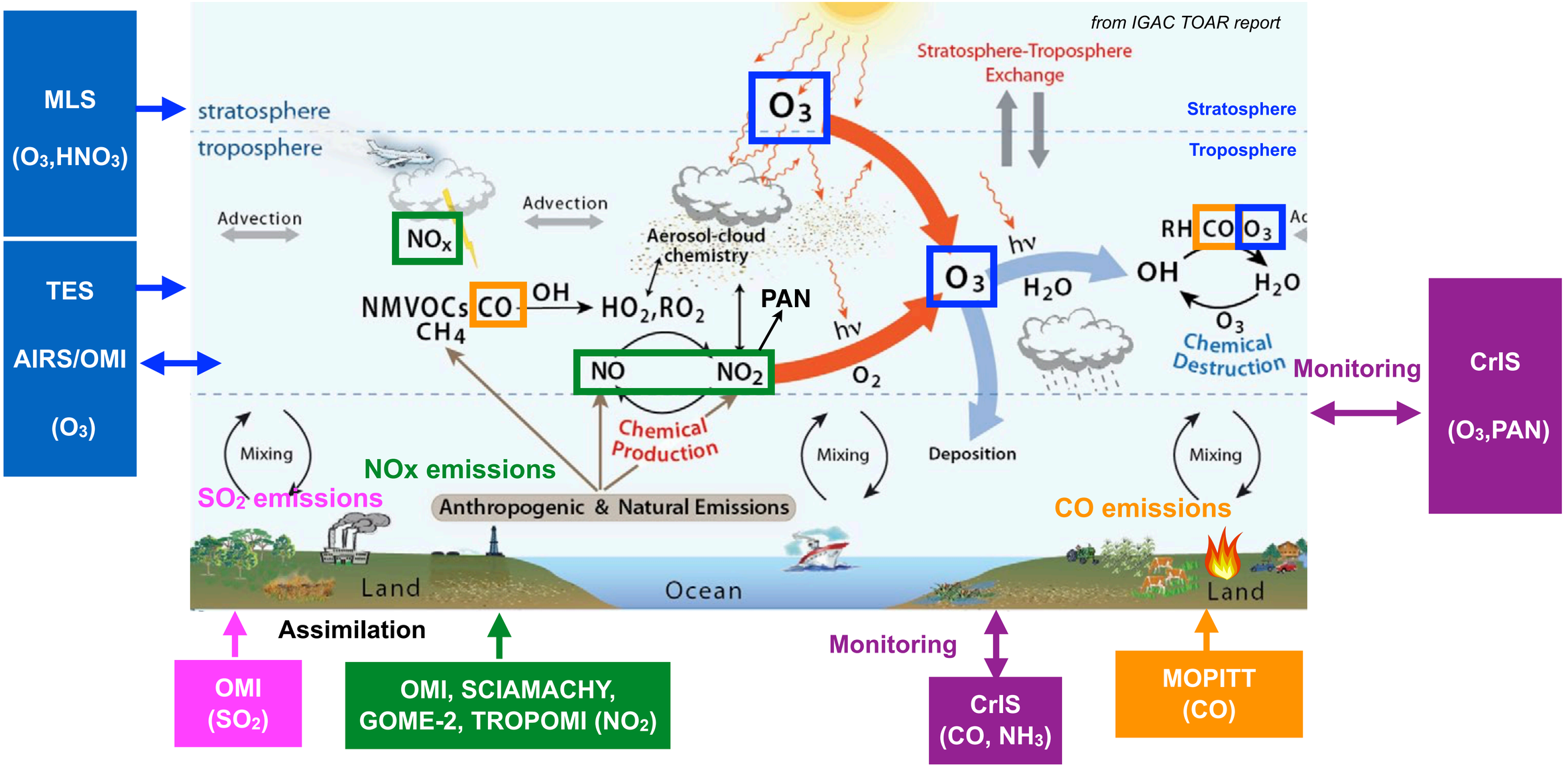
Jet Propulsion Laboratory
California Institute of Technology

Assessment of measurement representativeness by chemical reanalyses and TOAR-II chemical reanalysis Focus Working Group plan

Kazuyuki Miyazaki, *WG co-lead, JPL, USA*
Dylan Jones, *WG co-lead, Univ. of Toronto, Canada*
Helen Worden, *TOAR-II SC, NCAR, USA*
Kevin W. Bowman, *collaborator, JPL, USA*

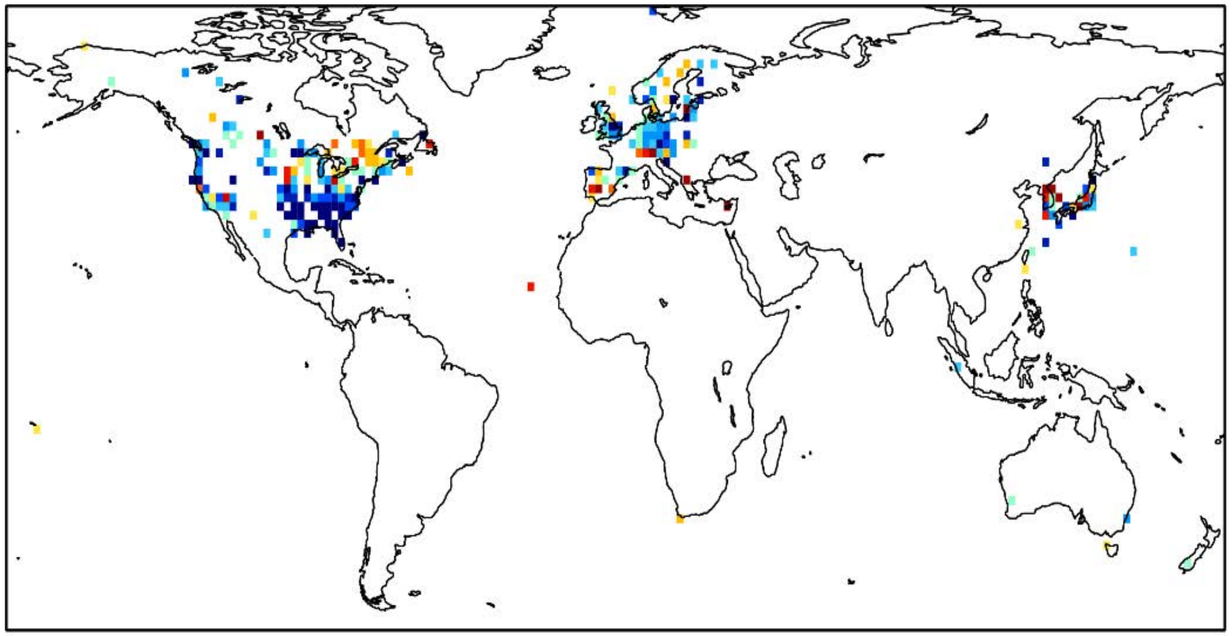
Chemical reanalysis *is a systematic approach to create a long-term data record of atmospheric composition, consistent with model processes and observations, using data assimilation.*



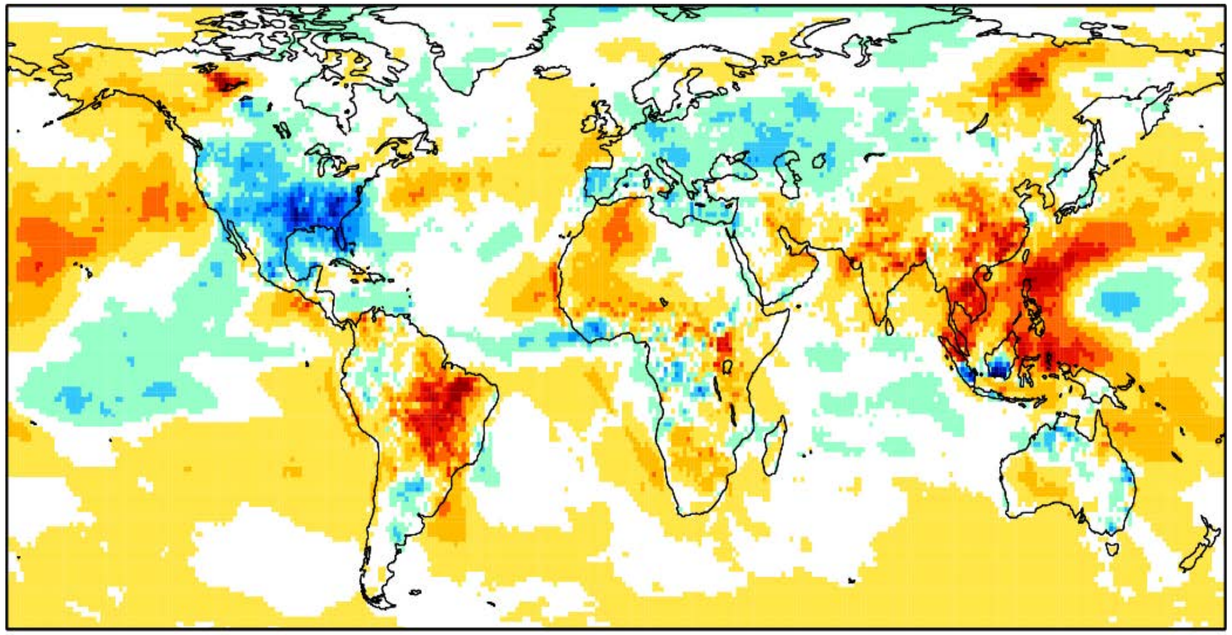
Chemical reanalysis surface ozone

Surface ozone changes: 2005-2014

Gridded Surface Obs (TOAR)



TCR-2



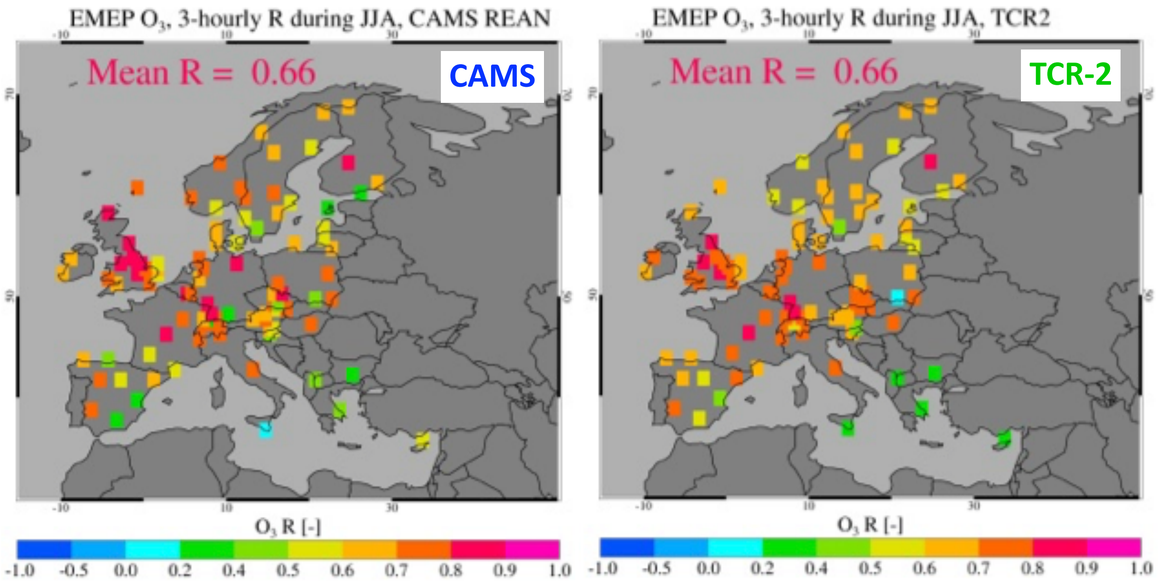
−5.5 −4.5 −3.5 −2.5 −1.5 −0.5 0.5 1.5 2.5 3.5 4.5 5.5

ΔO_3 (ppb)

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

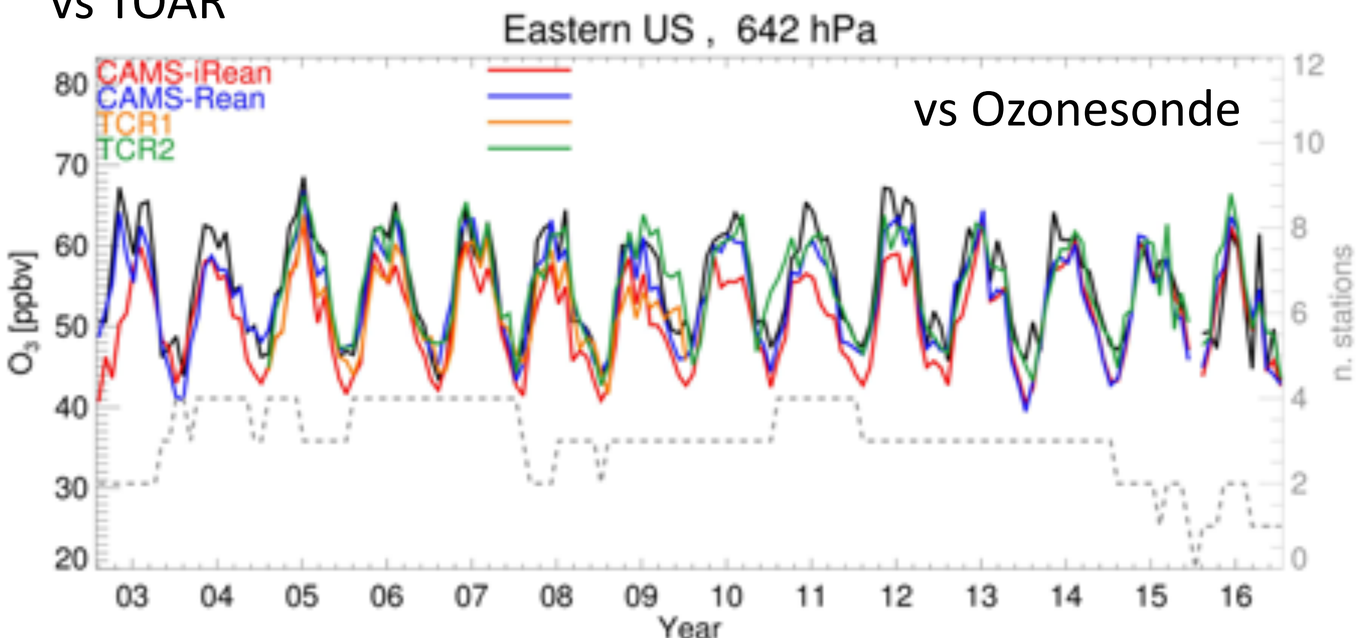
+0.2-0.3 ppb/yr over the US. Sampling biases can substantially influence trends (Lin et al., 2015)

Ozone reanalysis inter-comparisons



Products	Model	DA	Period
CAMS-iRA	IFS (CB05) T159 (1.1)	4D-VAR	2003-2018
CAMS-RA	IFS(CB05)+Aerosol T255 (0.7)	4D-VAR	2003-present
TCR-1	CHASER-EnKF T42 (2.8)	EnKF	2005-2016
TCR-2	MIROC-Chem-EnKF T106 (1.1)	EnKF	2005-2018

vs TOAR



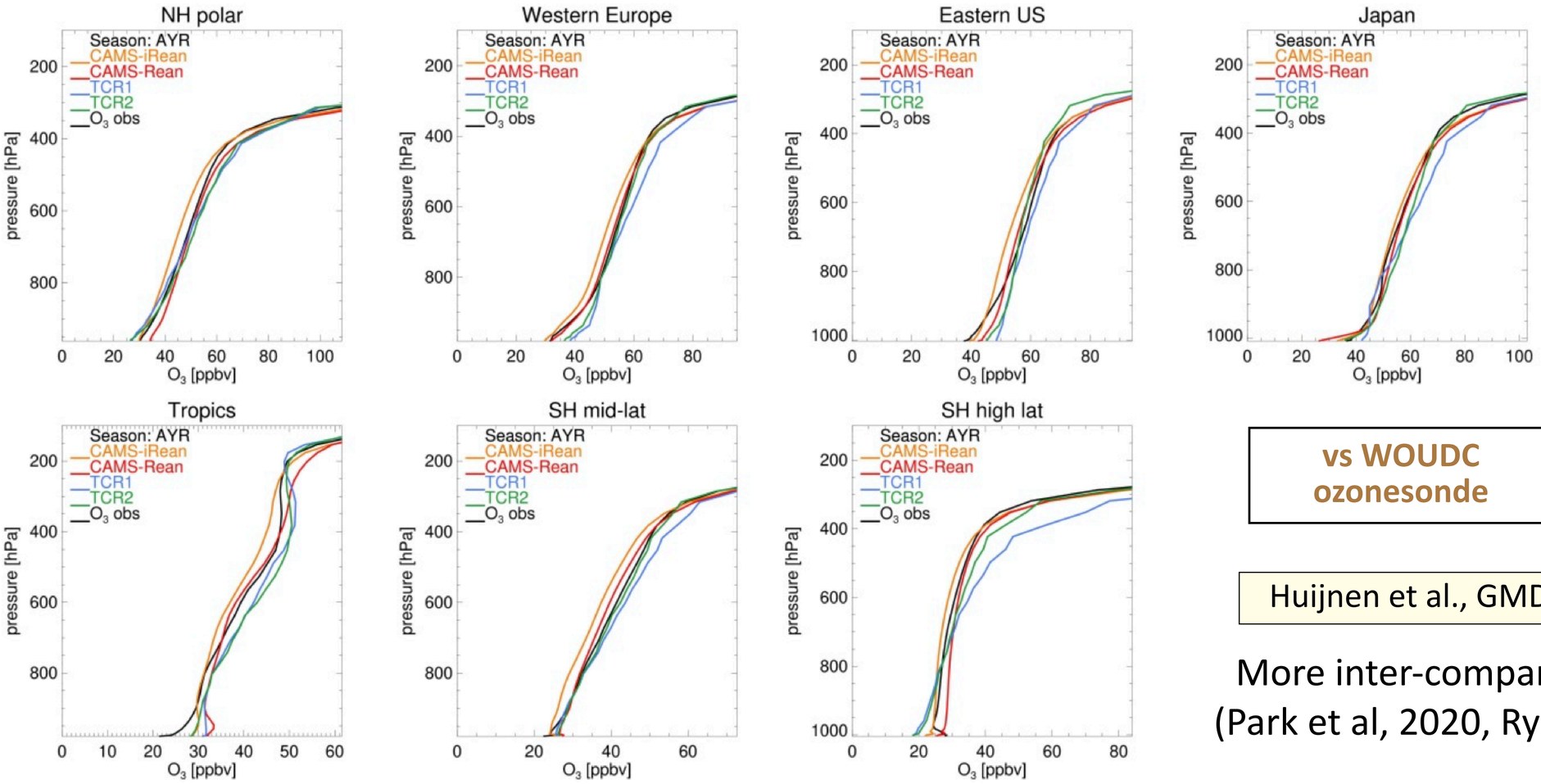
vs Ozonesonde

RMSE (ppbv)

CAMS-iRA	4.9
CAMS-RA	3.2
TCR-1	5.0
TCR-2	3.4

Huijnen et al., GMD, 2020

Ozone reanalysis inter-comparisons



vs WOUDC ozonesonde

Huijnen et al., GMD, 2020

More inter-comparison studies: (Park et al, 2020, Ryu et al., 2020).

- The updated chemical reanalyses agree well with each other for most cases, which highlights the usefulness of the current chemical reanalyses in a variety of studies.
- Significant temporal changes in the reanalysis quality in all the systems can be attributed to discontinuities in the observing systems.

TOAR-II chemical reanalysis WG

Overview and Goals in support of TOAR-II

- Evaluation of chemical reanalyses with TOAR-II observations and other data such as the ozonesonde record will assess the potential of using reanalysis data for studying spatial gradients at both regional and global scales and trends in areas with sparse in-situ observations. It will also assist in determining the contribution of precursor emissions and changing meteorology to observed ozone trends and surface ozone exceedances.
- Sensitivity analyses of the impacts of satellite and in-situ observations of ozone both at the surface and in the free troposphere and precursors will assess the relative importance of individual observations to improve surface ozone analyses and help to design observing systems that better capture the distribution and regional trends in tropospheric 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 that includes various observational constraints, 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 WG

Global chemical reanalyses: ECMWF CAMS, JPL TCR-2, GEOS-Chem adjoint, RAQMS

Regional chemical reanalyses: Chinese air quality reanalysis (CAQRA)

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.

- 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

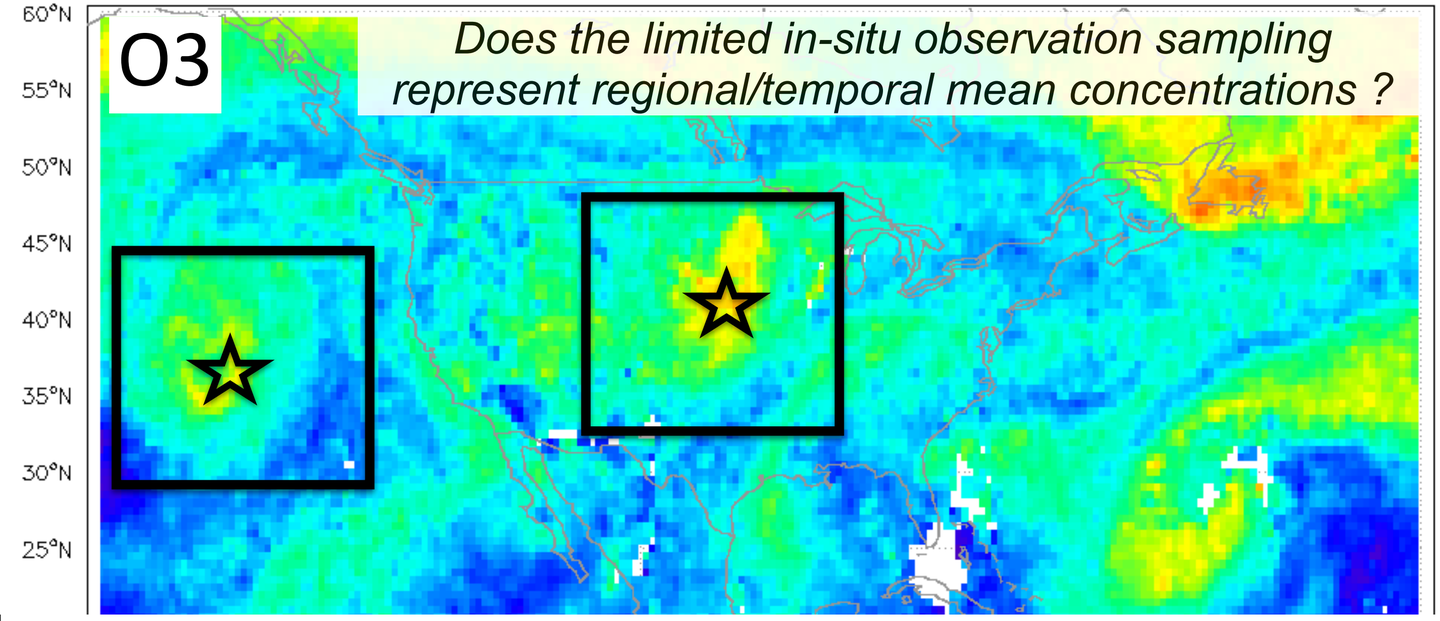
- demonstrate the value of individual satellite measurements to study surface/tropospheric ozone, which will be shared with the Satellite Ozone Focus Working Group. Reanalysis products will also be used as transfer functions to inter-compare different satellite products and evaluate representativeness of individual satellite measurements.

- use statistical approach proposed by Statistics Focus Working Group

Sampling bias

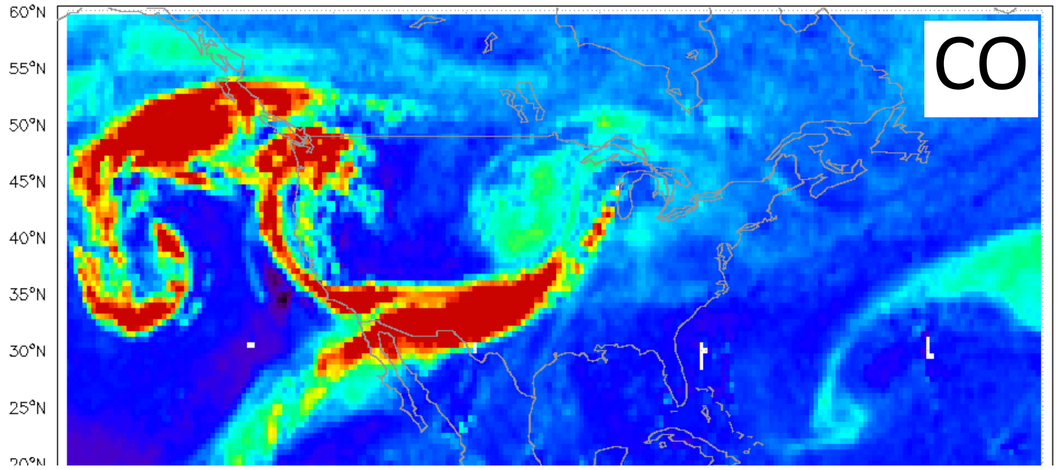
Aghedo et al., 2011; Foelsche et al., 2011; Toohey et al., 2013; Sofieva et al., 2014; Miyazaki and Bowman, 2017

- an error in a computed quantity that arises due to unrepresentative (i.e., insufficient or inhomogeneous) sampling, which induces spurious features in the average estimates and trends.
- Sampling bias may occur when the atmospheric state within the time–space domain over which the average is calculated is not uniformly sampled. In regions where variability is dominated by short-term variations, limited sampling may lead to a random sampling error.
- The primary technique for sampling bias estimation is to subsample model or reanalysis 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.



CrIS at 464 hPa, 2020-09-12

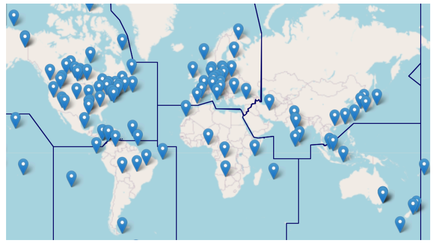
2020 California wildfires

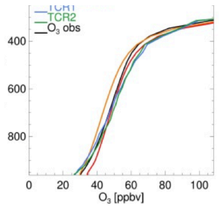


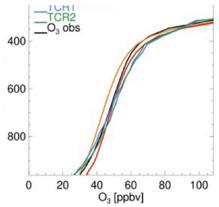
CrIS (JPL TROPESS products) provides detail spatial maps of complicated chemical responses linked to wildfires

Sampling bias

Sonde
(sparse, profiles)

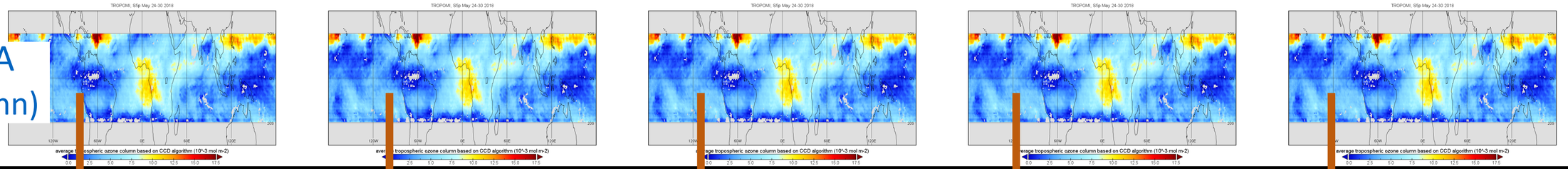




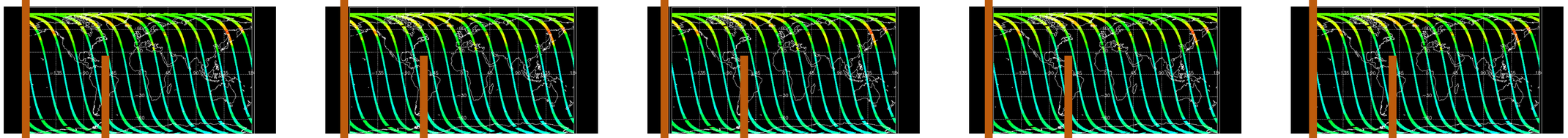


Time

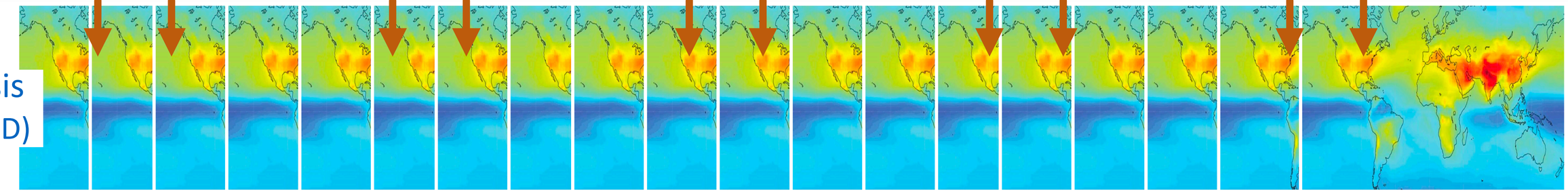
Satellite A
(daily, column)



Satellite B
(daily, column)



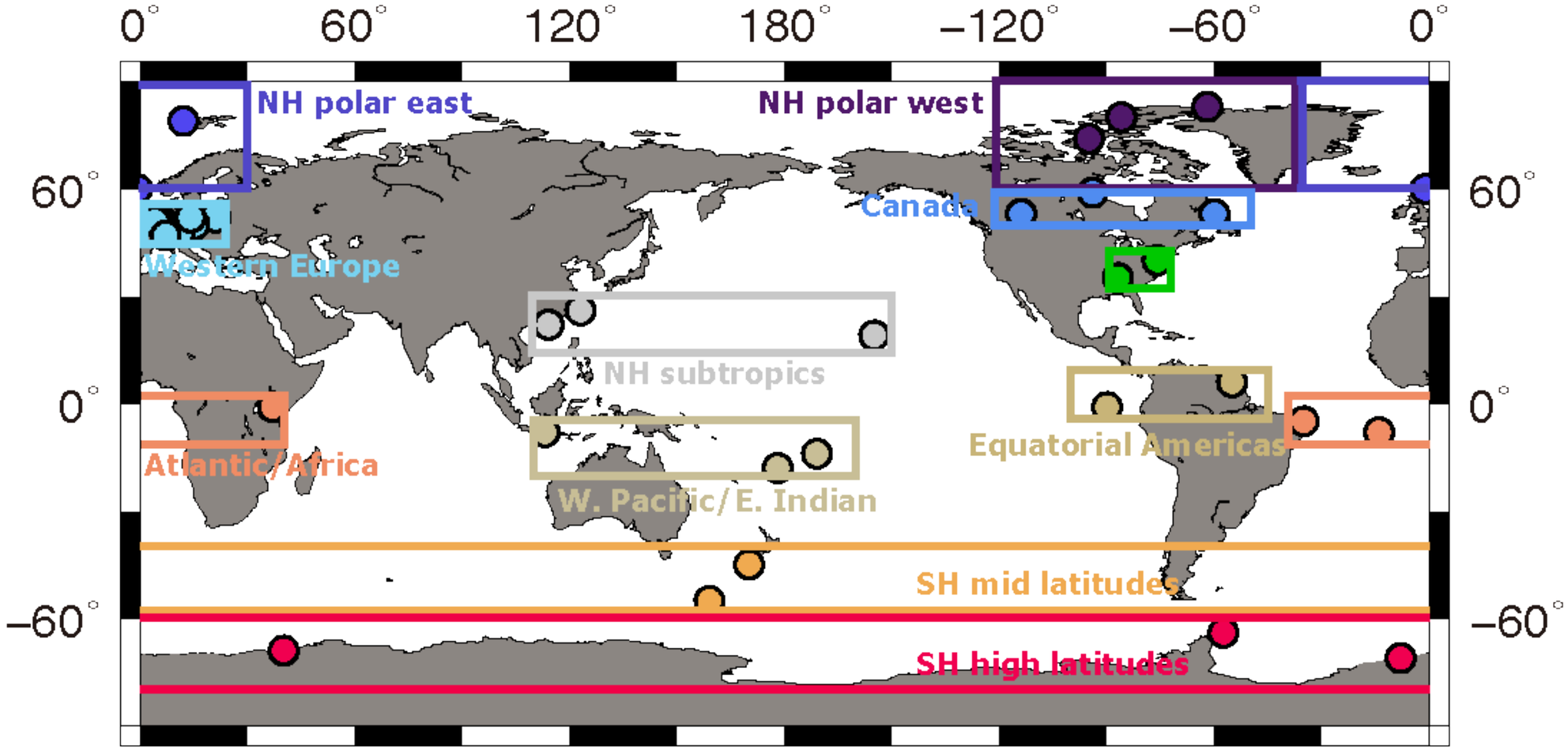
Reanalysis
(hourly, 3-D)



The reanalysis product provides comprehensive and unique information on global ozone distributions for the entire troposphere and on the weakness of the individual measurements and models.

→ limitation of the current ozonesonde network for evaluating temporally-spatially representative ozone fields

Impact of ozonesonde network sampling (both in space and time) on model evaluation

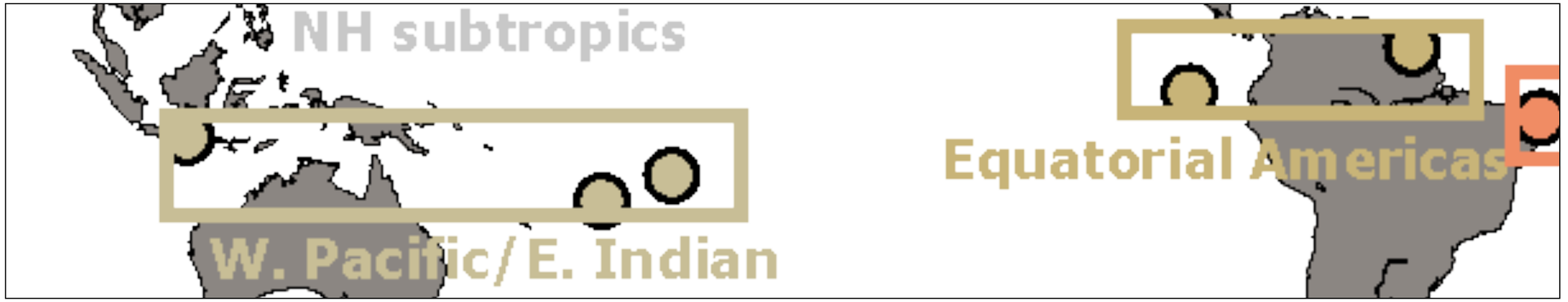


Regional aggregates based on the compilation by Tilmes et al. (2012)

Miyazaki and Bowman, 2017

The implications of model differences at ozonesonde locations (e.g., Young et al., 2013) to regional and seasonal processes is uncertain. **We quantified the ozonesonde network sampling bias** by comparing two evaluation results of the model bias using the reanalysis based on the complete and ozonesonde samplings,.

ACCMIP multi-model mean bias



- Regional: +16.1 ppb
- Ozonesonde: + 23.4 ppb

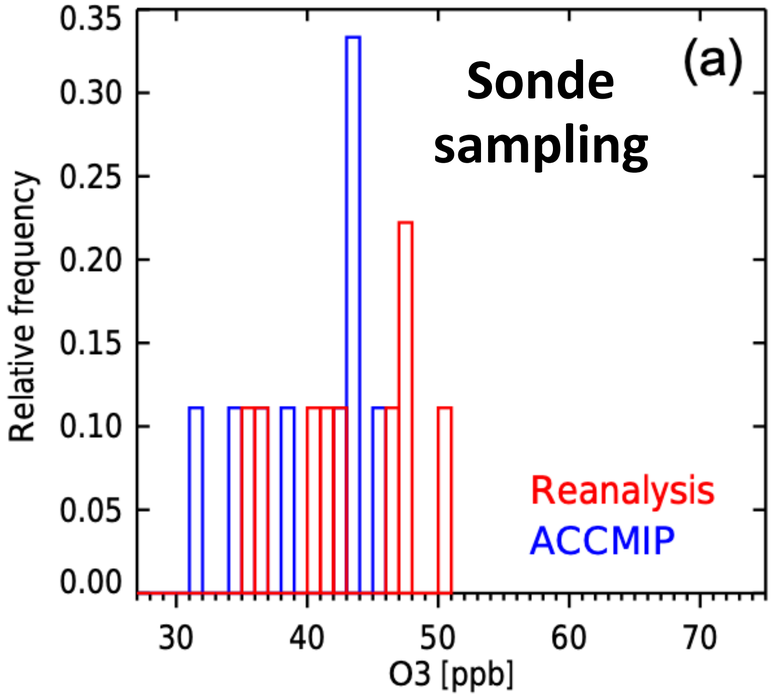
Regional: -4.5 ppb

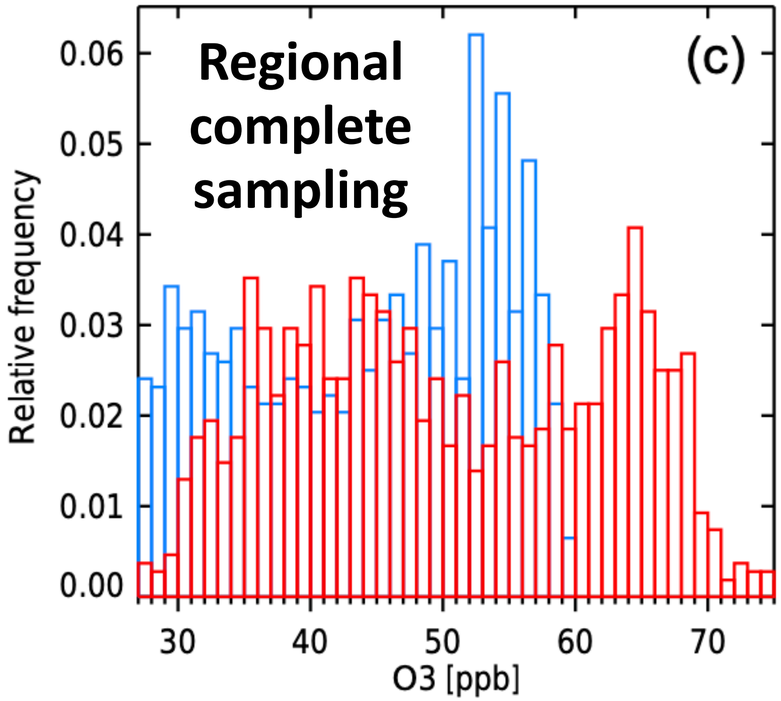
Ozonesonde: -9.6 ppb

The ozonesonde measurements reveal a large (by 40–110 %) sampling bias

Large variability of ozone, its associated model error, and the sparse ozonesonde network

Ozone PDFs from the ACCMIP multi-model mean (blue) and the reanalysis (red) at 500 hPa for W. Pacific/E. Indian Oceans





Miyazaki and Bowman, 2017

Ozonesonde sampling bias

- The ozonesonde sampling bias in the evaluated model bias is largely negative in MAM and positive in DJF by 40–50 % over the W. Pacific and E. Indian Ocean and largely negative by 110 % in MAM over the equatorial Americas at 500 hPa.
- For the global tropics, the ozonesonde sampling bias is largely negative by 80 % in the NH (Eq–30◦ N) in SON and by 50% in the SH (30◦ S–Eq) in MAM. The ozonesonde sampling bias is <30 % for the NH polar regions except in boreal winter and over the equatorial Americas, the Atlantic Ocean and Africa, and at the SH mid-latitudes in austral winter and spring.
- Although the spatial and temporal variability is generally smaller in the SH than in the NH, the ozonesonde sampling bias cannot be negligible even in the SH (> 60 %).
- The evaluation of the seasonal cycle of tropospheric ozone is also largely limited by the ozonesonde sampling bias.

please see Miyazaki and Bowman (2017)

There is an advantage of the reanalysis data for evaluating actual regionally and seasonally representative model performance required for model improvements. However, the network provides critical independent validation of the reanalysis, which can provide a much broader spatial constraint on CCM performance.

TOAR-II chemical reanalysis WG

Expected Outcomes

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

- 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

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

- 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