WIND ENERGY AND CLIMATOLOGY

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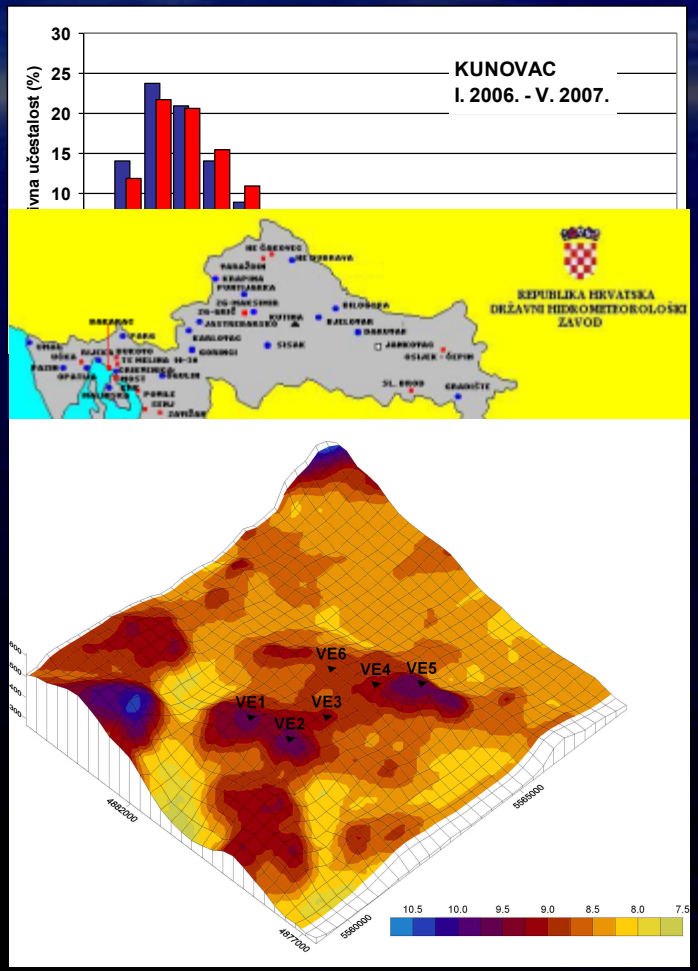
How to estimate potential wind energy on a location?

1. Measurement
   - Most accurate assessment
   - Not economical (for example measurement on 2 km x 2 km scale in Croatia for 10 years)
   - With complicated terrain more detailed measurement needed
   - =>Existing measurement should be used!

How to estimate potential wind energy on a location?

- Most accurate assessment is done after 30 years of measurement
- Disadvantages: costs, time consuming, different measurement heights than needed…

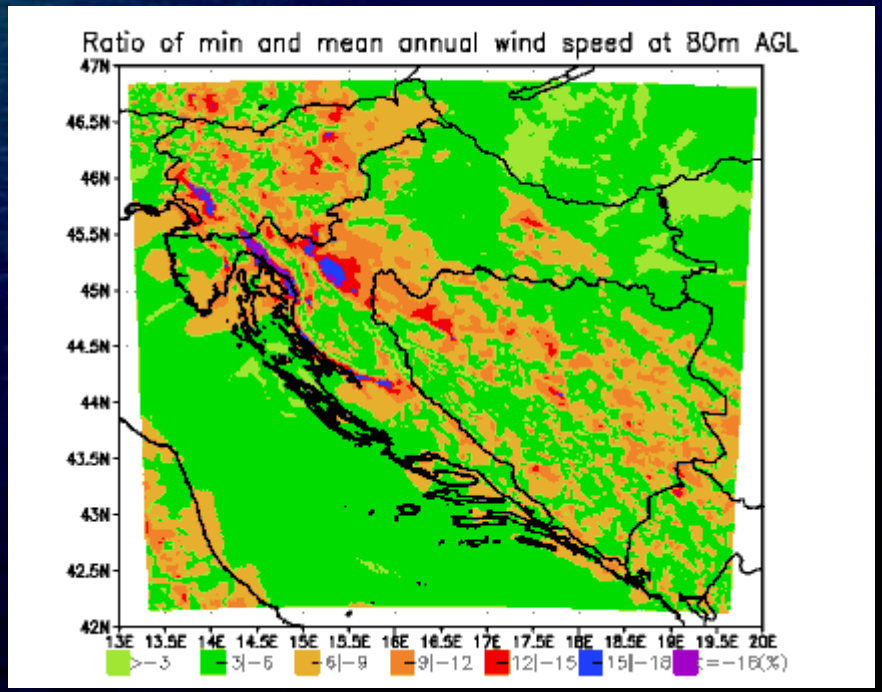


How to estimate potential wind energy on a location?

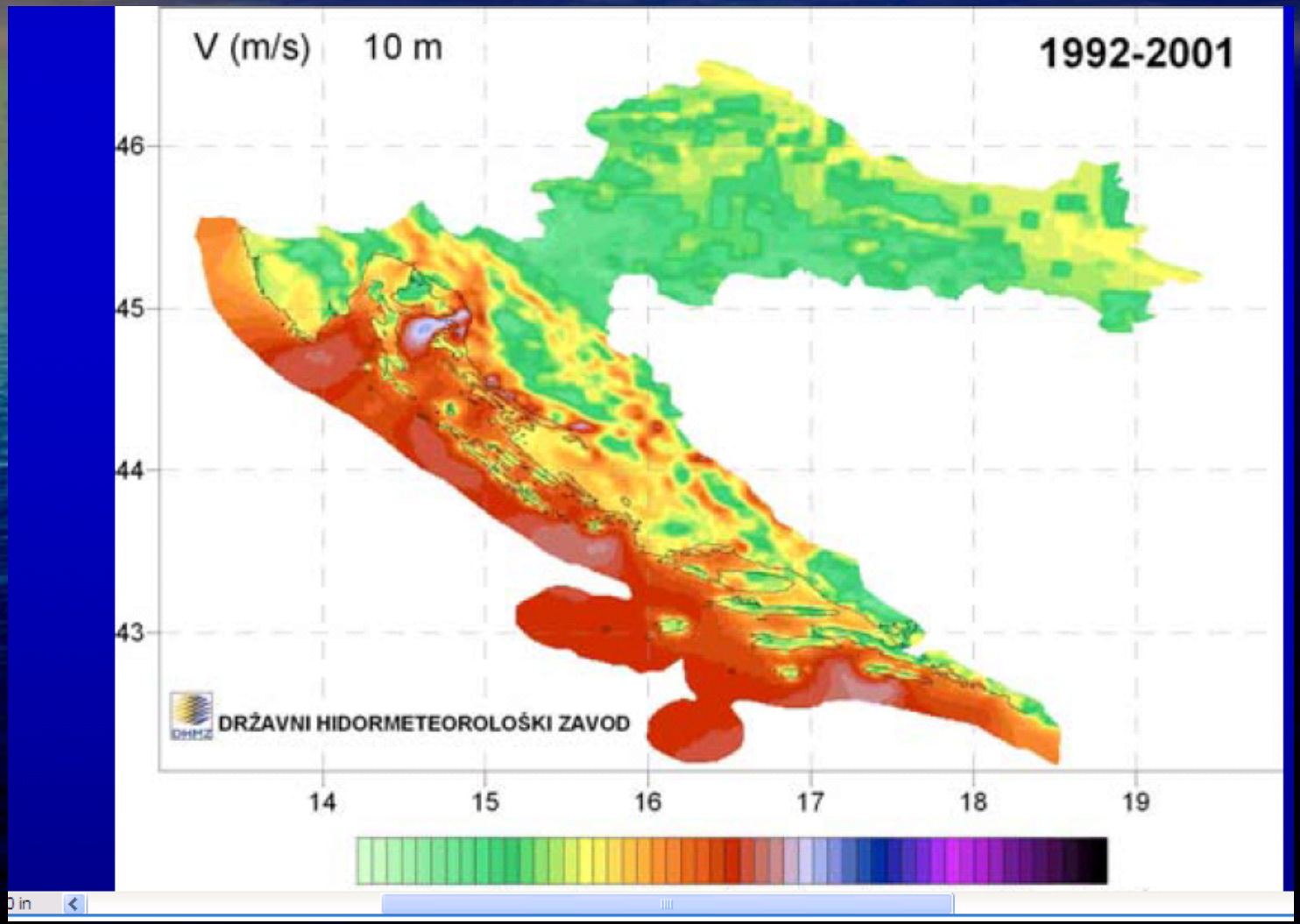
- Typically, measurement is being done only for one year, not 30
- How representative is that one year?
- Measured data needs long term scaling
- Especially important in “complex” terrain, such as Adriatic area or Mediterranean area

Interannual variability

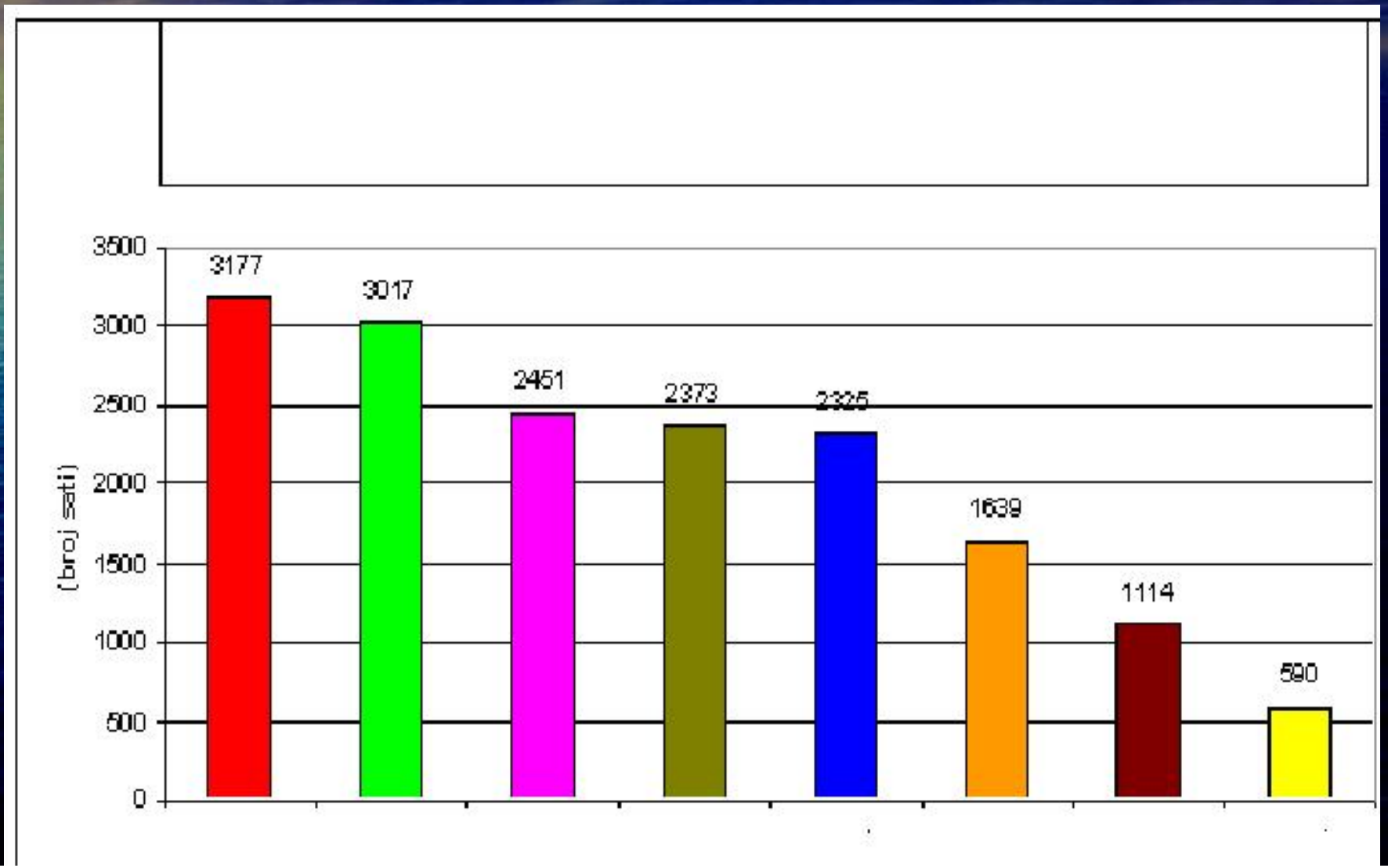
- In a 10-yr period, interannual variability or mean yearly wind speed up to 20% of the 10-yr mean
- The variability is higher over the mountains than over the flat terrain
- Strong spatial gradients and fine structure (local effects)



Example: where are the good wind resources (Croatia)

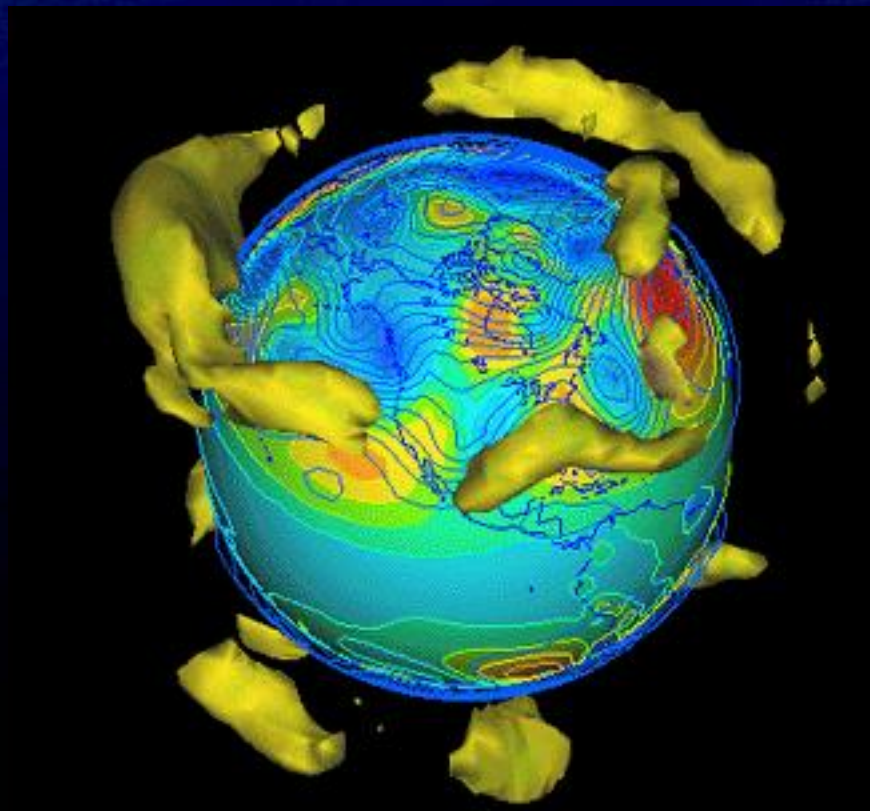


Number of hours working on nominal power for wind power plants in Croatia (2011)

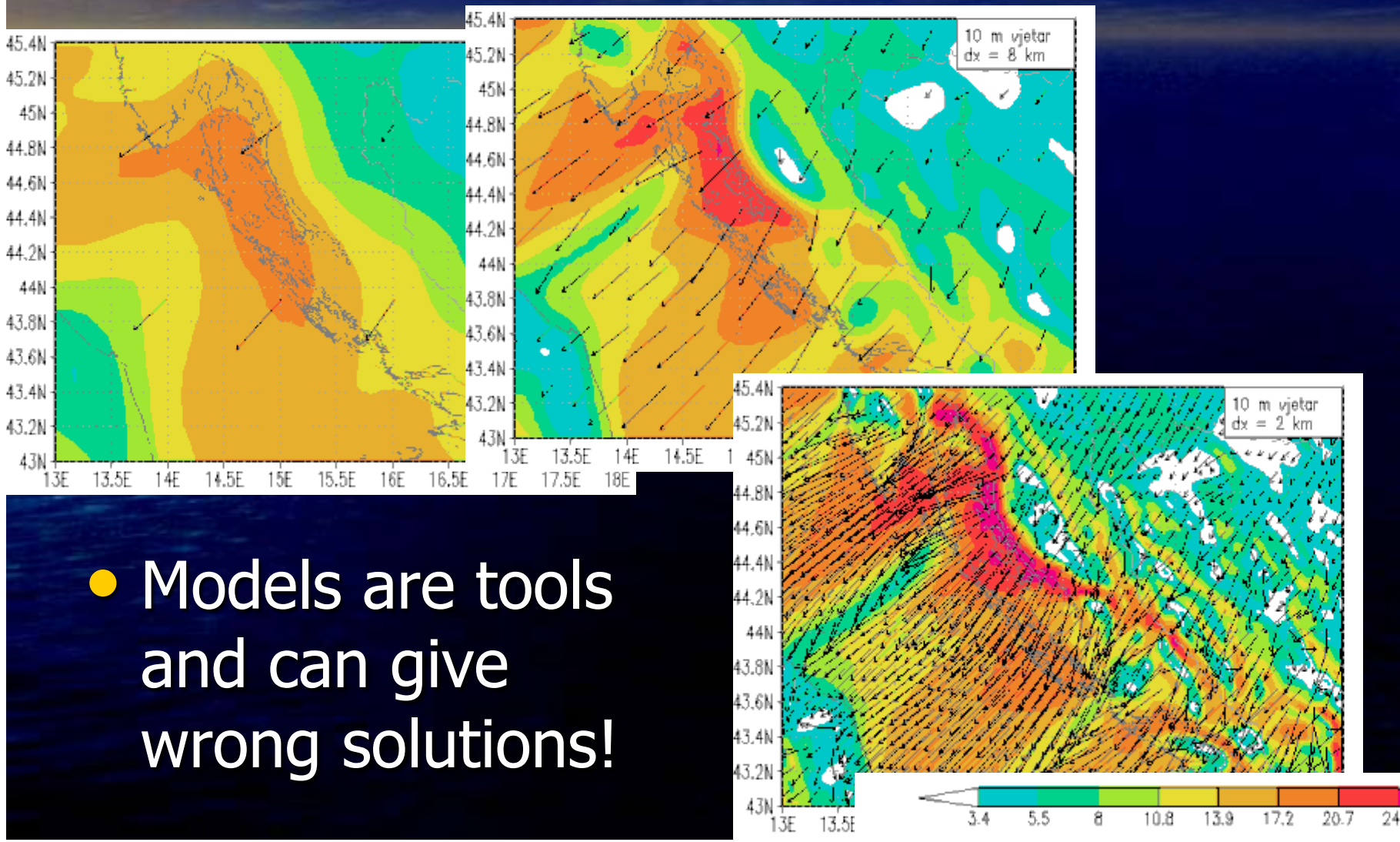


Wind Atlas: how to get wind potential on a location

2. Numerical atmosferical models
   - Lower measurement accuracy
   - Sofisticated computers are needed and educated experts – “know-how”
   - Cost effective (speed, price)



Wind Atlas: Numerical models: Differentces in resolution – importance on data quality (example for wind speed and direction)



- Models are tools and can give wrong solutions!

Wind Atlas: ALADIN model/method

- Method of dinamical downscaling with ALADIN model used in many EU countries (France, Austria, Hungary, Slovenia, Belgium)
- Estimation of average wind speed with ALADIN model
  - For every dot in a network 2 km x 2 km
  - Time frequency 60 min
  - Through 10 years

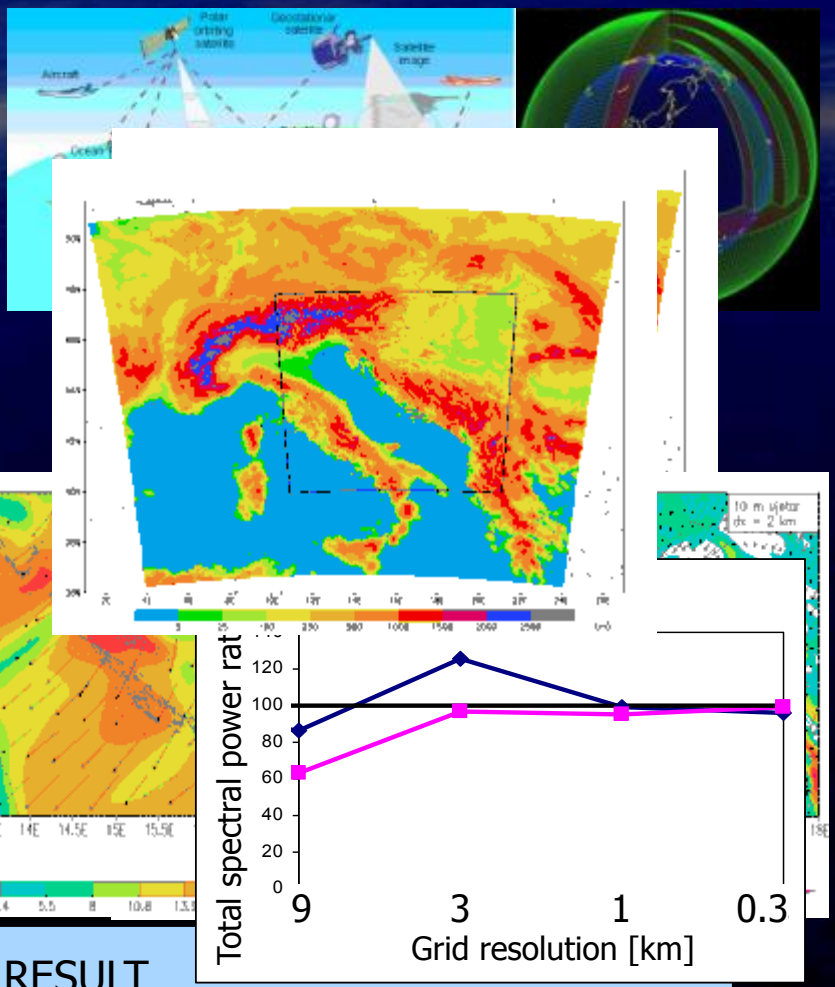
Mapping of national wind resource and extremes

START – GLOBAL RESOURCE
"Reanalysis" (ERA-40)
Grid increment ~125 km

REFINEMENT 1 – REGIONAL RESOURCE
Mesoscale model ALADIN/HR
Grid increment ~8 km

REFINEMENT 2 – SUBREGIONAL RES.
Dynamic adaptation ALADIN/DADA
Grid increment ~2 km

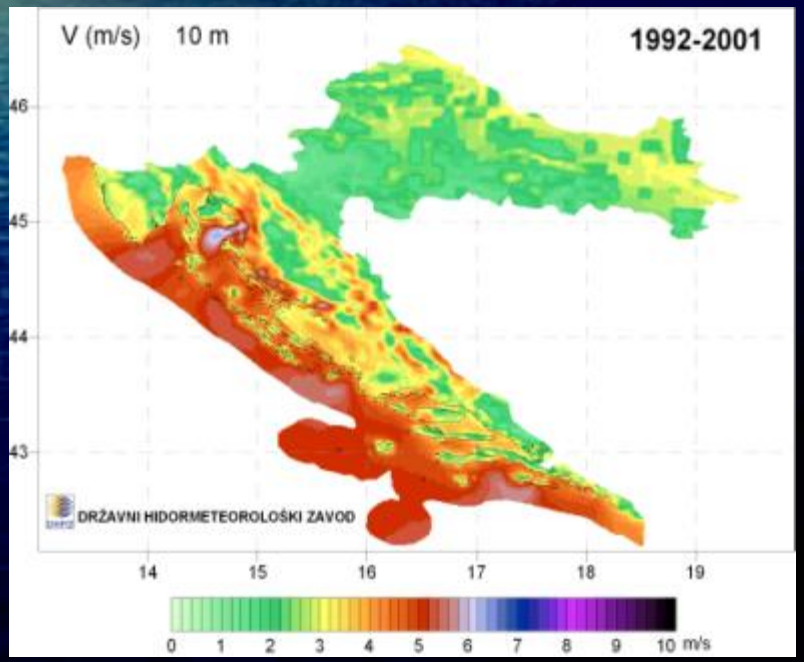
REFINEMENT 3 – LOCAL RESOU CE
Microscale models
Grid increment ~100 m

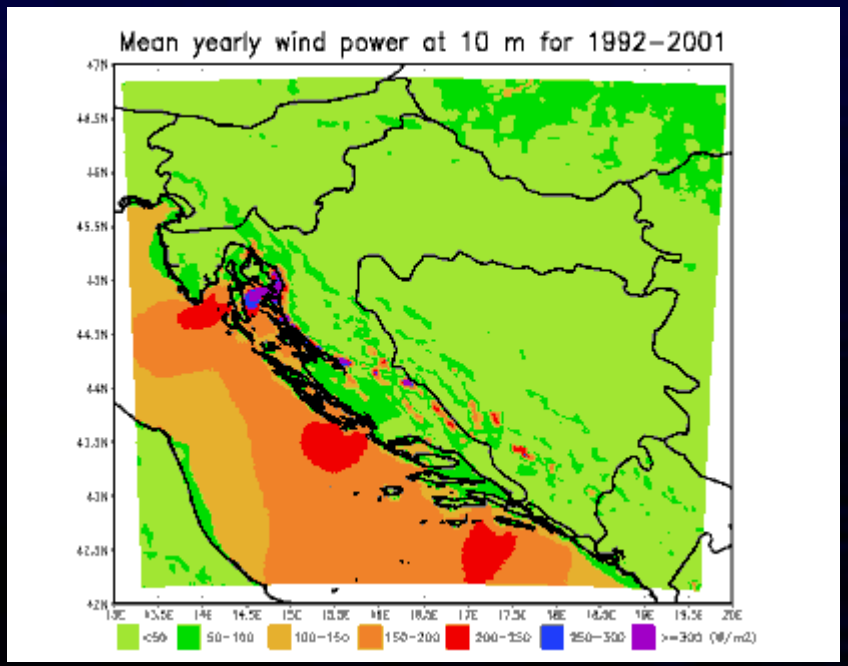


FINAL RESULT
Wind speed and direction at different heights *(u,v,∂u/ ∂z,T,q,p,ρ,...)*
Frequency: 60 min, Period 10 years

Wind Atlas: Results

- Average wind speed 1992-2001: 10 m height
- Annual wind speed variability 2 ms^{-1}





Most common wind energy models

- WAsP
- WindPRO
- Wind Farmer
- RETSCREEN

RETSCREEN

- Online wind resource mapping applications or non-interactive maps of wind resources like www.3tier.com; www.WindNavigator.com; www.windatlas.dk
- Poor quality for wind projects as shear and turbulence values not available
- Statistical distribution of wind speed is not available
- No site specific data
- Typical energy estimate: +/- 50%

WAsP

- Wind Atlas Analysis and Application Program
- WAsP is used for :
  - Wind farm production, efficiency
  - Micro-siting of wind turbines
  - Power production calculations
  - Wind resource mapping
- Time-series of wind data may be obtained from meteorological stations or from other sources
- Time coverage: 20-30 years of data preferred but several (2-3), whole years of data are often used and are ok

WindPRO

- Users are able to design wind farms, including wind turbine layout and electrical design
- Energy production, turbine noise levels, turbine wake losses, and turbine suitability can be calculated
- It is recommended to use measurement data from a local mast with measurements as close to hub height as possible
- The industry standard is 10 minute measurements covering a full integers of years
- In practice most sites are measured for one full year
- uses wind flow modeling inputs from WAsP software

WindFarmer

- WindFarmer and WindPRO have both been trusted by investment banks to develop the published wind energy assessments used to determine financing for proposed wind farms
- Prefer wind speed at 10-minute intervals for many years
- Uses its own algorithms and is independent of WAsP to that extent

Wind

- Increasing number of studies looking at changes in wind speed and impacts on electricity production. Two main impacts from CC:
  - - Change in wind speed (influence on quantity and timing of the wind resource and electricity produced)
  - - Increase in maximal wind speed for which wind power plants are designed (influence on equipment robustness)

$$P = \frac{1}{2}\rho U^3$$

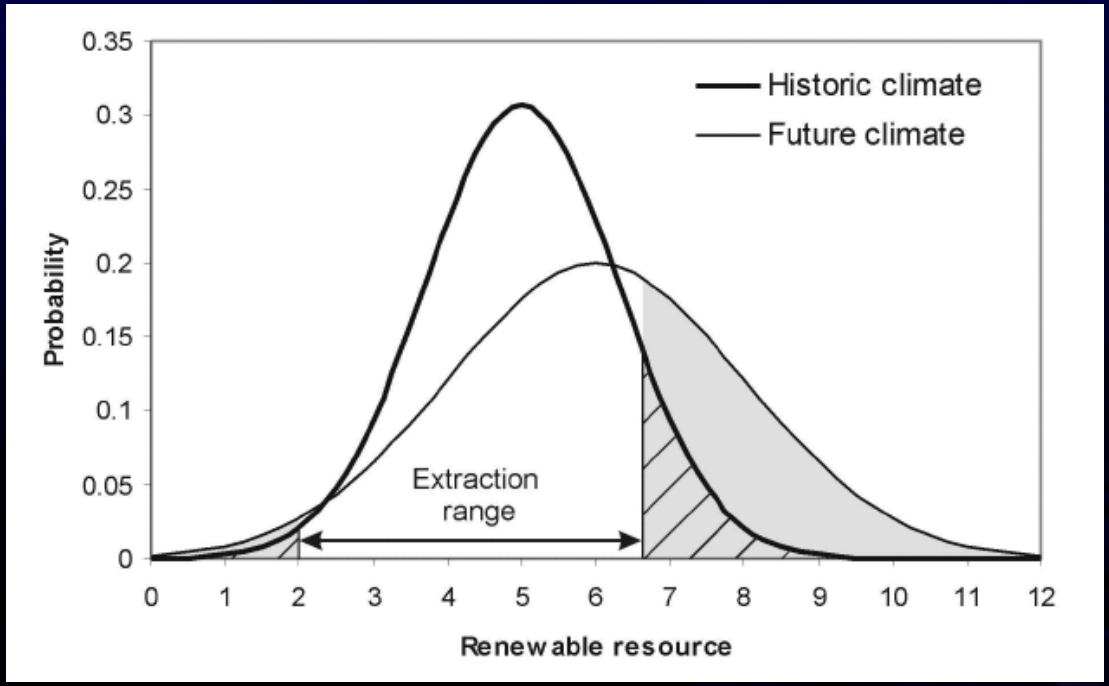
P – Power; U – wind speed, ρ – air density

- Due to this cubic relationship, 10% change in wind speed could alter energy produced by 13-25% (Baker et al, 1990)
- Wind turbines can extract energy over a defined band of wind speeds, typically between 3 and 25 m/s
- Rise in 1°C changes air density and production by 0,3%

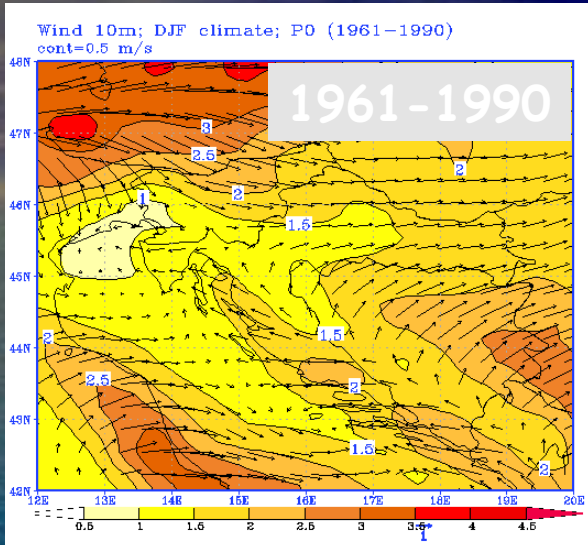
Wind speed variability

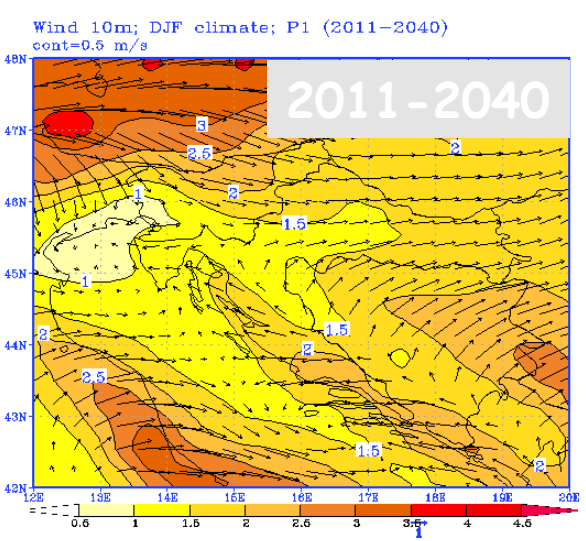
Can have significant impact on electricity production from wind power plants:

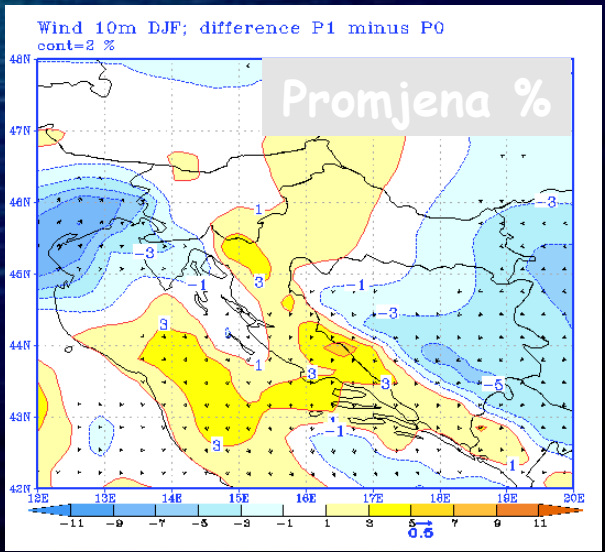
- wind speed rises
- due to the variability, most part of this wind speed rise is unexploited because it is out of the wind speed upper limit

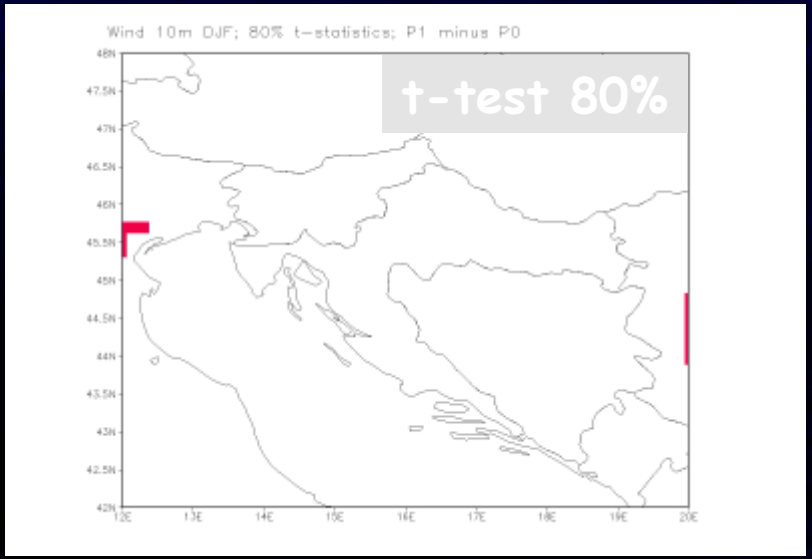


Climate change 2011-2040, A2 scenario
Wind at 10m, winter

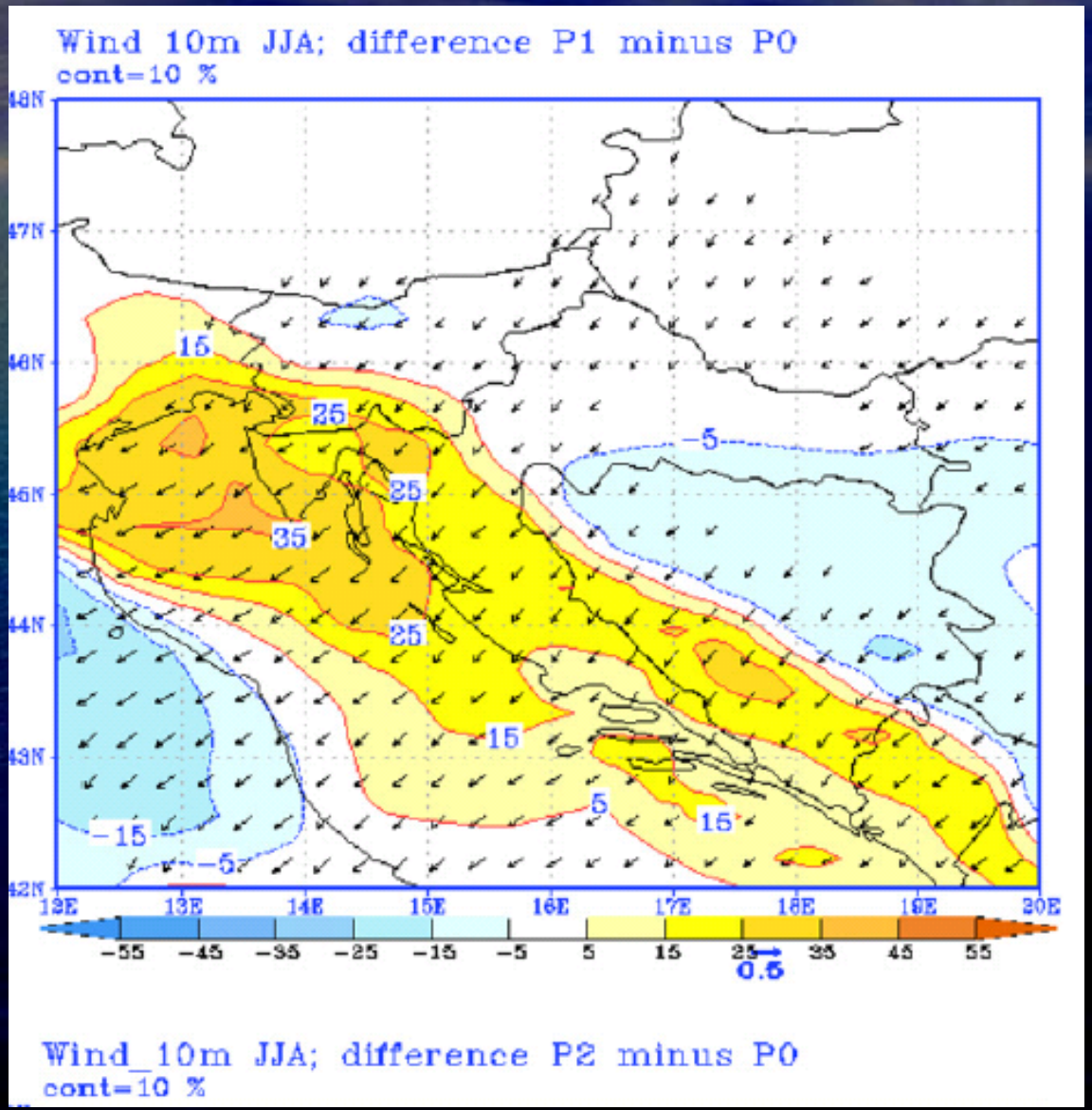




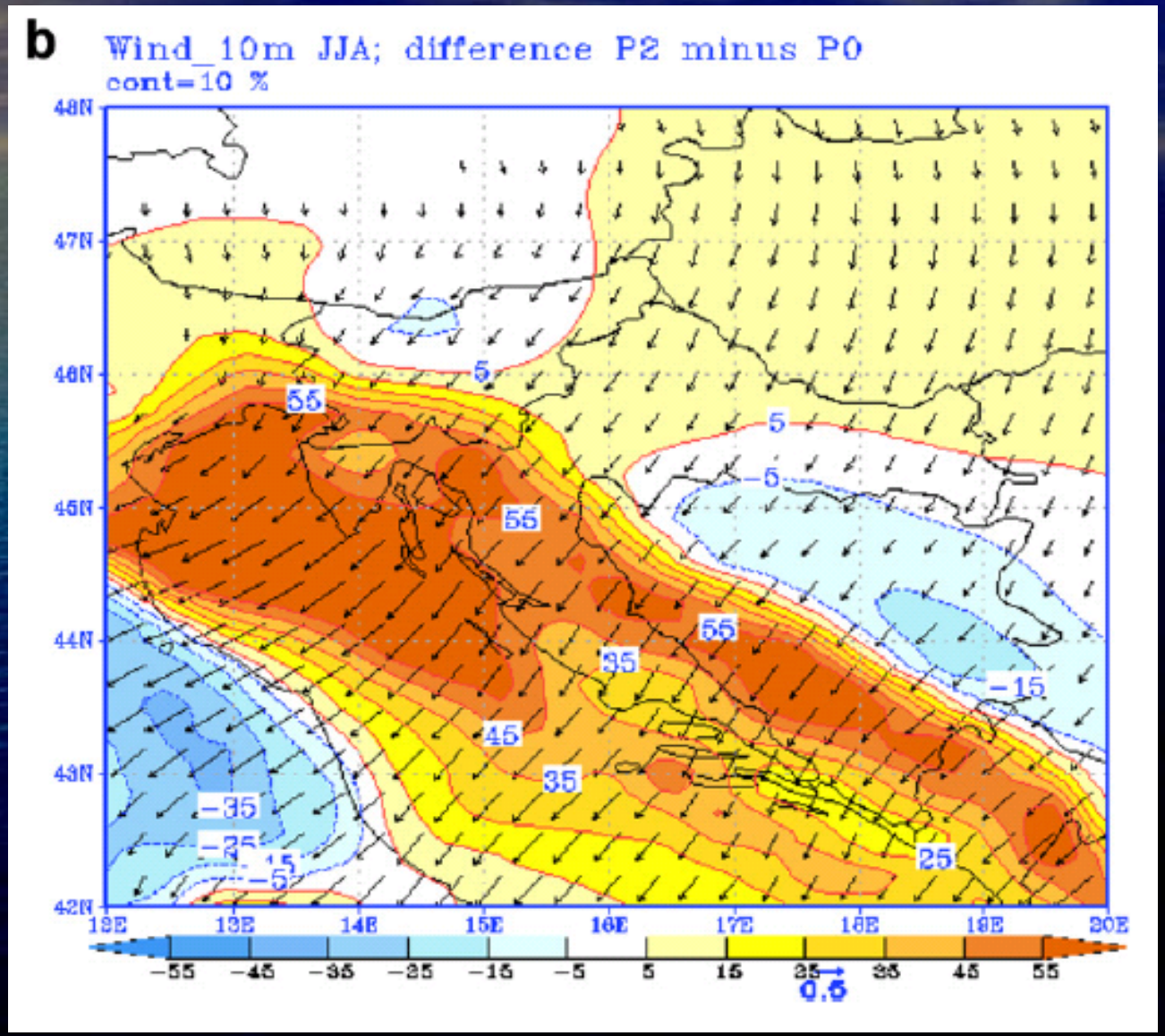




Climate change 2011-2040, A2 scenario
Wind at 10m, summer



Climate change 2041-2070, A2 scenario
Wind at 10m, summer



Temperature
Increase of one degree Celsius yields a decrease of about 0.5% of wind power electricity production. Overall, no more than 1% change expected

Extreme events
Winds stronger than the maximum anticipated could be expected

Wind speed change
More electricity could be generated from wind power plants in the southern regions of Croatia during the summer – 50% more the current production (until 2040) or more up to 2070

Change in wind speed variability
Potentialy big impact on electricity generation - with the wind speed increase, a higher variability of wind can lead to less generation of energy

Thank you!!!