Development of a multispecies data assimilation framework for tropospheric chemistry in the NASA GEOS-5 model

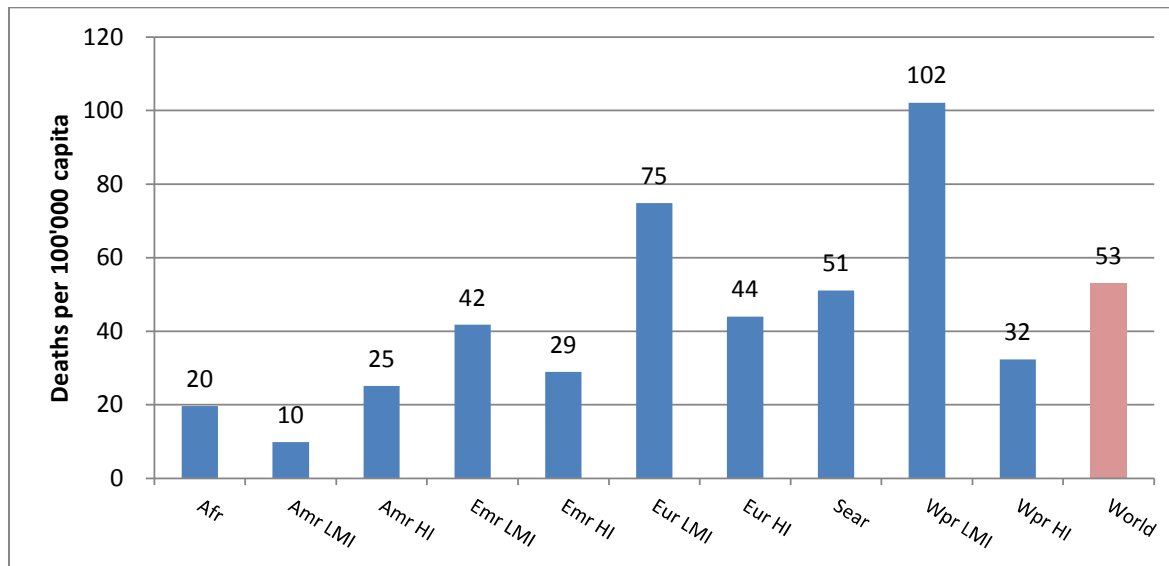## Christoph A. Keller

Steven Pawson, Kris Wargan, Brad Weir

21 October 2016

Atmospheric chemistry models are key to understand air pollution & climate change

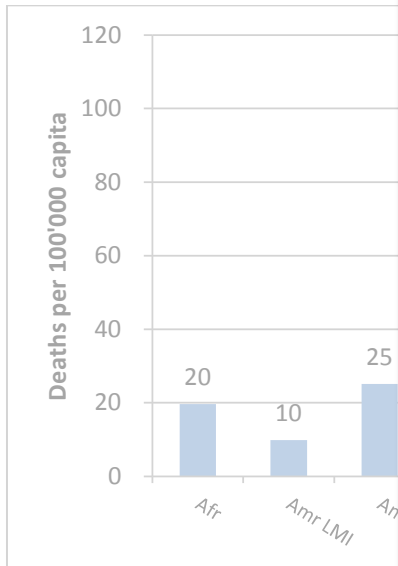WHO: air pollution is largest environmental health risk

AAP: Ambient air pollution; Amr: America, Afr: Africa; Emr: Eastern Mediterranean, Sear: South-East Asia, Wpr: Western Pacific; LMI: Low- and middle-income; HI: High-income.
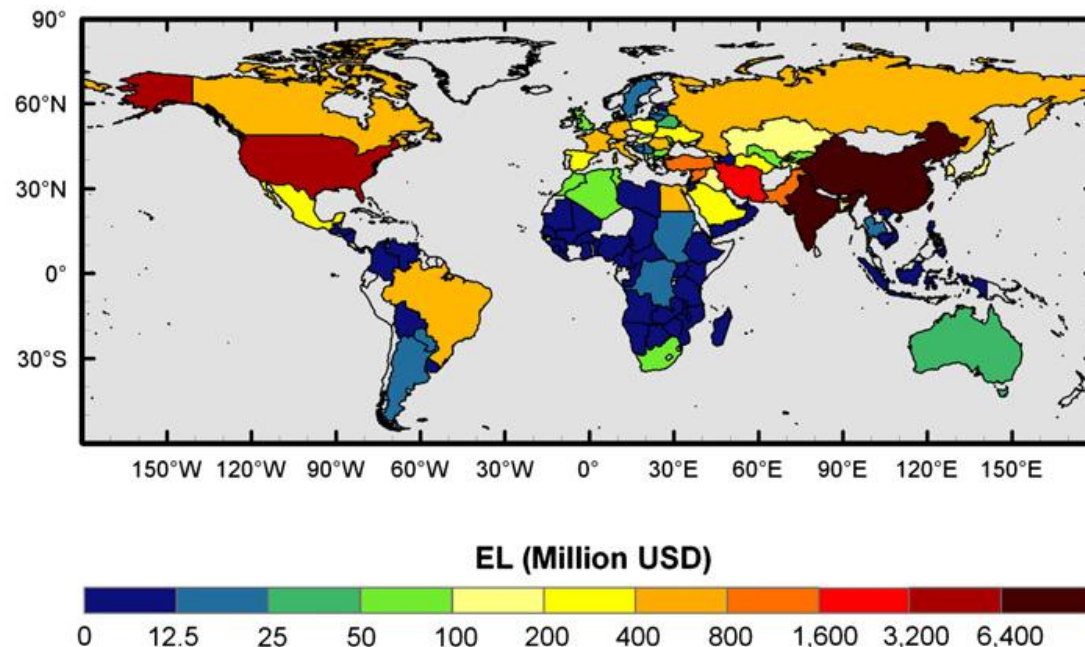
WHO, 2014

Atmospheric chemistry models are key to understand air pollution & climate change

WHO: air pollution is largest
environmental...

AAP: Ambient air pollution; Amr: Am...
Western Pacific; LMI: Low- and midd...

Potential economic loss due to increase in surface ozone concentration (crop loss)

EL (Million USD)

0 12.5 25 50 100 200 400 800 1,600 3,200 6,400

Avnery et al., Atmospheric Environment, 2011
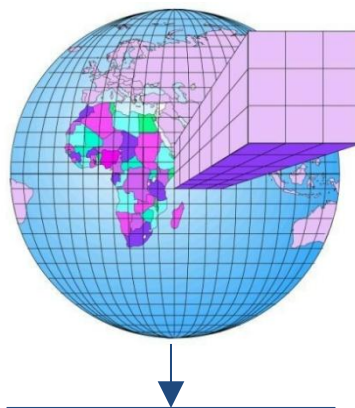
The GEOS-Chem chemical transport model

Input data
- NASA GEOS meteorological fields
- other

Model solves 3-D chemical continuity equations
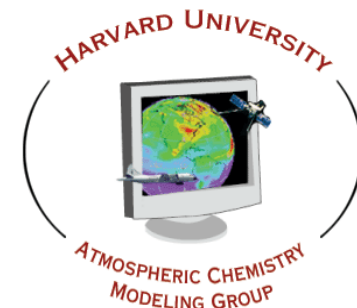on global or nested Eulerian grid

Modules
- emissions
- transport
- chemistry
- aerosols
- deposition
- sub-surface

Model adjoint

Applications
- chemical processes, transport, budgets
- inverse analyses
- radiative forcing
- air quality
- biogeochemistry
- …

Model capabilities:

- Atmospheric chemistry, aerosol microphysics, CO_2, methane, mercury, various tracers
- 1980-present GEOS meteorological data, past and future climates (GCMs)
- Horizontal resolution: 0.25°x0.3125° (native), 1/2°x2/3° , 2°x2.5°, 4°x5°, other grids
- Flexible implementation of new emission inventories (HEMCO)

HARVARD UNIVERSITY
ATMOSPHERIC CHEMISTRY MODELING GROUP

GEOS-Chem as an Earth System Model module
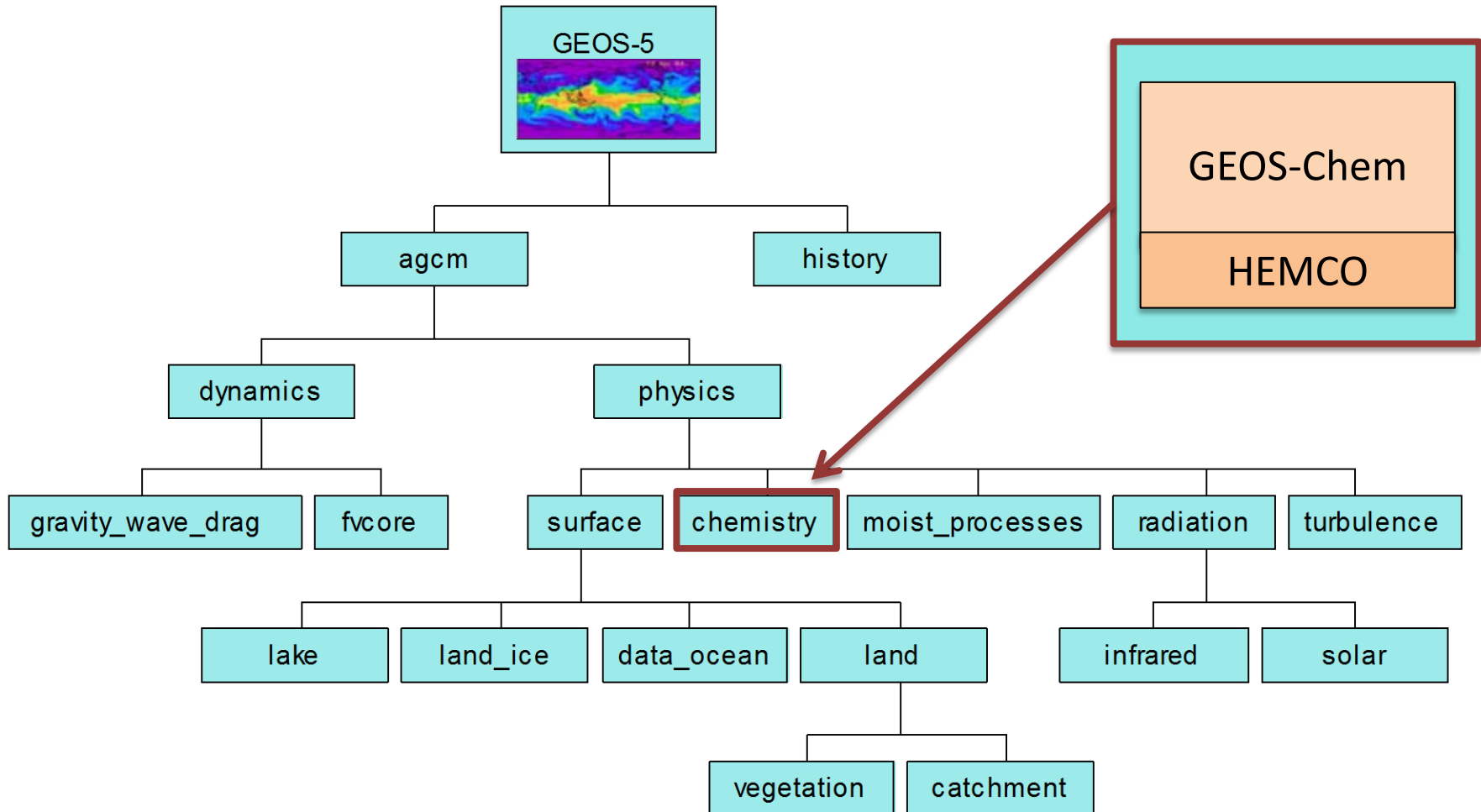
GEOS-5 12km nature run with GEOS-Chem

Surface Nitric Acid
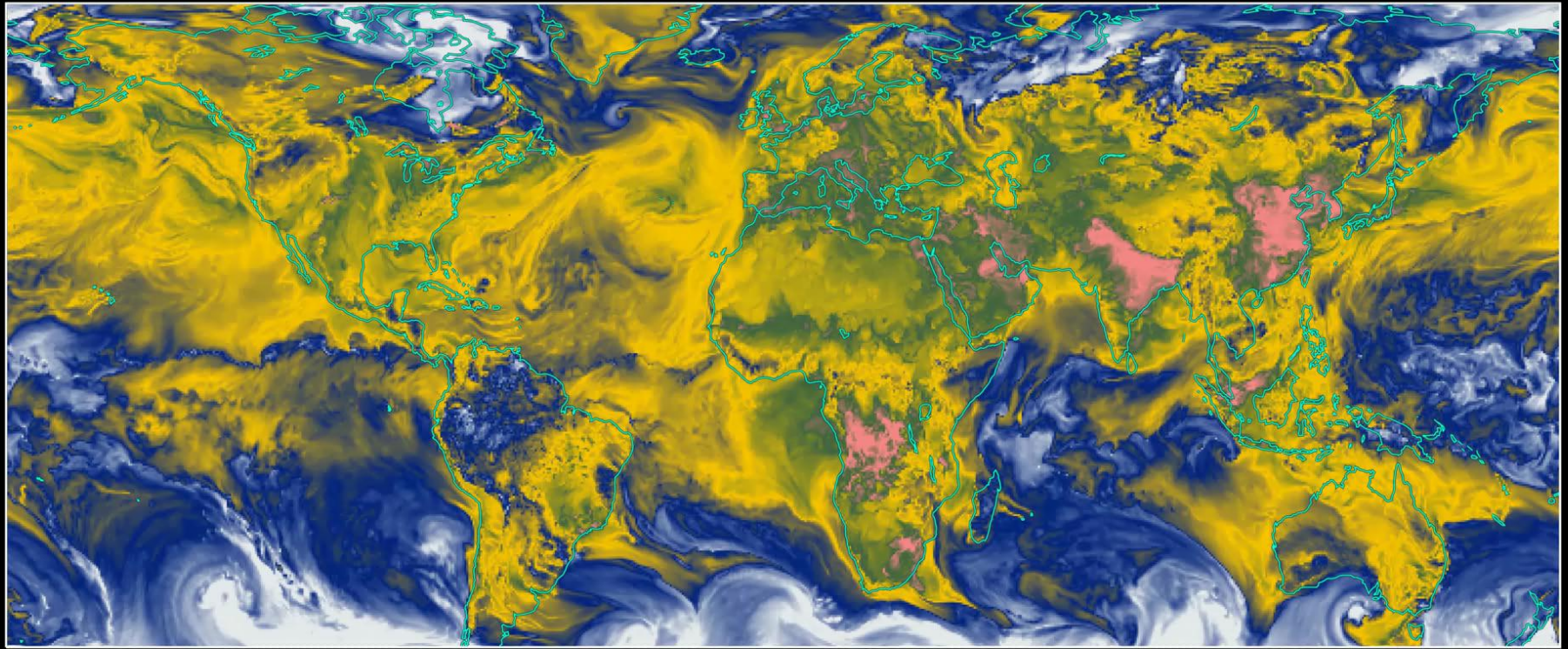
Fri 21 Jun 2013 — Sat 22 Jun — Sun 23 Jun — Mon 24 Jun — Tue 25 Jun — Wed 26 Jun — Thu 27 Jun — Fri 28 Jun — Sat 29 Jun — Sun 30 Jun
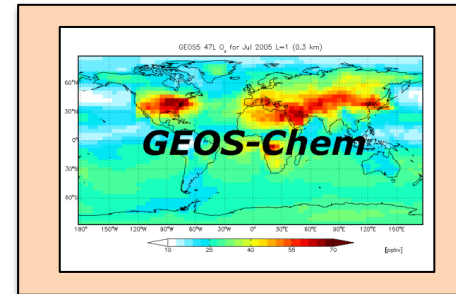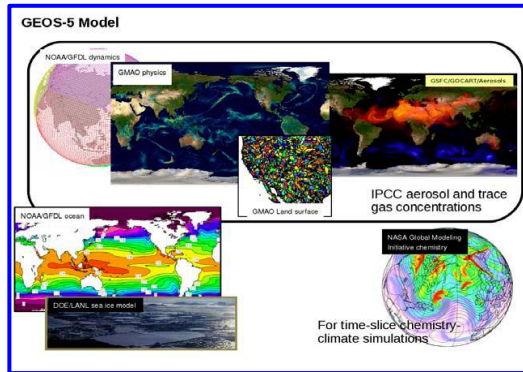
g5nr-chem-b2-c720

-2.50 -2.25 -2.00 -1.75 -1.50 -1.25 -1.00 -0.75 -0.50 -0.25 0.00 0.25 0.50 0.75 1.00

$\log_{10}$ ppbv

Global Modeling and Assimilation Office
NASA Goddard Space Flight Center
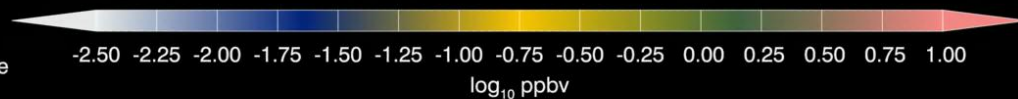
GEOS-5 GEOS Chem
12.5 km x 12.5 km

Courtesy of Eric Nielsen

Chemical data assimilation of tropospheric constituents in GEOS-5

GEOS-5 Earth System Model

GEOS-5 Model

NOAA/GFDL dynamics

GMAO physics

GSFC/GOCART/Aerosols

IPCC aerosol and trace gas concentrations

NOAA/GFDL ocean

GMAO Land surface

DOE/LANL sea ice model

NASA Global Modeling Initiative chemistry

For time-slice chemistry-climate simulations

GEOS-Chem

Data Assimilation System

• O_3, CO, NO_2, CO_2, …

GEOS-Chem improves tropospheric ozone assimilation
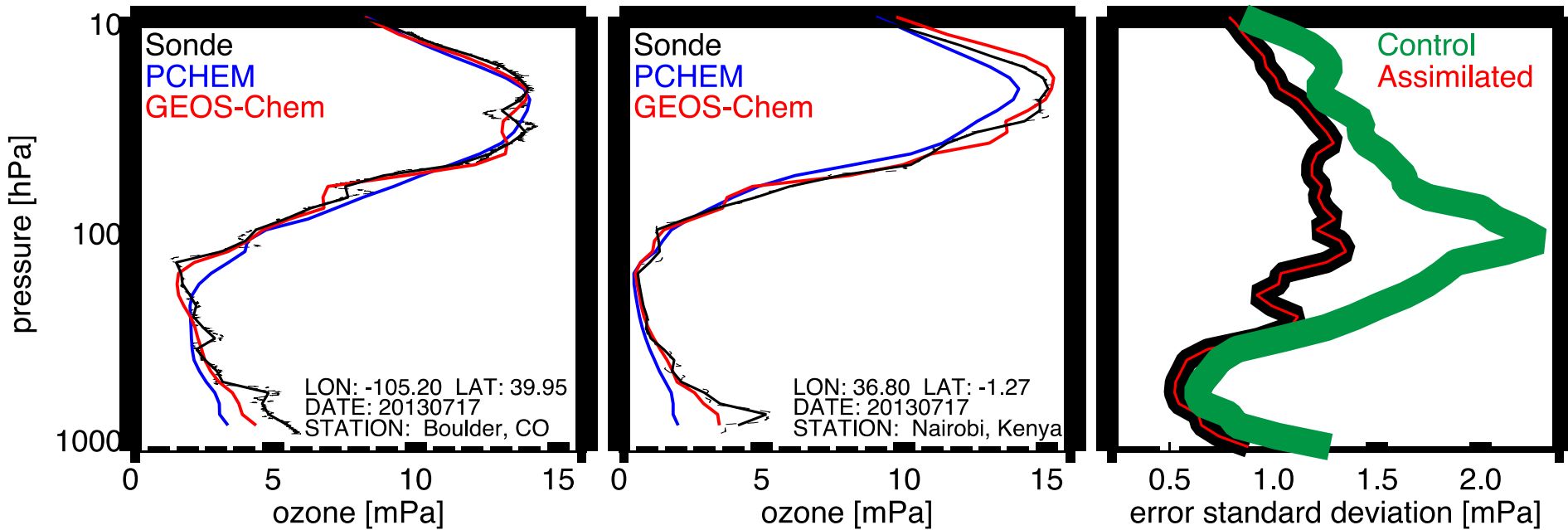
- PCHEM: parameterized chemistry scheme (operational)

Low bias in OCO-2 retrieval (?)
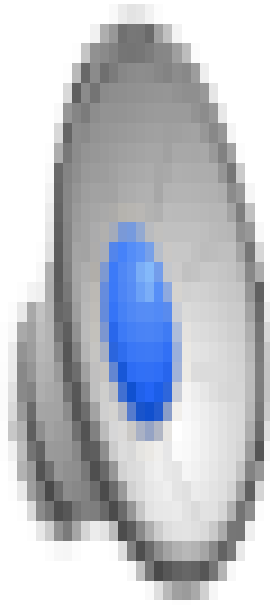
Chemical data assimilation is a boundary condition problem
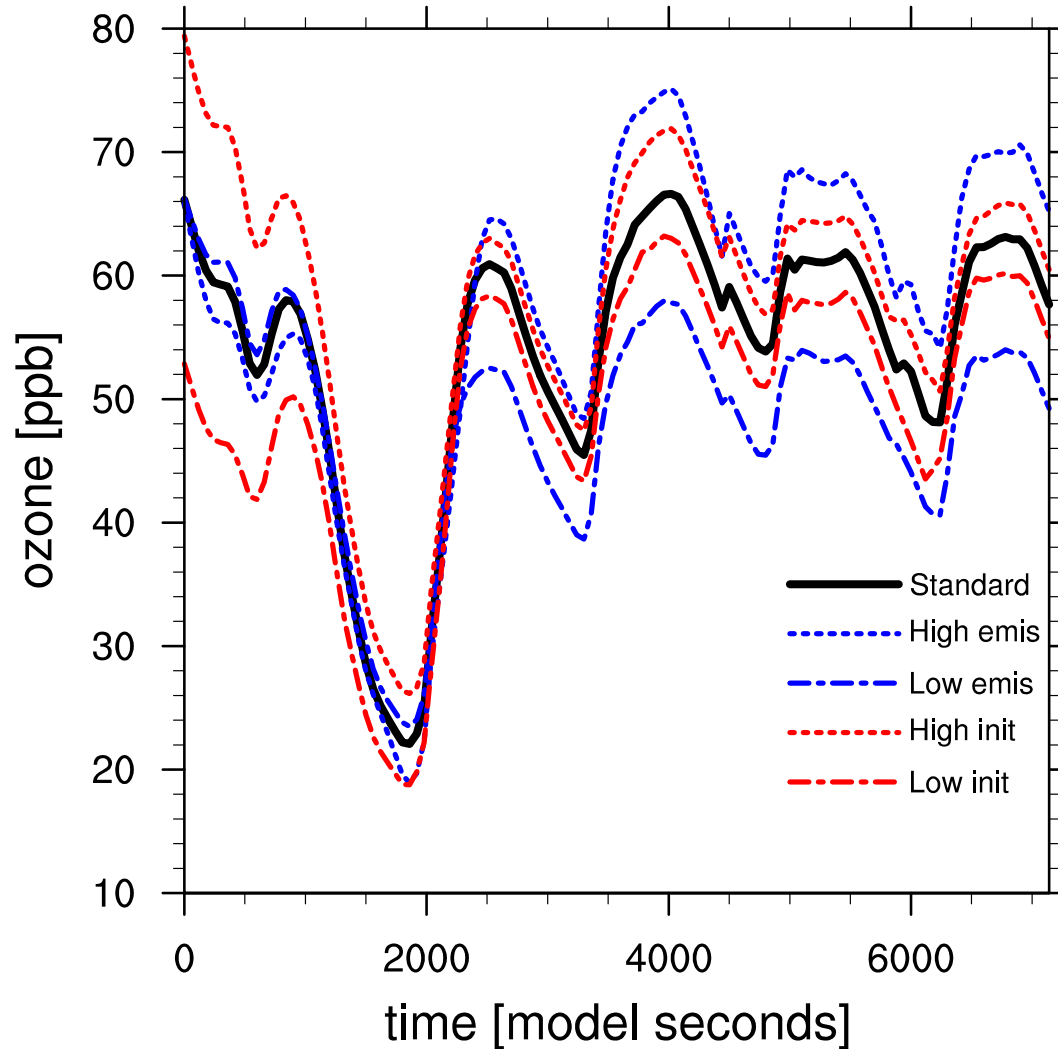
# Species error correlations differ from concentration correlations

- Error correlations reflect uncertainties in dynamics

- 'Chemical' error correlation is difficult to quantify based on traditional ensembles

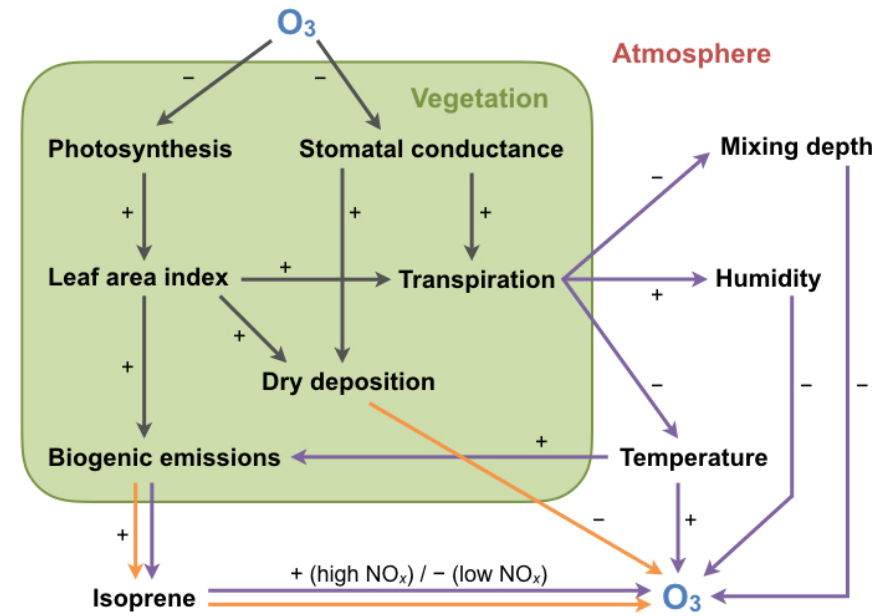Ozone-CO Concentration Correlation

Ozone-CO Error Correlation

Correlation Coefficient (R)
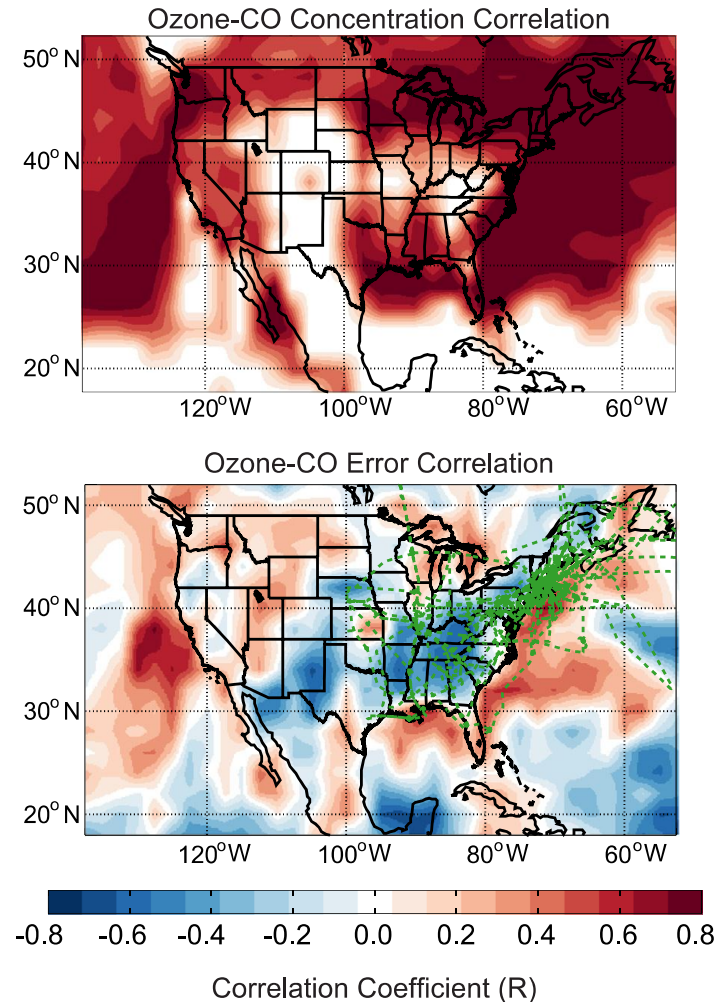
Zoogman et al., 2014

Coupling to ocean & land is crucial for boundary conditions

Sea salt aerosols
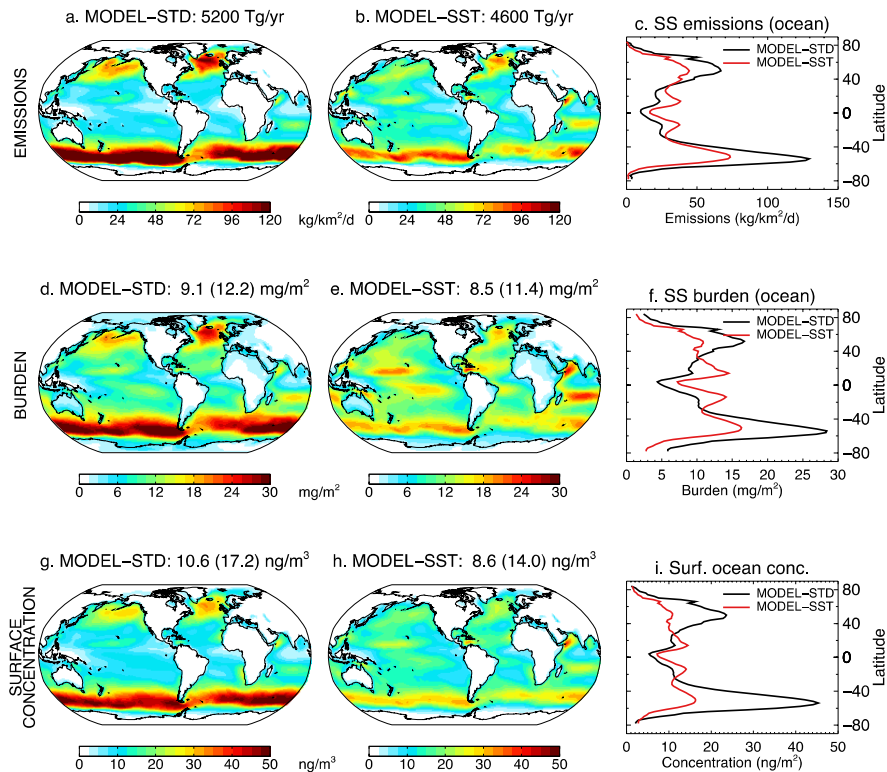
Biogenic compounds

Sadiq et al., 2016

Jaegle et al., 2011

Atmospheric chemistry is sensitive to model resolution
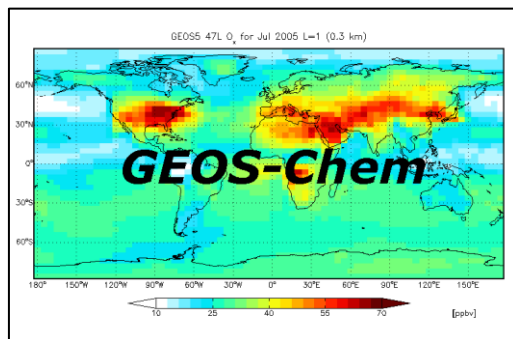

Isoprene emissions
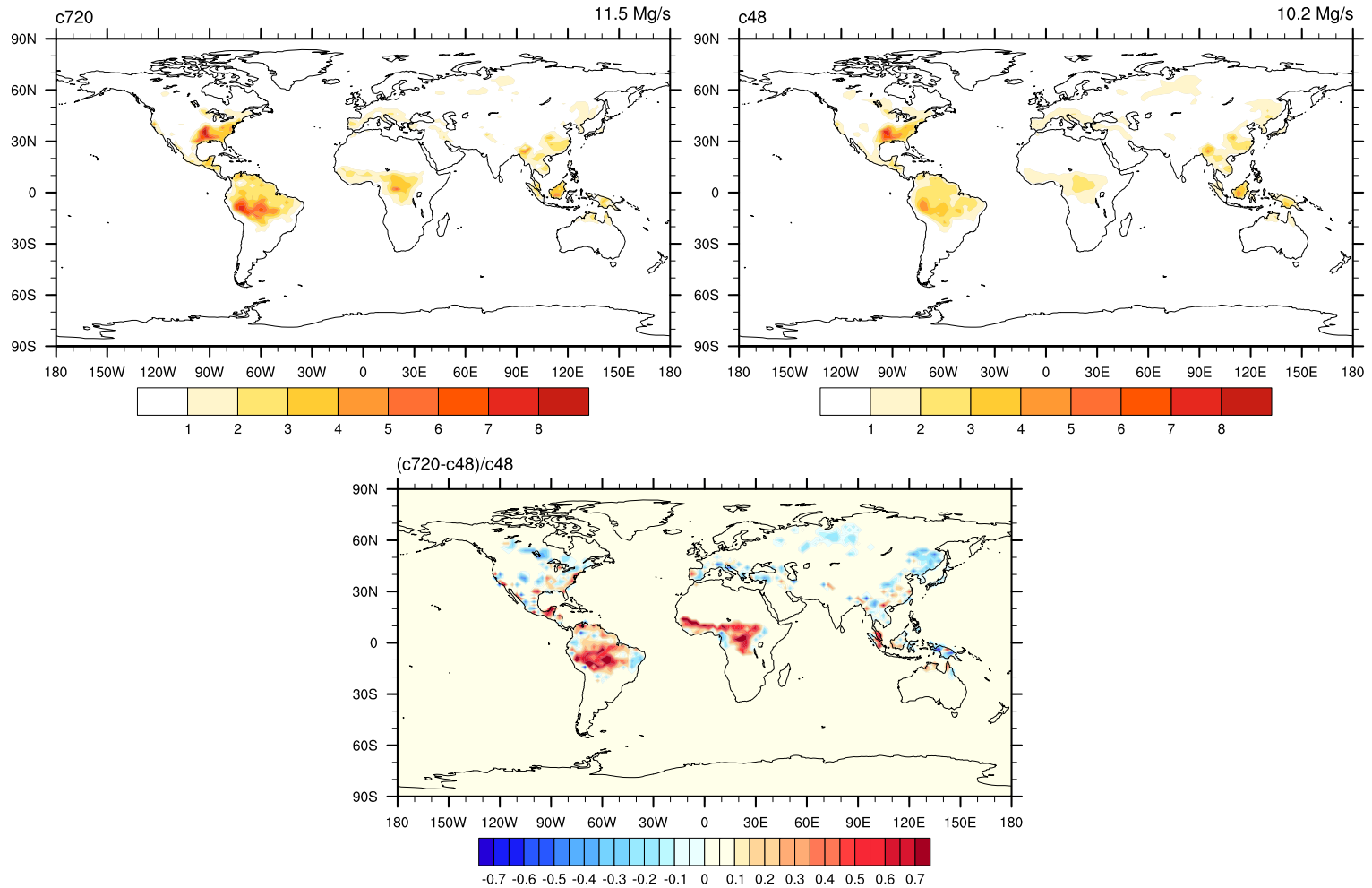
Summary

- (Weakly) coupled GEOS-5 chemical data assimilation system under development

- Special emphasis on boundary conditions (emissions) needed

- Applications: OSSE (nature run), reanalysis

christoph.a.keller@nasa.gov

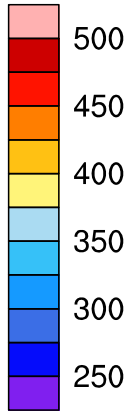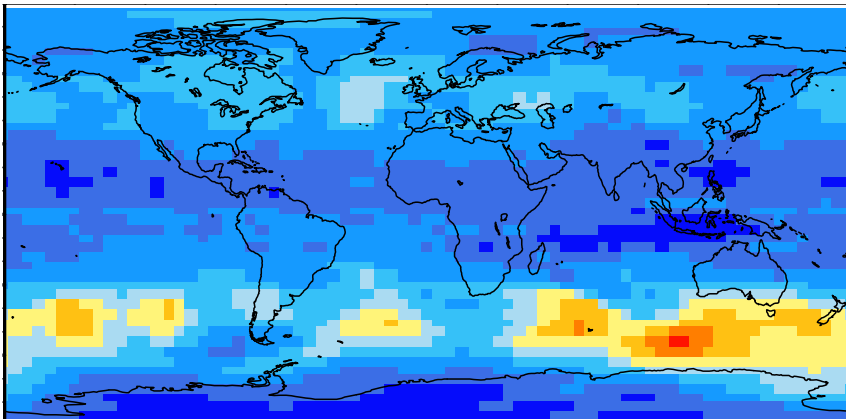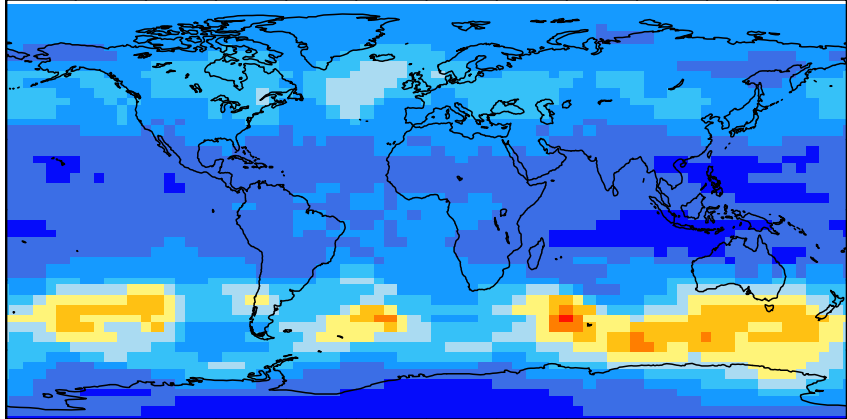# GEOS-Chem's boundary conditions are someone else's research career

Thank you

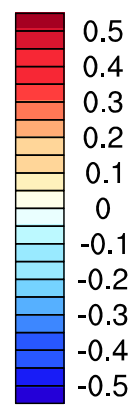# GEOS-Chem within GEOS-5 successfully reproduces ozone

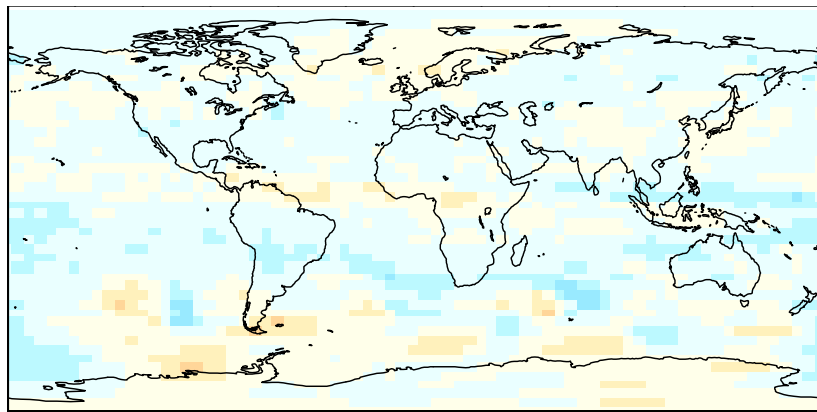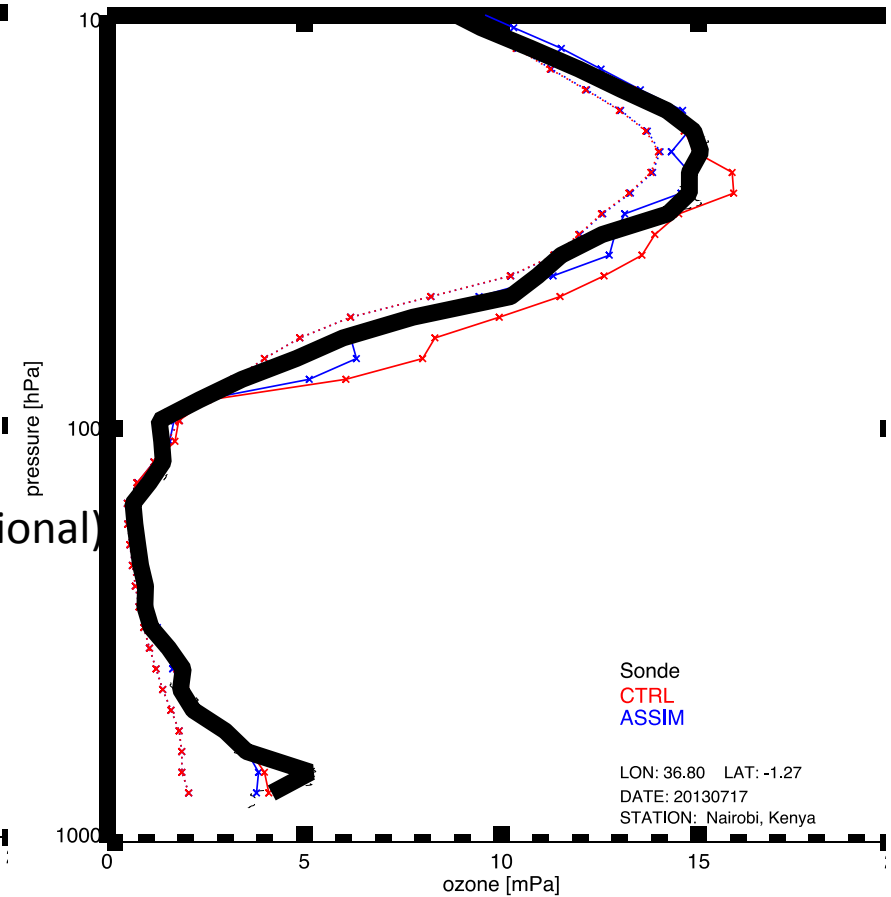## Column Ozone (July 31, 2013)
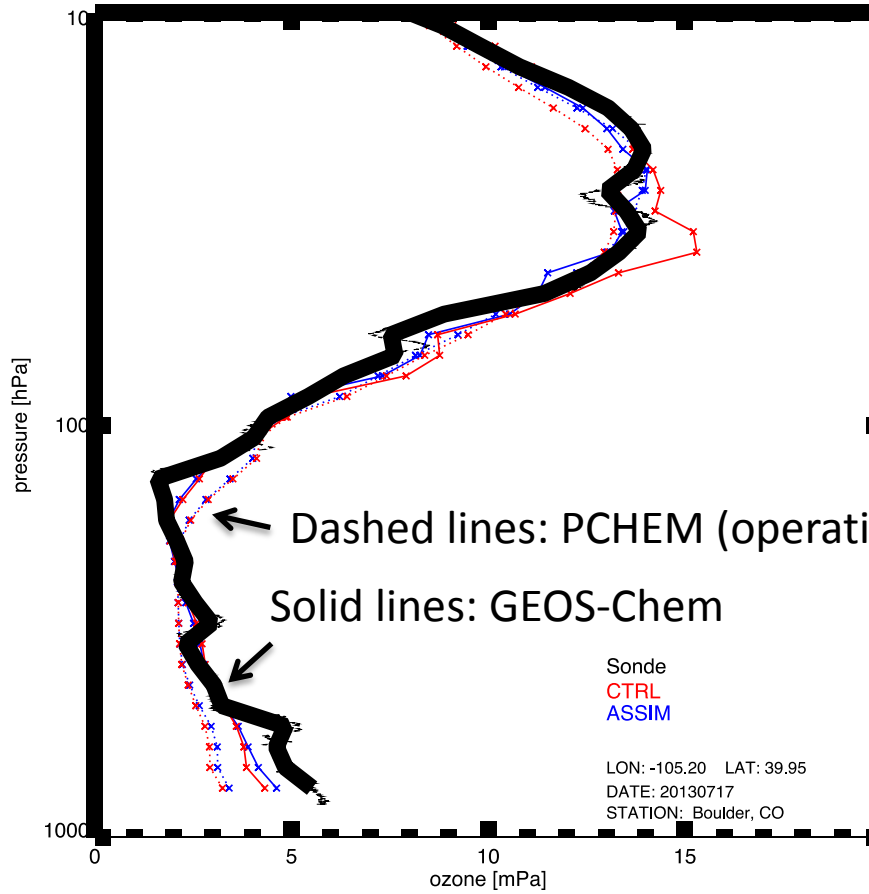

GEOS-5

GEOS-Chem

Relative difference: (GCC - GC) / GC

Dobson units

GEOS-Chem improves tropospheric ozone assimilation

Coupled GEOS-Chem/GEOS-5 Performance