Obtaining Offshore Wind Climatology for Renewable Energy and Other Research

S. V. Nghiem
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California, USA

Copyright 2010 California Institute of Technology. Government Sponsorship acknowledged.
Notable Developments

• The Copenhagen Summit: UN COP-15, 12-2009
• Energy & Climate Ministerial of the Americas: DC 4-2010
• Energy Innovation Summit: ARPA-E, DC 3-2010
• Wind energy contributes to the overall energy portfolio
Offshore Wind Climatology

• Critical for offshore wind power development

• Buoys: sparse point data

• Models: different values, boundary, need verified

• New breakthrough for offshore wind measurement using satellite data
NASA Earth Satellite Missions

OSTM/Jason 2
QuikSCAT
ACRIMSAT
Landsat 7
NMP/EO-1
Aqua
SORCE
GRACE
ICESat
TRMM
Terra
CALIPSO
Aura
CloudSat
NASA SeaWinds Mission

- Launched on the QuikSCAT satellite on 19 June 1999
- Orbited the Earth 14 times per day
- Collected global data for 10 years till November 2009
- Circled the Earth > 2 billion kilometers
The scatterometer is a stable and accurate radar

- 60 Watts power: like a light bulb in your house
- 800 km out in space: Cancún to Guatemala city
Ocean Wind Measurement across the World

- Covering 90% of the world in one day
- Coarse resolution of 25 km
- Valid at 50-60 km away from shore
The 1999 Orissa Disaster: In middle of October, a super cyclone hit Orissa in eastern India causing severe flooding. Shortly afterward, another one hit Orissa again causing more destruction and damages. This disaster affected 15 million people according to United Nations’ report.
QuikSCAT Scatterometer Data

- Conical scan with constant incidence angles
- Drifting orbits allow more azimuth diversity
- Footprint of radar around 25 km x 37 km
- Chirp transmission to get slice data: 6 km x 25 km
The New Method

\[ P_{Ri} = \frac{P_{Ti} \lambda^2}{(4\pi)^3 R^4} \int \int_A dx \, dy \, G(\phi_i, x, y) \, \sigma_0(\phi_i, t_i, x, y) \]

\[ P_{Ri} = \frac{P_{Ti} \lambda^2}{(4\pi)^3 R^4} \, \overline{\sigma}_0(\phi_i, t_i) \int \int_A dx \, dy \, G(\phi_i, x, y) \]

\[ \overline{\sigma}_0(\phi_i, t_i) = \frac{1}{\Gamma_A} \int \int_A dx \, dy \, G(\phi_i, x, y) \, \sigma_0(\phi_i, t_i, x, y) \]
The New Method

\[ \overline{\sigma}_0 = \frac{1}{N} \sum_{i=1}^{N} \overline{\sigma}_0(\phi_i, t_i) = \frac{1}{N \Gamma_A} \sum_{i=1}^{N} \int_A dx \, dy \, G(\phi_i, x, y) \, \sigma_0(\phi_i, t_i, x, y) \]

\[ \sigma_0(\phi_i, t_i, x, y) = \overline{\sigma}_0(x, y) + \varepsilon(\phi_i, t_i, x, y) \]

\[ \overline{\sigma}_{0M} = \frac{1}{\Gamma_A} \int_A dx \, dy \left[ \sum_{i=1}^{N} \frac{G(\phi_i, x, y)}{N} \right] \overline{\sigma}_0(x, y) \]

\[ \mathcal{R} = \frac{1}{\Gamma_A} \int_A dx \, dy \sum_{i=1}^{N} \left[ \frac{G(\phi_i, x, y)}{N} \varepsilon(\phi_i, t_i, x, y) \right] \]
Effective Footprints

Original
Slice
High res
Simulation
Verification - Príncipe Island
Procedure to Obtain Global Offshore Wind Climatology

- Use the DECADE of NASA QuikSCAT satellite scatterometer collected GLOBALLY
- Apply the new method for high-resolution data processing over offshore waters
- Calculate wind fields from empirical formulation [Yueh et al., 2001; Nghiem et al., 1997, …]
- Validate high-resolution results with available surface measurements from buoys and ships
- Variability at different time scales: Diurnal, seasonal, and interannual

ATLAS of HIGH-RESOLUTION WIND
Offshore Wind Pattern Of Hawaiian Islands
### National Renewable Energy Laboratory (NREL) Wind Power Classes

Table 1-1 Classes of wind power density at 10 m and 50 m\(^{(a)}\).

<table>
<thead>
<tr>
<th>Wind Power Class(^*)</th>
<th>10 m (33 ft)</th>
<th>50 m (164 ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wind Power Density (W/m(^2))</td>
<td>Speed(^{(b)}) m/s (mph)</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>4.4 (9.8)</td>
</tr>
<tr>
<td>3</td>
<td>150</td>
<td>5.1 (11.5)</td>
</tr>
<tr>
<td>4</td>
<td>200</td>
<td>5.6 (12.5)</td>
</tr>
<tr>
<td>5</td>
<td>250</td>
<td>6.0 (13.4)</td>
</tr>
<tr>
<td>6</td>
<td>300</td>
<td>6.4 (14.3)</td>
</tr>
<tr>
<td>7</td>
<td>400</td>
<td>7.0 (15.7)</td>
</tr>
<tr>
<td>7</td>
<td>1000</td>
<td>9.4 (21.1)</td>
</tr>
</tbody>
</table>

Comparison with NREL Classes
Translucent Overlay on NREL Wind Power Classes
Translucent Overlay on Bathymetry
Other Science Research and Applications

- Oceanography
- Coral biodiversity
- Aviation safety
- Tourist information
- Urban/suburban
Mexico City
Mexico City
Looking into the Future: Decadal Survey Mission Recommendations

Significant Wave Height: Wave Energy Resource
Contact
Son.V.Nghiem@jpl.nasa.gov