

# Online Supplement to “Bacteria in the global atmosphere — Part II: modelling of emissions and transport between different ecosystems”

S. M. Burrows, T. Butler, P. Jöckel, H. Tost,  
A. Kerckweg, U. Pöschl and M. G. Lawrence

Max Planck Institute for Chemistry, Mainz, Germany

Department of Atmospheric Chemistry

Correspondence to: [susannah.burrows@mpic.de](mailto:susannah.burrows@mpic.de).

## 1 Ecosystem lumping

The basis for ecosystem classification is the Olson World Ecosystems dataset (Olson, 1992), which is freely available from NOAA at the time of writing (<http://www.ngdc.noaa.gov/ecosys/>). Ecosystem classes are assigned at each point of a grid with a mixture of 30 minute and 10 minute spatial resolution. Each class is associated with an integer index from 0 through 73 (inclusive), with 14 of the indices remaining unused.

Because the Olson ecosystem classification was too detailed for the present purposes, the classes were lumped into groups as detailed in Table S1. The geographic distribution of the lumped ecosystems is illustrated in Figure 1 of the paper. The data were regridded onto the model grid points using `NCREGRID` (Jöckel, 2006). For each box of the new grid, `NCREGRID` returns a vector. Each element of the vector is the fraction of the new grid box covered by one ecosystem from the lumped set (see regridding type IFX in Jöckel 2006).

| Lumped group number | Lumped group name | Lumped group description                 | Olson number  | Olson code  | Olson description  |
|---------------------|-------------------|--|---|---|--|
| 0                   | seas              | Oceans, Seas, Inland Waters              | 0   | (none)  | Waters, including ocean and Inland Waters  |
| 1                   | shrubs            | Shrubs and scrubs (non-desert)           | 16<br>40<br>41<br>46<br>47<br>49  | BES<br>CGS<br>MGS<br>MES<br>DHS<br>HVI  | Broadleaf Evergreen Scrub, commonly with 46 and 47<br>Cool grass/shrub, showy in most years<br>Mild/warm/hot grass/shrub<br>Mediterranean-type Evergreen (mostly) broadleaved Scrub and forest relics<br>Dry or highland scrub, or open woodland<br>Hot-mild volcanic "islands" (Galapagos), with local denser forest on some older lava flows but wide areas of sparse cover on recent lavas)<br>Succulent and Thorn Woods or scrub is widespread   |
| 2                   | forests           | Forests (temperate, tropical and boreal) | 6<br><br>20<br>21<br>22<br>23<br>24<br>25<br>26<br><br>27<br>28<br><br>29<br>32<br><br>33<br>48<br>54<br>56<br><br>57 | TBE<br><br>SRC<br>MBC<br>SNB<br>CDF<br>TBC<br>SDF<br>TBF<br><br>NSC<br>TMC<br><br>TBS<br>RGD<br><br>TRF<br>DEW<br>TER<br>FFR<br><br>SFF | Temperate/Tropical-montane Broadleaf Evergreen covers warm temperate or montane broadleaf evergreen forest [Africa only]<br>Snowy, rainy coastal conifer<br>Main Boreal conifer forest, closed or open<br>Snowy non-Boreal conifer forest<br>Conifer/deciduous, snow persisting in winter<br>Temperate Broadleaf/Conifer forest: with deciduous and/or evergreen hardwood trees<br>Snowy Deciduous Forest, i.e. Summergreen (=cold-deciduous) types<br>Temperate broad-leaf forest: deciduous, semideciduous, and some temperate-subtropical broadleaf evergreen types that are least active in winter.<br>Non-snowy conifer forest<br>Tropical montane complexes, typically evergreen, including dwarfed ("elfin") forest, opening to grass, or tall or short forbs (puna, paramo)<br>Tropical Broadleaf Seasonal, with dry or cool season<br>Rain-green (drought-deciduous) or very seasonal dry evergreen forests to open woodlands, very frequently burned.<br>Tropical Rain Forest<br>Dry Evergreen Woodland or low forest, mapped mostly in interior Australia and South America<br>Temperate Evergreen Rainforest (e.g., in Chile)<br>Forest/Field complex with Regrowth after disturbances, mixed with crops and/or other non-wooded lands<br>Snowy Forest/Field, commonly openings are pasture and/or mires |
| 3                   | deserts           | Arid and semiarid deserts                | 8<br>50<br>71<br>2<br>51<br>52  | DMB<br>SDB<br>SSF<br>SSG<br>SDS<br>CSS  | Desert, mostly bare stone, clay or sand<br>Sand Desert, partly Blowing dunes<br>Salt/soda flats desert, playas, occasionally with intermittent lakes<br>Short or Sparse Grass/shrub of semiarid climates<br>SemiDesert/Desert Scrub/succulent/sparse grass<br>Cool/cold shrub semidesert/steppe  |
| 4                   | landice           | Land ice                                 | 17  | ICE   | Antarctic ice cap  |

Table S1: Lumping of Olson ecosystem classes. Original classification from Olson (1992).

| Lumped group number | Lumped group name | Lumped group description       | Olson number | Olson code | Olson description  |
|---------------------|-------------------|--------------------------------|--------------|------------|--|
| 5                   | crops             | and polar deserts<br>Croplands | 69           | PDL        | Polar desert with rock Lichens, locally abundant or productive (even between mineral grains) but provide little food. Animals import residues for localized humus  |
|                     |                   |                                | 70           | GLA        | Glaciers in polar or alpine complex, with rock fringes   |
| 6                   | wetlands          | Wetlands                       | 30           | CFC        | Cool Farmland: Settlements, more or less snowy   |
|                     |                   |                                | 31           | MFS        | Mild/hot farmland & settlements  |
|                     |                   |                                | 36           | PRA        | Paddy rice and associated land mosaics   |
|                     |                   |                                | 37           | WCI        | Warm/hot cropland, Irrigated extensively   |
|                     |                   |                                | 38           | CCI        | Cool cropland with Irrigation of variable extent   |
|                     |                   |                                | 39           | CCP        | Cold cropland and pasture, irrigated locally   |
|                     |                   |                                | 44           | MBF        | Mires, including peaty Bogs and Fens (mostly in high latitudes)  |
| 7                   | coastal           | Coastal regions, islands       | 45           | MOS        | Marsh or other swampy wetlands, includes various transitions to or mixtures with trees   |
|                     |                   |                                | 72           | MSM        | Mangrove and non-saline swamps and tidal Mudflats (Africa only)  |
|                     |                   |                                | 65           | CNW        | Coastal: NorthWest quadrant near most land   |
| 8                   | grasslands        | Grasslands and Savanna         | 66           | CNE        | Coastal: NorthEast quadrant near most land   |
|                     |                   |                                | 67           | CSE        | Coastal: SouthEast quadrant near most land   |
|                     |                   |                                | 68           | CSW        | Coastal: SouthWest quadrant near most land   |
|                     |                   |                                | 73           | ISL        | Islands and shore waters in oceans and/or lakes [Elba Island]  |
|                     |                   |                                | 43           | SGW        | Savanna/Grass, seasonal woods: Trees or shrubs above grass groundcover may be interspersed on many scales in savanna belts of varying drought duration and high fire frequency                           |
|                     |                   |                                | 55           | SFW        | Snowy Field/Woods complex  |
|                     |                   |                                | 58           | FWG        | Field/Woods with Grass and/or Cropland   |
| 9                   | tundra            | Tundras and Taigas             | 42           | CSM        | Cold steppe/meadow +/- larch woods (in Siberia), scrub (Bering sea) or tundra (Tibetan high-land)  |
|                     |                   |                                | 53           | TUN        | Tundra (polar, alpine)   |
|                     |                   |                                | 60           | SDT        | Southern Dry Taiga or similar aspen/birch with northern and/or mountain conifers   |
|                     |                   |                                | 61           | LT         | Larch Taiga with deciduous conifer   |
|                     |                   |                                | 62           | NMT        | Northern or maritime taiga typifies a wide latitude belt or a narrow altitude belt above denser forest or woodland   |
|                     |                   |                                | 63           | WTM        | Wooded tundra margin or mountain scrub/meadow)   |
|                     |                   |                                | 64           | HMW        | Heath and Moorland, wild or artificially managed, as by burning and/or grazing. Can include wetland (44-45) interspersed with drier heath, with dwarfed or taller, commonly dense scrub on peat or sand. |

Table S1: Lumping of Olson ecosystem classes. Original classification from Olson (1992).

## Tables

**Table S2.** Cross-correlations of columns of the transport matrix (Table 3 of paper), demonstrating the correlations between the make-up of the aerosol in different ecosystem regions. This table is presented visually in Figure 3 of the paper.

|            | coastal | crops | deserts | forests | grasslands | landice | seas  | shrubs | tundra | wetlands |
|------------|---------|-------|---------|---------|------------|---------|-------|--------|--------|----------|
| coastal    | 1.00    |       |         |         |            |         |       |        |        |          |
| crops      | 0.24    | 1.00  |         |         |            |         |       |        |        |          |
| deserts    | -0.08   | -0.21 | 1.00    |         |            |         |       |        |        |          |
| forests    | -0.05   | 0.51  | -0.32   | 1.00    |            |         |       |        |        |          |
| grasslands | -0.04   | 0.33  | -0.11   | 0.42    | 1.00       |         |       |        |        |          |
| landice    | -0.25   | -0.43 | -0.22   | -0.42   | -0.29      | 1.00    |       |        |        |          |
| seas       | 0.56    | -0.03 | -0.28   | -0.15   | -0.20      | -0.32   | 1.00  |        |        |          |
| shrubs     | 0.03    | 0.03  | 0.42    | -0.07   | 0.25       | -0.33   | -0.20 | 1.00   |        |          |
| tundra     | -0.11   | -0.02 | -0.25   | 0.21    | -0.27      | -0.13   | -0.19 | -0.30  | 1.00   |          |
| wetlands   | 0.08    | 0.05  | -0.06   | 0.43    | 0.21       | -0.21   | 0.21  | 0.13   | -0.21  | 1.00     |

**Table S3.** Global bacteria emissions ( $a^{-1}$ ), distribution of ensemble results.

|         | Free solution | Postive-constrained solution |
|---------|---------------|------------------------------|
| Minimum | -8.2e+23      | 3.4e+23                      |
| 1%ile   | -4.3e+23      | 5.5e+23                      |
| 5%ile   | -5.4e+20      | 7.6e+23                      |
| 10%ile  | 3.4e+23       | 8.8e+23                      |
| 25%ile  | 1.1e+24       | 1.1e+24                      |
| 50%ile  | 2.7e+24       | 1.4e+24                      |
| 75%ile  | 5.3e+24       | 1.9e+24                      |
| 90%ile  | 7.1e+24       | 3.0e+24                      |
| 95%ile  | 7.7e+24       | 3.5e+24                      |
| 99%ile  | 8.3e+24       | 4.2e+24                      |
| Maximum | 8.8e+24       | 4.6e+24                      |

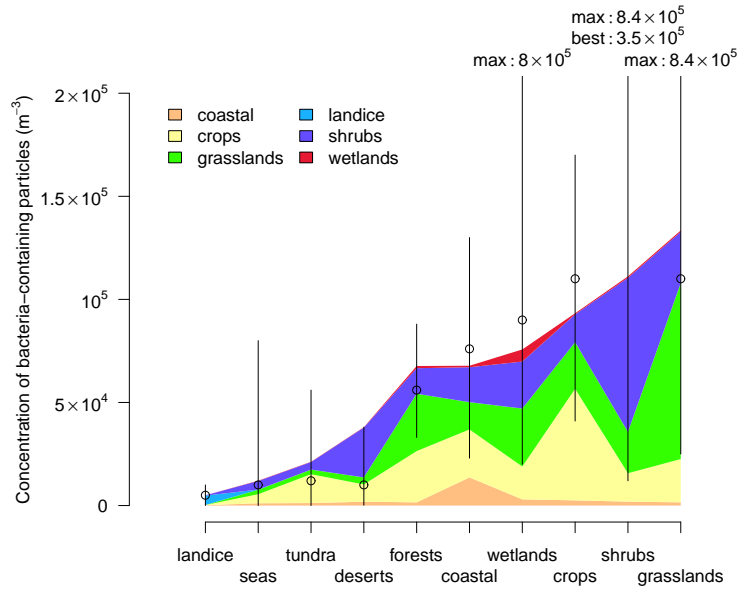
**Table S4.** Global bacteria emissions ( $\text{Gg a}^{-1}$ ), distribution of ensemble results.

|         | Free solution | Positive-constrained solution |
|---------|---------------|-------------------------------|
| Minimum | -430          | 179                           |
| 1%ile   | -227          | 287                           |
| 5%ile   | -0.28         | 400                           |
| 10%ile  | 180           | 463                           |
| 25%ile  | 584           | 575                           |
| 50%ile  | 1427          | 739                           |
| 75%ile  | 2782          | 1010                          |
| 90%ile  | 3743          | 1547                          |
| 95%ile  | 4031          | 1809                          |
| 99%ile  | 4367          | 2178                          |
| Maximum | 4627          | 2431                          |

**Table S5.** Ensemble estimates of the rate at which bacteria are emitted from each ecosystem,  $\text{m s}^{-1}$ . "Global mean" and "land mean" (last two rows) refer to the overall mean emissions, weighted by ecosystem area, from the entire earth and from land surface only, respectively. The estimates are based on simulated  $1 \mu\text{m}$  diameter, CCN-ACTIVE bacteria tracers.

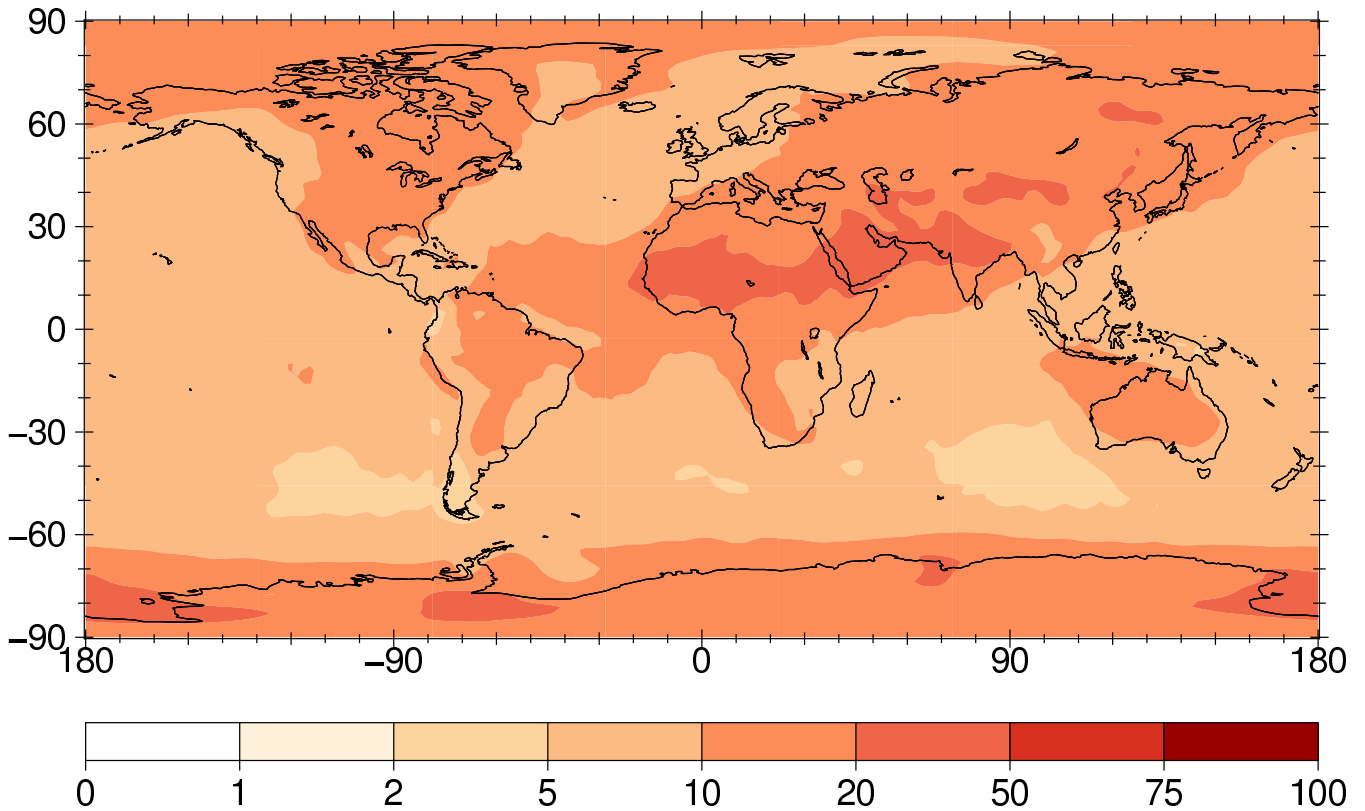
|             | 50%ile | 5%ile | 95%ile | Land area ( $10^6 \text{ km}^{-2}$ ) |
|-------------|--------|-------|--------|--------------------------------------|
| coastal     | 9.9    | 0     | 4996   | 0.81                                 |
| crops       | 0      | 0     | 1578   | 16                                   |
| deserts     | 0      | 0     | 52     | 19                                   |
| forests     | 0      | 0     | 187    | 36                                   |
| grasslands  | 568    | 0     | 1811   | 11                                   |
| landice     | 5.8    | 0     | 16     | 16                                   |
| seas        | 0      | 0     | 226    | 363                                  |
| shrubs      | 367    | 0     | 619    | 29                                   |
| tundra      | 0      | 0     | 579    | 17                                   |
| wetlands    | 292    | 0     | 14543  | 2.9                                  |
| global mean | 88     | 47    | 215    | 0.81                                 |
| land mean   | 246    | 140   | 377    | 16                                   |

## Figures



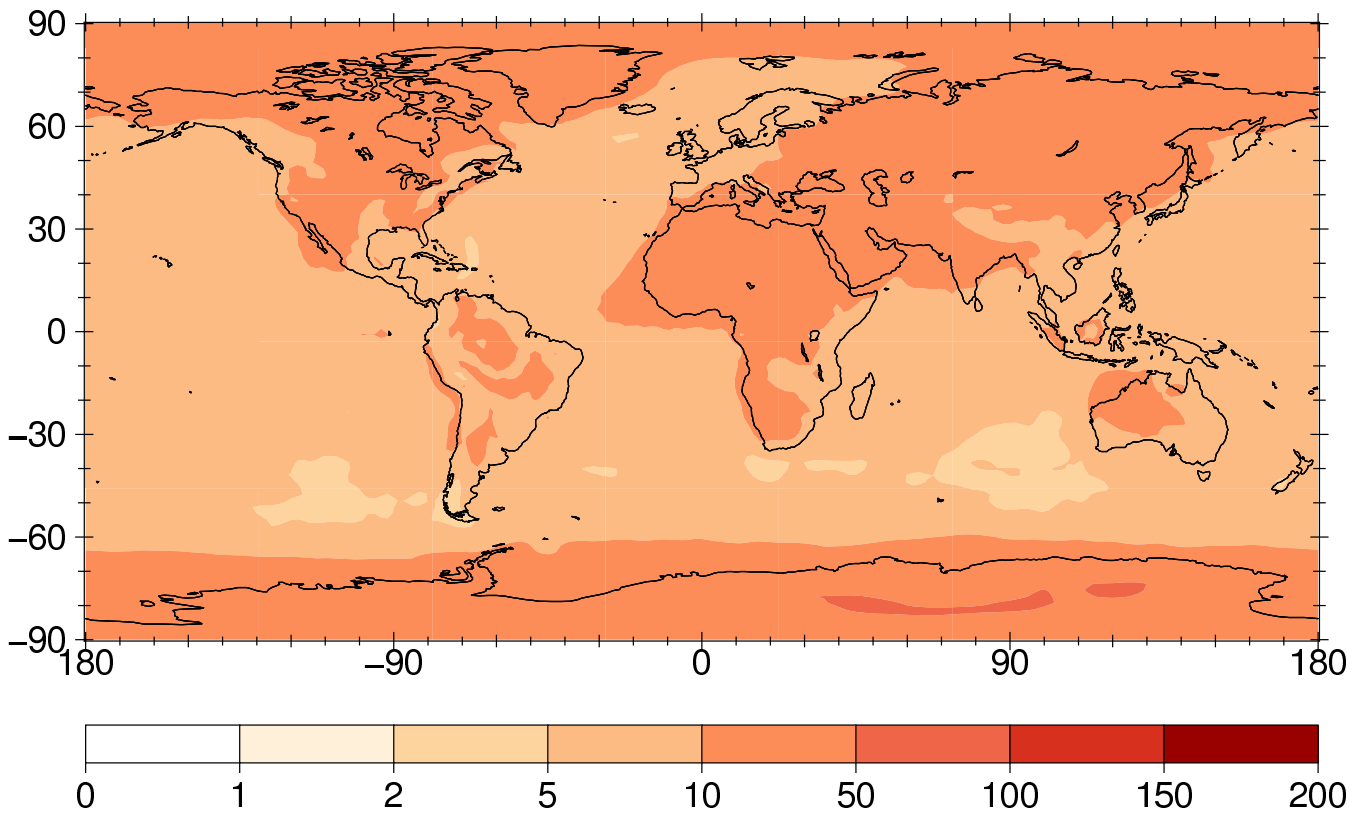
**Fig. S1.** Mean concentrations of bacteria tracer in near-surface air of all ecosystem classes. Colors indicate tracer source; dots are best literature estimates of concentration in each ecosystem, with range of literature estimate shown by vertical lines (Table ).

### Column density, homogeneous emissions



**Fig. S2.** Modelled column density of bacteria ( $10^6 \text{ m}^{-2}$ ). Figures are based on the CCN-ACTIVE simulation, with homogeneous emissions of  $35 \text{ m}^{-2} \text{ s}^{-1}$  in all ecosystems or the median of the ensemble of positive-constrained emissions estimates (global mean emissions in both cases are equal).

### Concentration, homogeneous emissions



**Fig. S3.** Modelled concentration of bacteria in near-surface air ( $10^3 \text{ m}^{-3}$ ). Figures are based on the CCN-ACTIVE simulation, with homogeneous emissions of  $35 \text{ m}^{-2} \text{ s}^{-1}$  in all ecosystems or the median of the ensemble of positive-constrained emissions estimates (global mean emissions in both cases are equal).

## References

- Jöckel, P.: Technical note: Recursive discretisation of geo-scientific data in the Modular Earth Submodel System (MESSy), *Atmos. Chem. Phys.*, 6, 3557–3562, 2006.
- Olson, J.: World ecosystems (WE1.4): Digital raster data on a 10 minute geographic 1080 (2160 grid square), *Global Ecosystem Database*, Version, 1, 1992.