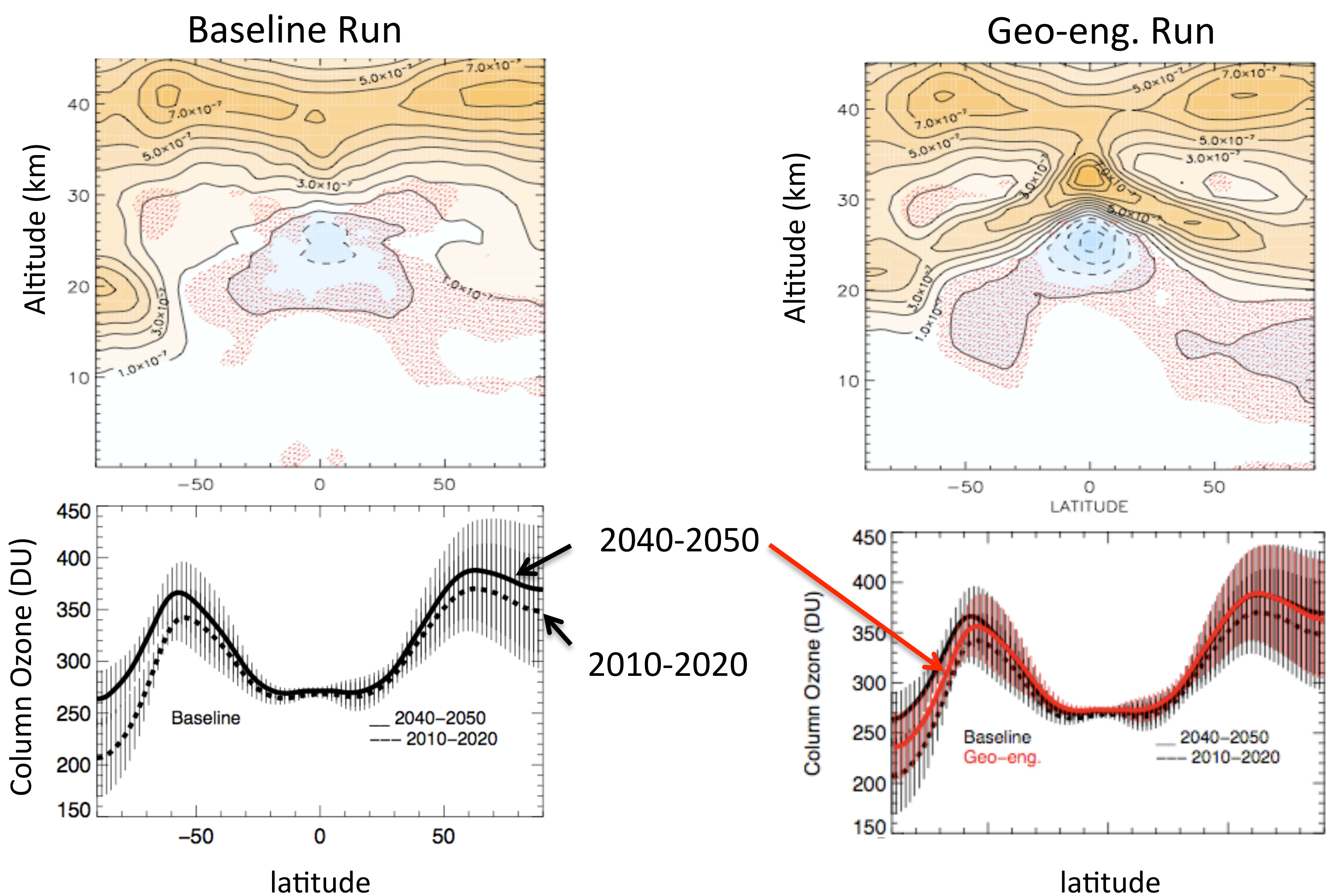
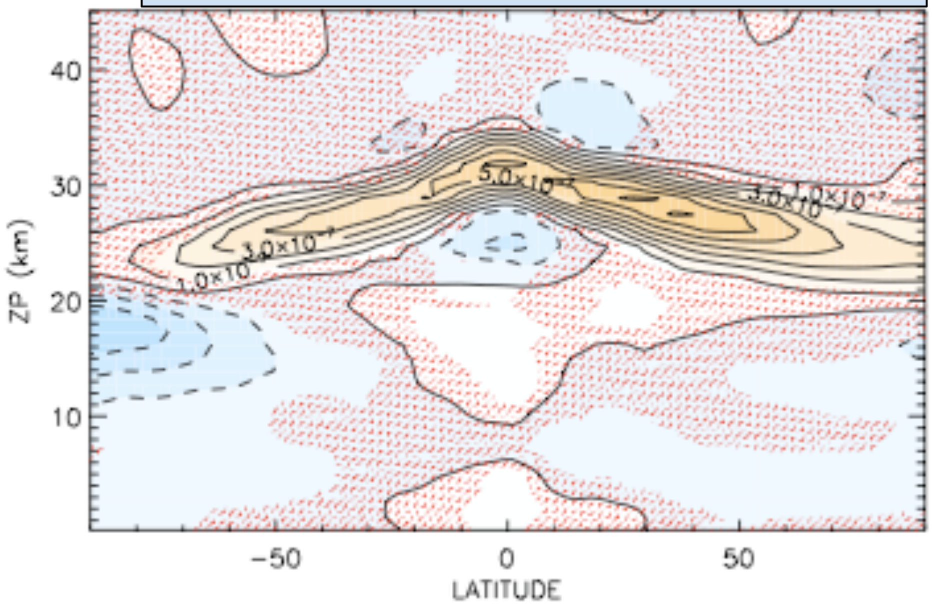
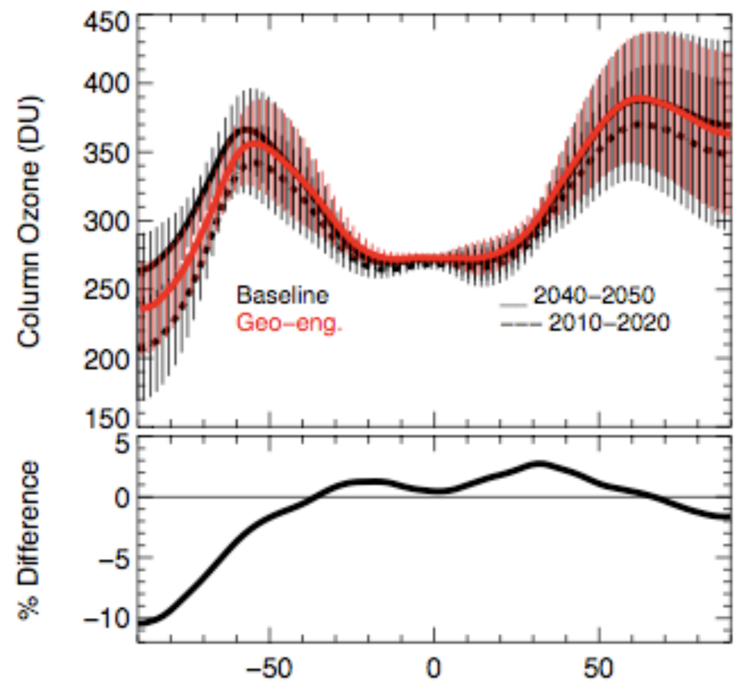


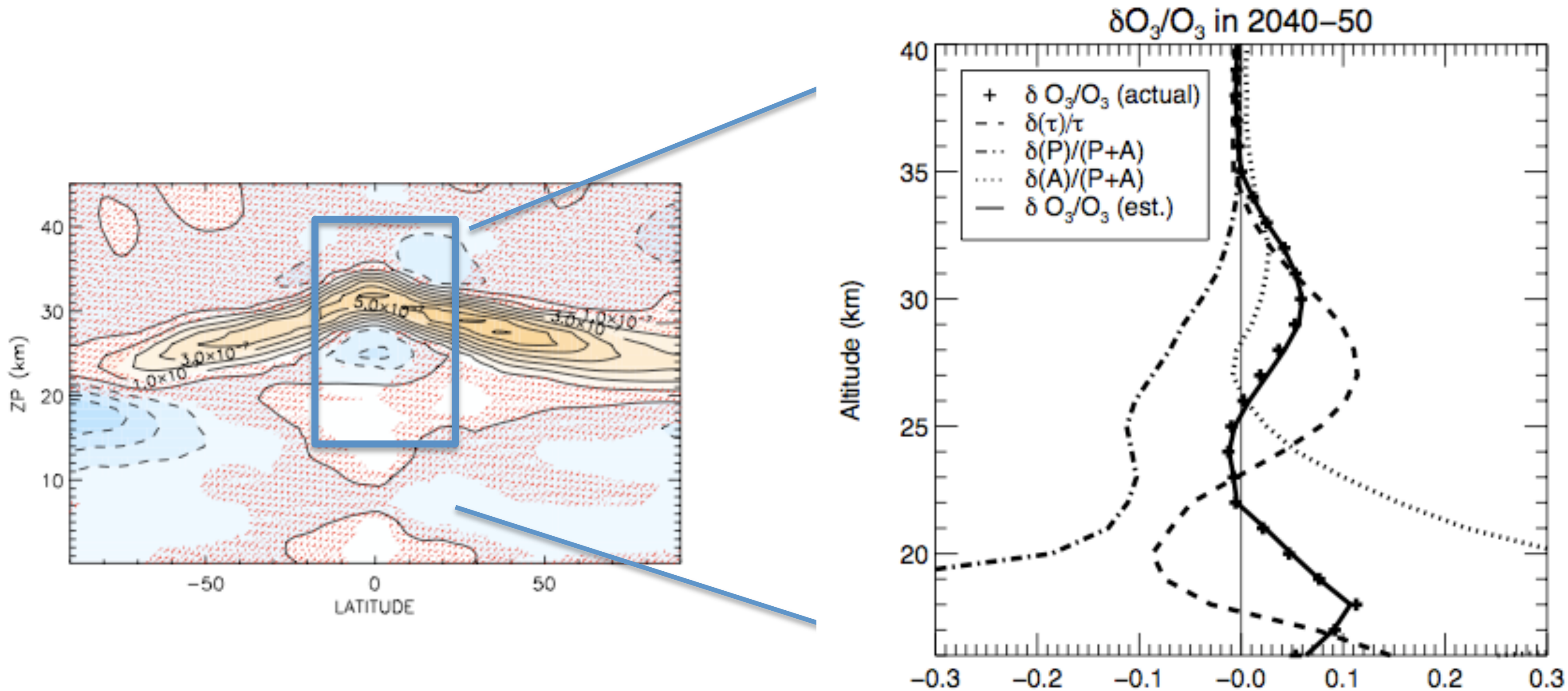
Ozone Difference Between
Geo-Engineering and Baseline 2040-2050

Annually averaged difference in Ozone





Difference Difference Between Geo-engineering and Baseline 2040-2050, Tropics



Significant dynamical and changes:

-> Increase of ozone around 30 km in the Tropics (chemistry and advection)

-> Decrease of ozone controlled by decreasing ozone production

-> Increase of ozone below 22km controlled by advection

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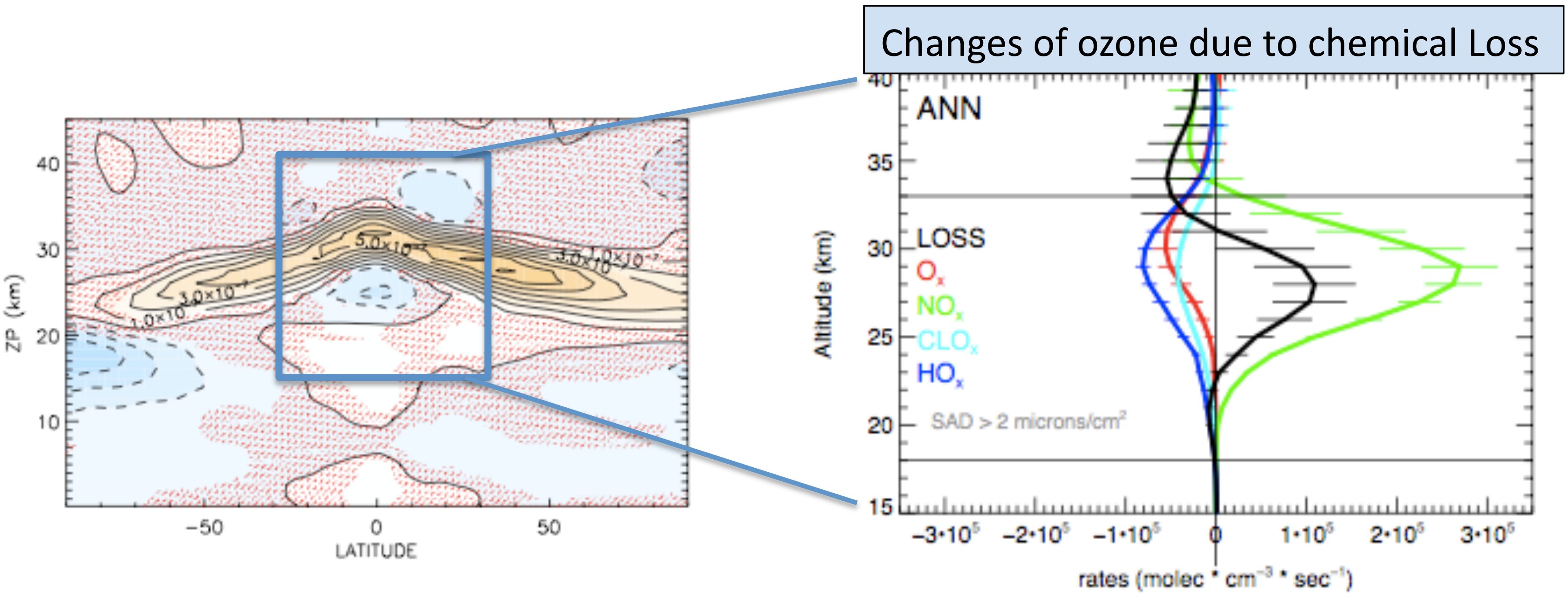


Increase of heterogeneous reactions

-> decrease of the NO_x/NO_y equilibrium (Fahey et al., 1993)

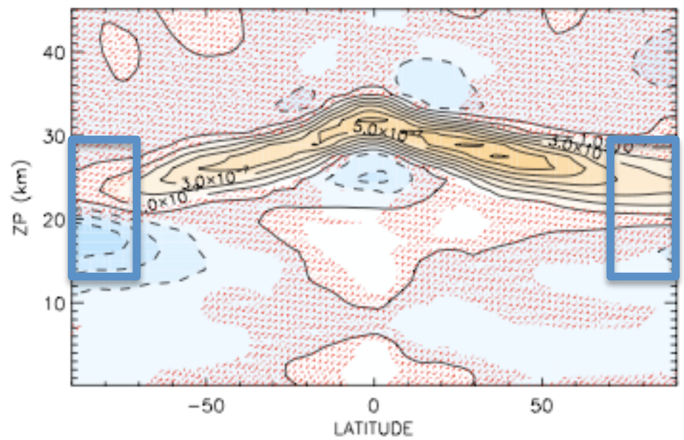
(1) $N_2O_5 + H_2O$ -> $2HNO_3$

(2) $ClONO_2 + H_2O$ -> $HOCl + HNO_3$ $T < 200$ K as important as (1)

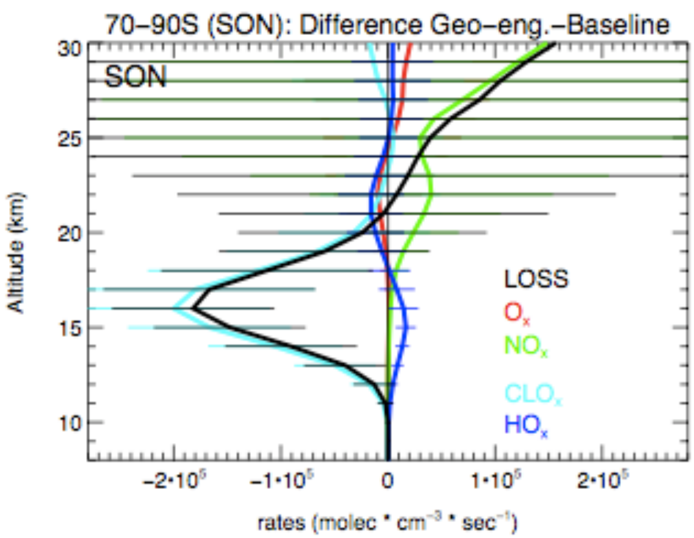
-> increase in the ClO_x and HO_x

Difference in Ozone Between Geo-engineering and Baseline 2040-2050, Polar Regions

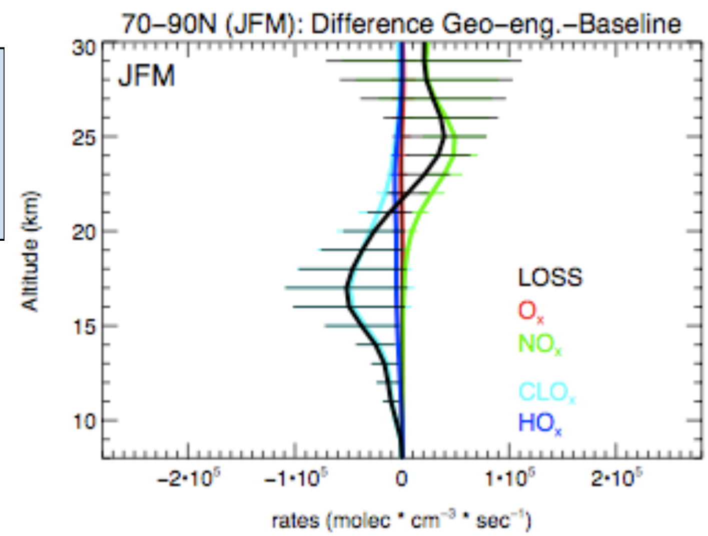
September/October/ November



January/February/March



Changes of ozone due to chemical Loss



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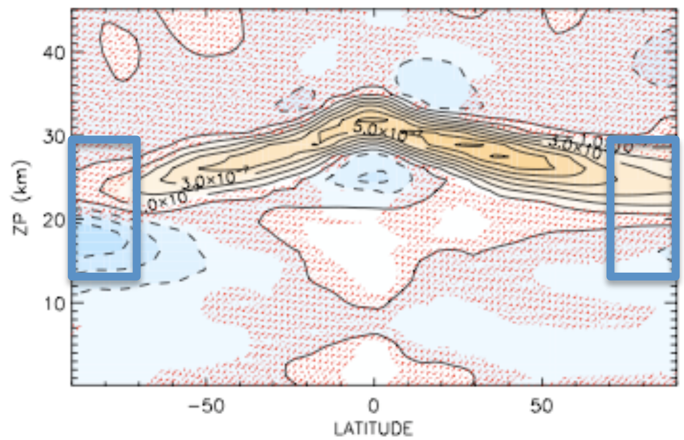


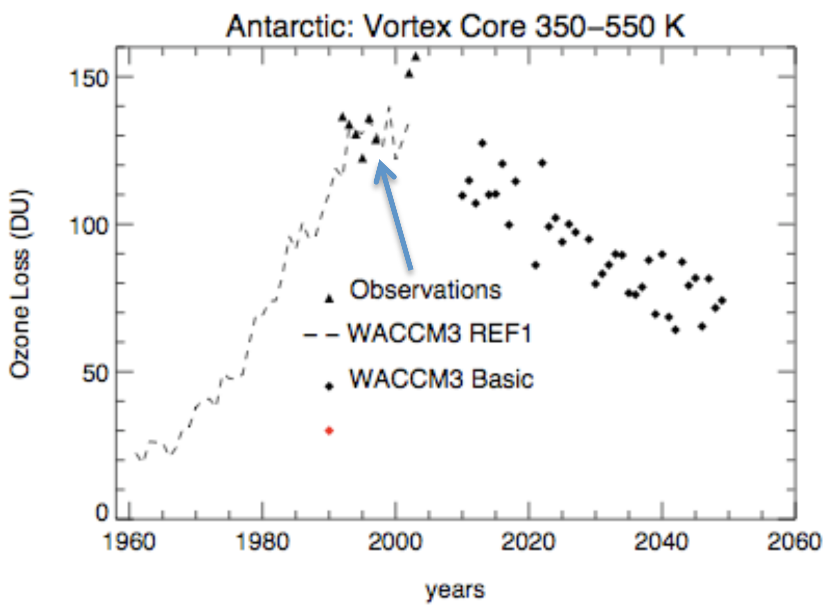
January/February/March

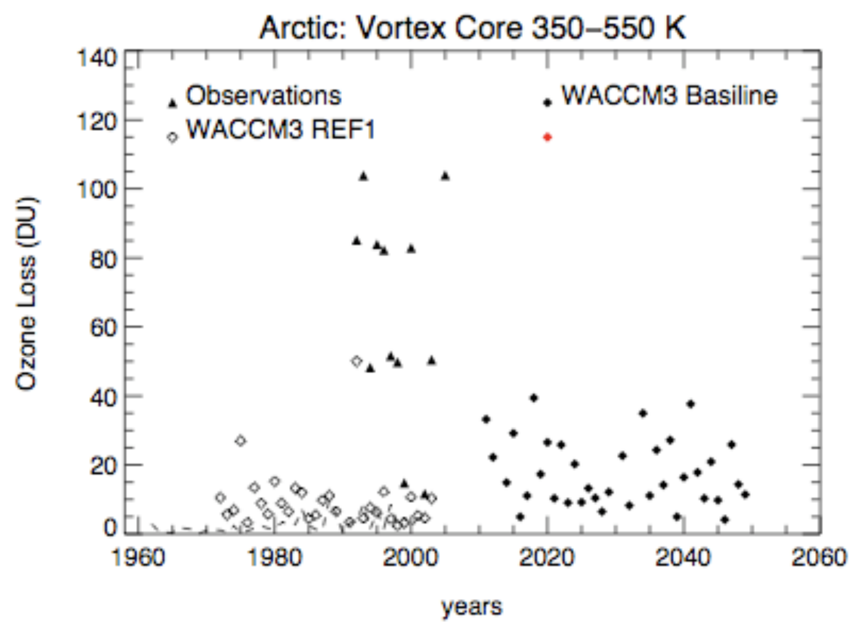
Changes of ozone due to Transport and Dynamics:

- decreasing Arctic temperatures
- stronger Polar vortex

Polar Ozone Loss: Antarctica and Arctic

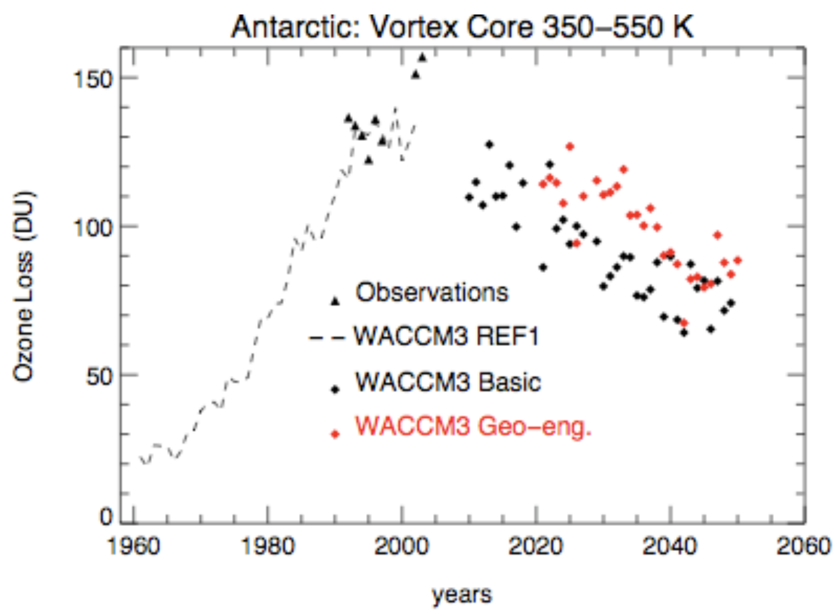
Baseline Run

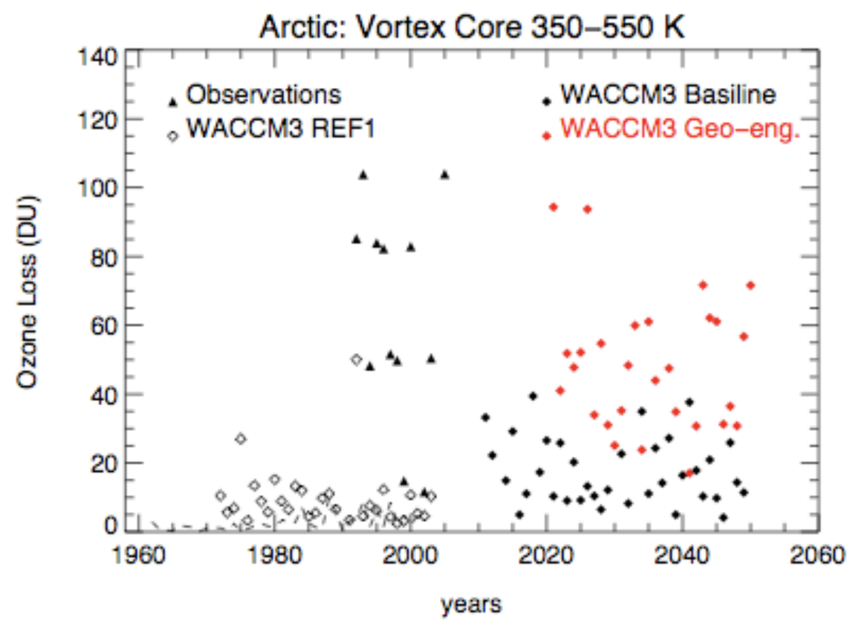




Polar Ozone Loss: Antarctica and Arctic

Baseline Run, Geo-engineering Run





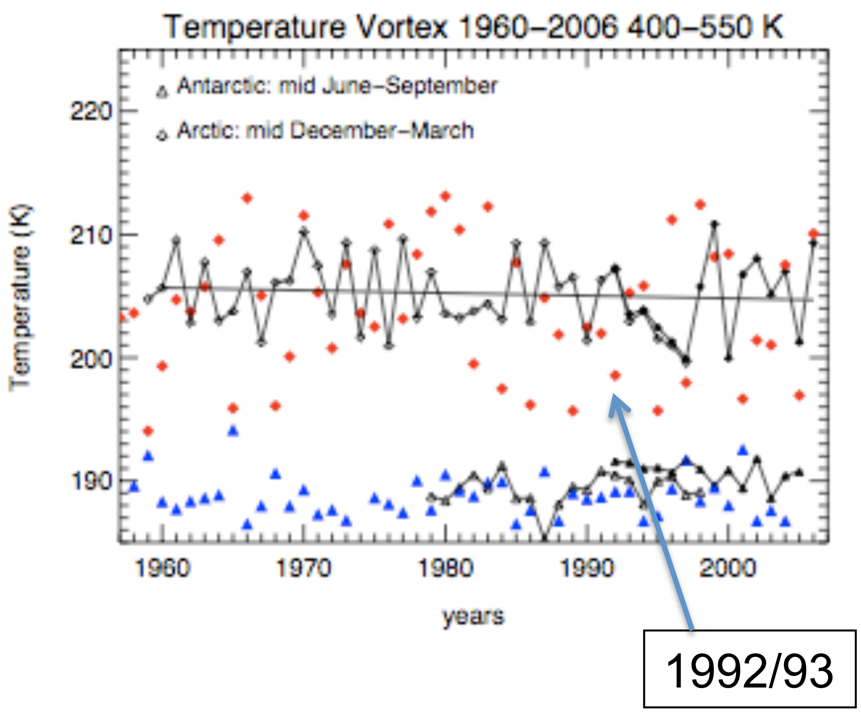
Antarctic ozone hole:

- 20-30 years delay of the recovery (model)
- Increase of ozone of ~20 DU

2-4 times increase in Ozone Loss

- Stronger polar vortex
- Colder temperatures
- Enhanced heterogeneous reactions

WACCM3548 Arctic Vortex Temperatures and Vortex



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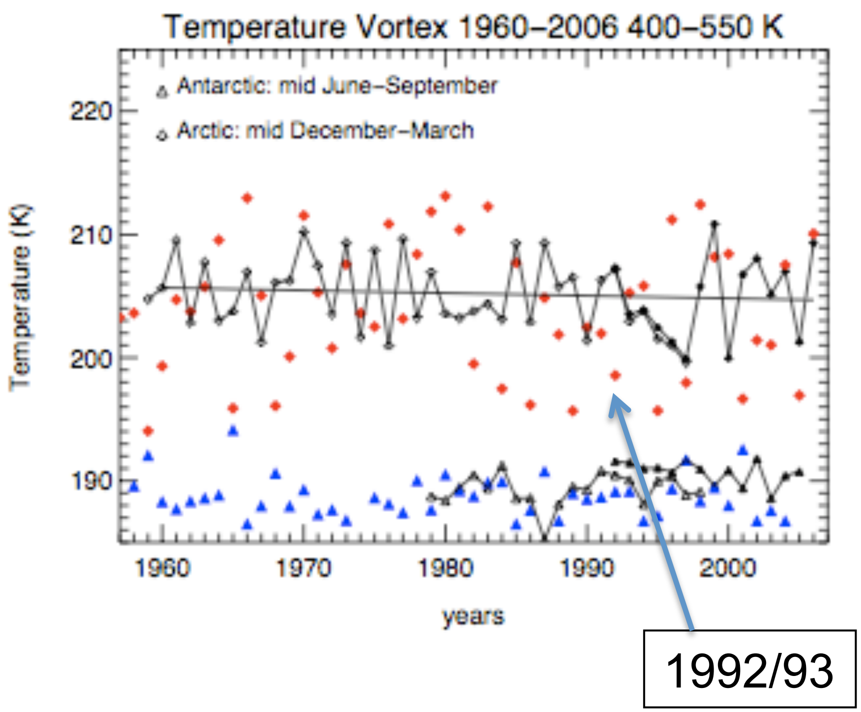

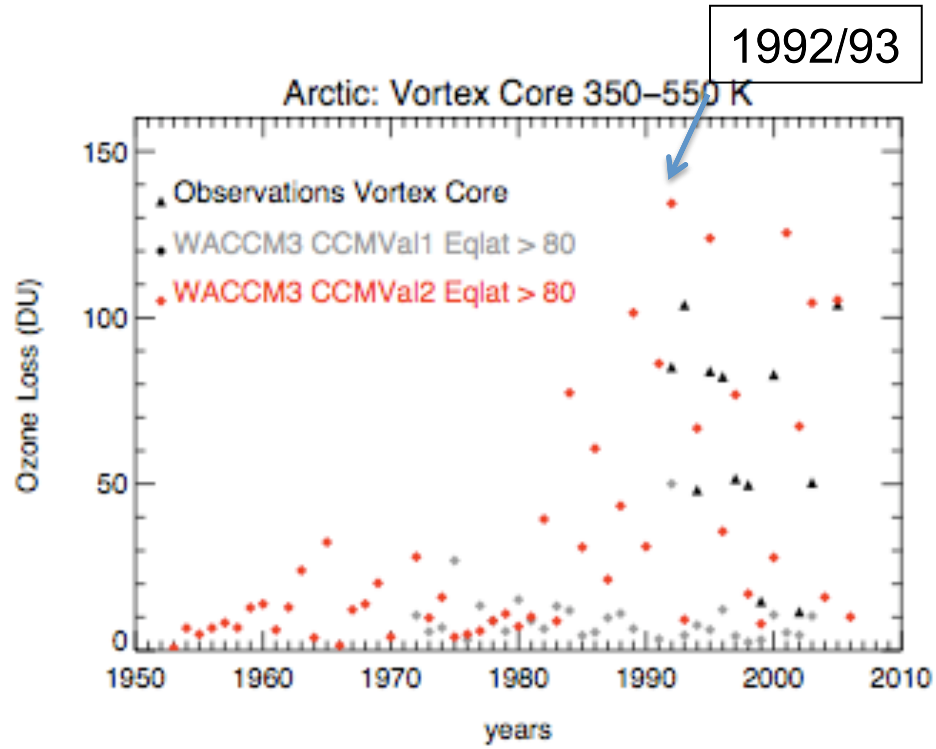

New WACCM Simulation Shows Colder Arctic Temperature

- Ozone depletion comparable with observations
- 1992/93 cold Arctic winter in the simulation
- largest chemical ozone depletion -> Potential for an improved Geo-engineering Simulation

Summary

Geo-engineered Aerosols in the Stratosphere result in:

- Cooling of the surface, delay of global climate change by 40 years
- Changes in climate due to changes in horizontal and vertical temperature gradient
- Impact of volcanic-sized aerosols on chemistry and dynamics
- Minor changes of column ozone in low and mid latitudes
- Significant decrease of the depth of the ozone layer in high latitudes (Underestimation of Arctic ozone depletion)
- Recovery of the Antarctic ozone loss delayed by 30-70 years (observations)

Possible improved Simulation:

- Using WACCM3548 + fully coupled ocean (improved Arctic conditions)
- Performing a ramp up experiment