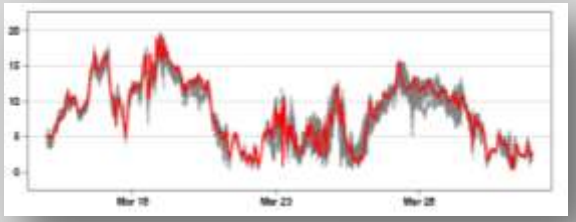
The use of high resolution prediciton models for energy asessment
-challenges in cold climate

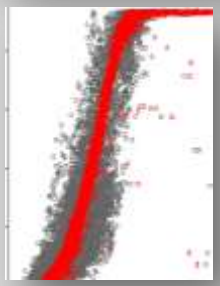
Gard Hauge
gard.hauge@stormgeo.com

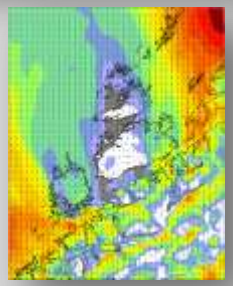
Outline

StormGeo
Control in a changing environment

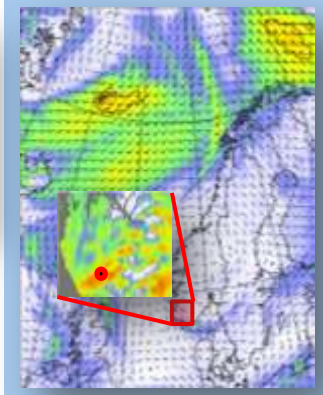
Models and methods

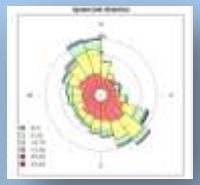


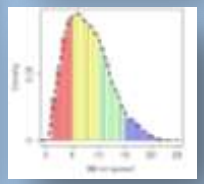




Wind Resource Mapping







Net Production

P99	P90	P75	P50
233	*265*	*279*	*298*

Challenges in cold climate

Industries and products

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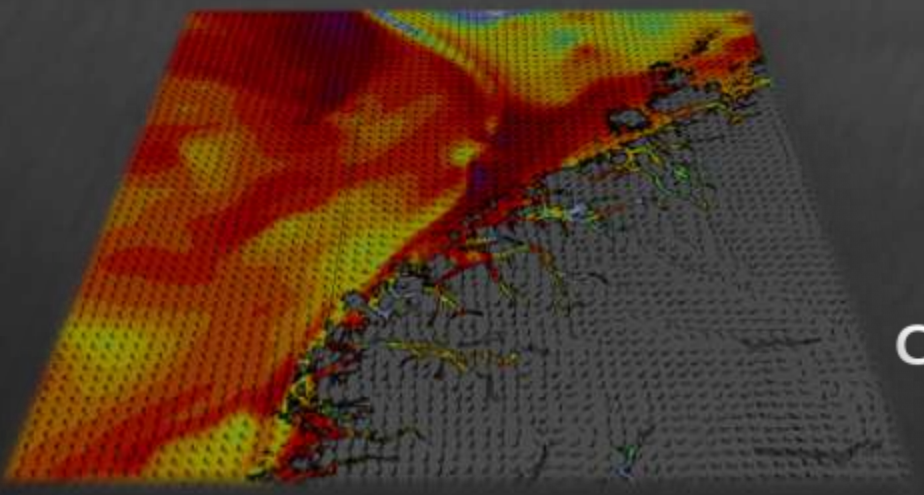
Industries	Offshore	Renewables	Shipping	Media
Services & Products	• MetOcean forecasting services • Offshore Consultancy • UK observation course • StormDrift Oilspill • Extreme weather reports • Aviation forecasting	• Wind energy asessment • PowerWeather • Wind consultancy • Wind Forecasts • Hydro Power • Energy Consultancy	• Seaware Routing • Seaware EnRoute • Seaware EnRoute Live • Seaware LNG Live • Seaware Fleet Manager • Seaware PVA	• Internet Weather Portals • TV Weather services • Print • Telecom

Offices								
							
Bergen	Stavanger	Oslo	Aberdeen	Copen-hagen	Stockholm	Houston	Baku

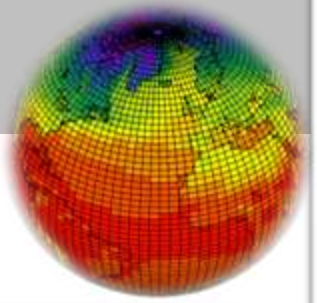
StormGeo

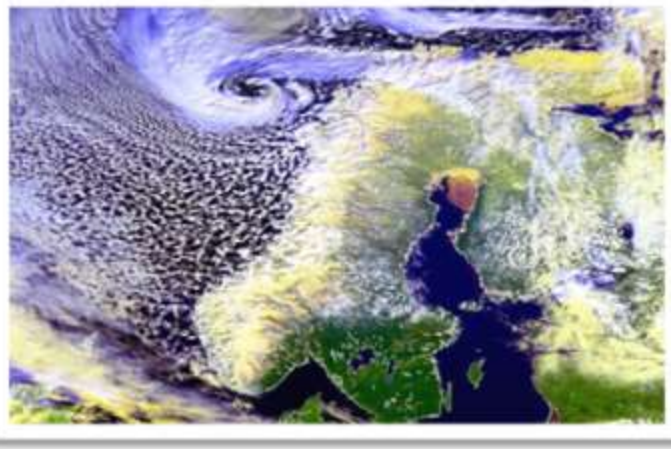
A model approach to wind energy asessement

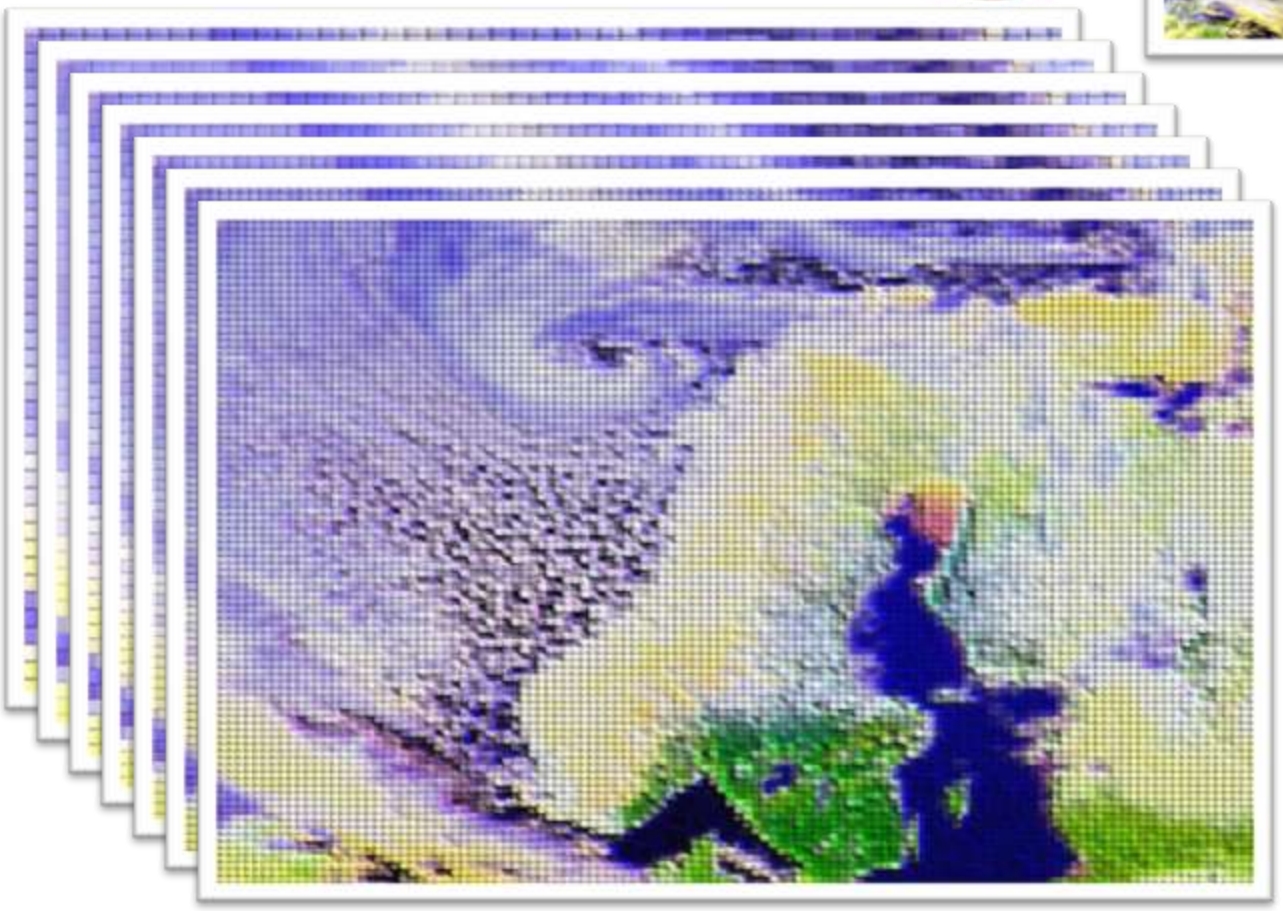


Control in a changing environment

Numerical models







The atmosphere is divided into a mesh

The size of a grid box determines the accuracy of the model

The state in every grid box is calculated forwards in time base on numerical AND physical principles

The fundamental working tool:

Numerical weather prediction models

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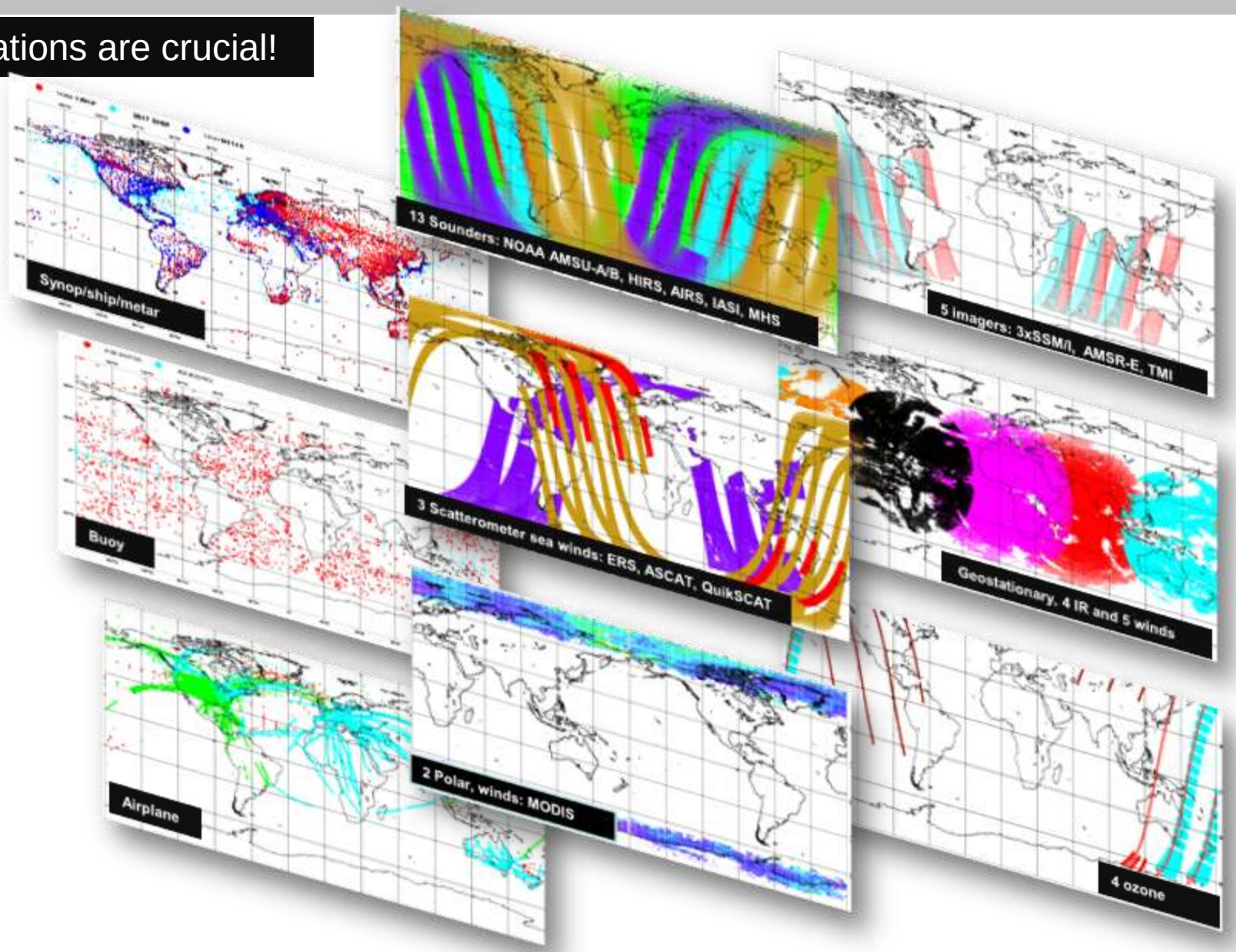
Observations are crucial!



Forecasting sources:

Numerical prediction models

StormGeo has access to all important global models

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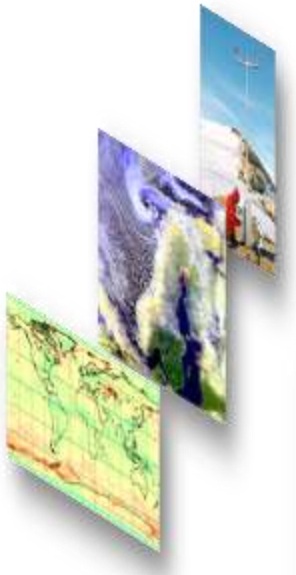
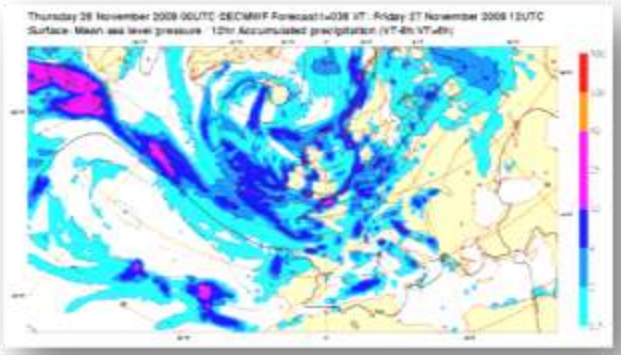
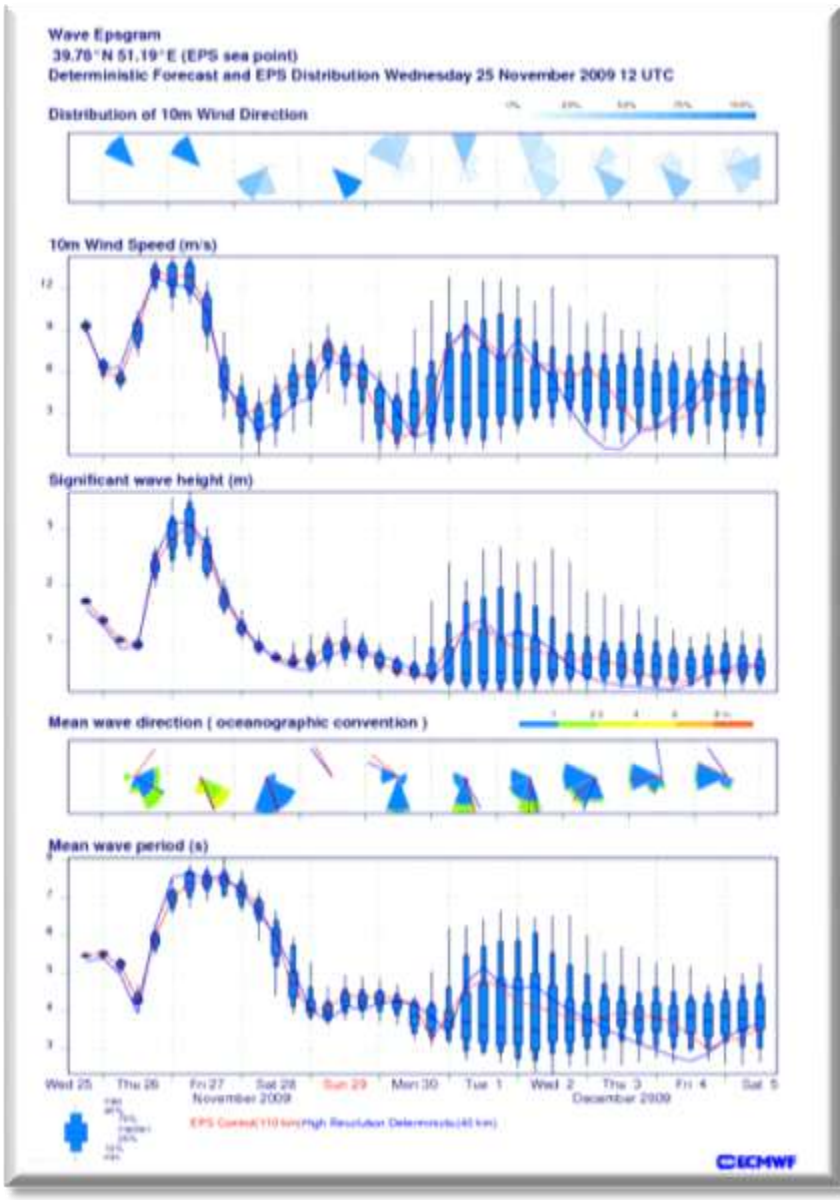


Observations

Global Models
16-100 km

NCEP





European **C**entre for **M**edium range **W**eather **F**orecasting

Proven to be the best global modelling system.

Used as boundary conditions for regional and local scale StormGeo models.

Local scale numerical modelling is strongly dependent on Initial Values used

The fundamentals working tool for weather forecasting:

Numerical prediction models

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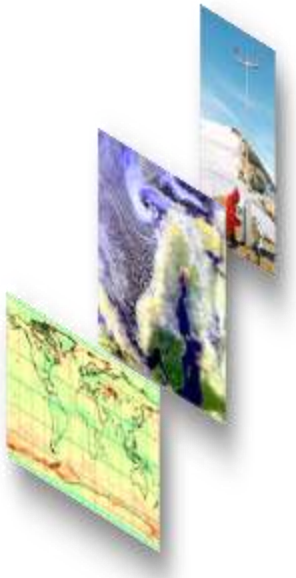


Observations

External Data

Global Models
16-100 km

NCEP

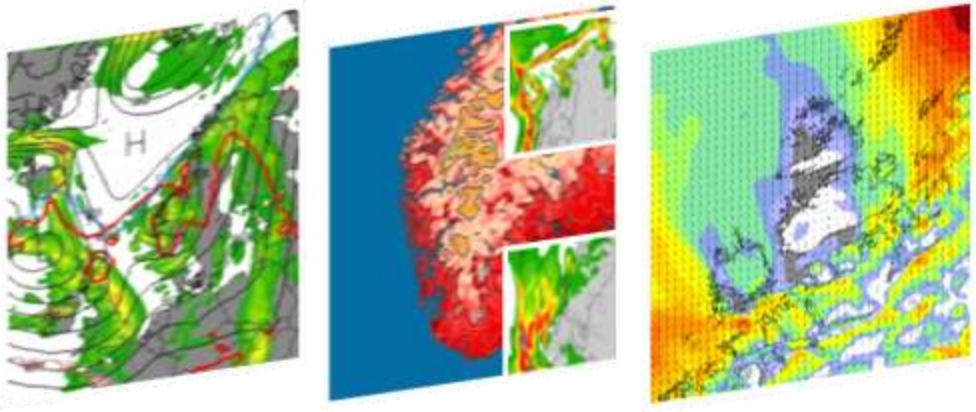
StormGeo data

Regional Models
1-9 km

WRF
MM5
SWAN

Wave and atmosphere

9 km → 3 km → 1 km



Computer power increases numerical possibilities all the time
-Models need to be tuned and improved

Methods for energy asessment by weather models

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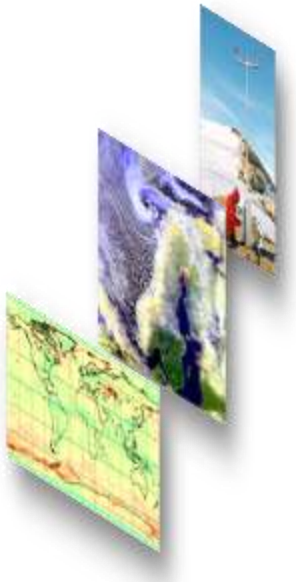


Observations

Input (Analysis)

Global Models
16-100 km

NCEP

Models

WRF
MM5
COAMPS
MIUU

Non-hydrostatic

hydrostatic

Local scale models
0.1 km-9 km

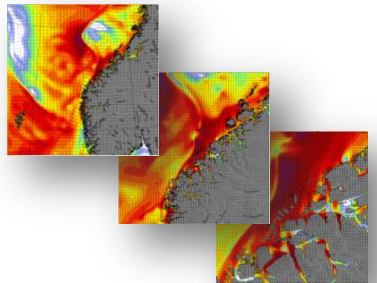
Methods

-Nesting of models to high resolution and long historical model runs (WRF,COAMPS, MesoNH,….)

- Weather classification (MIUU)

Land use and Roughness

-Corine
-USGS
-Other



Long term corrections

- Observations
- ERA – interim
- ERA40
- NCEP reanalysis

USGS landuse dataset vs Corine

- Very important for roughness felt by models

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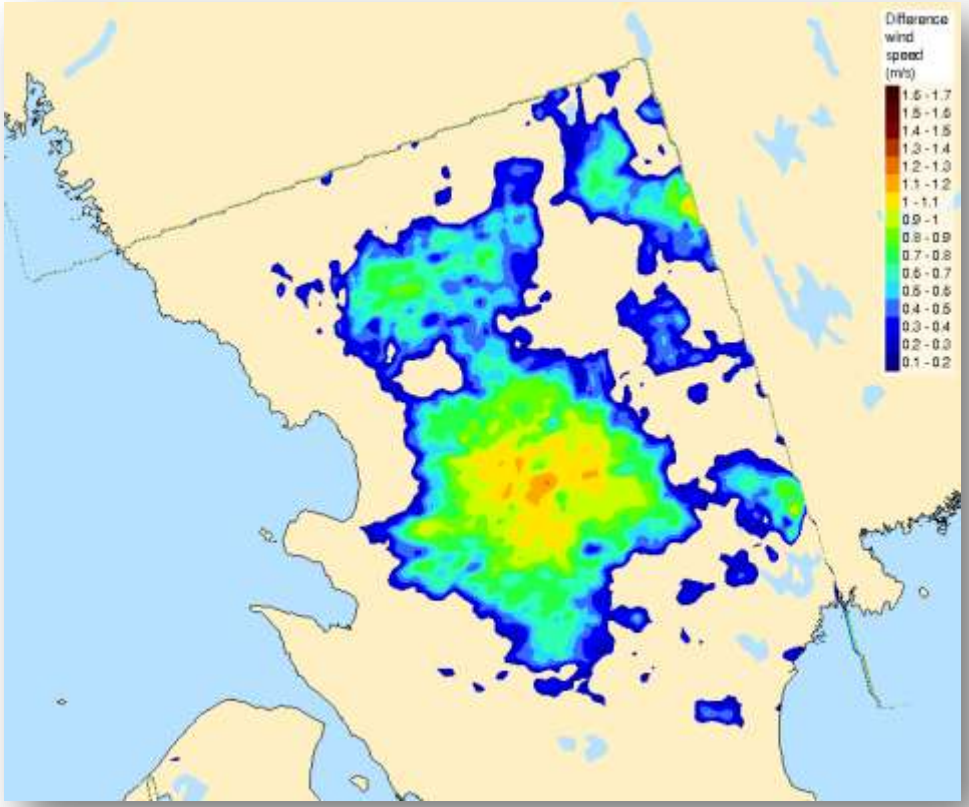
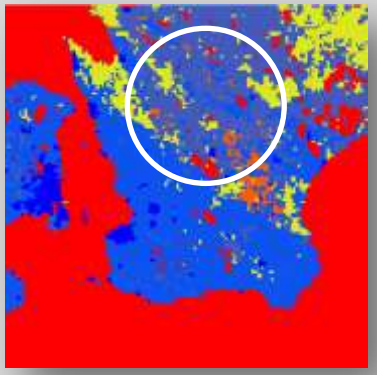
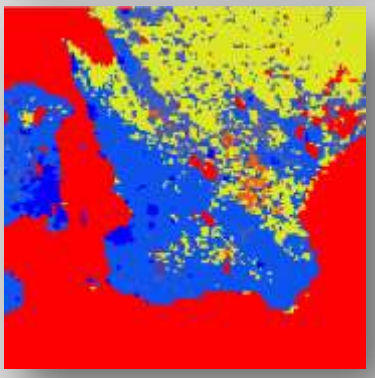


Difference in mean wind speed 70m for 2008: USGS – Corine 2000 dataset

USGS: U.S Geological survey



Yellow: forrest



Corine 2000: newer datdaset with higher accuracy

Local scale predictions

Nesting/downsacaling of models

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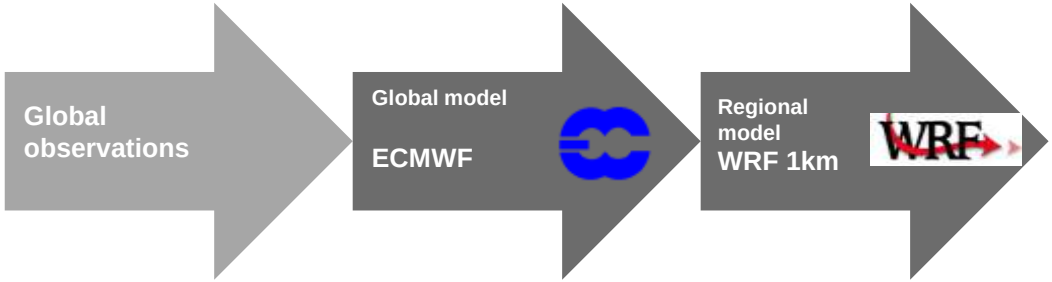
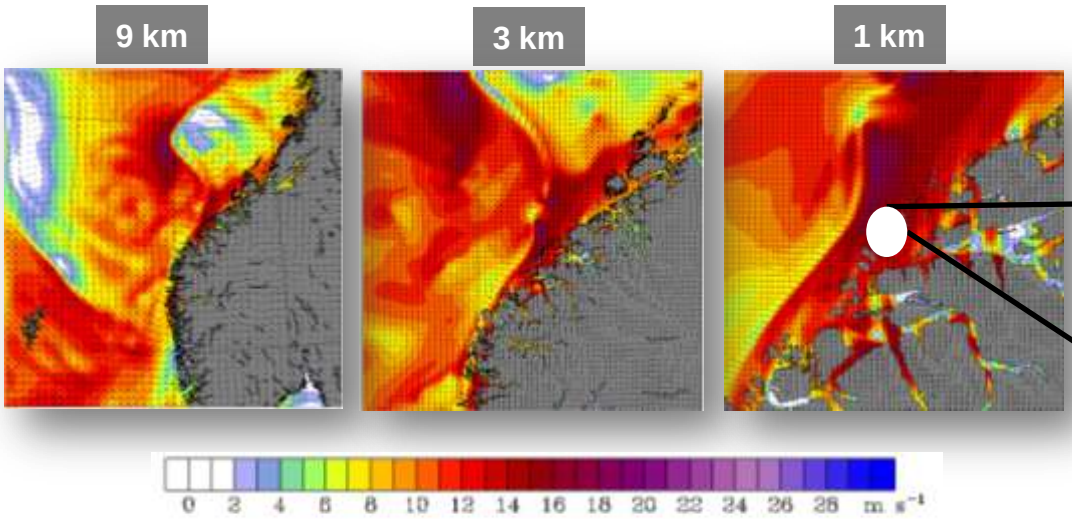
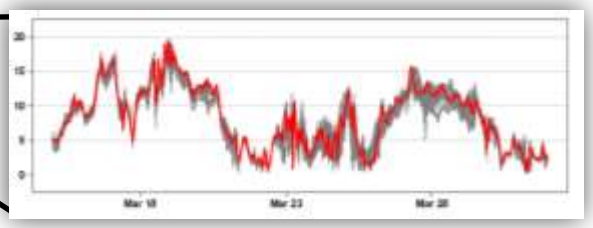




The choice of nesting technique is of vital importance.

When nesting down models from global scale models a factor of 3:1 should be used in complex terrain to capture mesoscale weather effects properly!

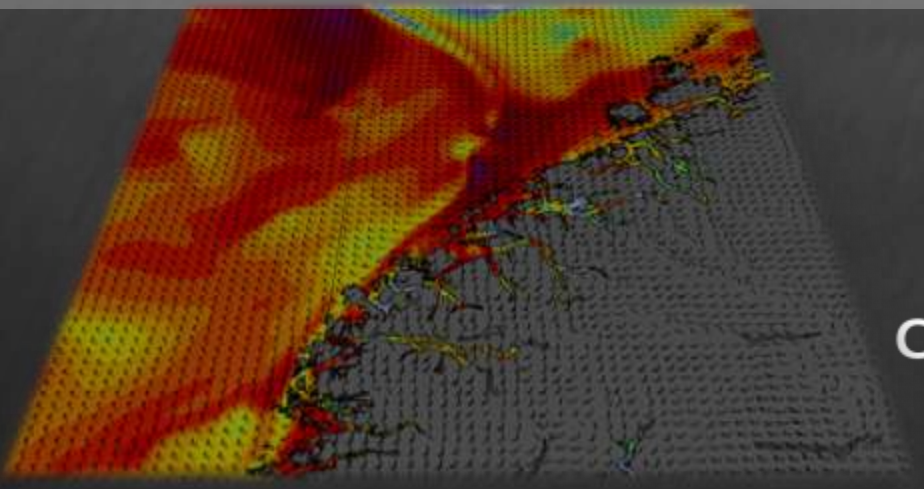


Large variance within a wind park

NEED: Good numerical models and good statistical postprocessing

StormGeo

Wind Energy asessment at StormGeo



Control in a changing environment

The StormGeo Wind planner

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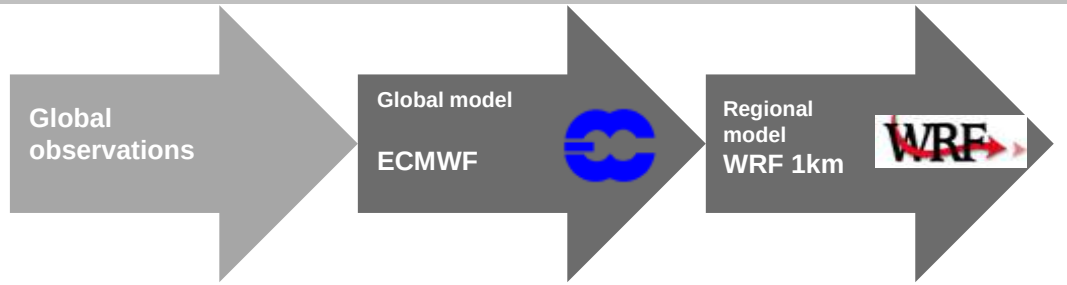
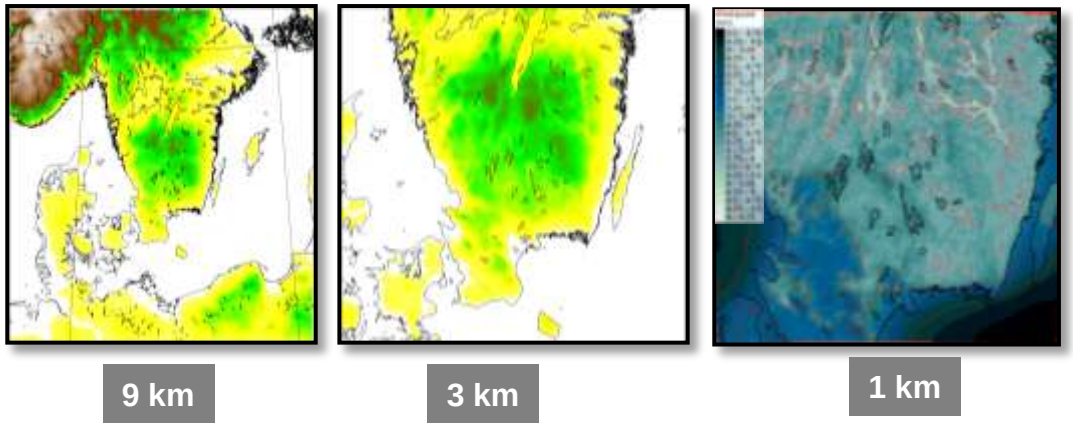
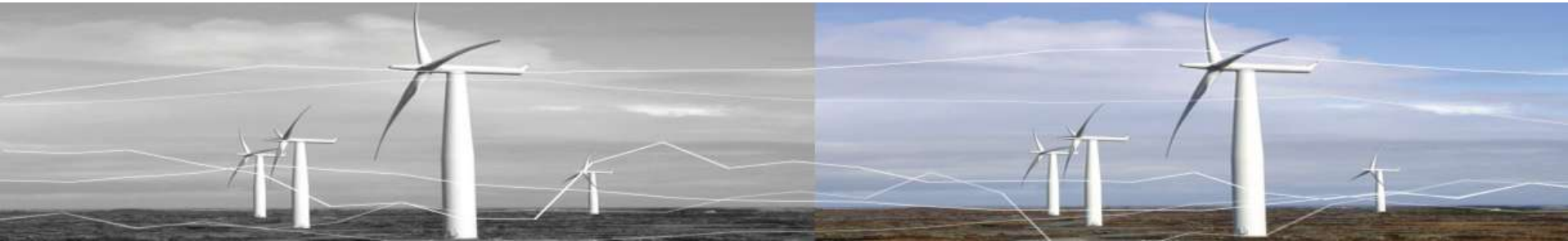
- Virtual measurements
- Long term climatology– ERA interim
- Wake loss
- Effects from atmospheric stability
- Turbulence
- Icing
- Maintenance







Virtual Measurements

Atmospheric Hindcasts at StomGeo

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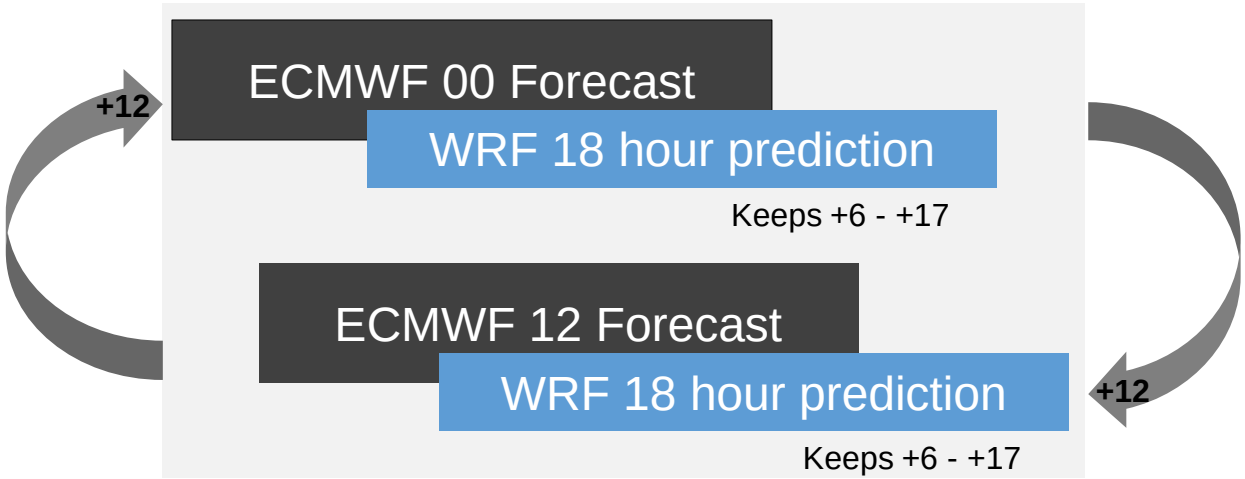
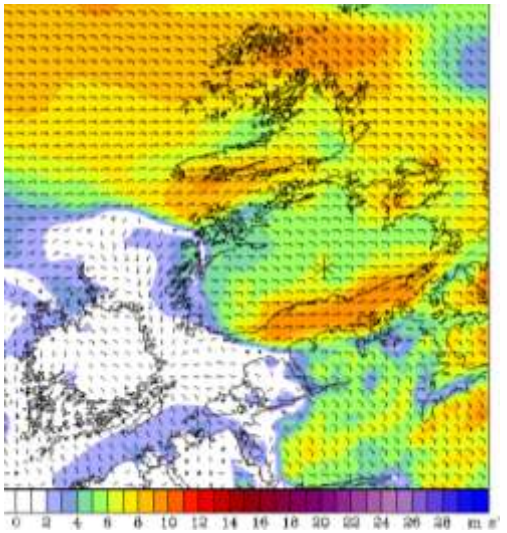
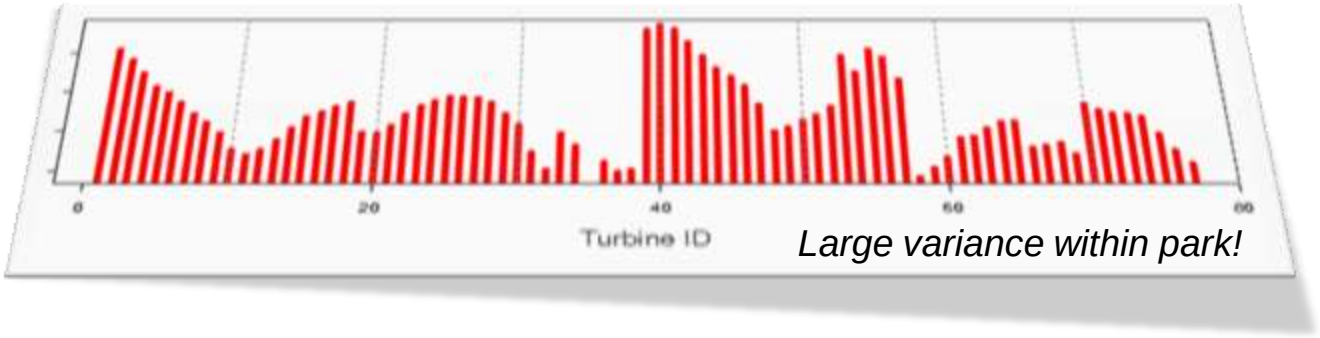
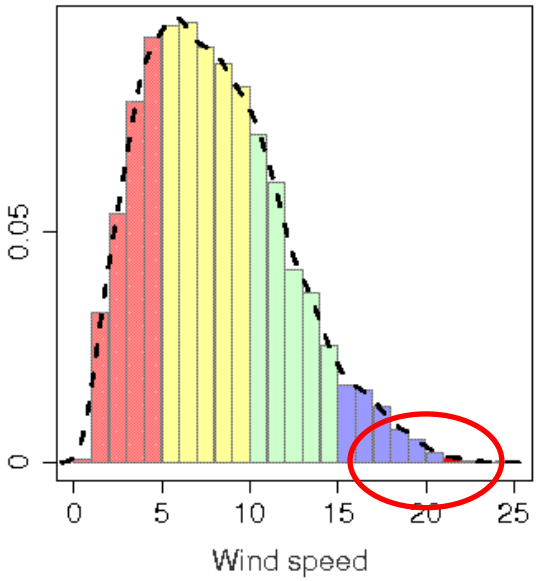
High resolution model used to create long and consistent time series







Large variance within park!



Hindcast ➡ ERA = Climatological Perspective

Height corrections – Complex terrain

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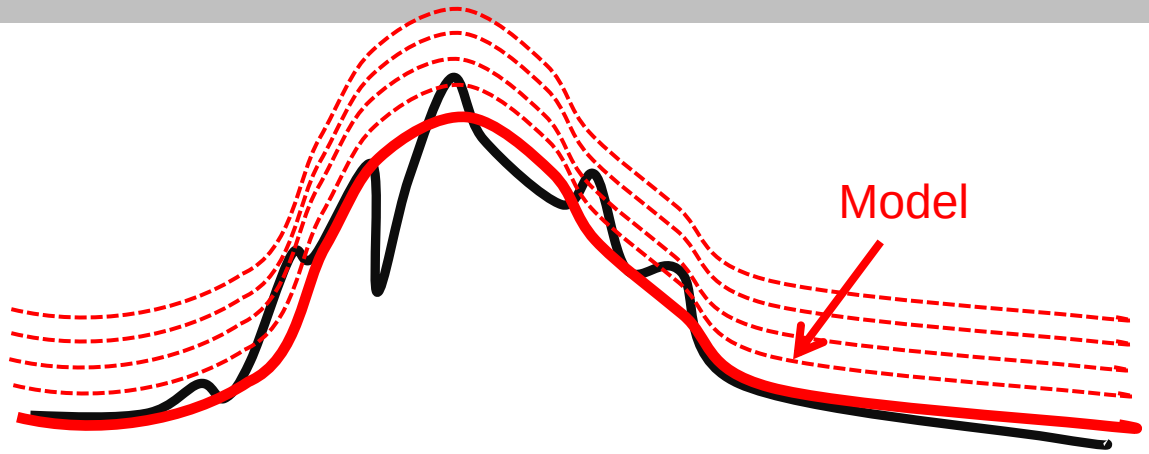
Control in a changing environment

- Due to small scale terrain effects not catched by a 1 km model.
- Input:
  - Height of the model surface
  - Surrounding ’real’ terrain
  - The exact altitude at the specified location
- This gives much more accurate wind speed estimates.
- The correction depends on model setup and type of terrain.



Long term corrections

- ERA interim and observations

StormGeo
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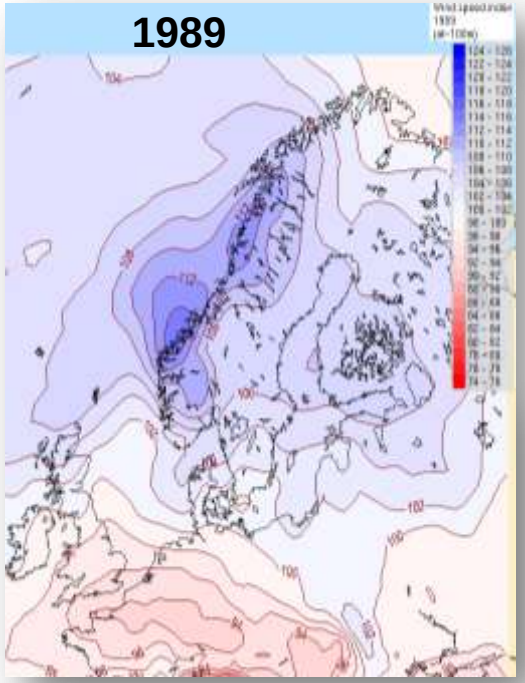
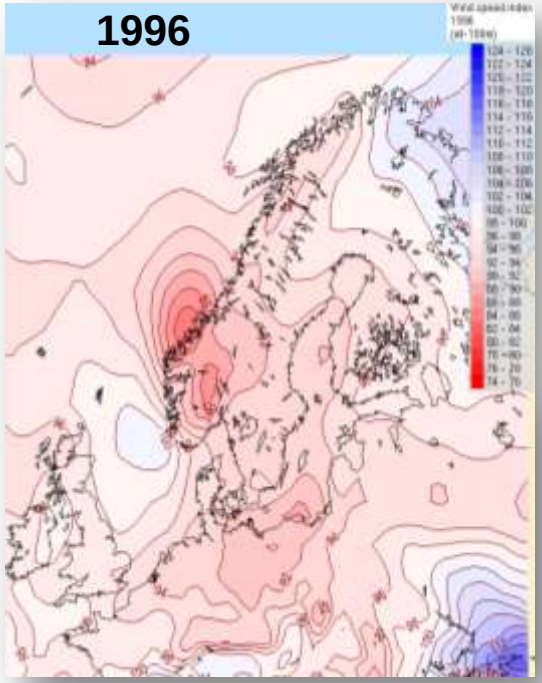
Based on available measurements and ERA-interim

ERA-interim is a global dataset at 70km resolution from 1989-present with 3hour time resolution





The main advances in the ERA-Interim data assimilation compared to ERA-40 are:

12 hour 4D-Var

70 km horizontal resolution

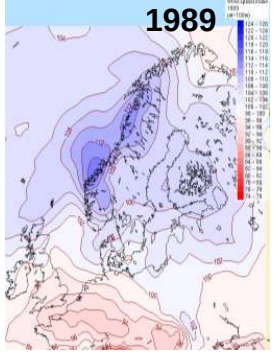
New humidity analysis

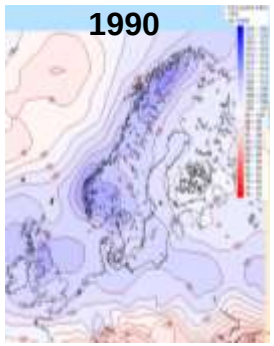
Improved model physics

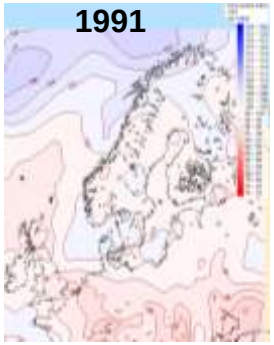
Data quality control that draws on experience from ERA-40

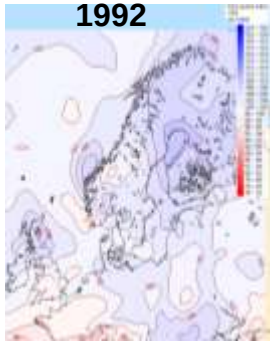
More extensive use of radiances, and improved fast radiative transfer model

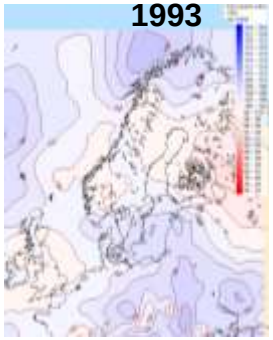
http://www.ecmwf.int/research/era/do/get/era-interim

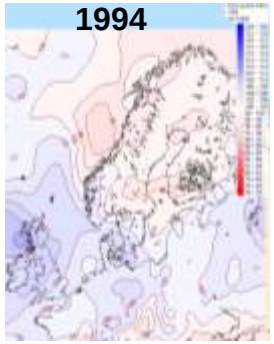


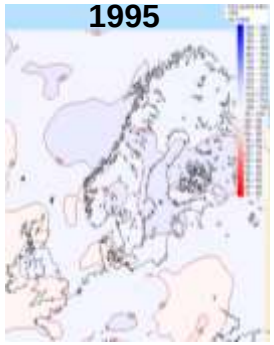


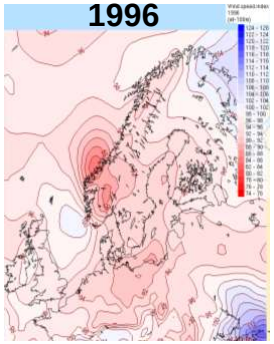


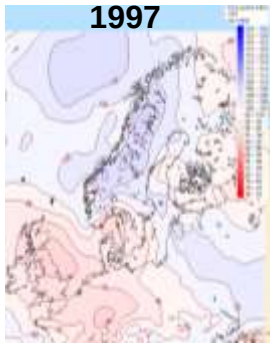


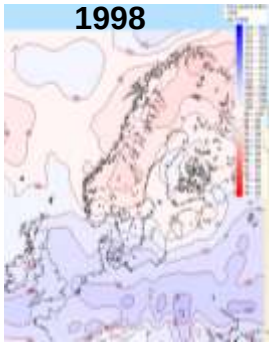


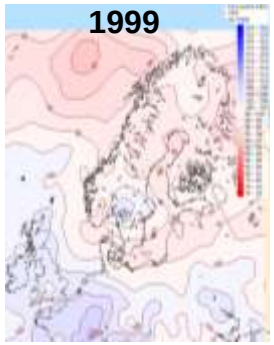


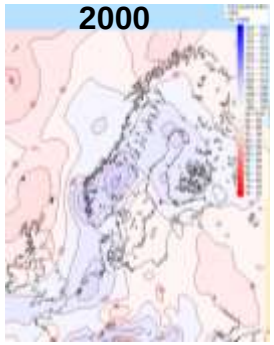


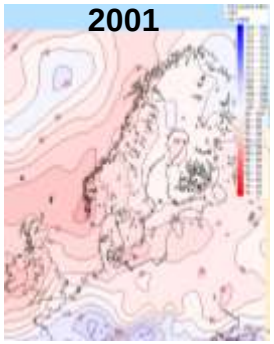


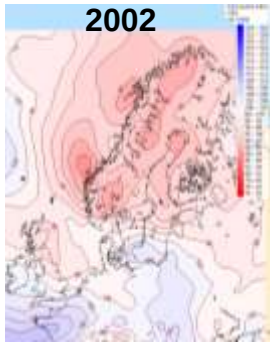


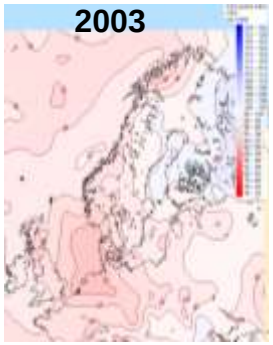


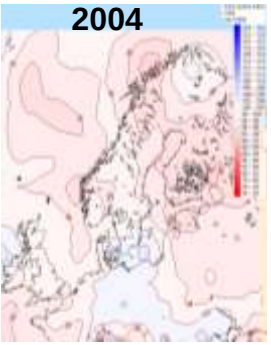


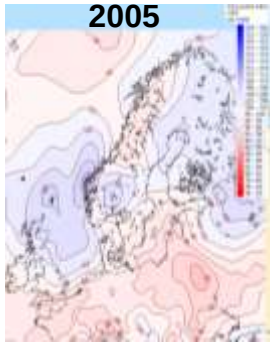


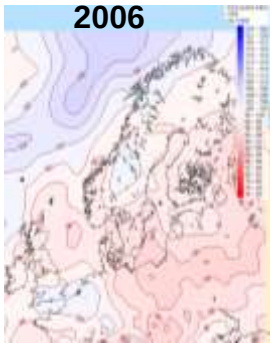


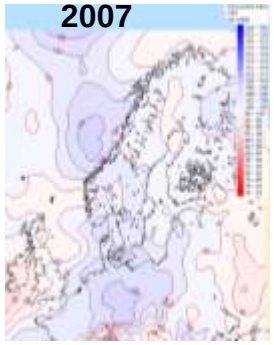


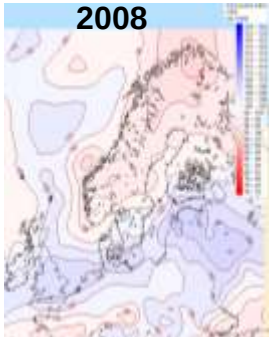


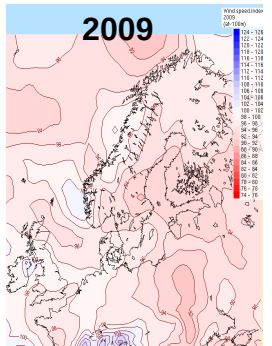












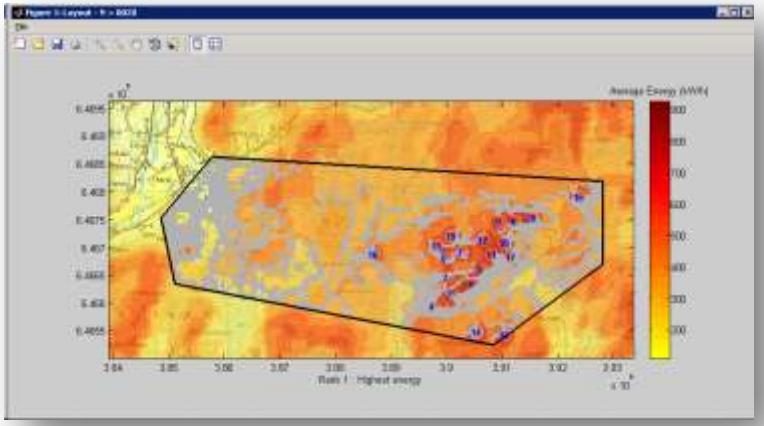
StormGeo

Control in a changing environment

ERA interim Analysis

1989 – 2009
70 km resolution

Park Design in coorporation with Agder Energy

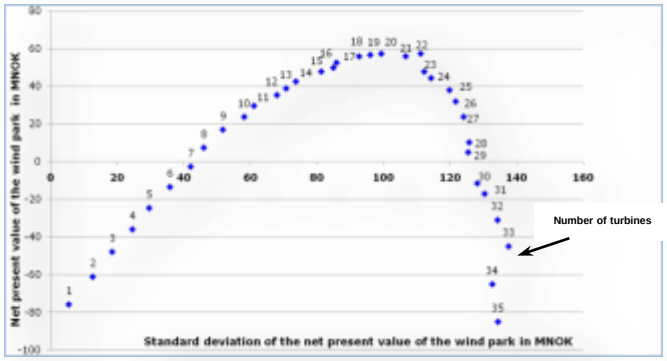


Screenshot from ParkDesign

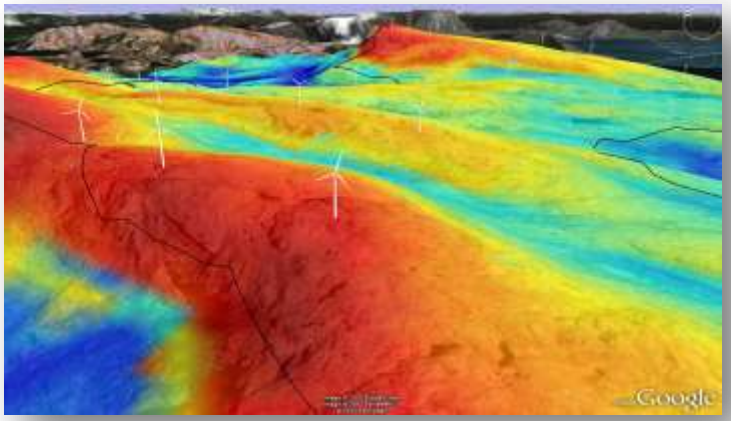
Optimised layouts

Risk assessment

Investment analysis

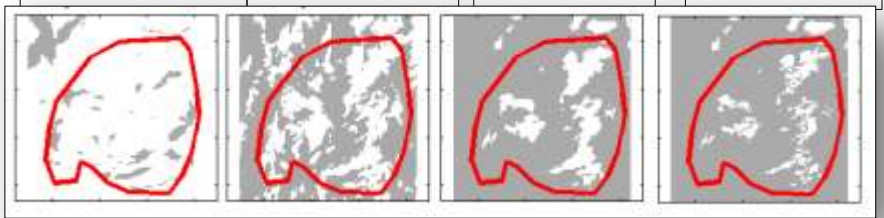


Profitability versus risk as function of project size



Optimal layouts visualised in Google Earth

Flow Inclination	Turbulence	Wind Shear	Total Exclusions



The effect of wakes

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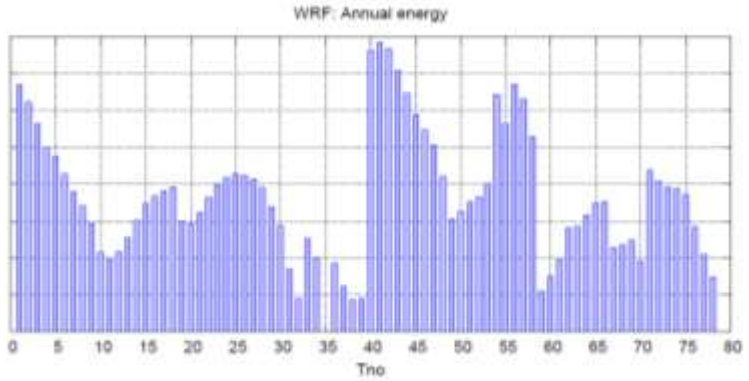
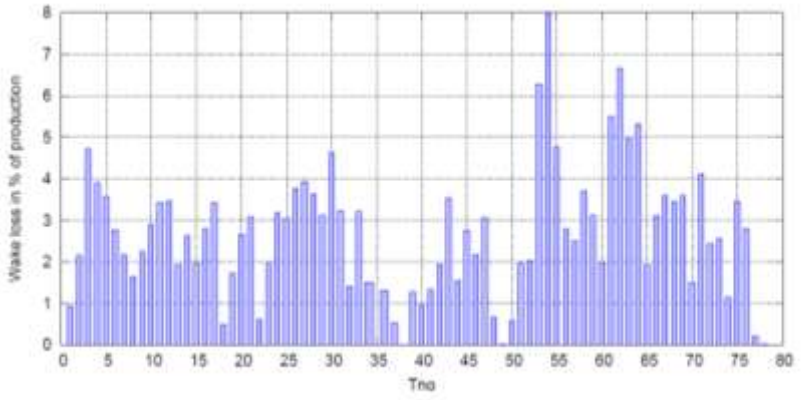
Control in a changing environment

Ex: The wake loss is calculated for every time step of the whole hindcast period





Wake loss on estimated energy production has been implemented into StormGeo planning software

StormGeo wind farm optimizer

StormGeo
Control in a changing environment

Park layout

[Note that this is very computer demanding stuff! Do not make more than one request at a time!]

Choose Positions:

Choose hindcast:
Agder

Lat / UTM Northing: 56.99288280
Lon / UTM Easting: 13.02978515
Altitude:

Geo coordinates are decimal degrees, UTM coordinates are in meter (ellipsoid WGS84)

If you're using UTM coordinates, the map won't update until the WRF data extract is finished (~5 min)

Add position

Upload a text file with coordinates, one pair of 'lon,lat,altitude' or 'utmE,utmN,altitude' on each line:
Coordinate file: Browse...

'Hub-height': Zero Displacement height for forest:

Hub height can be ~ 20-140 meters

IMPORTANT! Recommendations and information for each hindcast!

Input coordinates in UTM (default is geographic coordinates)

Automatic height correction

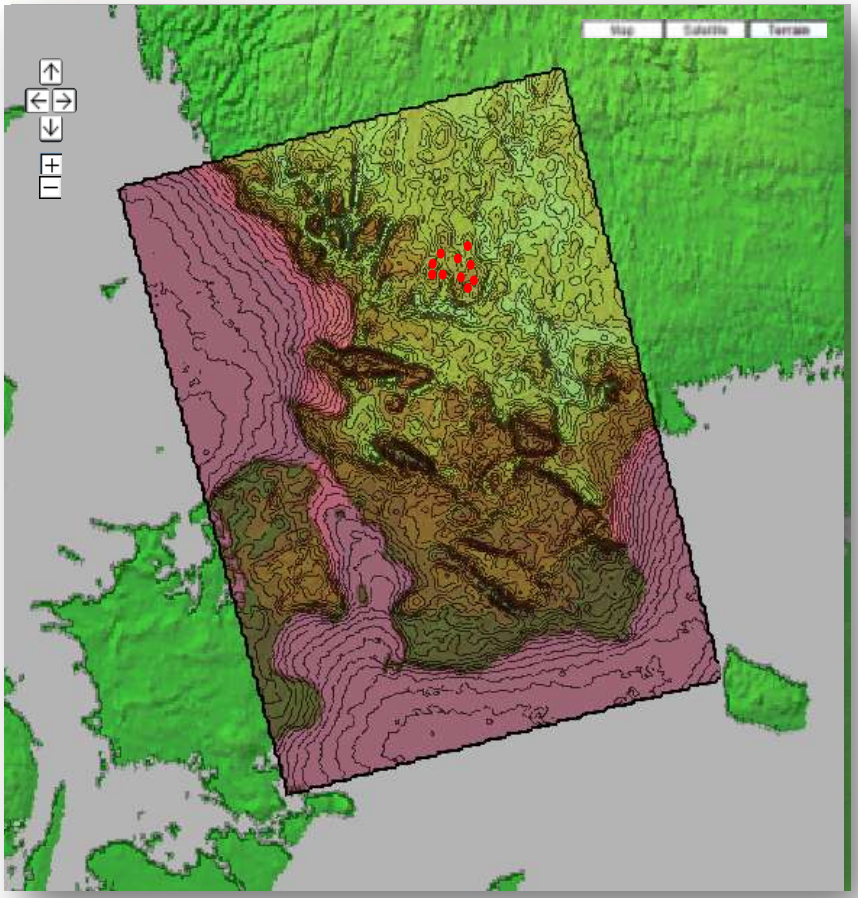
Output WRF virtual measurments in WindSim format

Energy loss estimates (%) used to get net energy production (information):

Icing:	Wakes:	Turbulence:	Electrical:	Maintenance:
1	4	2	2	2

Choose Turbine:
Siemens SWT 2.3MW-101

Start processing



An improved wind farm planner

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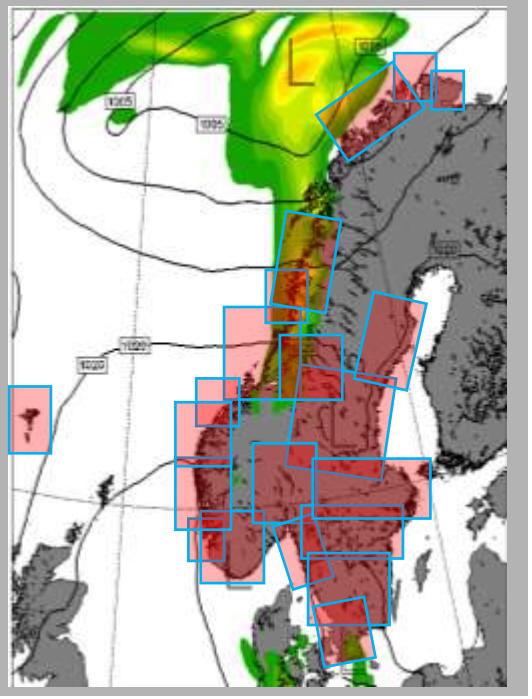
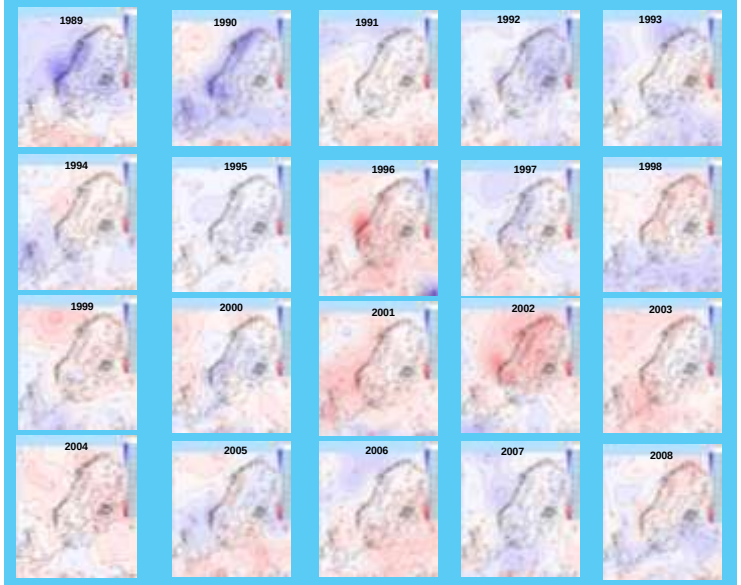
WRF Virtual Measurements

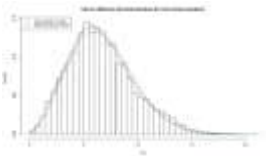


Long term climate

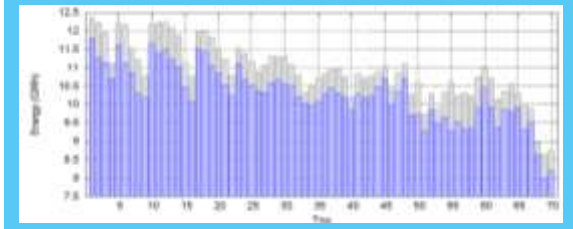


Net production

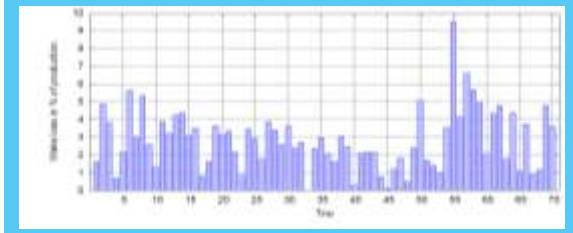
P99	P90	P75	P50
240	265	279	298



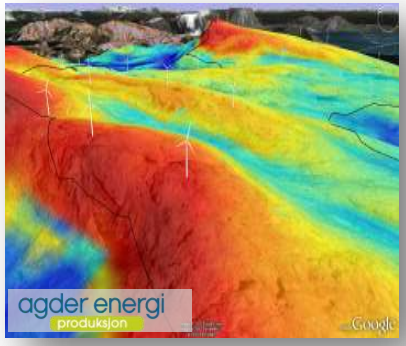
Annual Energy Production

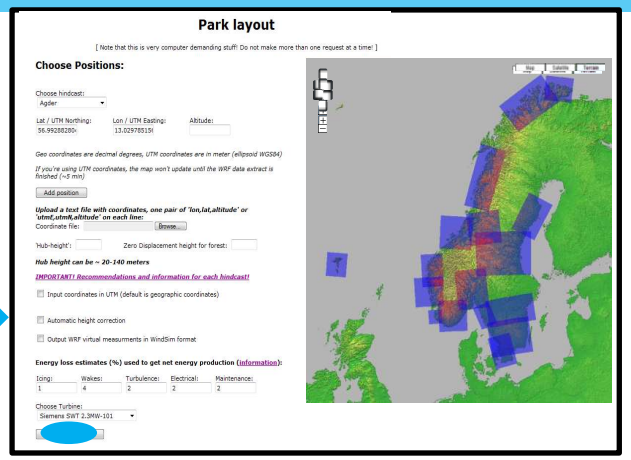


Wake Loss



Park Layout





”Normal” winter climate in scandinavia

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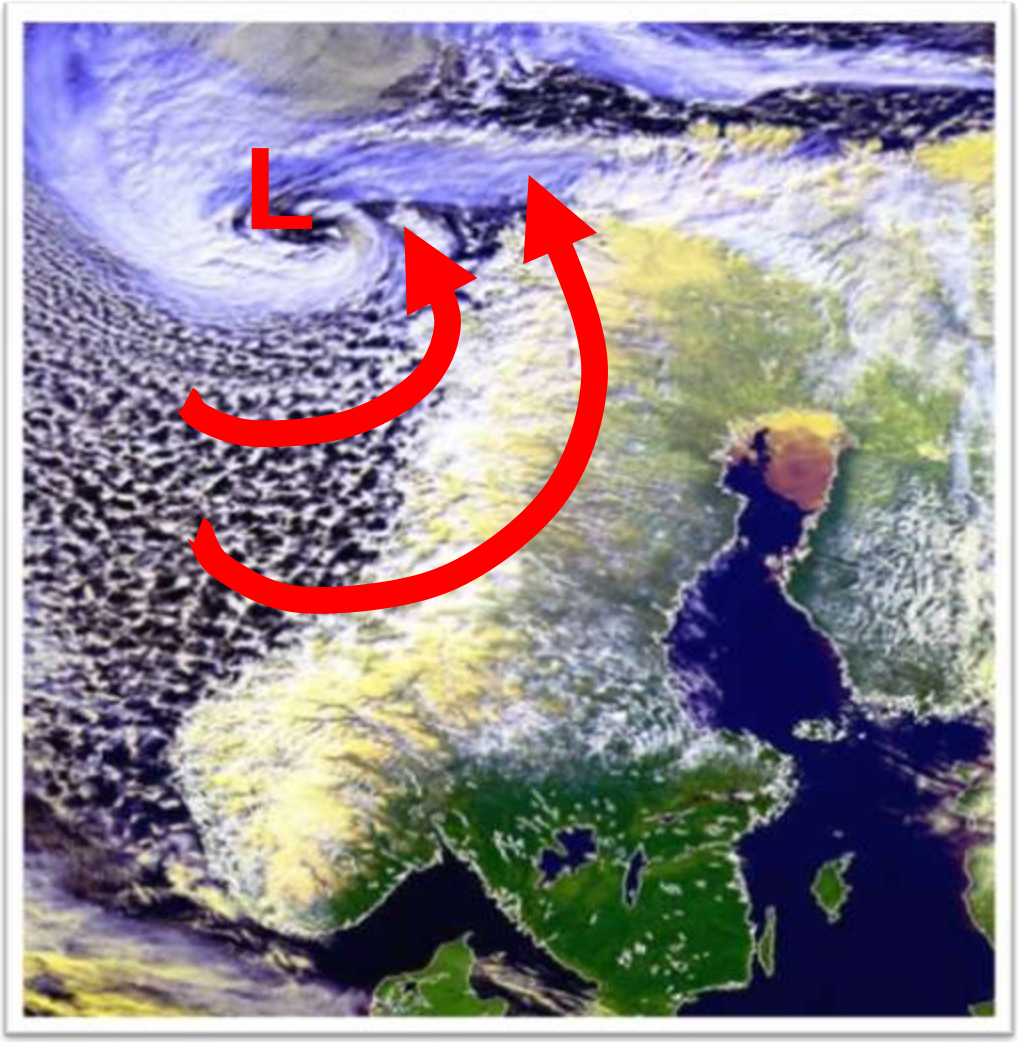
Control in a changing environment



Dominated by Low pressure systems coming in from the west

Normally high average winds during Desember, January and February

Cold climate – the 2008-2009 winter

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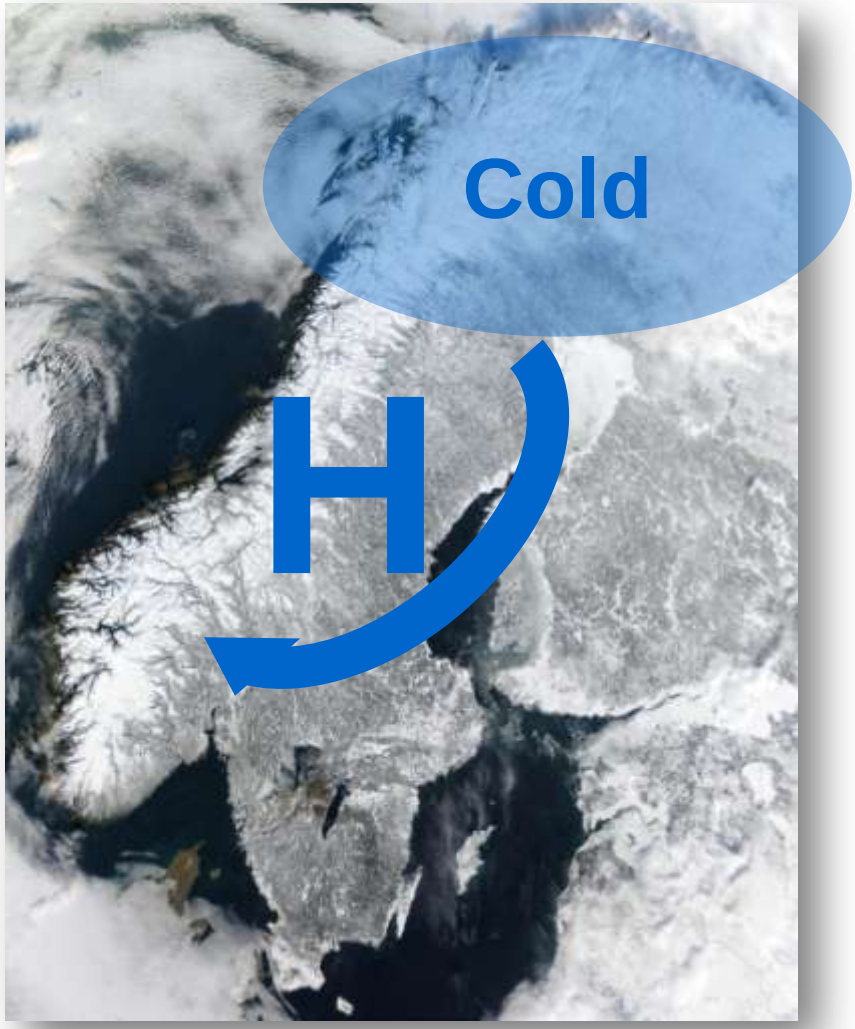
Control in a changing environment



Cold arctic air masses over Scandinavia

Cold temperatures

Easterly winds over large parts of Scandinavia for long periods

High atmospheric stability and very low wind speeds and ”non-logaritmic” wind profiles.

A closer look on 2009
- ERA interim

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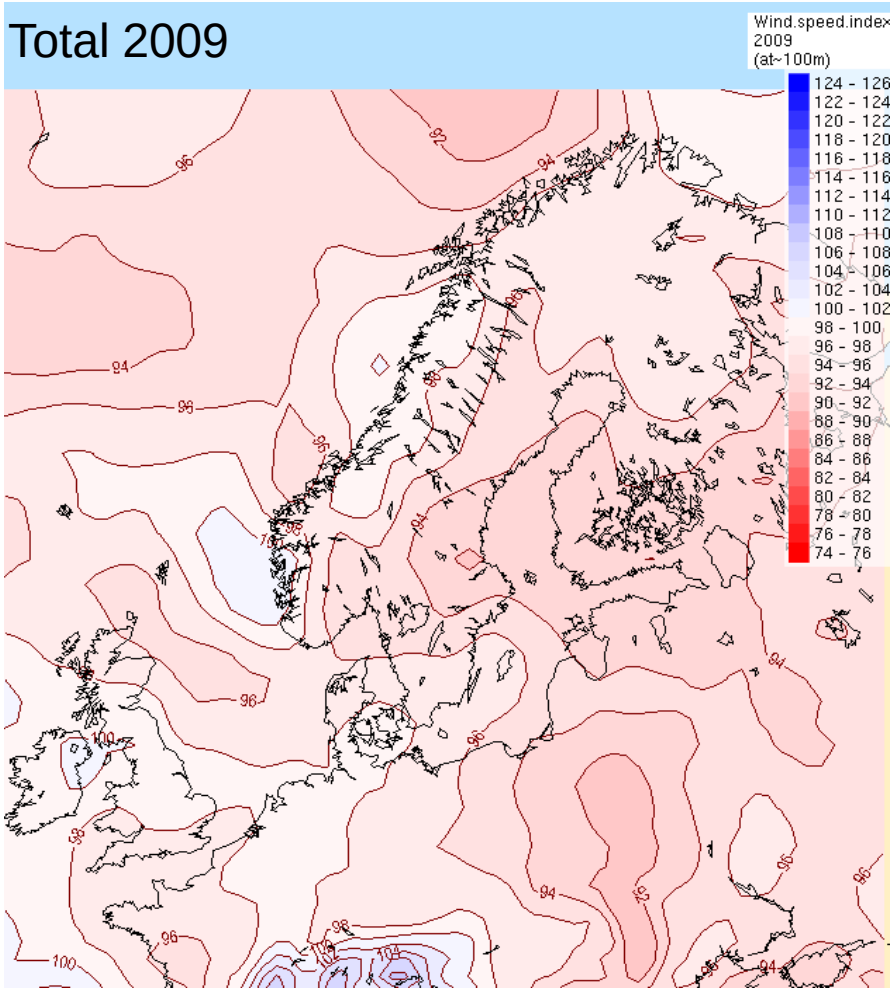
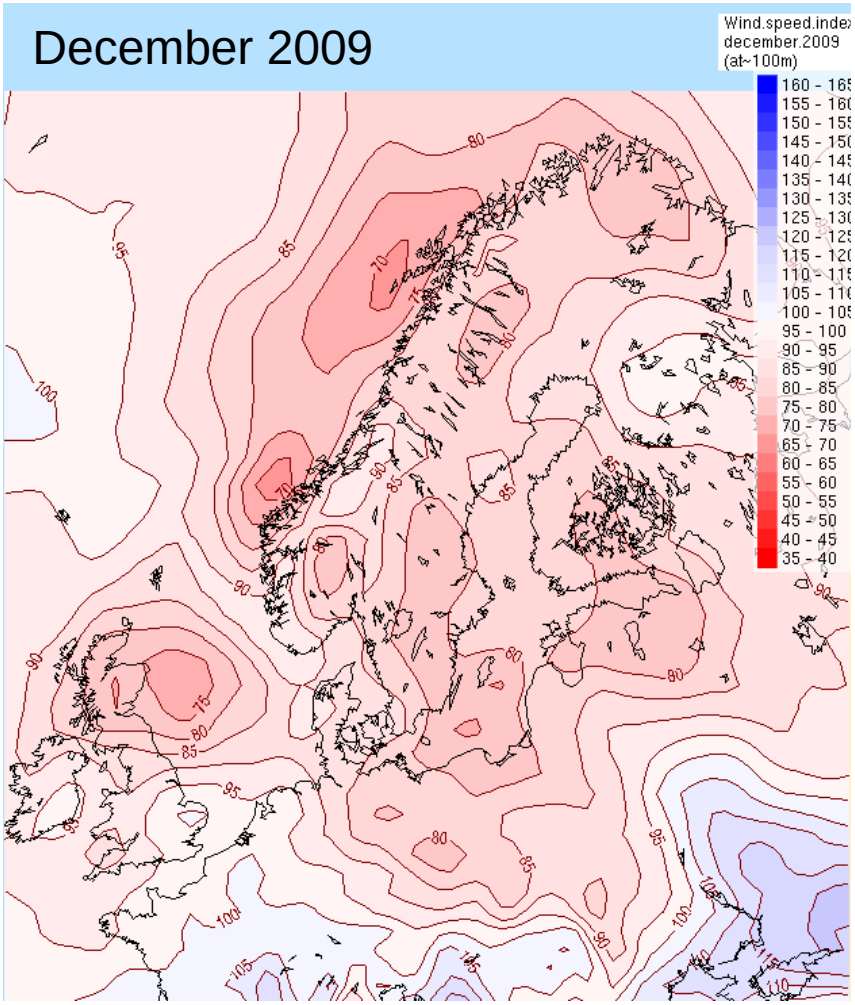
Average winds

Total 2009



December 2009



Cold climate and energy asessment

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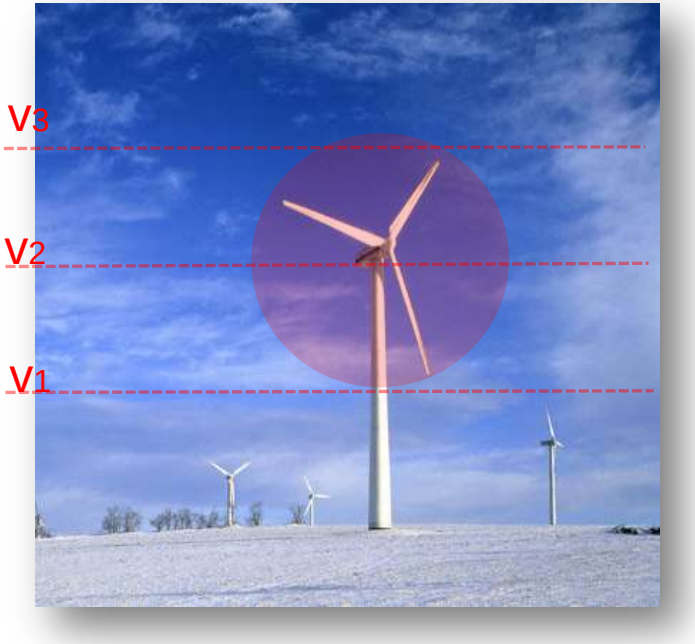
The stratification of the atmosphere is important for wind characteristics!

Non-logaritmic wind profiles based on model results

GEV correlation and linear regression based on sectors to better capture effects based on high atmospheric stability

The vertical wind profile from virtual measurements are used!



Weather prediction models have a much higher possibility to capture real weather and real wind condtions

It gives a high probability to capture the effects of cold weather with higher air densisty and a stratified atmosphere and its effects on the wind fields

Ongoing work

StormGeo
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Based on ERA-interim

10 years at 3km horizontal resolution: 2000-2010

Improve extreme value analysis and energy the uncertainty measures of energy estimates