MetOcean analysis of a low-level coastal jet off the Norwegian coast.

EERA DeepWind'2014 Deep Sea Offshore Wind R&D Conference, Trondheim, 22 - 24 January 2014

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Low level coastal jet

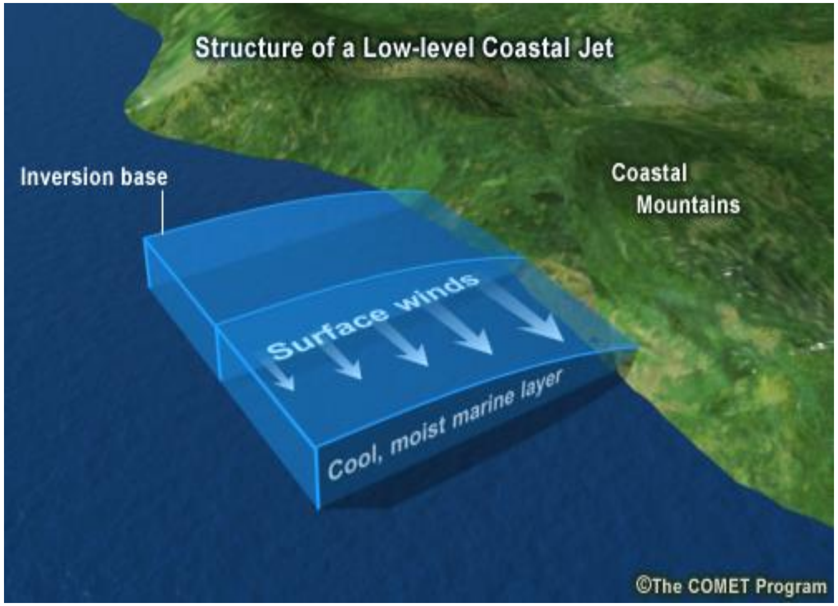
Low-level coastal jet (LLCJ) is a high speed air flow which occur along some coastlines.

Atmospheric conditions that lead to LLCJ:

- A well-mixed, cool and moist MABL which is capped by an inversion.
- Maximum of sea level pressure gradient close to the coast

The low level wind speeds increase and lead to a coastal jet.

- The presence of coastal mountains can keep the air flow parallel to the coastline.



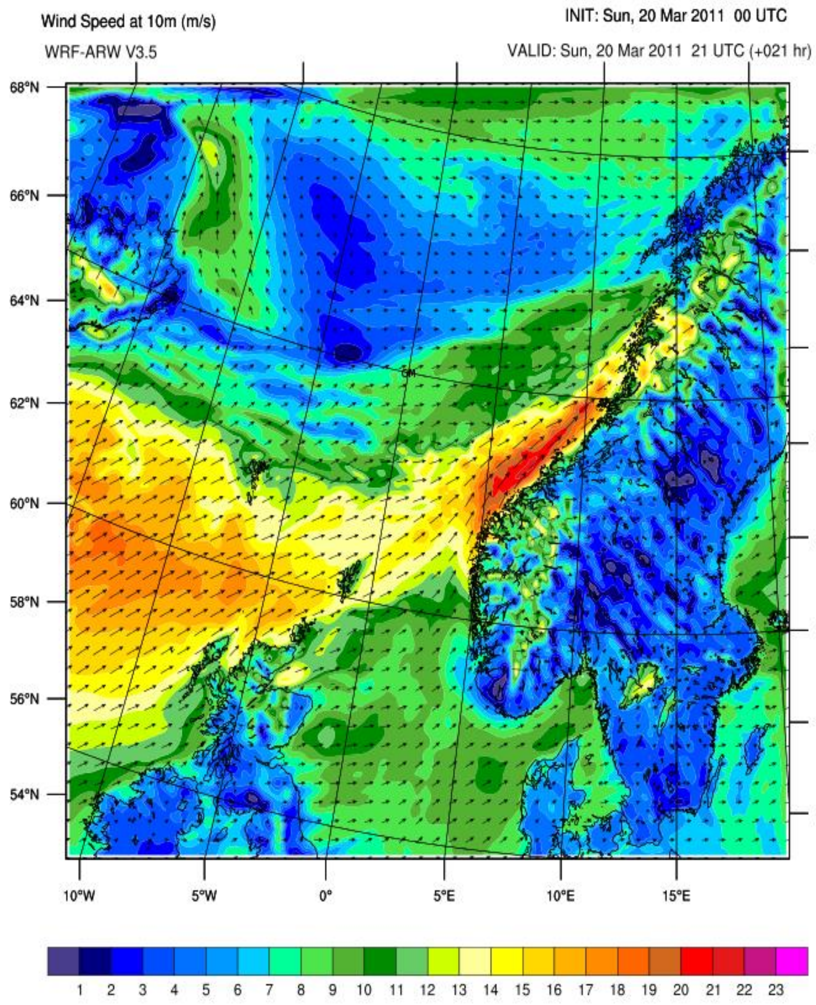
Source: https://www.meted.ucar.edu/mesoprim/coastaljets/

Important for offshore constructions and operations

- High offshore wind speeds (greater than 18 m/s)
- High waves
- Strong vertical wind shear.

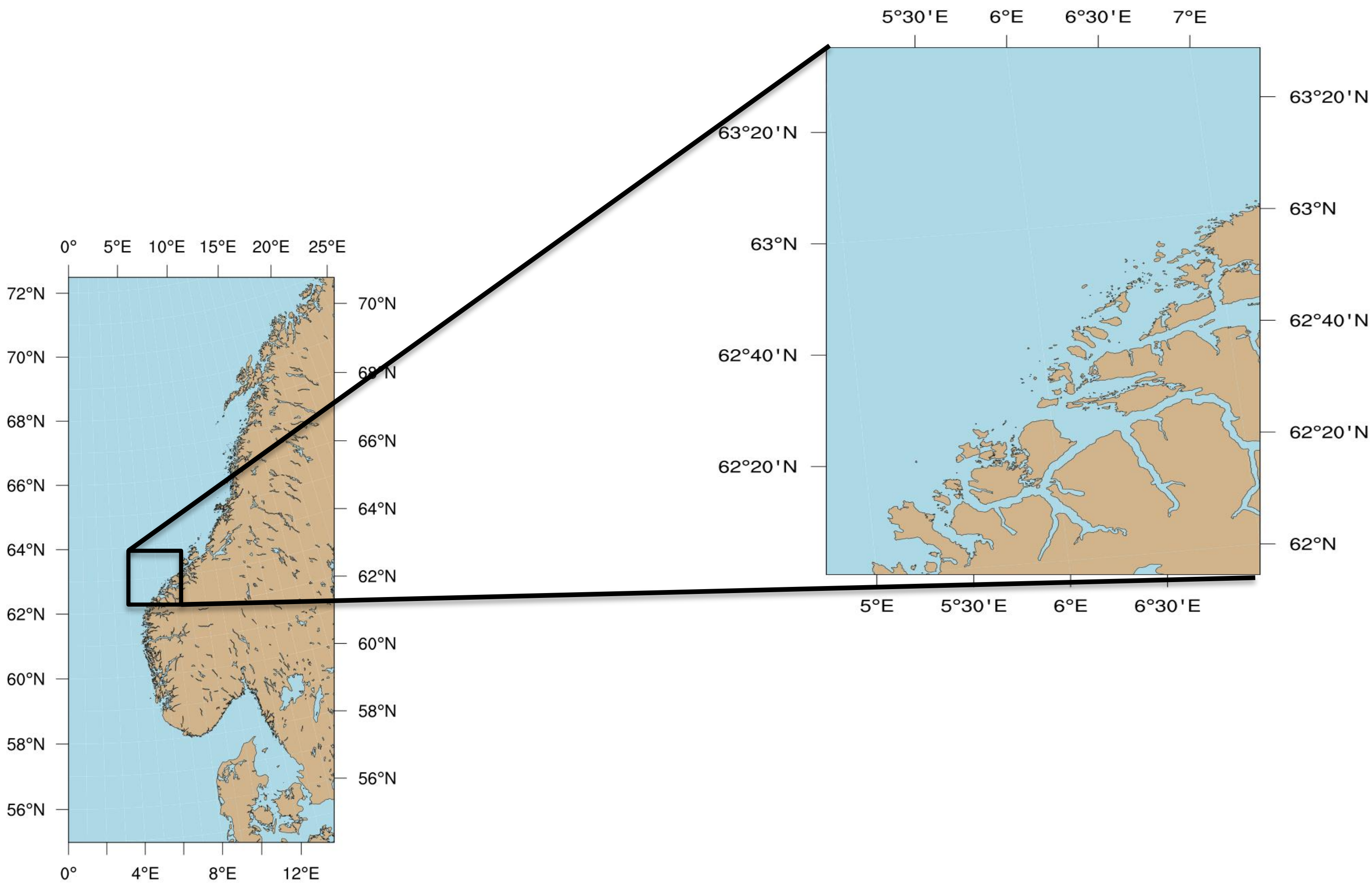
Width of the LLCJ is usually between 20 and 40 km

Source: https://www.meted.ucar.edu/mesoprim/coastaljets/

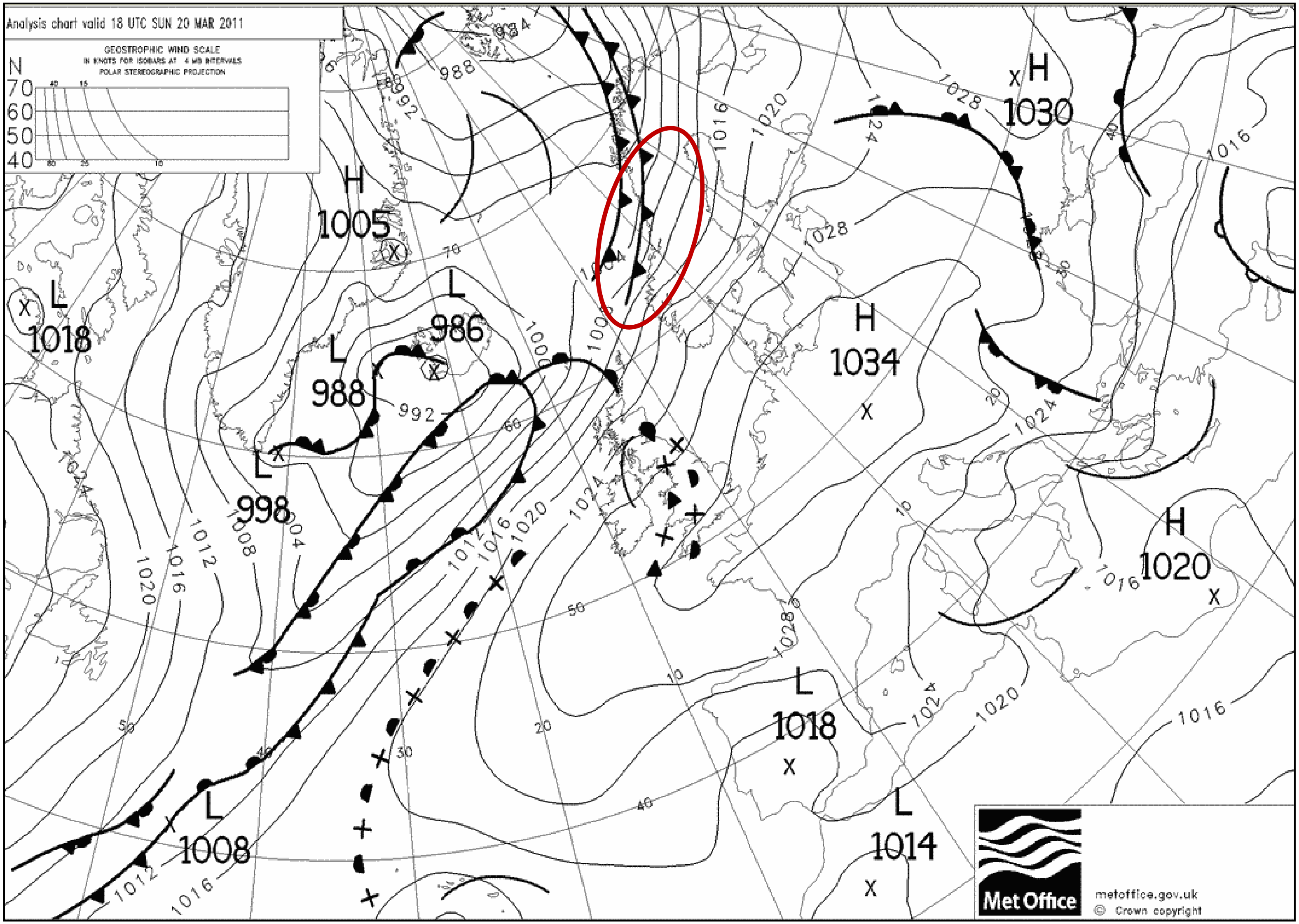


Case study:
Low Level Coastal Jet at Havsul region
20.03.2011

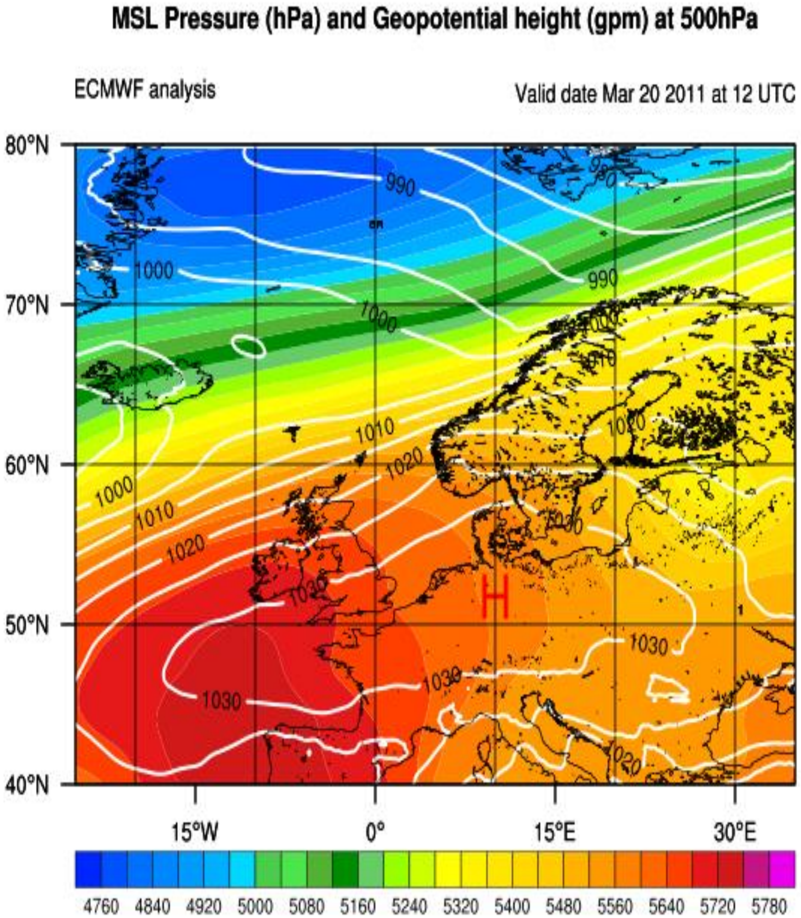
Study area: Havsul region

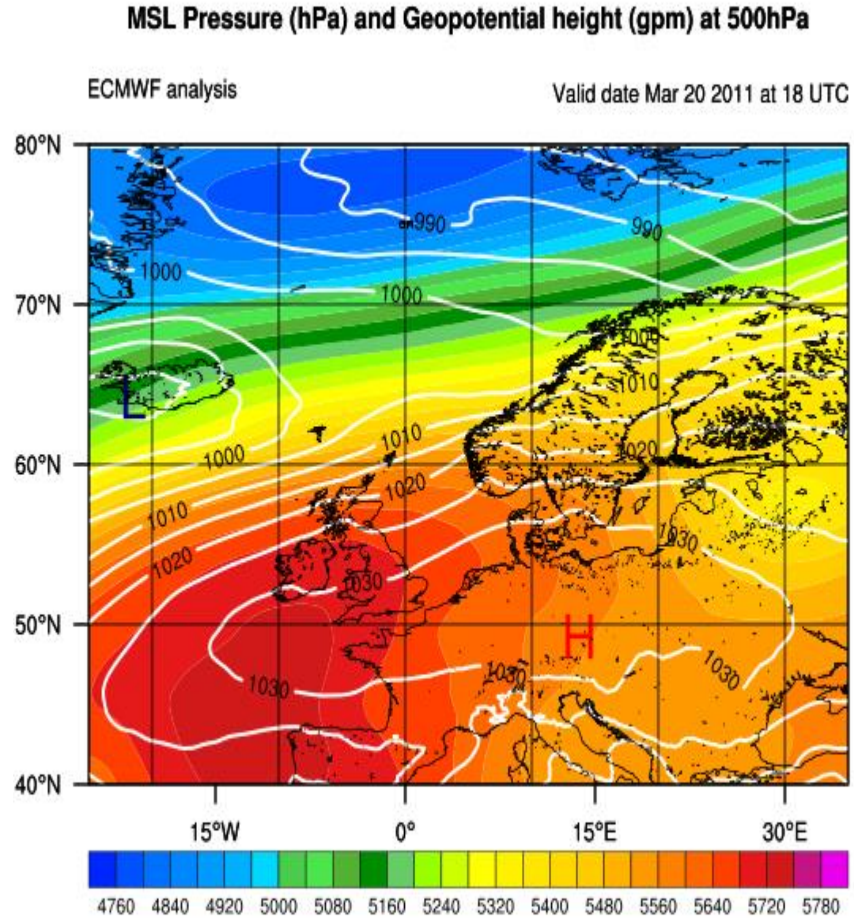


Synoptic Meteorological conditions
18:00 UTC, 20.03.2011



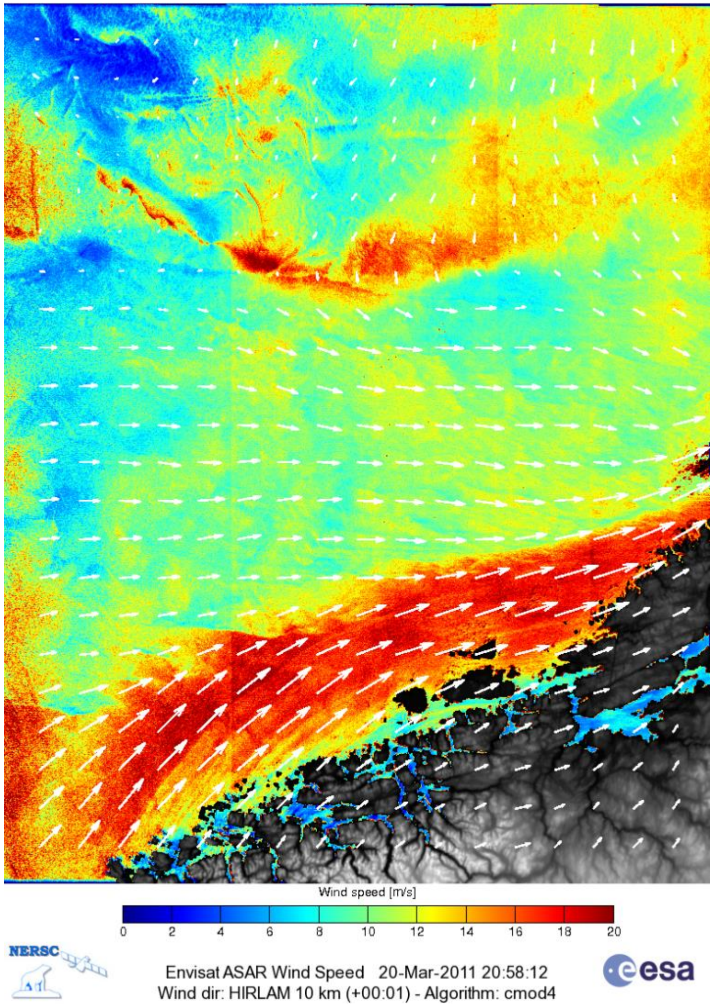
Synoptic Meteorological conditions, 20.03.2011





Observations:
Low level coastal jet at Havsul region
20.03.2011

Satellite Observation
21:00 UTC, 20.03.2011

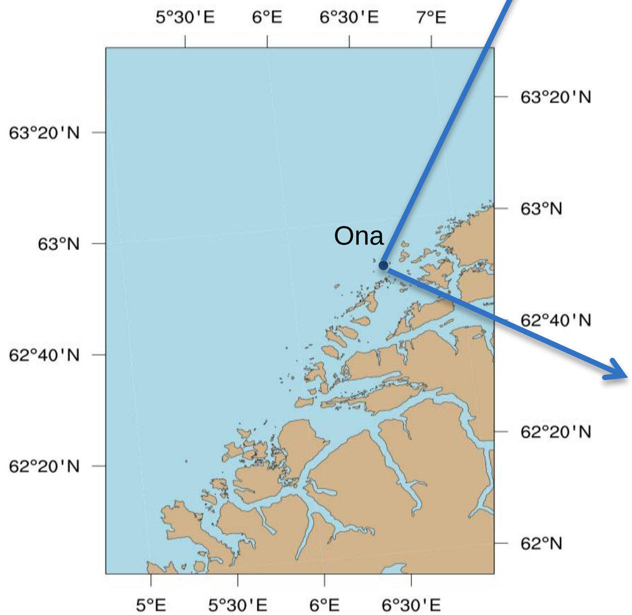


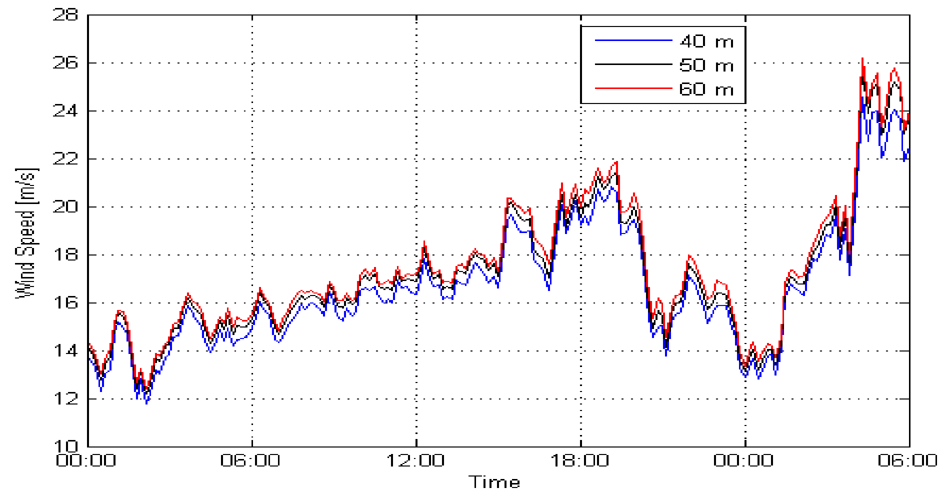
Source: Konstantinos Christakos, Characterization of the coastal marine atmospheric boundary layer for wind energy applications, Bergen Open Research Archive (BORA), June 2013, URI: http://hdl.handle.net/1956/7186

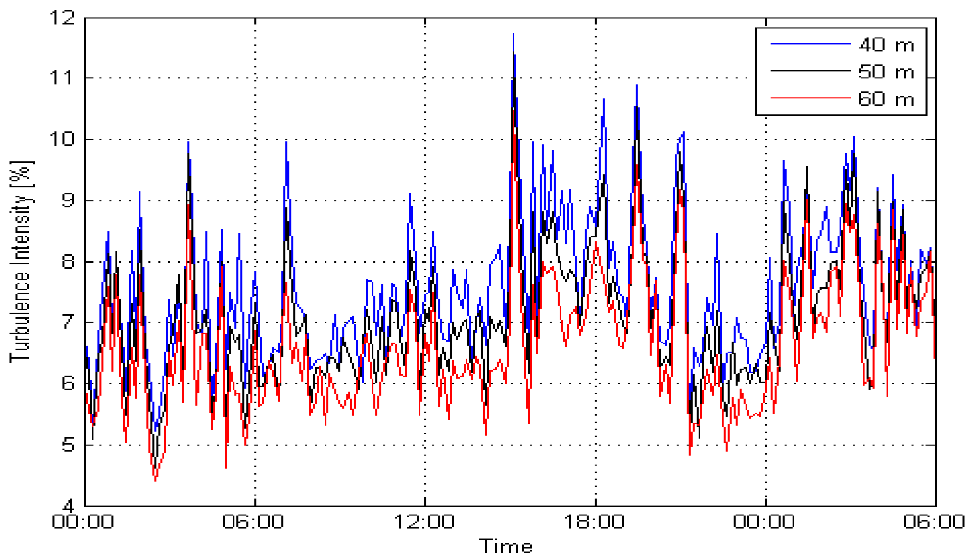
Observations at Ona (20.03.2011 – 21.03.2011)

Wind speed: 12 to 26 m/s

Turbulence Intensity: 5 % - 12 %







Source: Konstantinos Christakos, Characterization of the coastal marine atmospheric boundary layer for wind energy applications, Bergen Open Research Archive (BORA), June 2013,
URI: http://hdl.handle.net/1956/7186

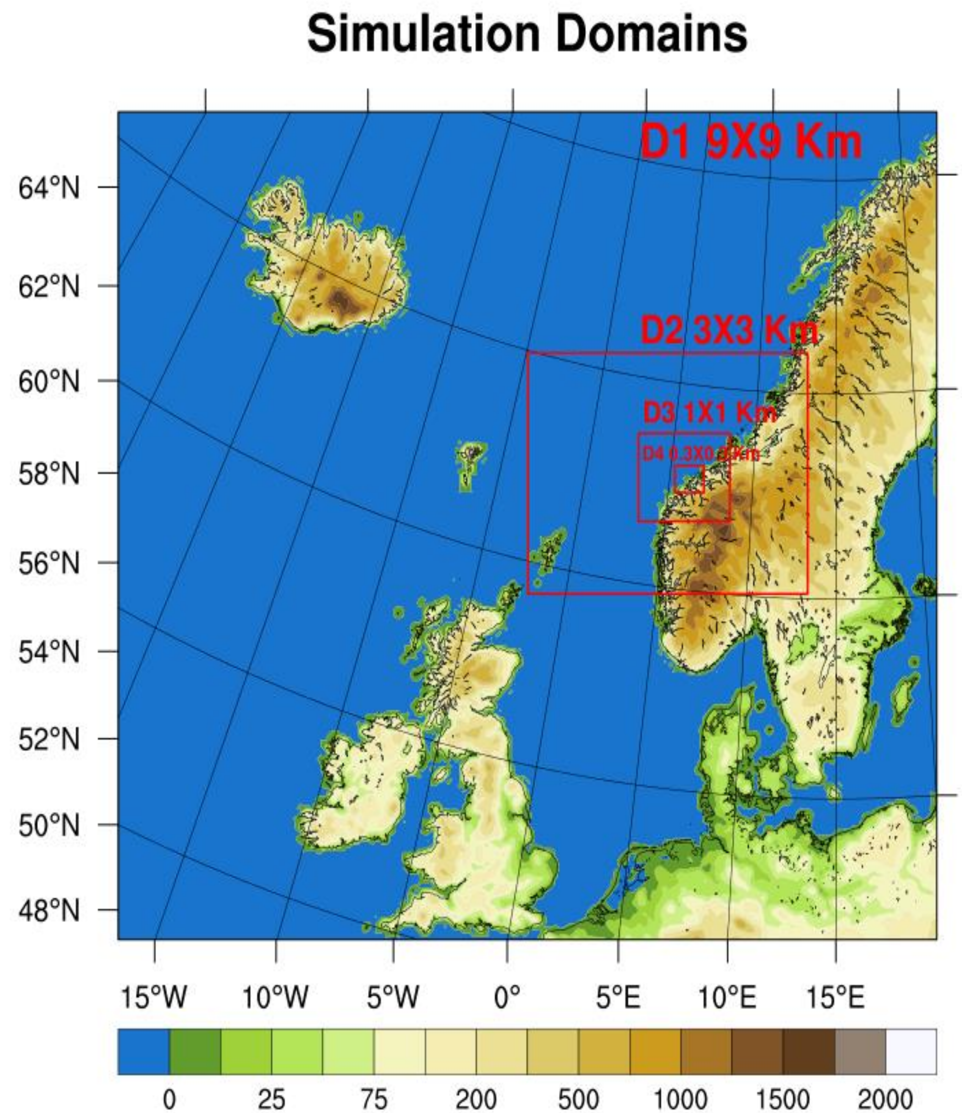
Simulation:
Low level coastal jet at Havsul region
20.03.2011

Model - Set up

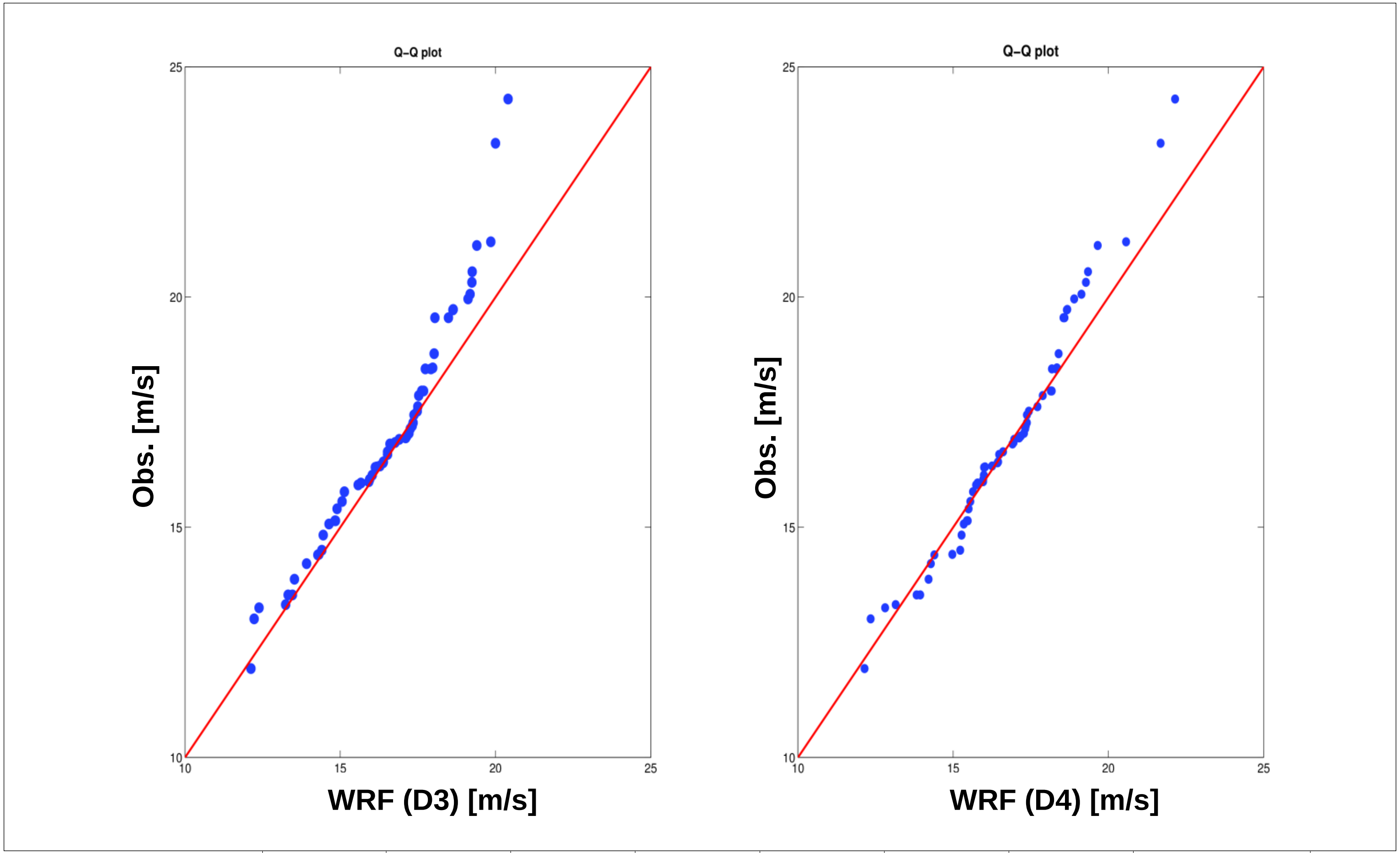
- WRF-ARW V3.5
- Non- Hydrostastic
- 2-way nesting
- Simulation period: 2011 March 20 at 00UTC to 21 at 06UTC

2 simulations:

- 3 Domains : 9x9, 3x3, 1x1 km
- 4 Domains: 9x9, 3x3, 1x1, 1/3x1/3 km



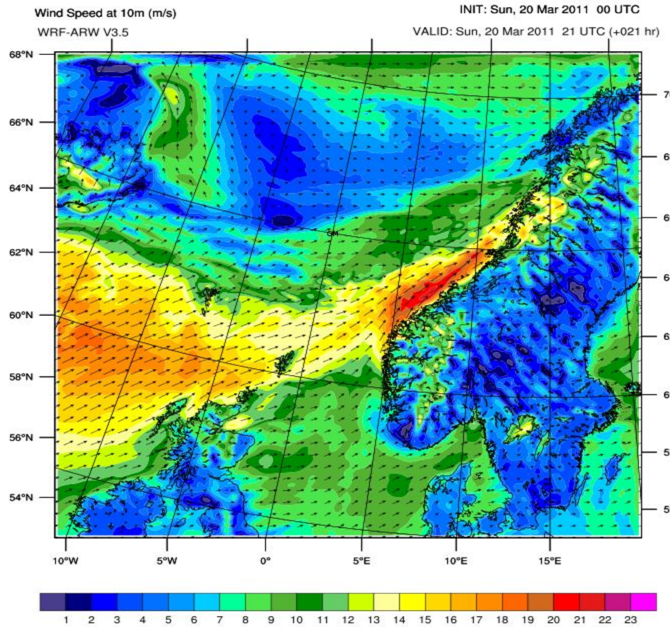
Obs. and WRF (D3 & D4) at 60 m



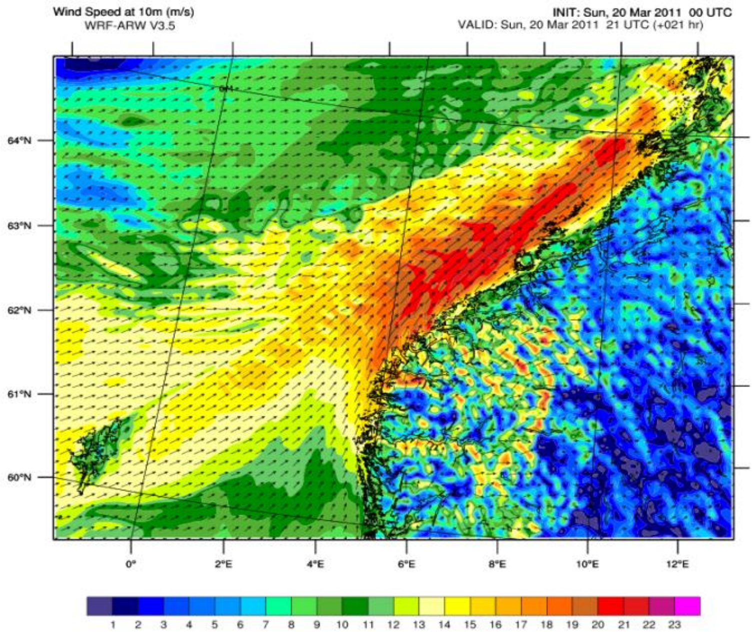
	Min	Max	Median	Mean	Q1	Q3	Std	Mean Error
Obs. [m/s]	11.93	26.21	16.76	17.03	15.34	18.44	2.59	-
WRF (D3) [m/s]	12.12	20.40	16.60	16.48	14.88	17.78	2.02	0.55
WRF (D4) [m/s]	12.15	22.15	16.91	16.77	15.49	18.21	2.08	0.26

WRF simulation of LLCJ
21:00 UTC 20.03.2011

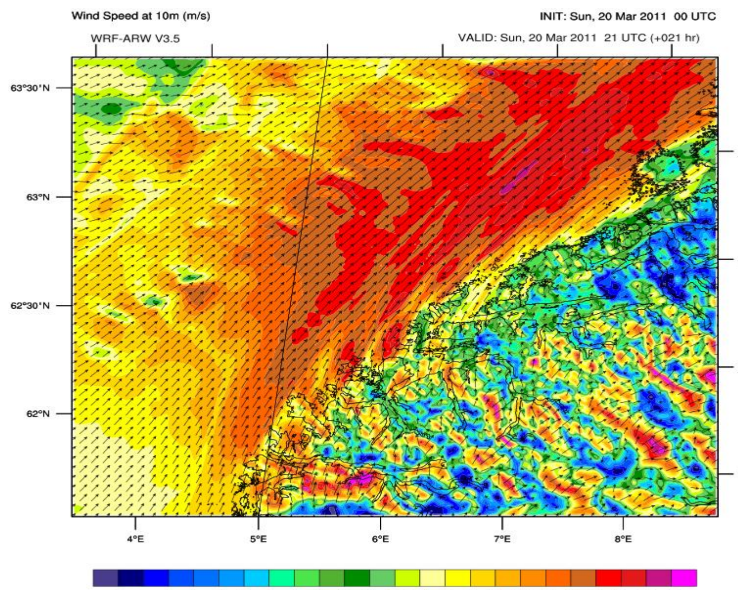
D1



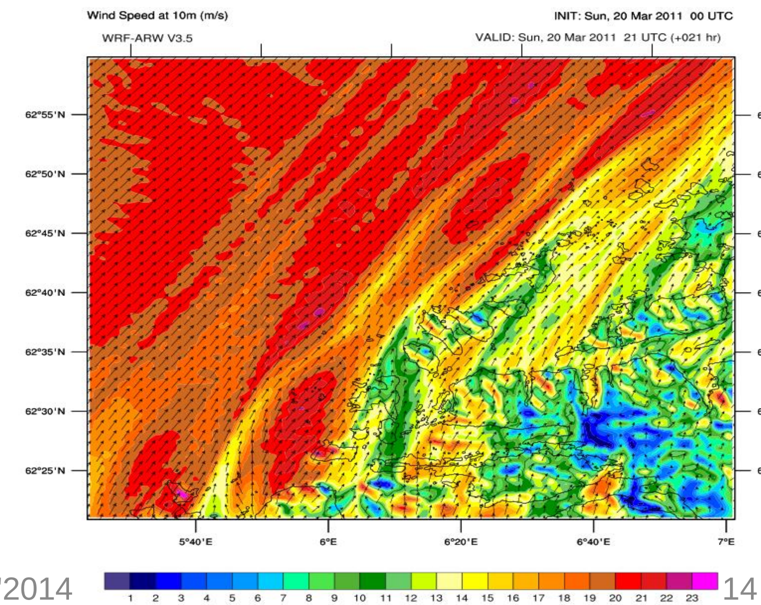
D2



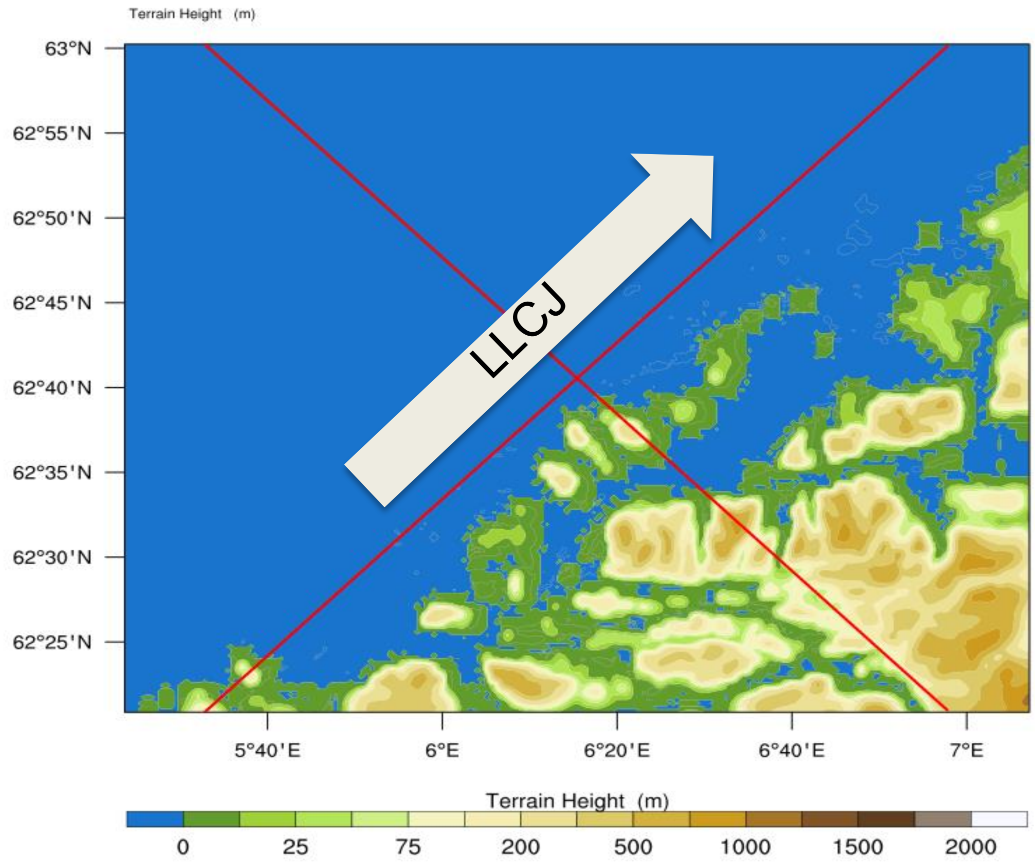
D3



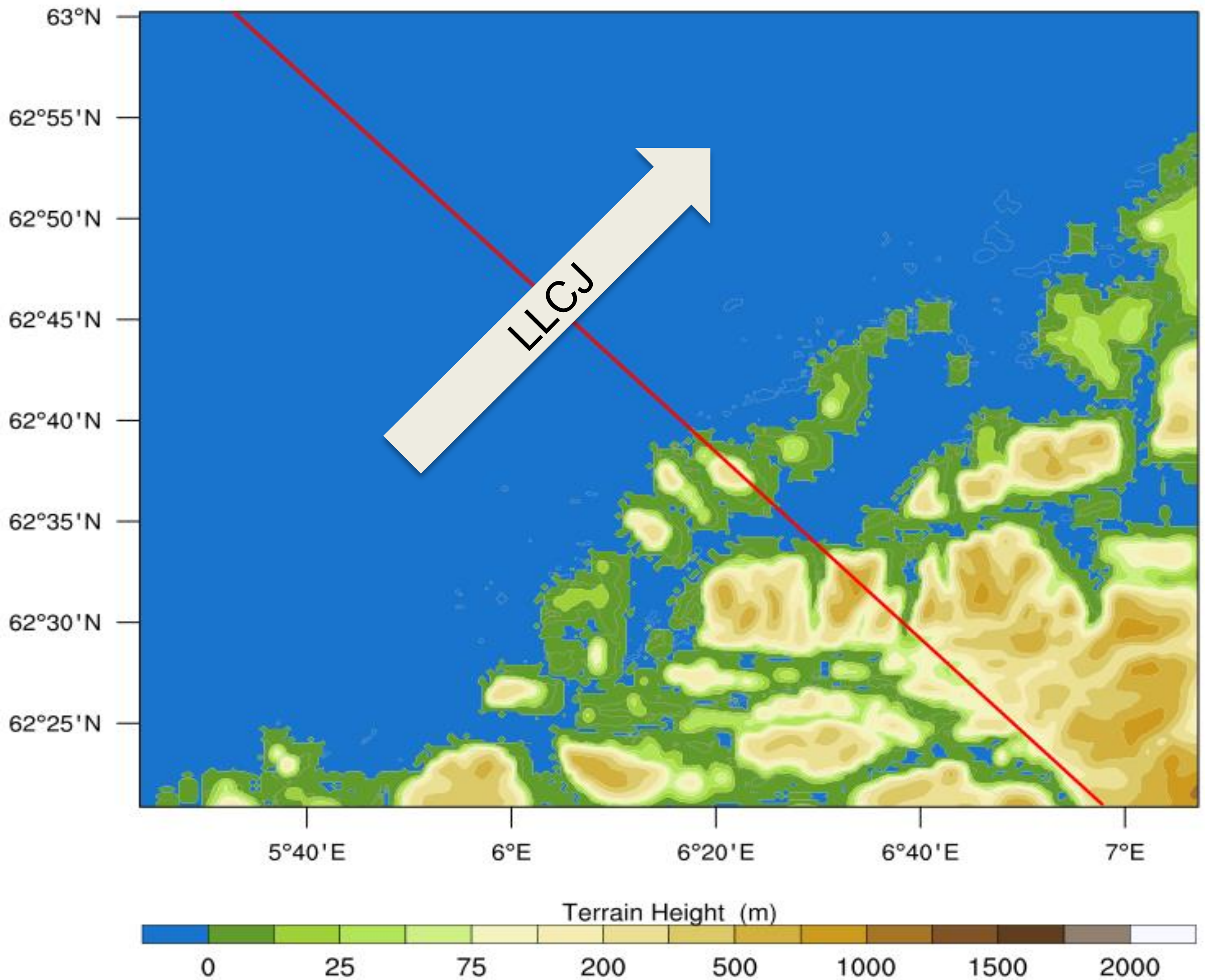
D4

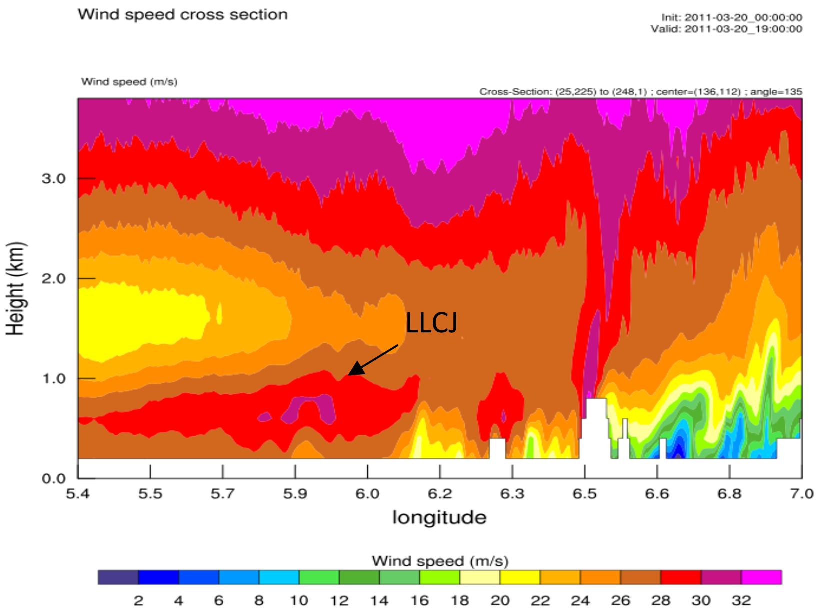


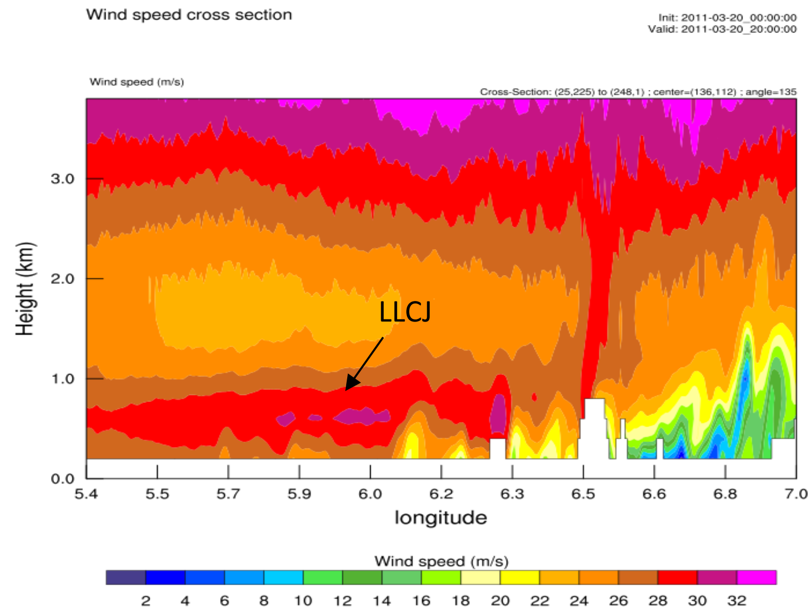
Cross section of wind speed

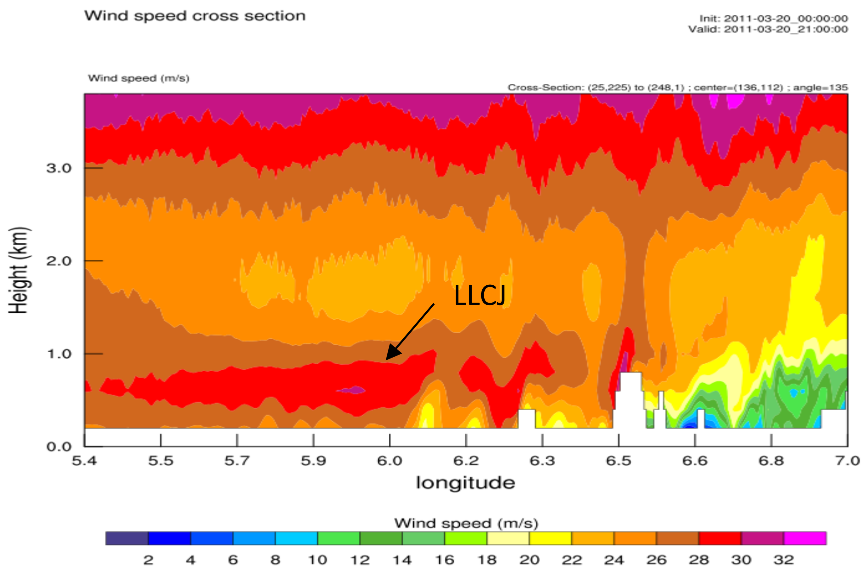


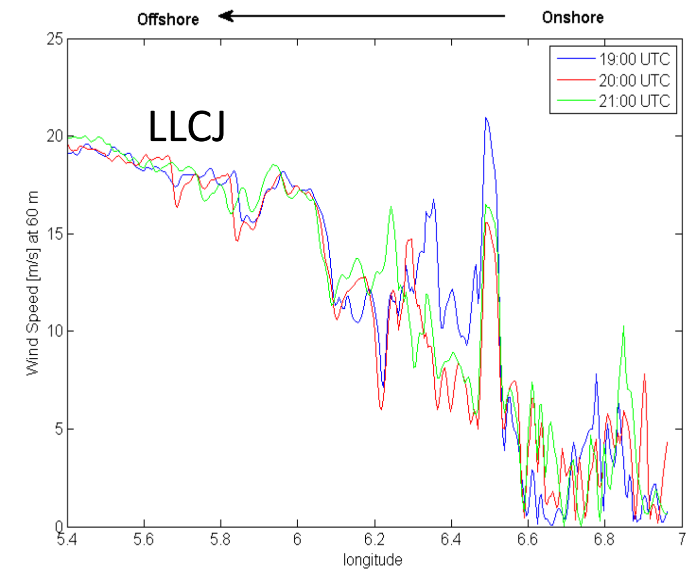
Cross section of wind speed normal to LLCJ





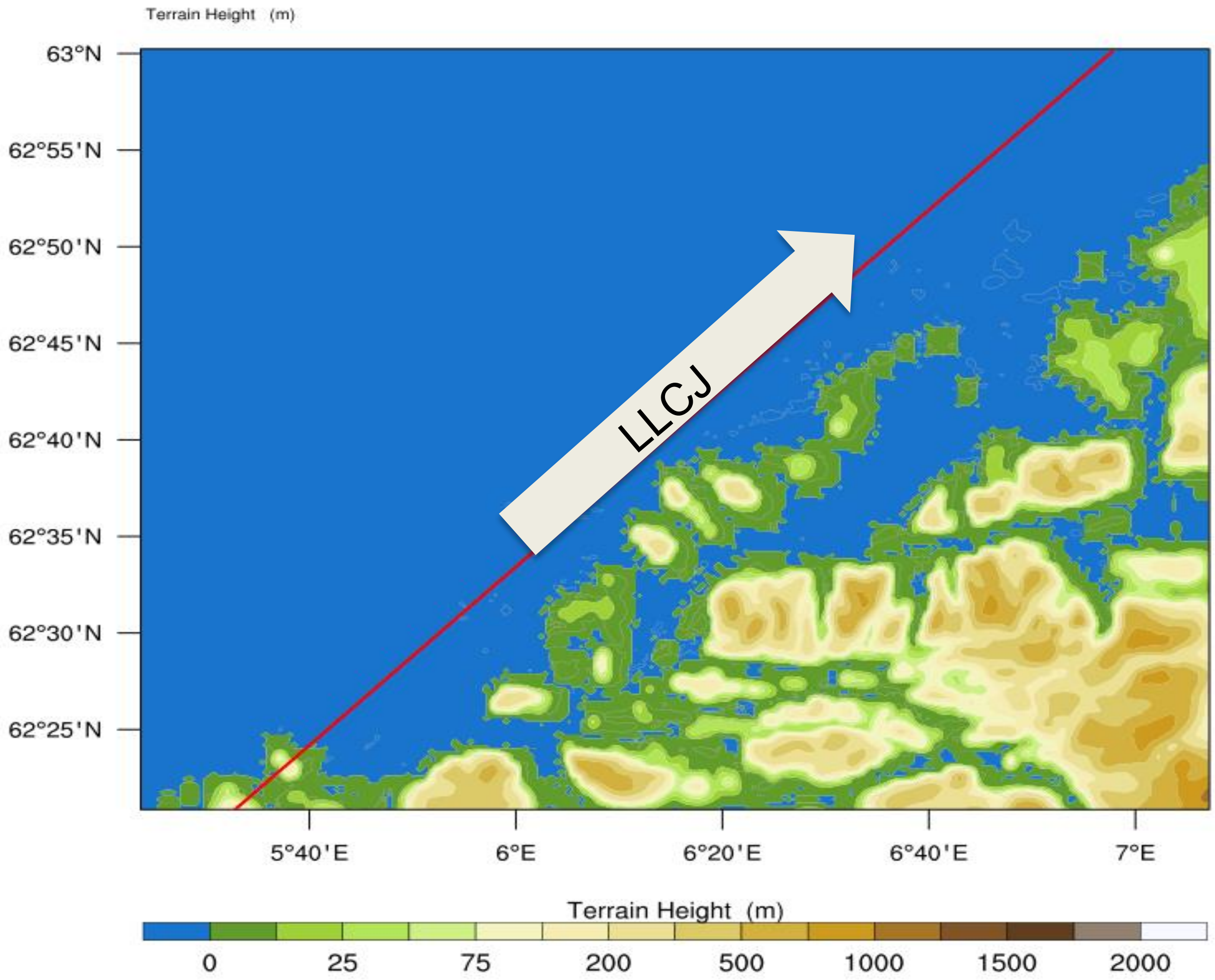


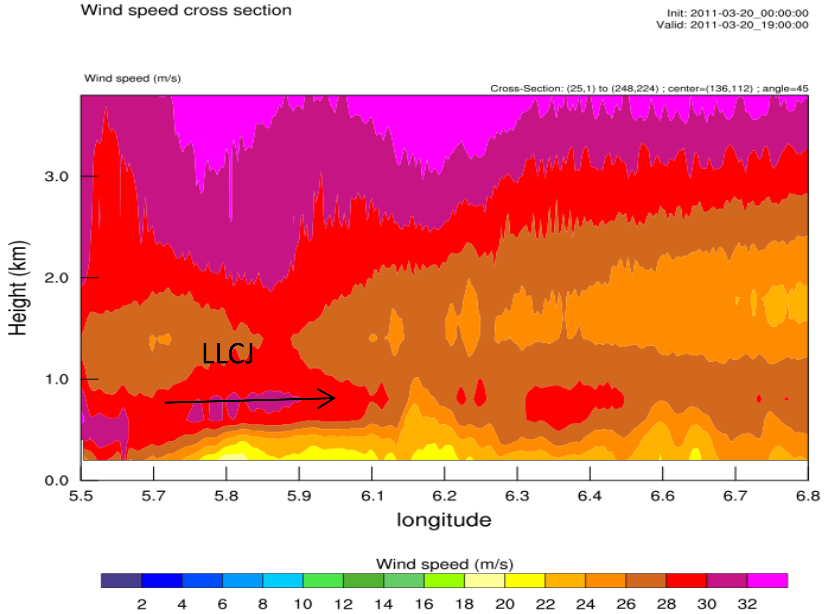


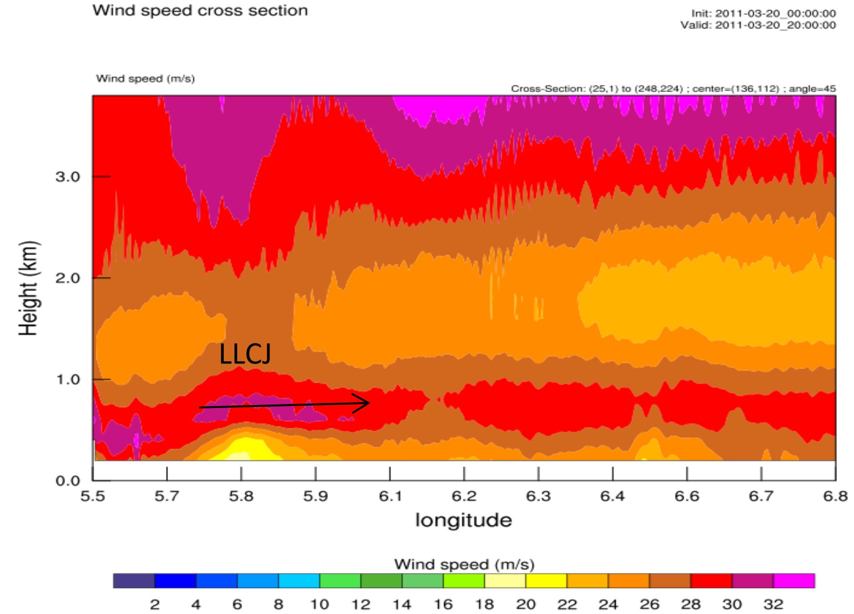


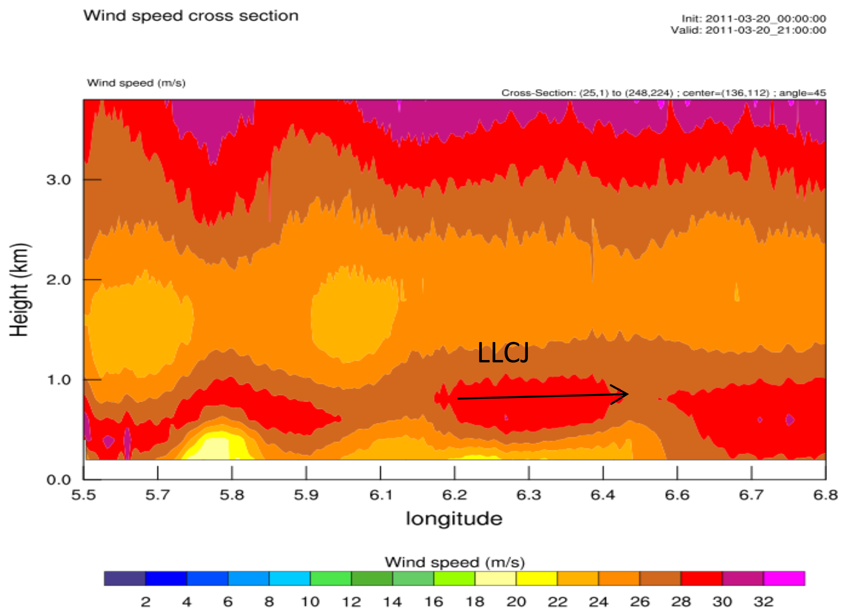
LLCJ width: approx. 30-40 km

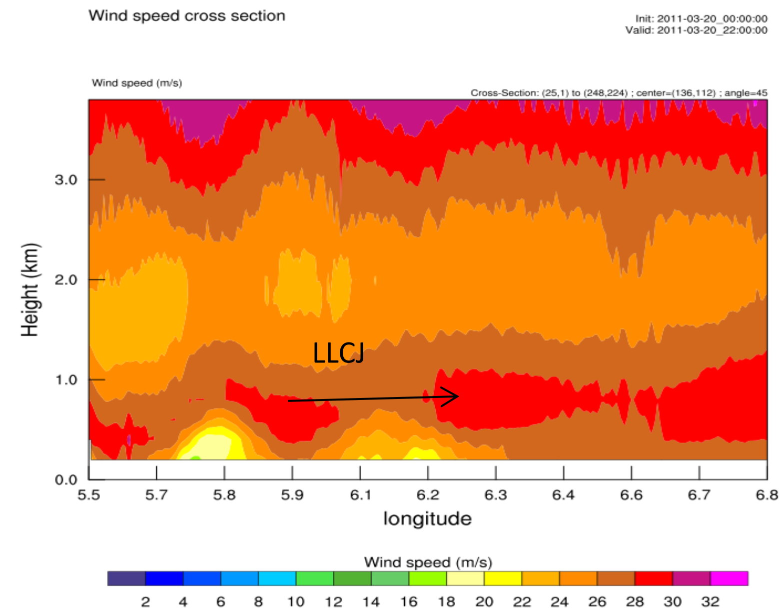
Cross section of wind speed parallel to the LLCJ



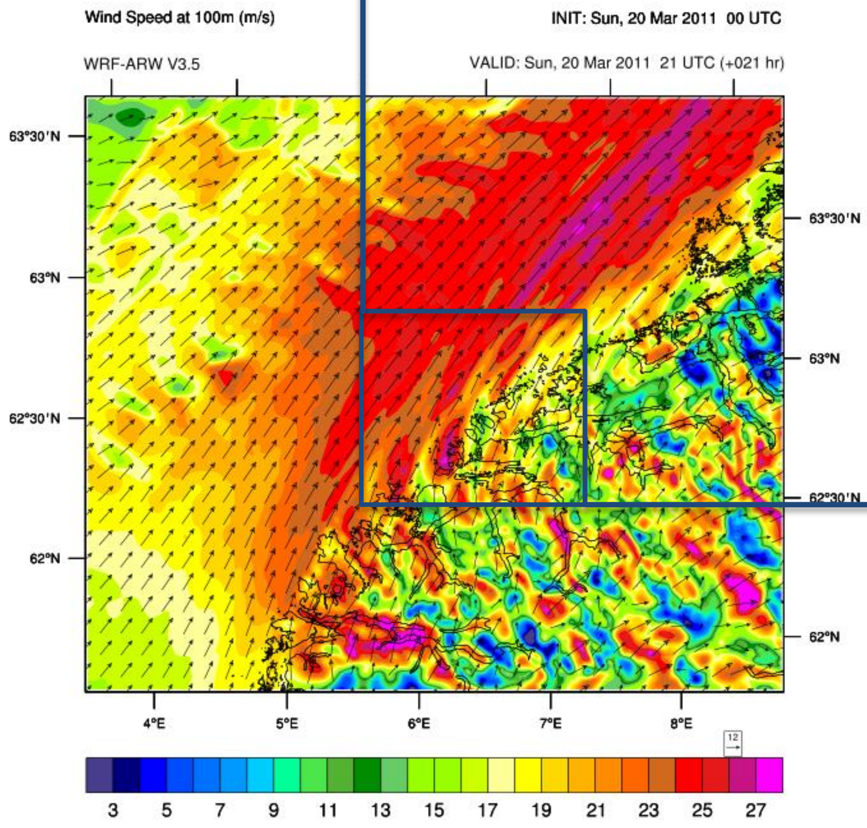

Wind speed cross section
Init: 2011-03-20_00:00:00
Valid: 2011-03-20_19:00:00
Wind speed (m/s)
Cross-Section: (25,1) to (248,224) ; center=(136,112) ; angle=45
Height (km)
3.0
2.0
1.0
0.0
LLCJ
5.5 5.7 5.8 5.9 6.1 6.2 6.3 6.4 6.6 6.7 6.8
longitude
Wind speed (m/s)
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32

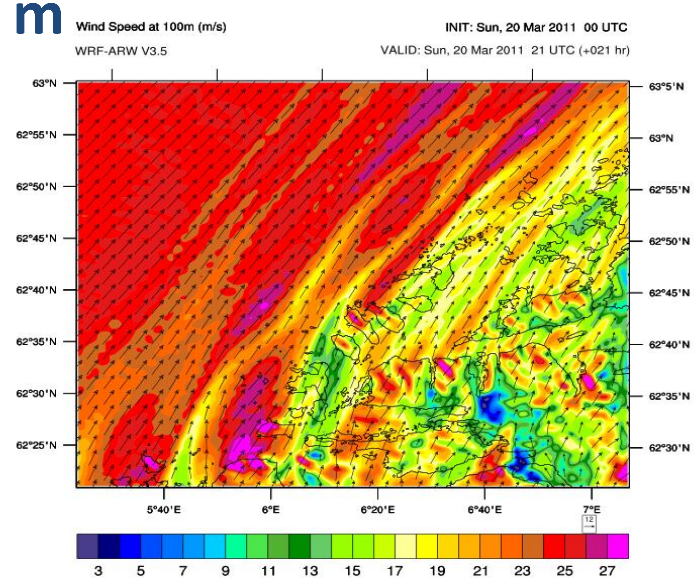

Wind speed cross section
Init: 2011-03-20_00:00:00
Valid: 2011-03-20_20:00:00
Wind speed (m/s)
Cross-Section: (25,1) to (248,224) ; center=(136,112) ; angle=45
Height (km)
3.0
2.0
1.0
0.0
LLCJ
5.5 5.7 5.8 5.9 6.1 6.2 6.3 6.4 6.6 6.7 6.8
longitude
Wind speed (m/s)
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32


Wind speed cross section
Init: 2011-03-20_00:00:00
Valid: 2011-03-20_21:00:00
Wind speed (m/s)
Cross-Section: (25,1) to (248,224) ; center=(136,112) ; angle=45
Height (km)
3.0
2.0
1.0
0.0
LLCJ
5.5 5.7 5.8 5.9 6.1 6.2 6.3 6.4 6.6 6.7 6.8
longitude
Wind speed (m/s)
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32


Wind speed cross section
Init: 2011-03-20_00:00:00
Valid: 2011-03-20_22:00:00
Wind speed (m/s)
Cross-Section: (25,1) to (248,224) ; center=(136,112) ; angle=45
Height (km)
3.0
2.0
1.0
0.0
LLCJ
5.5 5.7 5.8 5.9 6.1 6.2 6.3 6.4 6.6 6.7 6.8
longitude
Wind speed (m/s)
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32

Wind Speed at 100 m





Wind speed at 100 m: 20 to 28 m/s at the LLCJ

Wind shear over the rotor disk during LLCJ

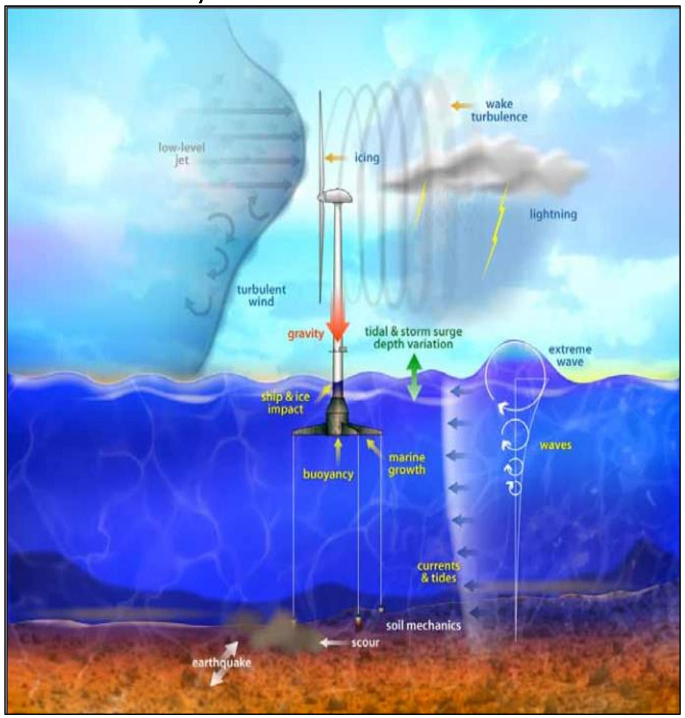
Wind power exponent:

$$\frac{U_2}{U_1} = \left(\frac{z_2}{z_1}\right)^{\alpha}$$

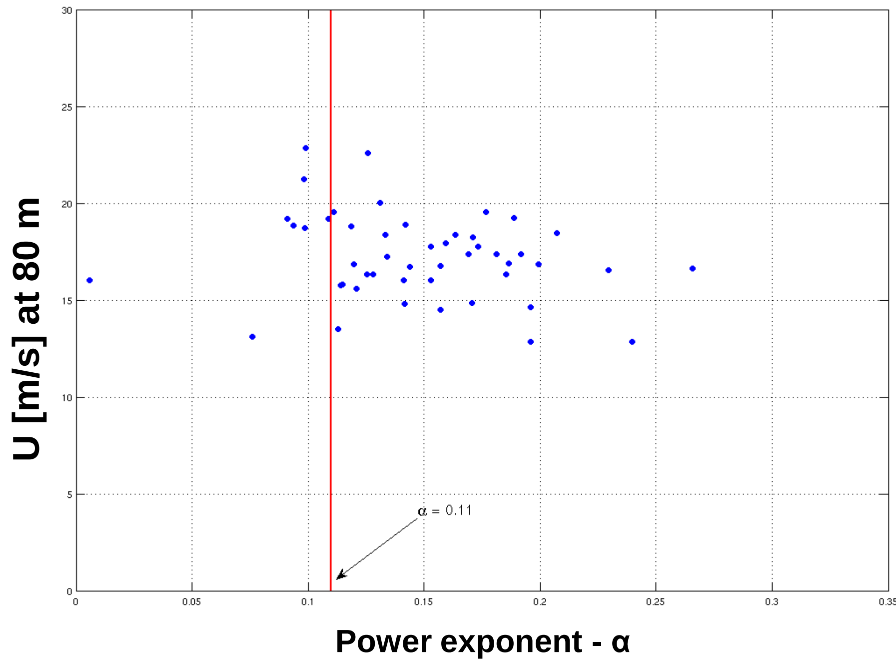
z_1= 60 m

z_2= 120 m

α > 0.10, neutral-stable conditions.



Source: http://www.ieawind.org/GWEC_PDF/GWEC%20Annex23.pdf



Stability class	Boundary layer properties	Hub-height wind speed	Wind shear
Strongly stable	Highest shear in swept-area, nocturnal LLJ may be present, little turbulence except just below the LLJ	Strong, especially at night	Highest: $\alpha > 0.3$
Stable	High wind shear in swept-area, low amount of turbulence unless a nocturnal LLJ is present	Strong, especially at night	High: $0.2 < \alpha < 0.3$
Near-neutral	Logarithmic wind profile	Generally strongest	Moderate: $0.1 < \alpha < 0.2$

Source: Wharton S and Lundquist J K (2012) Atmospheric stability affects wind turbine power collection, Environ. Res. Lett. 7

Summary

Case study of LLCJ, 20.03.2011 at Havsul region:

- The width of LLCJ: approx. 30 - 40 km
- Observed wind speeds: 12 to 26 m/s
- Observed Turbulence Intensity: 5 % - 12 %
- WRF model performs well (D3 and D4)
- Vertical wind shear– $\alpha > 0.10$

Thanks for your attention