Wind resource grand challenges: Integration of model and measurements
The Gulf of Suez case study

Søren Krohn, Soren Krohn Consulting, Oriol Lacave & Gil Lizcano, Vortex
Planet Wind: a diversity of wind flow conditions

Wind Resource complexity is more than a “slope of the terrain” issue

It is a multi-scale problem

Global to local initiative: GWA 2.0 -> Mesoscale (Vortex) & Microscale (DTU)
Gulf of Suez:  
- Strong winds  
- Arid conditions  
- Channel effects  
- Complex synoptic frame  
- Sea-land interaction ...  

North of Chile  
South Africa / Gouda Site  
North East of Brazil / Innerlands
2 years of measurements
9.88 m/s, 773 W/m² @ 80m

+ 4 more 80m masts, 1 year of measurements
Wind Resource Grand Challenges

Scale Issue: Models tend to underpredict wind conditions by more than 15%.

- k-shape & wind rose are really well represented.

Source: WB GWA 2.0 Mesolayer (WRF 9 km res)
A set of different resolution & domain **WRF** mesoscale model runs have been computed.

<table>
<thead>
<tr>
<th>Domain</th>
<th>Resolution</th>
<th>Period</th>
<th>Output</th>
<th>Driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regional</td>
<td>3Km</td>
<td>LT</td>
<td>Wind Resource Grid</td>
<td>CFSR ERA5</td>
</tr>
<tr>
<td>Regional</td>
<td>1Km</td>
<td>LT</td>
<td>Wind Resource Grid</td>
<td>CFSR ERA5</td>
</tr>
<tr>
<td>Project</td>
<td>500m</td>
<td>LT</td>
<td>Wind Resource Grid</td>
<td>ERA5</td>
</tr>
<tr>
<td>Project</td>
<td>100m</td>
<td>MP</td>
<td>Time SERIES (LES)</td>
<td>ERA5</td>
</tr>
<tr>
<td>Project</td>
<td>3Km</td>
<td>LT</td>
<td>Time Series</td>
<td>ERA5</td>
</tr>
</tbody>
</table>

LT=Long-term  
MP= concurrent with available measurements
### Model & Data

<table>
<thead>
<tr>
<th>REANALYSIS</th>
<th>MERRA</th>
<th>ERA-Interim</th>
<th>CFS-CFSR</th>
<th>MERRA2</th>
<th>ERA5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation</td>
<td>Third</td>
<td>3.5 *</td>
<td>Fourth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resolution</td>
<td>Hourly / 0.5° x 0.667° 72 levels</td>
<td>4xday 0.75° x0.75° 72 levels</td>
<td>Hourly 0.5°x 0.5° 64 level</td>
<td>Hourly 0.5° x 0.667° 72 levels</td>
<td>Hourly 30Km (/2) 137 levels (X2)</td>
</tr>
<tr>
<td>Latency (weeks)</td>
<td>4</td>
<td>12</td>
<td>1</td>
<td>2</td>
<td>Deterministic &amp; Ensemble (10 members)</td>
</tr>
<tr>
<td>User Notes</td>
<td>Overall good correlation</td>
<td>Arrived late *</td>
<td>Inconsistent SFC but Consistent 3D fields</td>
<td>Aerosol Assimilation</td>
<td></td>
</tr>
</tbody>
</table>

![Re-Analysis Diagram](image)

![Mesoscale Model](image)
Model & Data

3KM

1KM

500 m
## Validation

<table>
<thead>
<tr>
<th>Domain</th>
<th>Resolution</th>
<th>Period</th>
<th>Output</th>
<th>Driver</th>
<th>Mean Speed</th>
<th>k-shape</th>
<th>Power Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regional</td>
<td>9Km</td>
<td>LT</td>
<td>Wind Resource Grid</td>
<td>ERA-Interim</td>
<td>-17.53%</td>
<td>-5.41%</td>
<td>-42.03%</td>
</tr>
<tr>
<td>Regional</td>
<td>3Km</td>
<td>LT</td>
<td>Wind Resource Grid</td>
<td>CFSR</td>
<td>-12.37%</td>
<td>-3.04%</td>
<td>-31.50%</td>
</tr>
<tr>
<td>Regional</td>
<td>1Km</td>
<td>LT</td>
<td>Wind Resource Grid</td>
<td>CFSR</td>
<td>-17.53%</td>
<td>-5.07%</td>
<td>-42.16%</td>
</tr>
<tr>
<td>Project</td>
<td>500m</td>
<td>LT</td>
<td>Wind Resource Grid</td>
<td>ERA5</td>
<td>-4.12%</td>
<td>-1.69%</td>
<td>-11.00%</td>
</tr>
<tr>
<td>Project</td>
<td>100m</td>
<td>MP</td>
<td>Time SERIES (LES)</td>
<td>ERA5</td>
<td>-2.06%</td>
<td>-0.33%</td>
<td>-5.87%</td>
</tr>
</tbody>
</table>
Global Wind Atlas 2.0 Microscale check:
10m/s, 750W/m² @ 100m
2-Year Measurements

9.88 m/s, 773 W/m$^2$ @ 80m

~ 10.0 m/s 802 W/m$^2$ @ 100m
Wind resource complexity has a multiscale source.

At Mesoscale level, drivers & resolution are critical.

ERA5 show very promising results.

Gulf of Suez Challenge is done.
Epilogue: a map of difference between ERA5 & MERRA-2

Monthly correlation (R2)
ERA5-MERRA-2 (2010-2016)
Wind resource grand challenges: Integration of model and measurements
The Gulf of Suez case study

Søren Krohn, Soren Krohn Consulting, Oriol Lacave & Gil Lizcano, Vortex