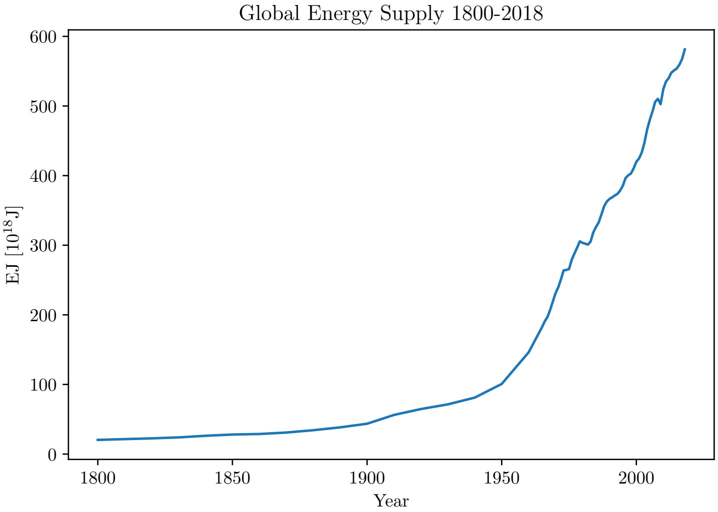
A study of the impact of very large wind farms on regional weather using the WRF model in high resolution

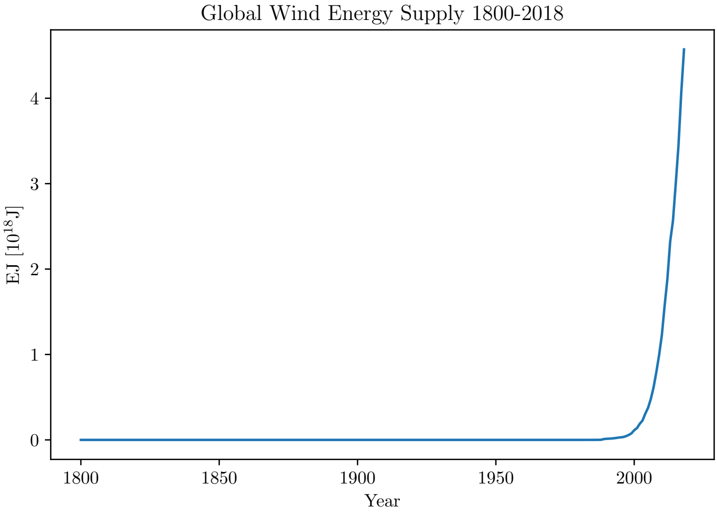
Simon Jacobsen
Supervisor: Aksel Walløe Hansen
Niels Bohr Institute

Overview

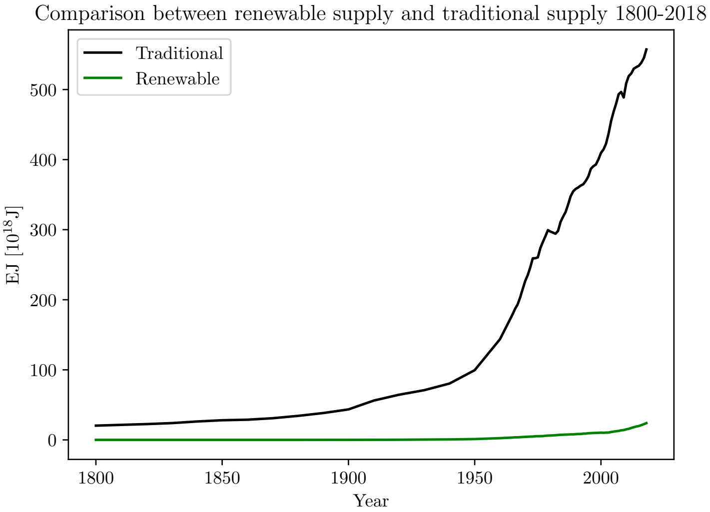
Introduction - Energy



Introduction - Energy



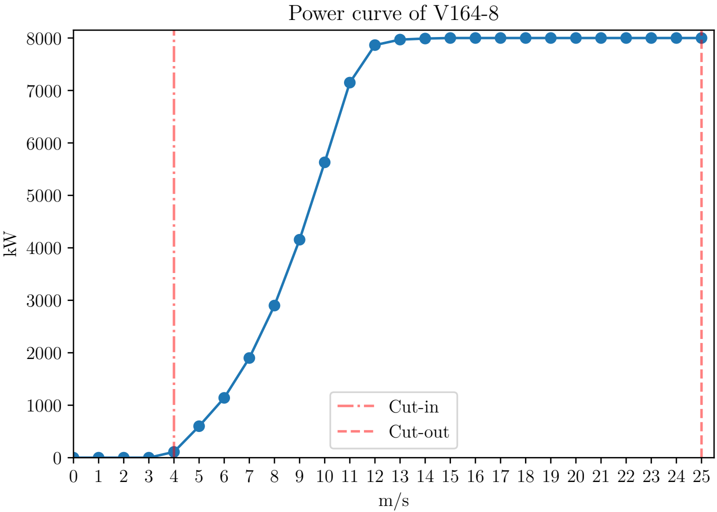
Introduction - Energy



Vestas V164-8

Hub height	Wing span	Area swept	Nacelle weight	Cut in speed	Cut out speed
110m	80m	$21124m^2$	390 Ton	$4m/s$	$25m/s$

Vestas V164-8

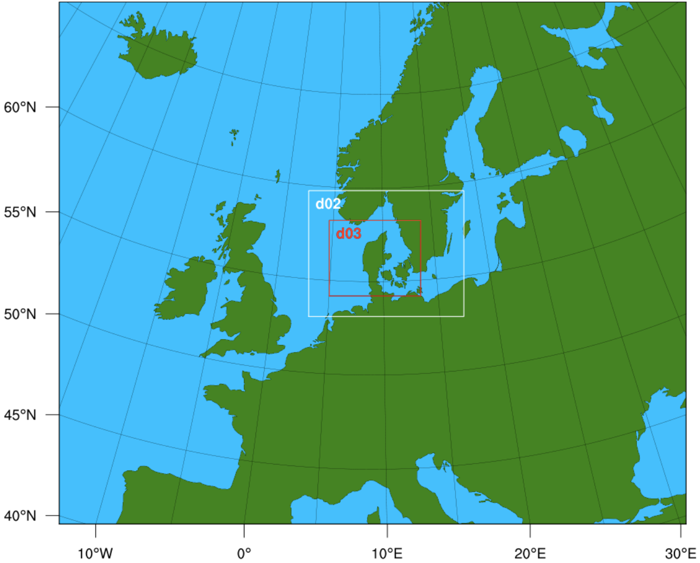


WRF - Setup

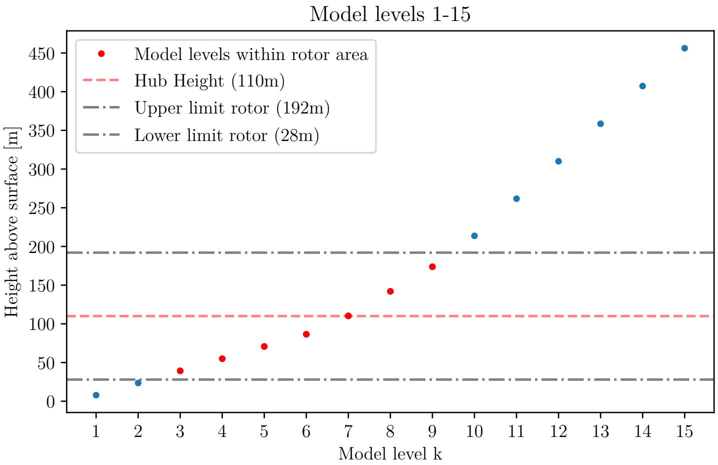
	Parent Domain	Nest 1	Nest 2
N/S Grid	300	371	1091
E/W Grid	250	301	901
Resolution	12500m	2500m	500m
Vertical Layers	61		
Model Top	50 hPa		

Settings applied in the namelist.input			
Domain	D01	D02	D03
PBL Scheme	5	5	5
Surface Layer Scheme	5	5	5
Cumulus Parameterization	1	1	0
Wind farm setting	0	0	1
Wind farm ij			1
MYNN 2.5 TKE Budget	1	1	1
MYNN 2.5 TKE Advection	.true.	.true.	.true.
Time Step	75s	15s	3s

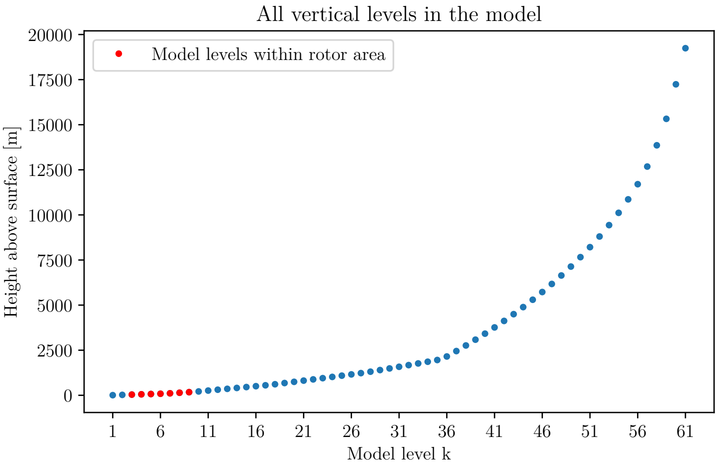
WRF - Setup



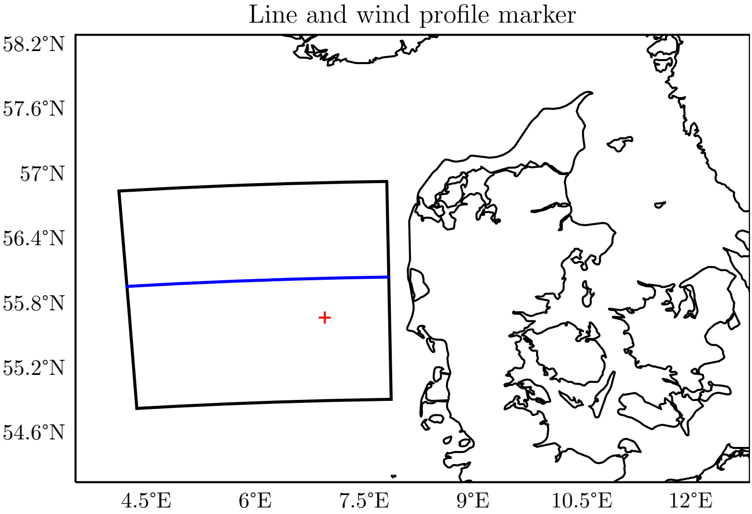
WRF - Setup


Model levels 1-15
Model levels within rotor area
Hub Height (110m)
Upper limit rotor (192m)
Lower limit rotor (28m)
Height above surface [m]
0
50
100
150
200
250
300
350
400
450
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Model level k

WRF - Setup


All vertical levels in the model
Model levels within rotor area
Height above surface [m]
20000
17500
15000
12500
10000
7500
5000
2500
0
1
6
11
16
21
26
31
36
41
46
51
56
61
Model level k

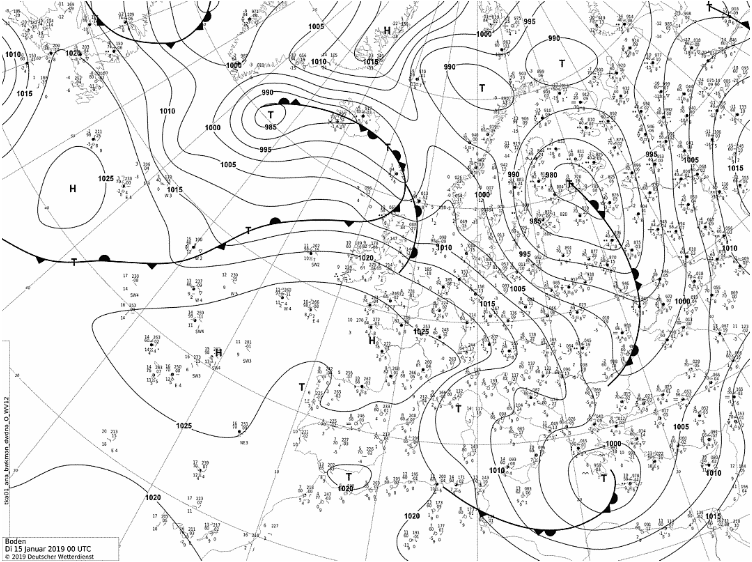
WRF - Setup


Line and wind profile marker
58.2°N
57.6°N
57°N
56.4°N
55.8°N
55.2°N
54.6°N
4.5°E
6°E
7.5°E
9°E
10.5°E
12°E

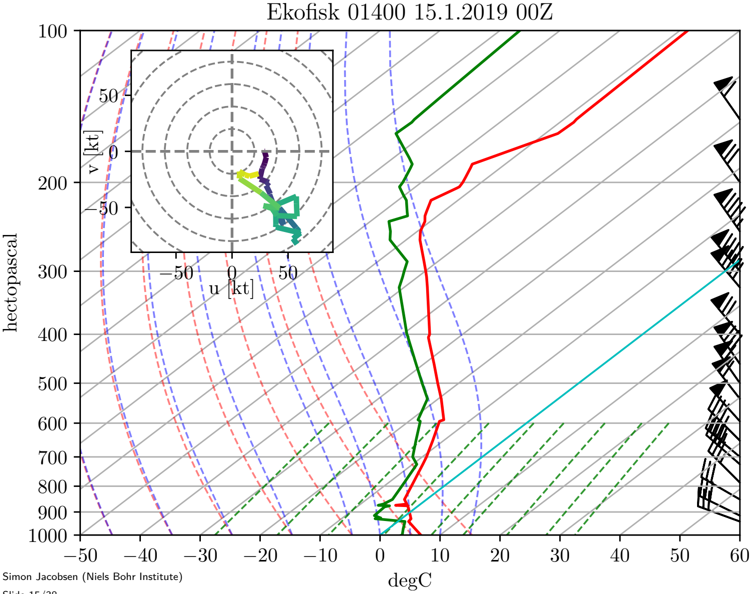
WRF - Setup

Wind turbine configurations				
Setup	Amount	Grid	Spacing	Capacity
1	202,500	450*450	500m	1620 GW
2	50,176	224*224	1000m	401.4 GW
3	12,544	112*112	2000m	100.3 GW

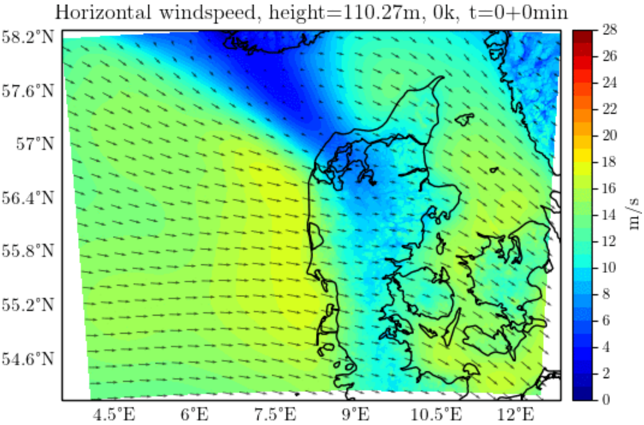
Case 1 - 00 UTC 15/01/2019



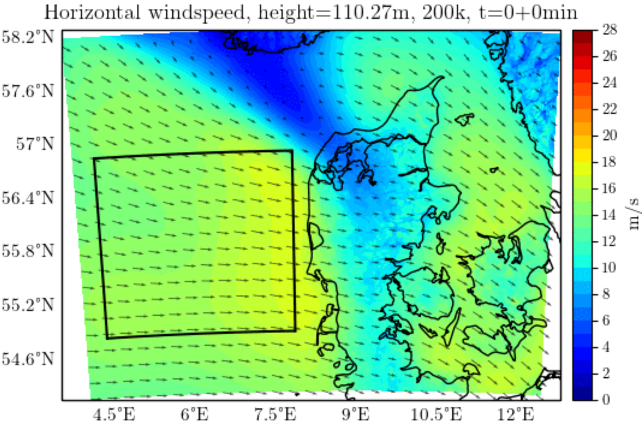
Case 1 - 00 UTC 15/01/2019



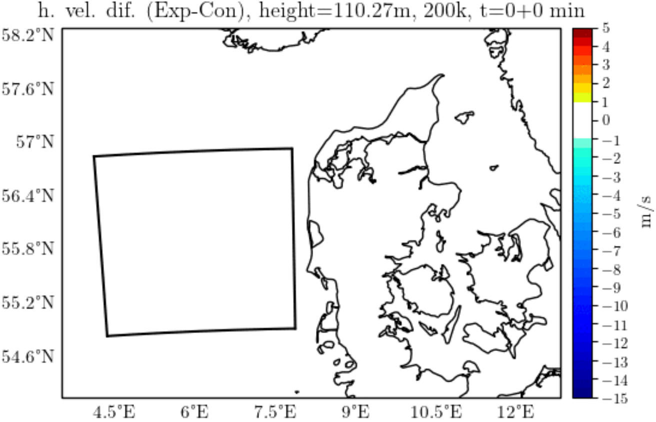
Results Case 1 - Control 110m



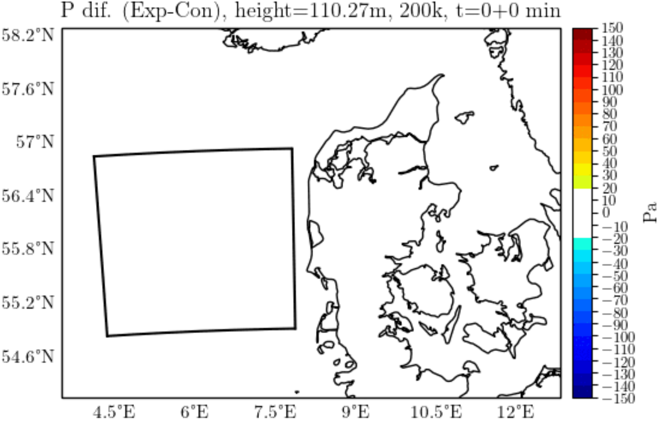
Results Case 1 - 200k 110m



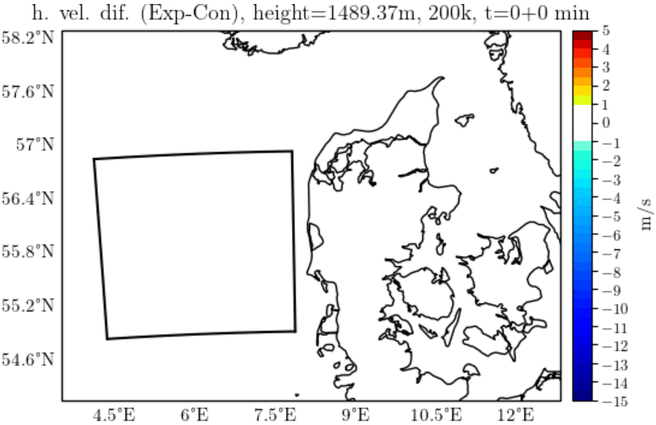
Results Case 1 - 200k 110m dif.



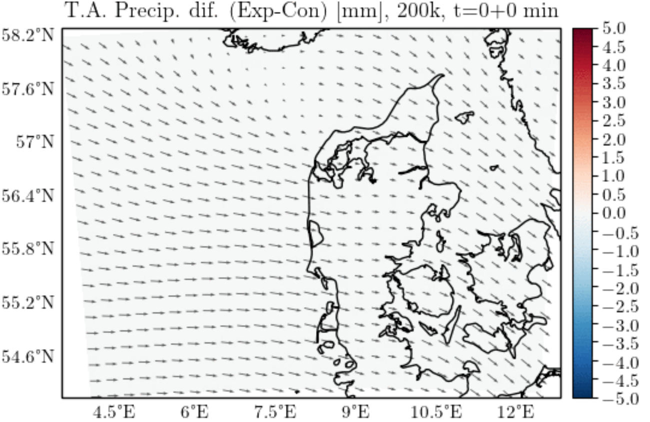
Results Case 1 - 200k 110m pressure



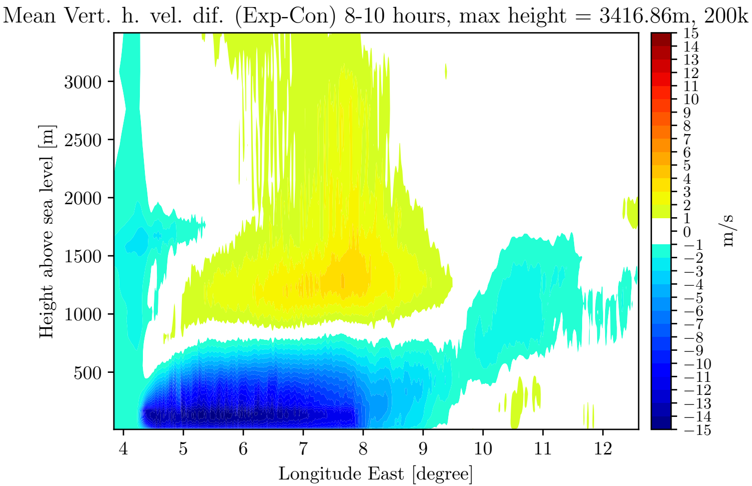
Results Case 1 - 200k 1489m



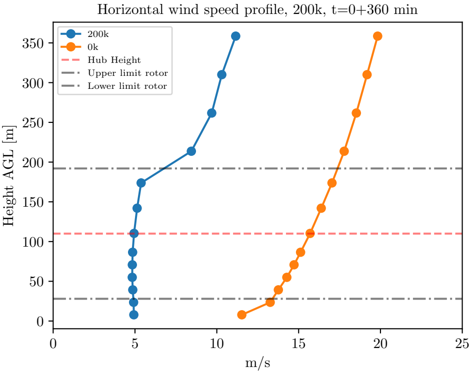
Results Case 1 - 200k precipitation dif.

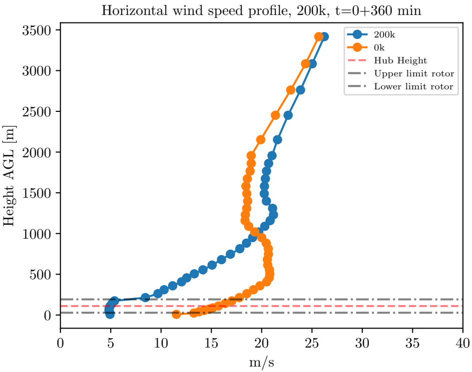


Results Case 1 - 200k cross section

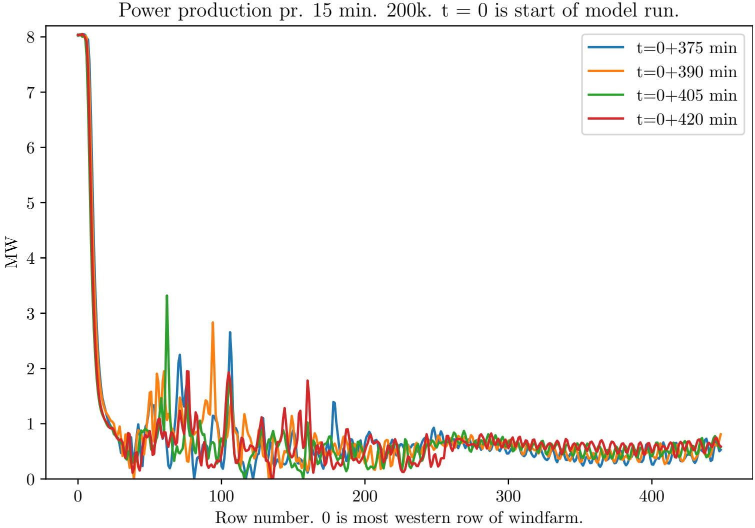


Results Case 1 - 200k wind profile

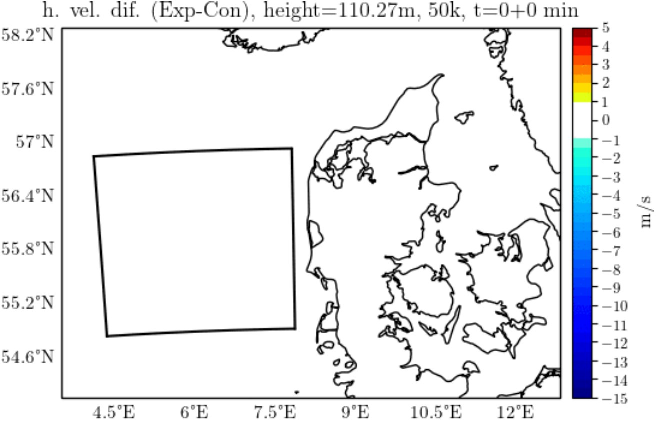




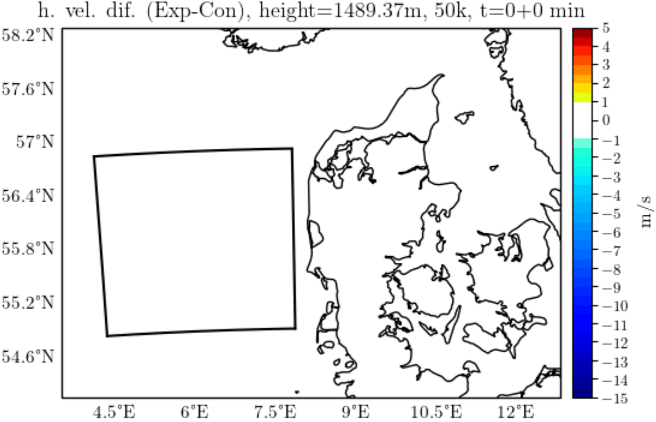
Results Case 1 - 200k energy



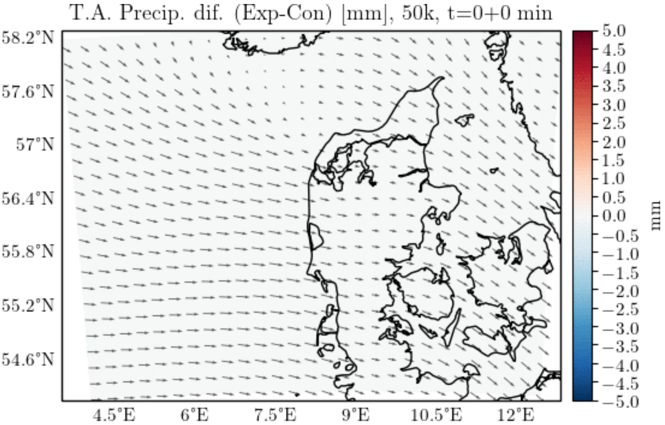
Results Case 1 - 50k 110m dif.



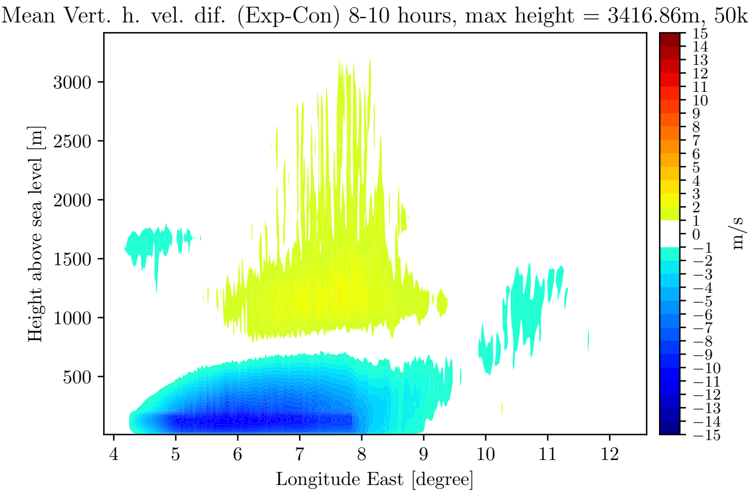
Results Case 1 - 50k 1489m dif.



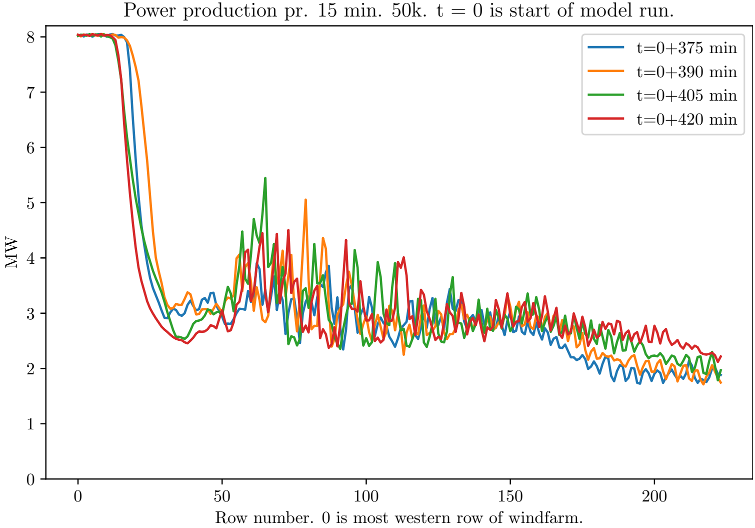
Results Case 1 - 50k precipitation dif.



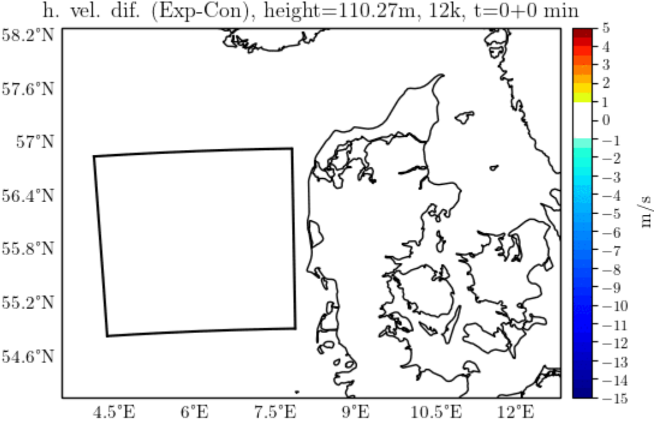
Results Case 1 - 50k cross section



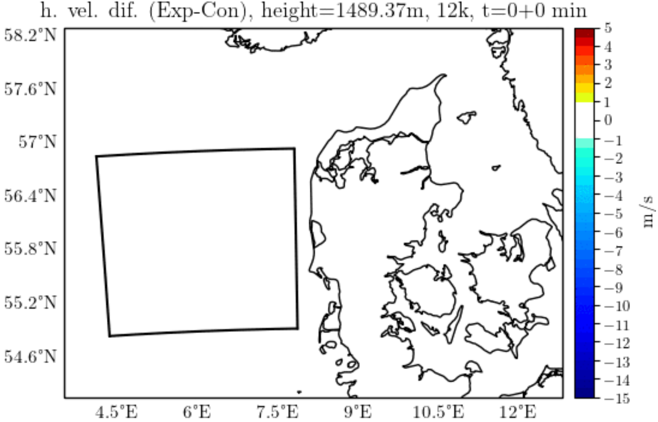
Results Case 1 - 50k energy



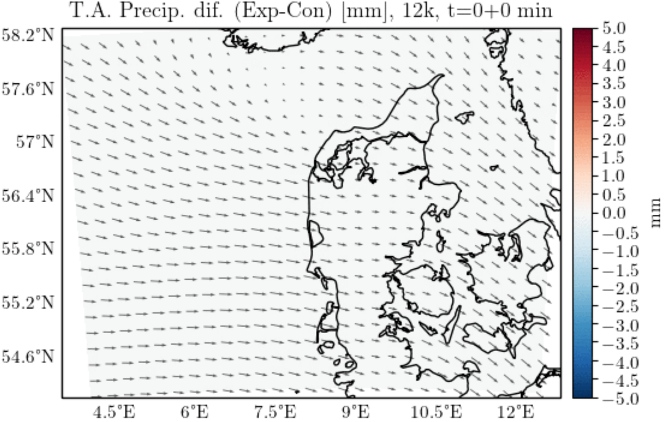
Results Case 1 - 12k 110m dif.



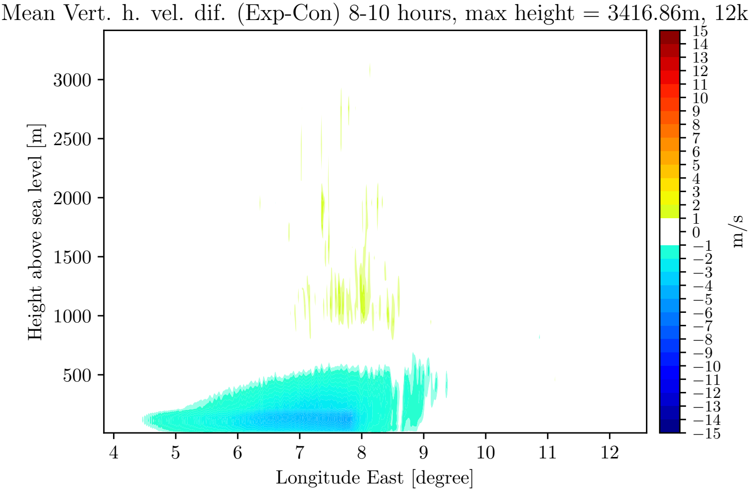
Results Case 1 - 12k 1489m dif.



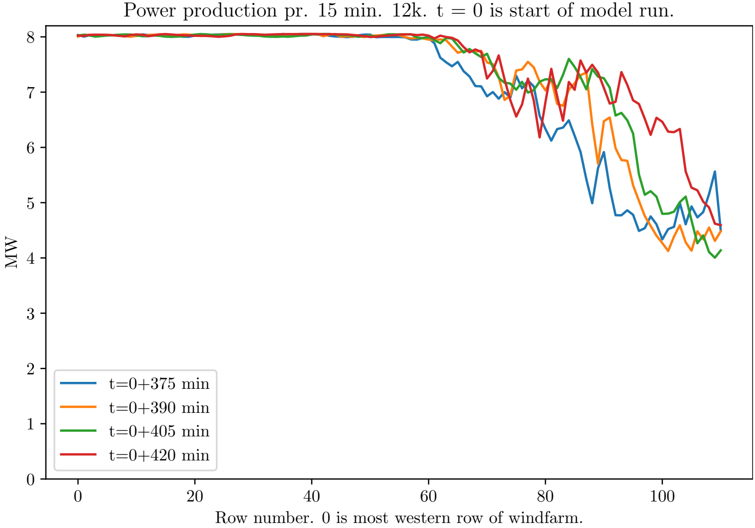
Results Case 1 - 12k precipitation dif.



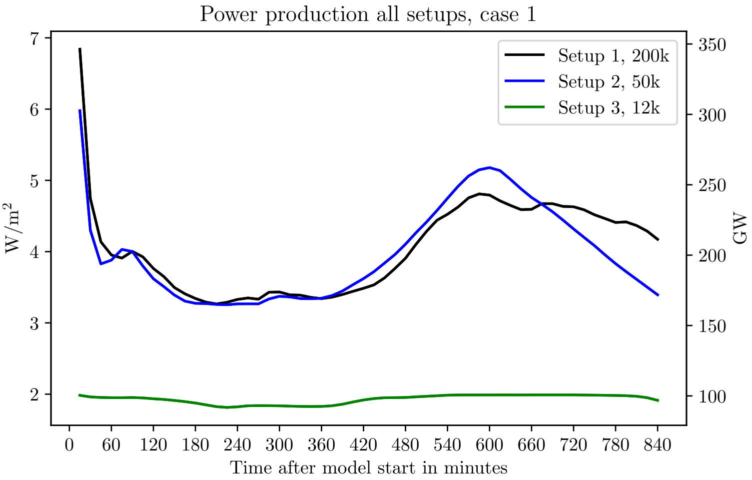
Results Case 1 - 12k cross section



Resulys Case 1 - 12k energy



Results Case 1 - Energy Production



Results Case 1 - Energy Production

Case 1	Setup 1, 200k		Setup 2, 50k		Setup 3, 12k	
Hour	Mean W/m^2	CF %	Mean W/m^2	CF %	Mean W/m^2	CF %
0-2	4.41	13.8	4.17	52.1	1.95	97.5
2-4	3.38	10.6	3.32	41.5	1.86	93.0
4-6	3.38	10.6	3.33	41.6	1.83	91.5
6-8	3.57	11.2	3.70	46.3	1.91	95.5
8-10	4.54	14.2	4.79	59.9	1.98	99.0
10-12	4.64	14.5	4.72	59.0	1.99	99.5
12-14	4.40	13.8	3.79	47.4	1.97	98.5

Conclusion

- Very large wind farms disturb the general atmospheric flow in the same way as a mountain (Foehn wind).
- Distance between V164-8 wind turbines should be 1000m or greater.
- Setup 3 requires 4.000.000 km^2 to cover EU energy consumption.
- Setup 2 requires 1.000.000 km^2 to cover EU energy consumption.
- Changes to waveheights and the wind driven circulation in the North Sea.
- Challenges for ship traffic.

Thank you for your time!

Questions?