Improving Gap Flow Simulations Near Coastal Areas of Continental Portugal

11th Deep Sea Offshore Wind R&D Conference
Trondheim, 22-24 January 2014

Section Met Ocean Conditions

paulo.costa@lneg.pt  antonio.couto@lneg.pt  raquel.marujo@lneg.pt  ana.estanqueiro@lneg.pt
amouche@cls.fr
Gap Flows

- Gap flows are locally generated wind currents that spread abruptly to the ocean, triggered by non-linear atmospheric phenomena.
- Its intensity and spreading may bring several impacts near coastal areas in particularly where offshore wind parks can be deployed.
• Modelling this phenomena is still a challenge from the meteorological point of view since models still not reproduce efficiently way gap flows, especially, the ones occurring very near the coasts.

• A high resolution satellite SAR image is nowadays the “best observational spatial wind tool” to detect the phenomena in action
Gap Flows in Portugal

- At 9th December 2010 strong gap flows were identified along some western coastal regions of Continental Portugal.

- This region contains several promising sea areas with high sustainable wind resource for offshore wind park’s deployment.
Gap Flows in Portugal

The phenomena in action...

This “zoomed” SAR image on day, 9th December 2010 @ ~ 22:30h shows the gap flows (surface).

“red zones” wind speeds ~ 20 to 30m/s
“green zones” – vicinity ~ 10 to 13 m/s
“blue zones” -around ~ 3 to 6 m/s
LNEG operates three anemometric masts in the region. At that day & time, observed mean wind speed and direction was:

IN01 (sensor height 10m):
~ 9.86 m/s ; ~ 90°

IN33 (sensor height 10m):
~ 8.76 m/s ; 65°

IN166 (sensor height 21m):
~ ? m/s ; ?°
(data with -9999 error code)
Gap Flow Simulation

Simulation tasks:

• To set up a high resolution mesoscale simulation with the WRF model for the case study day (09.12.2010);

• To use the 3D-VAR data assimilation technique;

• To compare model’s results with and without data assimilation and to validate the simulated wind flow with LNEG’s anemometric masts
Assimilation advantages

- Assimilation of observations will reduce error forecasts
- Reducing error forecasts means getting better forecasts!
A “BLUE” method ...

"Best Linear Unbiased Estimate"

$\cong$ Kalman Filter

$$\mathbf{x}^a = \mathbf{x}^b + d\mathbf{x}$$

$$= \mathbf{x}^b + K (\mathbf{y}^o - H(\mathbf{x}^b))$$

Gain $K = B^H (HB^H + R)^{-1}$

Innovation $d = \mathbf{y}^o - H(\mathbf{x}^b)$

**Mean forecasts @12h - @00h**
As a background “run”

- Three domains covering the area under study; 50x50km ; 10x10km and 2x2km;

- Historical initial and boundary conditions from GFS forecast model @ 0.5x0.5º, ingested every three hours;

- Running period:
  1 day - 1200h 09-12-2010 to 1200h 10-12-2010
Setup WRF model …

Assimilation “run” - 3D-VAR

- Assimilated “SAR” wind data image at 21h (09-12-2010) @ all model domains;

- Assimilated surface synoptic data at 12h, 18h and 21h from LPPT Lisbon station \( (T,Hr,P,U,V) \);

- Assimilated IN01 & IN33 at 12h, 18h and 21h;

- Validation: IN01 & IN33 (daily period)
WRF forecasted results (2x2km) – (surface) @ **2200h** 09-12-2010

**Control run**

*No assimilation.*

**Assimilation run**

*SAR data*

Assimilation improvement
WRF forecasted results (2x2km) – (surface)
from 1200h 09-12-2010 to 1200h 10-12-2010

Wind speed comparison (m/s) @ IN01 (h=10m)

<table>
<thead>
<tr>
<th></th>
<th>Correl –NA (%)</th>
<th>Correl – A (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>77.22</td>
<td>83.19</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wind speed (m/s) @ 22h</th>
<th>WRF-NA</th>
<th>WRF-A</th>
<th>Obs</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRF-NA</td>
<td>8.18</td>
<td>8.21</td>
<td>9.60</td>
</tr>
<tr>
<td>Obs</td>
<td>8.29</td>
<td>7.98</td>
<td>7.83</td>
</tr>
</tbody>
</table>

**FORCED:**
- 3D-VAR @ 12h & 18h
- IN01 + IN33 + synoptic LPPT
- **FORCED:** 3D-VAR @ 21h
- SAR + IN01 + IN33 + synoptic LPPT

**Gap Flow event**

**Assim. run**
- Obs IN01

**“background run”**

**WRF-NA**

**WRF-A**
• Observational assimilated data slightly improved WRF forecasted estimates in IN01 place - very near to the coast.

• SAR image helped in the description of the phenomena - with positive (30%) and negative (-35%) impacts when compared with “background run”. The origins of the phenomena are being studied and further simulations are being conducted in order to improve its performance.

• Other similar coastal phenomena cases will be investigated and, if possible, on other countries’ offshore wind deployment areas.
Thank you!

Improving Gap Flow Simulations Near Coastal Areas of Continental Portugal

11th Deep Sea Offshore Wind R&D Conference
Trondheim, 22-24 January 2014

Section Met Ocean Conditions

This work was partially sponsored by the European Union FP7 under project DEMOWFLOAT

Paulo Costa
paulo.costa@lneg.pt

Ana Estanqueiro
ana.estanqueiro@lneg.pt