Meteorological and Hydrological Service

HEP OIE d.o.o. OBNOVLJIVI IZVORI ENERGIJE

UNITY THROUGH KNOWLEDGE FUND

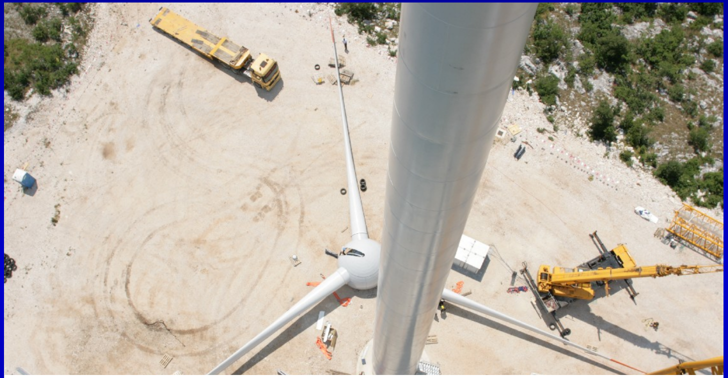
Dynamical downscaling of ERA-40 reanalysis with mesoscale model ALADIN: wind mapping of Croatia

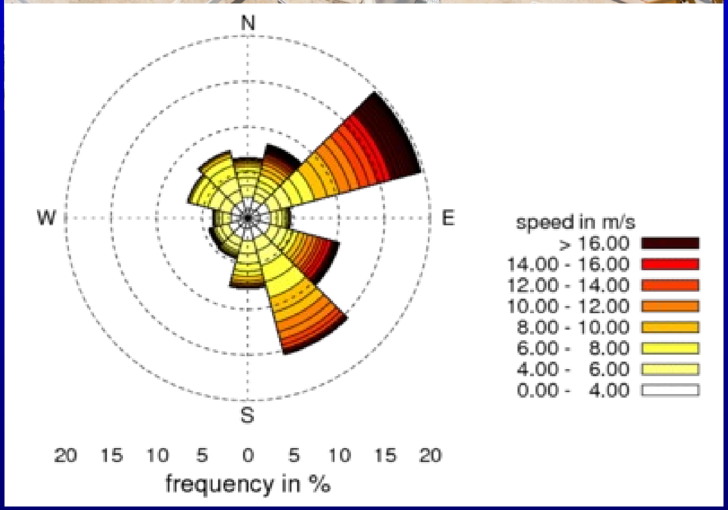
Kristian Horvath, Alica Bajić, Stjepan Ivatek-Šahdan

Research Department, Meteorological and Hydrological Service, Croatia

Introduction

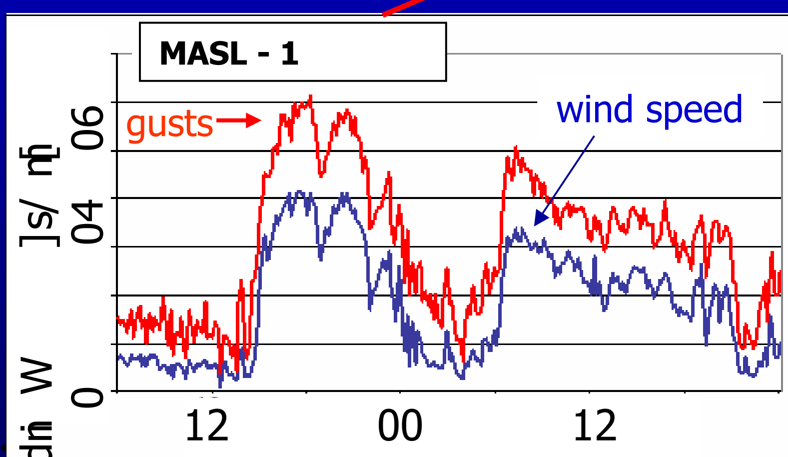
- In the last decade, wind energy grew rapidly worldwide
- The positive effects of wind energy:
  - Help mitigate the climate change
  - Secure energy supply
  - Bring new jobs
- Wind power plants are emerging in the coastal part of Croatia
- In 2011, 7 wind farms (89 MW) were integrated into electric network
- The largest portion of wind energy is due to north-easterly bora winds

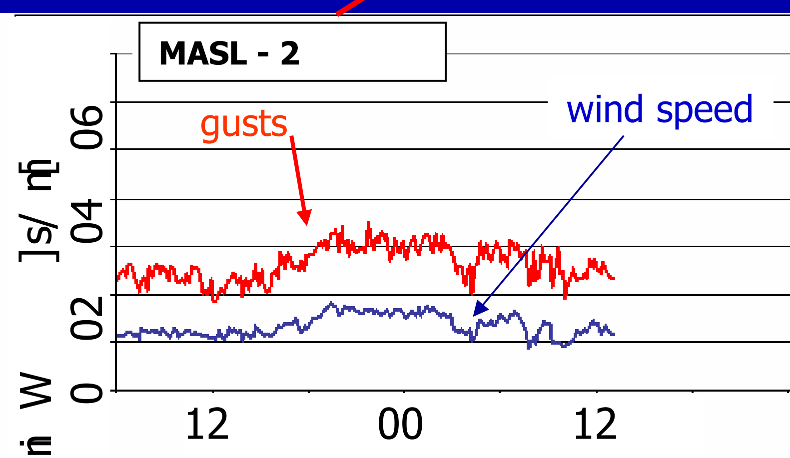




The bora winds: the Croatian “brand”

- The violent and unique character of bora:
  - Wind speeds over 40 m/s with gusts reaching H5 scales (~70 m/s)
  - Time variability (GF>2.5, TKE>65 J/kg)
  - Space variability (> 5m/s over 100 m)
  - Specific vertical profiles
  - Specific sub-phenomena (pulsations)



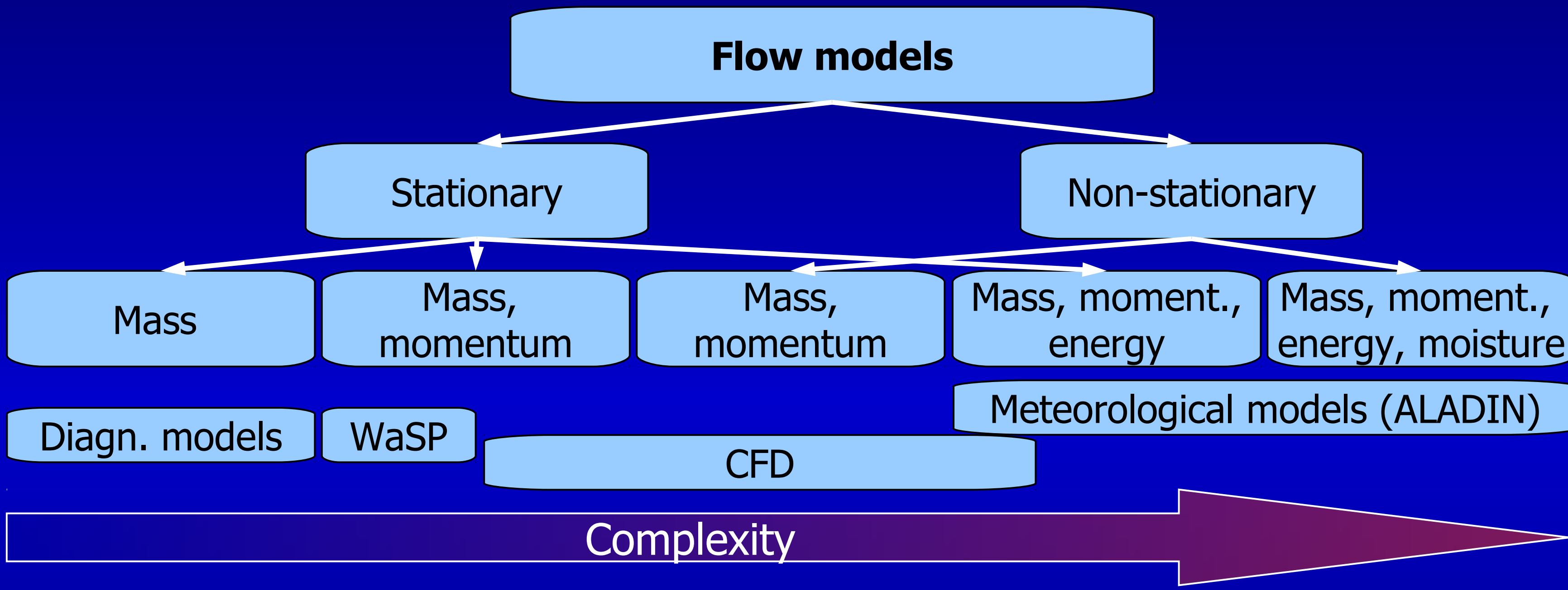


Mapping of wind resource/climate/regime

- Wind is a nation's resource
- The most accurate estimate is from long-term measurements (30 y)
- Challenges:
  - Cost
  - Longevity
  - Small spatial representativeness in mountainous terrain

- Q: How to map the wind resource/climate/regime?

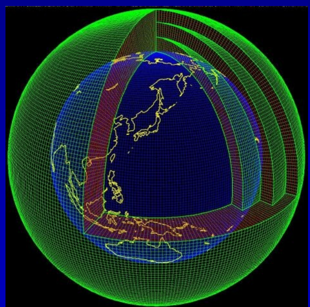
Wind mapping: Numerical flow models

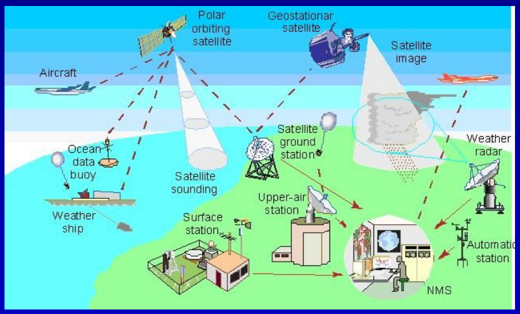


- Wind mapping should be done with mesoscale atmospheric models
  - DISADV: Less accurate than measurements, large HPC resources required

Dynamical downscaling:: Methodology

“Dynamical downscaling”





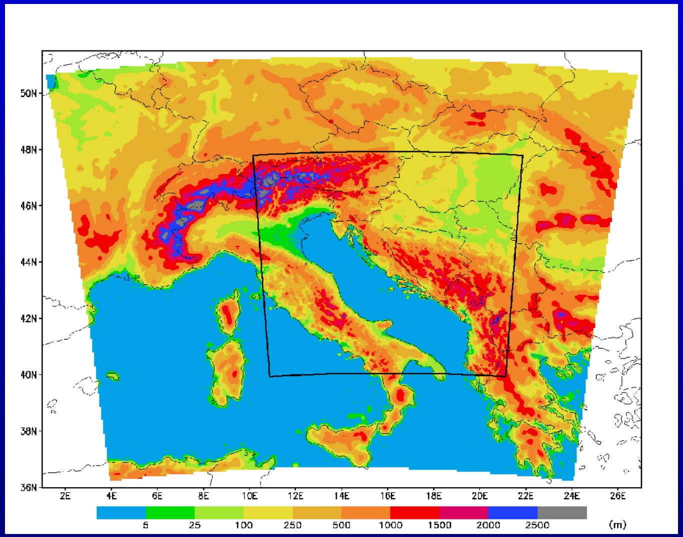
STARTING LEVEL - GLOBAL
ECMWF reanalysis ERA-40
Grid increment ~125 km

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

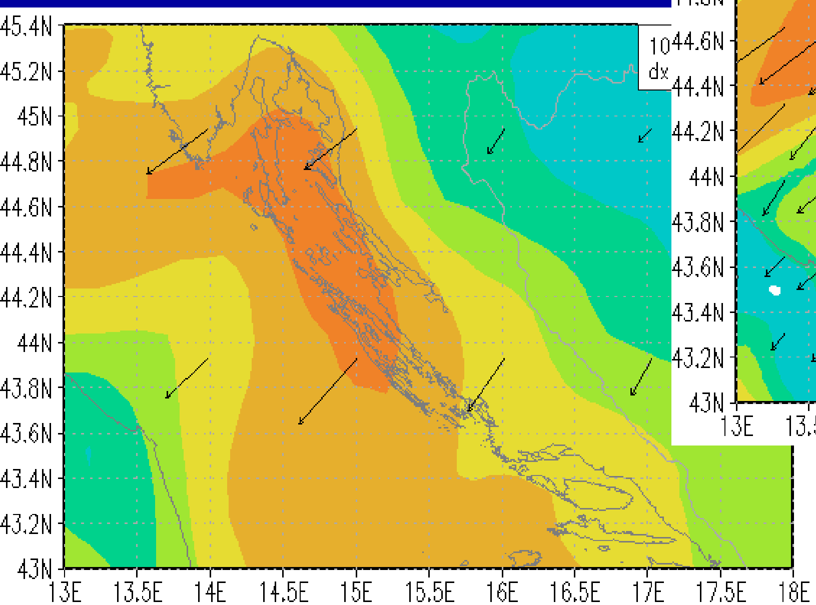
REFINEMENT 2 – SUB-REGIONAL
“dynamical adaptation” ALADIN/DADA
Grid increment ~2 km

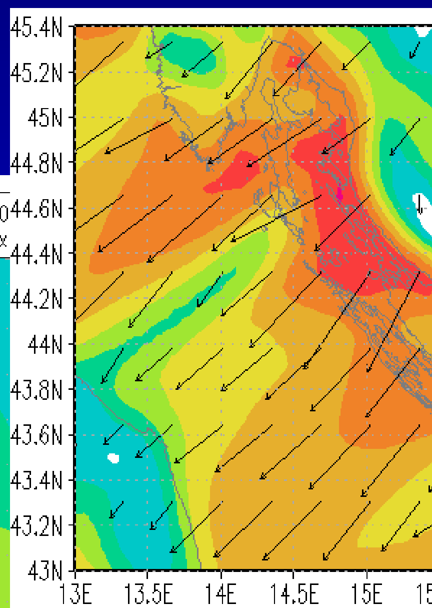
REFINEMENT 3
MICROSCALE

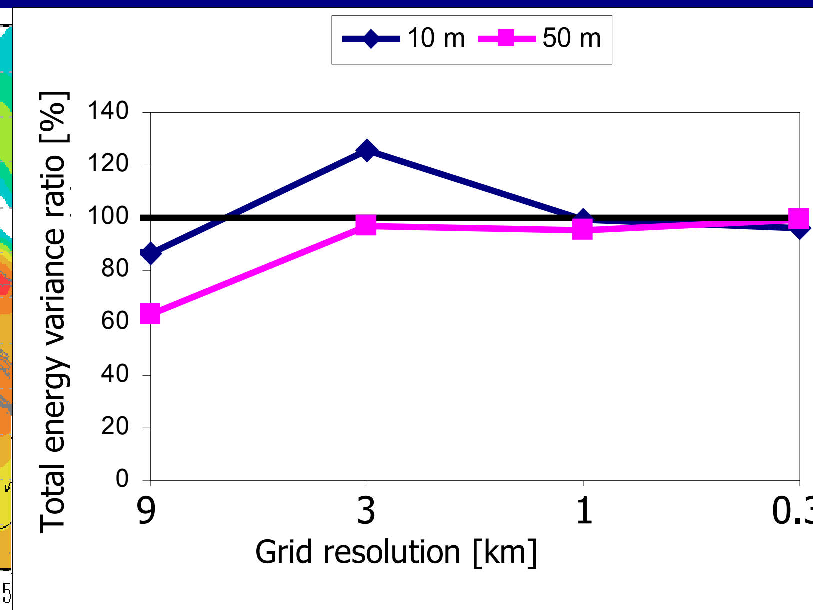
THE OUTPUT
10yrs of data with 60-min time interval
u,v,w,T,p,q,(ρ), and many others
At different levels above the ground

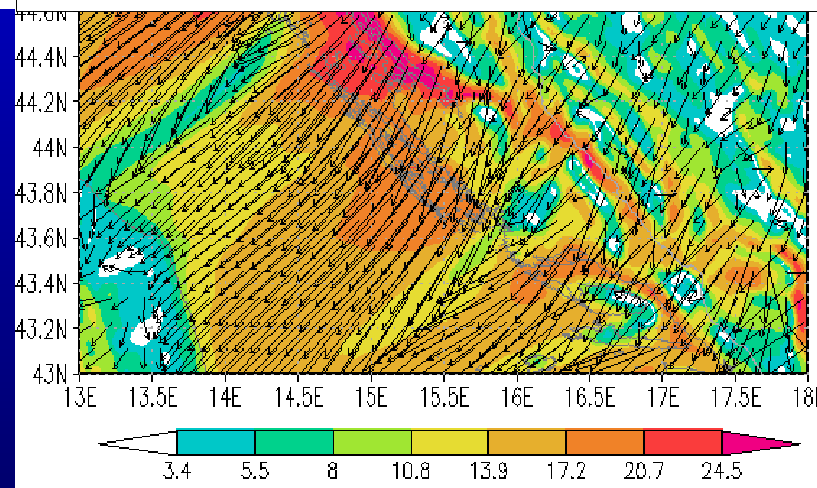


Dynamical downscaling:: Refinement





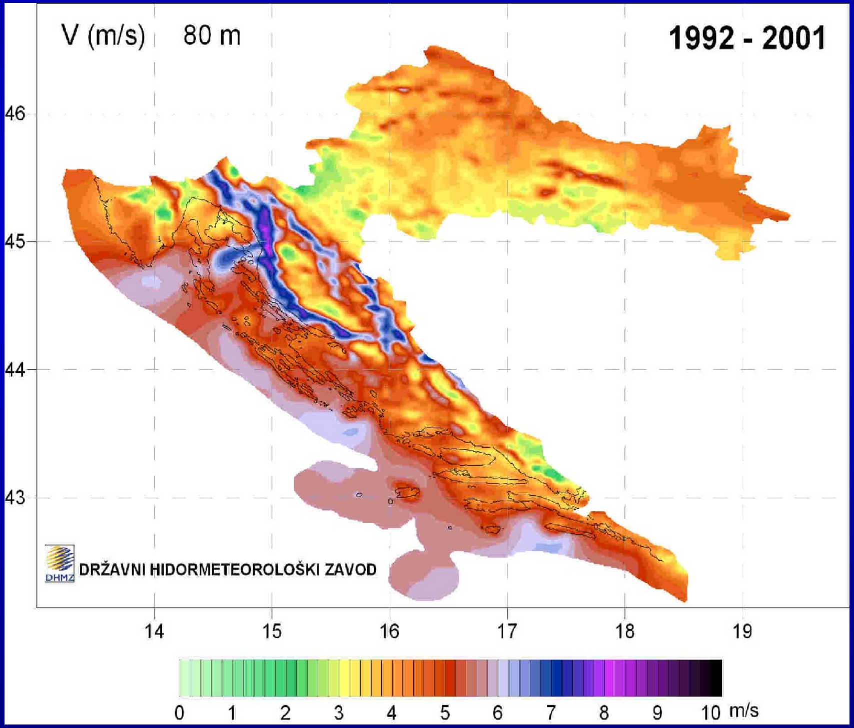


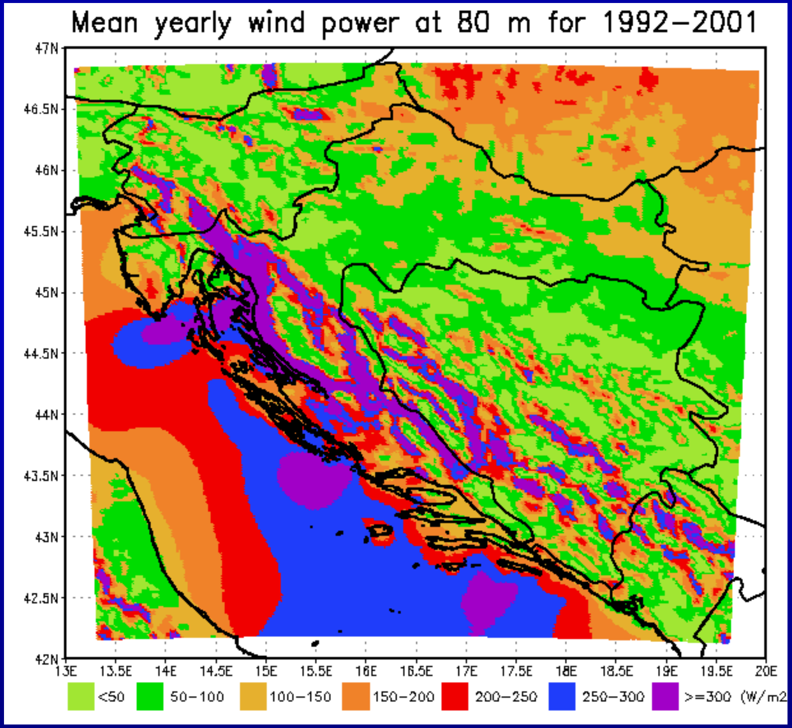


More details & spatial variability
Large changes of wind speed and direction

Dynamical downscaling:: Mean wind speed at 80 m AGL

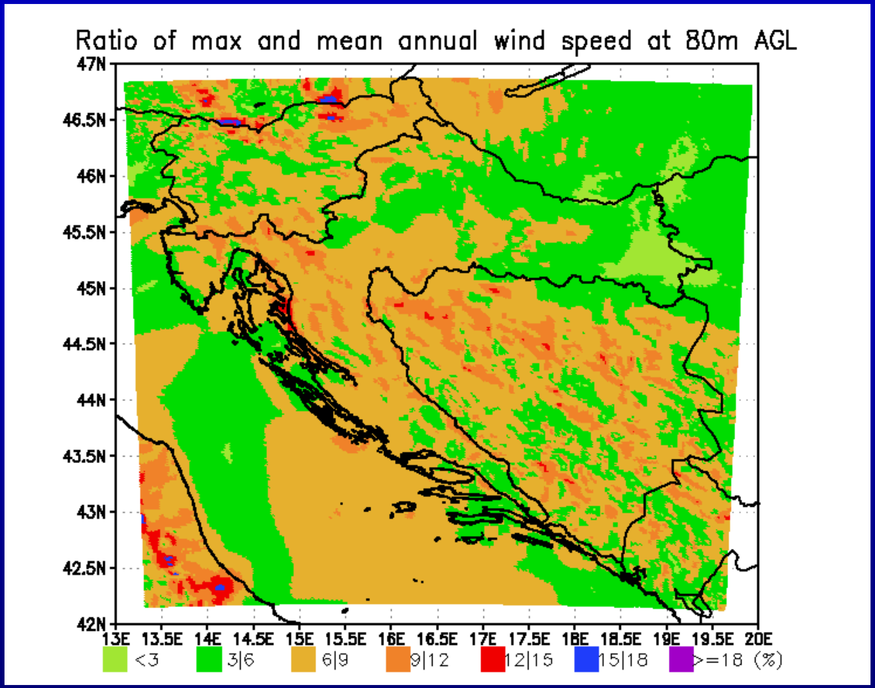
- Methodology applied during a 10-year period (1992-2001)

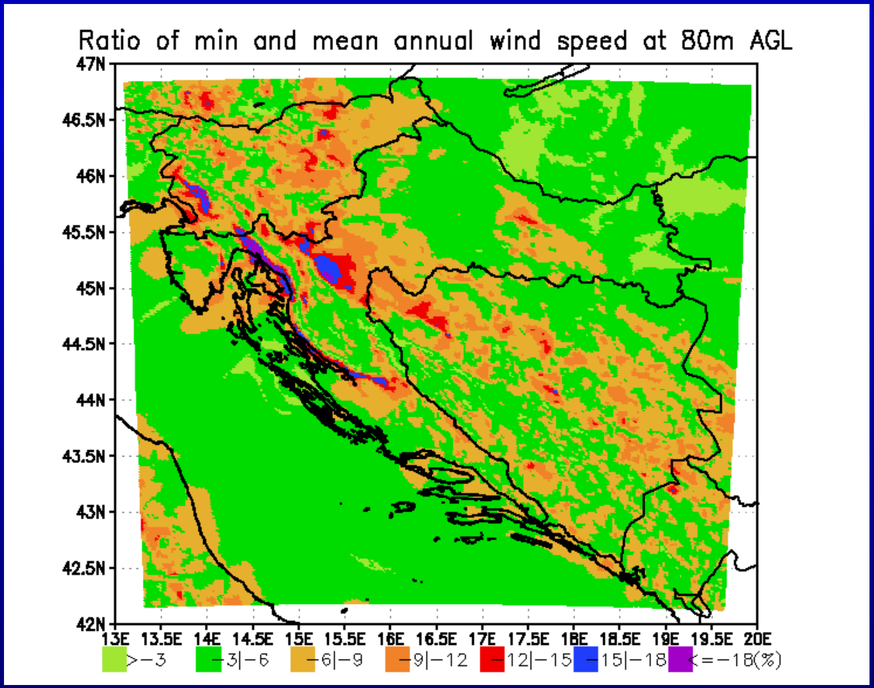




Dynamical downscaling:: Interannual variability

- In a 10-yr period, interannual variability or mean yearly wind speed up to ± ~20% of the 10-yr mean
- May have strong spatial gradients





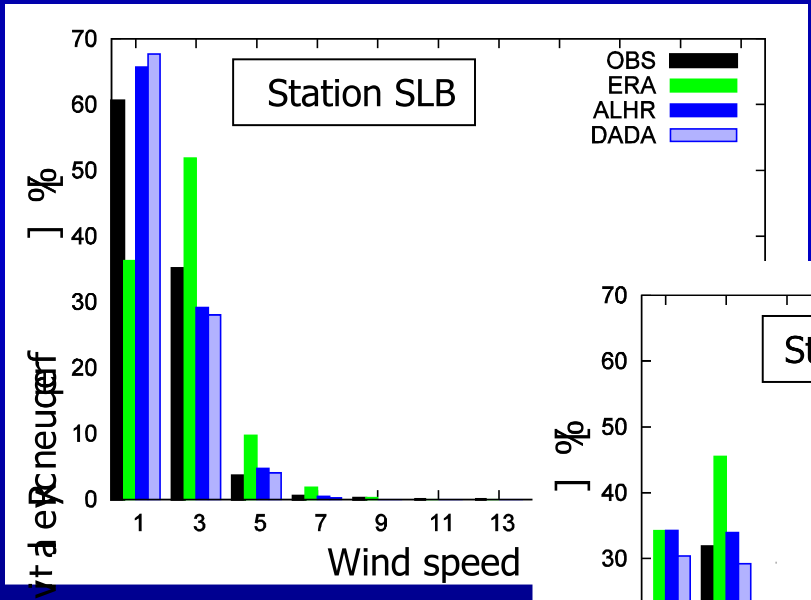
Statistical verification and distributions

- Statistical verification in different climate regimes of Croatia

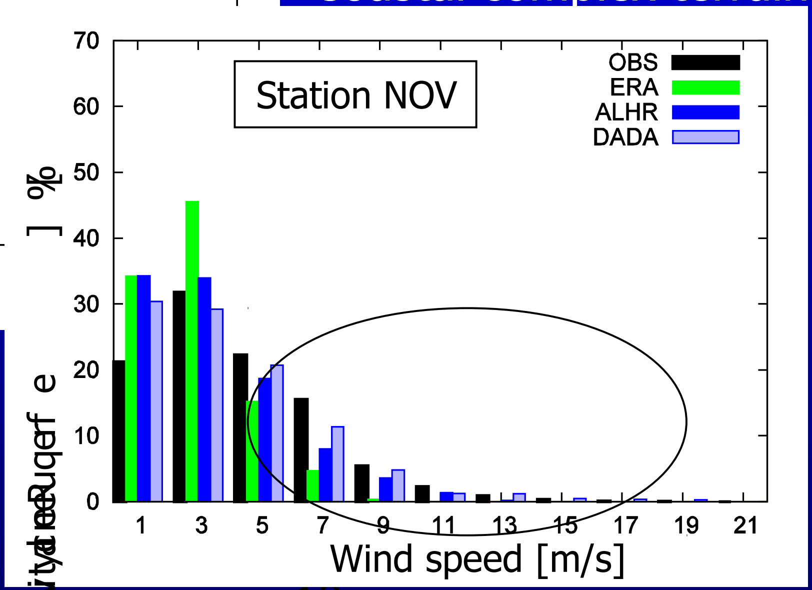
MBIAS (1=perfect)	
	DADA
SLB	**1.01**
NOV	**0.92**
STM	**0.89**
DUB	**0.91**

RMSE	
	DADA
SLB	**0.19**
NOV	**0.73**
STM	**0.58**
DUB	**0.33**

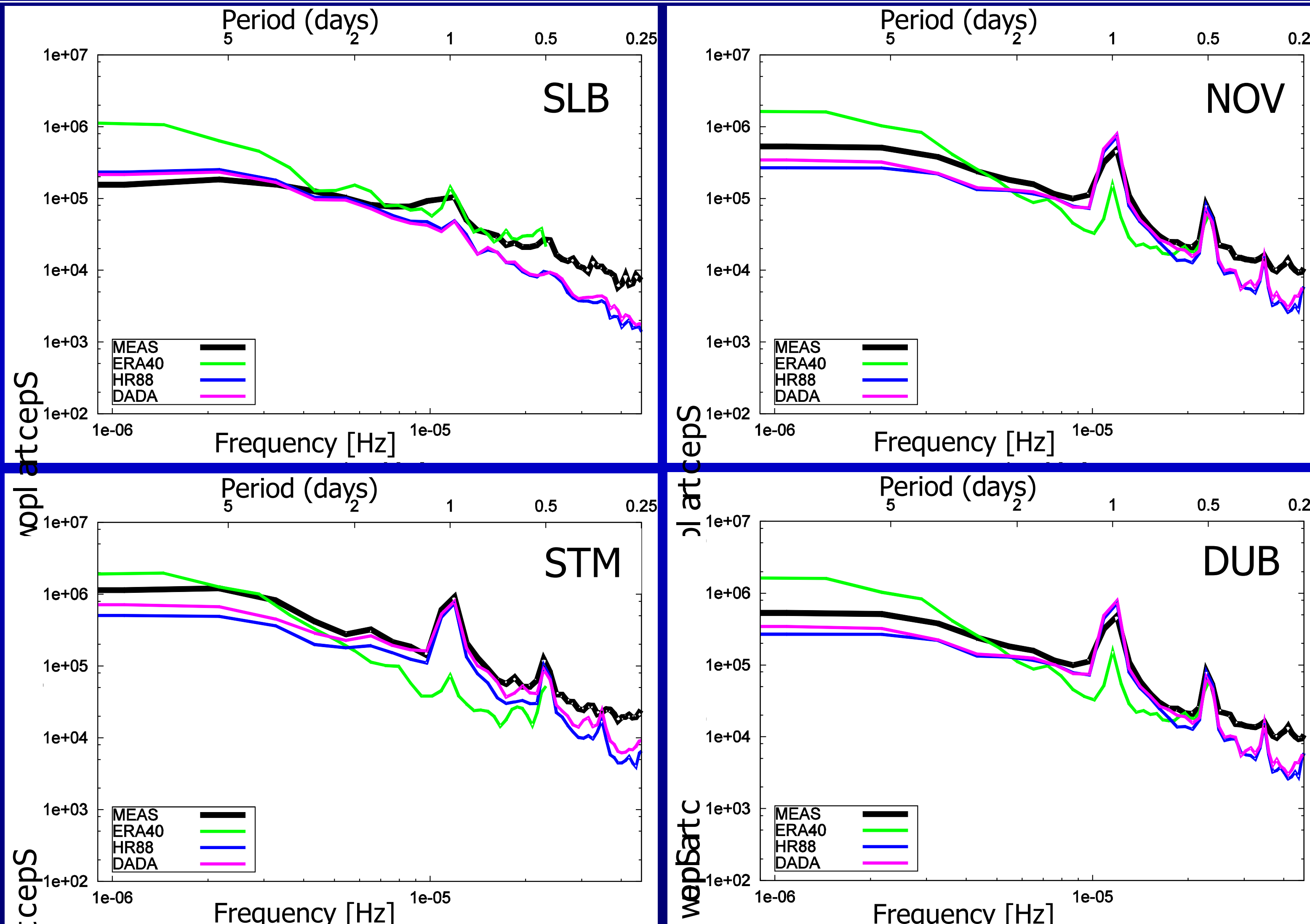
Flat terrain



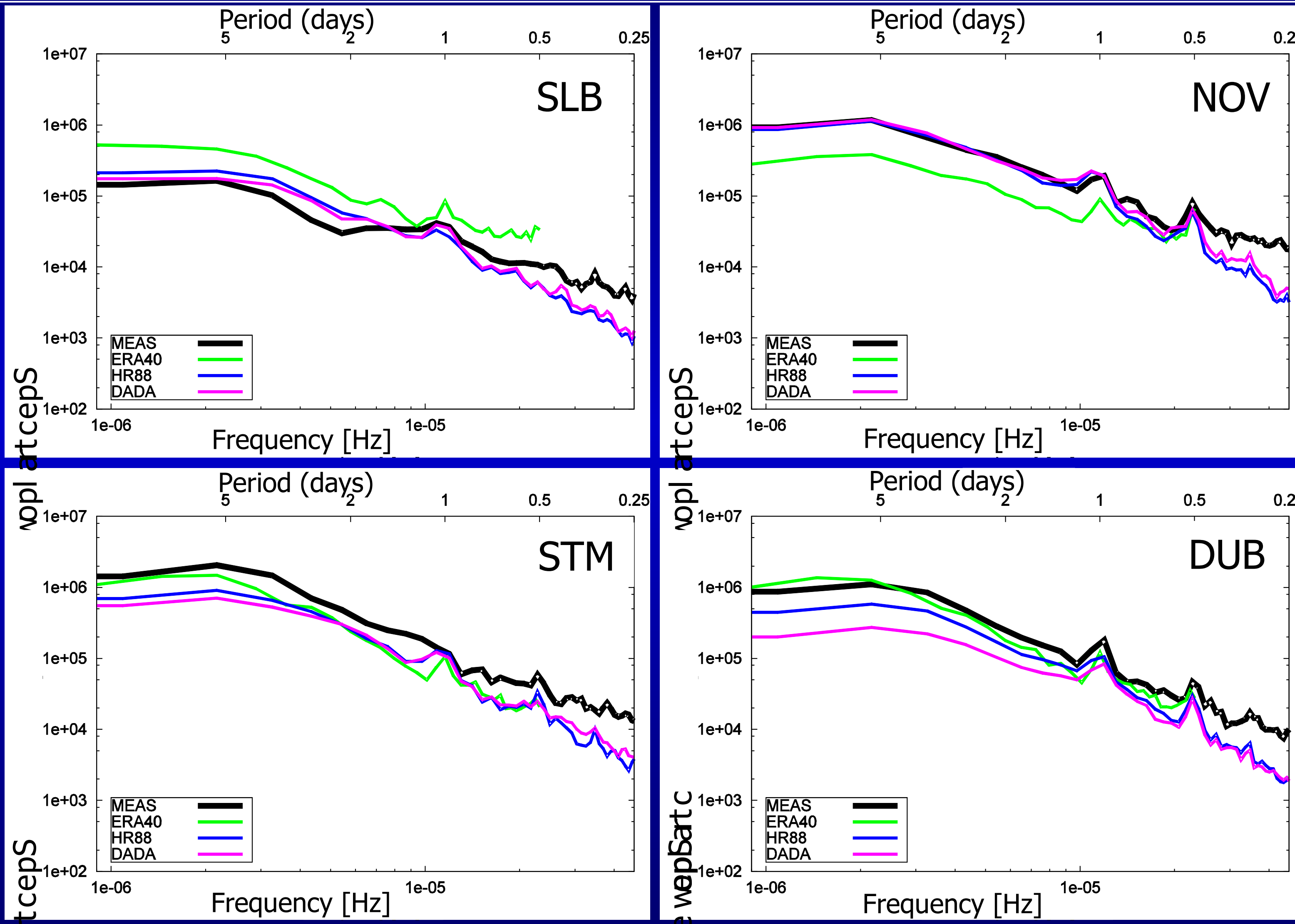
Coastal complex terrain



Spectral verification:: Zonal/cross-mnt component



Spectral verification:: Meridional/along-mnt component



[Horvath, Bajić, Ivatek-Šahdan, 2011: Journal of Applied Meteorology and Climatology]

Conclusions

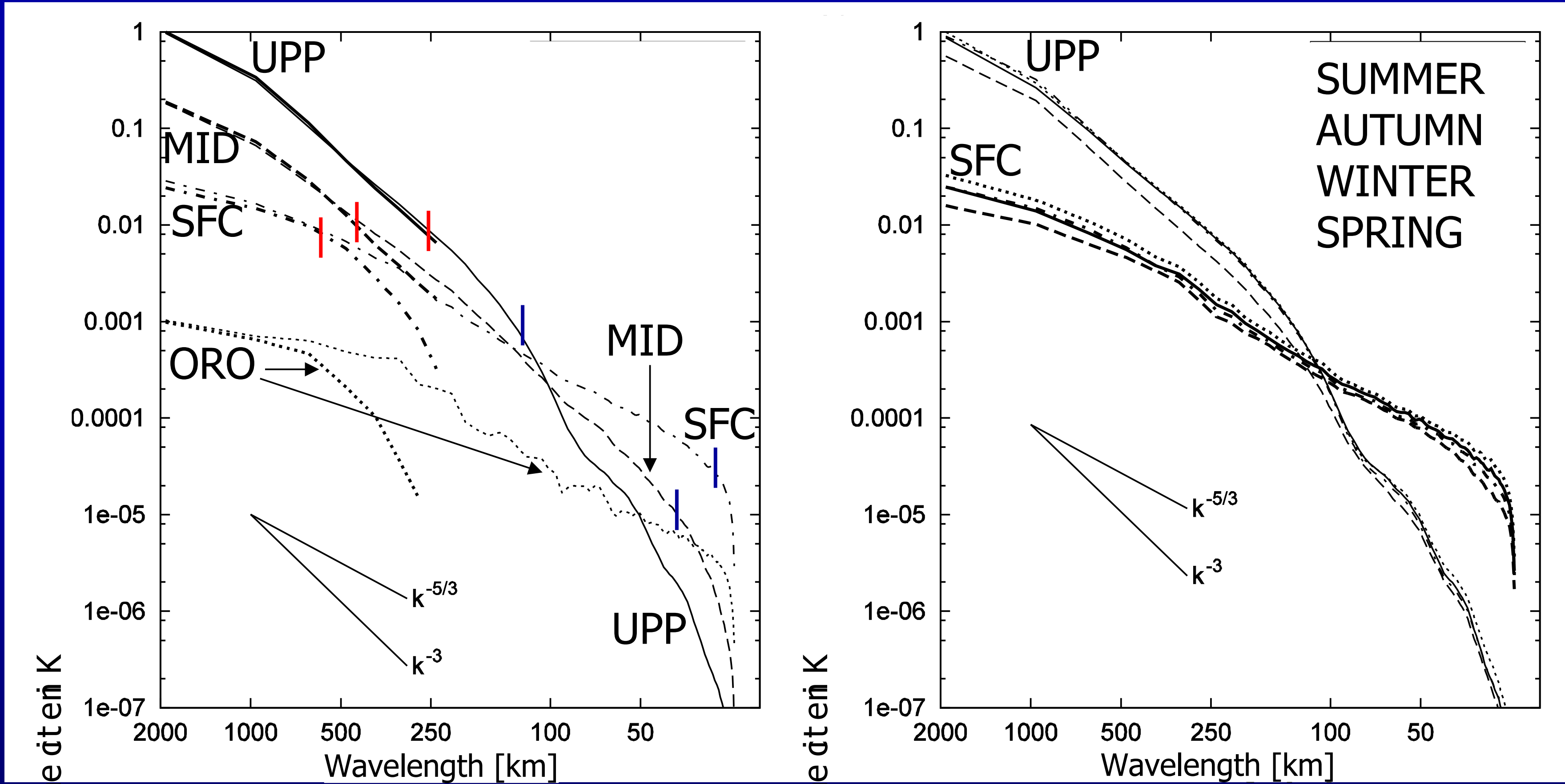
- Wind resource mapping is necessary for the uptake of wind energy
- European solutions may not work in Croatia’s specific wind climate
- “Sub-regional” wind mapping of Croatia was successfully performed with added value of refinement in both flat and coastal areas
- Wind speed errors are rather small, but some issues important for wind energy remain
  - The mean and strongest winds on the coast are still somewhat underestimated
- The dedicated mapping of national wind resource
  - Use more local and remote sensing obs. as input for num. modeling
  - Use non-simplified model versions at high-level of refinement, such as grid spacing of ~1 km
  - Account for local microscale effects in mnt. terrain, such as “speed-up”
  - Estimate the related uncertainties

Thanks for your attention !

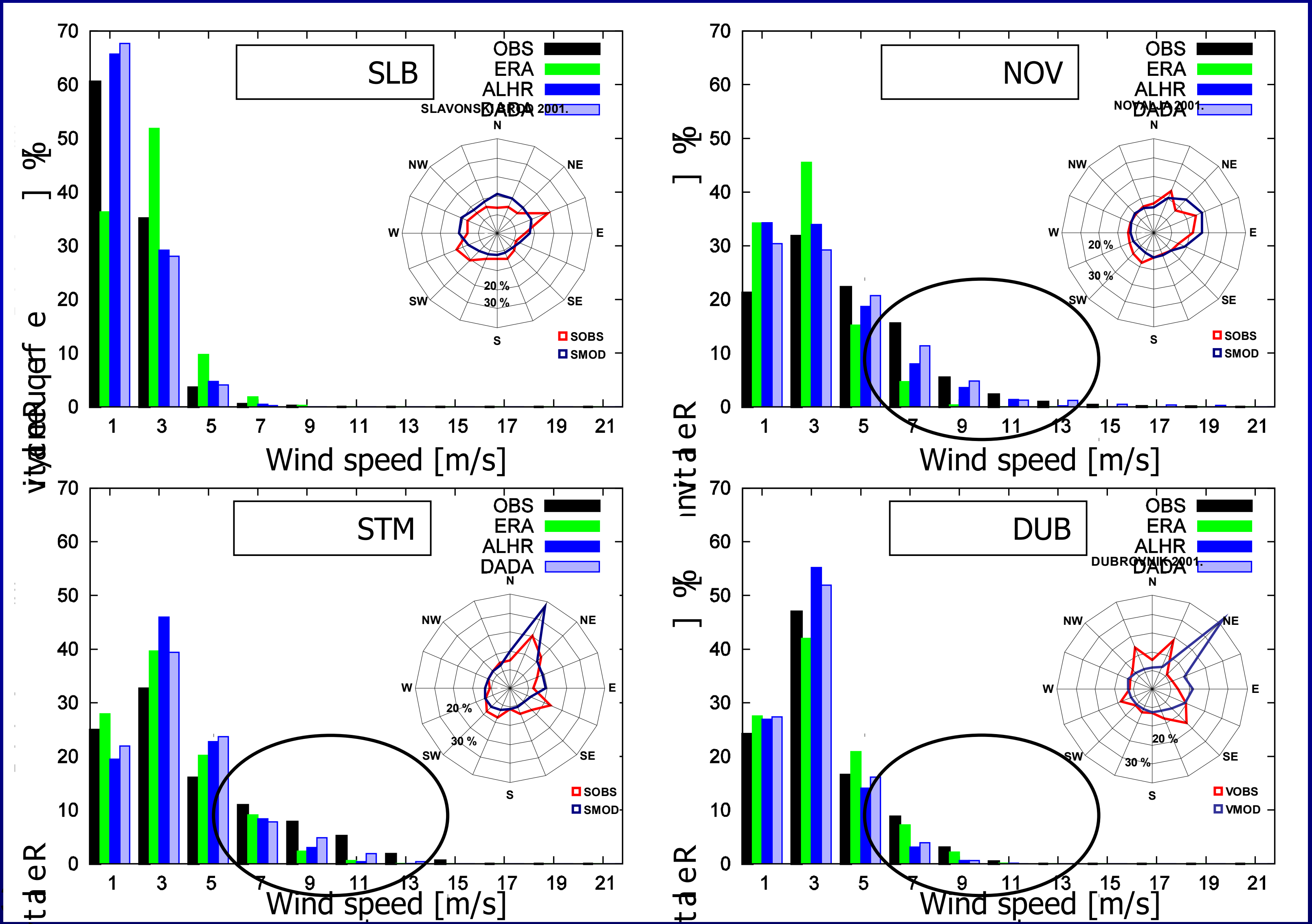
- More info: JAMC2011, HMC2009, WINDEX project (www.windex.hr)

Dynamical downscaling:: Spectral evaluation

- Kinetic energy spectrum, and it's seasonal variability



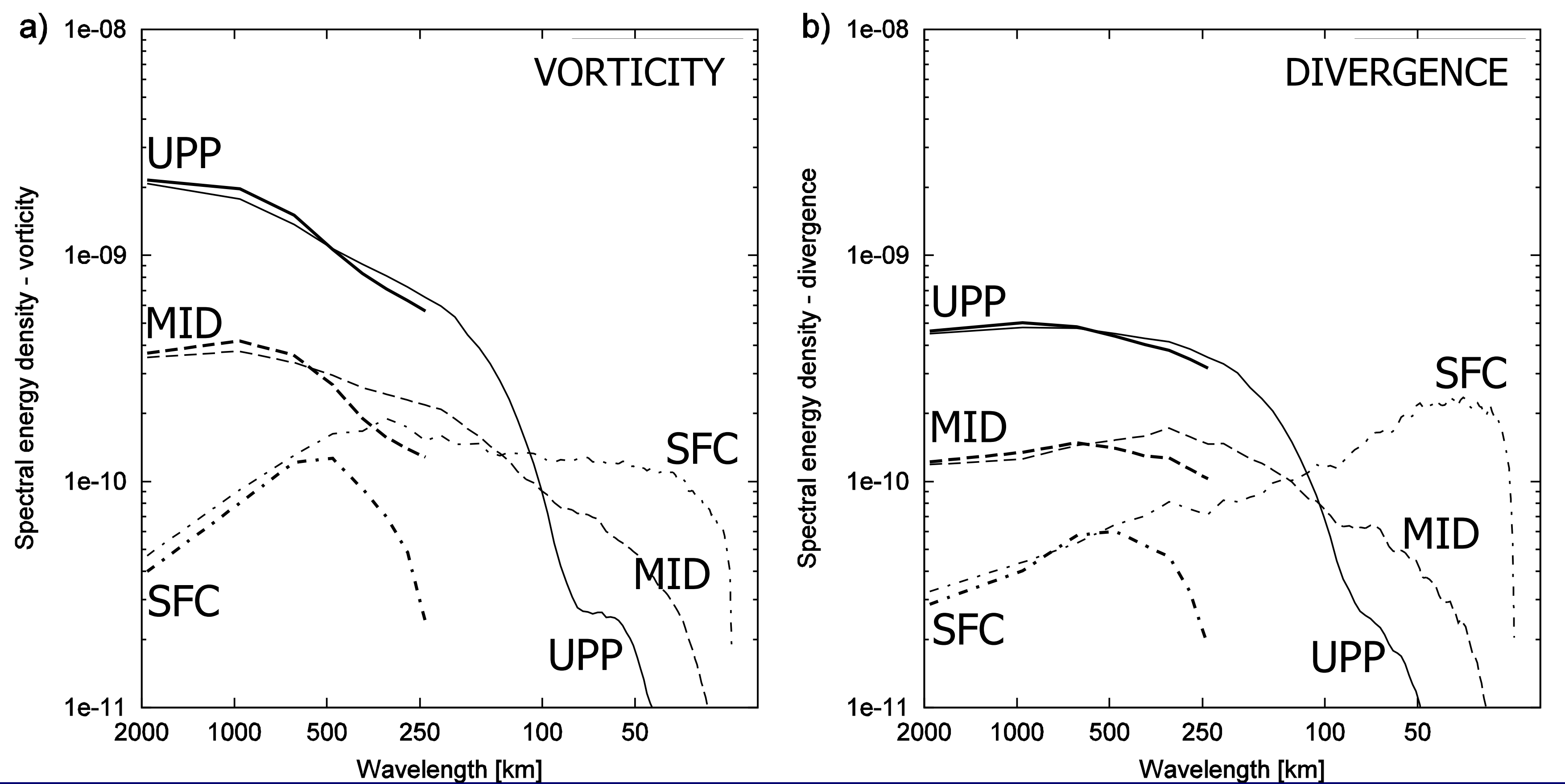
Statistical verification:: histograms



7.

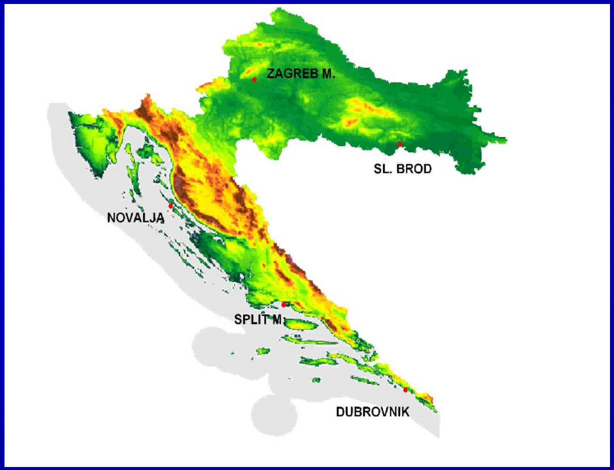
Dynamical downscaling: Spectral evaluation

- Vorticity and divergence spectra



Statistical verification:: bias & rmse

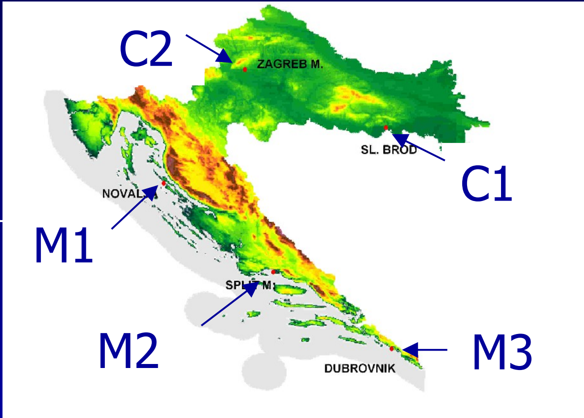
- Verification performed in different climate regimes during 2001 at 10 m AGL



	MBIAS			RMSE		
	ERA	AL8	**DA2**	ERA	AL8	**DA2**
SLB	1.51	**0.99**	**1.01**	0.85	0.22	**0.19**
NOV	0.69	0.79	**0.92**	1.55	1.03	**0.73**
STM	0.78	0.85	**0.89**	1.12	0.73	**0.58**
DUB	**1.00**	0.91	0.91	**0.18**	0.35	0.33

- Errors of moderate magnitudes; improvement found in both flat terrain and complex terrain
- Systematic underestimation in the vicinity of complex terrain

Dyn. downscaling:: Statistical verification



- Verification in different climate regimes (2001)

RMSE

	ERA	AL8	DA2
C1	0.85	0.22	**0.19**
M1	1.55	1.03	**0.73**
M2	1.12	0.73	**0.58**
M3	**0.18**	0.35	0.33

MBIAS

	ERA	AL8	DA2
C1	1.51	**0.99**	**1.01**
M1	0.69	0.79	**0.92**
M2	0.78	0.85	**0.89**
M3	**1.00**	0.91	0.91