Predictability of European windstorms

Workshop on “climate change and weather modelling”

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Outline

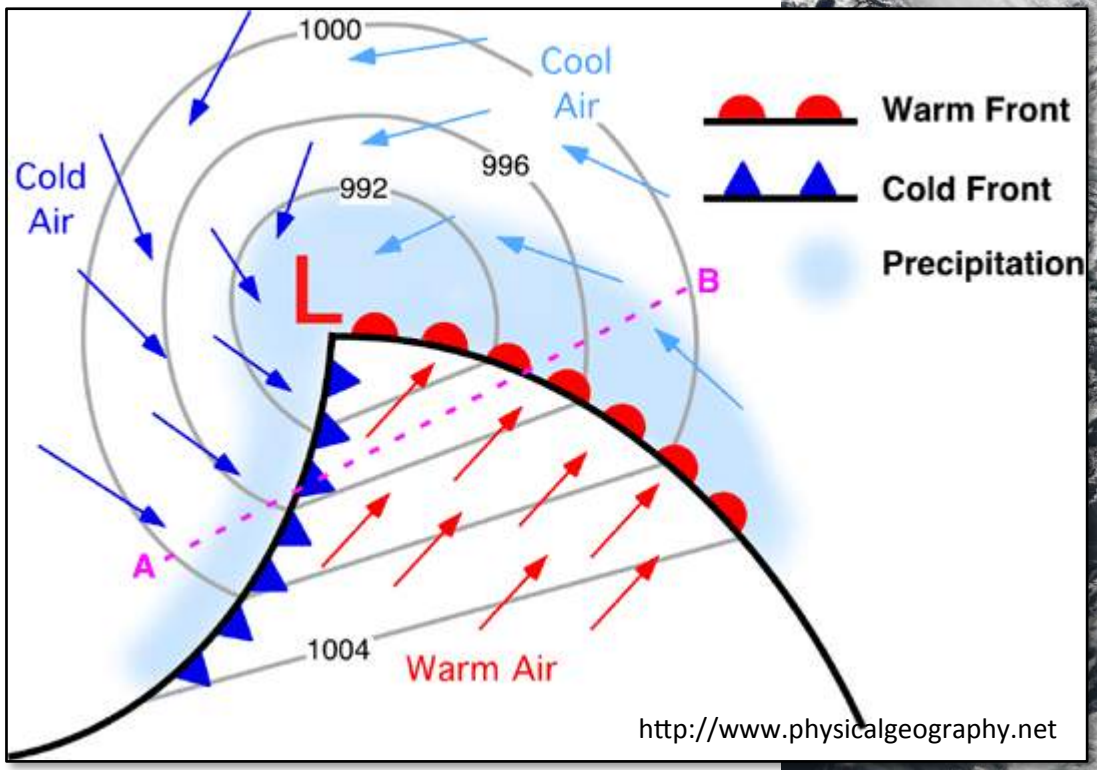
- Extra-tropical cyclones and related windstorms
- Numerical weather prediction
- Identification and tracking of windstorms
- Predictability of European windstorms
  - From ensemble forecasts to windstorm probabilities
  - Are forecasted probabilities reliable?

This project is funded by the European Union

Extra-tropical Cyclones

Low-pressure systems in the mid-latitudes, which are related to

- Cloudiness
- Precipitation
- Increased wind speeds



http://eoimages.gsfc.nasa.gov

Extra-tropical Cyclones
Windstorms and impacts

- Extra-tropical cyclones are a day to day phenomenon in Europe
- However, certain atmospheric conditions can cause an intensification of cyclones
- Intense extra-tropical cyclones can lead to **severe windstorms**

Some prominent examples of severe windstorms:

Name	Date	Insured losses	Fatalities
Lothar and Martin	Dec 1999	>10 billion €	140
Kyrill	Jan 2007	4.3 billion €	53
Xynthia	Feb 2010	1.3–3 billion €	51

Extra-tropical Cyclones
Impacts on critical infrastructure

- Extreme windstorms can affect different types of **critical infrastructure**

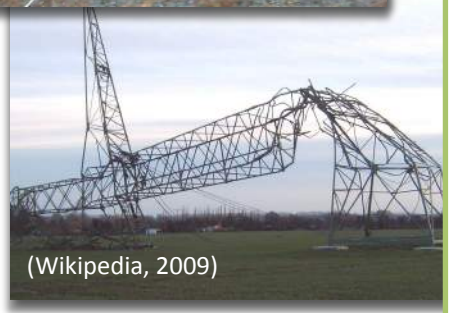
Roads

(focus.de, 2007)


(focus.de, 2013)

Electricity network


(S. Marcos, Sada, Pedrido)


(Wikipedia, 2009)

Rail transport


(focus.de, 2007)


(tagesspiegel.de, 2015)

Extra-tropical Cyclones
Results from stakeholder interviews

Interviews with stakeholders of different critical infrastructures

- 93% of the stakeholders state that their infrastructure can be affected by windstorms
- Windstorm forecasts are needed, for example, to
  - prepare power grids
  - reduce speed limits of trains
  - deploy extra personnel for road management and emergency services
- Important aspects for windstorm predictions:
  - timing, location and intensity of the event

- **Skillful predictions of windstorms are important!**
  - How does numerical weather prediction work?
  - How skillful and reliable are windstorm forecasts?
  - On which time range are skillful forecasts possible?

Numerical weather prediction

Introduction

Observations

Atmospheric Model

- Equations based on physical principles

$$
\begin{aligned}
\rho\frac{d\mathbf{v}}{dt} &= -\nabla p + \rho\mathbf{g} - 2\boldsymbol{\Omega}\times(\rho\mathbf{v}) - \nabla\cdot\underline{\mathbf{t}} \\
\frac{d\rho}{dt} &= -\rho\nabla\cdot\mathbf{v} \\
\rho\frac{dq^x}{dt} &= -\nabla\cdot\mathbf{J}^x + I^x \\
\rho\frac{de}{dt} &= -p\nabla\cdot\mathbf{v} - \nabla\cdot(\mathbf{J}_e + \mathbf{R}) + \varepsilon.
\end{aligned}
$$

Initial conditions

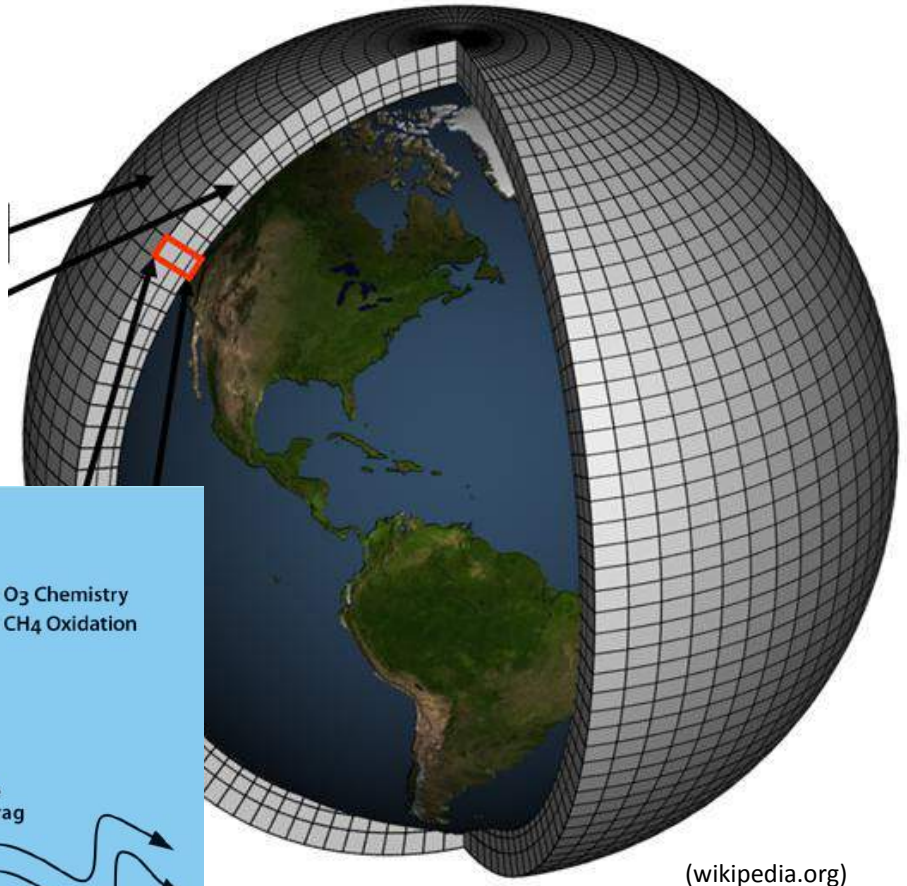
Best estimate of the current state of the atmosphere

Forecast

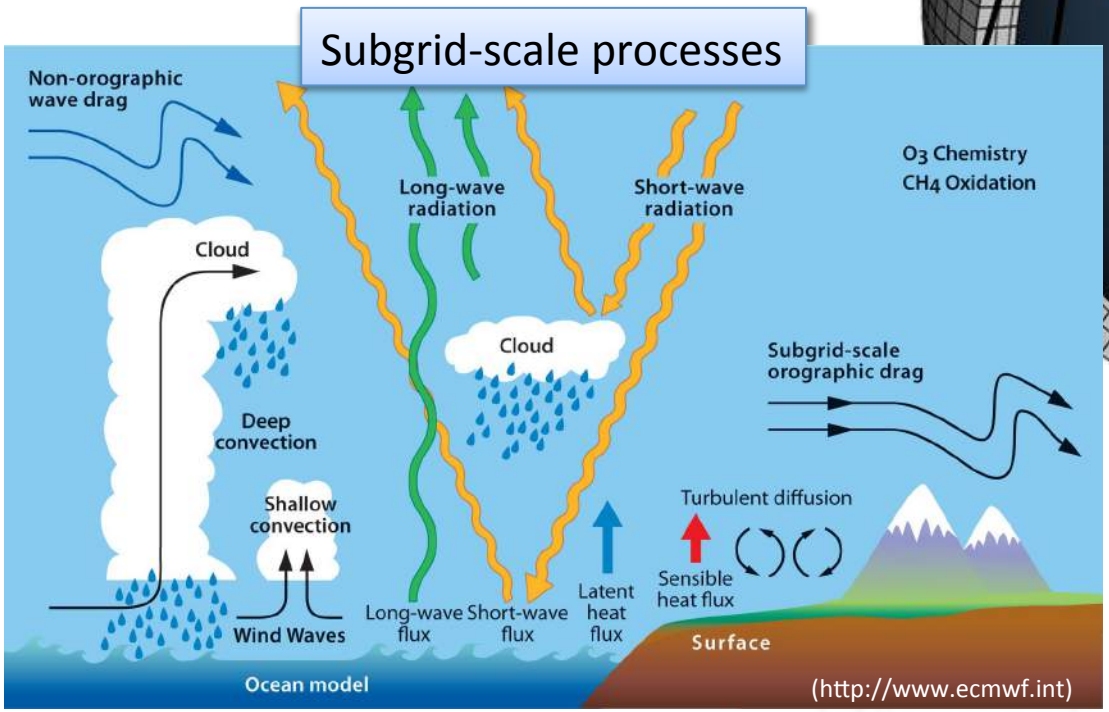
Numerical weather prediction

Global atmospheric models

- The atmosphere is covered by a three-dimensional grid
- Equations are solved for each grid cell
- Subgrid-scale processes are calculated by parameterizations



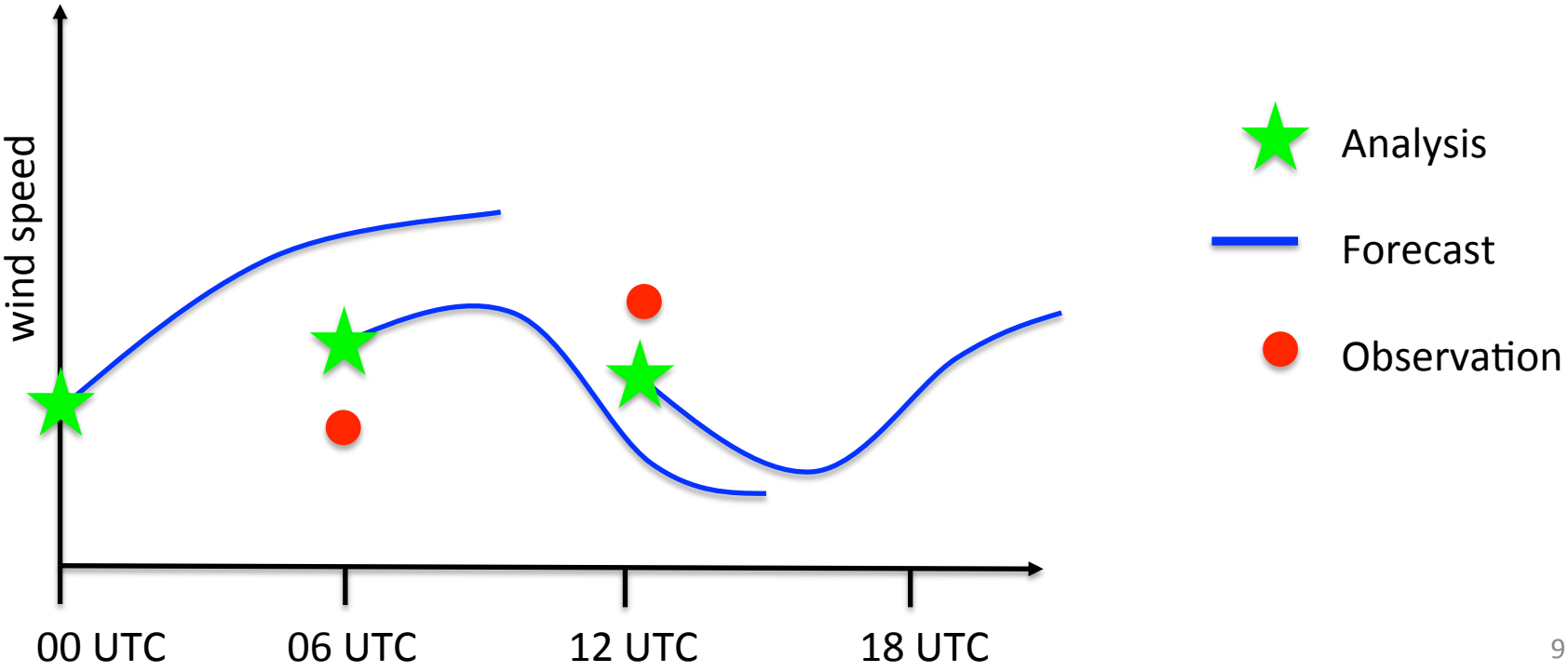
(wikipedia.org)



Numerical weather prediction

Schematic forcasting cycle

- The **analysis** is the best estimate of the current atmospheric state
- **A forecast** is initialized with the **analysis**
- A new **analysis** is created by combining the latest **forecast** with new **observations** **(data assimilation)**
- This procedure is repeated at regular time intervals



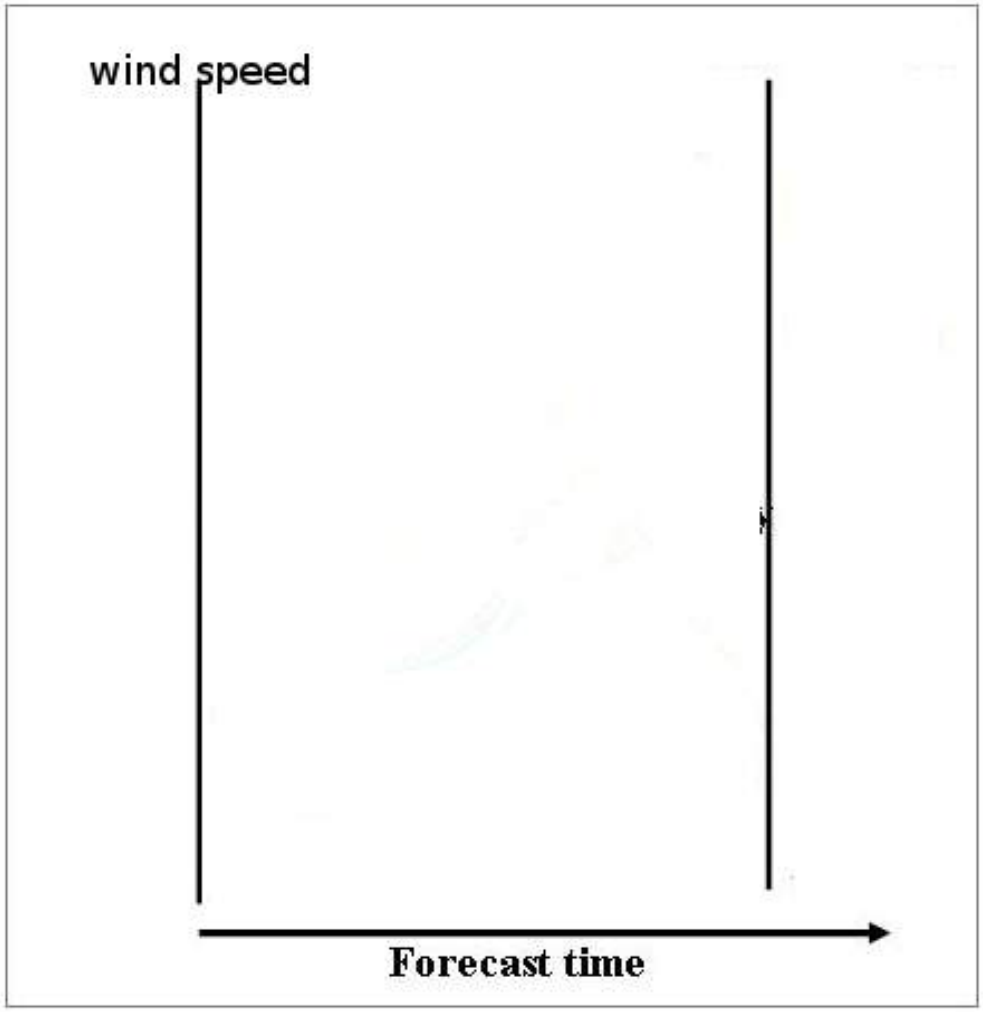
Numerical weather prediction

Ensemble prediction systems

- Weather forecasts are very sensitive to the initial conditions
- ➢ Small differences in the analysis can lead to large differences in the forecast

Keywords

- Ensemble prediction system (EPS)
  - ➢ several forecasts are made at the same time
- Ensemble members
  - ➢ individual forecasts of an ensemble
  - ➢ perturbed initial conditions
- Ensemble spread
  - ➢ Forecast uncertainty

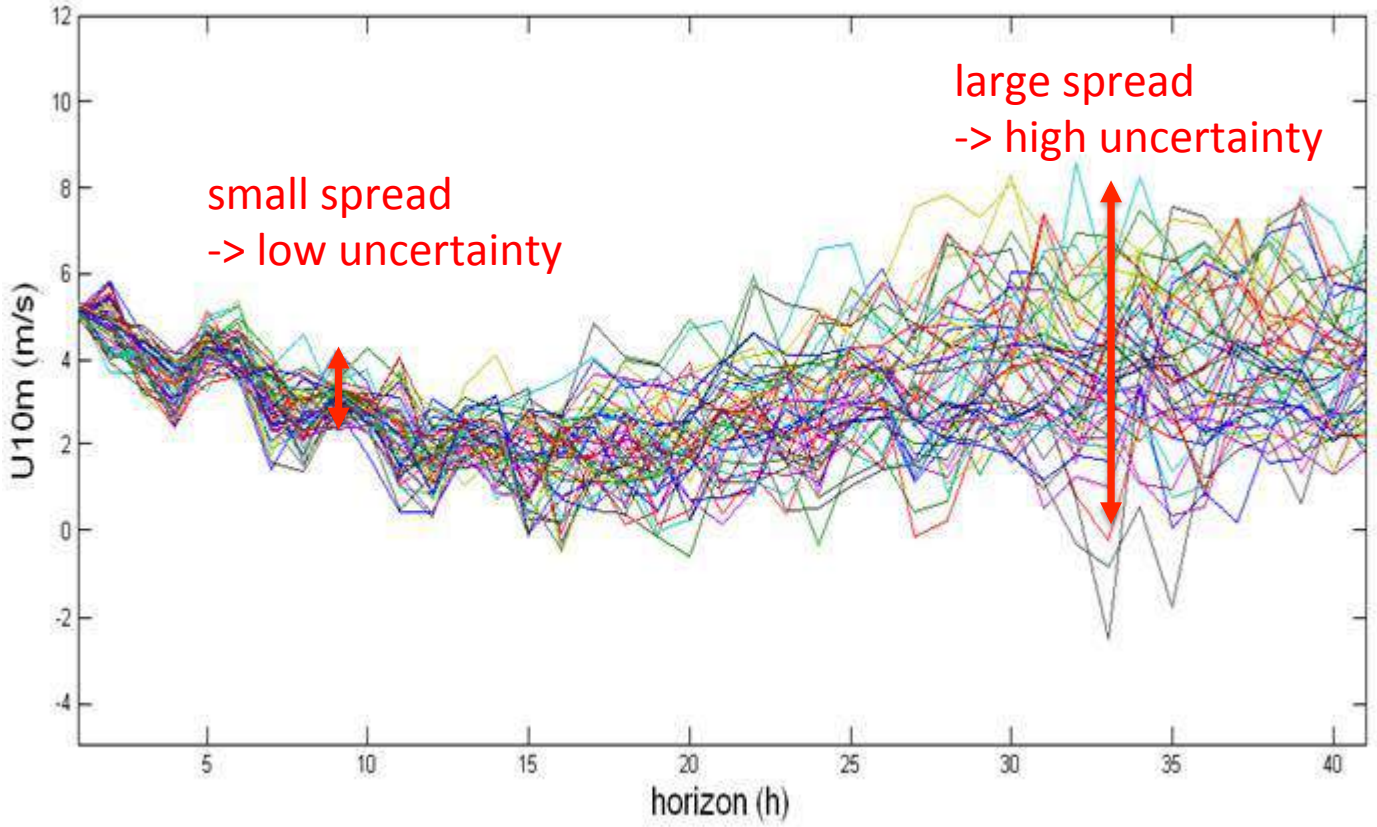


(http://grida3.crs4.it)

Numerical weather prediction

Ensemble prediction systems

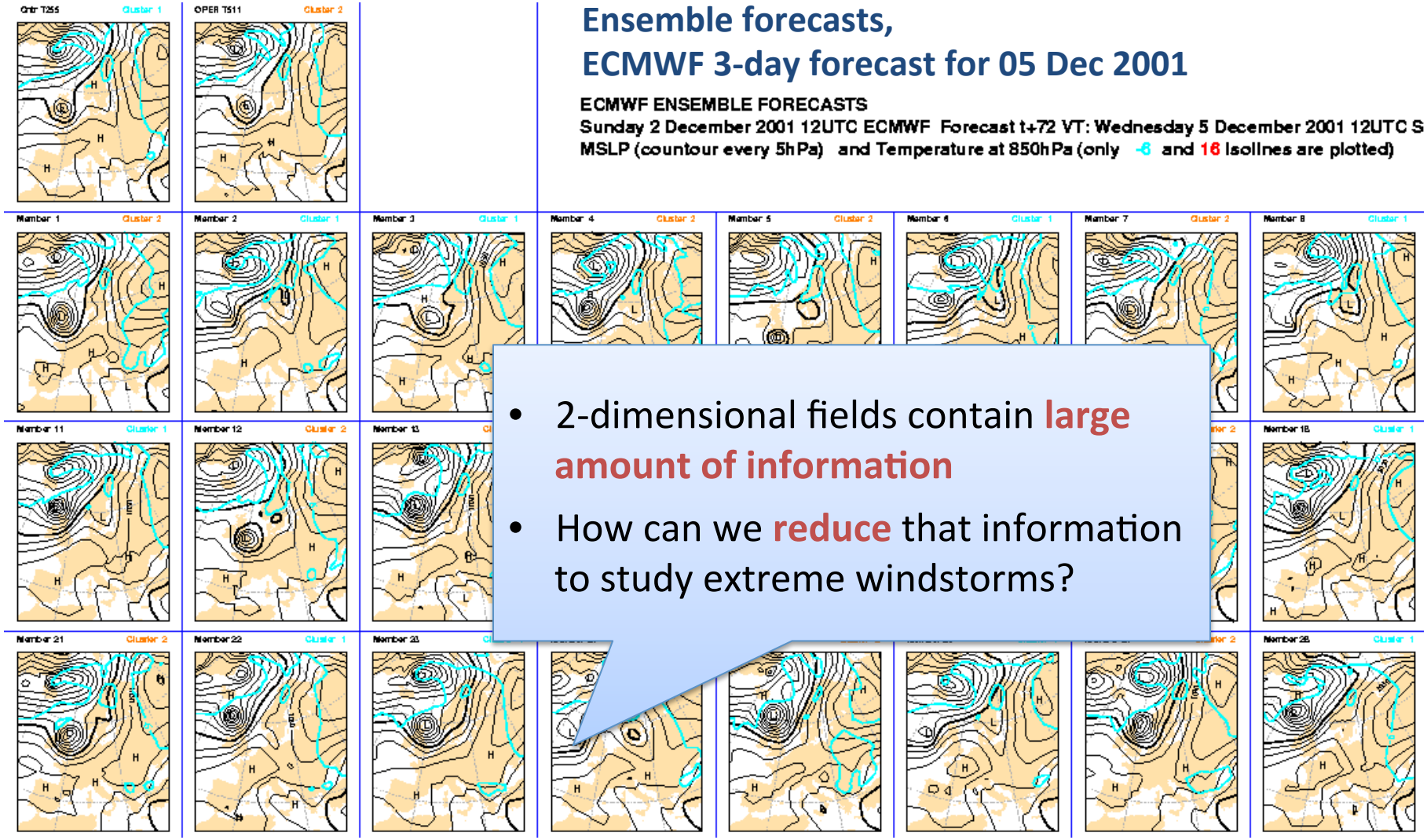
- **Example:** Ensemble forecast of wind speed at 10m height for a wind farm in France



(http://www.ewea.org/events/workshops/wp-content/uploads/2013/04/Ensemble-prediction-01.jpg)

Numerical weather prediction

Ensemble prediction systems



Ensemble forecasts,
ECMWF 3-day forecast for 05 Dec 2001

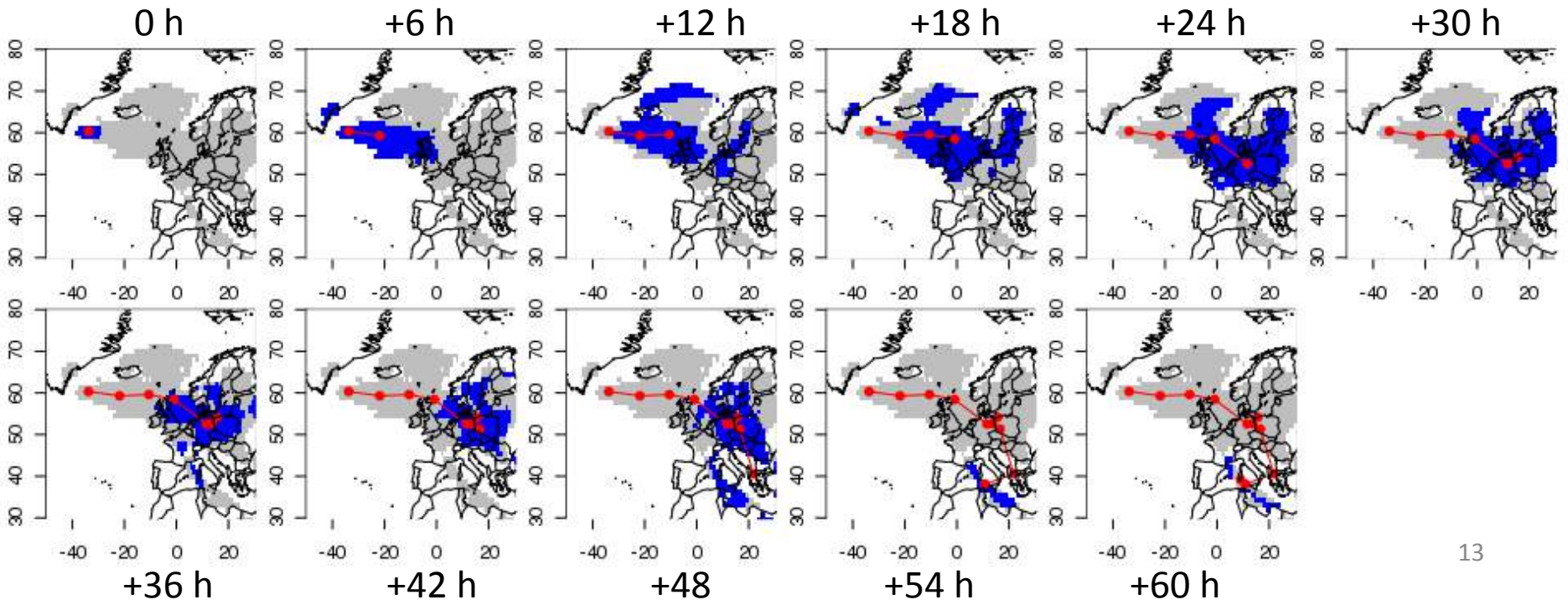
ECMWF ENSEMBLE FORECASTS
Sunday 2 December 2001 12UTC ECMWF Forecast t+72 VT: Wednesday 5 December 2001 12UTC S
MSLP (countour every 5hPa) and Temperature at 850hPa (only -8 and 16 isolines are plotted)

- 2-dimensional fields contain **large amount of information**
- How can we **reduce** that information to study extreme windstorms?

Identification and tracking of windstorms

2D wind fields → trajectories of windstorms

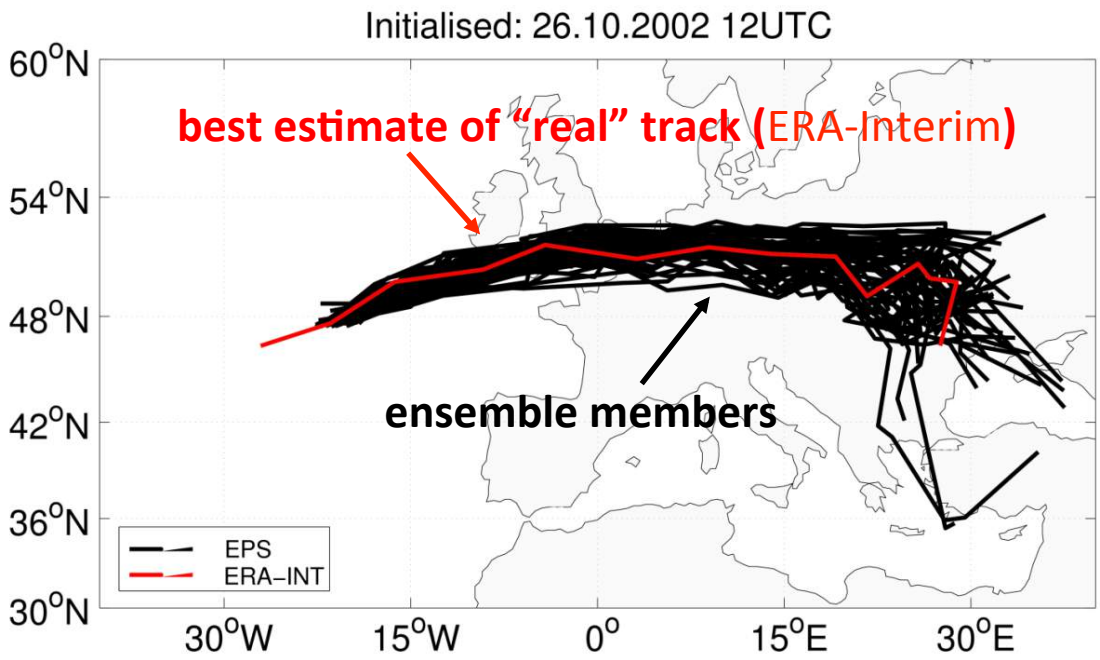
- How does the tracking work?
  1. Coherent areas of extreme wind speed are identified (>98th percentile)
  2. The area centres are tracked in time using a nearest neighbour approach
- Tracking of windstorms allows a **tailored evaluation** focusing on relevant events
- It is possible to assign **intensity measures** to single events



Data

- **Ensemble Prediction System (EPS) of the European Centre for Medium Range Weather Forecasts (ECMWF)**
- Time period: 01.02.2006 - 25.01.2010, October-March
- 10-day forecasts
- 50 ensemble members, every 12 hours
- Windstorm tracks are identified in each forecast and ensemble member

Example:
Storm „Jeannette"
26.10.2002 06UTC –
29.10.2002 12UTC



Windstorms in the ECM

Example: 10-day forecast

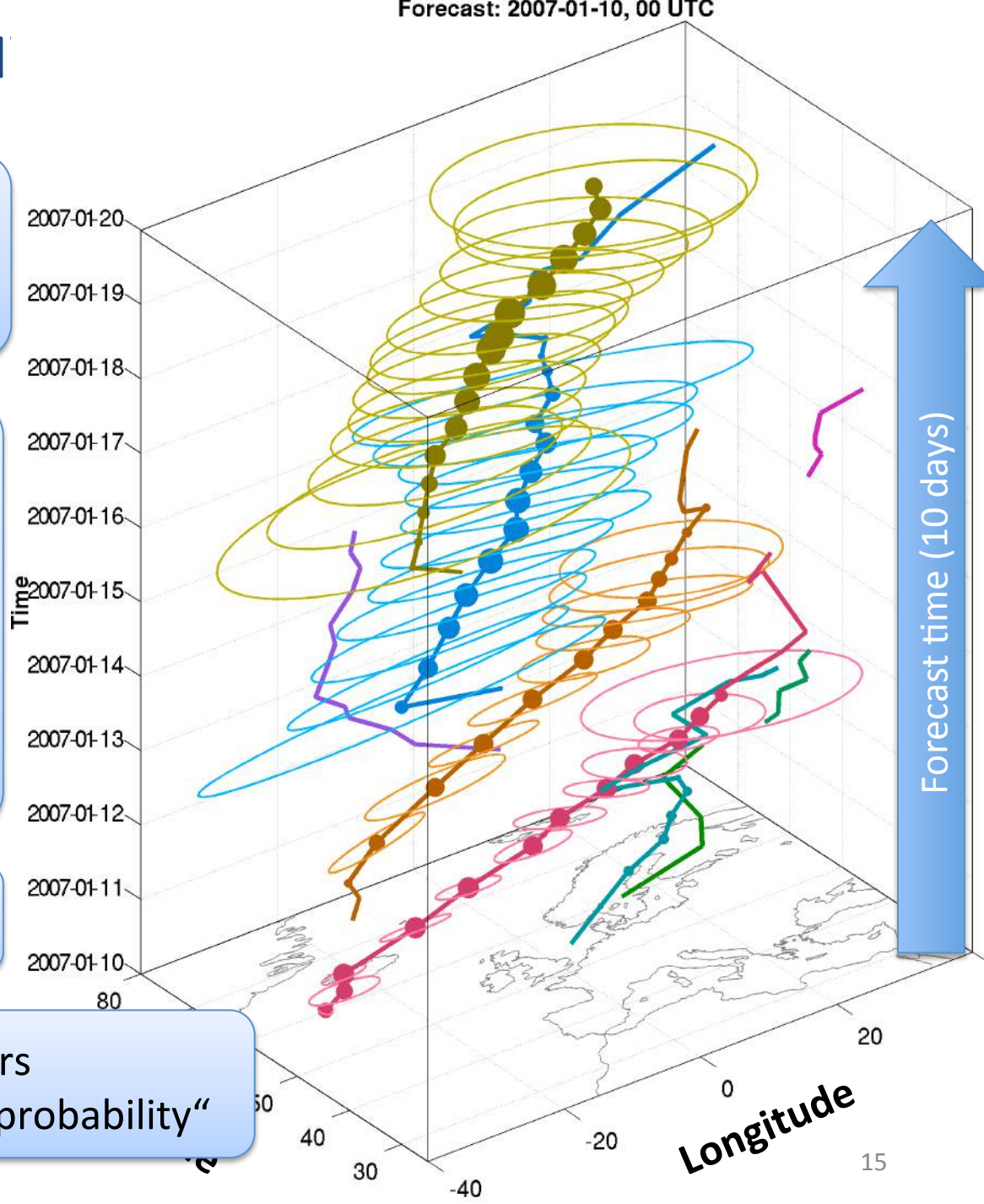
- Initialized on 10 Jan 2007
- 50 ensemble members

Identification of clusters

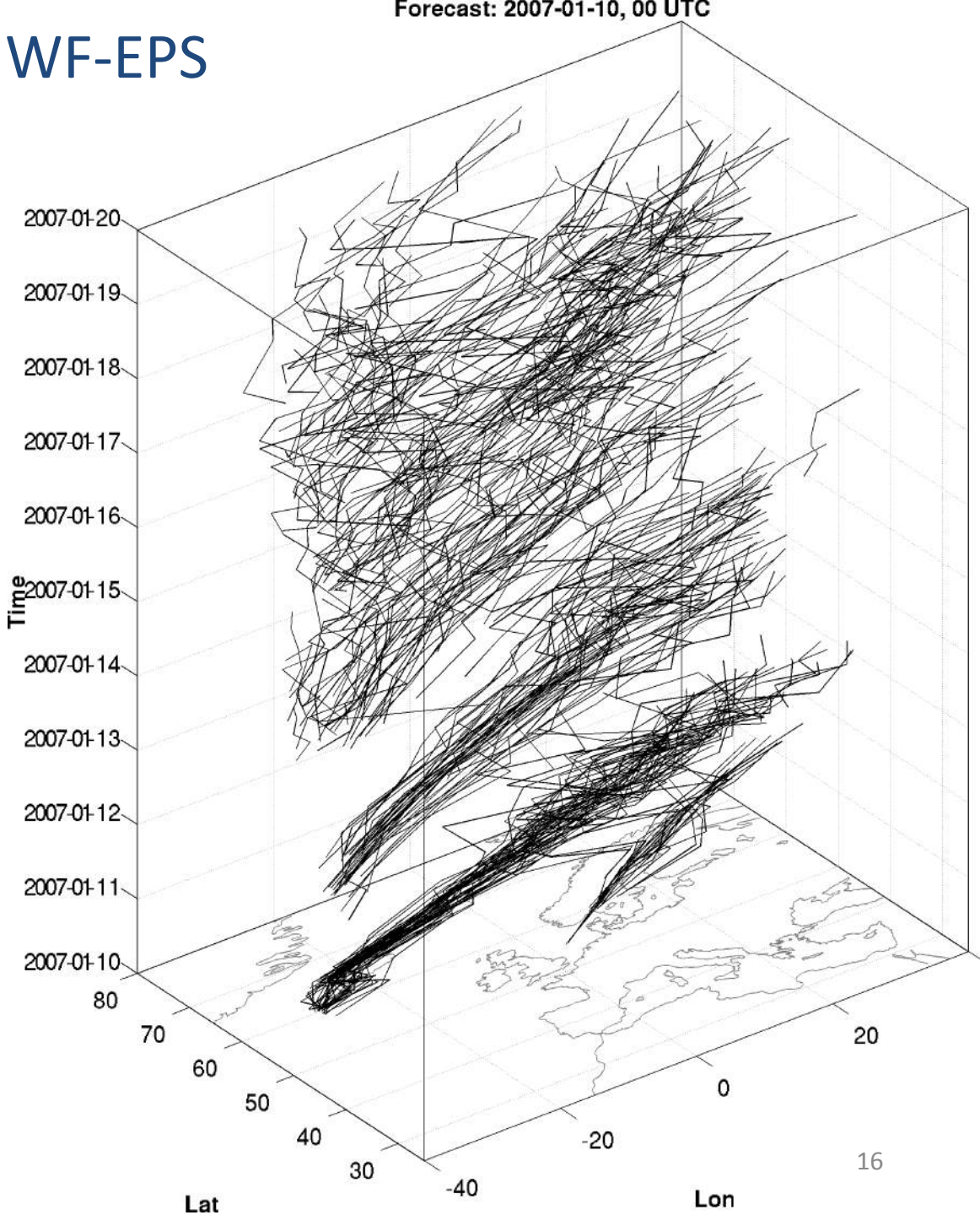
- storm cluster = different realizations of the same storm
- matching criteria: dinstance in space and time

- 9 clusters

- Mean tracks of storm clusters
- Areas with a certain „strike probability“



Windstorms in the ECMWF-EPS



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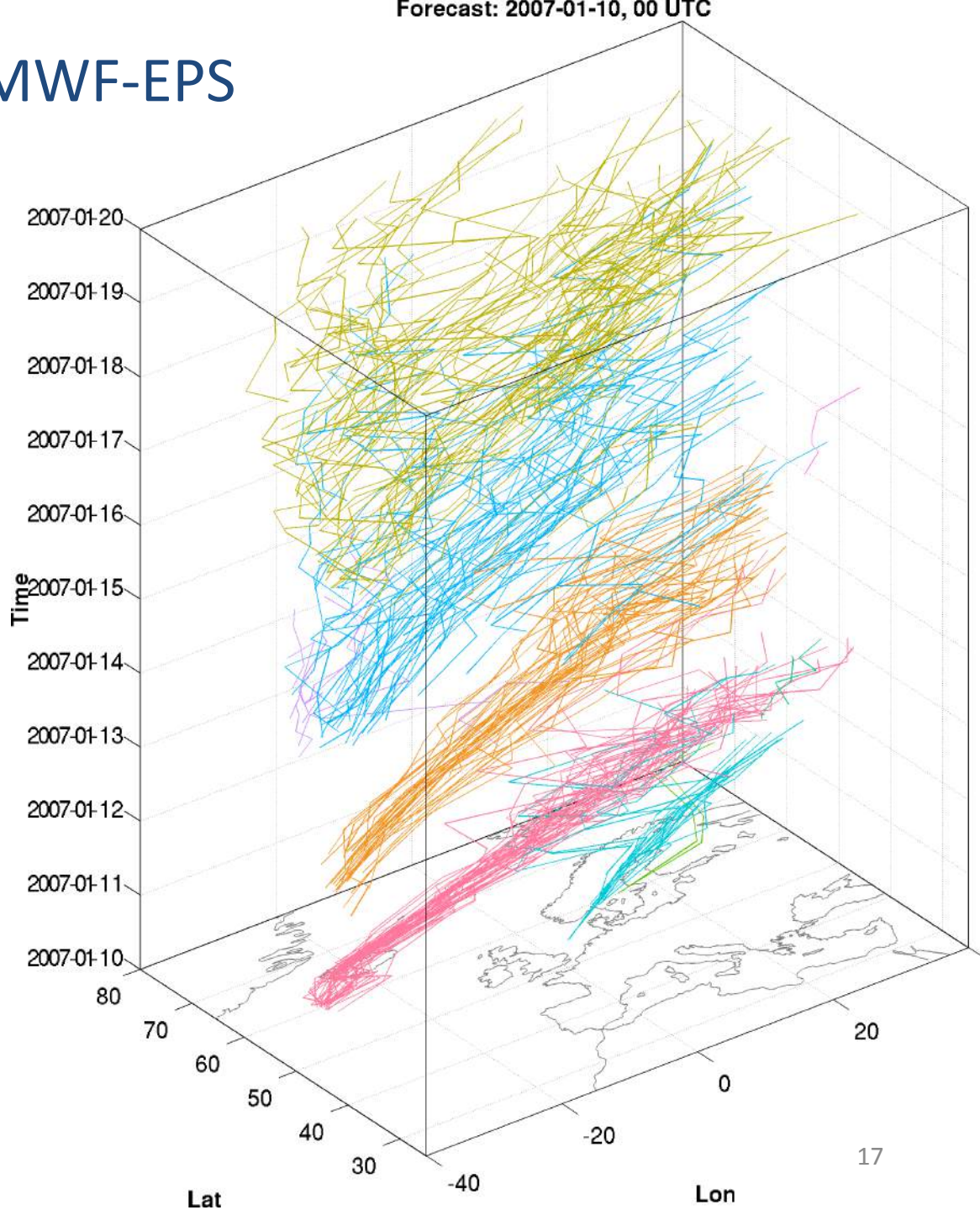
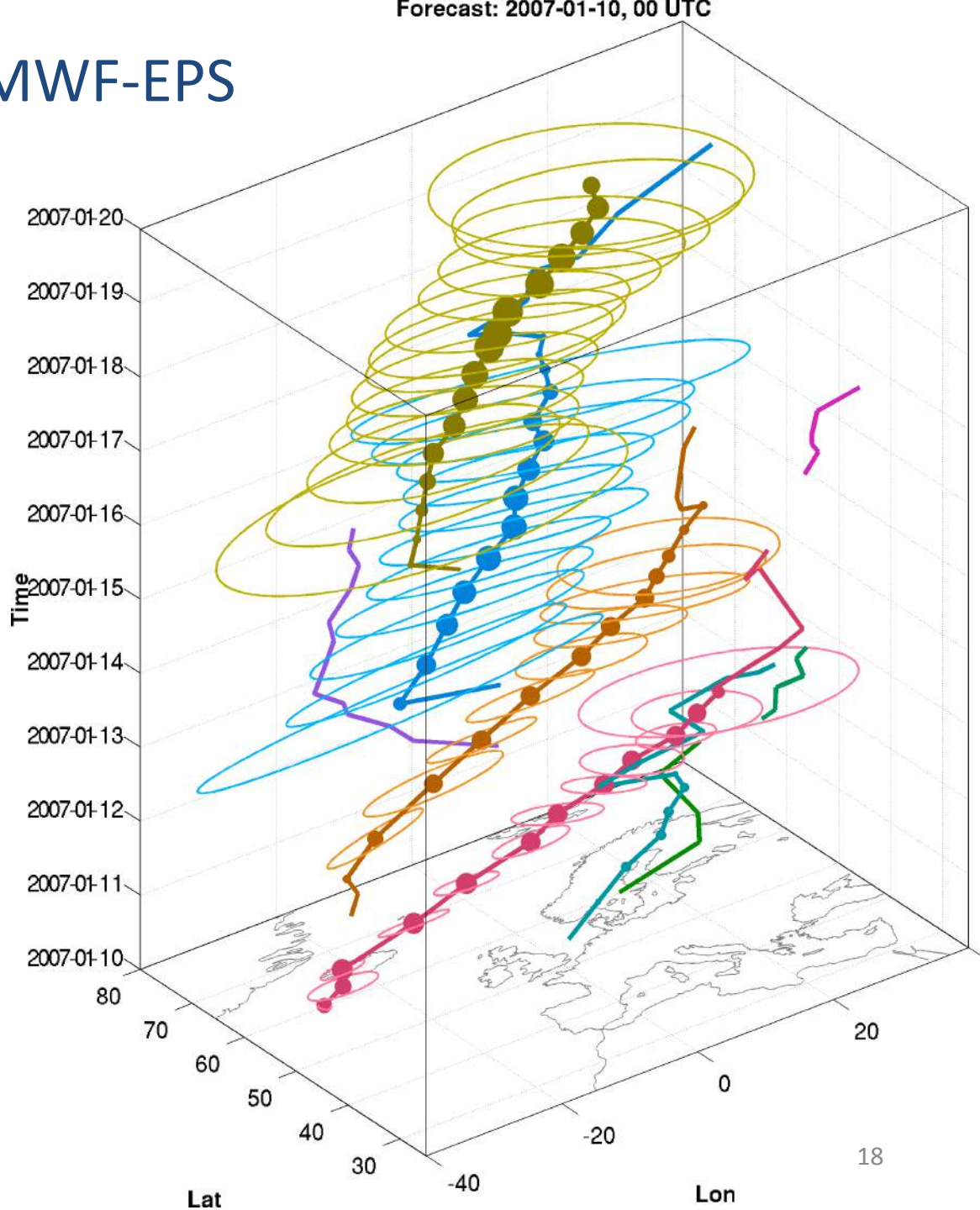
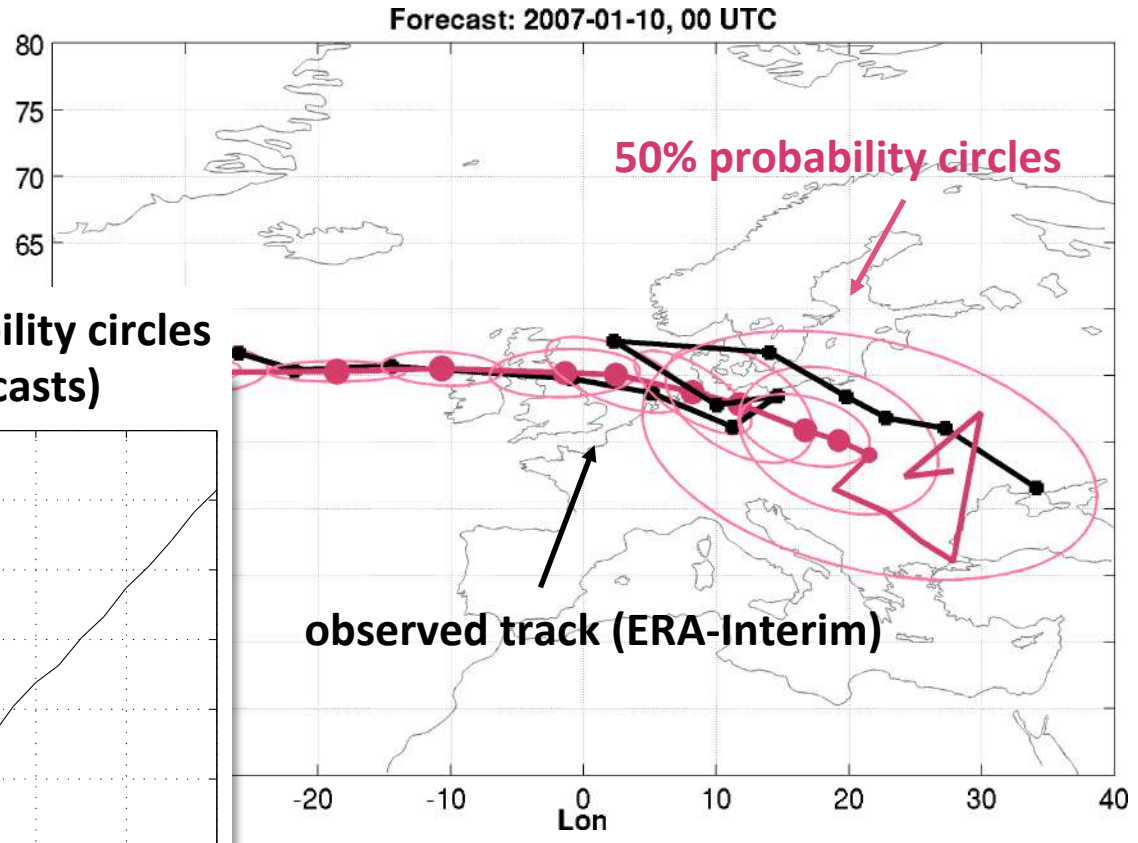


Windstorms in the ECMWF-EPS

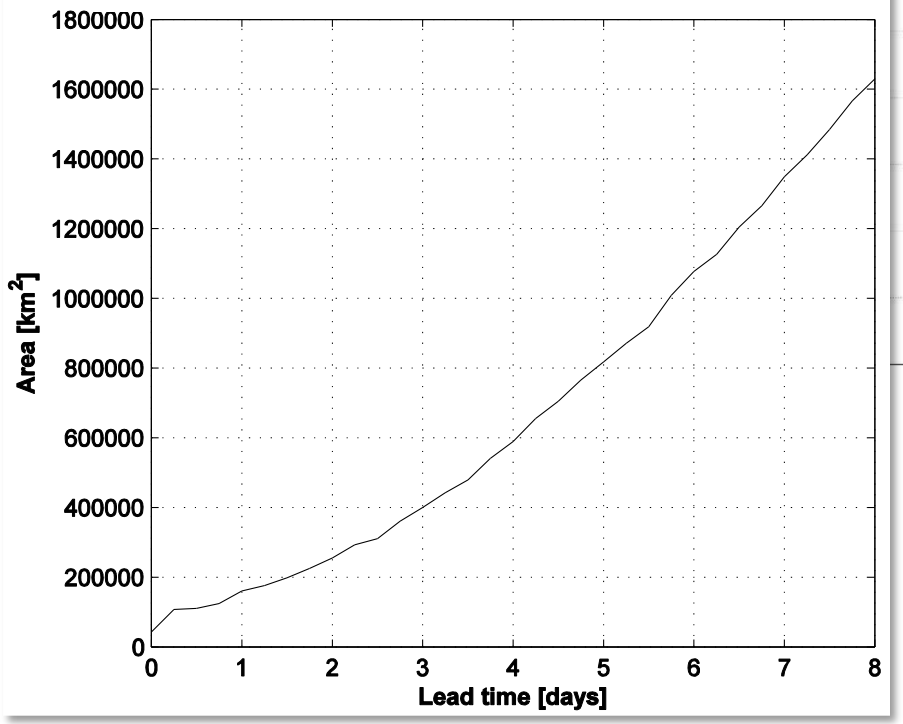


Windstorms in the ECMWF-EPS

- How does the spatial uncertainty depend on the lead time?



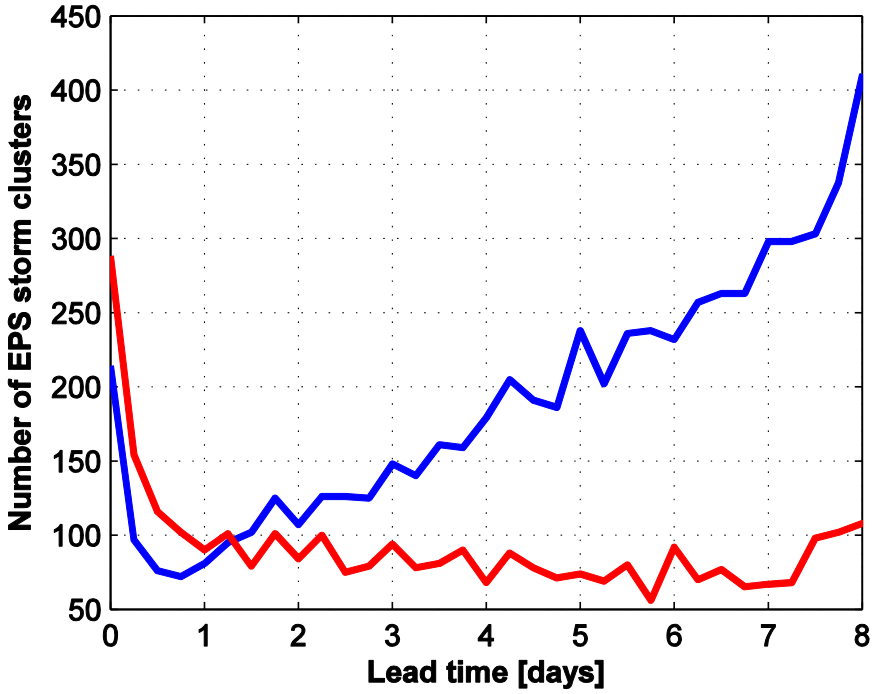
Average size of 50% probability circles (all clusters in all forecasts)



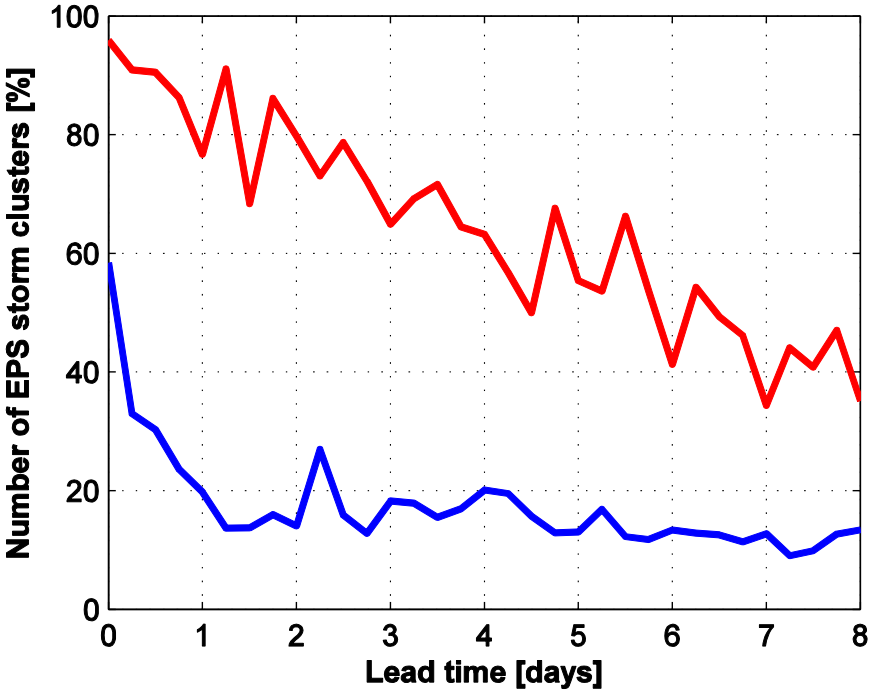
Windstorms in the ECMWF-EPS

- How many clusters are found in total, depending on lead time
  - Few storm clusters with high probability
  - Increasing number storm clusters with low probabilities at longer lead times
- How many clusters are associated to an observed storm?
  - Clusters with a high probability are frequently associated to an observed storm

Total number of clusters



Number of clusters with an observed storm



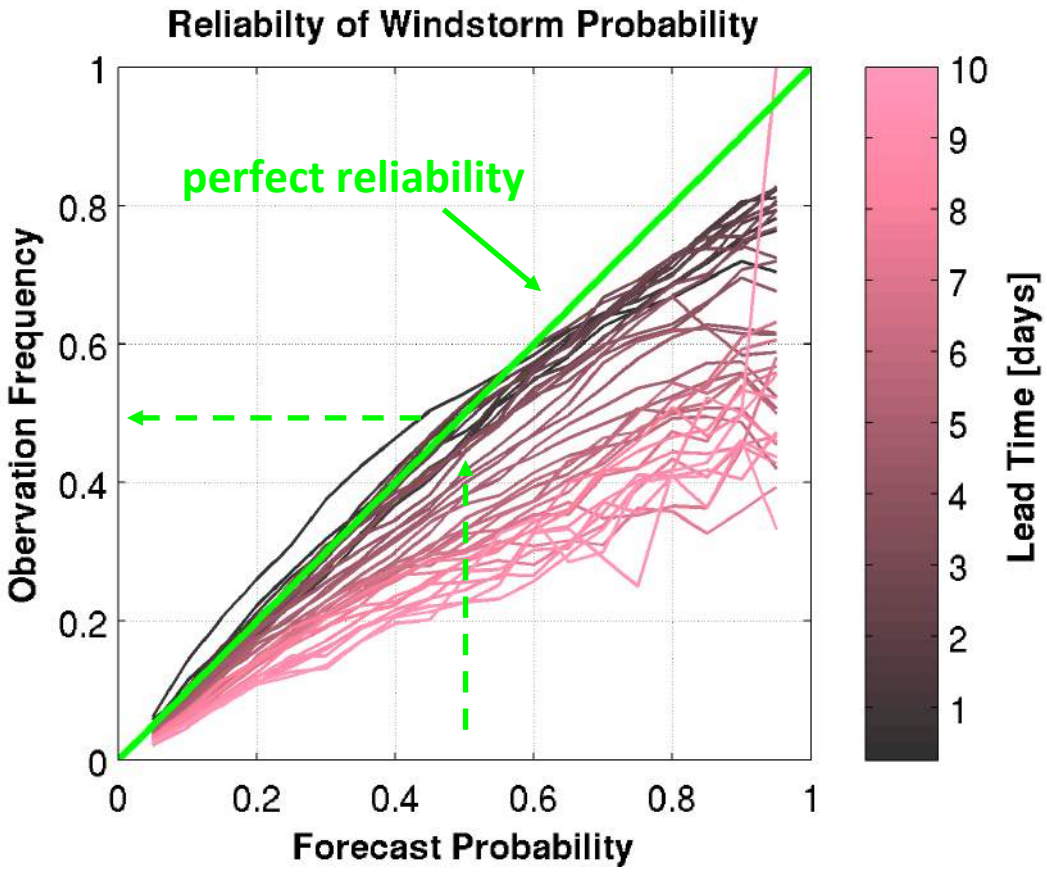
clusters with >50% of the members -> high probability

clusters with <50% of the members -> low probability

Evaluating all storm clusters

- How reliable are the forecasted cluster probabilities?

- <u>Ideally:</u> If an occurrence probability of 50% is predicted 100 times, a storm should be observed 50 times
  - ➢ The probability circles are reliable for lead times of around 3 days
  - ➢ At lead times larger than 3 days the occurrence probabilities are overestimated



Summary

- Windstorms caused by extra-tropical cyclones can cause severe damages
- Skillful forecasts are necessary
- Ensemble prediction systems provide forecasts with uncertainty information
- Tracking of windstorms allows event-based evaluation of windstorm predictions
- Windstorms were analyzed in the ECMWF ensemble prediction system
- Clustering approach to group different realizations of the same storm
- Forecast probabilities are derived for the storm clusters
- Storm forecasts with high probabilities are frequently related to observed storms
- Probabilities related to the track position are reliable up to around 3 days lead time

RAIN Project

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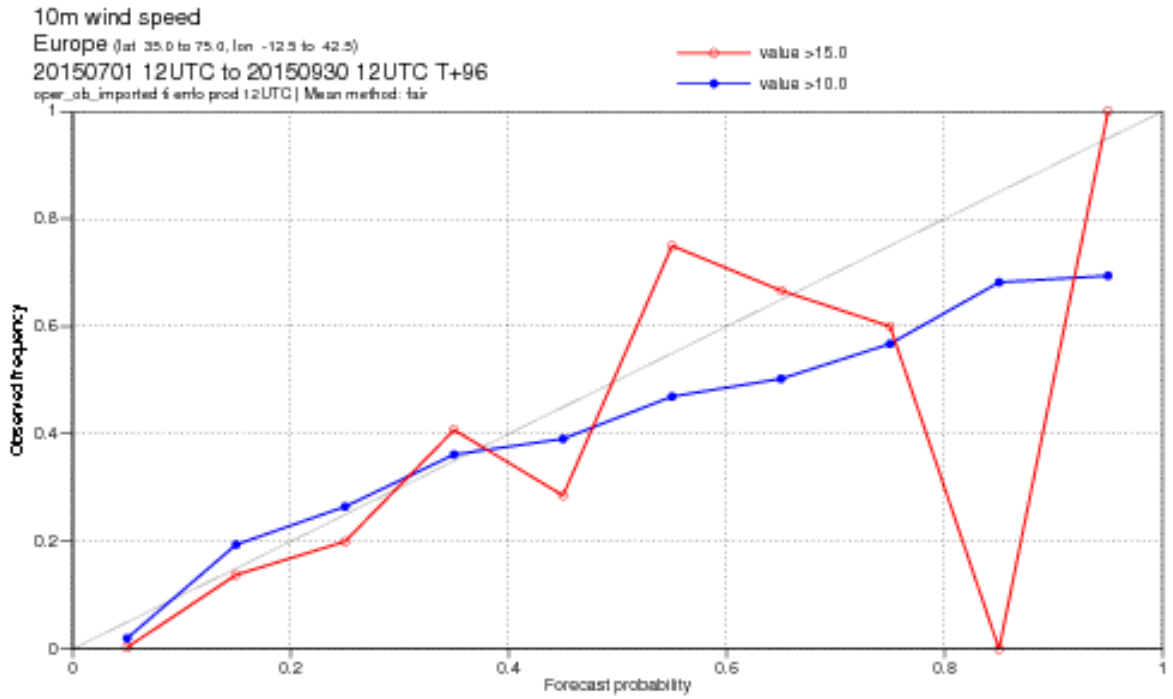
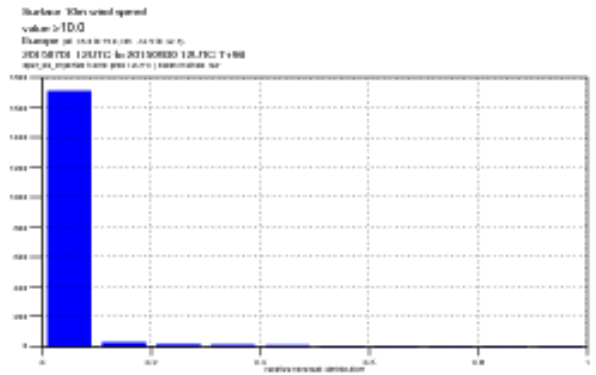
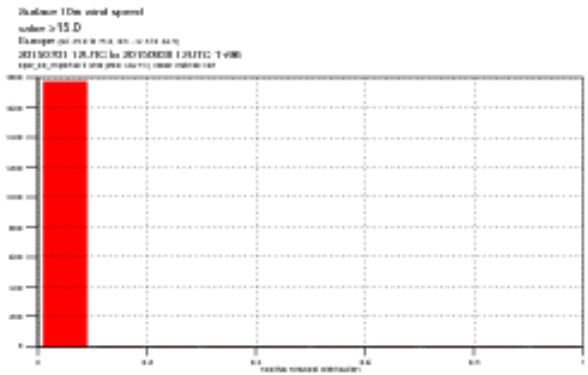


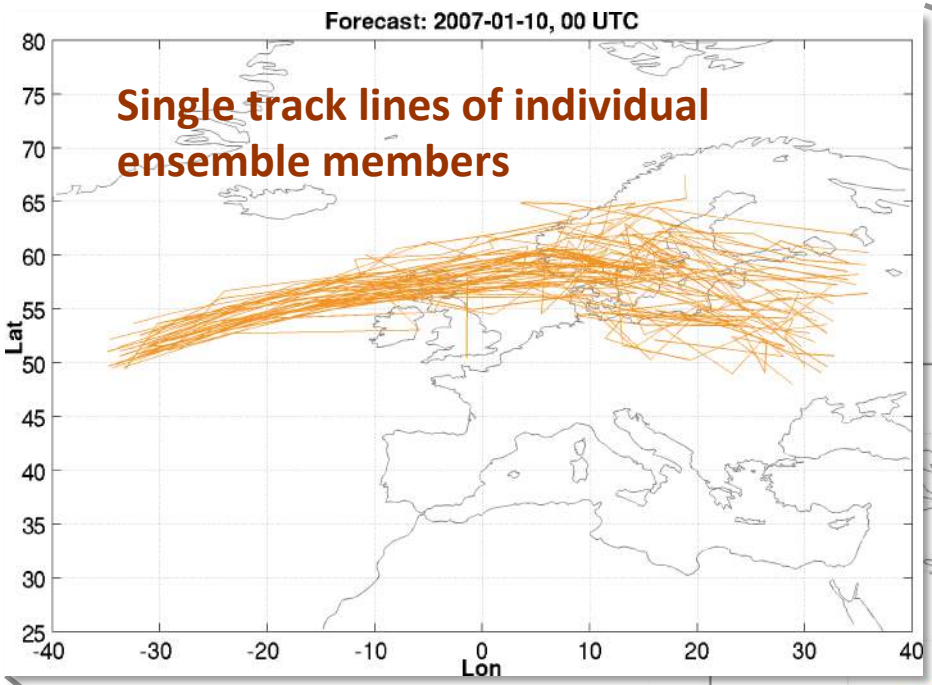


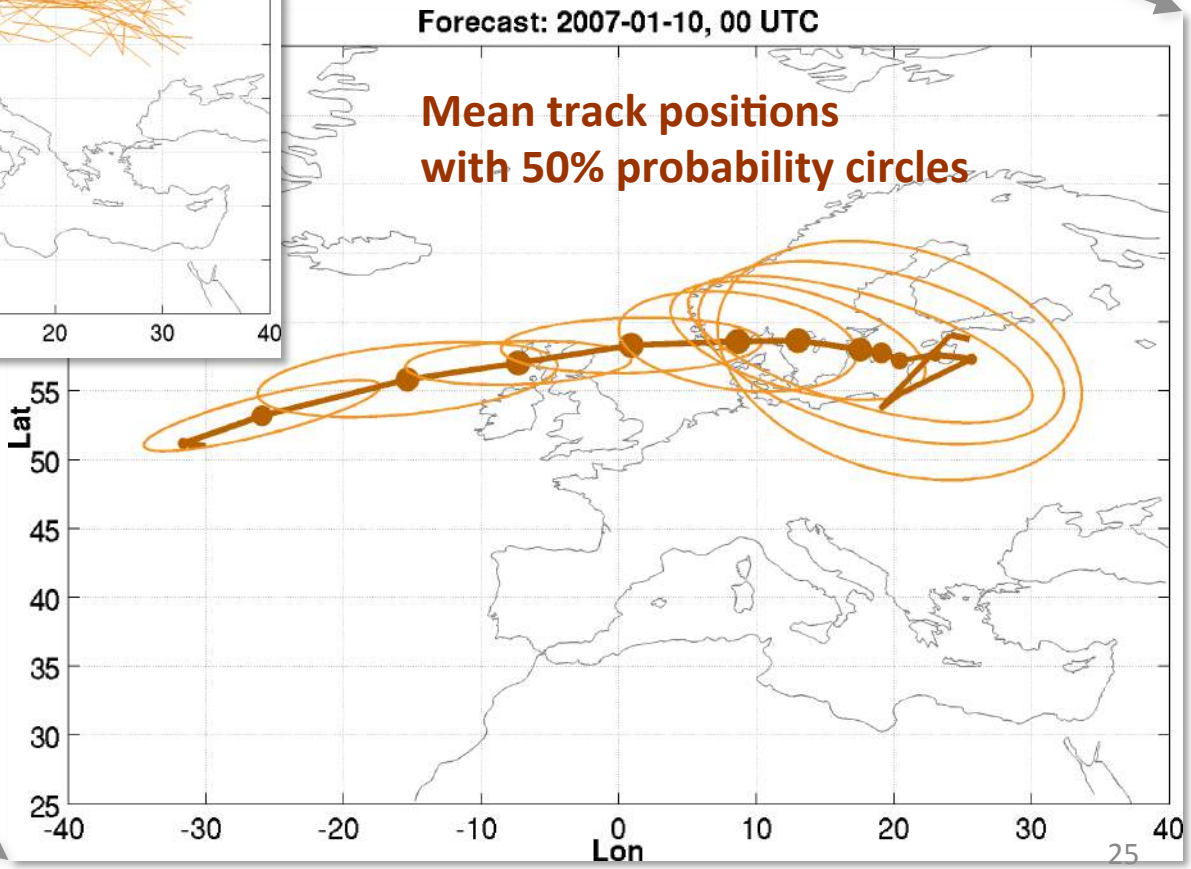


http://download.ecmwf.org

Predictability of Winterstorms

Clustering of storms

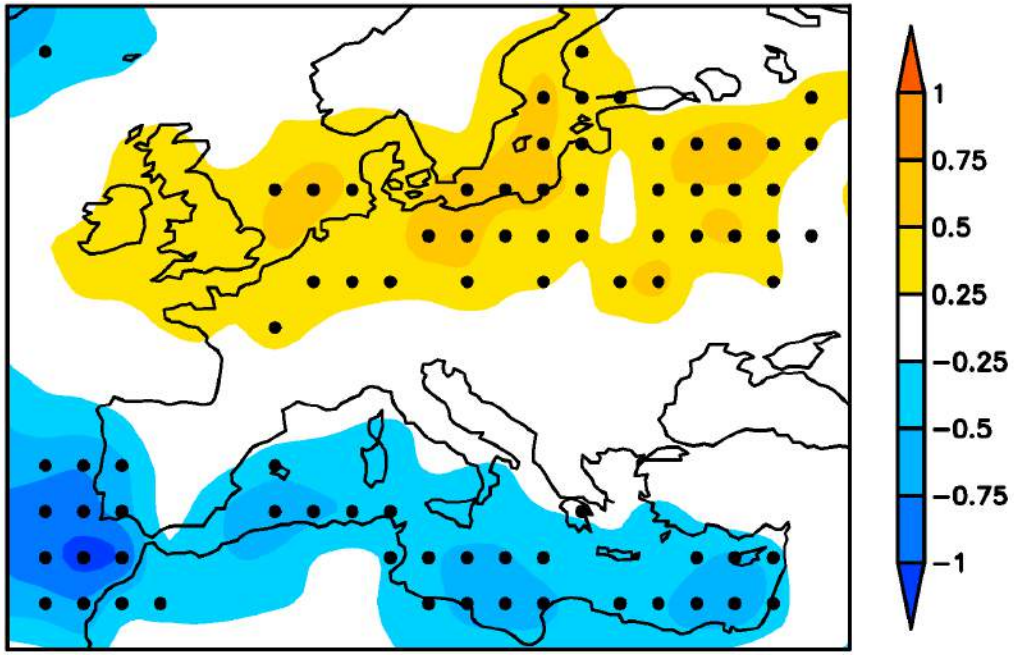




Extratropical Cyclones

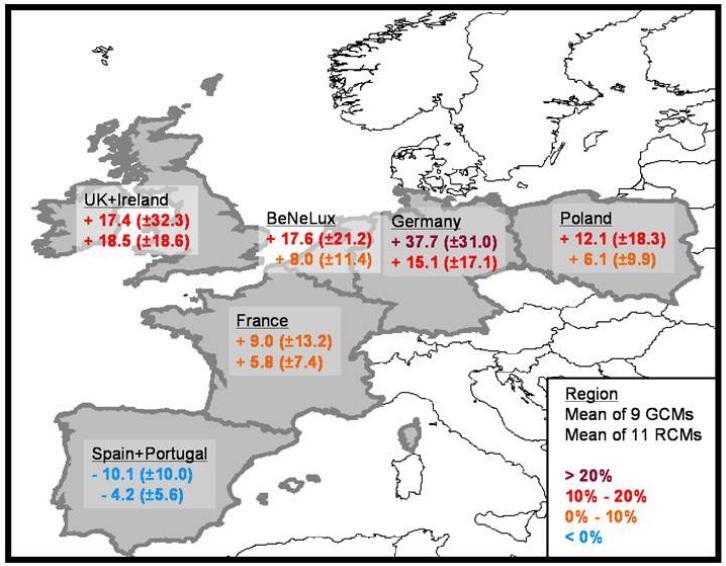
Windstorms and climate change

98th percentile of wind speeds, changes for A1B (2071–2100) relative to 20C (1961–2000):



(Donat et al., 2011)

Relative changes (unit: %) of mean annual storm loss potential for A1B (2071–2100) relative to 20C (1961–2000)



Extratropical Cyclones

Windstorms and climate change

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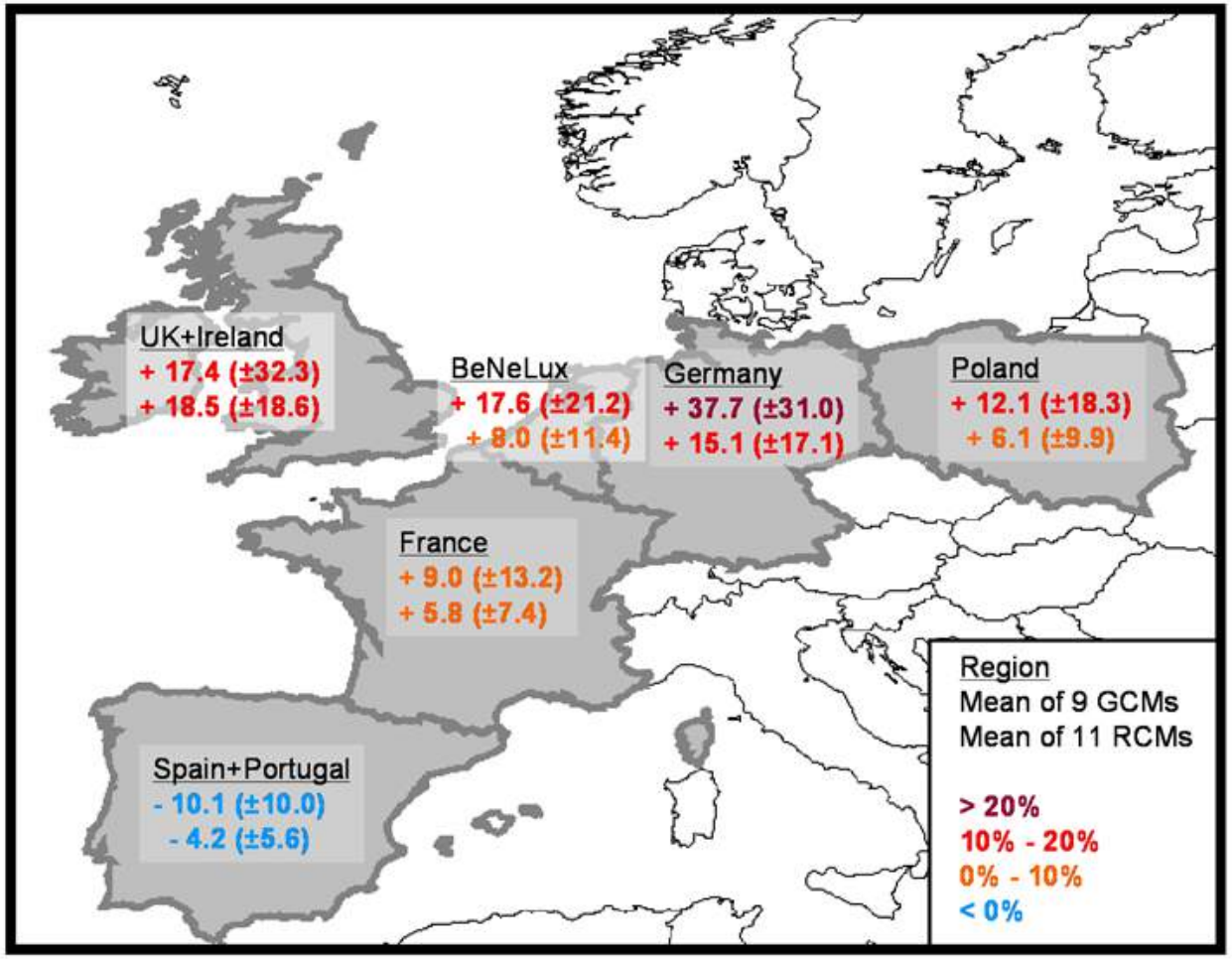

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