Jet Propulsion Laboratory
California Institute of Technology

IGAC TOAR-II chemical reanalysis Focus Working Group

Kazuyuki Miyazaki, *WG co-lead, Jet Propulsion Laboratory, California Institute of Technology, USA*

Dylan Jones, *WG co-lead, Univ. of Toronto, Canada*

Helen Worden, *TOAR-II SC, NCAR, USA*

Chemical reanalysis

- A systematic approach to create a long-term data record of atmospheric composition, consistent with model processes and observations, using data assimilation.
- Has the great potential to provide comprehensive information on atmospheric composition variability in order to improve understanding of the processes controlling the atmospheric environment.

Global — **ECMWF CAMS, JPL TCR-2, GEOS-Chem adjoint, RAQMS Aura**

Regional — **Chinese air quality reanalysis (CAQRA), European**

Do they agree/disagree with each other and with new TOAR-II observations?

What is the relative importance of assimilated measurements to improve surface/tropospheric ozone?

TOAR-II chemical reanalysis focus WG

Overview and Goals in support of TOAR-II

- Evaluation of chemical reanalyses with TOAR-II observations and other data (e.g., ozonesonde) will assess the potential of using reanalysis data for studying spatial gradients at regional/global scales and trends in areas with sparse in-situ observations. It will also assist in determining the contribution of precursor emissions/meteorology to observed ozone trends and surface ozone exceedances.
- Sensitivity analyses of the impacts of satellite and in-situ observations of ozone and precursors will assess the relative importance of individual observations to improve surface ozone analyses and help design observing systems that better capture the distribution and regional trends in ozone.
- Inter-comparisons of top-down precursor emissions from reanalyses, and their impacts on surface/tropospheric ozone and subsequent radiative effects, within the reanalysis framework, will facilitate evaluation of emission scenarios and environmental policy in realistic conditions.
- Well-validated chemical reanalysis ozone fields will provide an opportunity to improve the TOAR-II observation quality control processes and representativeness by providing first guess information.

TOAR-II chemical reanalysis focus WG

Expected Outcomes

- Ability of current reanalysis products to study regional and global ozone trends. We will review and inter-compare global and regional (for many regions) surface/tropospheric ozone from the latest chemical reanalyses validated against TOAR-II observations (***publication 1***).

- What is the effective observing network to study surface/tropospheric ozone variations? We will assess the impact of satellite and in-situ ground-level ozone and precursor measurements on surface/tropospheric ozone analysis using multiple reanalysis systems (***publication 2***)

- Quantitative assessment of the impact of current emission inventories on chemistry/climate model simulations of surface/tropospheric ozone. We will inter-compare top-down and bottom-up precursor emissions inventories and their impacts on surface/tropospheric ozone using multiple reanalysis systems (***publication 3***)

- Provide representativeness information of various in-situ and satellite observational measurements

TOAR-II chemical reanalysis focus WG

Synergies with other TOAR-II Focus Working groups and IGAC activities

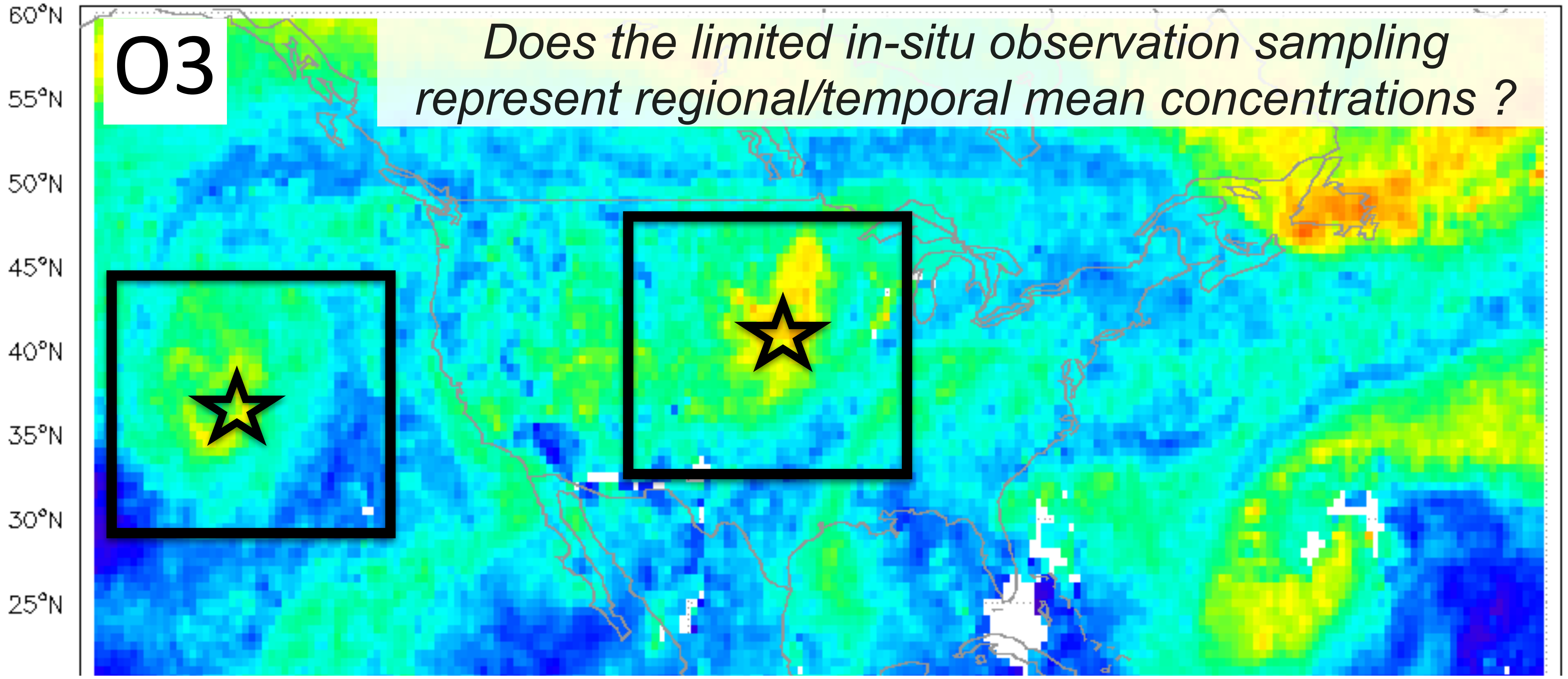
- facilitate quality control processes (first-guess) and provide representativeness information of various observational measurements for HEGIFTOM Focus Working Group.
- demonstrate the value of individual satellite measurements to study surface/tropospheric ozone, which will be shared with the Satellite Ozone Focus Working Group. Reanalysis products will also be used as transfer functions to inter-compare different satellite products and evaluate representativeness of individual satellite measurements.
- provide observationally-constrained information on the relationship between surface/tropospheric ozone and its precursors while constraining other chemical environments, which will benefit Ozone and Precursors in the Tropics (OPT) Focus Working Group & Tropospheric Ozone “Precursors (TOP) Focus Working Group
- use statistical approach proposed by Statistics Focus Working Group
- IGAC AMIGO, SPARC S-RIP

Sampling bias

Aghedo et al., 2011; Foelsche et al., 2011; Toohey et al., 2013; Sofieva et al., 2014; Miyazaki and Bowman, 2017

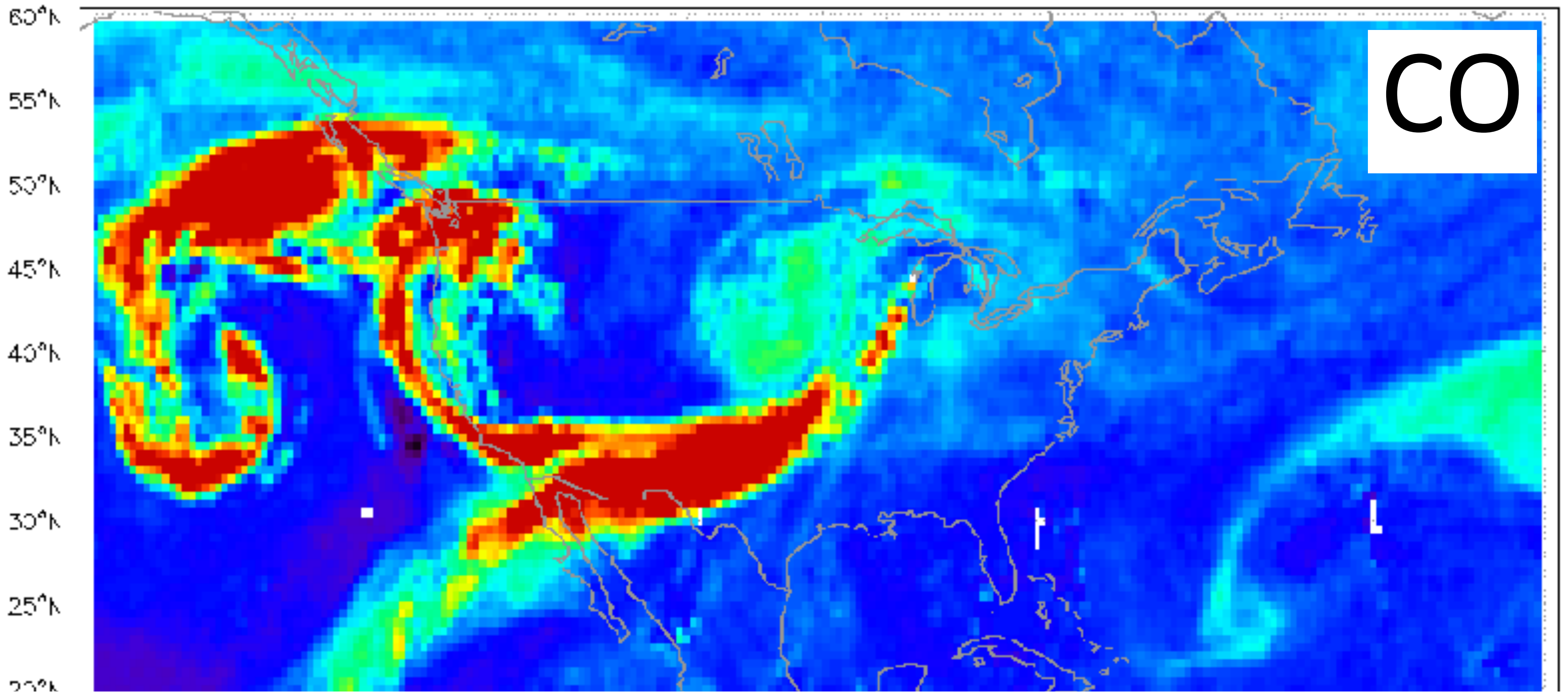
- an error that arises due to unrepresentative (i.e., insufficient or inhomogeneous) sampling
- Sampling bias may occur when the atmospheric state within the time–space domain over which the average is calculated is not uniformly sampled.
- The primary technique for sampling bias estimation is to fields based on the sampling patterns of the measurements and then to quantify differences between the mean fields based on the measurement sampling and those derived from the complete fields.

tropess



CrIS at 464 hPa, 2020-09-12

2020 California wildfires



CrIS (JPL TROPESS products) provides detail spatial maps of complicated chemical responses linked to wildfires

Sampling bias

The reanalysis product provides comprehensive information on global ozone distributions and on the weakness of the individual measurements. The ozonesonde measurements reveal a large (by 40–110 %) sampling bias in the tropical/subtropical troposphere (Miyazaki and Bowman, 2017).

JPL MOMO-Chem (Multi-mOdel Multi-cOnstituent Chemical) Data Assimilation System

MLS

TES

OMI

MOPITT

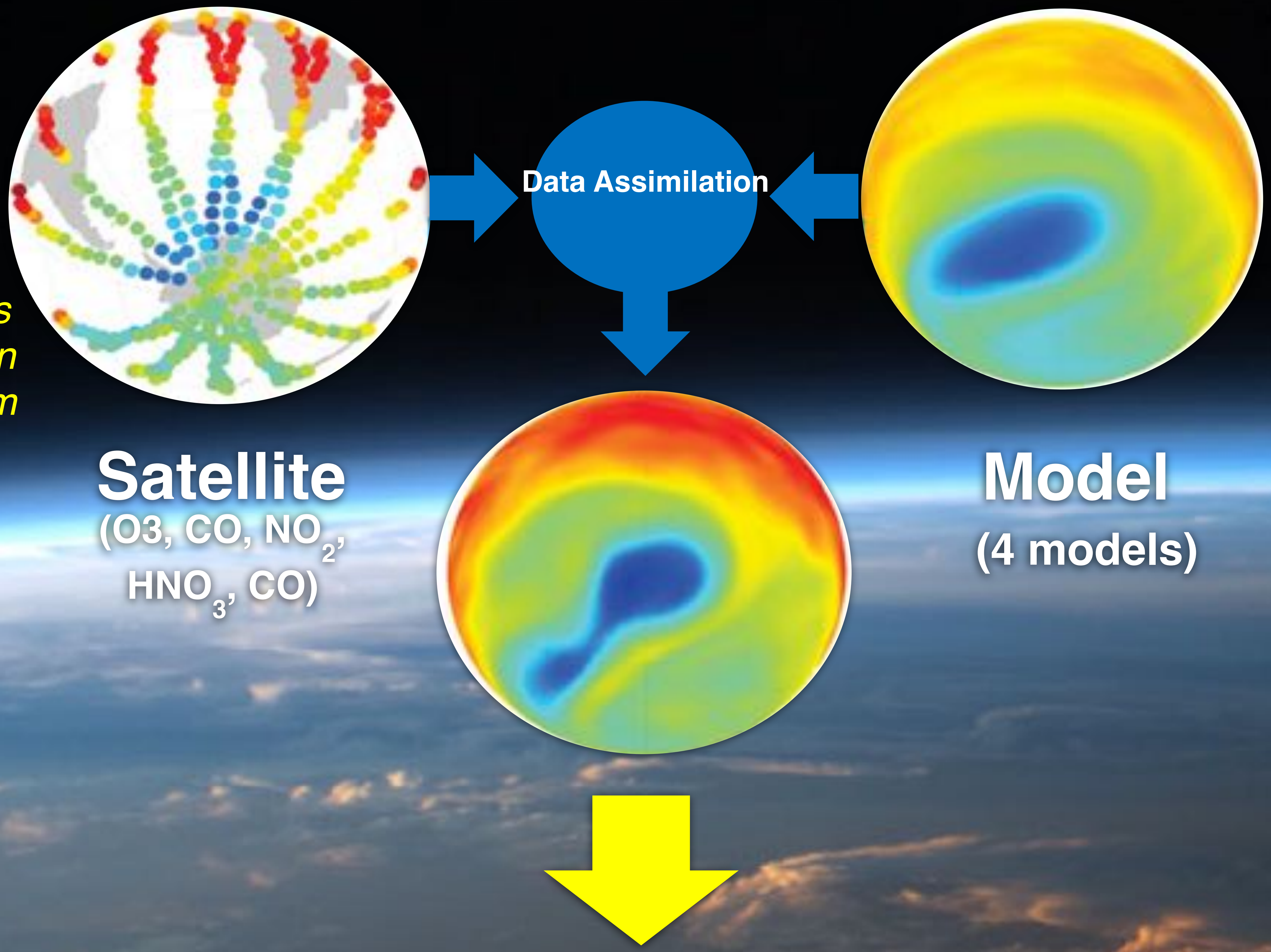
AIRS

SCIAMACHY

GOME-2

TROPOMI

Satellite Observations Assimilated in MOMO-Chem



Models Used for Assimilation

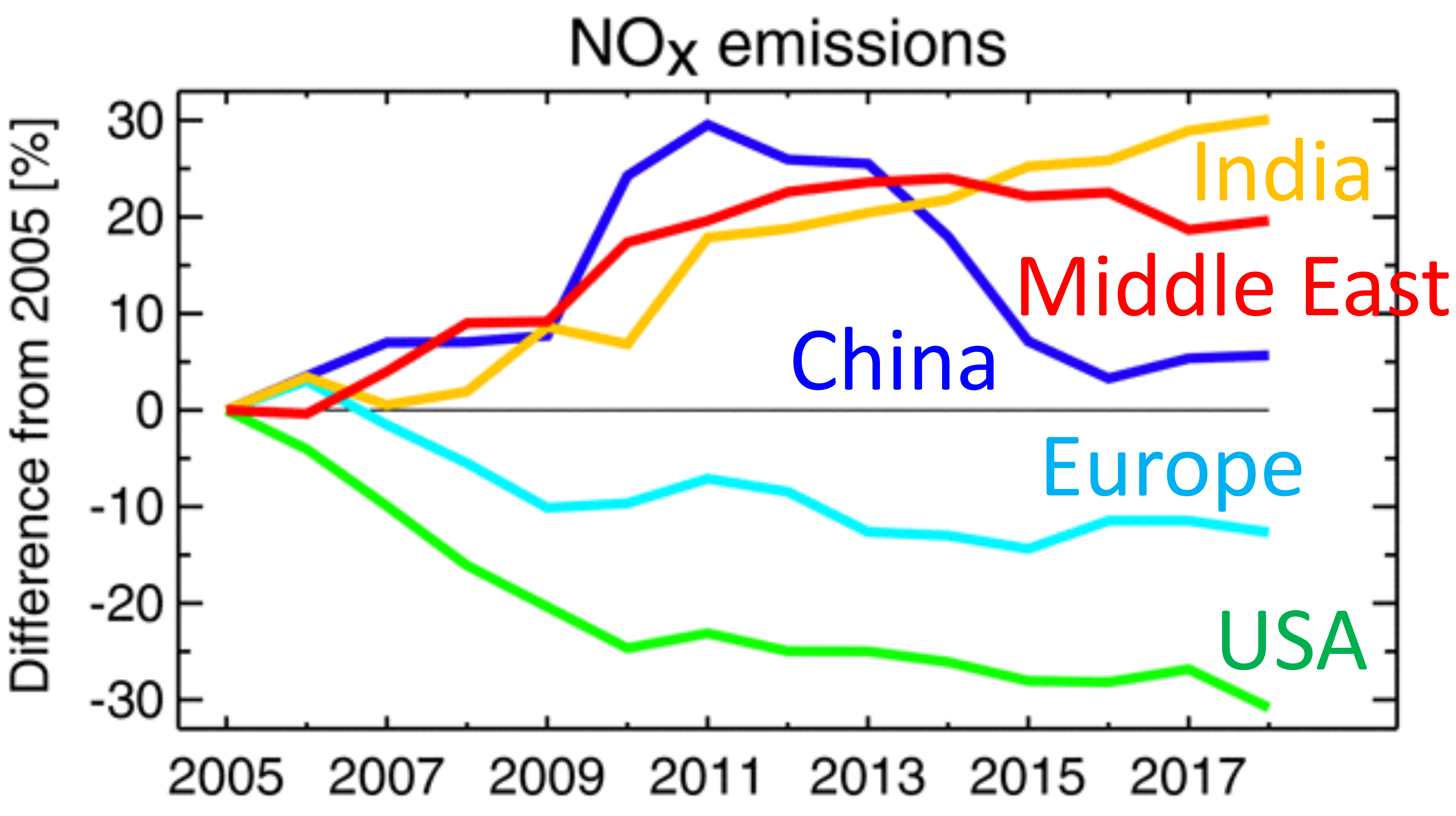
Validation against in-situ & aircraft measurements

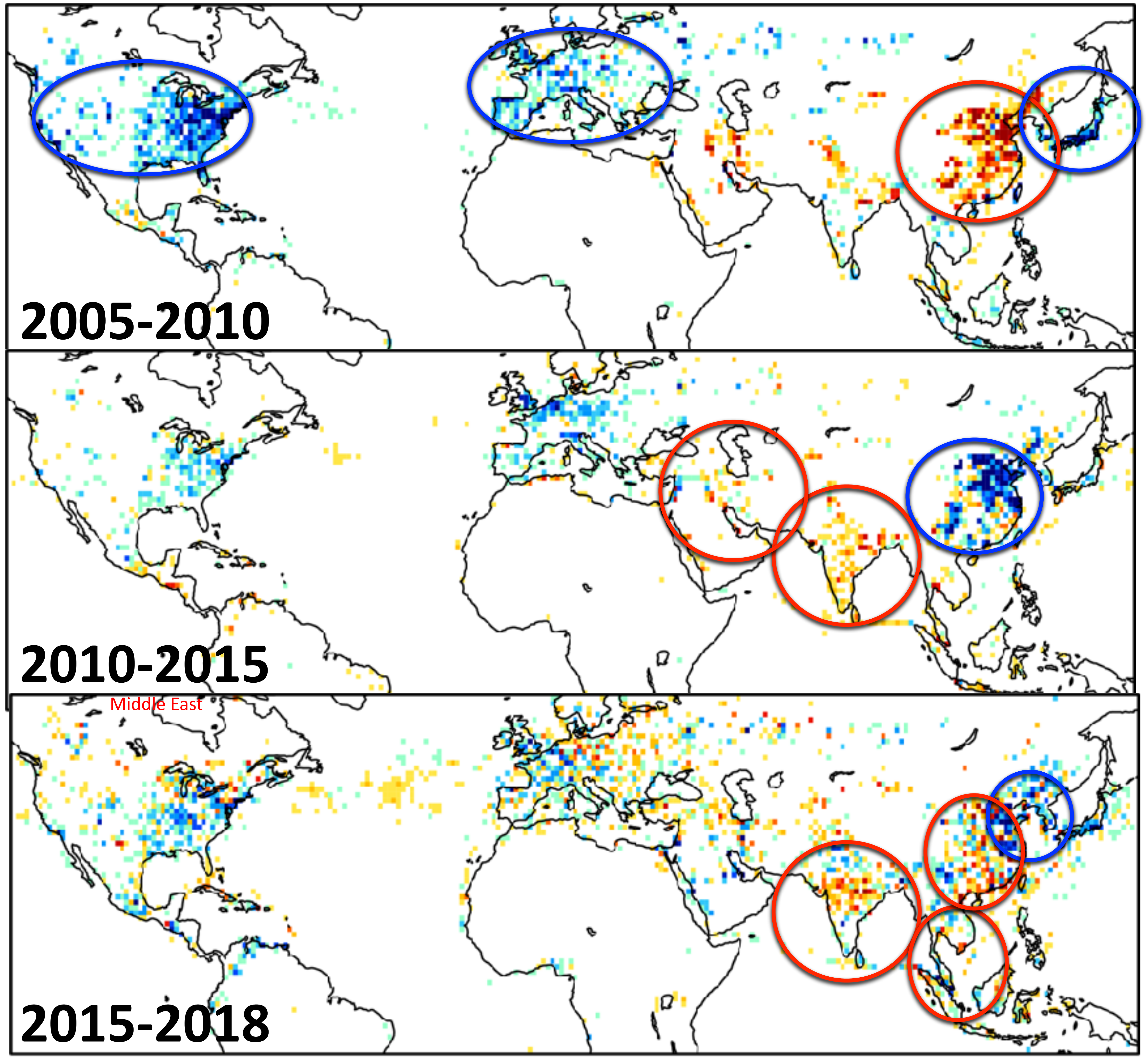
Tropospheric Chemical Reanalysis

- 16 years (2005-present), two-hourly, global, surface to lower stratosphere chemical concentrations of 35 species, including O_3, NOx, OH, SO_2, VOCs
- Anthropogenic, biogenic, biomass burning, and lightning emissions (NOx, CO, SO_2)
- Used in various science applications, including validation of NASA satellite products
- Able to support OSSE activities in support of mission formulation

OPT & TOP WG

Global shifts in anthropogenic NOx emissions





1. Emissions (NOx, SO2, CO) → **2. Concentrations** → **3. Health & climate Impacts**

Global grid-scale emissions are derived from NASA satellite observations

Air pollutants are distributed through chemical transport modeling

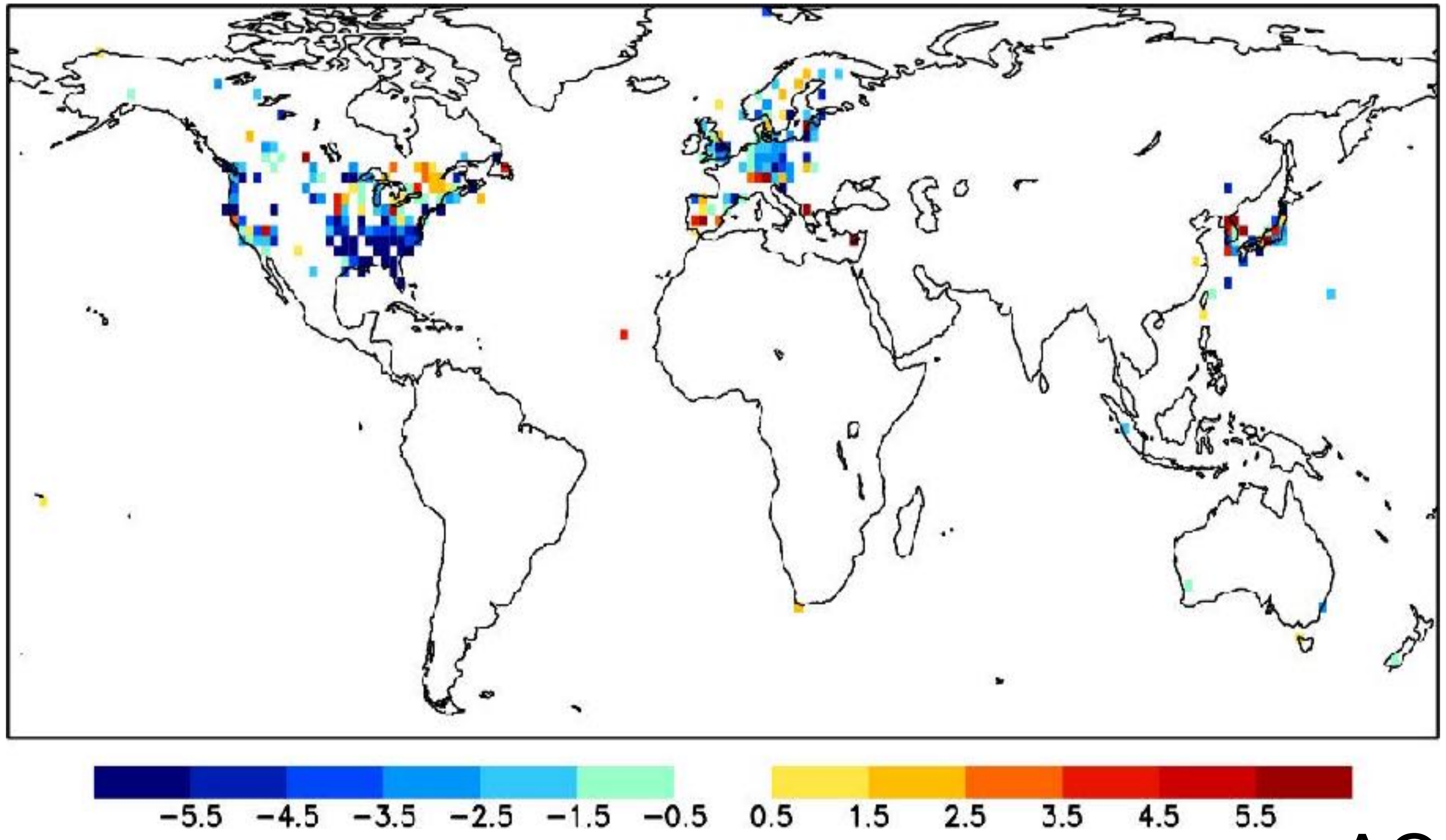
From population, mortality rate, and concentration response

Free tropospheric and surface ozone validation

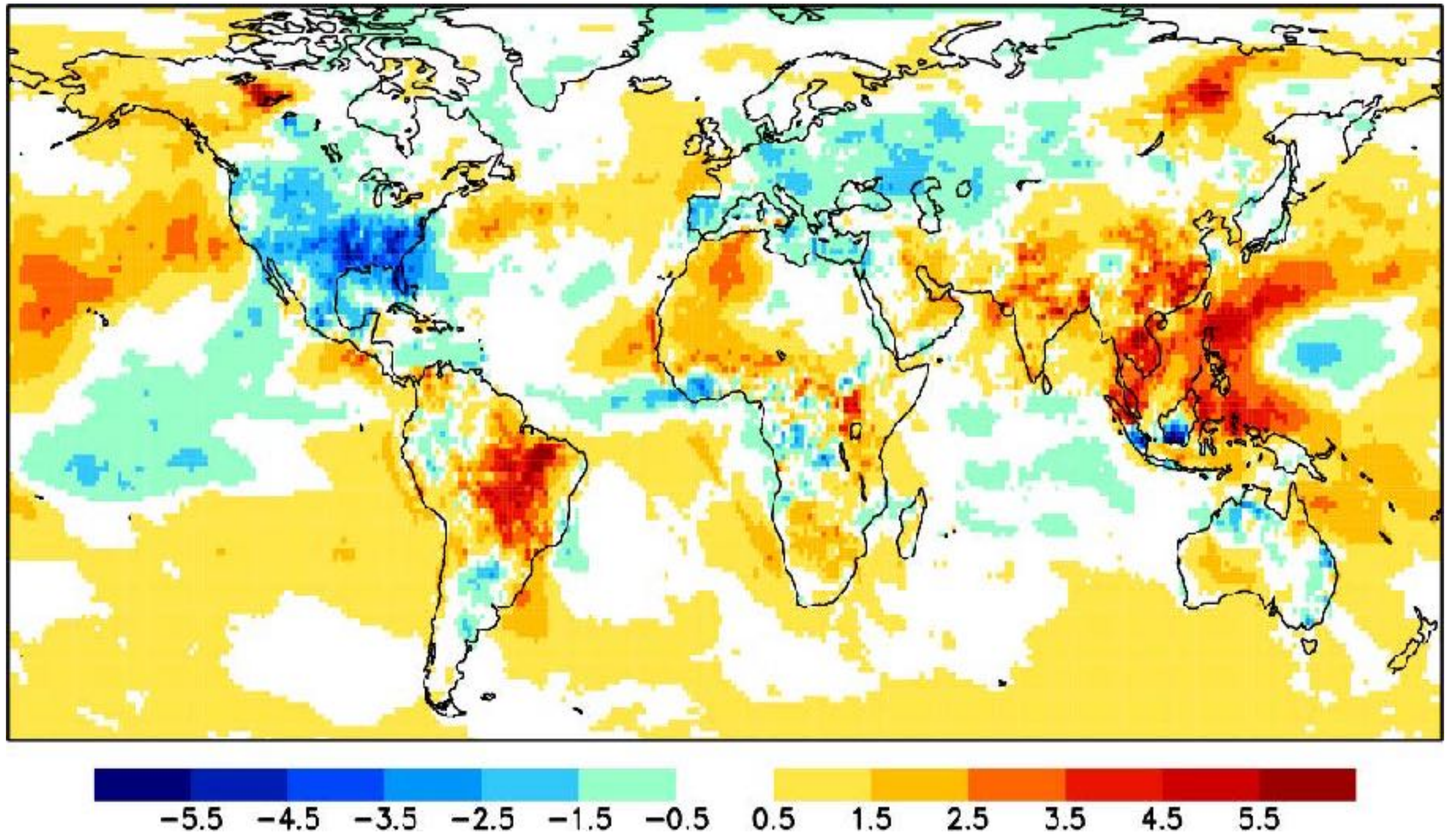
2. Concentrations

Surface ozone changes: 2005-2014

Gridded Surface Obs (TOAR)



TCR-2



ΔO_3 (ppb)

OPT & TOP WG

2005-2018: Strong increases over India (+0.25 ppb/yr) and Southeast Asia (+0.4 ppb/yr)

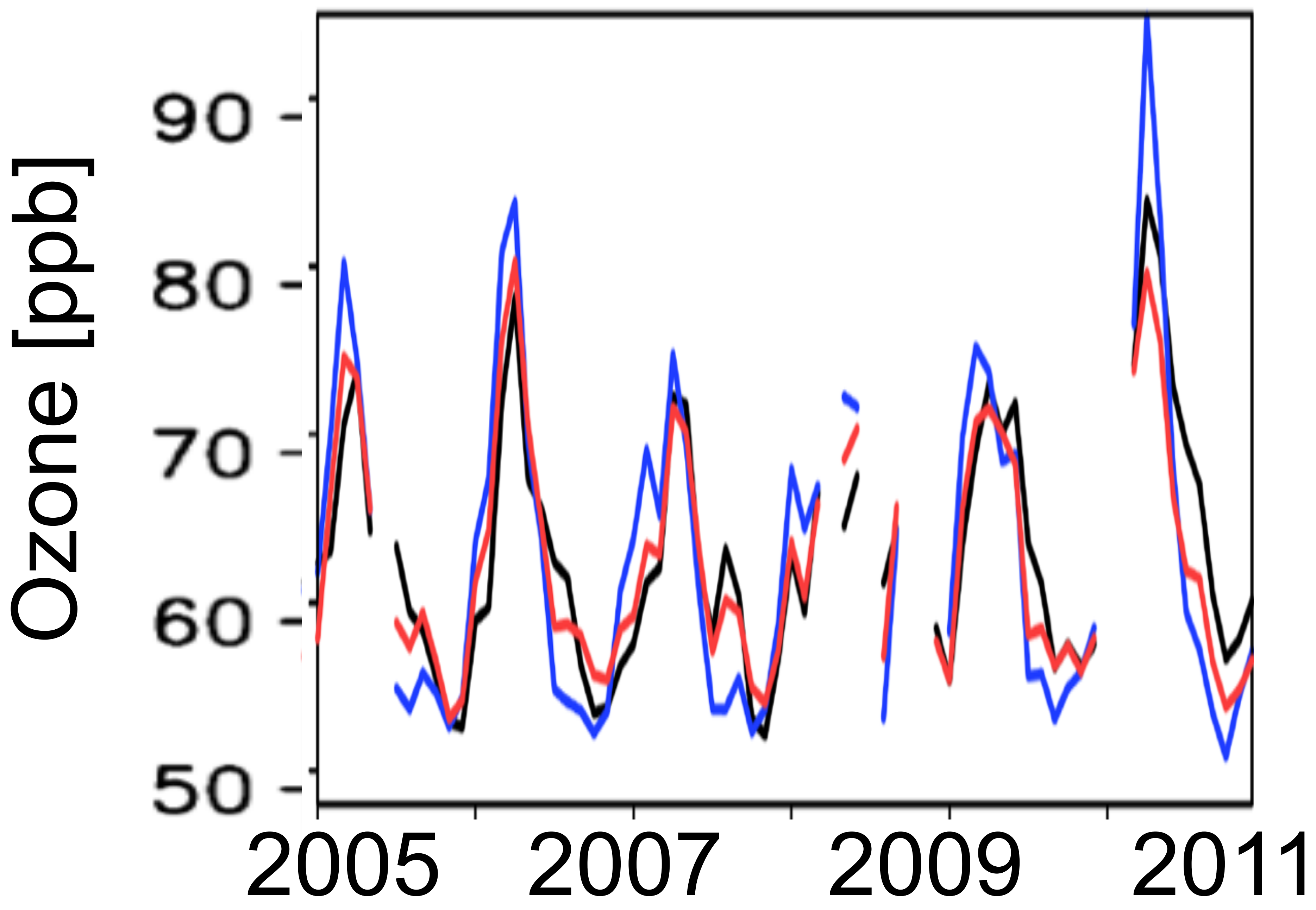
Free tropospheric and surface ozone validation

2. Concentrations

Satellite WG

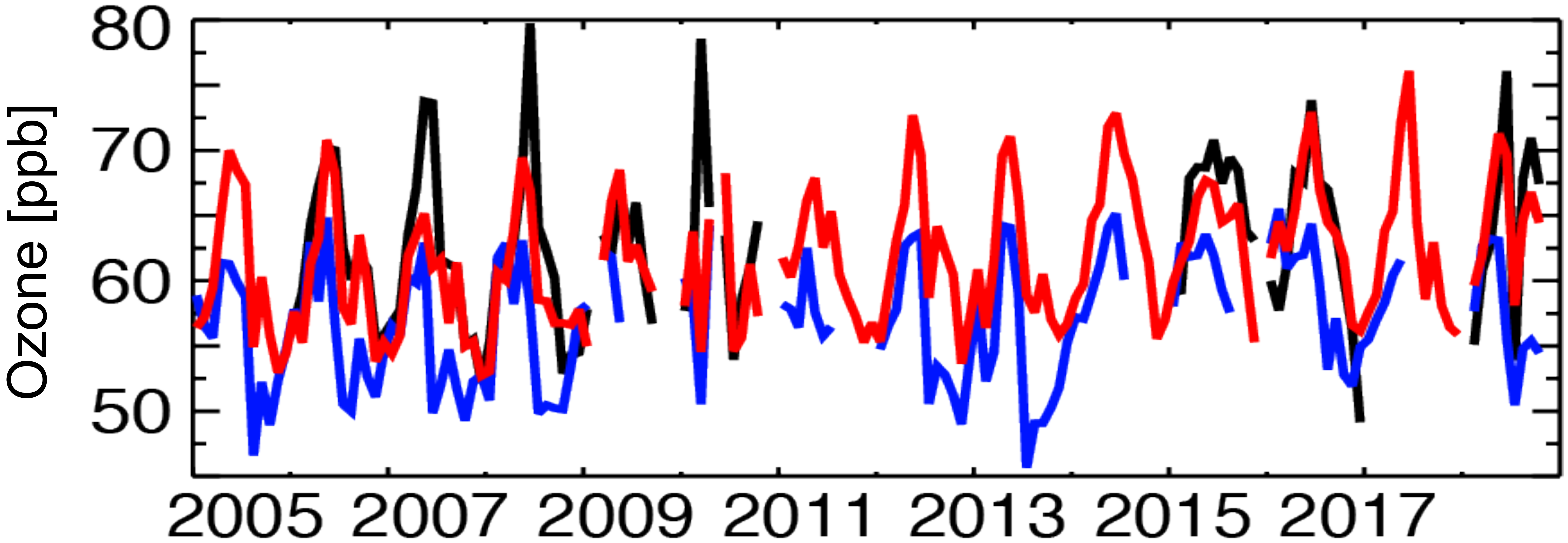
700-300 hPa:
vs **TES** (China)

TES
Model
Reanalysis (w/o TES)



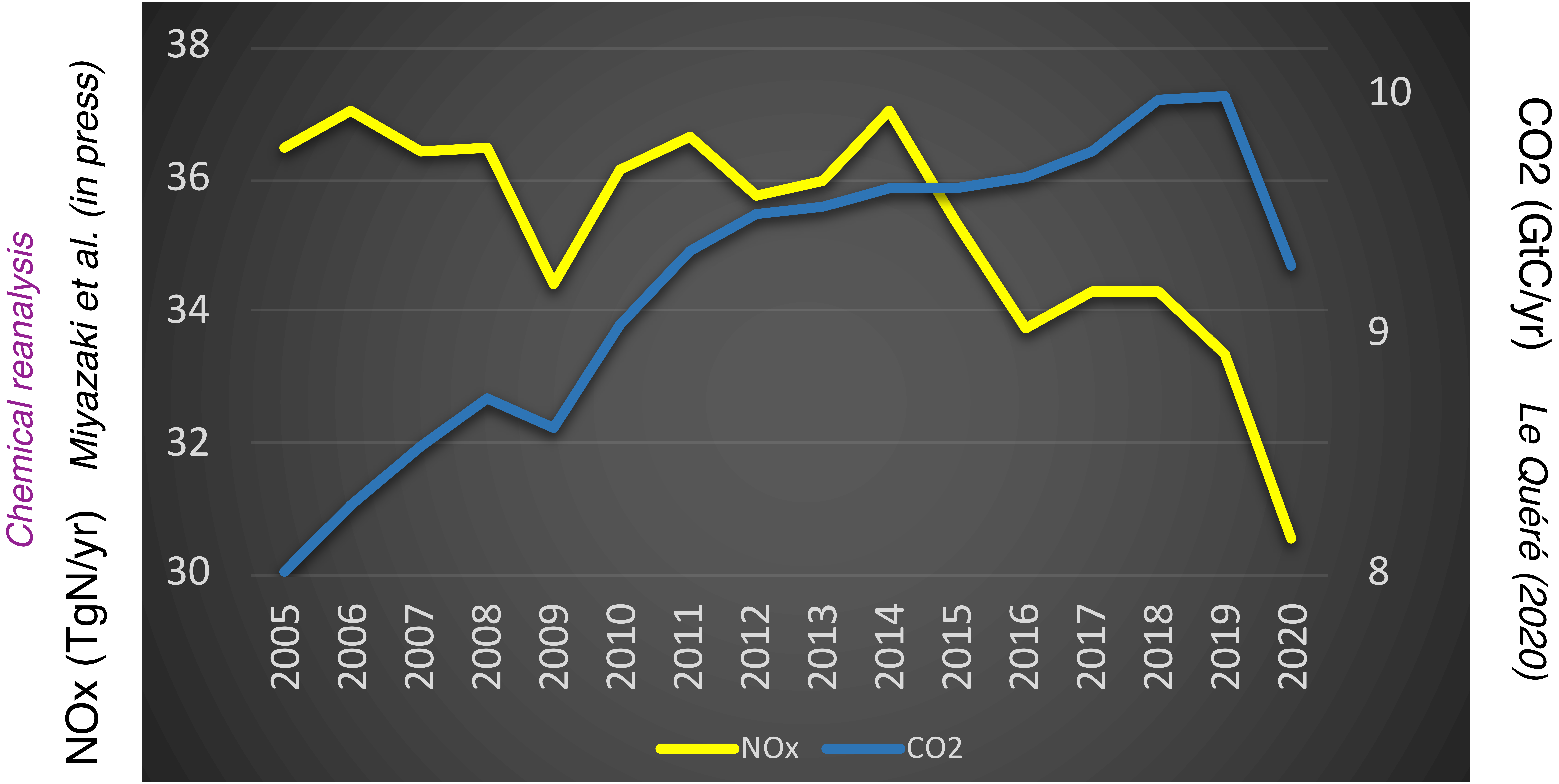
700-500 hPa:
vs **AIRS/OMI** (China)

AIRS/OMI
Model
Reanalysis



Miyazaki et al., 2020b

Global anthropogenic emission reductions in 2020: 7% (CO_2) 8% (NOx)



Laughner et at. (in revison)

Global tropospheric ozone responses during the COVID-19 era

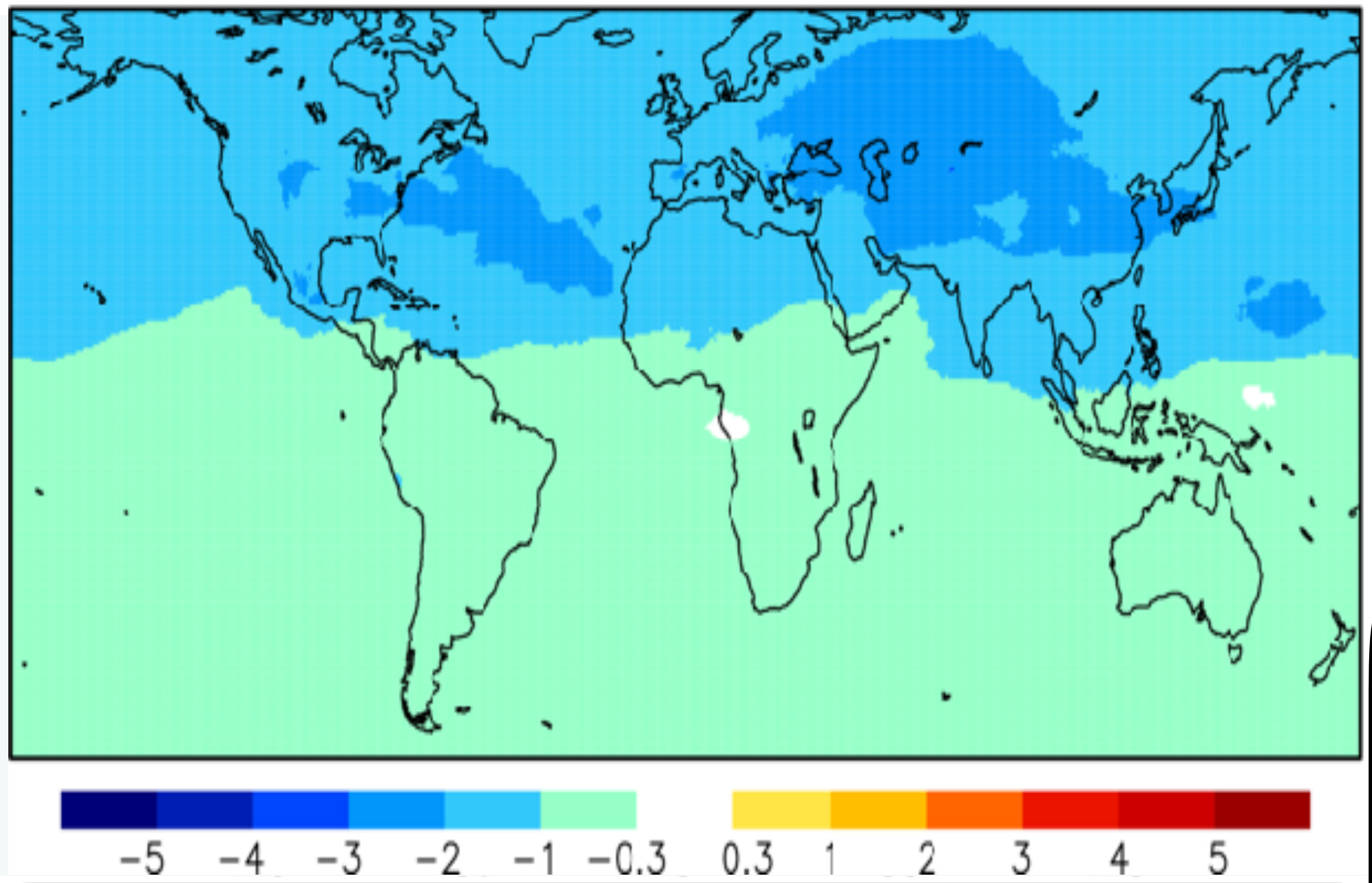
Jet Propulsion Laboratory
California Institute of Technology

We quantify the impact of emission reductions linked to the worldwide lockdowns on tropospheric ozone

1. Top-down Emissions → **2. Concentrations** → **3. Air quality & Climate**

Model simulation

Figure:
Free tropospheric (FT) ozone changes due to COVID-19 NOx emission reductions
in May, 2020 (in ppb)



Satellite CrIS ozone

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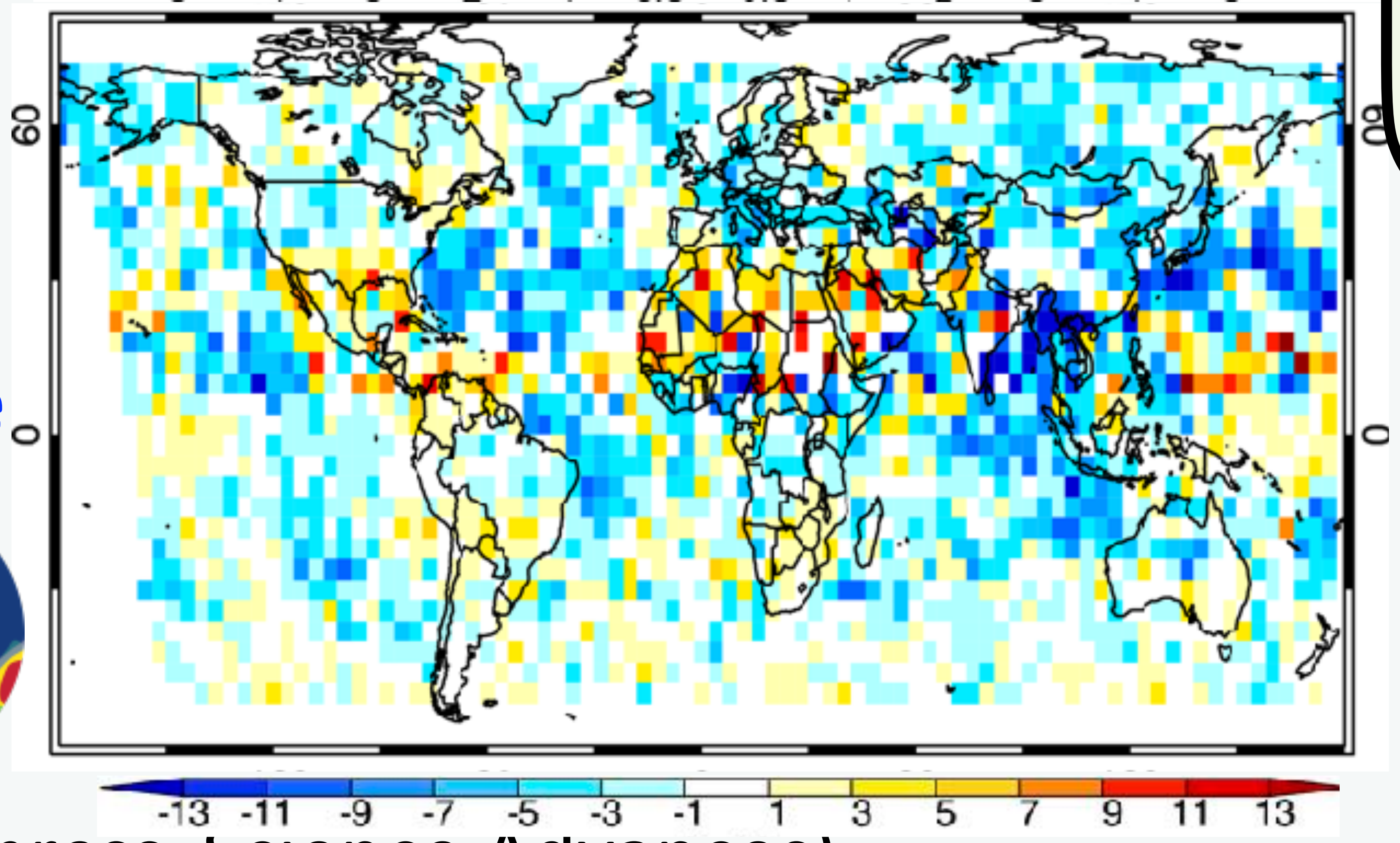

1. Top-down Emissions: Anthropogenic NOx emissions dropped by at least 15% globally and 18-25% regionally.

2. Concentrations: Up to a 5 ppb decrease in FT ozone, consistent with satellite observations, and a 6TgO_3 (-2%) decrease in tropospheric ozone burden largely due to emission reductions in Asia and the Americas. *15 times more rapid than what is viewed as achievable through "normal" policies to reduce emissions.*

3. Air quality & Climate: COVID-19 mitigation led to a global atmospheric signature that altered the oxidative capacity (up to 30% OH reductions, increases CH4 lifetime by 4 months) and climate radiative forcing (233-350 mWm^{-2}) and *can be used to inform policies that co-benefit air quality and climate*.

(Miyazaki et al., *in press*, Science Advances)

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- Inter-comparisons of top-down precursor emissions from reanalyses, and their impacts on surface/tropospheric ozone and subsequent radiative effects will facilitate evaluation of emission scenarios and environmental policy in realistic conditions
- Improve the TOAR-II observation quality control processes and representativeness