Parameterization Approach and Multimodel Analysis of Ozone Deposition

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Dry deposition in the Earth System

- **Important atmospheric process**
  - Governs atmospheric abundance of many compounds including pollutants, e.g. $O_3$

- **Important process for the biosphere**
  - Governs input of key nutrients at vegetative surfaces

- **Links the atmosphere and biosphere**
  - Contributes to climate and earth system feedbacks

- **Has important policy-relevant implications for air quality, ecosystem health and crop yields**
Many global atmospheric and earth system models use resistance in series schemes (e.g. the “Wesely” scheme) to represent dry deposition.

\[ |v| = (r_a + r_b + r_c)^{-1} \]
\[ v = F_c / C_c \]

1. Turbulent transport through the atmosphere (controlled by meteorology)

2. Molecular diffusion through laminar sub-layer (controlled by depositing species)

3. Uptake on surface by adsorption, followed by dissolution or reaction (depends on surface type: vegetation, soil, water, light, etc.)

Recent understanding from measurement campaigns and models such as DO3SE have not been implemented.
1. Analysis of \( \text{O}_3 \) dry deposition in global-scale atmospheric and Earth system models

2. Towards metrics for evaluating \( \text{O}_3 \) dry deposition in global scale models
O$_3$ dry deposition in HTAP data: Global trends

Annual range across ensemble = ~500 Tg year$^{-1}$

Monthly range across ensemble = ~50 Tg month$^{-1}$

<table>
<thead>
<tr>
<th>Model</th>
<th>Deposition Scheme</th>
<th>O$_3$ dry deposition / Tg$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAMCHEM-3311m13</td>
<td>Wesely</td>
<td>816</td>
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<tr>
<td>CAMCHEM-3514</td>
<td>Wesely</td>
<td>818</td>
</tr>
<tr>
<td>CHASER-v03</td>
<td>Wesely</td>
<td>939</td>
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<tr>
<td>FRSGCUCI-v01</td>
<td>Hough</td>
<td>943</td>
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<tr>
<td>GEMAQ-EC</td>
<td>Wesely</td>
<td>878</td>
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<tr>
<td>GESOCHEM-v07</td>
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<td>GISS-PUCCINI-A</td>
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<td>ULAQ-02</td>
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<td>844</td>
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<tr>
<td>UM-CAM-v01</td>
<td>Ganzeveld and Lelieveld or Wesely</td>
<td>1116</td>
</tr>
</tbody>
</table>

Average (± 1 sd) 978 (± 127)
O$_3$ dry deposition in HTAP data: Latitudinal variation

Modelled

Normalised
Variability in $O_3$ dry deposition partitioned to land cover

Total annual $O_3$ dry deposition

Average annual $O_3$ dry deposition flux

Olson land cover data set: 11 land cover classes

- SI = Snow/Ice
- DF = Deciduous Forest
- CF = Coniferous Forest
- AC = Agricultural/Crop Land
- GL = Grass Land
- TF = Tropical Forest
- TN = Tundra
- DT = Desert
- WL = Wetland
- WT = Water
Olson land cover: Asia

- Deciduous Forest
- Coniferous Forest
- Tropical Forest
- Agri. + Crops
- Grass land
- Tundra
- Water
- Desert
- Snow Ice

Fractional coverage
Spatial variability: Total $O_3$ dry deposition flux
Spatial variability: $O_3$ dry deposition flux to non-vegetated land cover
Spatial variability: $O_3$ dry deposition flux to forests

Deciduous Forest

Coniferous Forest

Tropical forest
Spatial variability: $O_3$ dry deposition flux to other vegetation
1. Analysis of $O_3$ dry deposition in global-scale atmospheric and Earth system models

2. Towards metrics for evaluating $O_3$ dry deposition in global scale models
Grid point comparison between observed and modelled O₃ dry deposition fluxes at four sites:

**Ulborg, Denmark**
- Modelled $r = 0.93$
- Modelled slope = 0.50
- Surface $[O_3] r = 0.84$

**Harvard Forest, MS, USA**
- Modelled $r = 0.94$
- Modelled slope = 1.64
- Surface $[O_3] r = 0.96$

**Auchencorth Moss, Scotland**
- Modelled $r = 0.78$
- Modelled slope = 0.64
- Surface $[O_3] r = 0.73$

**Hyytiala, Finland**
- Modelled $r = 0.96$
- Modelled slope = 1.74
- Surface $[O_3] r = 0.74$
Partitioned fluxes at measurement locations

Ulborg, Denmark

Harvard Forest, USA

Auchencorth Moss, UK

Hyytiala, Finland
Points for regional modellers

1. More detailed diagnosis of dry deposition fluxes
   - Fluxes partitioned to land cover
   - Separate aerodynamic ($r_a$), vegetation ($r_{can}$) and soil fluxes ($r_{soil}$)
   - Stomatal/non-stomatal fluxes $\Rightarrow$ important for diagnosing O$_3$ risk to crops

2. Ensure consistency in dry deposition fluxes across ensemble

3. Land cover
   - Use consistent vegetation cover across models
   - Use land cover with good vegetation representation $\Rightarrow$ possibly more important for local air quality in regional-scale models?

4. Measurements
   - Collate relevant data sets for comparison with models (MORE DATA!!)
   - Regional models may be useful for comparing to measurements
$O_3$ dry deposition fluxes at short-term European measurement sites