Measured and Modeled Ozone Distributions over the Atlantic and Pacific Oceans from the ATom Mission

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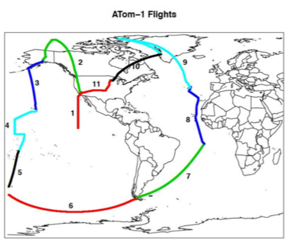
Introduction

The NASA Atmospheric Tomography (ATom) Mission provided a large data set of chemical and other measurements over the Atlantic, Pacific, Southern, and Arctic Oceans from near the surface to about 12 km in each season. The mission was designed to study ozone and methane chemistry, atmospheric oxidation, and other chemical cycles on large scales, and to challenge chemical transport models. Data and intercomparisons from ATom deployments are presented here, focusing on analysis of the distributions of ozone, related gas phase species, and model results (some from arbitrary recent years and some using meteorology from the ATom time periods, with results mapped onto ATom flight tracks). The goals are to 1) find the distributions of tropospheric ozone along N-S transects across the Atlantic and Pacific Oceans and the polar regions as a function of altitude, latitude, and season, 2) compare with model results both along flight tracks and as probability distributions, and 3) improve our understanding of model-measurement agreement or differences resulting from chemistry and transport.

The ATom Mission

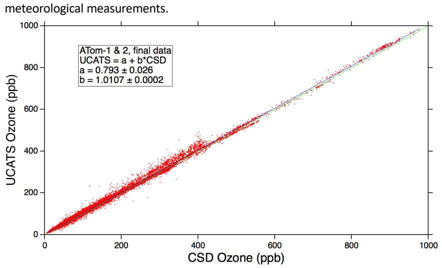
To map out the large-scale distributions of greenhouse gases, pollutants, oxidants, and aerosols, along with their source gases and reaction products, the NASA DC-8 aircraft profiled the atmosphere over the Atlantic and Pacific Oceans from ~0.2-12 km. ATom-1 took place in July-August 2016, ATom-2 in January-February 2017, ATom-3 in October 2017, and ATom-4 in April-May 2018, to achieve coverage in all seasons. Each deployment started and ended in Palmdale, CA and took about a month, with over ten different locations over the globe.



(left) ATom-1 flight tracks (July 29-August 23, 2016). All deployments followed the same basic circuit, based on availability of airfield facilities, weather, etc. Flights from Punta Arenas, Chile over Antarctica and back were added for ATom-3 and -4. DC-8 flights can be ten hours or longer, with each profile taking close to one hour. (below) The DC-8 landing in Thule, Greenland, February 19, 2017. Surface conditions ranged from tropical to sub-zero over the course of a few flights.

ATom data

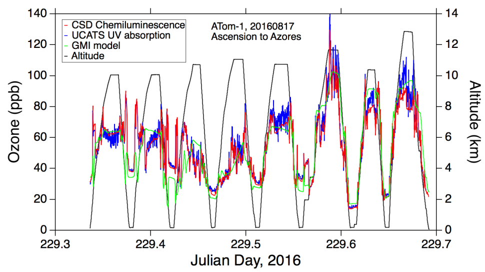
Ozone was measured on ATom by the NOAA Chemical Sciences Division chemiluminescence instrument, and by direct absorption with the UCATS instrument, a two-channel gas chromatograph packaged with small ozone and water vapor sensors. Model data were obtained from the NASA Global Modeling Initiative (GMI) CTM, the GEOS-Chem, GFDL AM3, and GISSE-2 models, the UC Irvine CTM, and the NCAR CAM-Chem model. Other DC-8 data used included nitrogen oxides (NOx) by chemiluminescence, CO from the Harvard QCLS and NOAA Picarro instruments, and meteorological measurements.



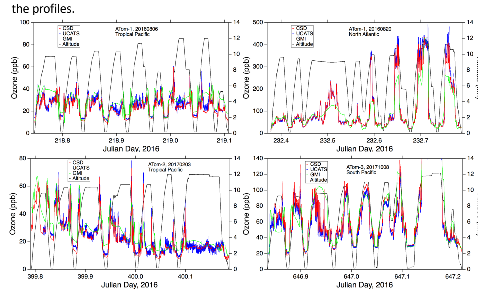
Comparison of UCATS and CSD data for all ATom-1 and 2 flights, showing agreement to about 1% overall. Many of the outliers are due to slight timing differences between the two instruments during periods with rapidly changing ozone.

Participating Models		Model year
GMI	NASA Goddard	2001
GEOS-Chem	Harvard/U of Rochester	2013
GFDLAM3	GFDL	2013
GISSE2	NASA GISS/ Rochester	2013
CAMChem	NCAR	2008
UCI-CTM	UC Irvine	2005

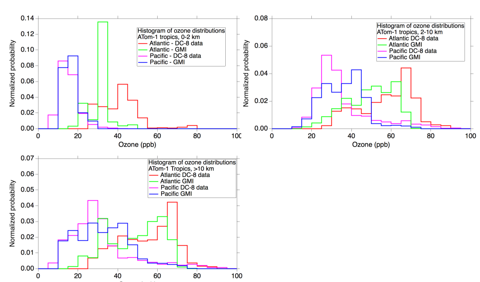
Prior to ATom, all models were run for mid-August in an arbitrary year. In addition, the GMI model was run for each flight date and interpolated onto DC-8 flight tracks.



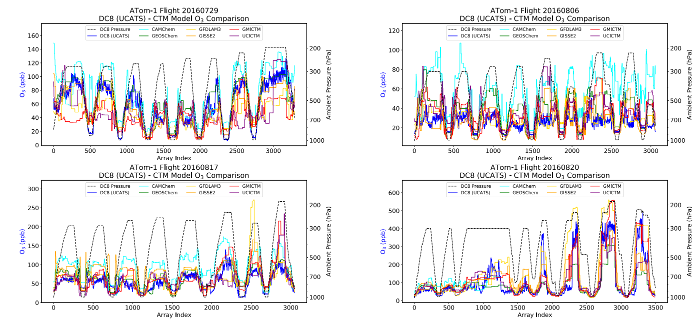
Time series data of ozone over the Atlantic (segment 8 on map), from Ascension Is. to the Azores. The GMI model (run in hindcast mode) shows good overall agreement with the *in situ* data, particularly as the aircraft moved from the tropics to the North Atlantic, and even captures some of the fine scale features from narrow layers near the bottom of the profiles.



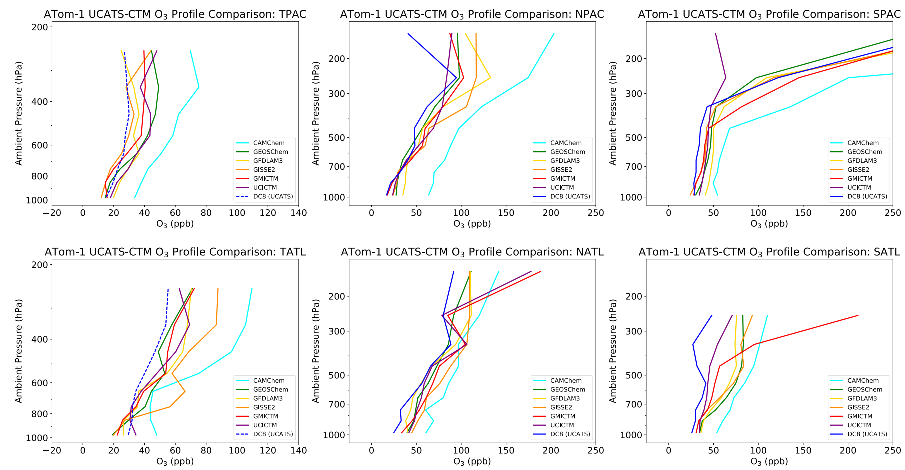
Additional time series plots of ozone from the first three ATom deployments. Maximum ozone over the tropical Pacific Ocean is about a factor of 2 less than over the Atlantic. In mid-latitudes the top of profiles reach the tropopause, where ozone increases rapidly. The focus of ATom is on oxidation and pollutants in the troposphere, however.



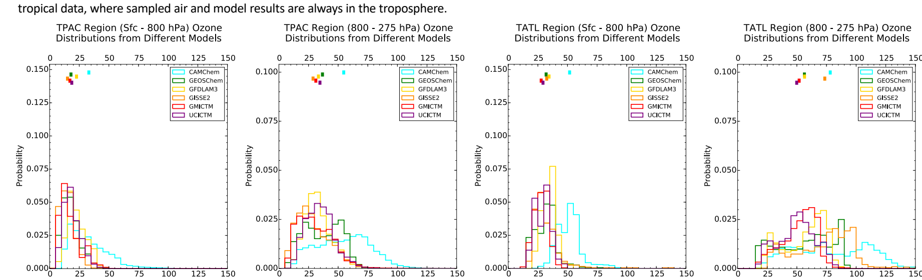
Histograms of measured and GMI model ozone for the tropics (20°S – 20°N), for the marine boundary layer, mid-troposphere, and upper troposphere. As was also seen in the time series plots, there is more ozone over the Atlantic than the Pacific. Ozone is somewhat underpredicted over the Atlantic by the GMI model, particularly at low altitudes.



Ozone mixing ratios from the six global models and measured on the DC-8, interpolated onto ATom-1 flight tracks, along with static pressure (black dashed line). The panels (ordered by date) correspond to flights 1, 4, 8, and 9 on the map. The model calculations use meteorology from different years (see Table of Participating Models), none of them the same year as ATom-1 (2016), so individual features are not expected to match the flight data. Nonetheless, the models often capture the overall structure of the profiles reasonably well.



Average vertical profiles of ozone from the DC-8 and the six global models, interpolated onto the ATom-1 flight tracks for the tropical Pacific (TPAC), north Pacific (NPAC; 20°N – 60°N), and south Pacific (SPAC; 20°S – 60°S) on the upper row. The corresponding profiles over the Atlantic are shown in the lower row. The modeled ozone results are often higher than the *in situ* data, though as described above, the model and DC-8 flight dates are from different years. Note the different scales for the tropical data, where sampled air and model results are always in the troposphere.



Histograms of modeled tropical ozone distributions in larger boxes covering longitudes 200-150°W over the Pacific and 30-20°W over the Atlantic, near the surface (up to 800 mbar) and in the mid-troposphere (800-275 mbar). Mean values of ozone from each model are shown by the symbols near the top of each panel. A large fraction of atmospheric oxidation takes place at these latitudes and altitudes. The models have a large range of predicted ozone, particularly over the tropical Atlantic mid-troposphere.

Summary

- GMI model runs along flight tracks (with 2016 meteorology) reproduce ozone reasonably well.
- The Atlantic was much "dirtier" than the Pacific during ATom-1 (summer 2016). This held true for the remaining ATom deployments in other seasons.
- Some discrepancies exist between modeled and measured data over the tropical Atlantic.
- The full model runs (from different years) predict different distributions of ozone over the tropical oceans and elsewhere.

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