Stratospheric dynamical response and ozone feedbacks in the presence of SO$_2$ injections

Jadwiga (Yaga) Richter
Simone Tilmes, Michael Mills, Ben Kravitz, Doug MacMartin, Sasha Glanville, Joe Tribbia, J. F. Lamarque

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Introduction

• **SO$_2$ injections** into the stratosphere are one of the most promising suggested methods of geoengineering

• **SO$_2$ injections** into the stratosphere have been shown to heat the stratosphere and change the stratospheric and tropospheric circulation

• A pioneering study by Aquila et al. 2014 showed that **equatorial SO$_2$ injections prolong westerly phase** or completely interrupt the Quasi-biennial Oscillation

• **U. Niemeier** has shown similar findings (personal communication)

• Most previous studies have been based on equatorial injections
This study

- Use NCAR’s Community Earth System Model, version 1 (CESM1)
- Examine the response of stratosphere including QBO to SO₂ injections at equator and at different latitudes
- Examine the role of interactive chemistry
- Examine stratospheric response in a century long simulation with strategically designed geoengineering
CESM1(WACCM)

- Modified Community Earth System Model, version 1 (CESM1)

- Atmospheric component: ‘WACCM5’

- 0.9° x 1.25° horizontal resolution, 70 levels up to 140 km

- Fully coupled atmosphere, land, ocean, sea ice

- Interactive stratospheric chemistry, 158 species
Simulations

Single Injection Matrix Experiments

WACCM Control:
- RCP8.5 Scenario

Matrix Simulations:
- Inject in Year 2040
- 10 year simulations
- Constant injection amount every year
Role of NCAR in NGGPS

SO$_4$

Equatorial Injection

15°S Injection

30°S Injection

15°N Injection

30°N Injection

12 Tg SO$_2$/year

Tilmes et al. 2017
Temperature Changes

Equatorial Injection

15°S Injection

30°S Injection

15°N Injection

30°N Injection

12 Tg SO₂/year

Richter et al. 2017
Ozone feedbacks affect changes due to aerosol heating
Thermal Budget

Interactive Chemistry

Specified Chemistry
Thermal Budget: Specified Chemistry

Interactive Chemistry

Specified Chemistry

Temperature Change

Residual Vertical Velocity Change

Richter et al. 2017
Tropical Injection: Interactive vs Specified Chemistry

Interactive Chemistry

Specified Chemistry

The QBO period lengthens from 3.5 to 7.5 years when specified chemistry version is used

Richter et al. 2017
SO$_2$ injections at other locations

- 12 Tg 15°S
- 12 Tg 15°N
- 12 Tg 30°S
- 12 Tg 30°N
Century Long Simulation

Kravitz et al. 2017
Century Long Simulation: Temperature Changes

2020-2039

2040-2059

2060-2079

2080-2099
QBO Changes

T ~ 15 months

T ~ 24 months
Summary

• SO2 injections at equatorial and extratropical latitudes cause **warming in the tropical stratosphere**

• **Ozone feedbacks** change SW and LW heating rates

• The period of the **QBO lengthens** due to equatorial SO2 injections

• SO2 injections away from equator **decrease QBO period**

• **If geoengineering is strategically designed**, the QBO period likely remains close to present day