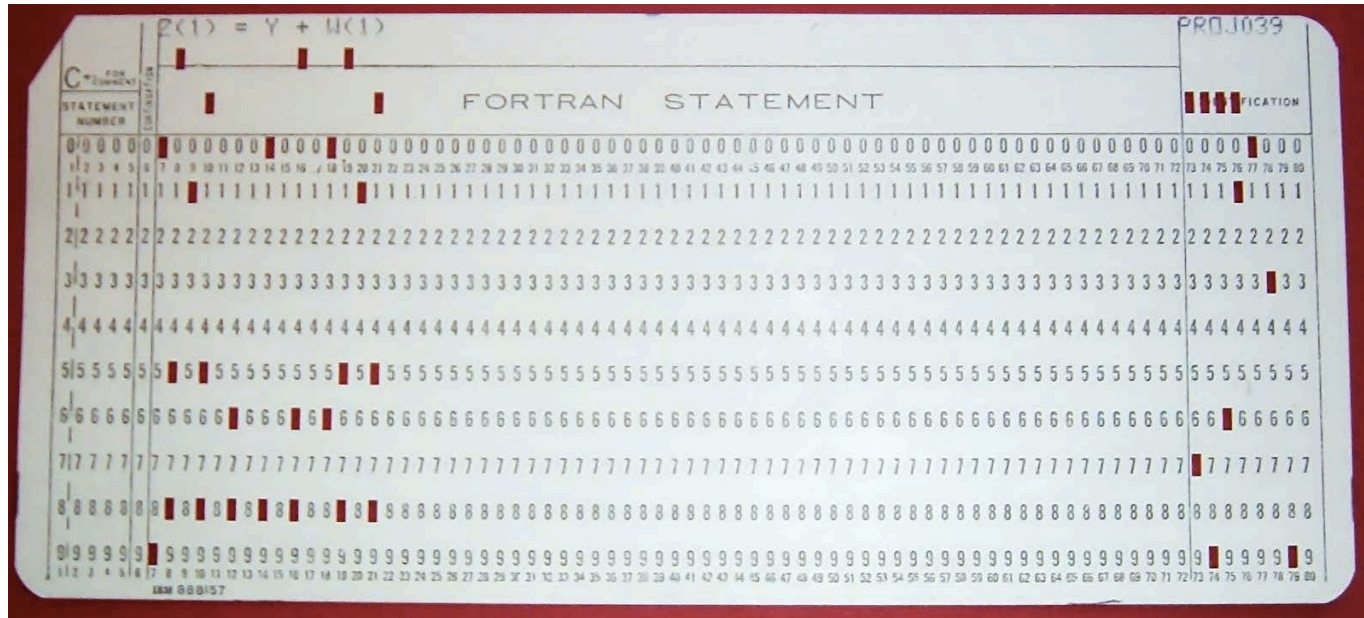# The GEOS-Chem chemical transport model:
Introduction and application to understanding atmospheric composition and air quality
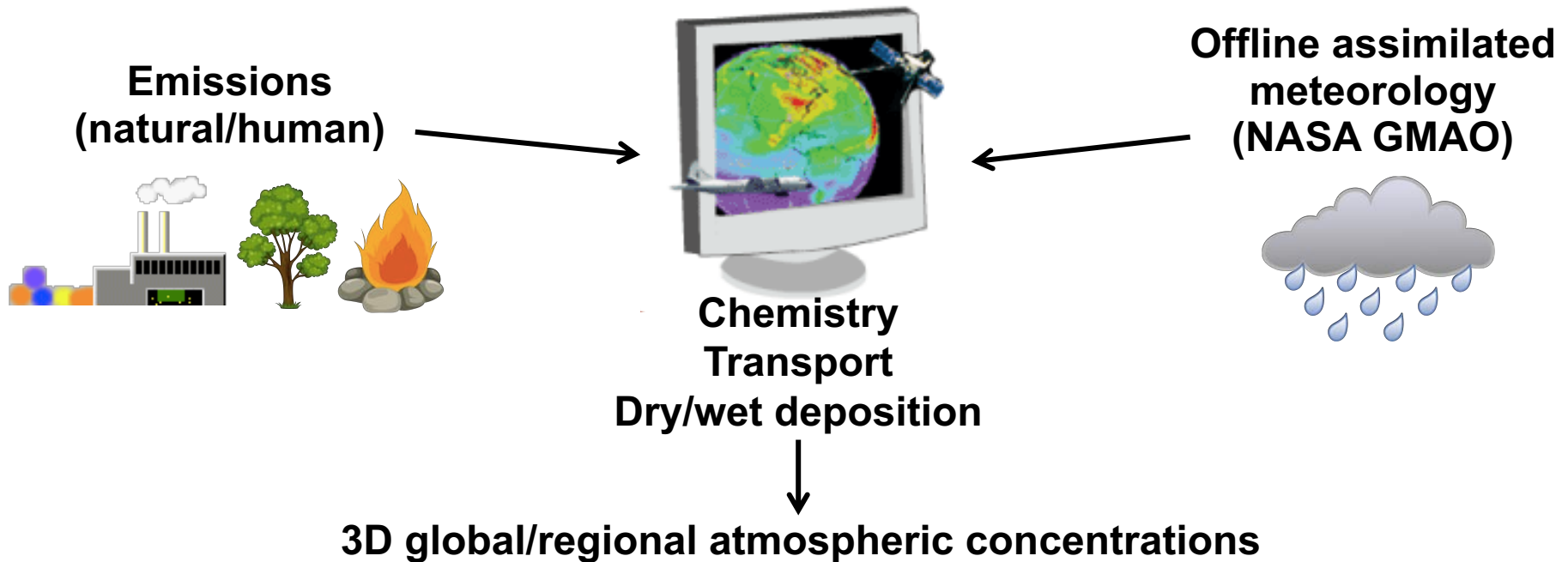

Academic Programmers SIG
13th February 2017

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GEOS-Chem: Atmospheric chemical transport model

GEOS-Chem

**Emissions
(natural/human)**

**Offline assimilated
meteorology
(NASA GMAO)**

**Chemistry
Transport
Dry/wet deposition**

3D global/regional atmospheric concentrations

Code: Fortran (historical, but also efficient for solving mathematical equations)
Input/output: mix of binary punch and NetCDF files (intention is to be 100% NetCDF)
Compile: a few minutes
Run: depends on model version. Walltime is ~10-12 hours for 1 month (1 NODE, 8 CPUs)

Not very computationally demanding, but requires lots of space for input/output
Version history tracked with git; debugging with Totalview (*not on BlueBEAR!*);
visualization with **IDL**, Python, NCAR Common Language, R.

GEOS-Chem Community

Meetings	About GEOS-Chem	Manuals and Documents

GEOS-Chem Model

GEOS-Chem Community Mission: to advance understanding of human and natural influences on the through a comprehensive, state-of-the-science, readily accessible global model of atmospheric co

The 8th International GEOS-Chem Meeting (IGC8) will be from May 1-4, 2017 @ Harvard!

Current provisional release:	GEOS-Chem v11-01	v11-01 benchmark history
Version in development:	GEOS-Chem v11-02	v11-02 benchmark history
Other resources:	GEOS-Chem HP	Supported meteorological fields

Users throughout the world

Users Meeting every 2 years

GEOS-Chem Management

Designed for seamless incorporation of scientific updates (and bug fixes!)
Science Working Group Leaders and team leader decide on model updates.
These are incorporated by the programming team, benchmarked,
scrutinized, and finally added to the official model release (now at version 11)

GEOS-Chem team leader: Daniel Jacob

GEOS-Chem subgroups led by 2 experts
(number of subgroups reflects model diversity)

Mercury/POPs   **Emissions**   **Transport**

Oxidants/Chemistry   **Regional (Nested) Models**

Aerosols   **Chemistry-Climate**   **Adjoint/Data Assimilation**

GEOS-Chem Applications

Majority of applications use the **model in combination with observations** from multiple measurement platforms (ground sites, balloon sondes, ships, drones (?), aircraft, satellites)

Too many to mention, but here are some examples:

- Human health impact of fossil fuel use in Europe
- Surface ozone damage to staple crops in China
- Ozone enhancements due to nitrogen oxides (NO_x) from lightning
- Air mass factor formulation to convert satellite slant columns to true vertical columns
- Assess the impact of future air quality policy decisions like emission control strategies, fuel switching (renewables/natural gas) on atmospheric composition
- Develop methane emission inventories for the US, Canada, and Mexico.
- Intercontinental pollution transport from China to North America
- Transport and fate of bioaccumulators like mercury.
- Plan a measurement network (location/number of ground monitors to effectively monitor particulate matter and ozone pollution).
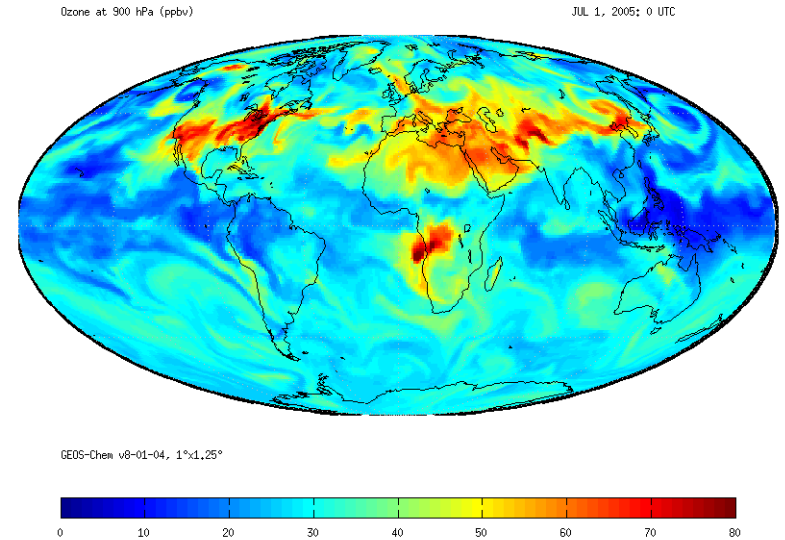
Example Model Output

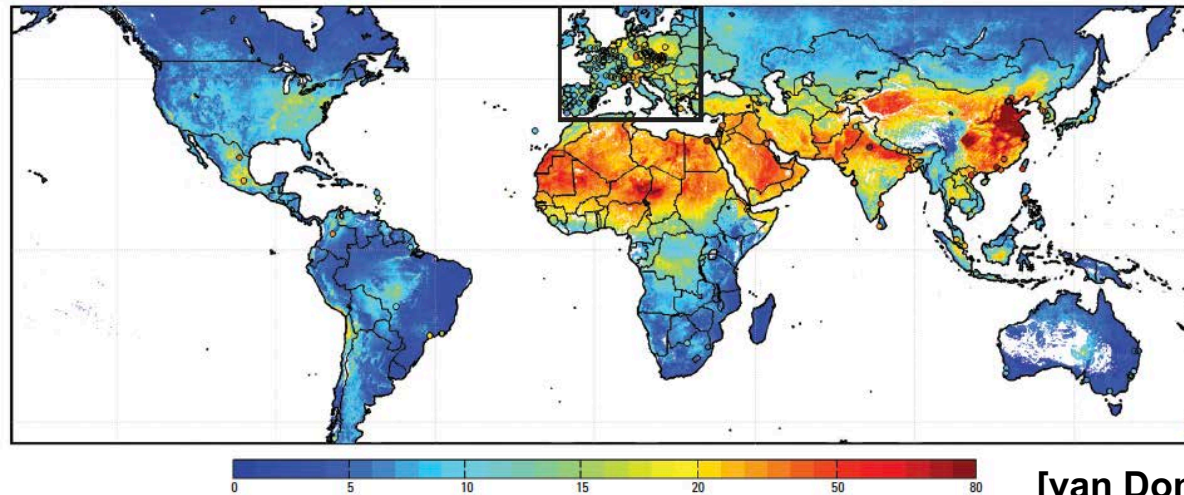**Excessive nitrogen input to the Earth's surface:**
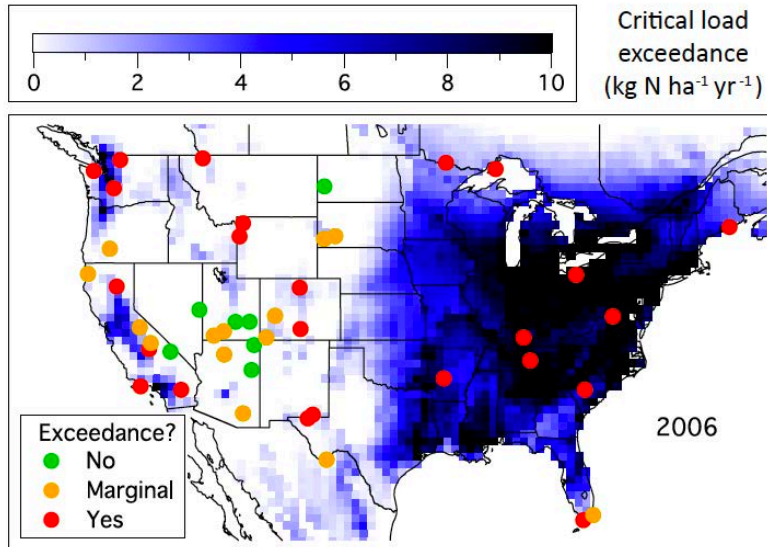
[Ellis et al., 2013]

Surface ozone concentrations:

[http://fizz.phys.dal.ca/~atmos/animation/]

Combine with satellite observations to derive surface particulate matter concentrations

[van Donkelaar et al., 2010]

GEOS-Chem Models that Exist are Many

Some examples:

Standard model: global air quality model (NOx-O3-VOC-aerosol chemistry) at **2x2.5 degrees** (~200x250 km) or 4x5 (~400x500 km) degrees.

Other specialized options:

**SOA model**: Standard model with explicit treatment of secondary organic aerosols

High-performance model: Standard model at high resolution (under development)

Nested models: Standard model, but at high resolution over a specific region (China, Europe, North America, **Africa**, West Africa) with boundary conditions at the coarse global resolution. High resolution dictated by resolution of meteorological fields

Others: Mercury, POPs, radon, Methane

RED: GEOS-Chem models used in my research

Major Development Initiative
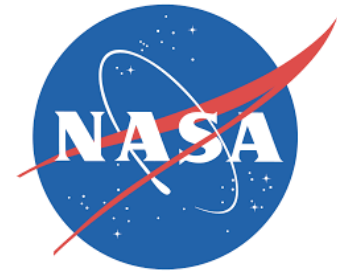
Reformat GEOS-Chem to be used within the Earth System Modelling Framework (**ESMF**)

Dynamic representation of earth systems (ocean/forest/atmosphere) (**advantage**)
Plug-and-play framework to couple different model components (**advantage**)
Very high computational demand (**disadvantage**)

NASA GEOS-5 model

GEOS-Chem