WRAP RTOWG Telecon

Using Satellite Data to Improve Background Ozone Estimates: Outlook for a New Project from NASA's HAQAST

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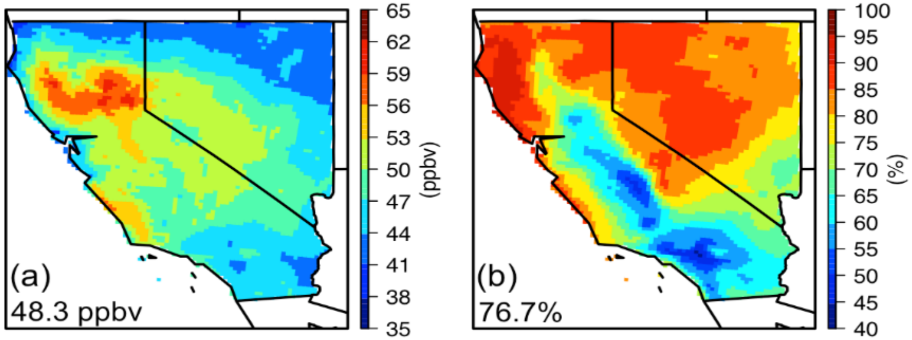


Huang et al., 2015

HAQAST Tiger Team on Background Ozone

- Background ozone is the focus of one of four HAQAST Tiger Teams selected for FY19: “Satellite-Evaluated and Satellite-Informed Ozone Distributions for Estimating U.S. Background Ozone”
  - Contributions from 6 HAQAST PIs
  - Initial list of 11 stakeholders from state and local air agencies, regional groups including WESTAR and WRAP, and the US EPA. We are more than happy to incorporate other stakeholders - everyone is welcome!

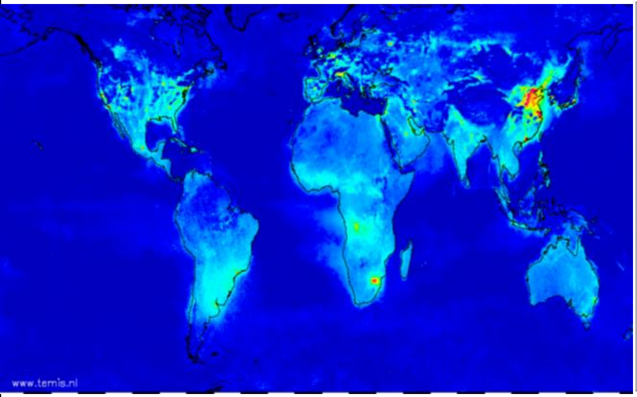
- The stakeholder needs addressed by the Background Ozone TT are:
  - Accurate specification of boundary conditions for regulatory air quality and health modeling
  - Reliable estimates of ozone attributable to background sources, including separate quantification of natural ozone and that transported from other nations, particularly during high-ozone episodes

Boundary conditions for 2016 are particularly needed since that year has been selected as the base year for ozone NAAQS attainment planning.

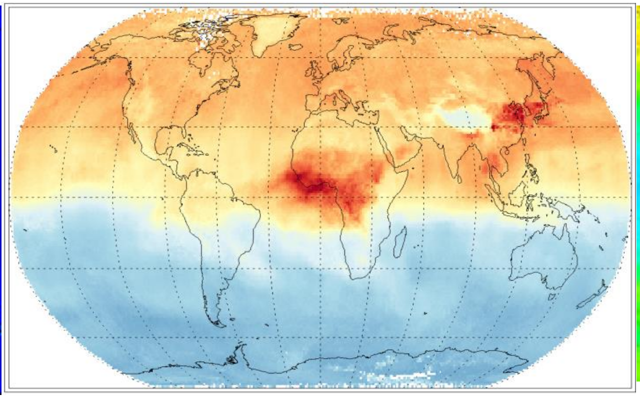
How can satellite measurements be used to improve model representations of ozone?

- The team aims to use satellite measurements to provide the best-possible boundary conditions from global models for use in regional models that are used to develop SIPs.
  - Measurements to be used include those of ozone precursors (NO_2, CO) and ozone itself
- Satellite measurements will be used in 3 ways:
  1. For evaluation of model emissions and ozone fields and quantification of their biases
  2. For correction of model emissions either through mass balance or assimilation
  3. For correction of model fields through assimilation

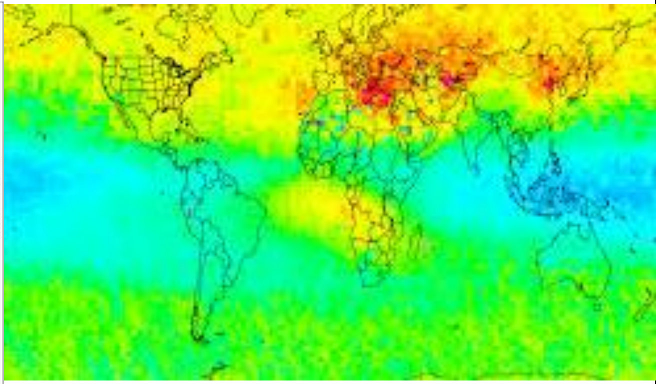
OMI Column NO_2



AIRS Column CO

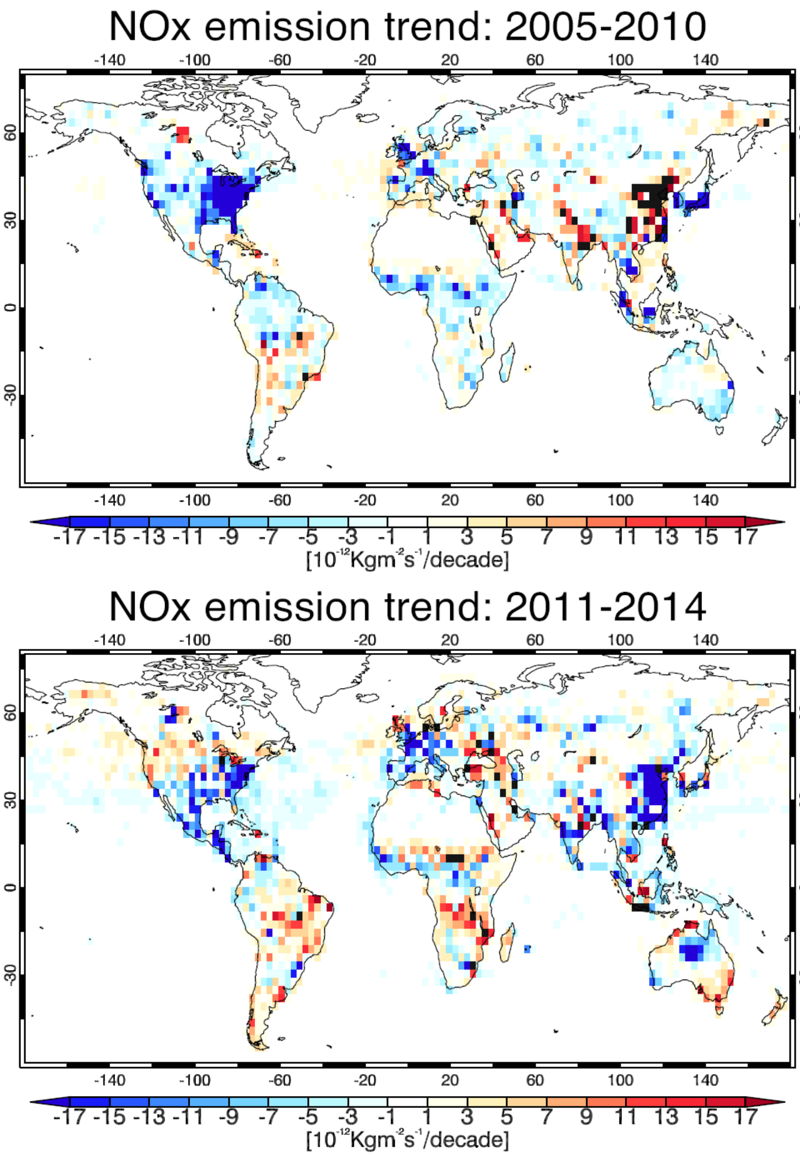


TES 510 hPa Ozone



Example 1: Constraints on Emissions

- Satellite measurements of NO_2 are used to inform NO_x emissions through either mass balance or assimilation
  - Mass balance is based on $E = \frac{E_G}{\Omega_G} x \Omega$
  - Adjusting emissions via assimilation requires 4D-var or Ensemble Kalman Filter (EnKF) techniques
- Miyazaki et al. (2017) use EnKF assimilation with OMI NO_2 measurements and find that NO_x emissions began decreasing throughout much of Asia in 2011.
- Latest results indicate that Chinese emissions dropped below 2005 levels in 2015, but emissions from India continue to increase.

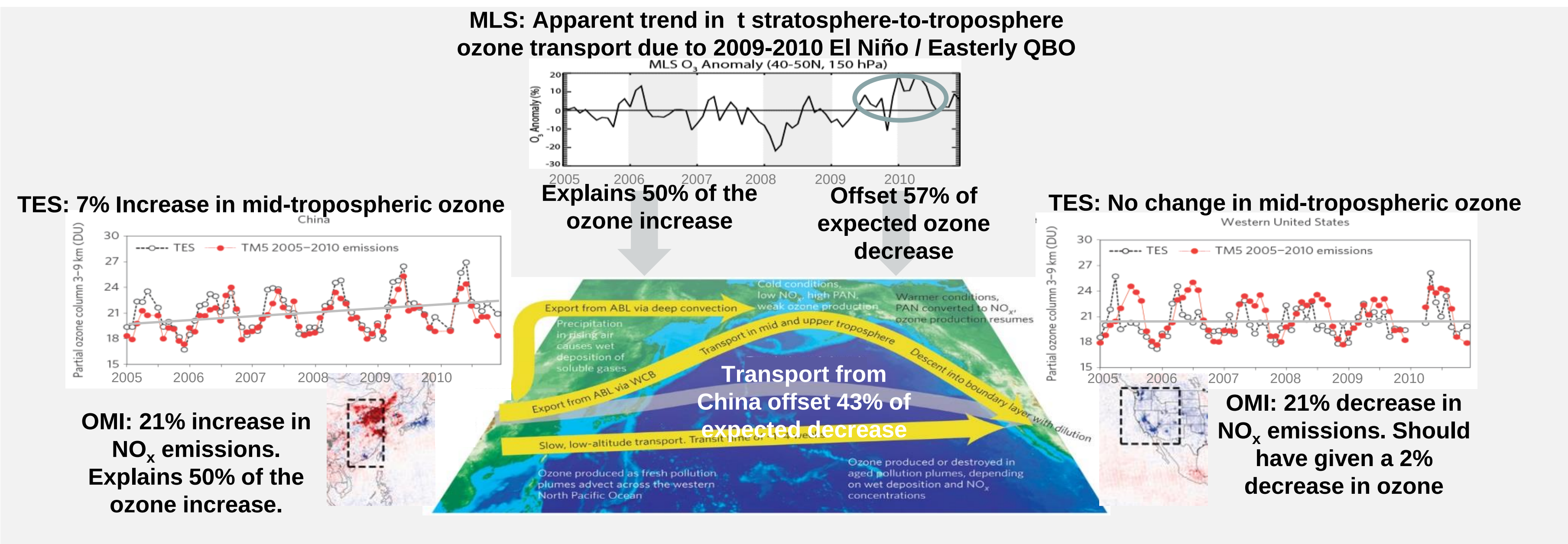


Miyazaki et al., ACP, 2017.

Example 2: Constraints on emissions and stratospheric ozone + evaluation of model tropospheric ozone

- Verstraeten et al. (2015) use mass balance NO_x emissions based on OMI NO_2 and an ad-hoc correction of their model stratosphere-to-troposphere transport based on MLS O_3
- They then compared the model's mid-tropospheric O_3 to measurements from TES and used the model, including a simulation with East Asia anthropogenic emissions set to zero, to attribute changes in Western US ozone to various sources

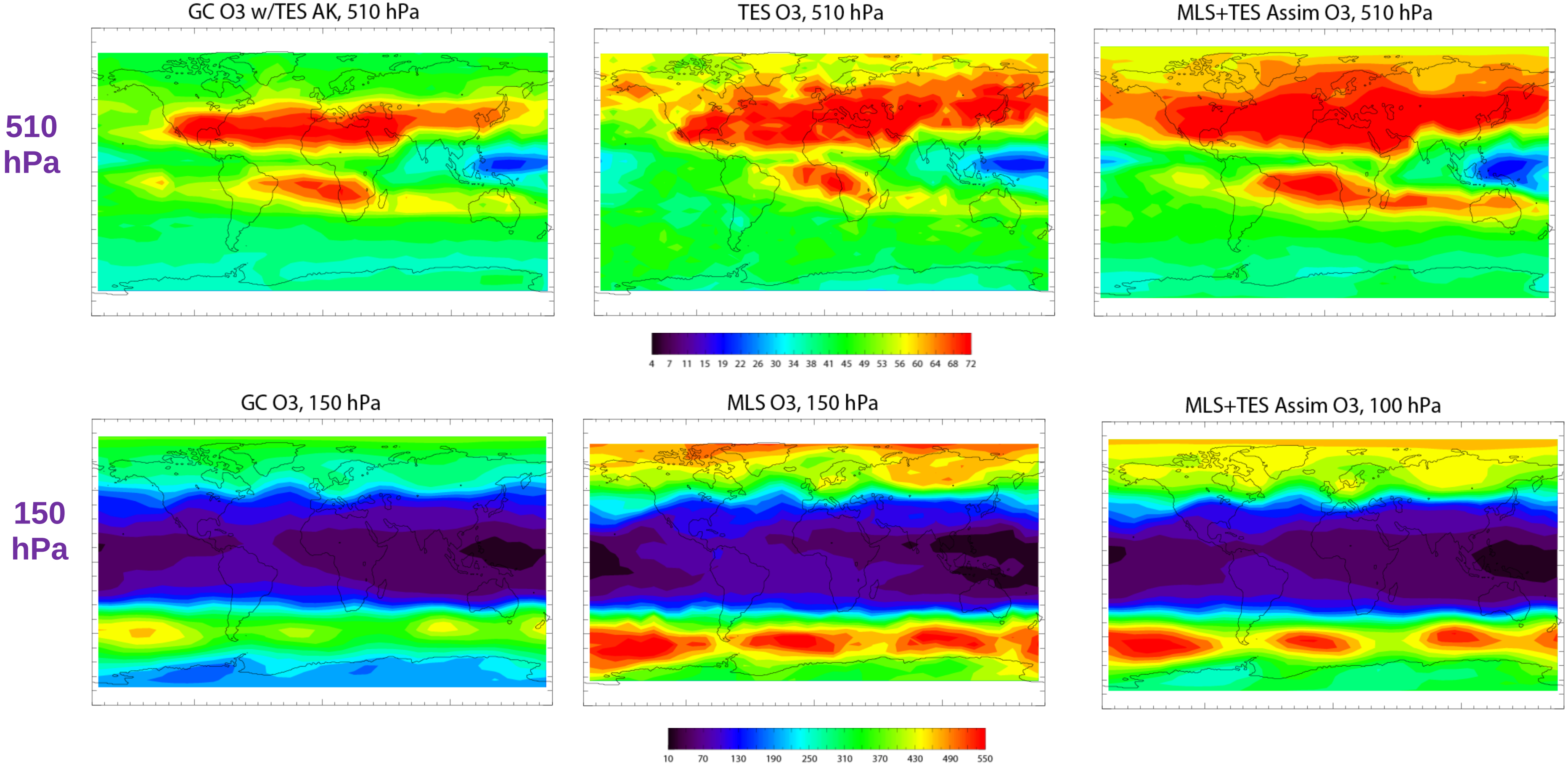
Drivers of Regional Ozone Changes



Verstraeten et al., *Nat. Geosci.,* 2015

Example 3: 3-Dvar assimilation of ozone

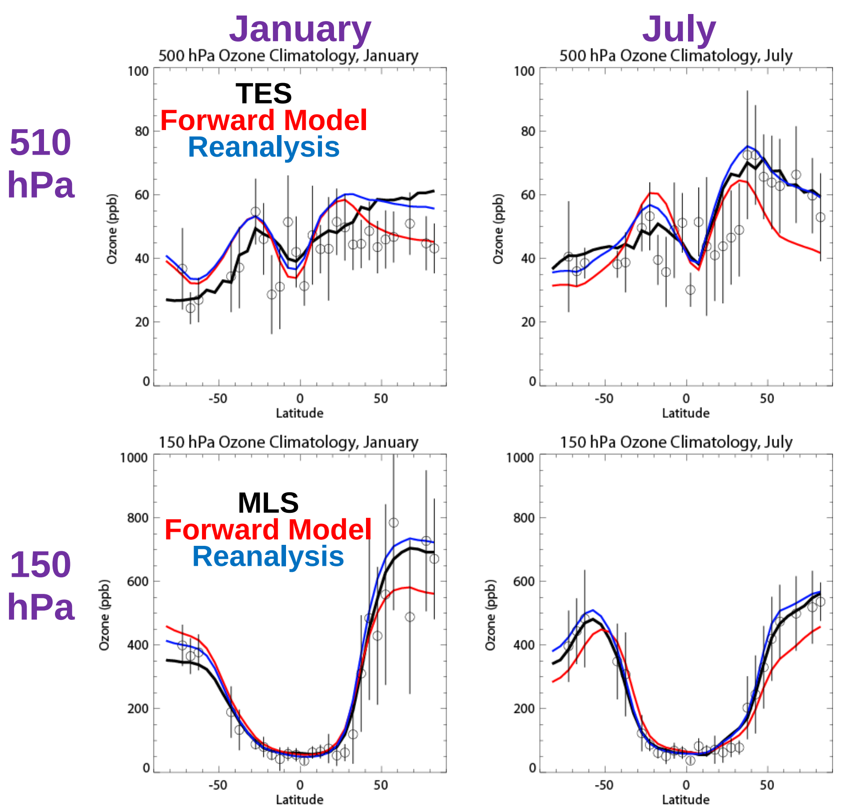
GEOS-Chem Free Running | **Observations** | **Assimilation**



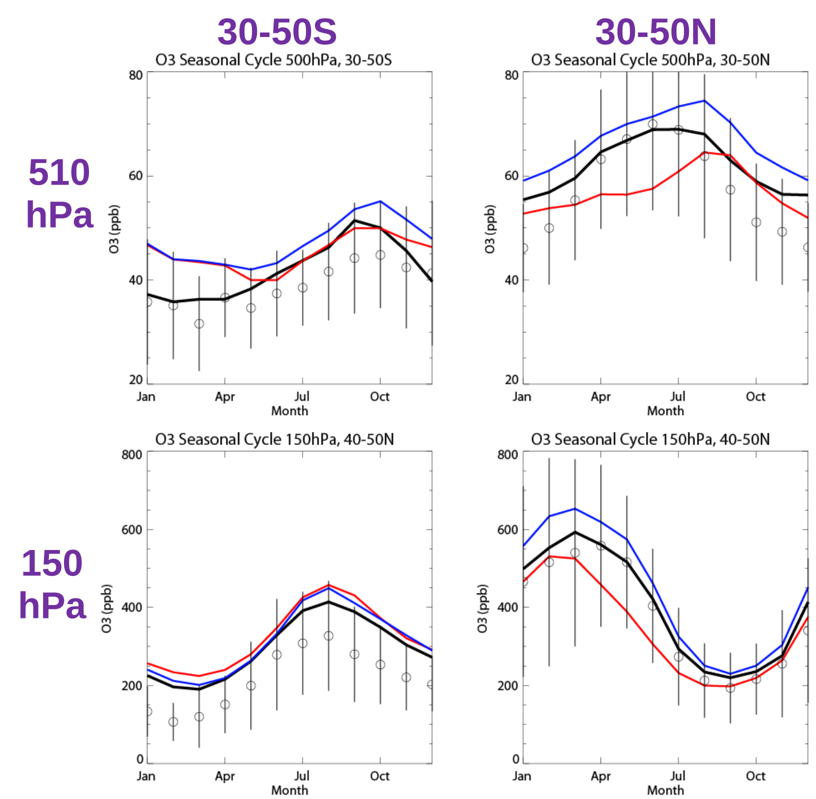
- 3D-var assimilation corrects the model fields using observations but does not adjust model emissions or chemistry to be in balance with those fields
- Assimilation of both tropospheric and stratospheric ozone profiles provides a better estimate of the STE contribution to tropospheric ozone.

Example 3 (cont'd): Evaluation of the assimilation

Climatological (2005-2010) Zonal Mean Ozone on Pressure Surfaces



Climatological (2005-2010) Ozone Seasonal Cycle in Midlatitudes

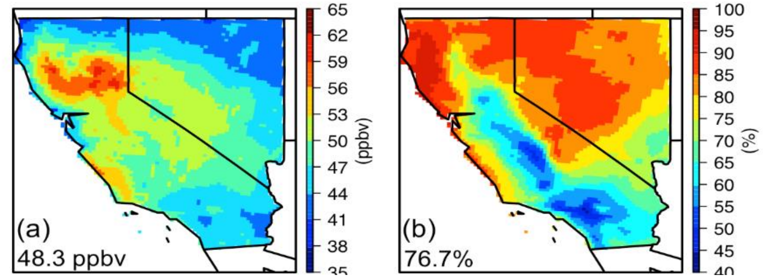


- The assimilation must be evaluated against independent measurements to determine the degree to which the satellite measurements improve the fidelity of the model. Biases in the satellite measurements will generate biases in the assimilation that can, in theory, be corrected for.

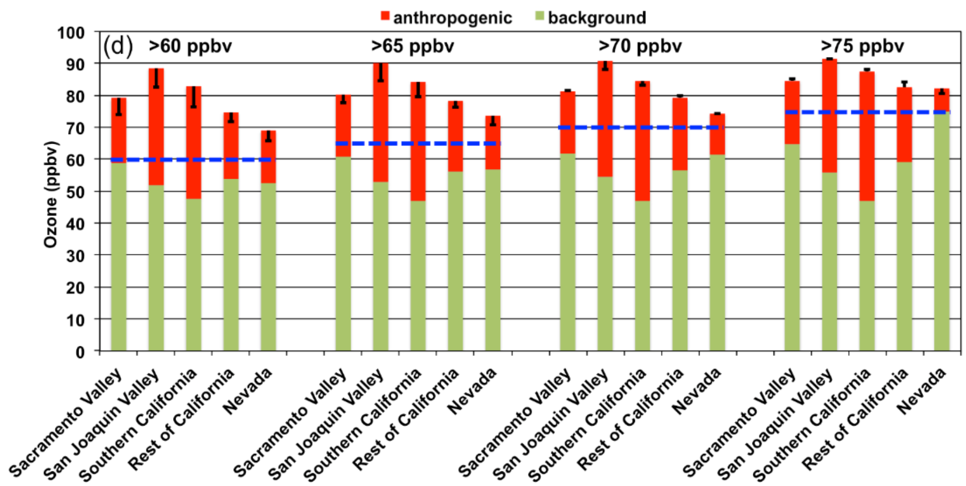
Example 4: Multi-scale assimilation for quantifying background ozone

- Huang et al. (2015) used a global model in which TES ozone profiles were assimilated to provide boundary conditions for a regional model in which NO_x emissions were adjusted via assimilation of OMI NO_2
- They found that background ozone was ~77% of total ozone in CA and NV for 2008, when there were anomalously high wildfire emissions. TES and OMI indicate a larger role for non-local pollution (+3.3 ppb) and a smaller role for wildfires (-5.7 ppb) than seen in the free-running model.
- Outside Southern California, less than 15 ppb of local anthropogenic ozone can be generated without violating a 70 ppb threshold in a high background ozone year such as this one.

Mean Background Ozone and its Contribution to Total Surface Ozone as Constrained by TES and OMI



Contribution of Background and Anthropogenic Ozone to Exceedances for Ozone Standards from 60 to 75 ppb



Huang et al., *JGR*, 2015

Tiger Team Goal and Proposed Simulations

Goal: improve the quantification of background ozone in SIPs, a critical component of the development of our stakeholders' attainment plans. To do so, we will:

- Provide a coordinated set of boundary conditions for ozone, background ozone (no U.S. anthropogenic emissions), and natural ozone (no global anthropogenic emissions) for 2016 from multiple global models that are evaluated with or informed by satellite data.
- Establish 'best practices' for evaluating models with satellite ozone measurements, and for evaluating satellite-informed simulations with independent datasets such as those from surface stations and ozonesondes.

Deliverable, Milestone	AM3	GEOS-Chem	RAQMs
Boundary Conditions From Satellite-Evaluated Models (Nov 2018)	Fiore	Neu Henze	Pierce
Boundary Conditions from Satellite-Informed Models (Feb 2019)		Neu (OMI NO_2, AIRS O_3, MLS O_3) Henze (OMI SO_2, NO_2)	Pierce (OMI NO_2, O_3, AIRS CO, MLS O_3, MODIS AOD)
Background and Natural O_3 (U.S. and global Anthropogenic Emissions set to 0) (Feb 2019)	Fiore	Neu (Standard model) Neu (OMI NO_2, MLS O_3) Henze (OMI SO_2, NO_2)	Russell (OMI NO_2, O_3, AIRS CO, MLS O_3, MODIS AOD)

Details

- 3-hourly, 3D model fields will be archived for 2016 for a region encompassing the entire US with boundaries TBD in conjunction with stakeholders. These fields can then be sub-setted for various smaller regional domains.
- Standard model fields (simulations that do not assimilate satellite data) will be evaluated against Level 2 satellite ozone products (e.g., AIRS and OMI) and all model fields will be compared to ozone from surface sites, sondes and commercial aircraft
    - Analysis will focus on differences in fidelity between standard simulations and satellite-informed simulations.
    - Stakeholders requesting specific analyses will be provided with products relevant to transport (e.g., AIRS CO) and wildfires (e.g., MODIS AOD) as resource permit.
    - We will also evaluate the background ozone simulations with ozone profiles from sondes and commercial aircraft that have been classified as representing background ozone air masses

Communications plan

- Monthly phone meetings between HAQAST members and stakeholders will be hosted by WESTAR/WRAP.
- A 1-page web summary will be posted to the HAQAST website that: (1) defines background, with links to more detailed information on the various background “flavors”, (2), describes the standard versus U.S. background simulations.
- A user-friendly technical report will be written for broad dissemination to accompany the global model fields that will be distributed to EPA and other interested national, regional, state, and local agencies.
- A summary of best practices will be written, targeting potential regional and state air quality modeling groups with guidance on how to use the global model boundary conditions generated by our team for quantifying background ozone in SIP simulations.
- A journal article will be written describing the results of model evaluation activities, focusing on assessing the value added by incorporation of satellite data.

Expected Outcomes

- Increased awareness among stakeholder groups of the potential for NASA products, current and future, to help quantify background ozone and assess uncertainties in these estimates.
- First-ever set of multi-model background ozone simulations, each with a companion base simulation that either incorporates or is evaluated with satellite data, providing options for driving regional air quality models for regulatory applications or health assessments.
- Key step towards developing a standard set of 'best practices' for establishing credibility in the boundary conditions used in regional model simulations for adoption by the broader community.
- Opportunity to evaluate the impact of boundary conditions on regional model accuracy by comparing regional simulations driven by the suite of global model fields we provide to *in situ* data (e.g., ground-based and sonde measurements).
- Ensure continued capability to map global model fields to regional model boundary conditions to quantify U.S. background ozone at the scales directly relevant to air quality decision-making.