Geographic distribution of global lakes and rivers

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And many others!

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Long-term average annual runoff (1961-90)

Source: WaterGAP model (Döll et al. 2003)
Freshwater Ecoregions of the World
Main problem: different scales

- Global scale hydrological models typically focus on long-term average conditions (annual or monthly flows) and operate on coarse spatial scales (~ 10-50 km resolution)

- Ecological applications typically require high resolution data, such as daily flows at a spatial resolution of meters
Ecological application: Large scale habitat types

► On a global scale, we don’t have much information on the distribution of aquatic species.

► As a surrogate, we assume that differences in physical characteristics, geomorphology or hydrologic conditions can indicate differences in freshwater biodiversity.

Global Lakes and Wetlands Database GLWD (Lehner and Döll 2004)
Lake databases

► Various country, regional, continental and global registers and inventories

► Global Lakes and Wetlands Database (GLWD; Lehner & Döll 2004)
  - Encompasses ~ 250,000 lake polygons
  - Based on various source data, but mainly DCW (VMAP0)

► SRTM Surface Water Body Database (SWBD; NASA/NGA 2003)
  - Encompasses ~ 600,000 lake polygons
  - Based on remote sensing imagery at 30m resolution
  - Covers globe up to 60°N
  - ~ 15,000 single tiles, needs to be cleaned
Numbers & areas of mapped lakes worldwide

- **GLWD (Lehner and Döll 2004)**
  - Total of 250,000 lake polygons (~ \( \frac{3}{4} \) are north of 50°)
  - Total lake area ~ 2.4 million km²
  - Total number of lakes larger than 1 km²: 155,000
    (of which 100,000 are south of 60° N)

- **SWBD (NASA/NGA 2003)**
  - Total of 600,000 lake polygons south of 60° N
  - Total lake area ~ 2.1 million km²
  - Total number of lakes > 1 km²: 100,000

- **Conclusion:** most lakes > 1 km² are mapped
Fractal distribution of lake surfaces

$N = 155791 \cdot A^{-0.9926}$

Global trend:

Based on 250,000 lake polygons, Lehner & Döll (2004)
### Estimated numbers & areas of lakes world wide

<table>
<thead>
<tr>
<th>Size class</th>
<th>Nr. of lakes</th>
<th>Area of lakes</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 1 km²</td>
<td>155,000</td>
<td>~ 2.3 mill. km²</td>
</tr>
<tr>
<td>&gt; 0.1 km²</td>
<td>1-2 million</td>
<td>~ 2.9 mill. km²</td>
</tr>
<tr>
<td>&gt; 1 ha</td>
<td>15-26 million</td>
<td>~ 3.5 mill. km²</td>
</tr>
<tr>
<td>&gt; 0.1 ha</td>
<td>~ 304 million</td>
<td>~ 4.2 mill. km²</td>
</tr>
<tr>
<td></td>
<td></td>
<td>~ 2.8% of land area</td>
</tr>
</tbody>
</table>

Estimates by Lehner & Döll (2004), Downing et al. (2006), and others

► **Conclusions:**

- small lakes are significant in numbers and area, and we need to include them in hydrological, ecological, and biogeochemical assessments
- we don’t have good estimates on lake volumes
Global Reservoir and Dam (GRanD) Database

coordinated by Global Water System Project (GWSP)

~ 7000 largest reservoirs – Total storage capacity ~ 5000 km³
referenced to SWBD polygons and HydroSHEDS river network
Global Reservoir and Dam (GRanD) Database

List of attributes

- Lat/long of reservoir
- Name of reservoir, dam, lake
- River name
- Main basin, Sub-basin
- Administrative unit, Country
- Height of dam [m]
- Year of completion
- Max. storage capacity reported [m$^3$]
- Max. reservoir area reported and calculated [km$^2$]
- Purpose: Hydropower, Irrigation Water Supply, Flood Control
- Data quality: reliable/fair/unreliable
- General comments
Global Reservoir and Dam (GRanD) Database

What we don’t know

• Which small water bodies are reservoirs vs. lakes
• Operation rules of the different types of reservoirs

Conclusions:

• We need to distinguish between lakes and reservoirs when interpreting height measurements
• We need high resolution height and surface area measurements representing all types of reservoirs in order to derive typical operational modes
HydroSHEDS
Hydrological data and maps based on Shuttle Elevation Derivatives at multiple Scales

Derived products include:
- watershed boundaries
- river network
- flow distances
- slopes along rivers
- flow quantities
- riverbed geometry

Provided resolutions
- 90 m, 500 m, 1 km, ...

Free distribution online via http://hydrosheds.cr.usgs.gov/
DDM30 – Global Drainage Direction Map at 30 min resolution (Döll and Lehner 2001)
HydroSHEDS Africa

River network and basin outlines derived from SRTM elevation data at 500m resolution

- **Major basin**
- **Endorheic basin**
- **River**
- **River in endorheic basin**

River lines (particularly those of endorheic basins) may represent dry valleys.

River line width proportional to upstream basin area.

Only major rivers and streams are visualized.
HydroSHEDS
Global river network derived from SRTM elevation data at 10 km resolution
HydroSHEDS
South America

Only major rivers and streams are visualized.

River line width proportional to upstream basin area.

River network and basin outlines derived from SRTM elevation data at 1 km resolution.

- Major basin
- Endorheic basin (inland sink)
Only major rivers and streams are visualized.

River line width proportional to upstream basin area.
HydroSHEDS
Upper Madre de Dios Basin

River network derived from SRTM elevation data at 90 m resolution

Kilometers

Only major rivers and streams are visualized

River line width proportional to upstream basin area
River line width proportional to upstream basin area

HydroSHEDS
Tributary of the Manu watershed
River network derived from SRTM elevation data at 90-m resolution

WWF
Quality comparisons

HydroSHEDS 500 m

50 km
Quality comparisons

Local high resolution river map
Hydro1k (1 km)
ESRI 1:3 Mio.
DCW 1:1 Mio.
HydroSHEDS 500 m

50 km

HydroSHEDS 500 m
Problems and inaccuracies
Southwest Amazon headwaters
Simulation of flow regime

Madre de Dios basin

Discharge [m³/s]
- 0 - 0.5
- 0.5 - 1
- 1 - 5
- 5 - 10
- 10 - 50
- 50 - 100
- 100 - 500
- 500 - 1000
- 1000 - 5000
- 5000 - 10000
For global scale hydrology related to lakes, reservoirs, rivers (and wetlands), all kinds of spatial and temporal resolutions important, as there are very different types of applications.

My personal wish list:
- a true seamless, global coverage (rather than a focus on select locations), including all northern latitudes
- a very high resolution (90 m or less) permanent land/water mask that is able to resolve even small lakes and inundation areas; and
- repeated height and extent measurements at high temporal and spatial resolutions (~1 km²; weekly)
A strategic measurement network for special high-resolution samplings should include selected lakes of all size classes and climate regions, as well as selected reservoirs of all operational types. If the highest spatial resolutions cannot be provided, sub-grid information may be a good alternative. Connectivity of small lakes is important; this could be achieved with a lake-mask at highest resolution or by providing area and number of lakes per km$^2$. Data should be provided in common and standard format, projection and resolution to the public. We need better estimates of lake volumes. Can wetlands be identified by saturated soils rather than open water?