List of Exposure and Dose Metrics

First approved by the TOAR Steering Committee on July 31, 2015, and revised on June 27, 2016 to add two additional metrics.

Following is the list of exposure and dose metrics to be calculated and made publicly available in fulfillment of the goals of the Tropospheric Ozone Assessment Report. The TOAR Steering Committee approved the original list on July 31, 2015. This revision adds two exposure metrics:

- Number of exceedances of daily maximum 8-h values greater than 70 ppb per year.
- Annual and summertime mean of the daily maximum 8-h values

Model-measurement comparison metrics

Surface O₃ metrics at individual sites:

a) Monthly means of 24-h average concentrations and maximum daily 8-h average (MDA8) concentrations, and their standard deviation, median, 5th, 25th, 75th, and 95th percentiles.

b) Monthly mean diurnal cycle (monthly average of all 0100h, 0200h, 0300h, etc. values).

c) Monthly average of daily minimum and maximum of hourly average concentrations.

Free Tropospheric metrics:

d) Monthly, seasonal, and decadal means from ozonesonde, aircraft, and lidar measurements at high vertical resolution (e.g., at intervals of 25hPa pressure surfaces). Standard deviations, median and 5th, 25th, 75th, and 95th percentiles where sampling is sufficient.

e) Monthly mean diurnal cycle with high frequency aircraft data (e.g., MOZAIC).

f) Monthly mean tropospheric column ozone (TCO) from a variety of satellite instruments (OMI/MLS, TES, IASI, GOME...) harmonized to a common horizontal (e.g., 1degx1.25deg as for OMI/MLS) and vertical (if possible) grid.

g) Monthly mean TCO from ozonesondes.

h) Estimate of annual variation averaged over a decade in TCO and on 25hPa pressure surfaces.

Special metrics to be calculated by a single TOAR investigator and posted to the TOAR portal:

i) Polynomial fits (i.e., power series expansions) at selected baseline sites: polynomial “shape factors” that describe long-term trends will be calculated for selected baseline sites and made available in table form, as described by Parrish et al. (2014). The polynomials will be computed by David Parrish, and he will submit his results to Jülich and the files will be posted to the TOAR portal. The results will not be in the TOAR database and will not be accessible through the TOAR JOIN interface. The results will be listed on a Jülich TOAR web page. David Parrish will also compute the same metrics from the model results.
j) Fourier series expansion of seasonal cycles at selected baseline sites: a very few harmonic terms adequately describe seasonal cycles. These will be calculated for select baseline sites by David Parrish and will be provided in table form that will be submitted to Jülich. The files will be posted to the TOAR portal. The results will not be in the TOAR database and will not be accessible through the TOAR JOIN interface. The results will be listed on a Jülich TOAR web page. David Parrish will also compute the same metrics from the model results.

Data to be included in TOAR dataset:

k) Gridded (1degx1deg) hourly surface O$_3$ concentrations from US and Europe networks (Schnell et al. 2014).

l) Trajectory mapped ozone - gridded product that uses global wind fields to distribute ozonesonde observations several days upwind and downwind (Liu et al., 2013).


Human health metrics

a) 4$^{th}$ Highest 8-h Average Concentration for Each Year. Twenty-four running 8-h averages are used to identify the daily maximum 8-h value. The 8-h running mean for a particular hour is calculated on the concentration for that hour plus the following 7 hours.

b) 4$^{th}$ Highest 8-h Average Concentration for Each Year. Twenty-four running 8-h averages are used to identify the daily maximum 8-h value. Using the procedures specified in the EU Airbase, the 8-h running mean is determined based on the concentration for that hour and the previous 7 hours.

c) 4$^{th}$ Highest 8-h Average Concentration for Each Year. For each day a daily maximum 8-h value is determined, the running 8-h values are calculated between 0700 and 2300 h as per the recommendation of the U.S. EPA’s November 25, 2014 Proposed Ozone Standard. The last 8-h period of the day begins at 2300 h and ends at 0700 h the next day. (U.S. EPA Proposed Revision to the 8-h standard). The 8-h running mean for a particular hour is calculated on the concentration for that hour plus the following 7 hours.

d) Maximum daily 8-h average over the entire year.

e) Maximum daily 1-h average over the entire year.

f) SOMO35(i.e., the annual sum of the positive differences between the daily maximum 8-h ozone concentration and the cutoff concentration set at 35 ppb (70 $\mu$g/m$^3$) calculated for all days in a year). The 8-h average concentrations are determined as per Item (b) above.
g) SOMO10 (i.e., the annual sum of the positive differences between the daily maximum 8-h ozone concentration and the cutoff concentration set at 10 ppb (20 µg/m³) calculated for all days in a year). The 8-h average concentrations are determined as per Item (b) above.

h) 4th highest W90 5-h cumulative exposure index as described in Lefohn et al. (2010).

i) Annual and seasonal percentiles (median, 5th, 25th, 75th and 95th) of hourly average concentrations over 24-h period.

j) Number of exceedances of daily maximum 8-h values greater than 50, 60, 70 and 80 ppb per year.

k) Number of exceedances of daily maximum 1-h values greater than 90, 100, and 120 ppb.

l) Running mean of the 3-month average of the daily 1-h maxima, and the date of the annual maximum of this metric. The date of the mid-point of the maximum value of the 3-month running mean will be available in the database.

m) Annual and summertime (Apr-Sep in N. Hemisphere and Oct-Mar in S. Hemisphere) mean of the daily maximum 8-h values


Vegetation metrics

a) W126 (3-month, 24-h (monthly periods specified in accompanying documentation).

b) W126 (6-month, 24-h (monthly periods specified in accompanying documentation).

c) W126 (7-month, 24-h (monthly periods specified in accompanying documentation).

d) W126 (12-month, 24-h (for tropical or subtropical moist climate zones).

e) W126 (3-month, 12-h (0800-1959h) (monthly periods specified in accompanying documentation).

f) W126 (6-month, 12-h (0800-1959h) (monthly periods specified in accompanying documentation).

g) W126 (7-month, 12-h (0800-1959h) (monthly periods specified in accompanying documentation).

h) W126 (12-month, 12-h (for tropical or subtropical moist climate zones) (0800-1959h).

i) AOT40 (3-month, 0800-1959h) (monthly periods specified in accompanying documentation).

j) AOT40 (6-month, 0800-1959h) (monthly periods specified in accompanying documentation).

k) AOT40 (7-month, 0800-1959h) (monthly periods specified in accompanying documentation).

l) AOT40 (12-month, 0800-1959h) (for tropical or subtropical moist climate zones).

m) AOT40 (3-month, daylight over the period when clear sky radiation > 50 W/m²) (monthly periods specified in accompanying documentation).

n) AOT40 (6-month, daylight over the period when clear sky radiation > 50 W/m²) (monthly periods specified in accompanying documentation).

o) AOT40 (7-month, daylight over the period when clear sky radiation > 50 W/m²) (monthly periods specified in accompanying documentation).

p) AOT40 (3-month, nighttime over the period when clear sky radiation < 5 W/m²) (monthly periods specified in accompanying documentation).

q) AOT40 (6-month, nighttime over the period when clear sky radiation < 5 W/m²) (monthly periods specified in accompanying documentation).

r) AOT40 (7-month, nighttime over the period when clear sky radiation < 5 W/m²) (monthly periods specified in accompanying documentation).
s) Daily 12-h average averaged over 3 months, (0800-1959h) (monthly periods specified in accompanying documentation).

t) Daily 12-h average averaged over 6 months, (0800-1959h) (monthly periods specified in accompanying documentation).

u) Daily 12-h average averaged over 7 months, (0800-1959h) (monthly periods specified in accompanying documentation).

v) Daily 12-h average averaged over 12 months, (0800-1959h).

w) Flux-Based Indices will be externally generated for a selected number of sites and provided to the TOAR database for entry for the time periods specified in accompanying documentation.

x) Seasonal percentiles of hourly average concentrations (March-May, June-August, September-November, December-February) (median, 5th, 25th, 75th and 95th, 98th, and 99th) of hourly average.

**Data to be included in TOAR dataset:**

- W126 24-h monthly values.
- W126 12-h (0800-1959h) monthly values.
- AOT40 12-h (0800-1959h) monthly values.
- AOT40 daytime
- AOT40 nighttime
- Daily 12-h average (0800-1959h) averaged over one month with associated number of monthly hours reported.
Table 1. Time windows for 3-, 6-, and 7-month metrics.

<table>
<thead>
<tr>
<th>zone</th>
<th>Simplified Climate Zone</th>
<th>Climate zones represented</th>
<th>Hemisphere</th>
<th>3 month metrics, wheat</th>
<th>3 month metrics, rice</th>
<th>6 month metrics, fixed per hemisphere</th>
<th>7 month metrics, fixed per hemisphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Polar</td>
<td>Polar</td>
<td>NH</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>2</td>
<td>Boreal, moist/dry</td>
<td>Boreal, moist and Boreal, dry</td>
<td>NH</td>
<td>June, July, Aug</td>
<td>Apr to Sep</td>
<td>Mar to Sep</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Cool Temperate</td>
<td>Cool Temperate moist and Cool Temperate, dry</td>
<td>NH</td>
<td>Apr, May, June</td>
<td>May, June, July</td>
<td>Apr to Sep</td>
<td>Mar to Sep</td>
</tr>
<tr>
<td>4</td>
<td>Warm Temperate</td>
<td>Warm Temperate, moist and Warm Temperate, dry</td>
<td>NH</td>
<td>Mar, Apr, May</td>
<td>Jun, July, Aug</td>
<td>Apr to Sep</td>
<td>Mar to Sep</td>
</tr>
<tr>
<td>5</td>
<td>Tropical, wet/moist/montain</td>
<td>Tropical, montain; Tropical, wet and Tropical, moist</td>
<td>NH</td>
<td>Jan, Feb, Mar</td>
<td>July, Aug, Sep</td>
<td>Apr to Sep</td>
<td>Mar to Sep</td>
</tr>
<tr>
<td>6</td>
<td>Tropical, dry</td>
<td>Tropical, dry</td>
<td>NH</td>
<td>Jan, Feb, Mar</td>
<td>Aug to Oct</td>
<td>Apr to Sep</td>
<td>Mar to Sep</td>
</tr>
<tr>
<td>3</td>
<td>Cool, Temperate, 0 - 30 degrees south</td>
<td>Cool Temperate, moist and Cool Temperate, dry</td>
<td>SH</td>
<td>Feb, Mar, Apr</td>
<td>Dec to Feb</td>
<td>Oct to Mar</td>
<td>Sep to Mar</td>
</tr>
<tr>
<td>3</td>
<td>Cool, Temperate, &gt; 30 degrees south</td>
<td>Cool Temperate, moist and Cool Temperate, dry</td>
<td>SH</td>
<td>Nov, Dec, Jan</td>
<td>Dec to Feb</td>
<td>Oct to Mar</td>
<td>Sep to Mar</td>
</tr>
<tr>
<td>4</td>
<td>Warm Temperate, dry</td>
<td>Warm Temperate, dry</td>
<td>SH</td>
<td>Aug - Oct</td>
<td>Jan to March</td>
<td>Oct to Mar</td>
<td>Sep to Mar</td>
</tr>
<tr>
<td>4</td>
<td>Warm Temperate, moist</td>
<td>Warm Temperate, moist</td>
<td>SH</td>
<td>Mid-Aug, Nov to mid Dec, Jan</td>
<td>Nov, Dec, Jan</td>
<td>Oct to Mar</td>
<td>Sep to Mar</td>
</tr>
<tr>
<td>5</td>
<td>Tropical, wet/moist/montain</td>
<td>Tropical, montain; Tropical, wet and Tropical, moist</td>
<td>SH</td>
<td>July, Aug, Sep</td>
<td>Dec to Feb</td>
<td>Oct to Mar</td>
<td>Sep to Mar</td>
</tr>
<tr>
<td>6</td>
<td>Tropical, dry</td>
<td>Tropical, dry</td>
<td>SH</td>
<td>Aug, Sep, Oct</td>
<td>n.a.</td>
<td>Oct to Mar</td>
<td>Sep to Mar</td>
</tr>
</tbody>
</table>
Climate Zones