Global Climatology of Fine Particulate Matter Concentrations Estimated from Remote-Sensed Aerosol Optical Depth

Aaron van Donkelaar¹, Randall Martin¹,², Ralph Kahn³ and Robert Levy³

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¹Dalhousie University  ²Harvard-Smithsonian  ³NASA Goddard
We relate satellite-based measurements of aerosol optical depth to $PM_{2.5}$ using a global chemical transport model.

Following Liu et al., 2004:

\[ \text{Estimated } PM_{2.5} = \eta \cdot \tau \]

\[ \eta \]

- vertical structure
- aerosol type
- meteorological effects
- meteorology
- diurnal effects

\[ \tau \]

Combined MODIS/MISR Aerosol Optical Depth

van Donkelaar et al., EHP, in press
MODIS and MISR $\tau$

**MODIS $\tau$**
- 1-2 days for global coverage
- Requires assumptions about surface reflectivity

**MISR $\tau$**
- 6-9 days for global coverage
- Simultaneous surface reflectance and aerosol retrieval

Mean $\tau$ 2001-2006 at 0.1° x 0.1°
Agreement varies with surface type

9 surface types, defined by monthly mean surface albedo ratios, evaluation against AERONET AOD
Combining MODIS and MISR improves agreement

Combined MODIS/MISR

\[ r = 0.63 \] (vs. in-situ PM$_{2.5}$)

MODIS

\[ r = 0.40 \] (vs. in-situ PM$_{2.5}$)

MISR

\[ r = 0.54 \] (vs. in-situ PM$_{2.5}$)
AOD filters can be applied globally
Global CTMs can directly relate PM$_{2.5}$ to $\tau$

- Detailed aerosol-oxidant model
- $2^\circ \times 2.5^\circ$
- 54 tracers, 100’s reactions
- Assimilated meteorology
- Year-specific emissions
- Dust, sea salt, sulfate-ammonium-nitrate system, organic carbon, black carbon, SOA

GEOS-Chem
Significant agreement with coincident ground measurements over NA

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<thead>
<tr>
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<tbody>
<tr>
<td>MODIS $\tau$</td>
<td>0.40</td>
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<tr>
<td>MISR $\tau$</td>
<td>0.54</td>
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<tr>
<td>Combined $\tau$</td>
<td>0.63</td>
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<tr>
<td>Combined PM$_{2.5}$</td>
<td>0.77</td>
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$y = 1.07x - 1.75; r = 0.77$  
$n = 1057$  

Annual Mean PM$_{2.5}$ [µg/m$^3$] (2001-2006)
Method shows global agreement

- Annual mean measurements
  - Outside Canada/US
  - 244 sites (84 non-EU)
  - $r = 0.83$ (0.83)
  - slope = 0.86 (0.91)
  - bias = $1.15$ (-2.64) $\mu g/m^3$
High global PM$_{2.5}$ exposure

- Satellite-PM$_{2.5}$ + population map → exposure
- 80% of world population exceeds WHO guideline of 10 μg/m$^3$
- 50% of eastern Asia exceeds 35 μg/m$^3$