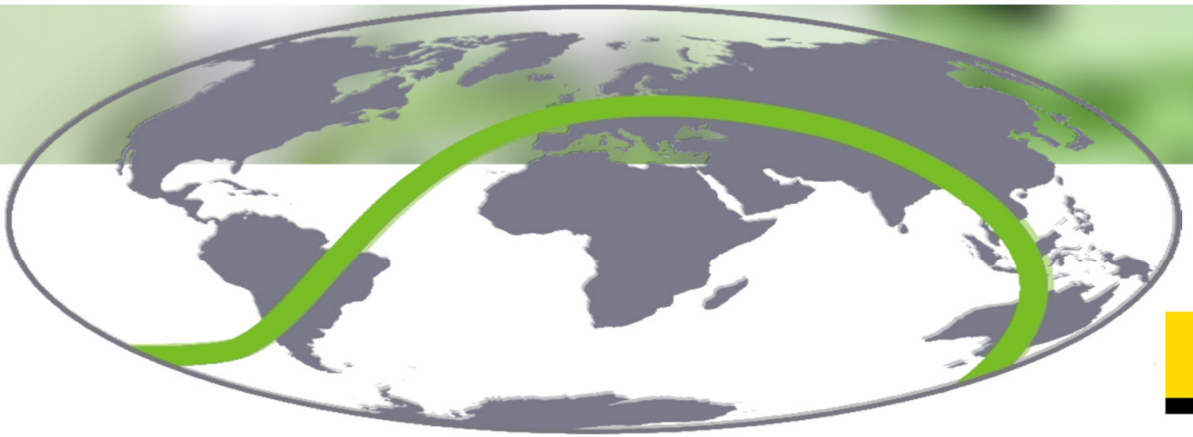

wege entstehen, indem wir sie gehen
paths emerge in that we walk them

Wegener Center
www.wegcenter.at

Regional and Local Climate Modeling Research Group
ReLoClim

Austrian Wind Potential Analysis - AuWiPot

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12th EnInnov Symposium 2012 @ TU Graz, Inffeldgasse 25/D, HS i5, Graz, Austria, Feb 15 – 17, 2012

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Project overview

The project AuWiPot

- Funded by Austrian Promotion Agency (FFG)
- Run time 3 years (March 2009 to April 2011)
- Team:

AUSTRIAN WIND POTENTIAL ANALYSIS
www.windatlas.at

Energiewerkstatt°, Austria
Project lead, technical/economical criteria, observation data

Wegener Center, University of Graz, Austria
Wind field modelling, observational data

Meteotest, Switzerland
Wind field modelling, observational data

iSpace, Austria
web-GIS modelling, data analysis

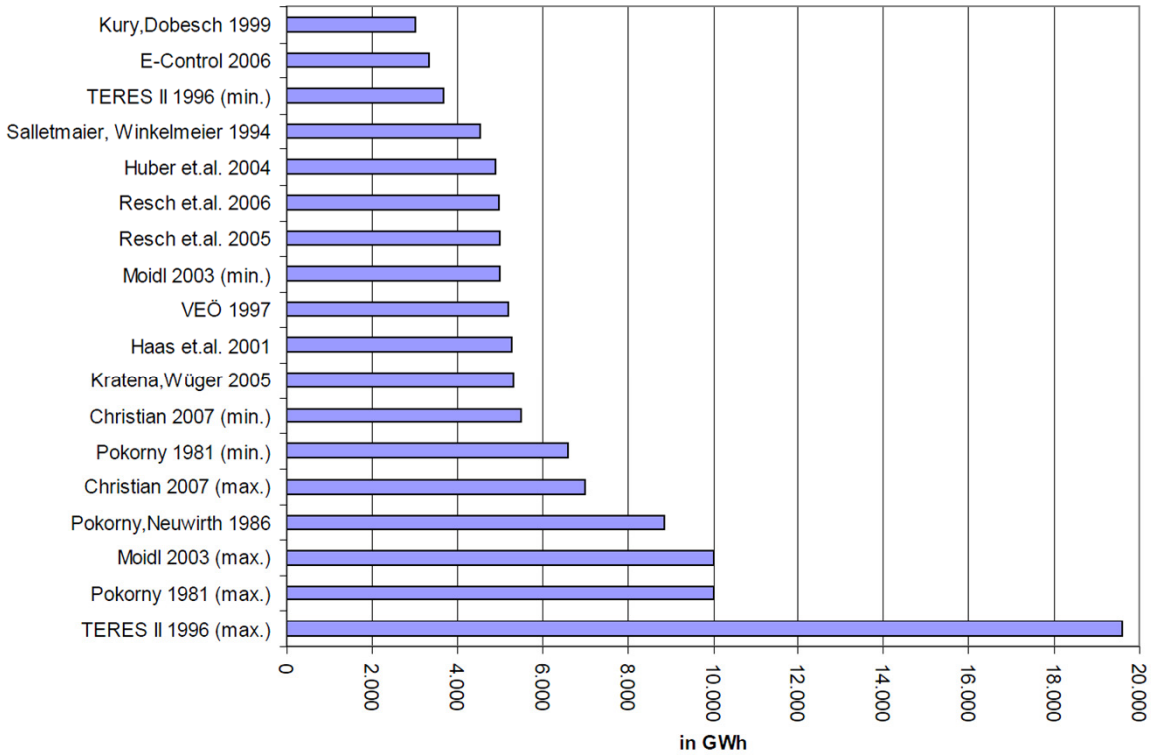
Outline

1. **Introduction and Motivation**
2. Methodology
3. Results
4. Conclusion

Introduction

Potential estimations so far

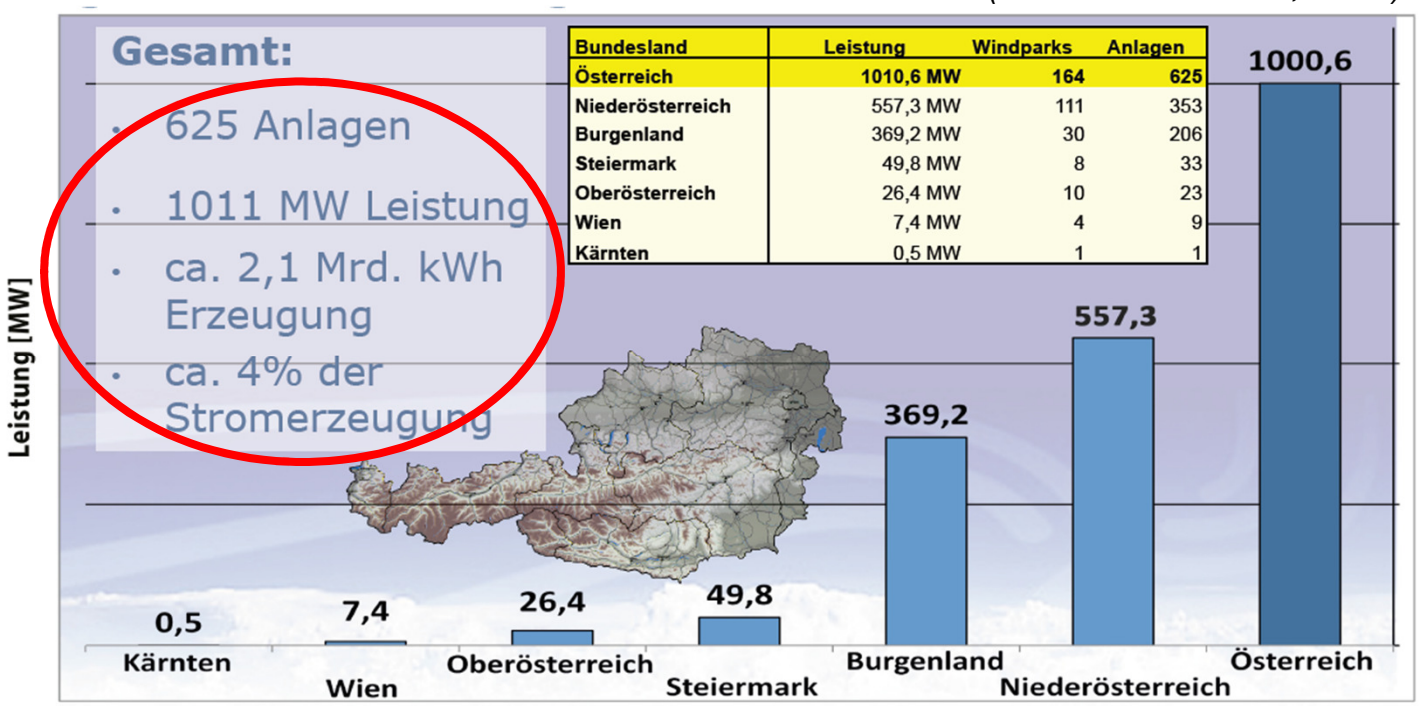
(from Hantsch and Moidl, 2007)



- Broad spectrum of estimations ranging between 3TWh/a and 20TWh/a, depending on the methods applied and underlying assumptions
- e.g. Pokorny (1981): 6.6 TWh/a – 10 TWh/a based on 150'000 50 kW turbines

Current status (end of 2011)

(from IG Windkraft, 2011)



Bundesland	Leistung	Windparks	Anlagen
Österreich	1010,6 MW	164	625
Niederösterreich	557,3 MW	111	353
Burgenland	369,2 MW	30	206
Steiermark	49,8 MW	8	33
Oberösterreich	26,4 MW	10	23
Wien	7,4 MW	4	9
Kärnten	0,5 MW	1	1

- Current status lies far behind any estimated potential
- Economical constraints have changed (e.g. feed-in tariff)
- New technological possibilities are available (e.g. turbine sizes have increased)
- Limiting factors can be considered much more in detail (wind, land use, feed-in tariff, …)

Motivation

→ Austrian Wind Potential Analysis – AuWiPot

AUSTRIAN WIND POTENTIAL ANALYSIS

Aims:

- Calculation of a detailed (100 m × 100 m grid spacing) wind map for the Austrian territory with known uncertainty
- Comprehensive modelling of the theoretically achievable wind potential under changing economic/technologic conditions
- Provision of a flexible potential estimation tool to the general public via a web-based GIS application capable of fast “on-the-fly” calculations

Outline

1. Introduction and Motivation
2. **Methodology**
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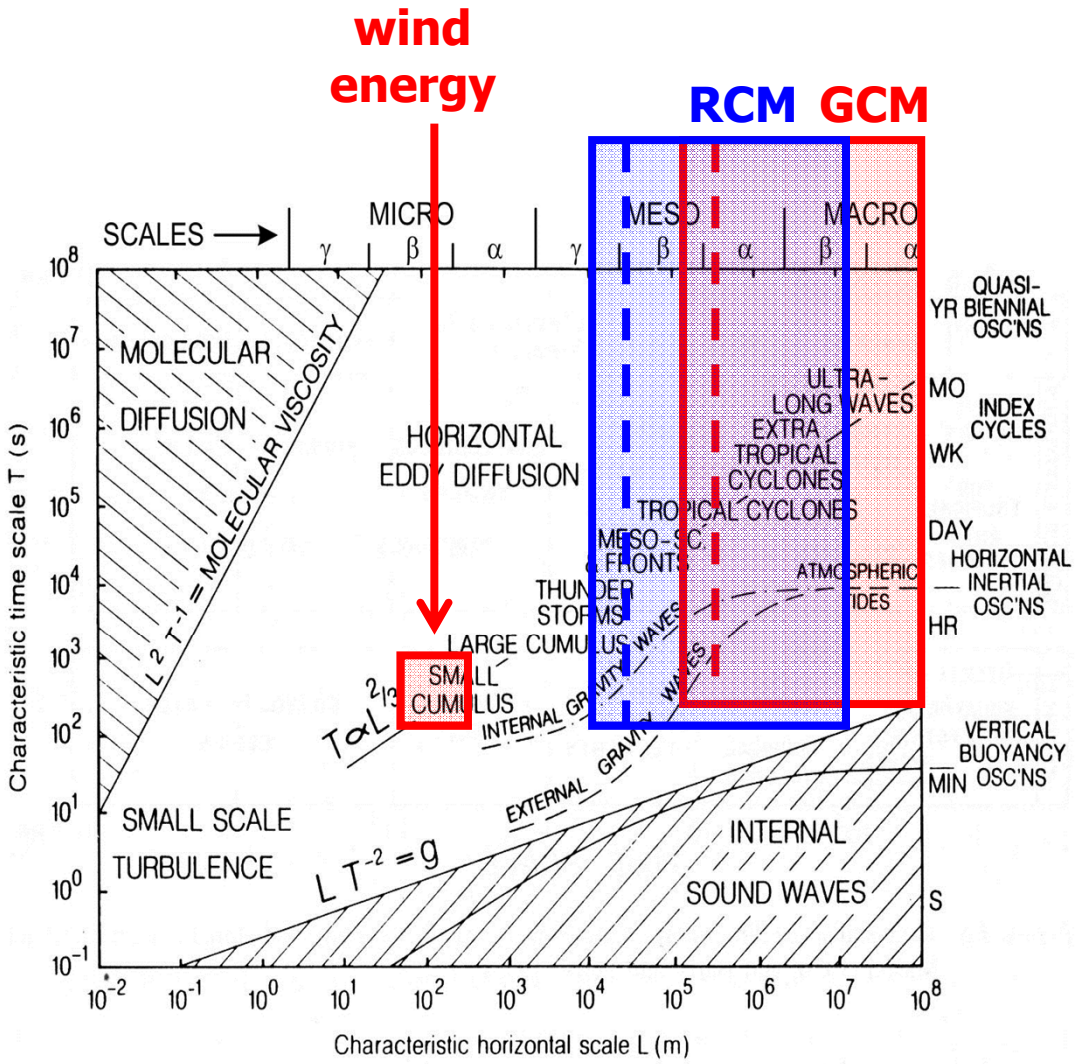
Methodology

Problem of scales

- **>1000 km**
  gobal circulation,
  ocean / atmosphere oscillations
  (e.g., Monsoon, ENSO)
- **100 km to 1000 km**
  Rossby Waves,
  high/low pressure systems,
  Hurricanes
- **10 km to 100 km**
  frontal systems, thunderstorms,
  cumulus nimbus
  Föhn, Bora
- **10 m to 10 km**
  cumulus, slope flows,
  local circulations, turbulence,
  Tornadoes

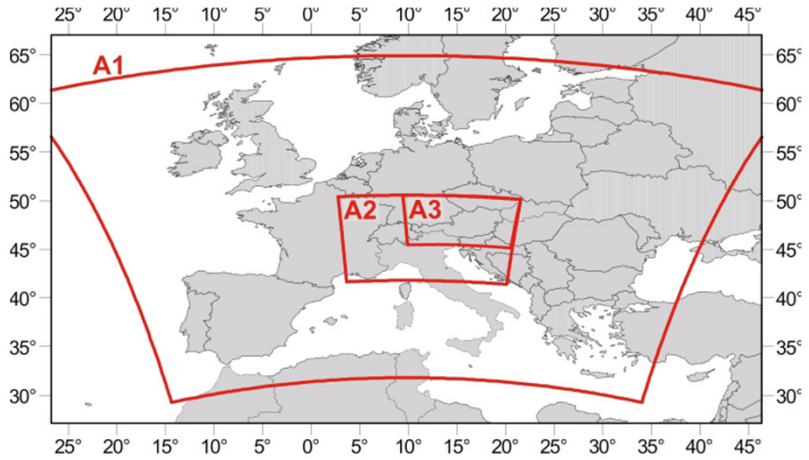


(Barry and Carleton, 2001)

Methodology

Dynamical model

- Regional climate model (RCM): **MM5**
- Driving data: **ERA-40** (~100 km)
- Three nesting steps:
  30 km (A1) → 10 km (A2) (**reclip:more**)
  → 2 km (A2) *(Loibl et al., 2007)*



(Truhetz et al., 2010)

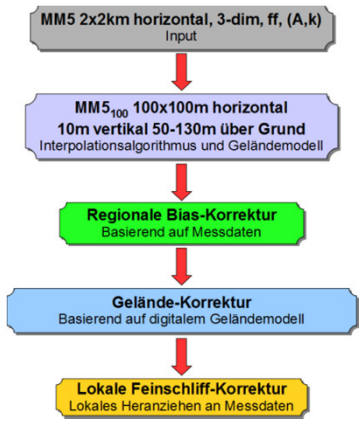
- Periods: 1981 to 1990 (from reclip:more)
- Evaluation: observation data from 65 ZAMG stations
- Output: mean annual wind speeds and frequency distributions

Geo-statistical model *(Kunz et al., 2004)*

- Observational data from MetServices (ZAMG, DWD, MeteoSwiss), local governments, University of Innsbruck, research projects (MAP, Alpine Windharvest), private observations from wind projects

  + data from **254** surface stations
  + results from dynamical model (A2)

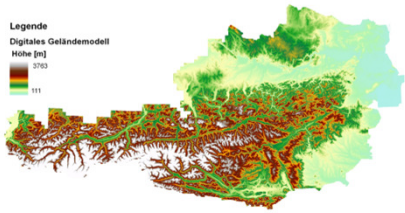
- simple bias correction included

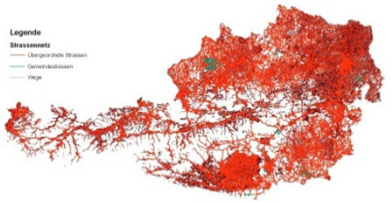


- Output: highly resolved (100 m) wind maps (mean annual wind speeds, Weibull parameters) in several heights a.g.l.

Methodology

Potential estimations and GIS application





First step (technical criteria)

- Surface altitude
- Terrain slope
- Land use
- Protection areas (national parks and other nature protection areas)
- Distances to settlements, buildings, streets and rail roads
- (access roads and socio-political limitations excluded)

Second step (economical criteria – derived from expert consultations via workshops)

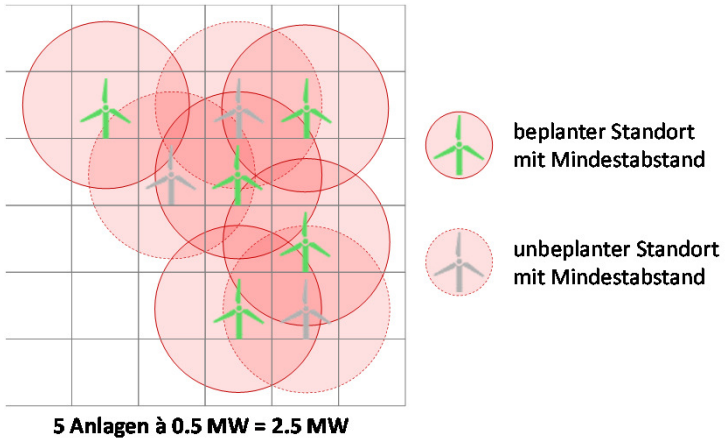
- Calculate **site-specific production costs** (per grid cell) from

  → **mean annual energy yield**
  (wind conditions, specific power curves, distances between turbines, technical and wake losses)

  → **costs** (Installation costs, costs of operation, capital costs, machine life, …)

- → **site-specific production costs / feed-in tariff**

→ **web-based GIS application**



Outline

1. Introduction and Motivation
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Results

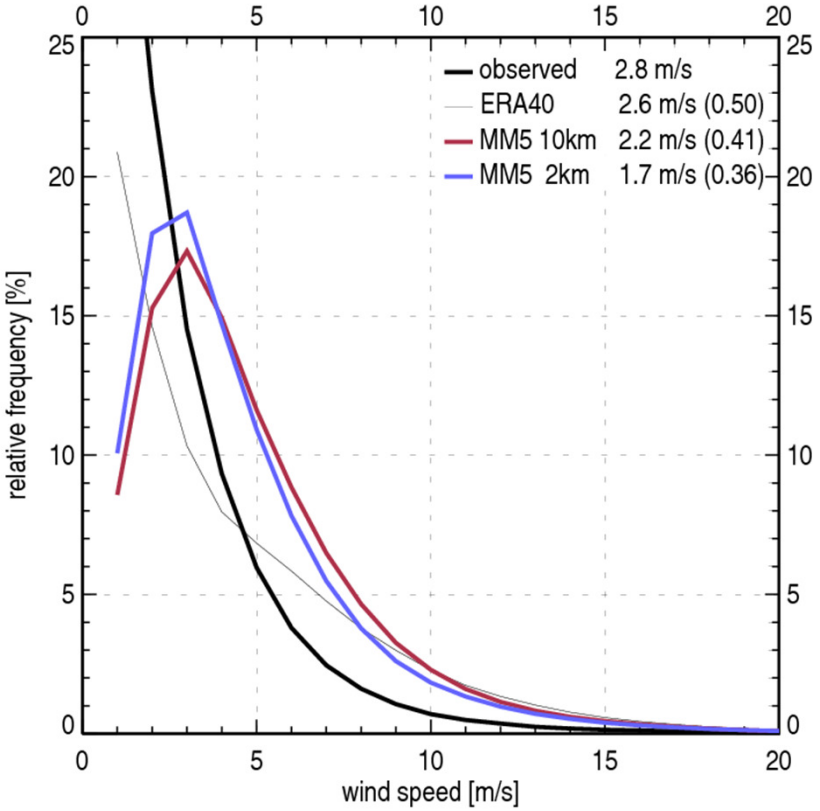
Evaluation of the dynamic modelling step (1981 to 1990)

- Station averaged (65 ZAMG stations)
- Deviations from observations are reduced

  mean absolute error:

ERA-40	2.6 m/s
10 km	2.2 m/s
2 km	1.7 m/s

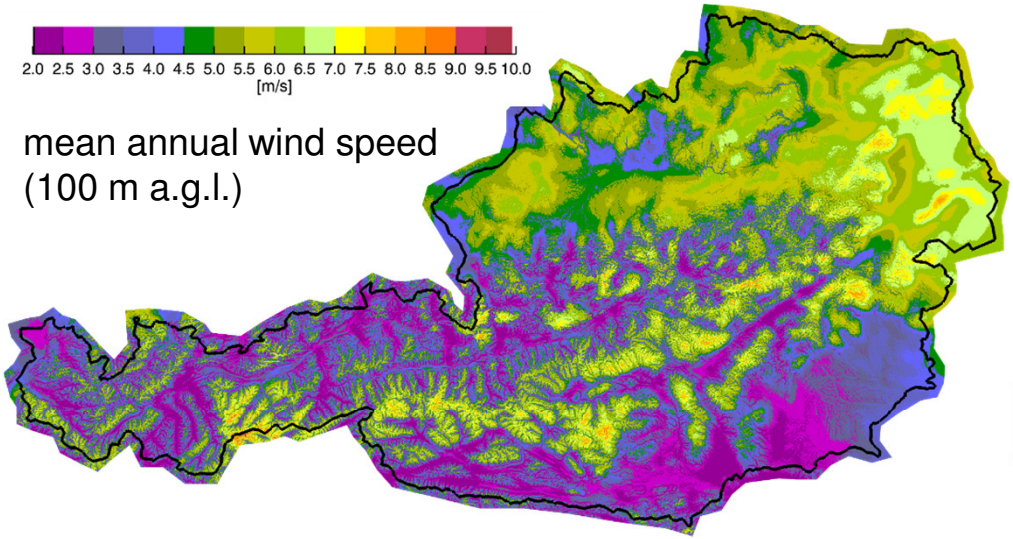
- frequency distributions are improved
- → overestimation of wind speeds
- → added value due to the increasing resolution of the dynamic model



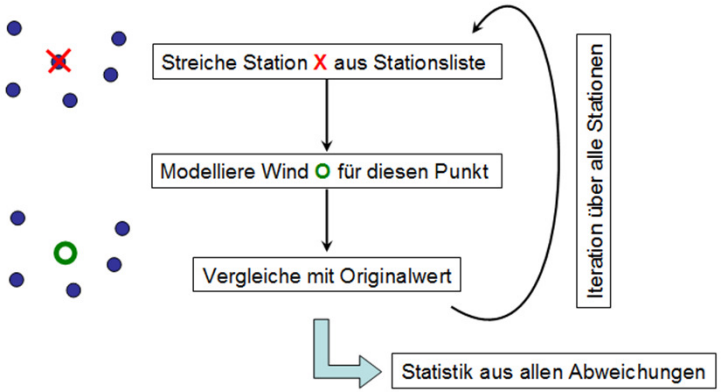
- → Output from dynamic models need to be “post-processed” (bias correction, MOS, etc.)

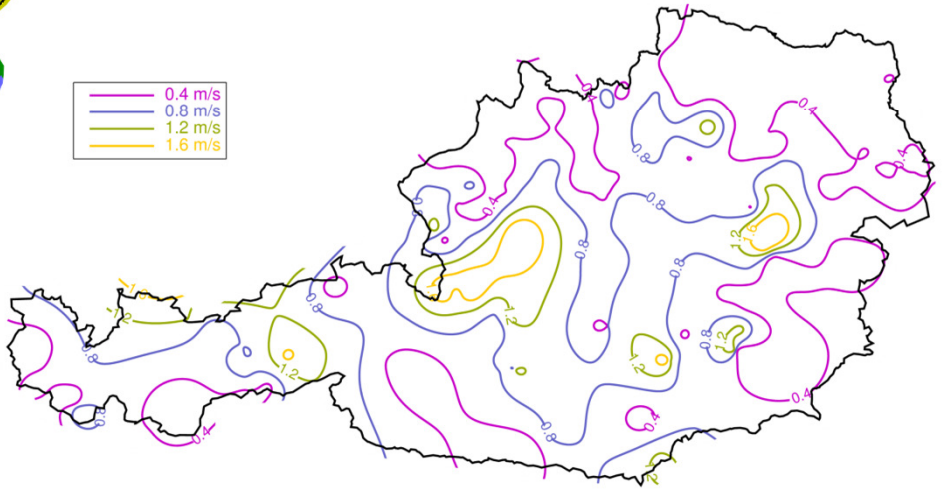
Results

Wind map and its uncertainty



mean annual wind speed
(100 m a.g.l.)



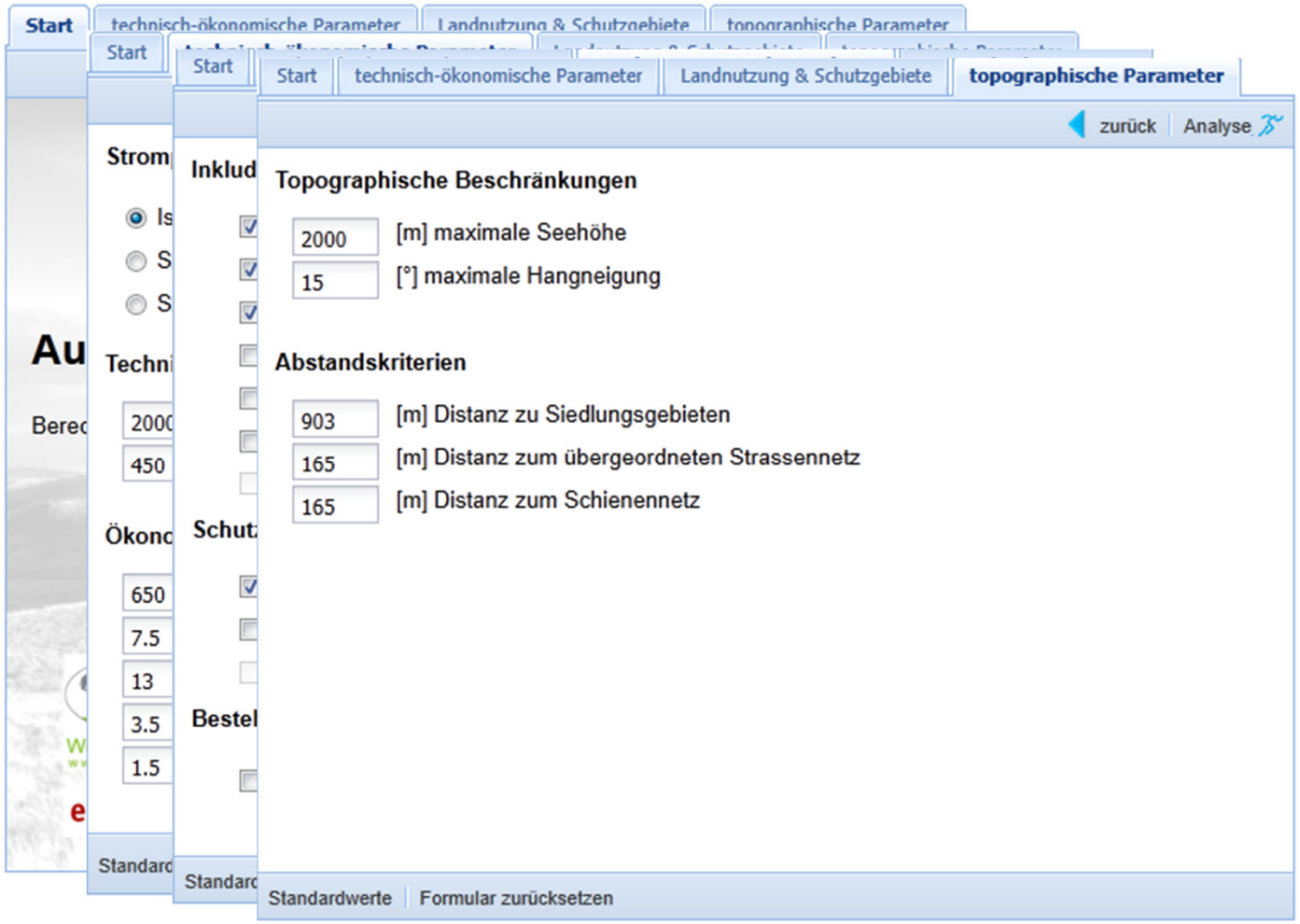


Available at http://www.windatlas.at

- Cross-validation (leave one out) over more than 200 stations
- → spatially distributed standard deviations of biases (~0.8 m/s on average)
- → roughly correlates with the density of the stations
- → uncertainty in energy yield < ±15% (for stddev 0.4 m/s) at single sites

Results

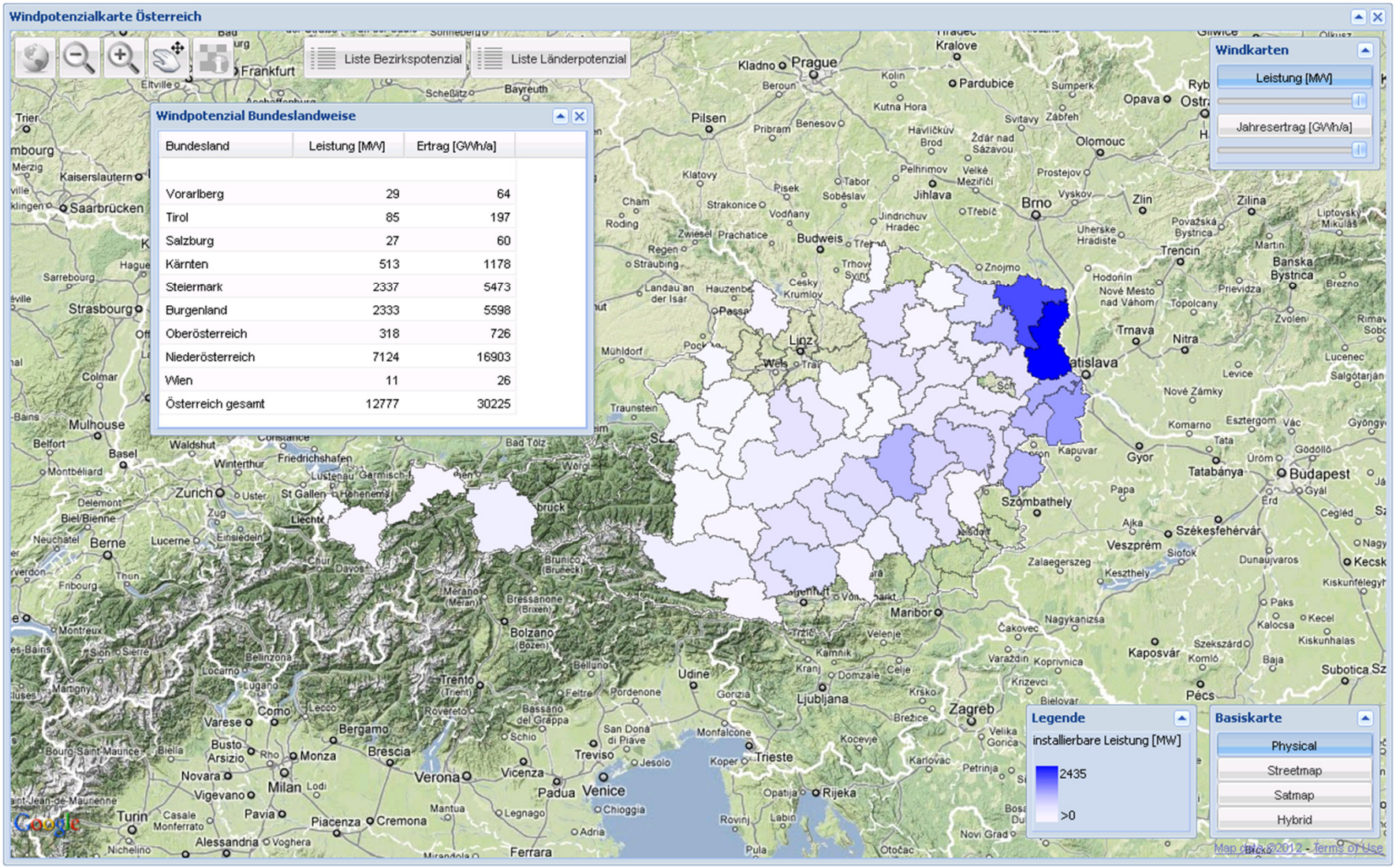
web GIS application



Available at http://www.windatlas.at

Results

Theoretically achievable wind potential (on a district level)



Realistically achievable wind potential

- Socio-political constraints have not been considered in AuWiPot
  (acceptance by the population, conflicting interests, praxis in awaiting approvals, …)

  → difficult to implement

- First attempt (conducted by Energiewerkstatt° as an add-on):
  expert consultations within the Austrian wind energy community
  wind farms installed in 2011
  estimation of planned wind farms under realistic conditions

- Comparison

Current status (observed)	theoretical potential (objective)	expert consultations (subjective)
~1 GW	12.8 GW	2.8 GW
~4%	~50%	~11%

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Conclusions

Wind field modelling

- Highly resolved wind maps have been generated and published via www.windatlas.at
- Added value due to increasing resolution of dynamic model
- Output from dynamic model needs to be post-processed
- An overall uncertainty of ~0.8 m/s is reached

Potential modelling

- Austria's wind potential estimated with respect to technical/economical constraints reflecting current state
- Flexible web-based GIS application with fast on-the-fly calculations implemented taking care of the complexity of wind potential estimations
- Wind potential analysis gives an upper limit per construction (access roads not considered; socio-political influences excluded)
- Realistically achievable potential is multiple times larger than currently installed wind energy turbines

- The modelling approach is ready to use for climate impact studies

Acknowledgements

Wegener Center
www.wegcenter.at

Danke für Ihre Aufmerksamkeit!

Methodology

→ Combined dynamical/geo-statistical modelling approach

Dynamical models (as used in NWP and climate research)

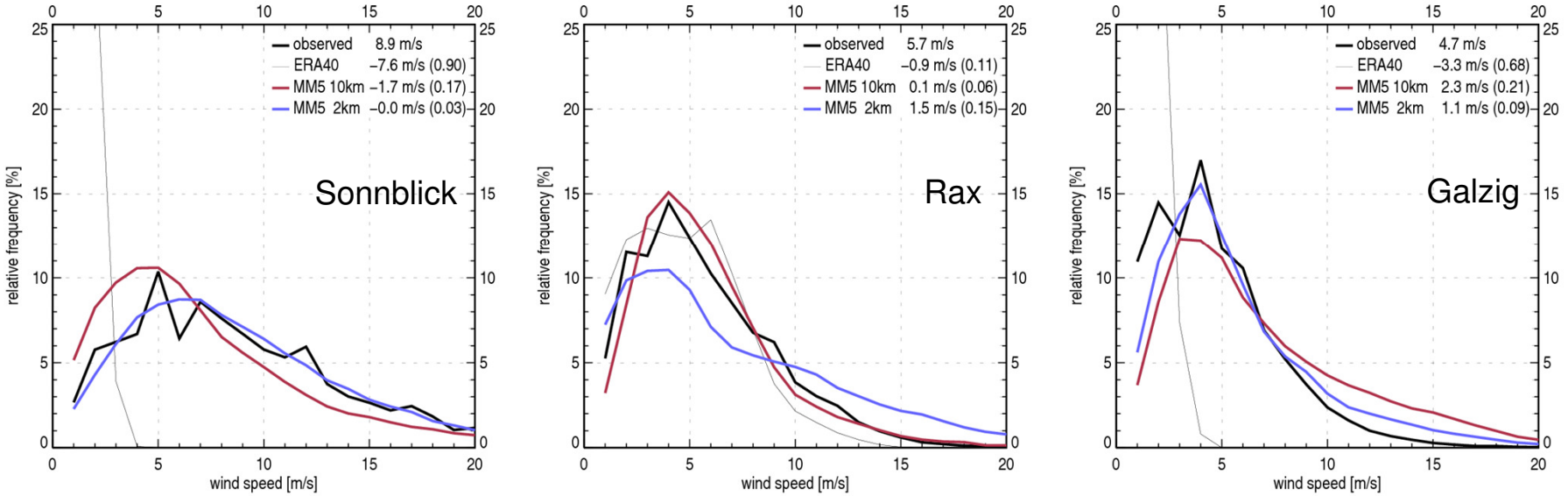
- Simulation of the temporal evolution of atmospheric processes
- Land/atmosphere interaction, planetary boundary layer processes, …
- + independent from observational data
- + generation of time series
- – limited spatial resolution (~km); small scales are unresolved
- – time consuming calculations (~months) → high performance computing systems

(Geo)-statistical models

- Interpolation of observational data based on empirical background information
- Small scale features are considered (land use, orography, …)
- + very high resolutions are achievable
- + short run times (desktop PCs are sufficient)
- – density and quality of observational data are crucial
- – generation of mean values; no sophisticated frequency distributions

Evaluation of the dynamic modelling step (1981 to 1990)

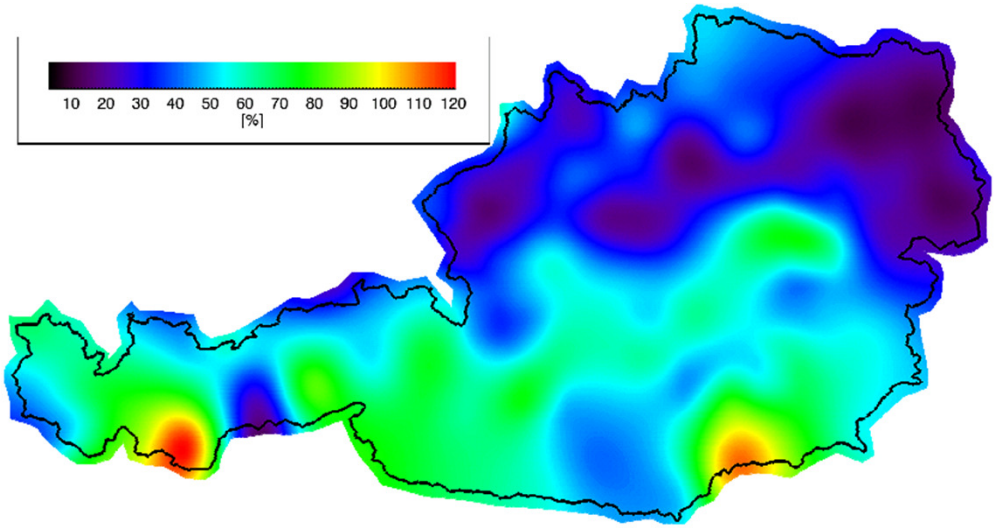
- Single stations show high variability

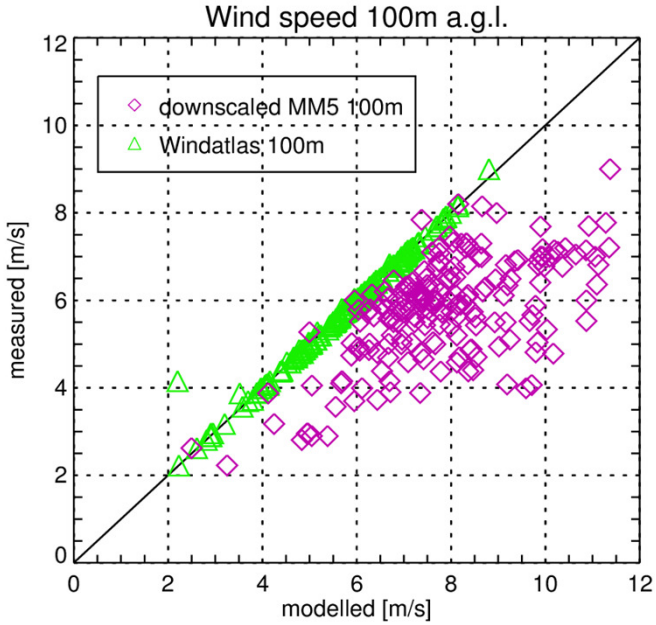


- → Output from dynamic models need to be “post-processed” (bias correction, MOS, etc.)

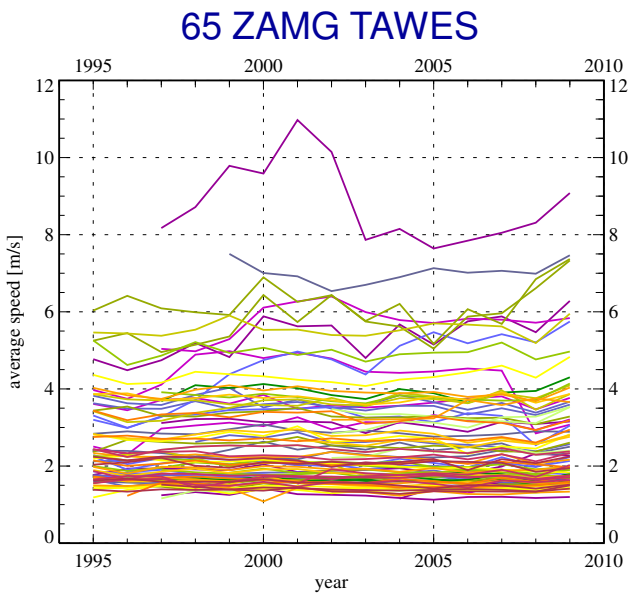
Statistical modelling step

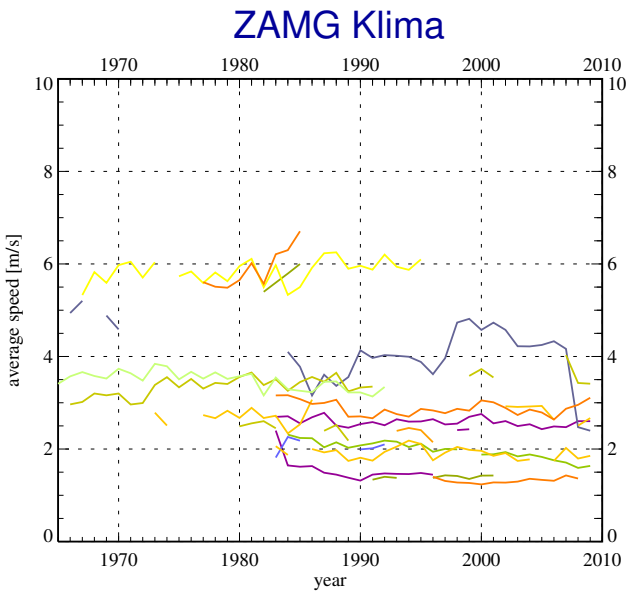
- Application of a spatially distributed scaling factor



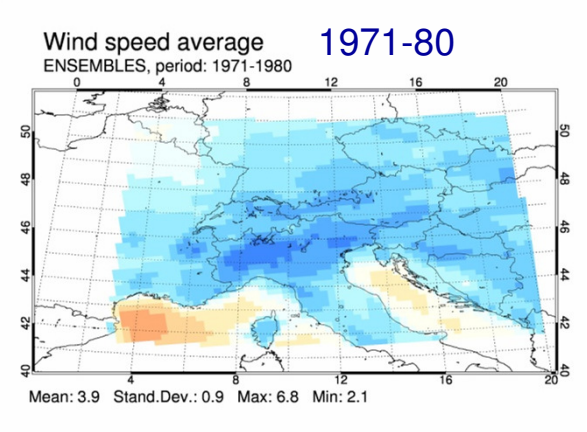


Results


65 ZAMG TAWES
1995
2000
2005
2010
0
2
4
6
8
10
12
average speed [m/s]
year

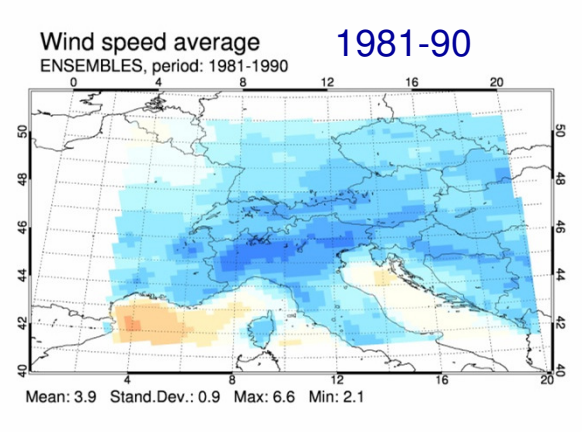

ZAMG Klima
1970
1980
1990
2000
2010
0
2
4
6
8
10
average speed [m/s]
year

Results



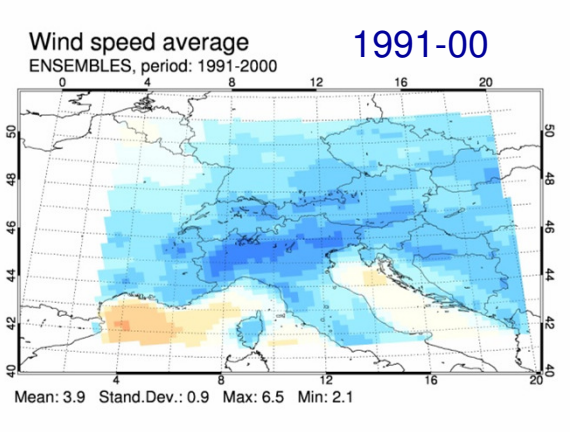
1971-80

Mittel: 3,9 m/s



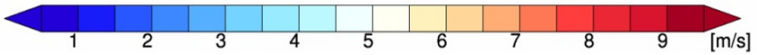
1981-90

Mittel: 3,9 m/s



1991-00

Mittel: 3,9 m/s



14 Modelle (18 km Auflösung) aus dem ENSEMBELS Projekt