The windstorms of tomorrow: What yesterday's extremes reveal

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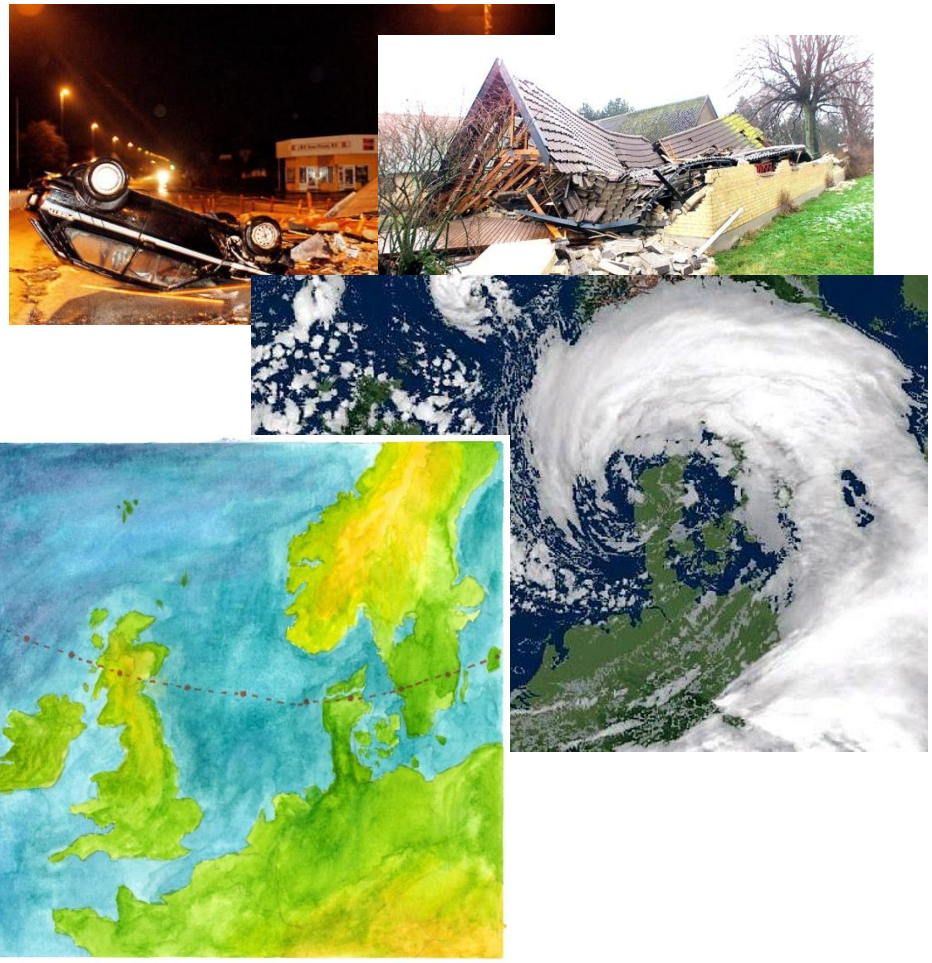
Overview

- Background story
- Model
- Results
- Further considerations

Storm Anatol December 1999

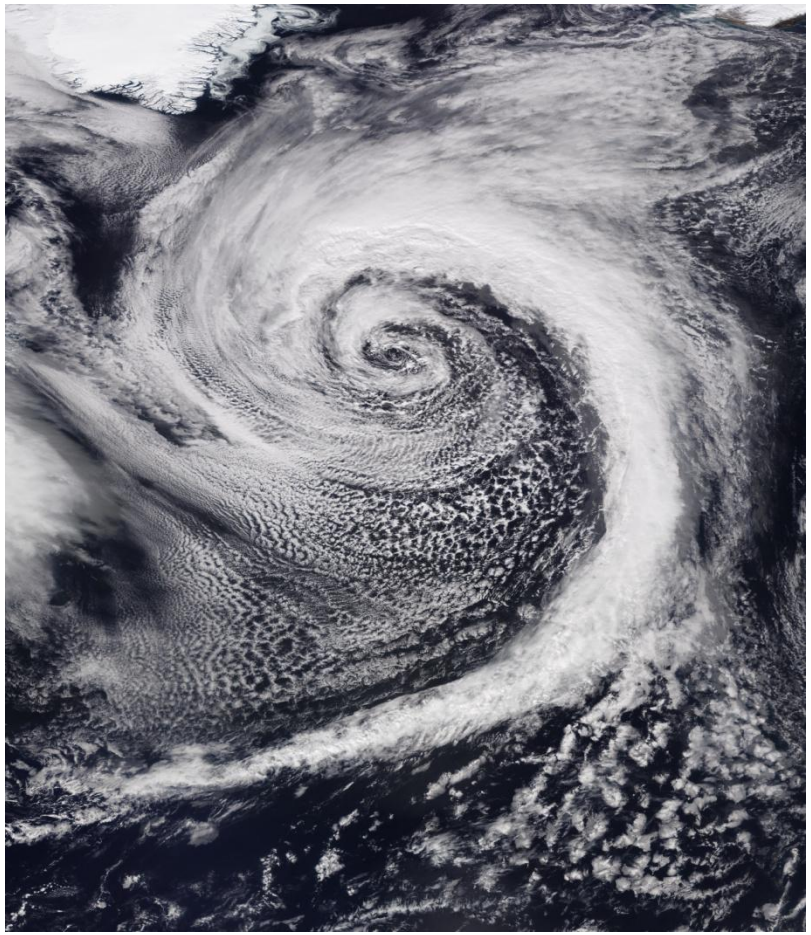
- Strongest storm measured in Denmark
- 800+ injured, 7 dead
- 4.000.000 m^3 forest destroyed
- Damaged for over 2.8 billion euro
- Max mean wind 38 m/s and gust 50 m/s



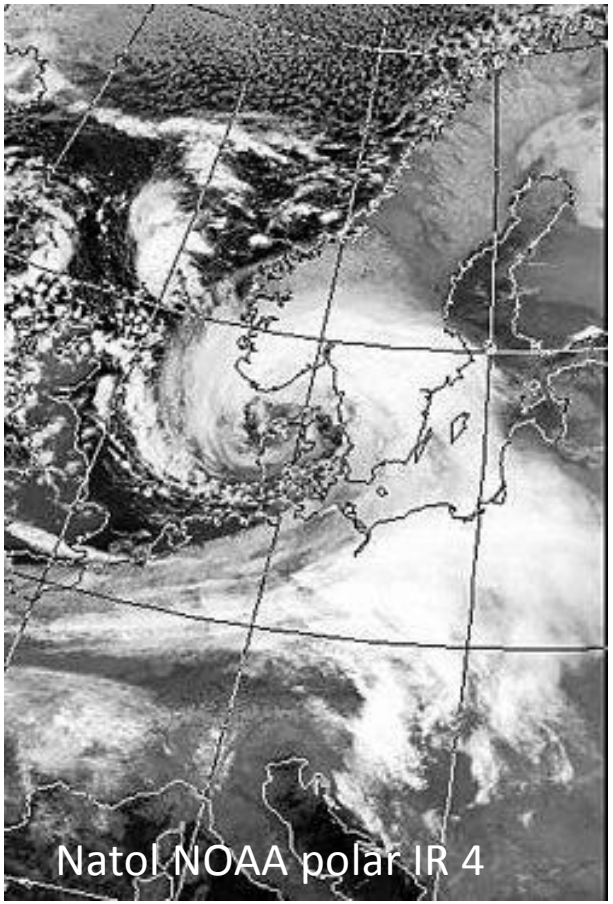
Billeder: sn.dk, jv.dk, dmi.dk

Theory/Methodology

- Warmer air – more moisture
- Warmer oceans – more energy
- Stronger atmospheric instability
- Changes in circulation patterns



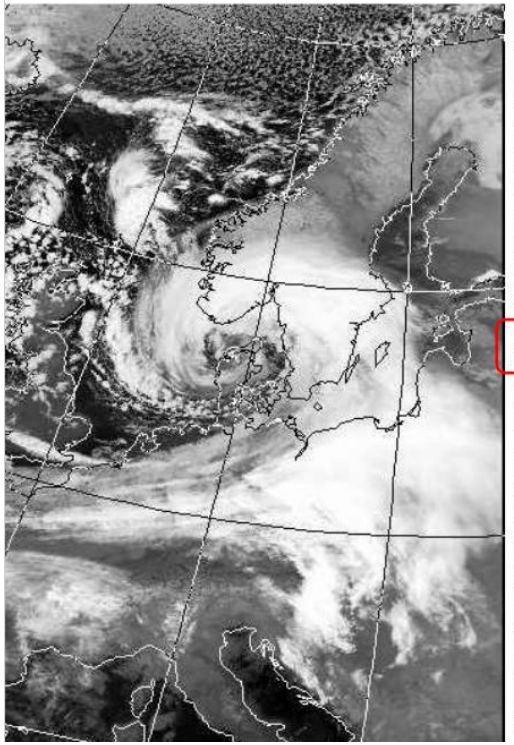
Storms in a future warmer climate



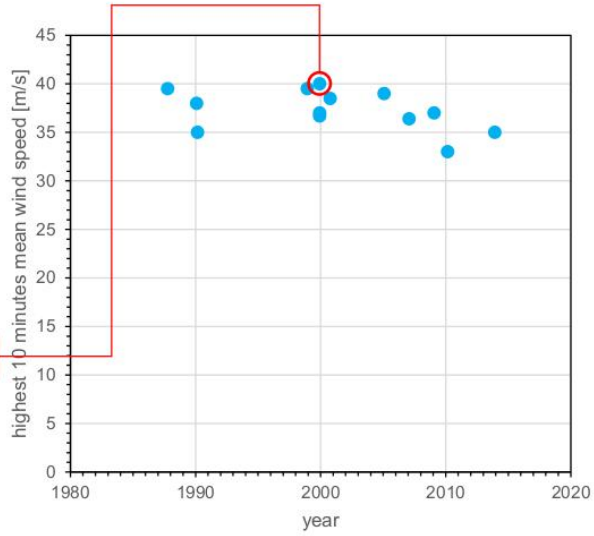
When we talk about future storms, which questions are important to ask?

- Are future storms getting stronger?
- Do they last longer?
- Are they getting bigger and affect a larger area?
- Will they occur more frequent?
- What else may change (turbulence structure)?

Storms in a future warmer climate



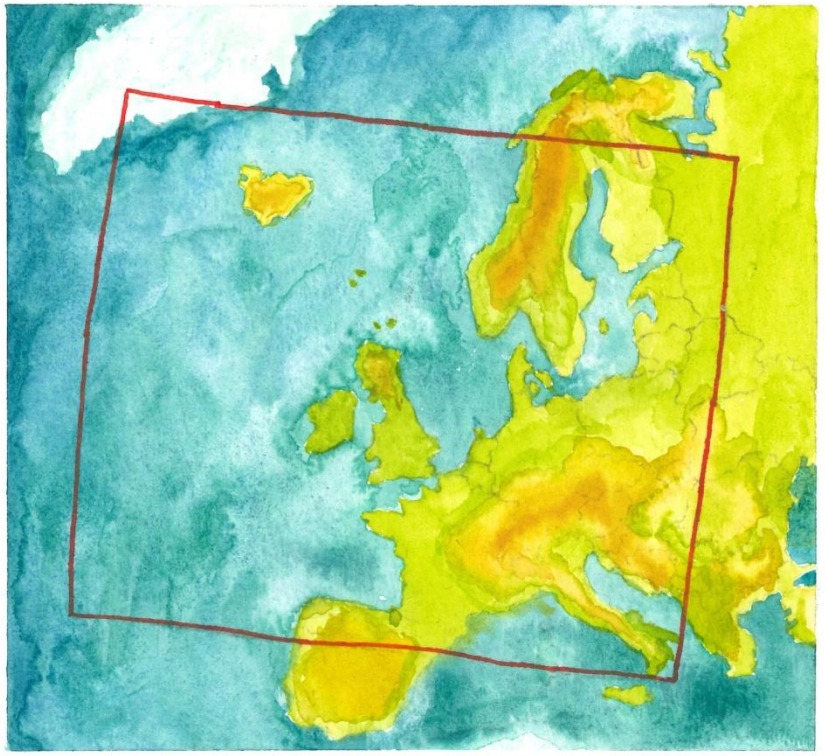
Storm	Date	Approx. Peak 10-min Mean Wind (m/s)
North Sea Flood Storm	Jan–Feb 1953	32.5
Great Storm (UK/France)	15–16 Oct 1987	39.5
Daria (Burns' Day Storm)	Jan 1990	38
Vivian	Feb 1990	35
Stephen	Dec 1998	39.5
Anatol	3 Dec 1999	40
Martin	Dec 1999	37
Lothar	Dec 1999	36.7
Oratia (Tora)	Oct 2000	38.5
Gudrun (Erwin)	Jan 2005	39
Kyrill	Jan 2007	36.4
Klaus	Jan 2009	37
Xynthia	Feb 2010	33
Xaver (Bodil)	Dec 2013	35



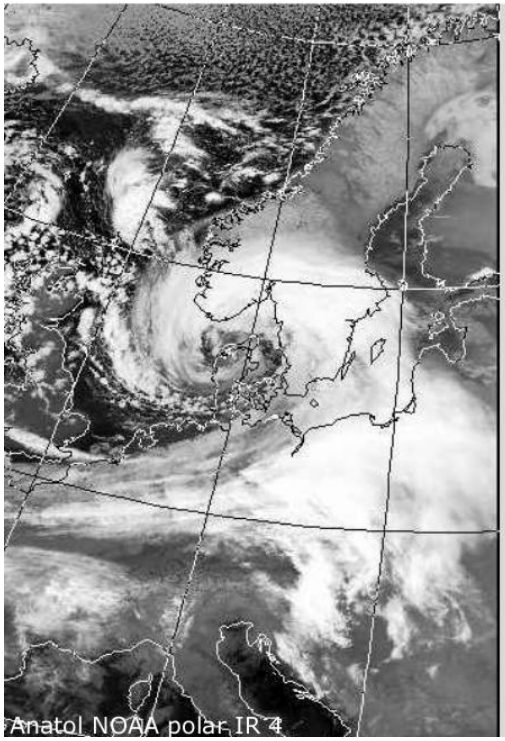
How much would these storms change in a future warmer climate?

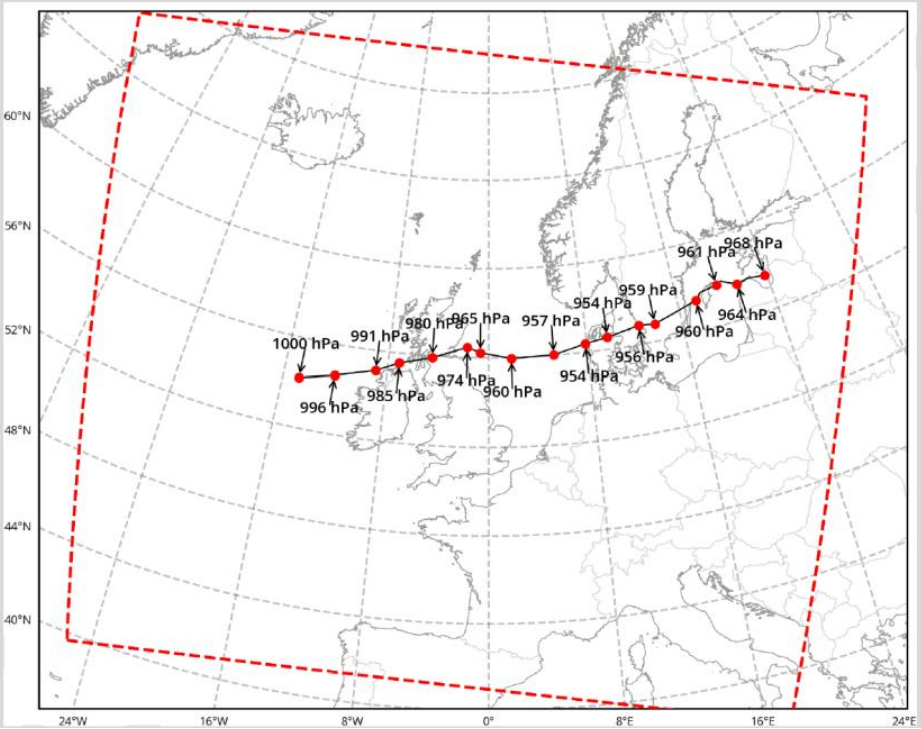
HARMONIE-AROME model

- High resolution NWP model
- DINI configuration
- High resolution 2 km
- Boundary derived from ERA5
- Output every hour
- 5 model runs with different temperatures.



Pseudo Global Warming simulation



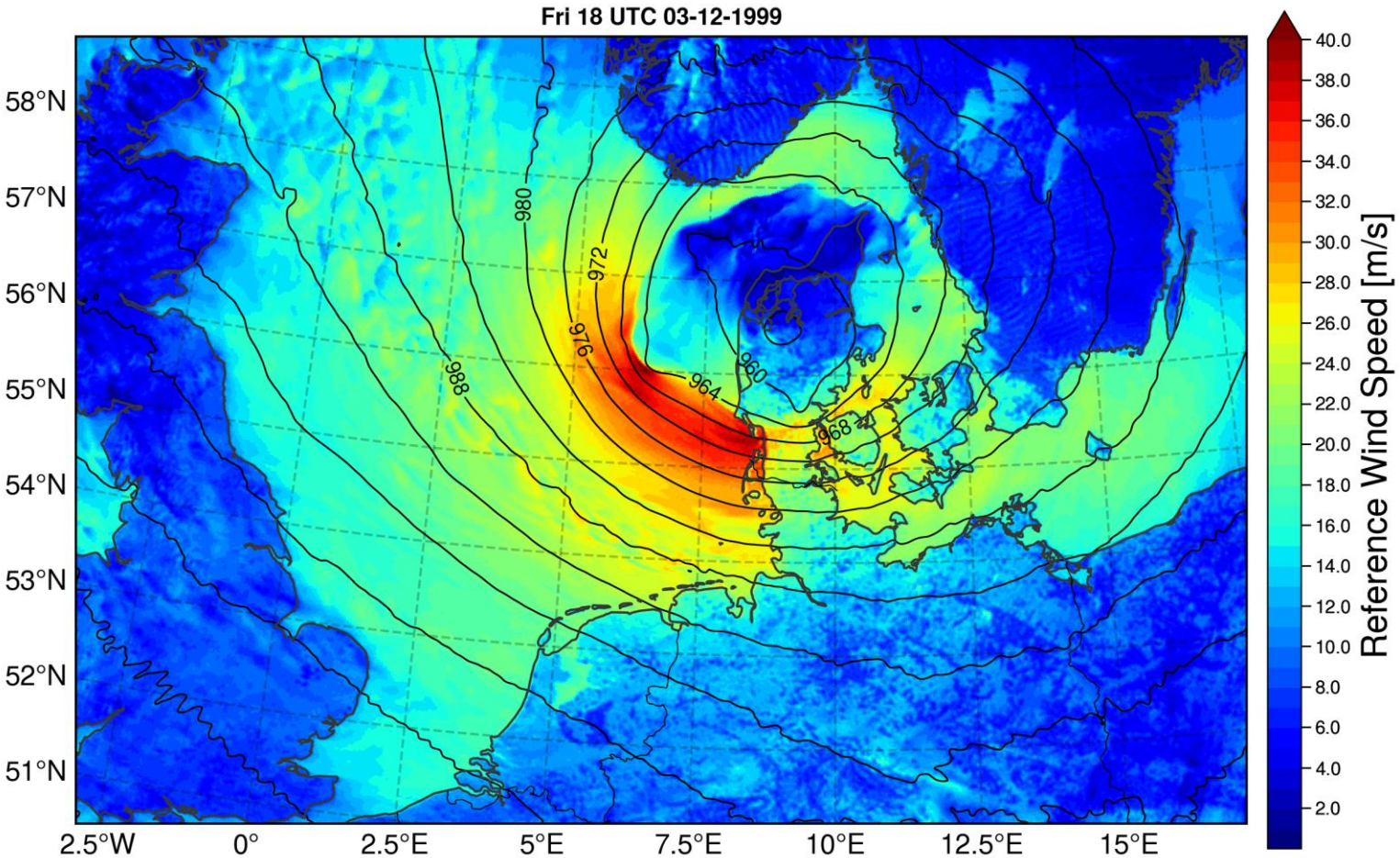


The simulation is based on cycle 43h2.2, with a horizontal grid resolution of **2km** with **90 vertical levels** between the surface and 10hPa, corresponding to approximately **25 km above sea level**.

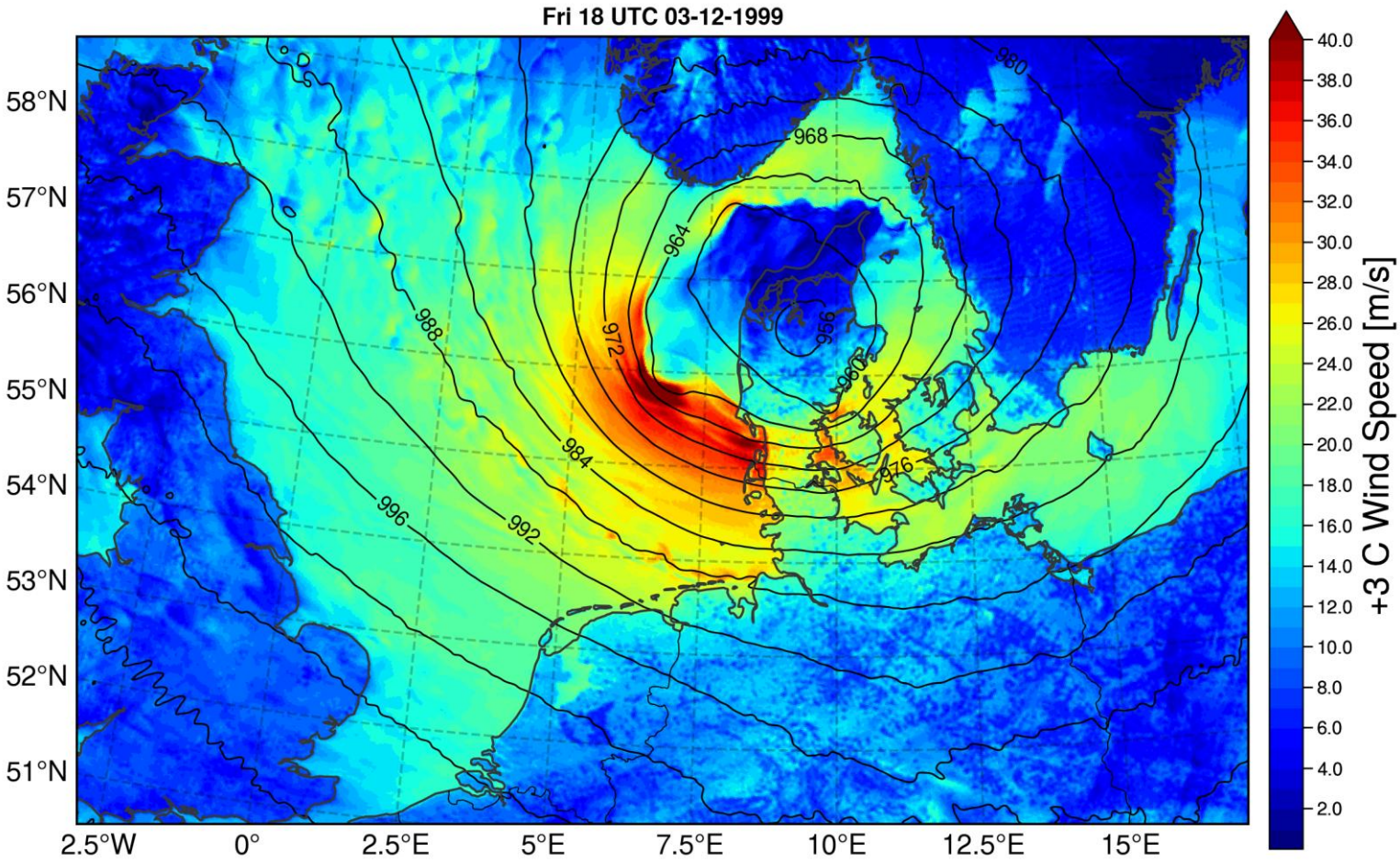
Climate Perturbation:

-1°C	pre-industrial
0°C	control reference
+1°C	
+2°C	warming
+3°C	

Model run - control

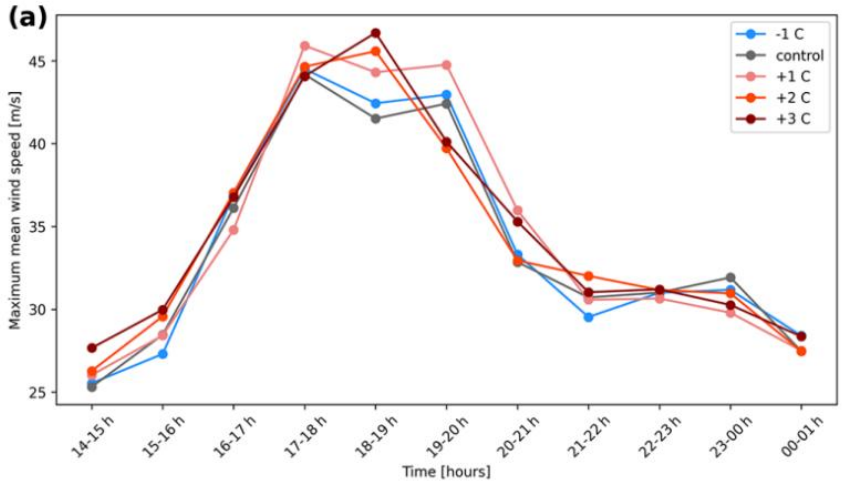


Model run +3 ^{o}C

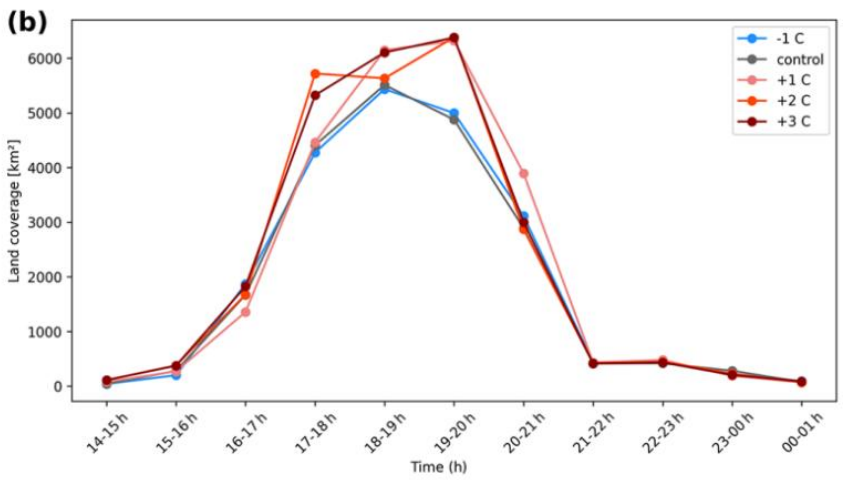


PGW Simulation

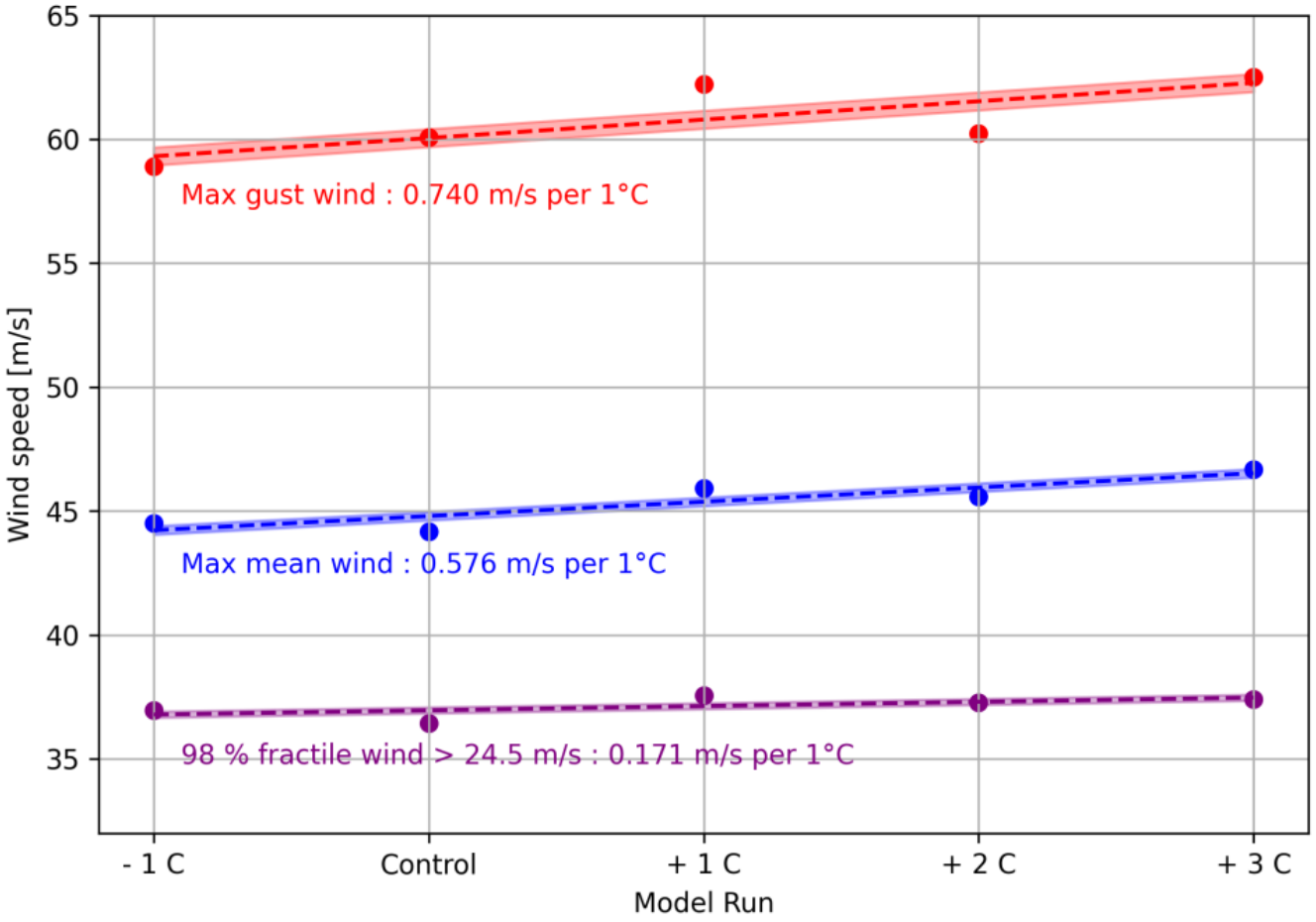
Maximum mean wind speed



Land covered by storm



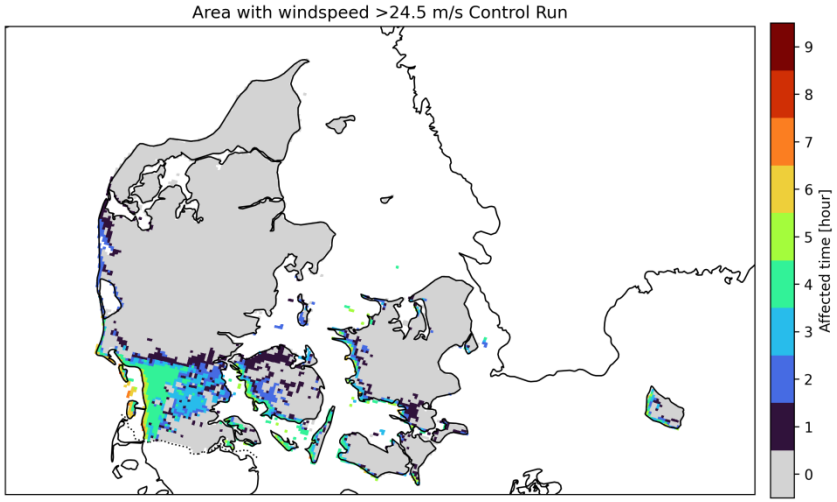
PGW Simulation



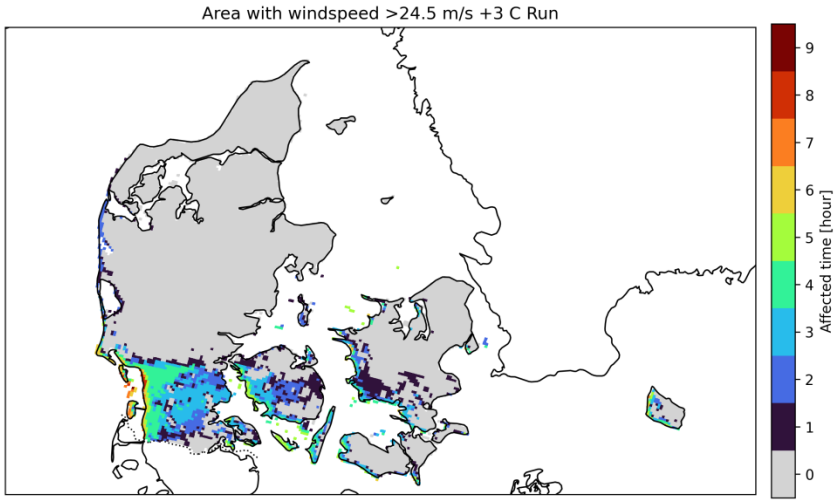
Maximum 10 m wind speed for maen and gust, obtained over the entire simulated periode over land.

Area affected

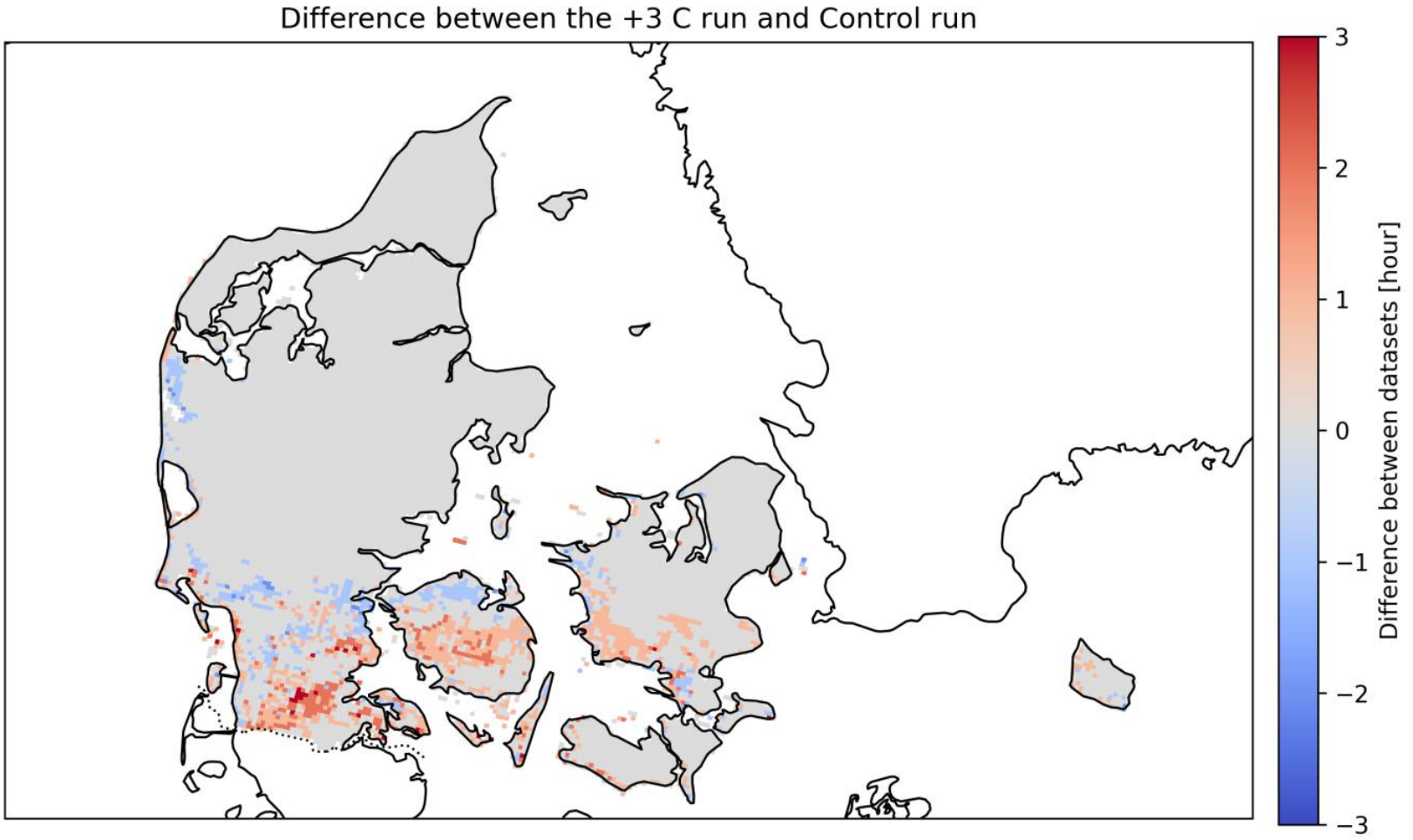
Control run



+3 ^{o}C run

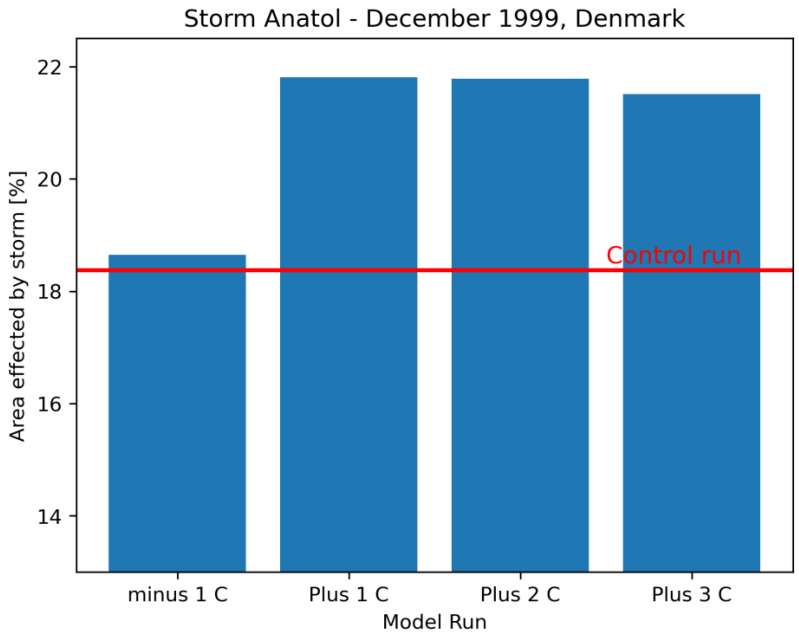


Change In area

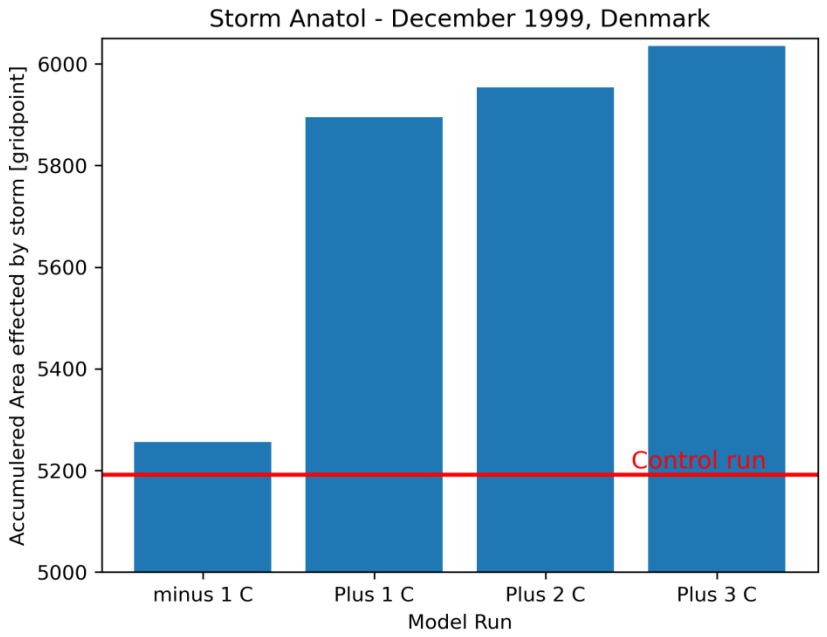


CWEI for Wind > 24.5 m/S

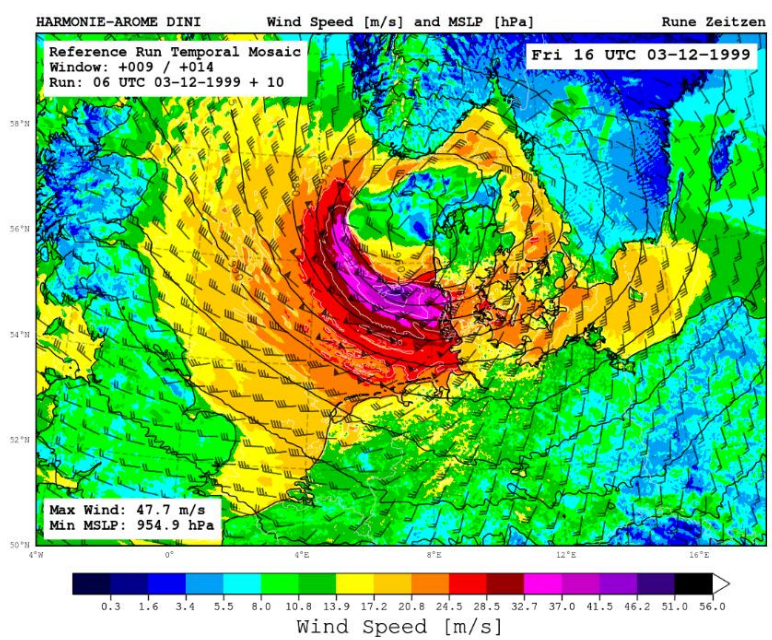
- Area

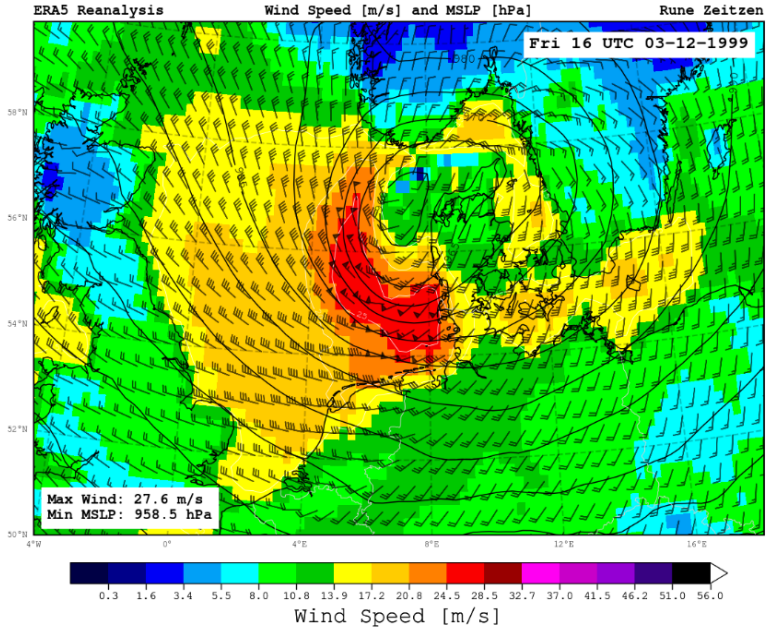


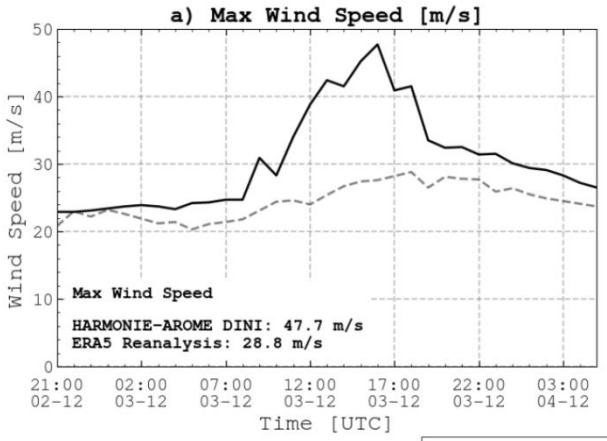
- CWEI

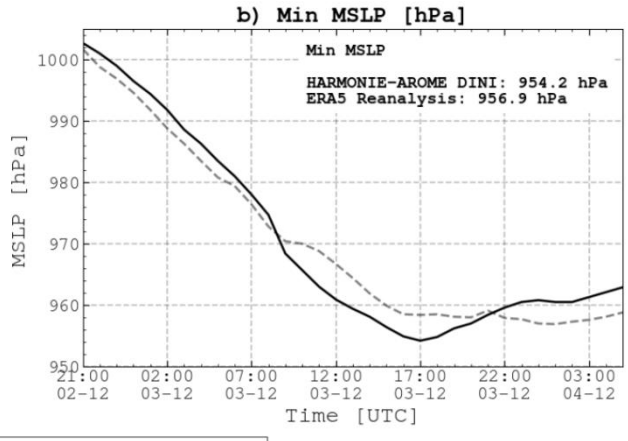


HARMONIE vs ERA 5









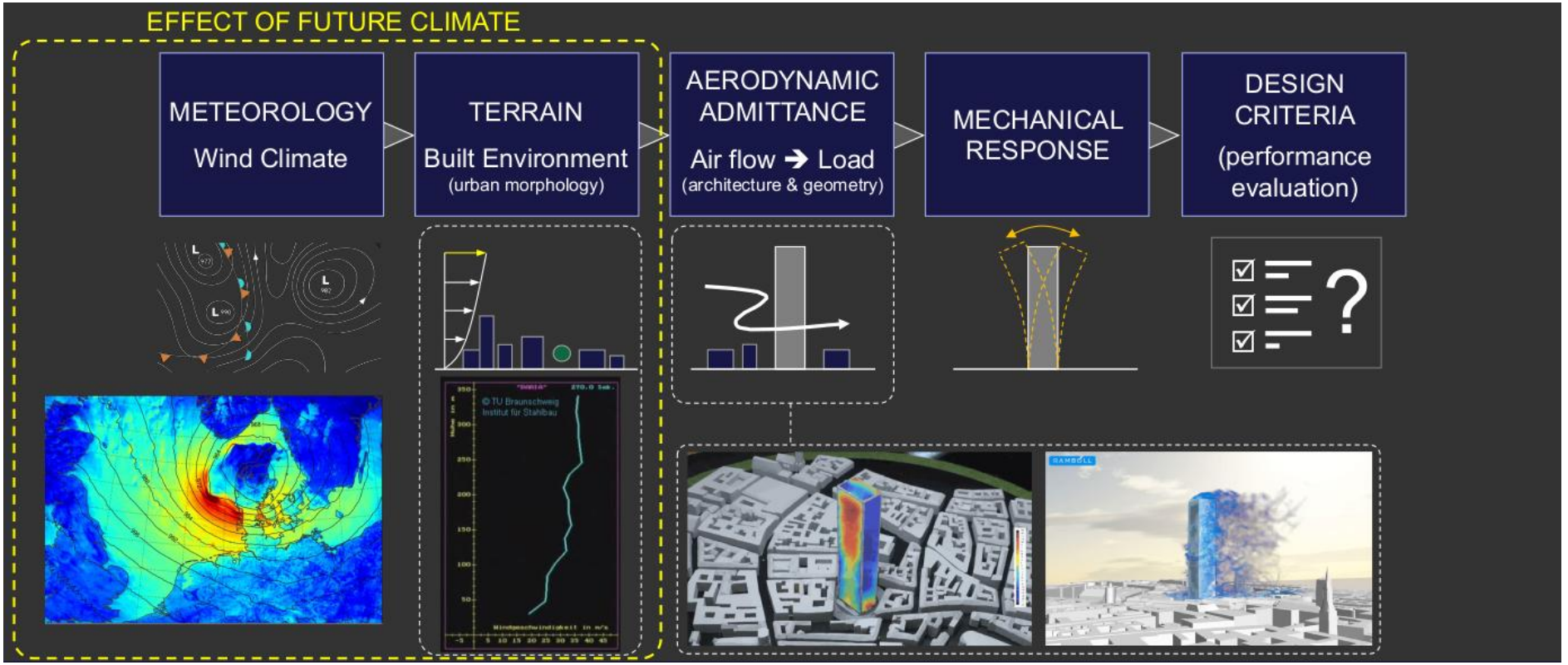
HARMONIE-AROME DINI --- ERA5 Reanalysis

Figur: Rune Zeitzen, DMI

Anatol anno 2100

- More powerful – mean wind 40 m/s, gust 54 m/s
- Land area experience up to 3 hours more extreme wind at +3 ^{o} C.
- Area exposed to wind speed over 24.5 m/s increases by approx 1500 km^2.

Consequences for cities



PALM-4U

Parallelized Large Eddy Simulation for Urban Applications

PALM is an advanced and state-of-the-art meteorological modelling system for atmospheric and oceanic boundary layer flows. It was developed as a turbulence-resolving large-eddy simulation (LES) model specifically designed to run on massively parallel computer architectures.

Computational domain: 2048 x 2048 x 512m

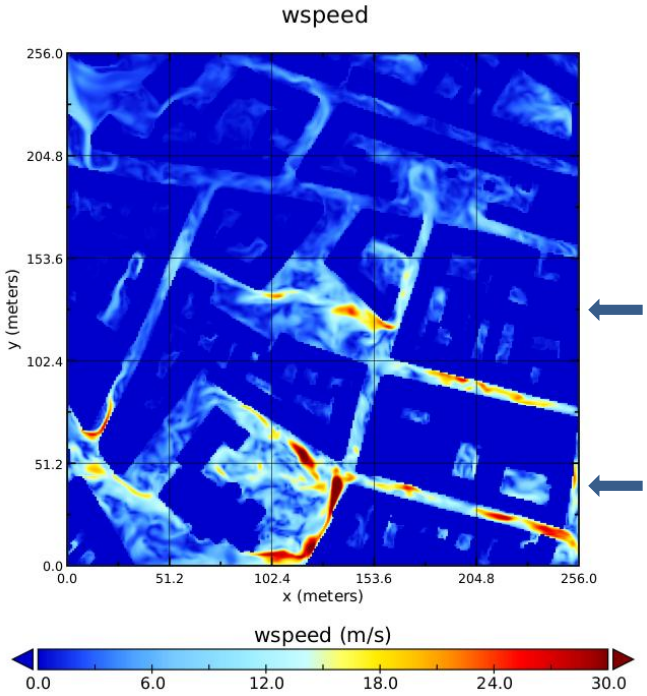
Parent: 2048 x 2048 x 512m – 8m cubic mesh

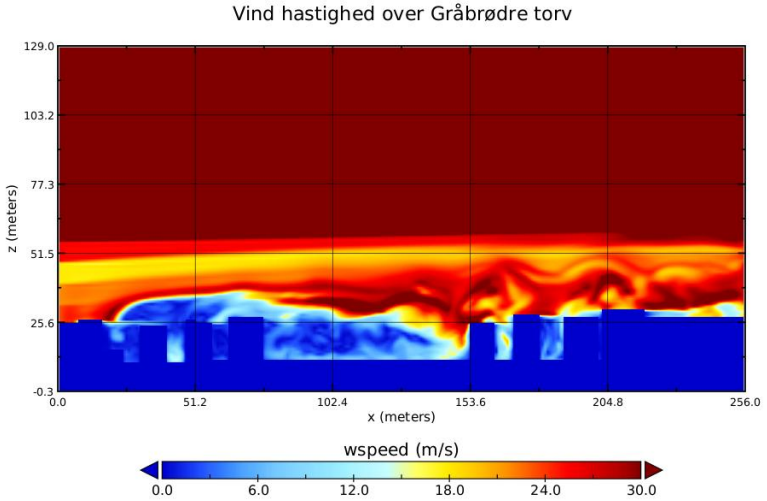
Child 1: 768 x 768 x 258m – 4m cubic mesh

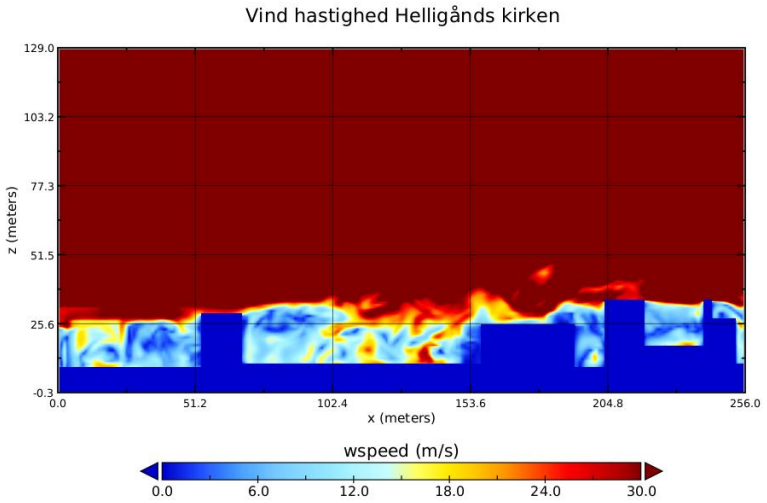
Child 2: 256 x 256 x 130m – 1m cubic mesh

Virtual measurement point at centre

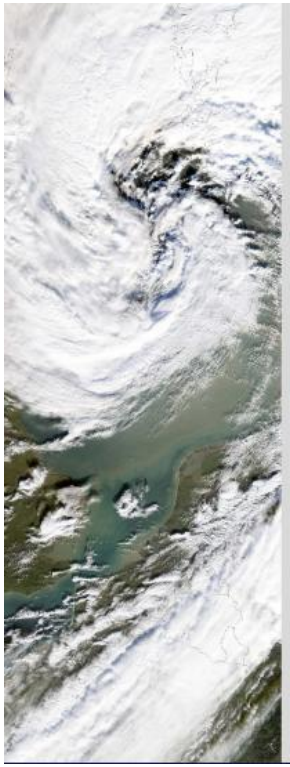
PALM-4U

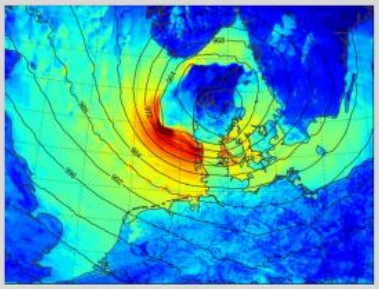

wspeed
256.0
204.8
153.6
102.4
51.2
0.0
y (meters)
0.0
51.2
102.4
153.6
204.8
256.0
x (meters)
wspeed (m/s)
0.0
6.0
12.0
18.0
24.0
30.0


Vind hastighed over Gråbrødre torv
129.0
103.2
77.3
51.5
25.6
-0.3
z (meters)
0.0
51.2
102.4
153.6
204.8
256.0
x (meters)
wspeed (m/s)
0.0
6.0
12.0
18.0
24.0
30.0


Vind hastighed Helligånds kirken
129.0
103.2
77.3
51.5
25.6
-0.3
z (meters)
0.0
51.2
102.4
153.6
204.8
256.0
x (meters)
wspeed (m/s)
0.0
6.0
12.0
18.0
24.0
30.0

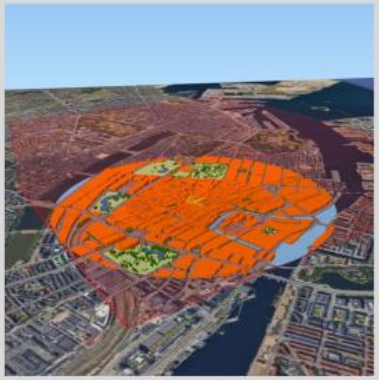
Takeaway message





The prediction from the pseudo global warming simulation with ARMONIE-AROME om the 1999 storm Anatol, **indicates an intensification** and increase of several parameters, amongst which is the **velocity** and **turbulence** crossing over into the high-frequent part of the van der Hoven spectrum.

To assess the effect of the intensification on wind loading on buildings and structures in the built environment, a **large-scale transient model** needs to be created to transfer the data from meso- to microscale.



PALM-4U is used because of the inherent simplification of the geometry and meshing, **allowing a significant upsizing of the computational domain** to capture as much information from mesoscale simulation.

First trials indicate a **good reflection** of the flow characteristic inside the **urban canopy layer** and in the transition layer. The free flow remains dominated by the generic flow generation in PALM (→ *to be improved*)

Heavy part is still ahead and requires re-run of the HARMONIE-AROME simulation to collect sufficiently dense **time histories** as input (precursor) and cross-wise **interpolation** to close the gaps in the 2 x 2 km horizontal grid.

Thank you for your attention.