EMODnet
European Marine Observation and Data Network

Sea Basin Checkpoints - Lot 4

"Black Sea"

NKUA/AM&WFG

WP2: Challenge 1 - Wind farm siting

TPD2:
Assessment of the available database through a detailed statistical analysis

National & Kapodistrian University of Athens,

School of Physics,

Atmospheric Modeling & Weather Forecasting Group

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Participating Institutes

IO-BAS: Institute of Oceanology – Bulgaria

NIMRD: National Institute for Marine Research and Development "Grigore Antipa“ - Romania

CMCC: Euro-Mediterranean Center for Climate Change - Italy

CLS - Collecte Localisation Satellites - France

NKUA – National and Kapodistrian University of Athens – Greece

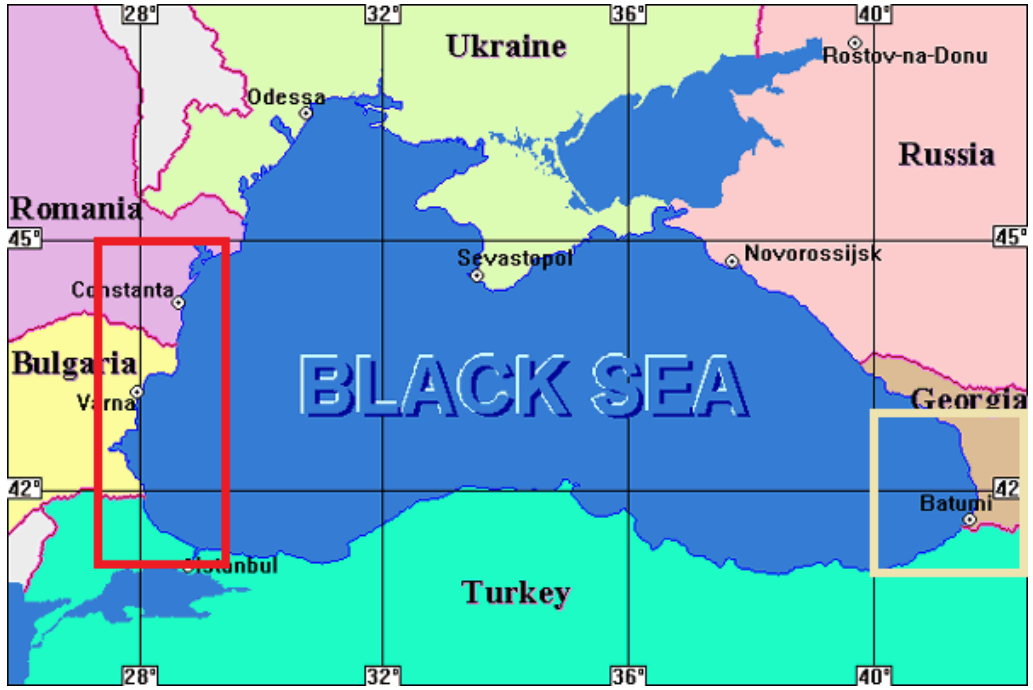
ORION - Joint Research and Development Centre (ORION) – Cyprus

Sofia University "St. Kliment Ohridski" (USOF) - Bulgaria

Plymouth University (UPL) - United Kingdom

Executive Summary

One of the main objectives of the Work Package 2 (Windfarm Siting) is the determination of the suitability of sites for wind farm development in specific predefined Black Sea areas



The target area: The Black Sea coastline and in particular:

The borders between Bulgarian and Romanian waters

The borders between Turkish and Bulgarian waters

The borders between Turkish and Georgian waters

Towards this direction a high resolution database has been developed, based on the outcomes of the FP7 MARINA Platform project (http://www.marina-platform.info/). The data base covers a time period of 10 years (2001 – 2010) containing hourly data and covering a wide range of atmospheric, wave and tidal information

The database

The data base covers a time period of 10 years (2001 – 2010) containing hourly data and covering a wide range of atmospheric, wave and tidal information.

State of the art numerical modeling systems have been used for the simulation of the above data. Namely, the atmospheric modelling system SKIRON (Kallos G. et al 1997, Spyrou C. et al, 2010) and the 3rd generation spectral model WAM (Bidlot J eta al, 2003, Komen G. et al, 1994, WAMDIG, 1988) CY33R1 (ECMWF) have been utilized.

The configuration of the two models:

SKIRON

Horizontal Resolution 0.05° x 0.05°

Time-step 15 seconds

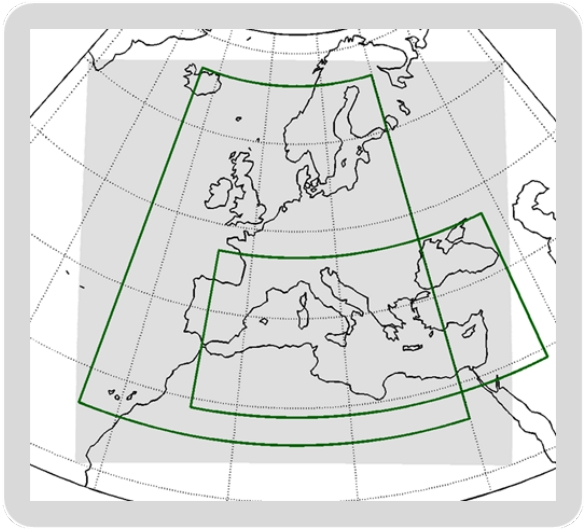
45 vertical levels up to 50 hPa

Initial and boundary conditions:

High-resolution reanalysis (15 x 15 Km)

Output at: {10, 40, 80, 120, 180} m a.s.l.

Full set of meteorological variables



The set up and the domains of the atmospheric model Skiron

WAM

Domain (20–75°N, 50°W–30°E)

Resolution: 0.05° x 0.05°

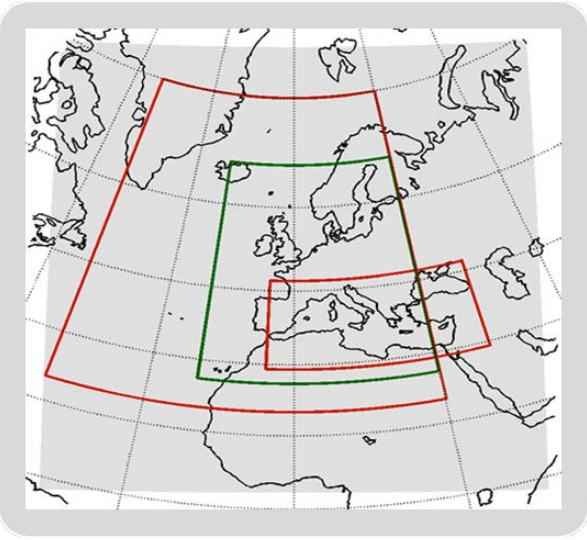
Number of frequencies: 25

Minimum frequency: 0.055 Hz

Number of directions: 24

Grid points: 1601 x 1101

Spectral output at selected locations



The set up and the domains of the wave model WAM

CHARACTERISTICS/PARAMETERS OF INTEREST

The parameters analyzed in this report for spotting advantageous areas for wind farms development are:

-- Wind power 80 m

-- Wind speed at 10 m

-- Wind Speed at 80 m

Statistical Analysis

A detailed statistical analysis of the wind-wave-energy information will be attempted by utilizing statistical measures that provide qualitative information for energy applications:

$$Mean = \frac{1}{N}\sum_{i=1}^{N} X(i)$$

Measuring the expected values

$$I = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}(X(i)-\mu)^2}}{\frac{1}{N}\sum_{i=1}^{N} X(i)}$$

Index of variation:
Measuring the variation
as a percentage of the mean value

$$Skewness = \frac{\frac{1}{N}\sum_{i=1}^{N}(X(i)-\mu)^3}{\sigma^3}$$

a measure of the asymmetry of the probability distribution

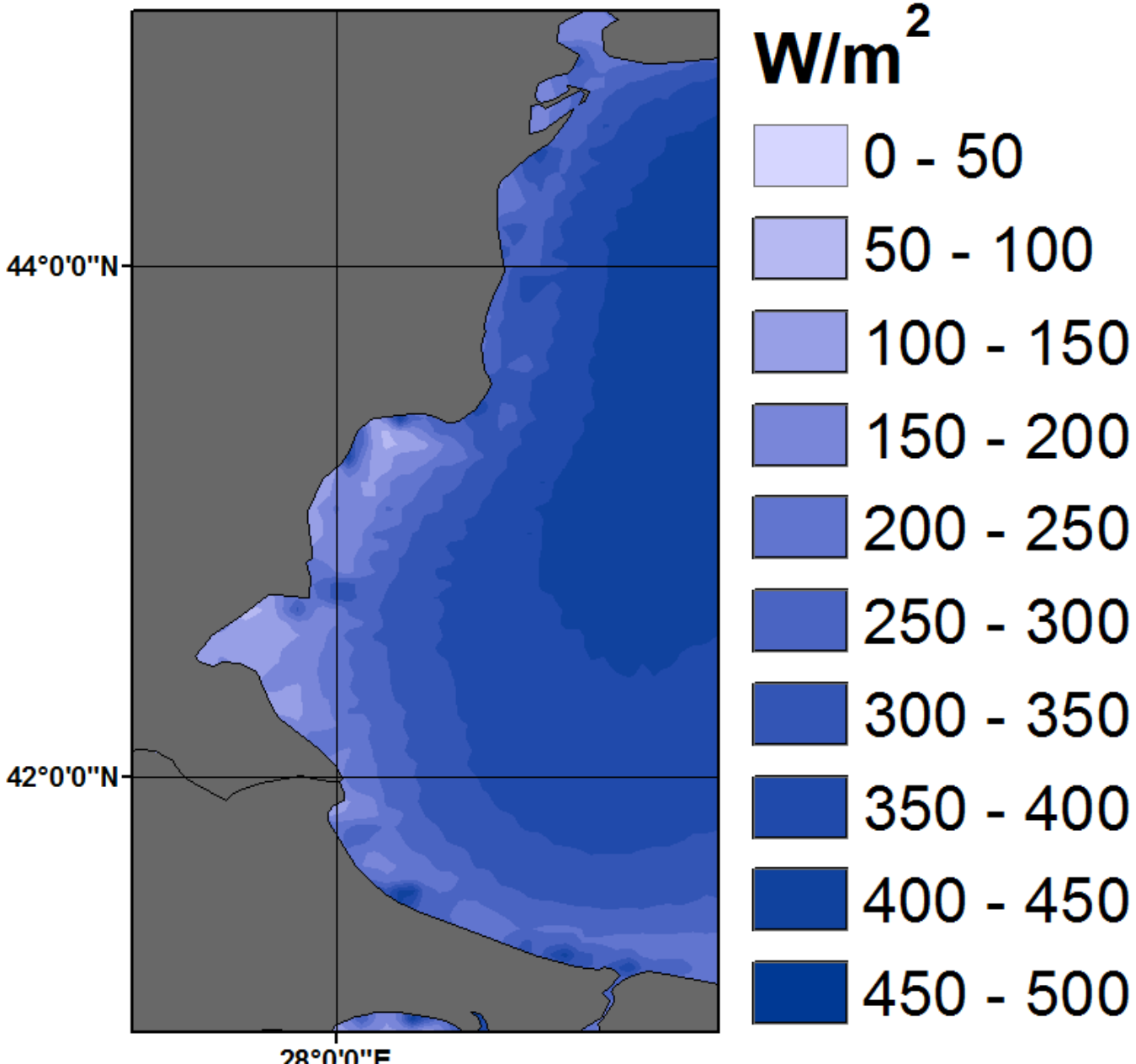
$$Kurtosis = \frac{\frac{1}{N}\sum_{i=1}^{N}(X(i)-\mu)^4}{\sigma^4}$$

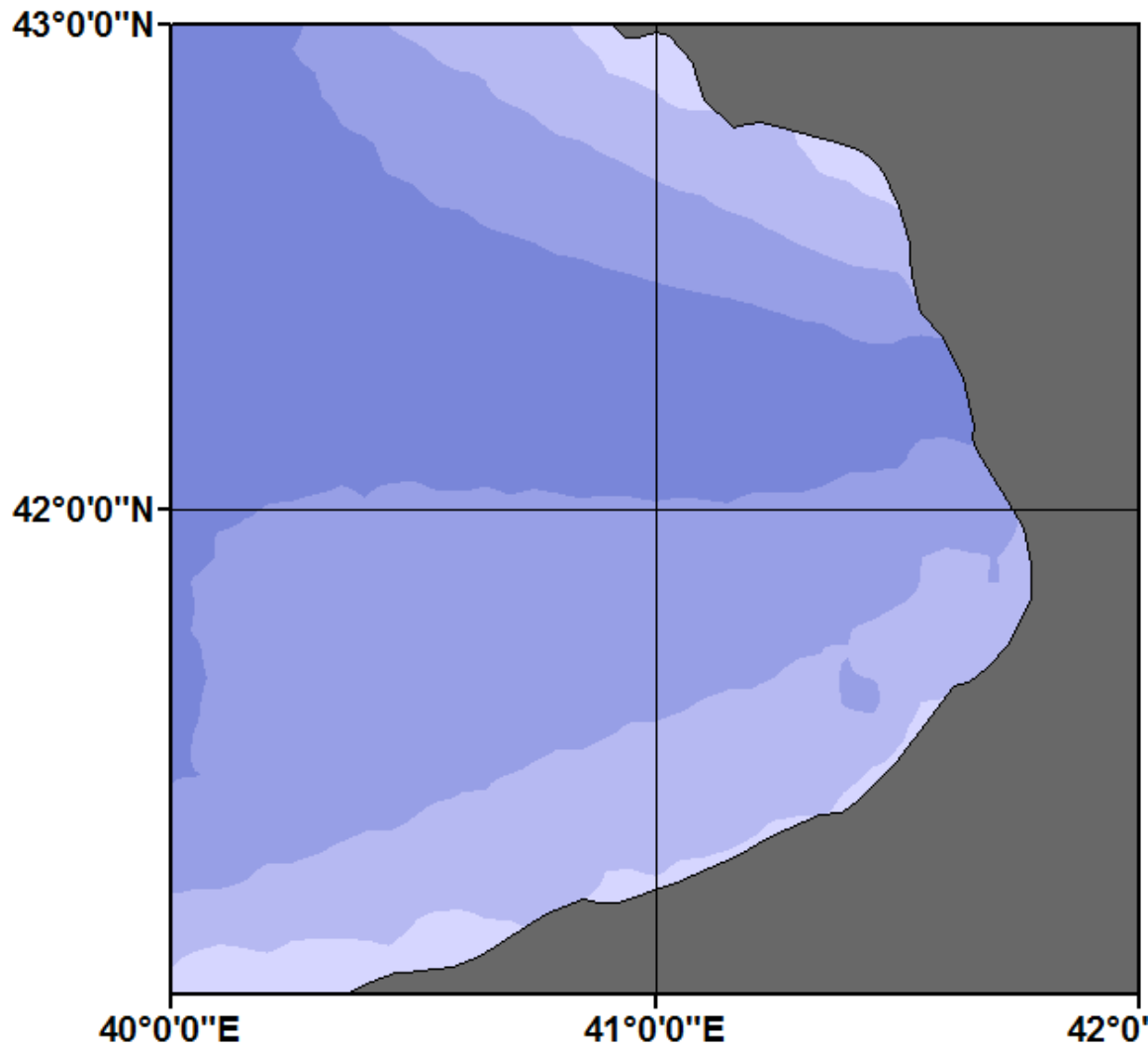
which measures the "peakedness" of the probability distribution
and the impact of possible extreme values

Wind power 80 m.

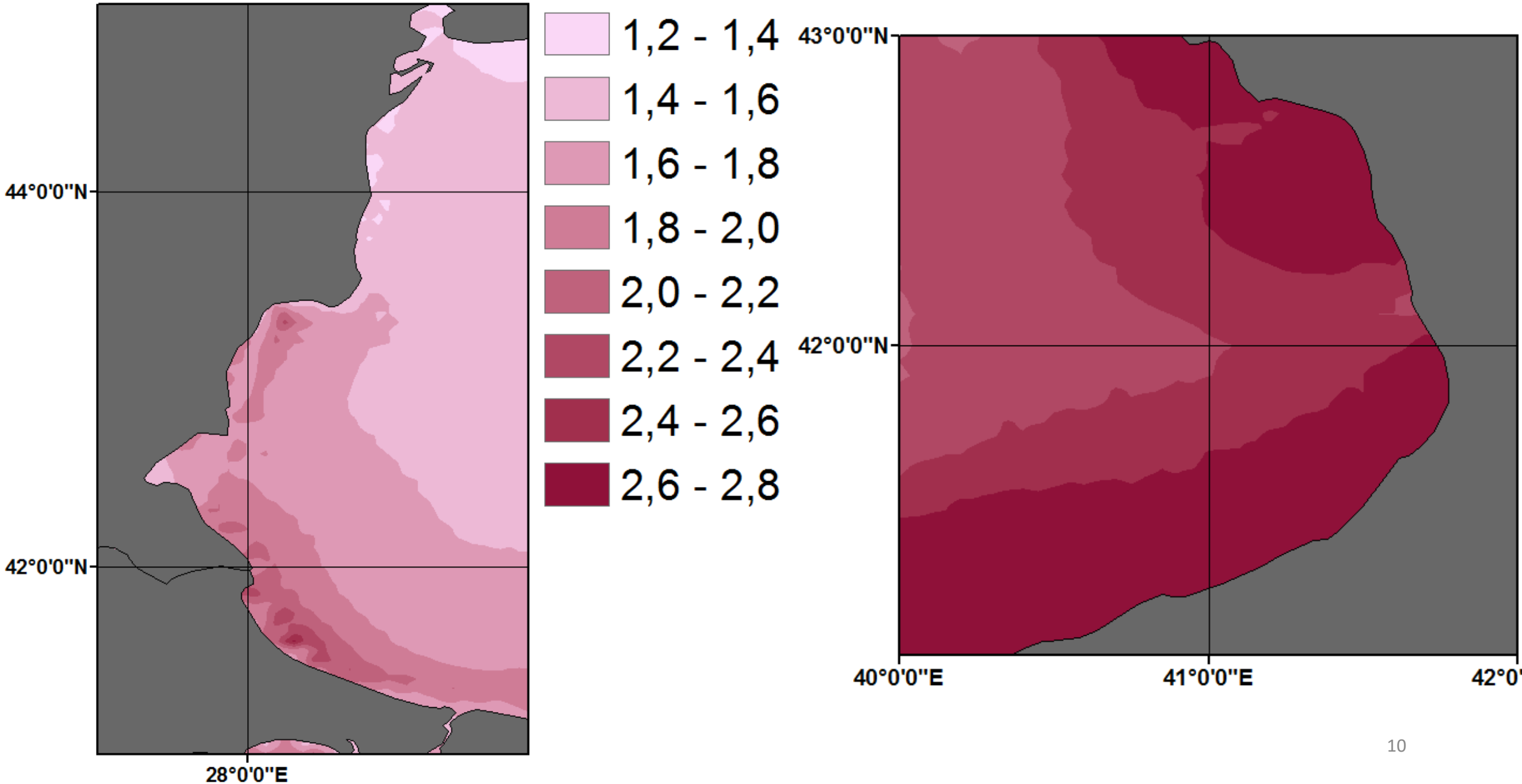
Statistics

Wind power mean (2001-2010 / 80 m.)

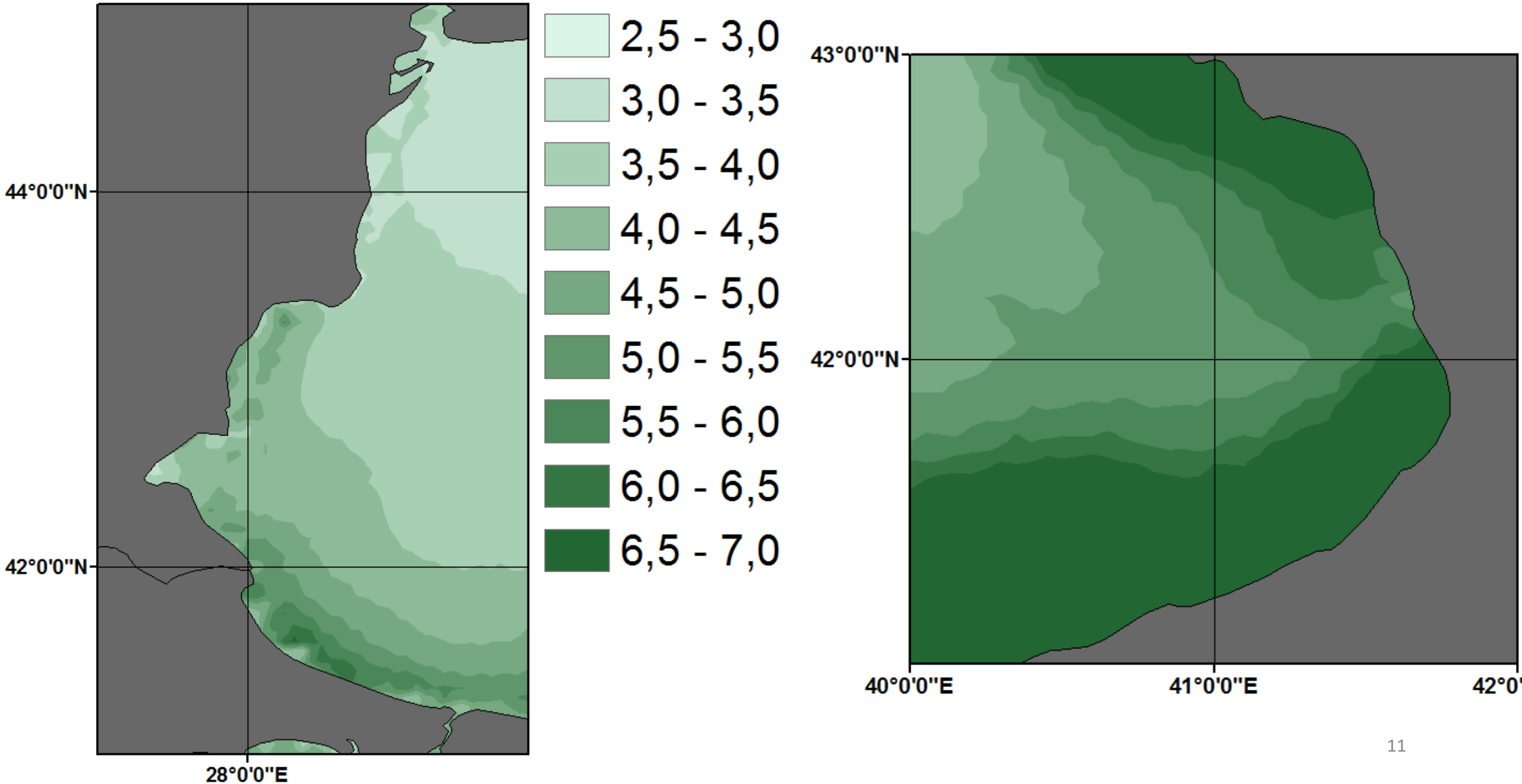




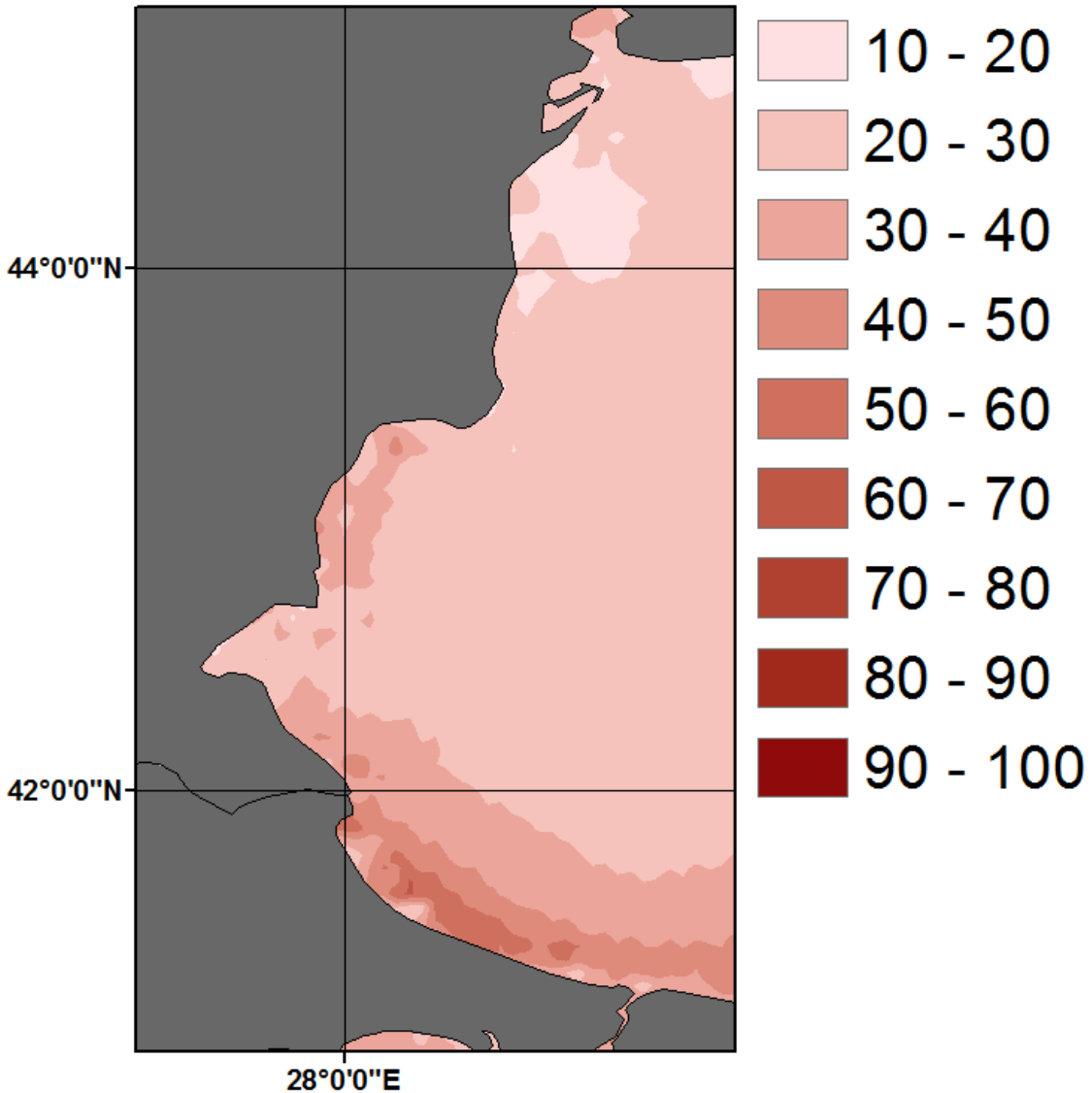
Wind power index of variation (2001-2010 / 80 m.)



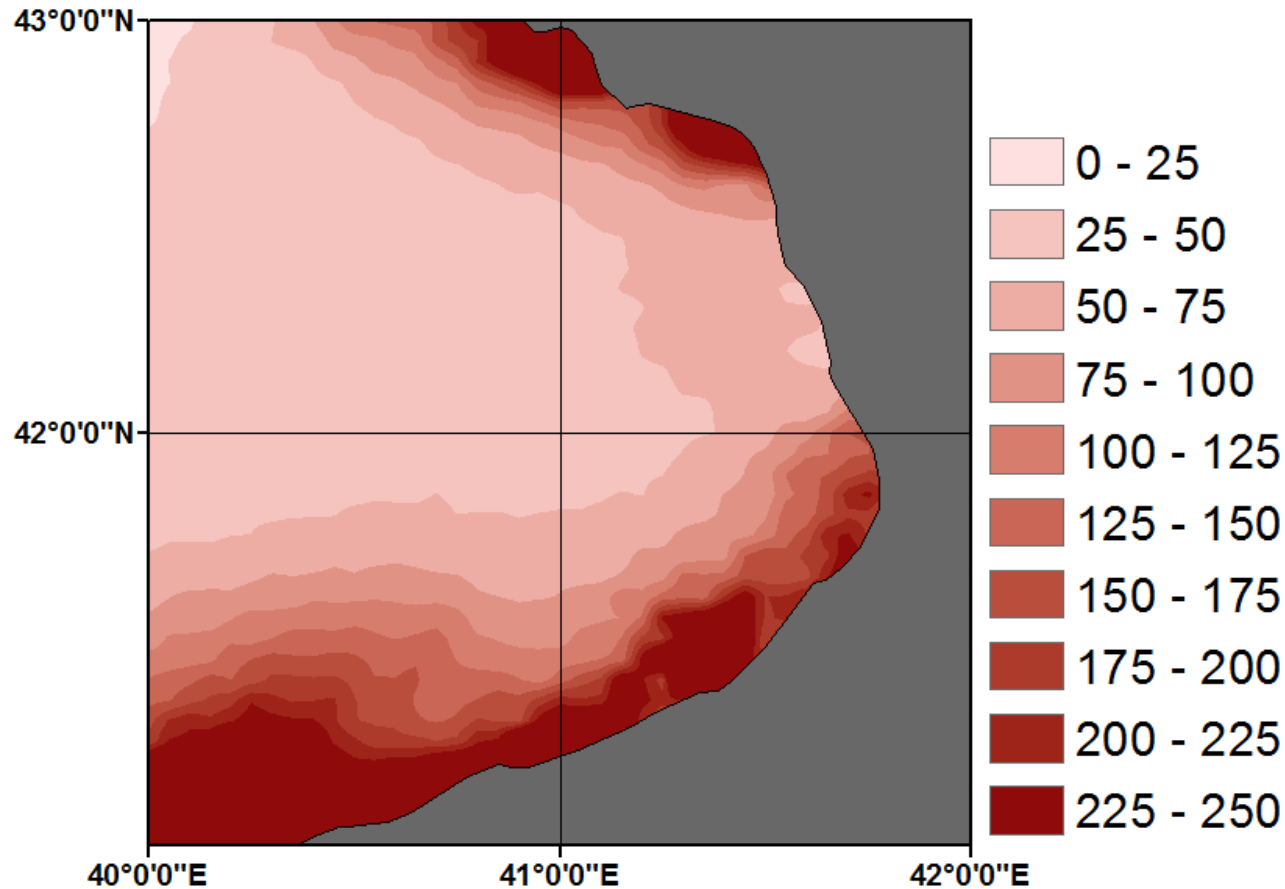
Wind power skewness (2001-2010 / 80 m.)



Wind power kurtosis (2001-2010 / 80 m.)



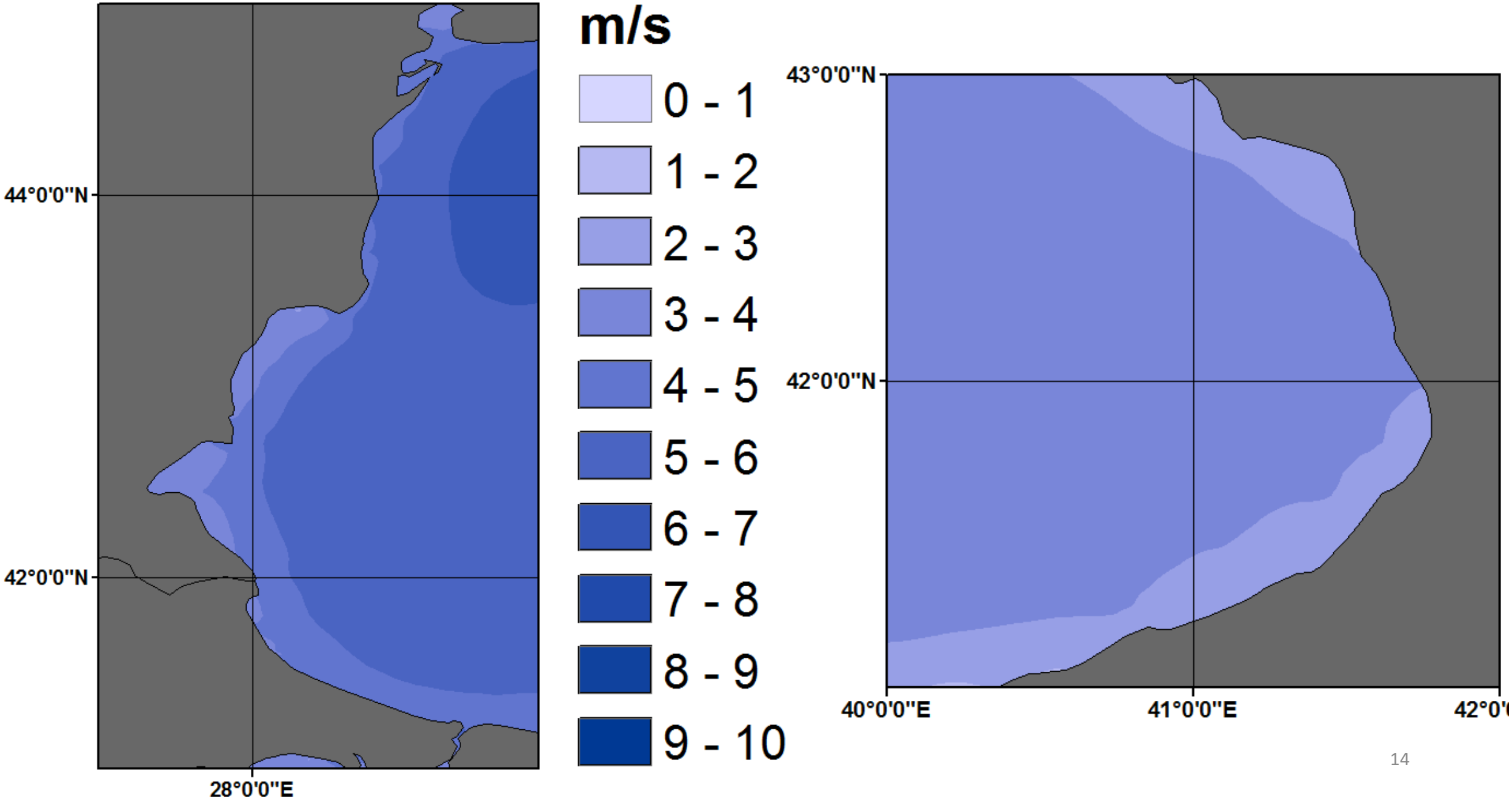
Wind power kurtosis (2001-2010 / 80 m.)



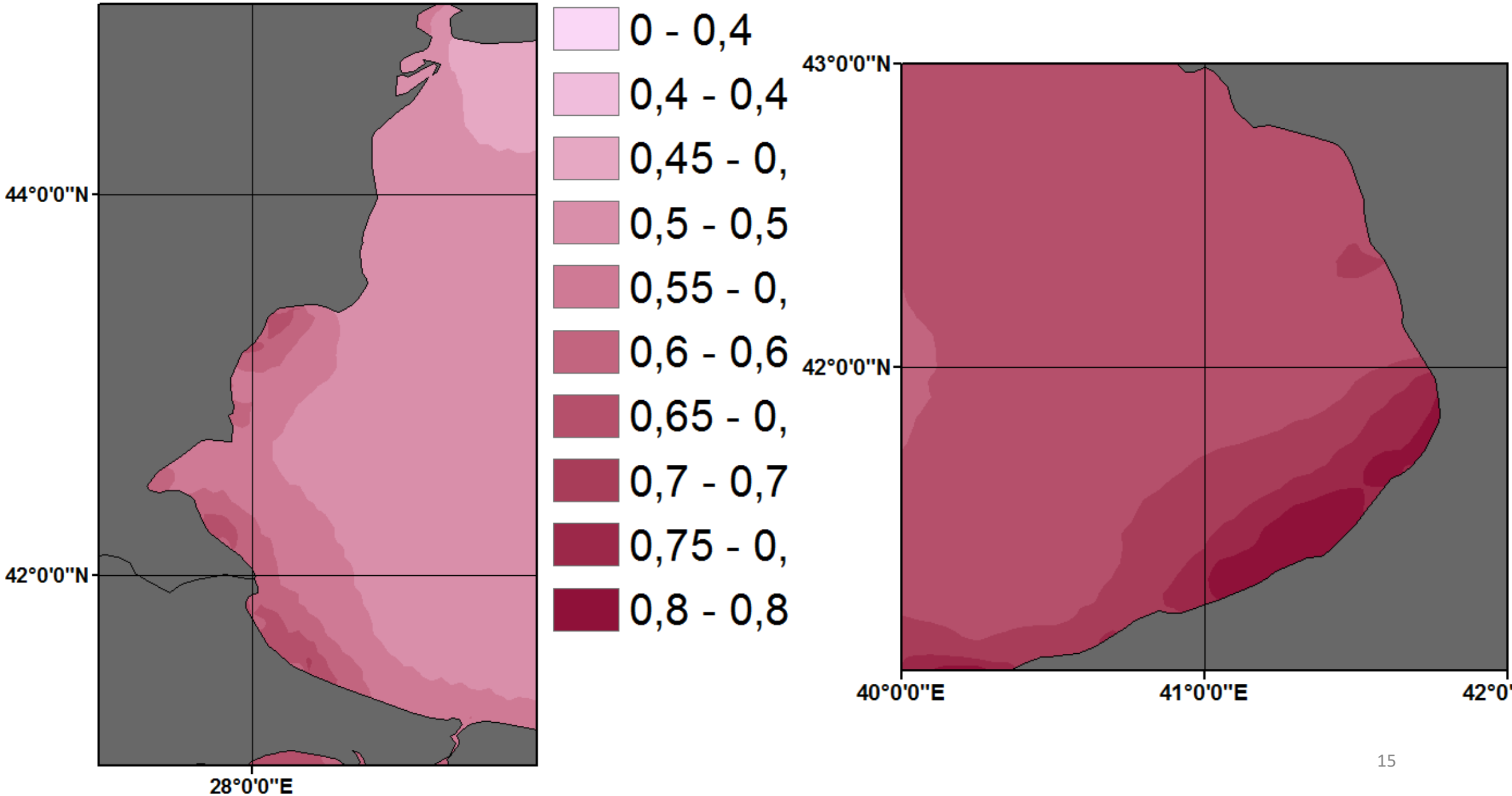
Wind speed, 10m.

Statistics

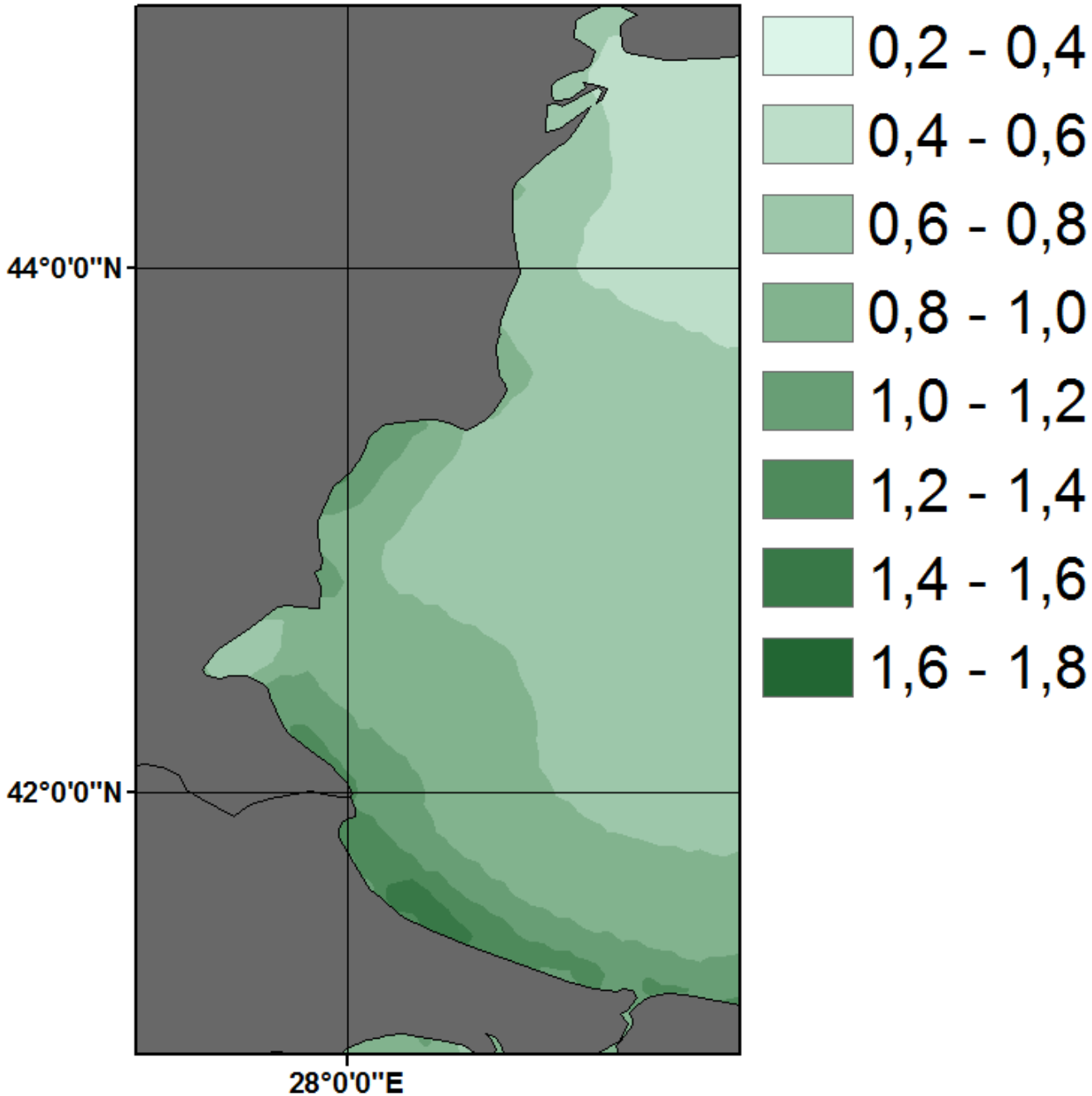
Mean wind speed (2001-2010 / 10 m.)

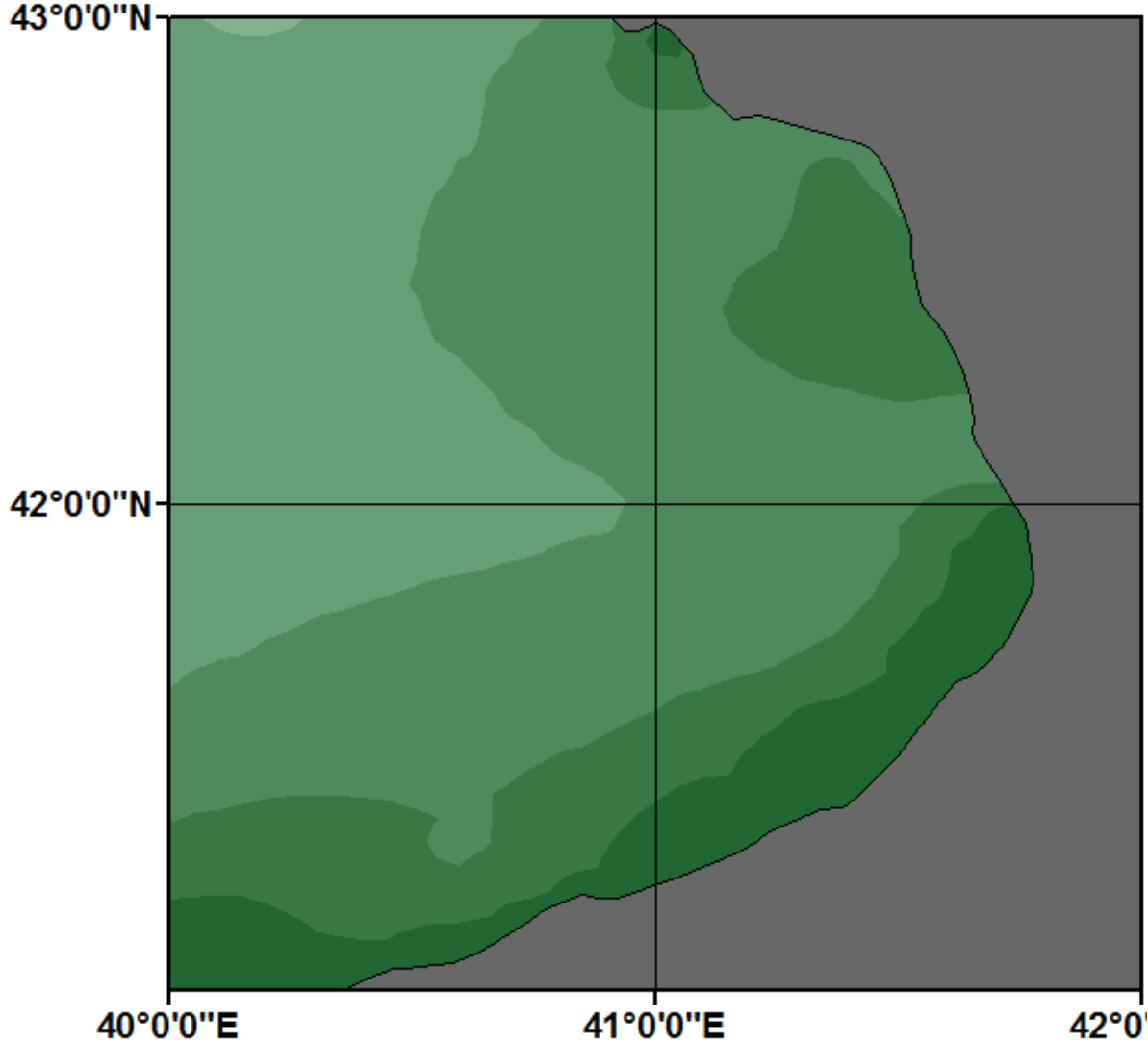


Wind speed index of variation (2001-2010 / 10 m.)

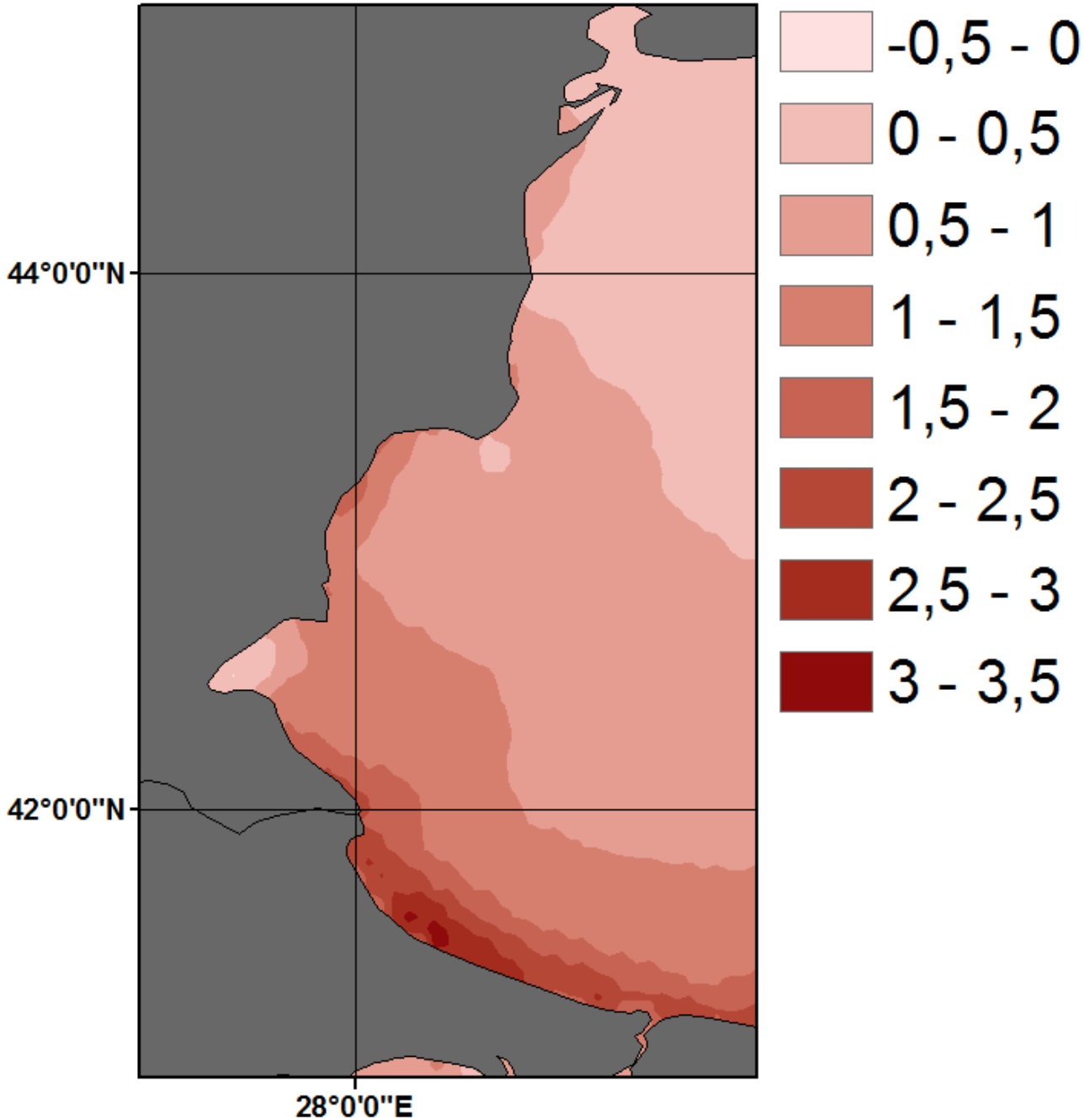


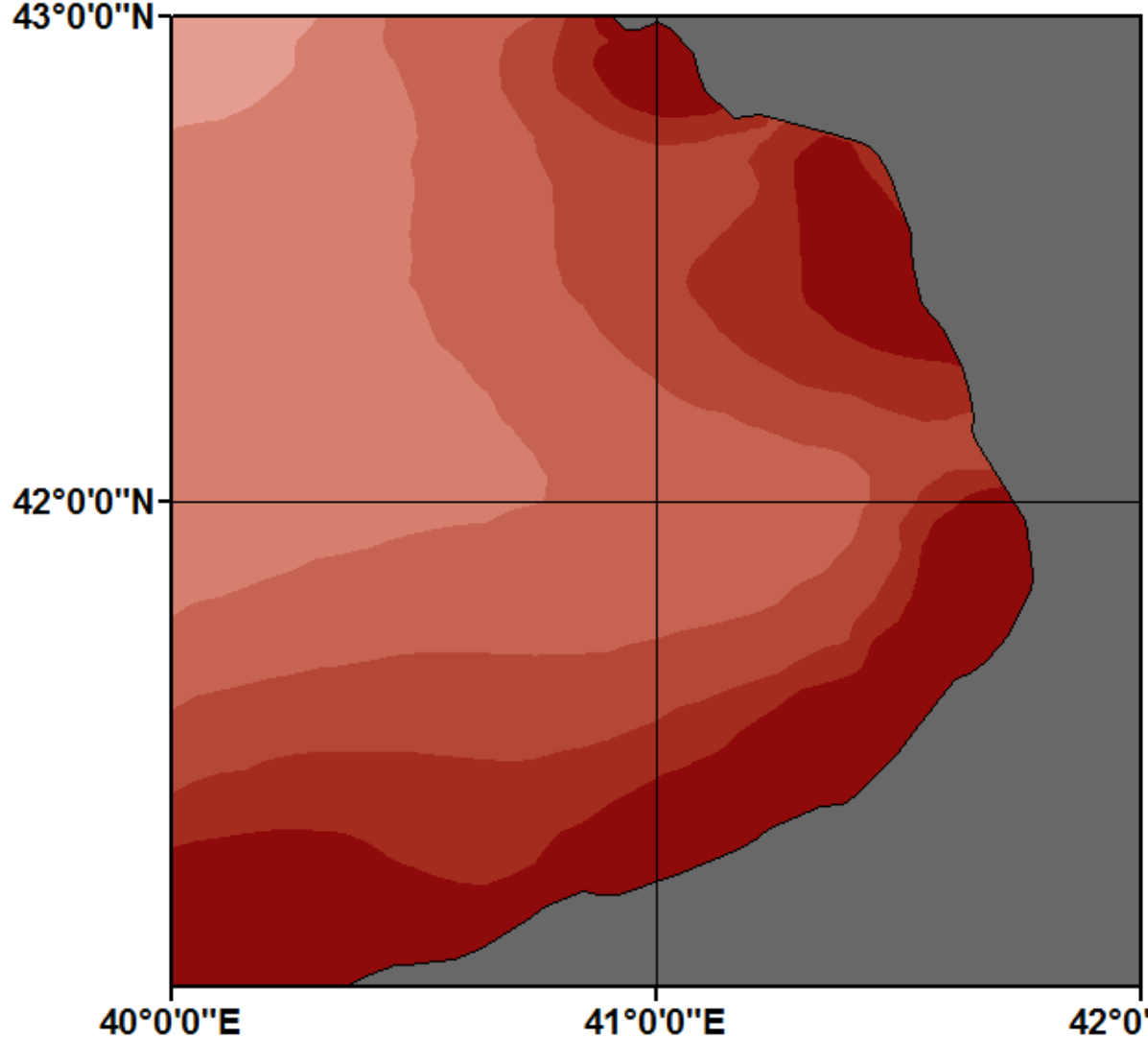
Wind speed skewness (2001-2010 / 10 m.)





Wind speed kurtosis (2001-2010 / 10 m.)

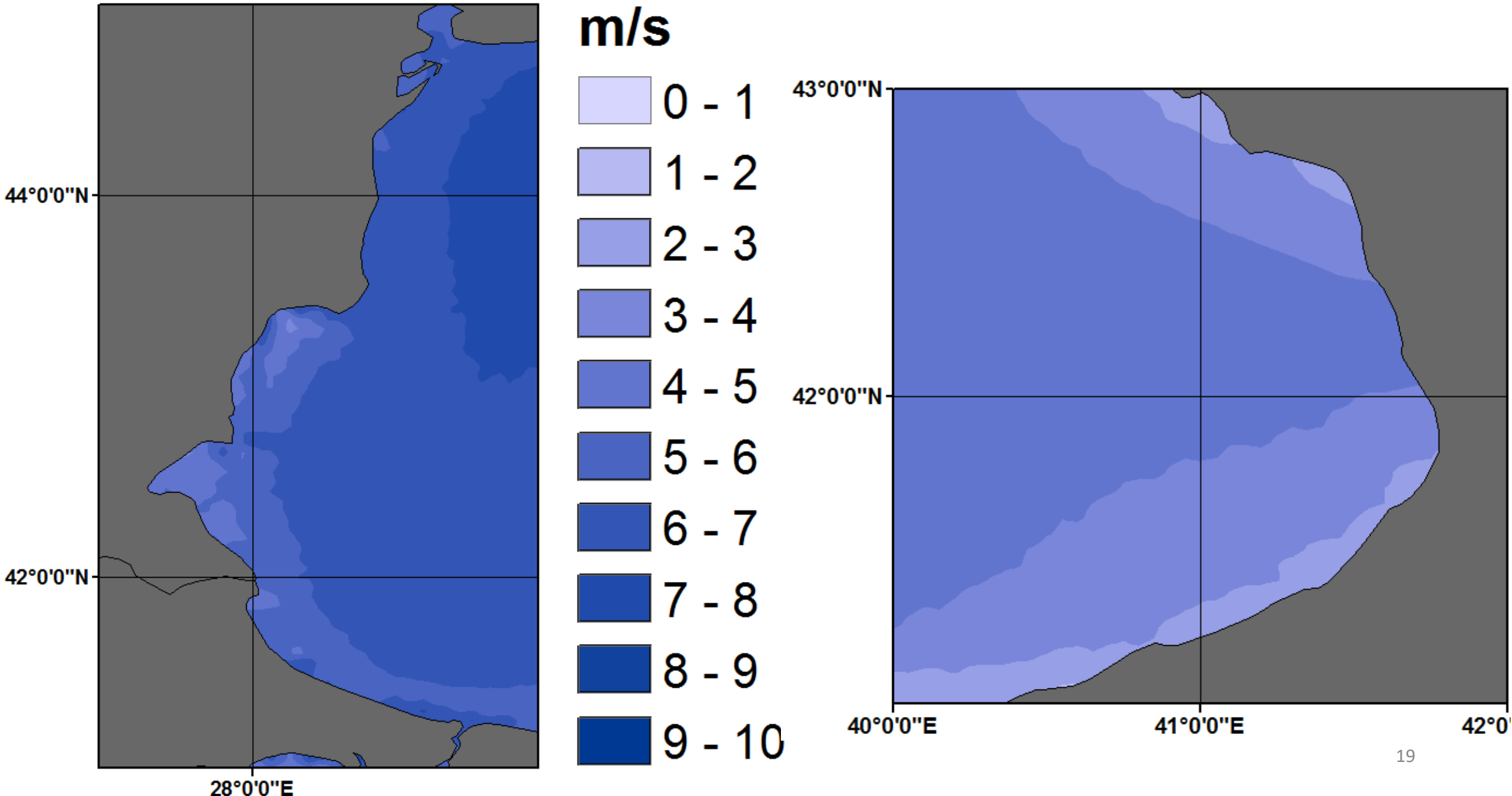




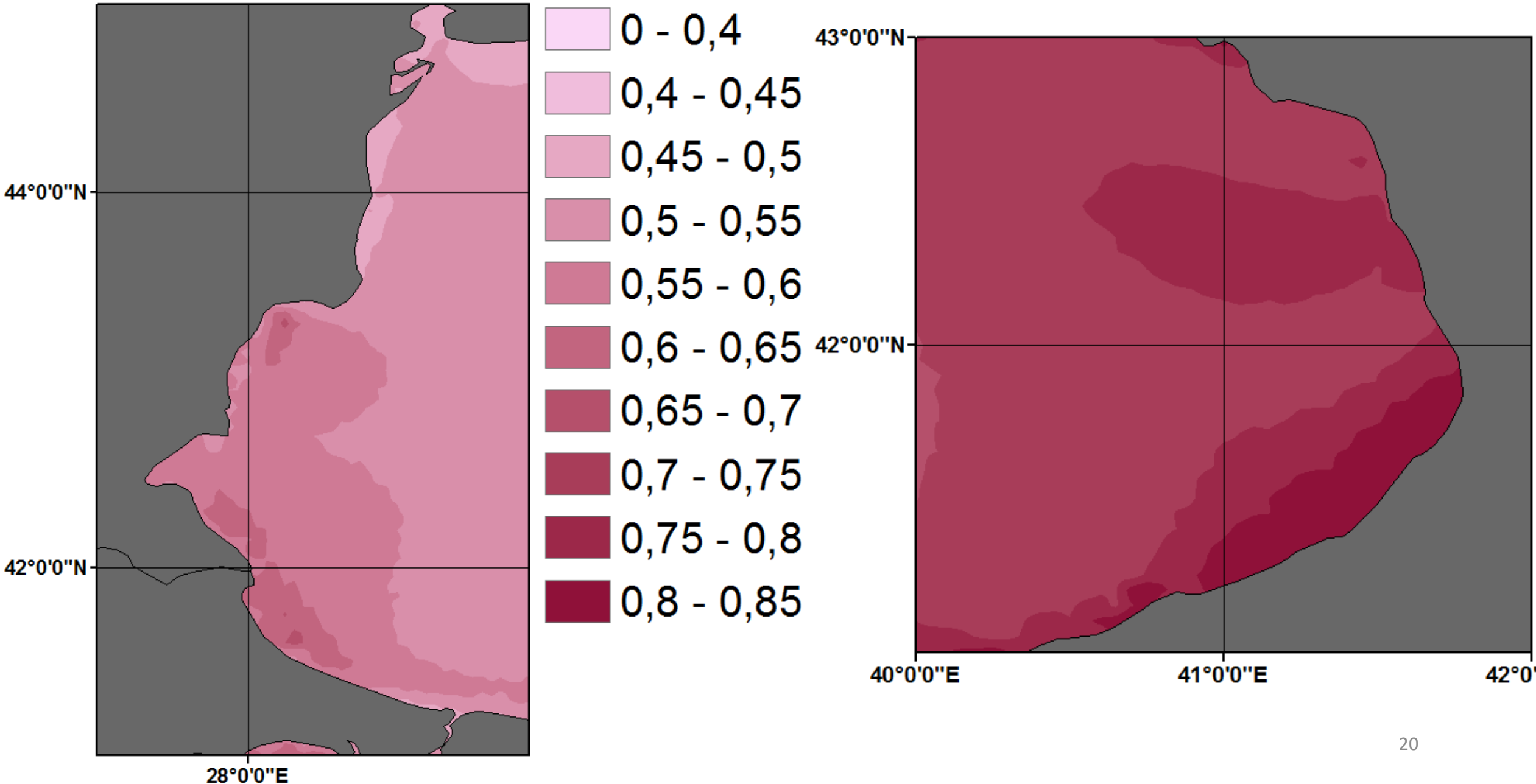
Wind speed, 80m.

Statistics

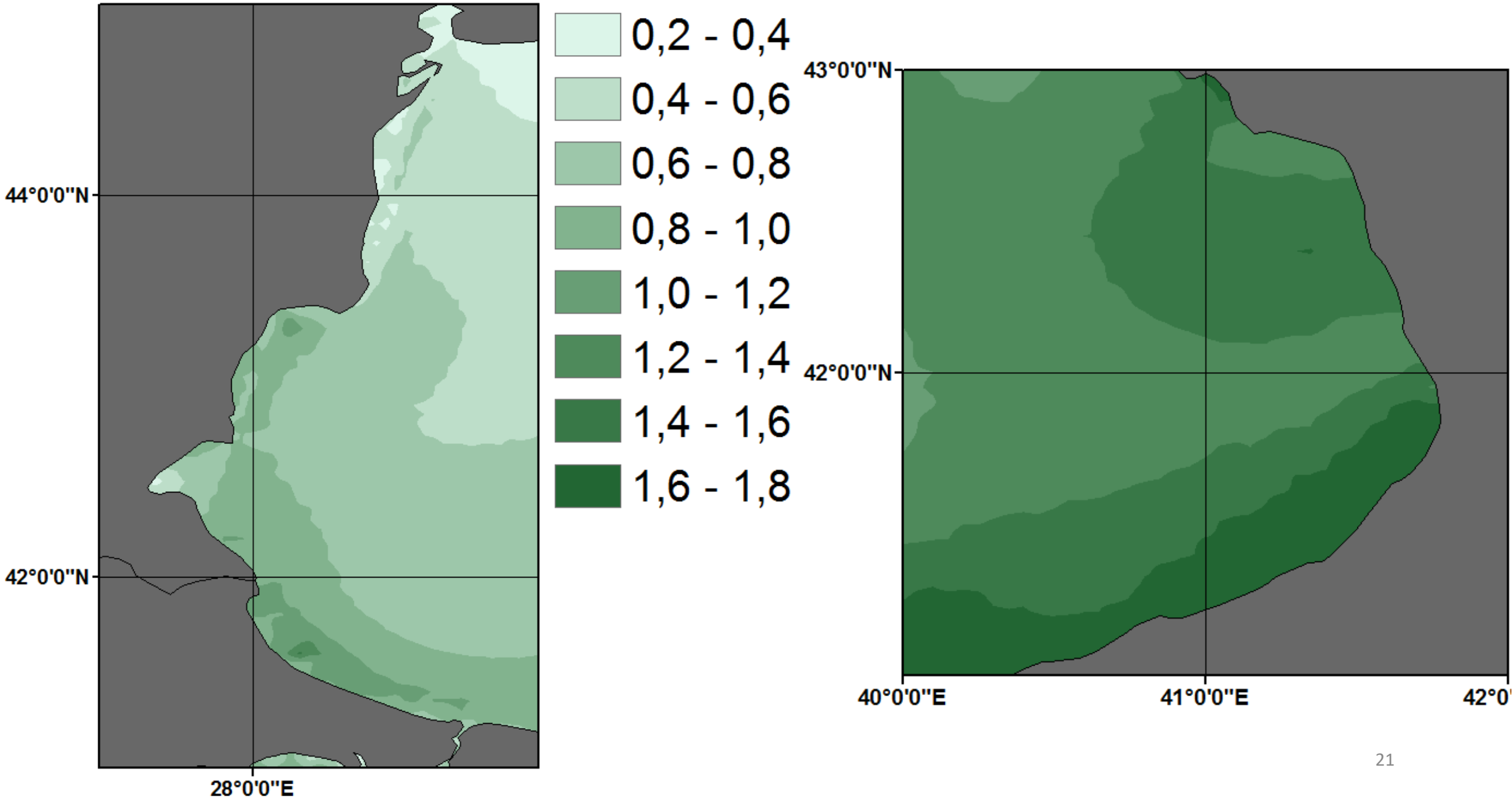
Mean wind speed (2001-2010 / 80 m.)



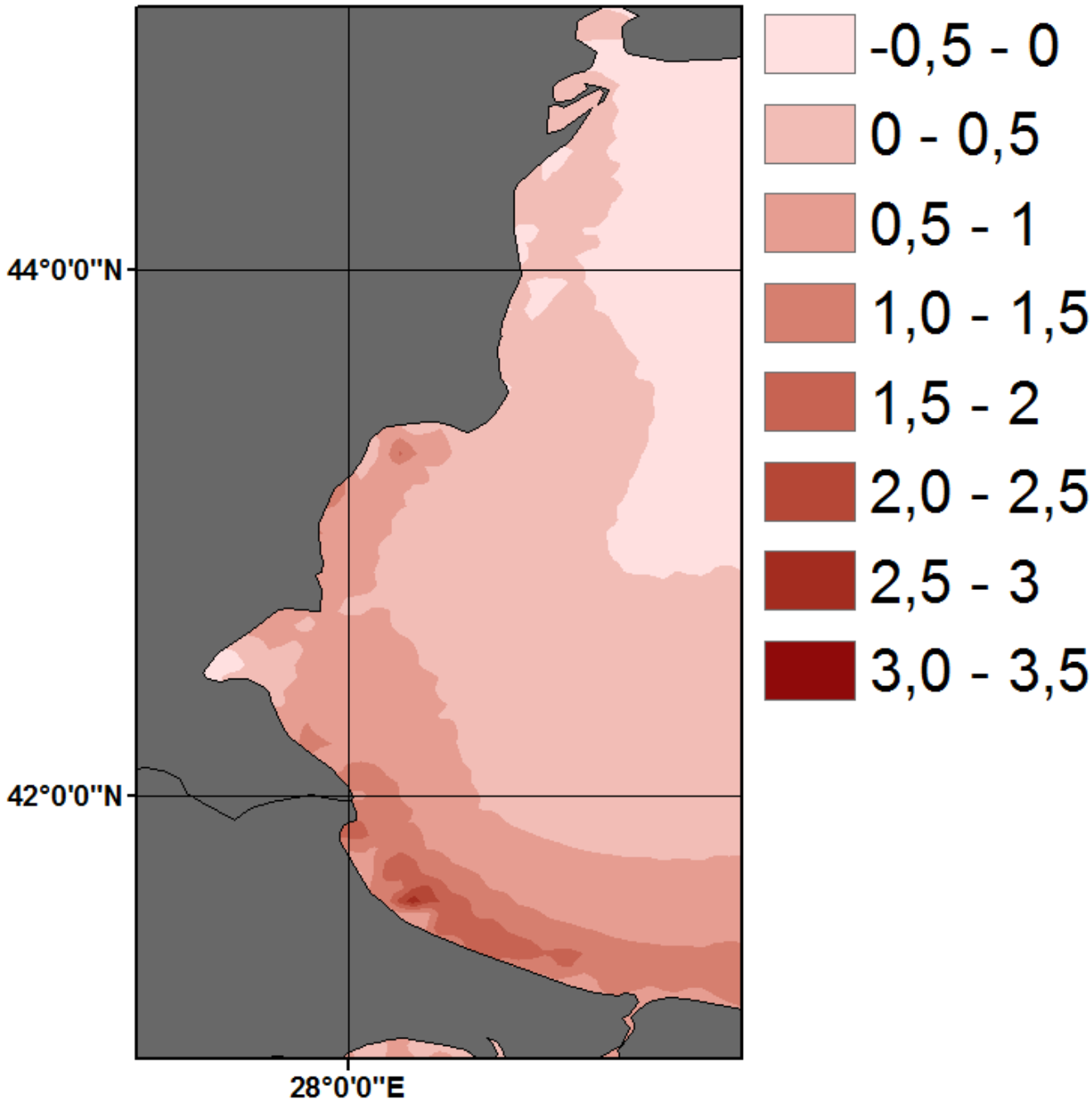
Wind speed index of variation (2001-2010 / 80 m.)

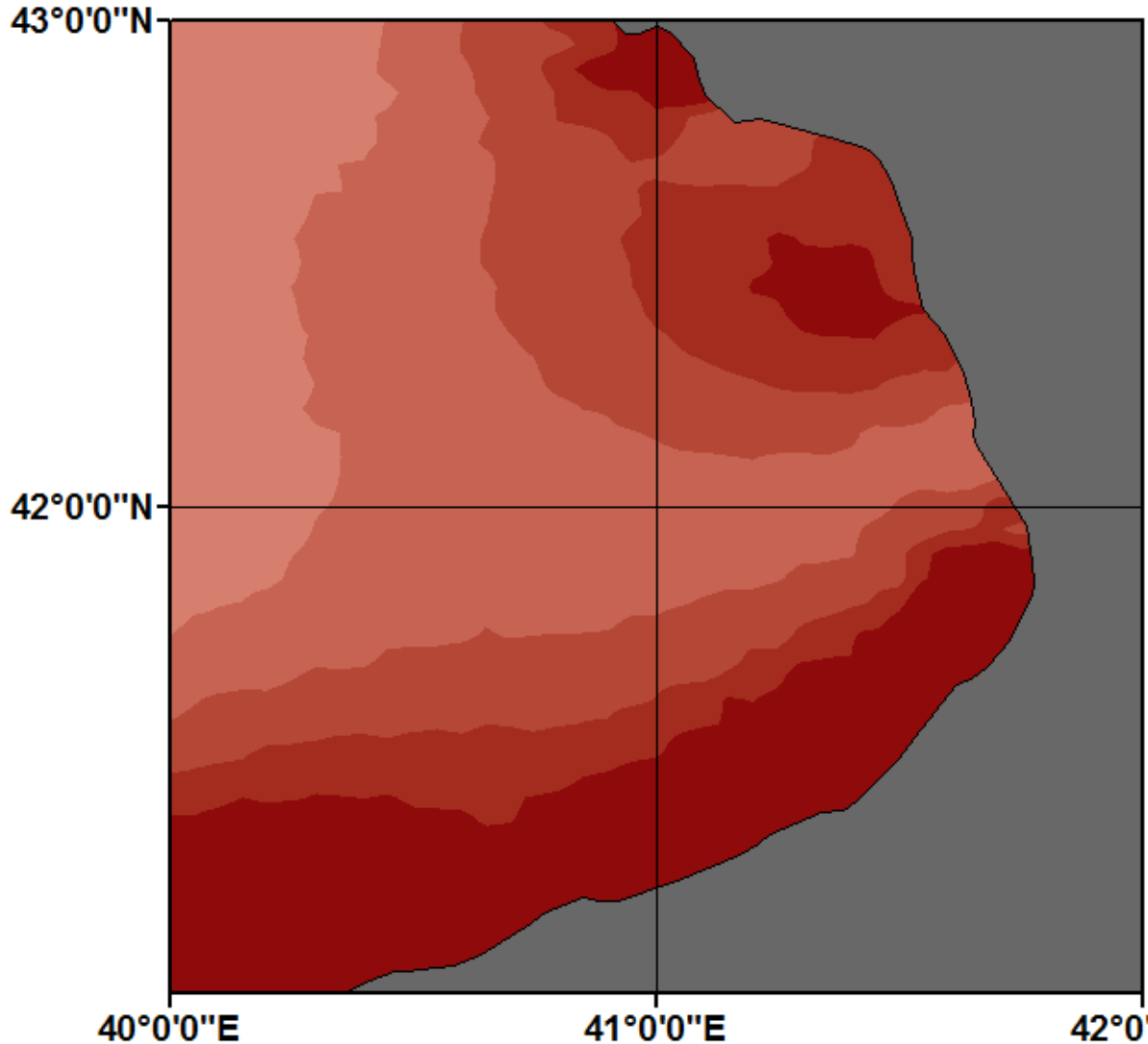


Wind speed skewness (2001-2010 / 80 m.)



Wind speed kurtosis (2001-2010 / 80 m.)





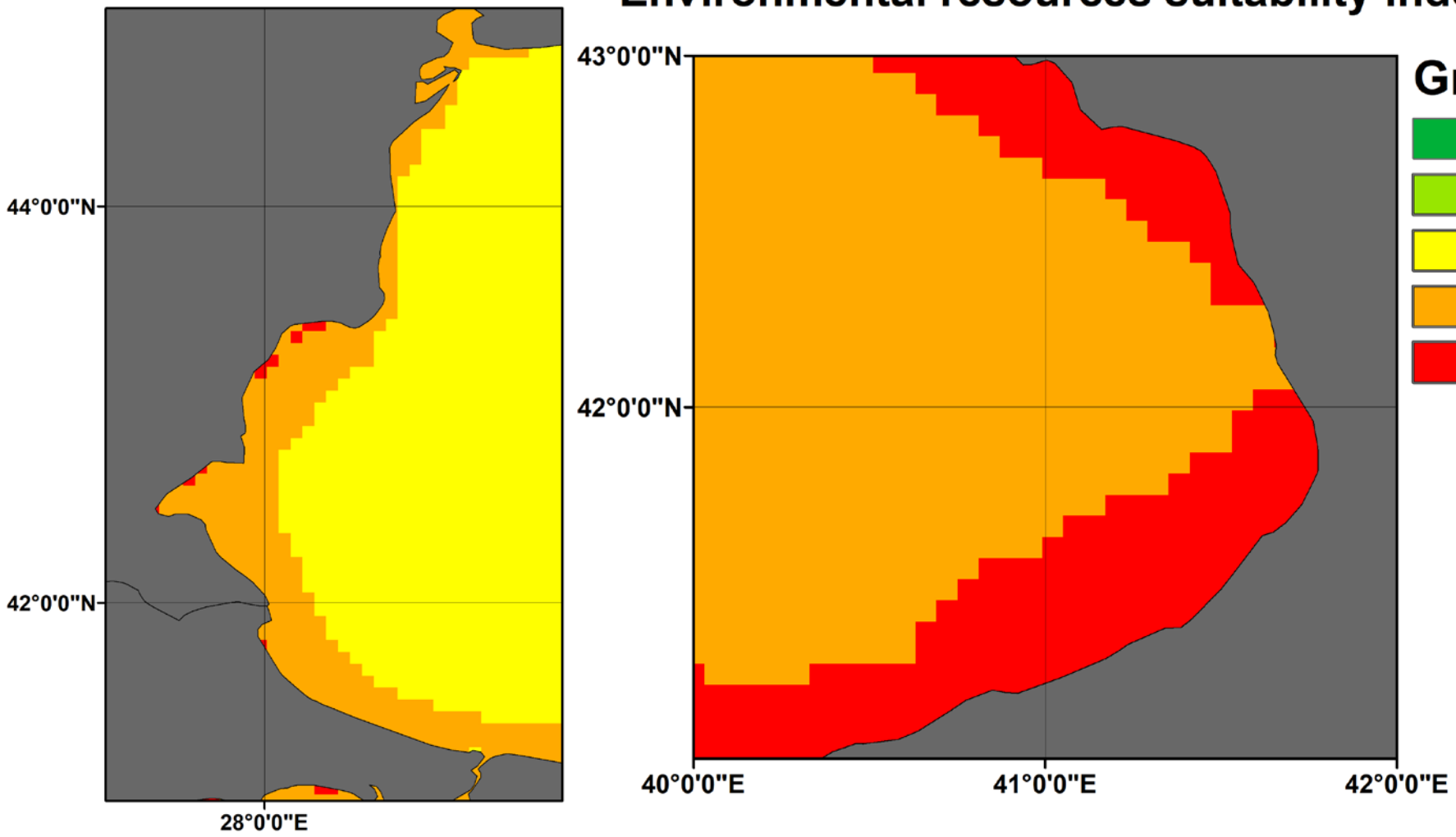
SUITABILITY INDEX FOR WIND FARM SITTING BASED ON ENVIRONMENTAL RESOURCES

SUITABILITY INDEX for WIND FARM SITTING

Following the categorization depicted in the table, the area of interest was characterized upon its suitability based on wind speed.

Mean wind speed (m/s)	Wind speed index of variation	Category	Site availability
0 - 3	-	**5**	**Very low**
3 - 3.25	>70%	**5**	**Very low**
3 - 3.25	<70%	**4**	**Low**
3.25 - 5	-	**4**	**Low**
5 - 5.25	>70%	**4**	**Low**
5 - 5.25	<70%	**3**	**Medium**
5.25 - 7	-	**3**	**Medium**
7 - 7.25	>70%	**3**	**Medium**
7 - 7.25	<70%	**2**	**High**
7.25 - 9	-	**2**	**High**
9 - 9.25	>70%	**2**	**High**
9 - 9.25	<70%	**1**	**Very High**
9.25 - …	-	**1**	**Very High**

Environmental resources suitability index



Grade

- 1
- 2
- 3
- 4
- 5

5	Very low
4	Low
3	Medium
3	Medium
2	High
1	Very High

Main Conclusions for wind power resources

- Increased mean wind power values at 80 m height over offshore areas
- The Western region (Romania-Bulgaria borders) is the more active one with wind power potential values reaching 450 – 500 W/m^2
- Associated with relevantly low variability in West Black Sea over and more variable over the Eastern region of Turkish-Georgian sea areas.
- The Western areas are also less skewed while nearshore the wind data are left skewed in the eastern Black Sea region.
- The impact of extreme values is elevated over the Turkish-Georgian border's sea area as indicated by the increased values of kurtosis.

Main Conclusions for wind speed at 10 & 80 m height

- Low mean wind speed values are recorded in both areas with less than 4m/sec at 10 m height and less than 10m/sec at 80 m
- The western area seems more promising having:
  - Relevantly elevated mean values
  - Low variability which increases when reaching near shore areas
  - Symmetric wind speed data with no obvious impact from extreme values

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