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EUDP 11-II, Globalt Vind Atlas, 64011-0347
Open access to global wind atlas data

Use the data and extend its application

Invite feedback and new ideas
Outline

• Project context
• Model chain
• Input data
• Output
• Web user interface, walk through
• Future plans
• Global assessments of the technical potential
Project context - International collaboration

23 participating CEM governments account for 80 percent of global greenhouse gas emissions
International collaboration
What is IRENA’s Global Atlas?

It is a high-level prospector for renewable energy opportunities
- builds on publicly available information
- information released by the private sector
- data released by institutions,
  - i.e. EUDP Global Wind Atlas
  - New European Wind Atlas

http://globalatlas.irena.org/
International collaboration
IRENA’s Global Atlas

It supports

- countries in prospecting their renewable energy opportunities
- companies to approach new markets
- the general public in gaining interest in renewable energy

http://globalatlas.irena.org/
The global wind atlas objective

• provide wind resource data accounting for high resolution effects

• use microscale modelling to capture small scale wind speed variability (crucial for better estimates of total wind resource)

• use a unified methodology

• ensure transparency about the methodology

• verify the results in representative selected areas

For:

• Aggregation, upscaling analysis and energy integration modelling for energy planners and policy makers

Not for:

• Not for wind farm siting
Model chain
Downscaling

GWA

large scale
(20 – 200 km)

medium scale
(1 – 20 km)

small scale
(0.1 – 1 km)

main method stream
reanalysis data sets
generalization
hi.-res. topography
microscale modelling
wind resource: hi.-res.
Model chain
Global Wind Atlas implementation

- Military Grid Reference System (MGRS) form basis of the job structure

- MRGS zones are divided into 4 pieces (total 4903)

- **2439 jobs required to cover land and 30 km offshore**

- Frogfoot system runs WAsP-like microscale modelling. Inputs
  - Generalized reanalysis winds
  - High resolution elevation and surface roughness data
**Model chain**

**What is Frogfoot?**

- Generalized wind climate datasets
- Climate data manager
- Climate Service
- Terrain Service
  - Orography and roughness maps

<table>
<thead>
<tr>
<th>Core Frogfoot-server components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ancillary components run on user PC</td>
</tr>
<tr>
<td>Data that is input into the system</td>
</tr>
<tr>
<td>Result outputs</td>
</tr>
</tbody>
</table>

**Job service**

- WAsP worker
- WAsP worker
- WAsP worker
- WAsP worker

**Results service**

- Results exporter
  - Output data

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Like WAsP this is developed in partnership with **World In A Box** based in Finland.
Frogfoot components

Job Creation

Job Management Console

Results Exporter

WAsP Worker
Model chain
How to work with Frogfoot?

WAsP Worker(s)
Microscale
Orographic speed-up

Streamlines closer together means faster flow

Winds speed up on hills
Winds slow down in valleys

Modification of the wind profile
Microscale
Surface roughness length

Geostrophic wind speed = 10 ms\(^{-1}\)

A. forest ($z_0 = 2.0$ m)
B. town ($z_0 = 0.5$ m)
C. field ($z_0 = 0.05$ m)
D. water ($z_0 = 0.0002$ m)
Microscale
Surface roughness change

Roughness change from 0.02 cm to 20 cm

IBL: upper
IBL: lower
Rule of thumb

Unchanged profile
Transition profile
New log-profile

Rule of thumb: 1:100

Accounted for by roughness speed-up and meso roughness parameters from WAsP flow model
## Datasets: atmospheric data

### Reanalysis

<table>
<thead>
<tr>
<th>Product</th>
<th>Model system</th>
<th>Horizontal resolution</th>
<th>Period covered</th>
<th>Temporal resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERA Interim reanalysis</td>
<td>T255, 60 vertical levels, 4DVar</td>
<td>~0.7° × 0.7°</td>
<td>1979-present</td>
<td>3-hourly</td>
</tr>
<tr>
<td>NASA – GAO/MERRA</td>
<td>GEOS5 data assimilation system (Incremental Analysis Updates), 72 levels</td>
<td>0.5° × 0.67°</td>
<td>1979-present</td>
<td>hourly</td>
</tr>
<tr>
<td>NCAR CFDDA</td>
<td>MM5 (regional model)+ FDDA</td>
<td>~40 km</td>
<td>1985-2005</td>
<td>hourly</td>
</tr>
<tr>
<td>CFSR</td>
<td>NCEP GFS (global forecast system)</td>
<td>~38 km</td>
<td>1979-2009 (&amp; updating)</td>
<td>hourly</td>
</tr>
</tbody>
</table>
Datasets terrain: elevation and roughness

Topography: surface description

Elevation

Shuttle Radar Topography Mission (SRTM) resolution 90 - 30 m

Viewfinder, compiles SRTM and other datasets resolution 90 - 30 m

ASTER Global Digital Elevation Model (ASTER GDEM) resolution 30 m

Land cover

ESA GlobCover resolution 300 m

Modis, land cover classification resolution 500 m
Challenges in determining surface roughness

**GLOBCOVER**

- European Space Agency initiative
- January – December 2009
- Global 300m resolution
- 22 Classes
- Data gaps near poles
  - Limited number of overpasses
  - Large number of cloudy images

<table>
<thead>
<tr>
<th>Value</th>
<th>GlobCover global legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Post-flooding or irrigated croplands</td>
</tr>
<tr>
<td>14</td>
<td>Rainfed croplands</td>
</tr>
<tr>
<td>20</td>
<td>Mosaic Cropland (50-70%) / Vegetation (grassland, shrubland, forest) (20-50%)</td>
</tr>
<tr>
<td>30</td>
<td>Mosaic Vegetation (grassland, shrubland, forest) (50-70%) / Cropland (20-50%)</td>
</tr>
<tr>
<td>40</td>
<td>Closed to open (&gt;15%) broadleaved evergreen and/or semi-deciduous forest (&gt;5m)</td>
</tr>
<tr>
<td>50</td>
<td>Closed (&gt;40%) broadleaved deciduous forest (&gt;5m)</td>
</tr>
<tr>
<td>60</td>
<td>Open (15-40%) broadleaved deciduous forest (&gt;5m)</td>
</tr>
<tr>
<td>70</td>
<td>Closed (&gt;40%) needleleaved evergreen forest (&gt;5m)</td>
</tr>
<tr>
<td>90</td>
<td>Open (15-40%) needleleaved deciduous or evergreen forest (&gt;5m)</td>
</tr>
<tr>
<td>100</td>
<td>Closed to open (&gt;15%) mixed broadleaved and needleleaved forest (&gt;5m)</td>
</tr>
<tr>
<td>110</td>
<td>Mosaic Forest/Shrubland (50-70%) / Grassland (20-50%)</td>
</tr>
<tr>
<td>120</td>
<td>Mosaic Grassland (50-70%) / Forest/Shrubland (20-50%)</td>
</tr>
<tr>
<td>130</td>
<td>Closed to open (&gt;15%) shrubland (&lt;5m)</td>
</tr>
<tr>
<td>140</td>
<td>Closed to open (&gt;15%) grassland</td>
</tr>
<tr>
<td>150</td>
<td>Sparse (&gt;15%) vegetation (woody vegetation, shrubs, grassland)</td>
</tr>
<tr>
<td>160</td>
<td>Closed (&gt;40%) broadleaved forest regularly flooded - Fresh water</td>
</tr>
<tr>
<td>170</td>
<td>Close (&gt;40%) broadleaved semi-deciduous and/or evergreen forest regularly flooded - Saline water</td>
</tr>
<tr>
<td>180</td>
<td>Closed to open (&gt;15%) vegetation (grassland, shrubland, woody vegetation) on regularly flooded or waterlogged soil - Fresh, brackish or saline water</td>
</tr>
<tr>
<td>190</td>
<td>Artificial surfaces and associated areas (urban areas &gt;50%)</td>
</tr>
</tbody>
</table>
## Challenges in determining surface roughness

### Roughness lengths used in the GWA

<table>
<thead>
<tr>
<th>Roughness</th>
<th>GLOBCOVER_Class</th>
<th>Modis_Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>Water bodies</td>
<td>Water</td>
</tr>
<tr>
<td>0.0004</td>
<td>Permanent snow and ice</td>
<td>Snow / Ice</td>
</tr>
<tr>
<td>0.005</td>
<td>Bare areas</td>
<td>Baren or sparsely vegetated</td>
</tr>
<tr>
<td>0.03</td>
<td>Closed to open (&gt;15%) herbaceous vegetation (grassland, savannas or lichens/mosses)</td>
<td>Grasslands</td>
</tr>
<tr>
<td>0.05</td>
<td>Sparse (&lt;15%) vegetation</td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>Post-flooding or irrigated croplands (or aquatic)</td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>Rainfed croplands</td>
<td>Croplands</td>
</tr>
<tr>
<td>0.1</td>
<td>Closed to open (&gt;15%) (broadleaved or needleleaved, evergreen or deciduous) shrubland (&lt;5m)</td>
<td>Closed Shrublands / Open Shrublands</td>
</tr>
<tr>
<td>0.2</td>
<td>Closed to open (&gt;15%) grassland or woody vegetation on regularly flooded or waterlogged soil - Fresh, brackish or saline water</td>
<td>Permanent Wetland</td>
</tr>
<tr>
<td>0.3</td>
<td>Mosaic vegetation (grassland/shrubland/forest) (50-70%) / cropland (20-50%)</td>
<td></td>
</tr>
<tr>
<td>0.3</td>
<td>Mosaic cropland (50-70%) / vegetation (grassland/shrubland/forest) (20-50%)</td>
<td>Cropland / Natural Vegetation Mosaic</td>
</tr>
<tr>
<td>0.5</td>
<td>Closed to open (&gt;15%) broadleaved forest regularly flooded (semi-permanently or temporarily) - Fresh or brackish water</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>Mosaic grassland (50-70%) / forest or shrubland (20-50%)</td>
<td>Savannas</td>
</tr>
<tr>
<td>0.6</td>
<td>Closed (&gt;40%) broadleaved forest or shrubland permanently flooded - Saline or brackish water</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>Closed to open (&gt;15%) broadleaved evergreen or semi-deciduous forest (&lt;5m)</td>
<td>Evergreen Broadleaf Forest</td>
</tr>
<tr>
<td>1.5</td>
<td>Closed (&gt;40%) broadleaved deciduous forest (&gt;5m)</td>
<td>Deciduous Broadleaf Forest</td>
</tr>
<tr>
<td>1.5</td>
<td>Open (15-40%) broadleaved deciduous forest/woodland (&gt;5m)</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>Closed (&gt;40%) needleleaved evergreen forest (&gt;5m)</td>
<td>Evergreen Needle Leaf Forest</td>
</tr>
<tr>
<td>1.5</td>
<td>Open (15-40%) needleleaved deciduous or evergreen forest (&gt;5m)</td>
<td>Deciduous Needle leaf Forest</td>
</tr>
<tr>
<td>1.5</td>
<td>Closed to open (&gt;15%) mixed broadleaved and needleleaved forest (&gt;5m)</td>
<td>Mixed Forest</td>
</tr>
<tr>
<td>1.5</td>
<td>Mosaic forest or shrubland (50-70%) / grassland (20-50%)</td>
<td>Woody Savannas</td>
</tr>
<tr>
<td>1.0</td>
<td>Artificial surfaces and associated areas (Urban areas &gt;50%)</td>
<td>Urban and Built-Up</td>
</tr>
<tr>
<td></td>
<td>No data (burnt areas, clouds,...)</td>
<td></td>
</tr>
</tbody>
</table>
Example output
250 m calculation node spacing
Web user interface, walk through
Roughness length
Orography
WAsP Mesoroughness per sector
Orographic speed-up per sector
Annual mean wind climate

Global Wind Atlas

Large-scale Wind Climatology
Landuse and Roughness
Terrain Height

High-resolution Wind Climatology
GWA 1km 50m
GWA 1km 100m
GWA 1km 200m

Power Density
Roughness Effects

Wind Speed (m/s)

< 1  |  < 2  |  < 3  |  < 4  |  < 5  |  < 6  |  < 7  |  < 8  |  < 9  |  < 10 |  ≤ 11 |  ≤ 12 |  ≤ 13 |  ≤ 14 |  ≤ 15 |  ≤ 16 |  ≤ 17 |  ≤ 18 |  ≤ 19 |  > 19
Selection of aggregation area
Wind rose
Windiest fractile plot
Wind speed distribution
Distribution of mean wind speed over area
Mean annual cycle over area
Still to complete

- Global runs with alternative reanalyses (1000 m)
- Complete verification
- Integration into IRENA global atlas
- Launch – IRENA-coordinated web event, September 2015
Future plans

• Following projects

  – Framework agreement led by ECN (NL) to supply renewable resource data to JRC TIMES-EU energy model.

  – Foundation for data inputs and concepts for server platform for the New European Wind Atlas
    • Roughness mapping improvements
    • Elevation data verification would be of value
    • Model chain development

  – Many possibilities for post processing of data
Global assessments of the technical potential

IPCC Special Report on Renewable Energy Sources and Climate Change: range tech. pot. **19 – 125 PWh / year** (onshore and near shore)

<table>
<thead>
<tr>
<th>Study</th>
<th>Scope</th>
<th>Methods and Assumptions</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Krewitt et al. (2009)</td>
<td>Onshore and offshore</td>
<td>Updated Hoogwijk and Graus (2008), itself based on Hoogwijk et al. (2004), by revising offshore wind power plant spacing by 2050 to 16 MW/km²</td>
<td>Technical</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(more constraints): 440 EJyr</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(limited constraints): 121,000 TWyrl</td>
</tr>
<tr>
<td>Lu et al. (2009)</td>
<td>Onshore and offshore</td>
<td>&gt;20% capacity factor (Class 1); 100 m hub height; 9 MW/km² spacing based on coarse simulated model data set; exclusions for urban and developed areas, forests, inland water, permanent snow/ice; offshore assumes 100 m hub height, 6 MW/km², &lt;92.5 km from shore, &lt;200 m depth, no other exclusions</td>
<td>Technical</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(more constraints): 3,050 EJyr</td>
</tr>
<tr>
<td>Hoogwijk and Graus (2008)</td>
<td>Onshore and offshore</td>
<td>Updated Hoogwijk et al. (2004) by incorporating offshore wind energy, assuming 100 m hub height for onshore, and altering cost assumptions; for offshore, study updates and adds to earlier analysis by Fellows (2000); other assumptions as listed below under Hoogwijk et al. (2004); constrained technical potential defined here in economic terms separately for onshore and offshore</td>
<td>Technical/Economic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(more constraints): 400 EJyr</td>
</tr>
<tr>
<td>Archer and Jacobson (2005)</td>
<td>Onshore and near shore</td>
<td>&gt;Class 3; 80 m hub height; 9 MW/km² spacing; 48% average capacity factor; based on wind speeds from surface stations and balloon-launch monitoring stations; near-shore wind energy effectively included because resource data includes buoys (see study for details); constrained technical potential = 20% of total technical potential</td>
<td>Technical</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(limited constraints): 2,260 EJyr</td>
</tr>
<tr>
<td>WBGU (2004)</td>
<td>Onshore and offshore</td>
<td>Multi-MW turbines; based on interpolation of wind speeds from meteorological towers; exclusions for urban areas, forest areas, wetlands, nature reserves, glaciers, and sand dunes; local exclusions accounted for through corrections related to population density; offshore to 40 m depth, with sea ice and minimum distance to shore considered regionally; constrained technical potential (authors define as 'sustainable' potential) = 14% of total technical potential</td>
<td>Technical</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(limited constraints): 1,000 EJyr</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(more constraints): 140 EJyr</td>
</tr>
</tbody>
</table>
Global assessments of the technical potential

We can use the EUDP Global Wind Atlas to determine global potential accounting for high resolution effects and get a better spatial breakdown.

The challenge is to create a consistent approach, with range of tested assumptions, available for the community to scrutinize.

The Global Wind Atlas makes this easier via

• Transparency of methodology
• Providing data to allow annual energy production calculation
• GIS integration of datasets
Assume 5 MW per km**2 capacity density

Annual production from wind
1 PWh = 1e15 Wh

<table>
<thead>
<tr>
<th>Power density</th>
<th>Capacity factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>0.00</td>
</tr>
<tr>
<td>400</td>
<td>0.25</td>
</tr>
<tr>
<td>600</td>
<td>0.32</td>
</tr>
<tr>
<td>800</td>
<td>0.36</td>
</tr>
<tr>
<td>1000</td>
<td>0.39</td>
</tr>
<tr>
<td>1200</td>
<td>0.42</td>
</tr>
<tr>
<td>1400</td>
<td>0.43</td>
</tr>
<tr>
<td>1600</td>
<td>0.45</td>
</tr>
<tr>
<td>1800</td>
<td>0.46</td>
</tr>
</tbody>
</table>

All: 581 PWh
Exclude complex terrain: 528 PWh
Simple terrain: 344 PWh
Thank you for your attention

Open access to global wind atlas data
Use the data and extend its application
Invite feedback and new ideas

Funding:
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