National Wind Erosion Risk Map

First stage: *WEPS/Compacted database preparation for climatic variables*

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INTERNATİONAL SAND AND DUST STORMS (SDS) WORKSHOP

4 – 7 OCTOBER 2016

ISTANBUL - TURKEY

Wind Erosion Prediction System (WEPS)

The Wind Erosion Prediction System (WEPS) is a process-based, continuous, daily time-step model that simulates:

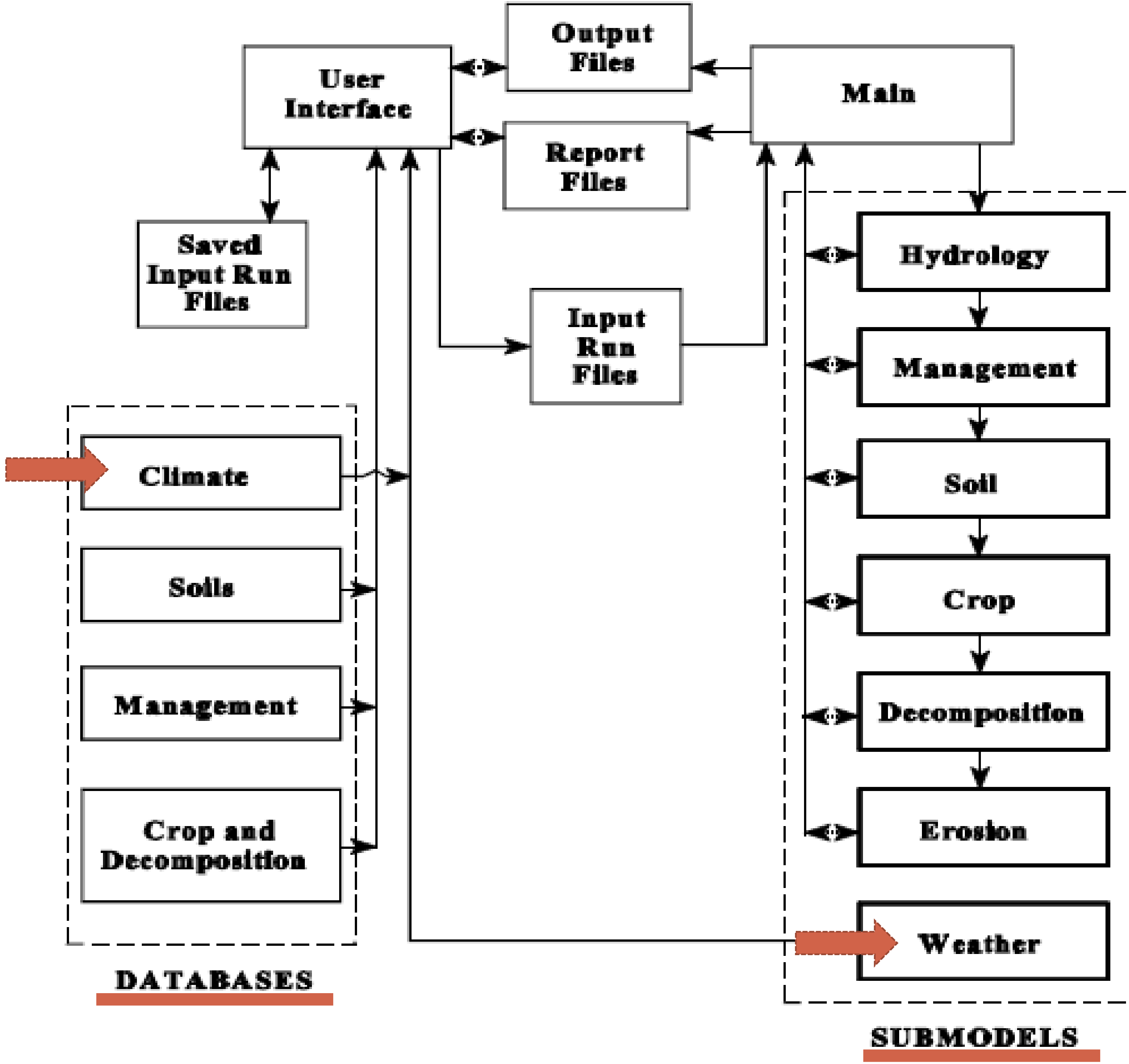
- Weather
- Field conditions
- and Erosion

Wind Erosion Prediction System (WEPS)

WEPS was designed to:

- Provide more accurate and detailed estimates of soil loss by wind from agricultural fields.
- Develop more cost-effective erosion control methods.
- ***Simulate the amount of soil loss by direction***.
- Separate soil loss into creep/saltation, suspension, and PM10 components.

Structure of the WEPS Model



Model Details: Main program

The purpose of the MAIN program is to control the initialization and execution of the Wind Erosion Prediction System (WEPS). The required files for MAIN are following:

- Simulation run file
- Initial field conditions file
- A tillage/management file and
- Two climate files, CLIGEN and WINDGEN that provide data on a daily basis.

Model Details: User inputs

- Weather (Wind speed, Wind direction, Dew point etc.)
- Location (Name and Coordinates)
- Field geometries (Rectangle, Square, Circle, Half circle, Quarter circle)
- Soil components (Order, Crust, Loose material, Roughness, Chemical and Physical properties)
- Management operations (Operation type, Crop & Residue, Row/Ridge direction)

Submodels: Weather

Weather variables like;

- wind speed,
- wind direction,
- dew point,
- air temperature,
- precipitation

are needed for WEPS to simulate the process of soil erosion by wind and driving temporal changes in hydrology, soil erodibility, crop growth, and residue.

Submodels: Weather

- CLIGEN: Is the weather generator developed for the Water Erosion Prediction Project (WEPP) family of erosion models (Nicks et al., 1987).
- WINDGEN: Is the program that simulates wind speed and direction for WEPS (Skidmore and Tatarko, 1990; Wagner et al., 1992).

Submodels: Hydrology

The HYDROLOGY submodel uses inputs generated by other WEPS submodels such as

- Weather,
- Crop,
- Soil,
- Management, and
- Decomposition

to predict the water content in the various layers of the soil profile and at the soil-atmosphere interface throughout the simulation period.

Submodels: Management

- The MANAGEMENT submodel simulates
  - typical cultural practices applied by land managers, and
  - the soil/surface "state"
- to accurately assess their affects upon wind erosion control

Submodels: Soil

- The objective of the SOIL submodel is
  - to simulate the soil temporal properties,
  - which control wind erodibility of soil on a daily basis in response to various driving processes.

Submodels: Soil

Effective factors on soil temporal properties:

- Ridge and furrow dike height
- Crust stability, thickness and cover fraction
- Loose erodible material on crust
- Dry aggregate stability
- Aggregate size distribution
- Bulk density, and
- Crust and aggregate density

Submodels: Erosion

- The EROSION submodel uses parameters supplied by other submodels that describe
  - soil surface,
  - flat biomass cover,
  - standing biomass leaf and stem areas, and
  - weather

to decide if wind erosion can occur in a simulation region.

Submodels: Erosion

- If erosion can occur, then the submodel simulates the process of soil movement.
- Finally, the submodel periodically updates any changes in the soil surface caused by soil movement.
- At the completion of user-selected simulation intervals, the submodel outputs estimates of soil loss/deposition from the simulation region.

Submodels: Erosion

The EROSION submodel is divided into several major functional sections to accomplish the following simulation objectives:

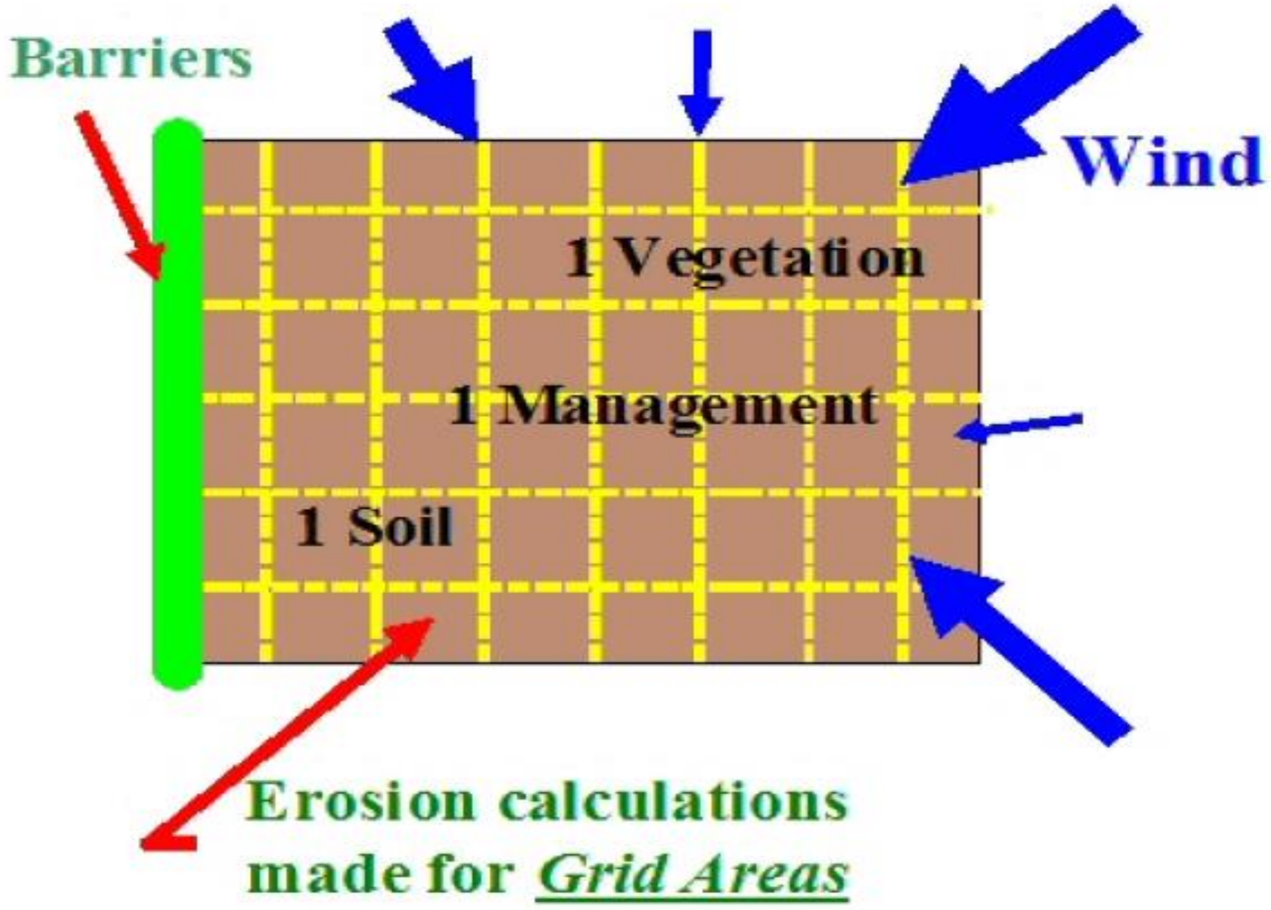
- Calculate threshold friction velocities and friction velocities in each subregion;
- Compute soil loss/deposition;
- Update surface variables changed by erosion and changed global subregion variables;

Submodels: Decomposition

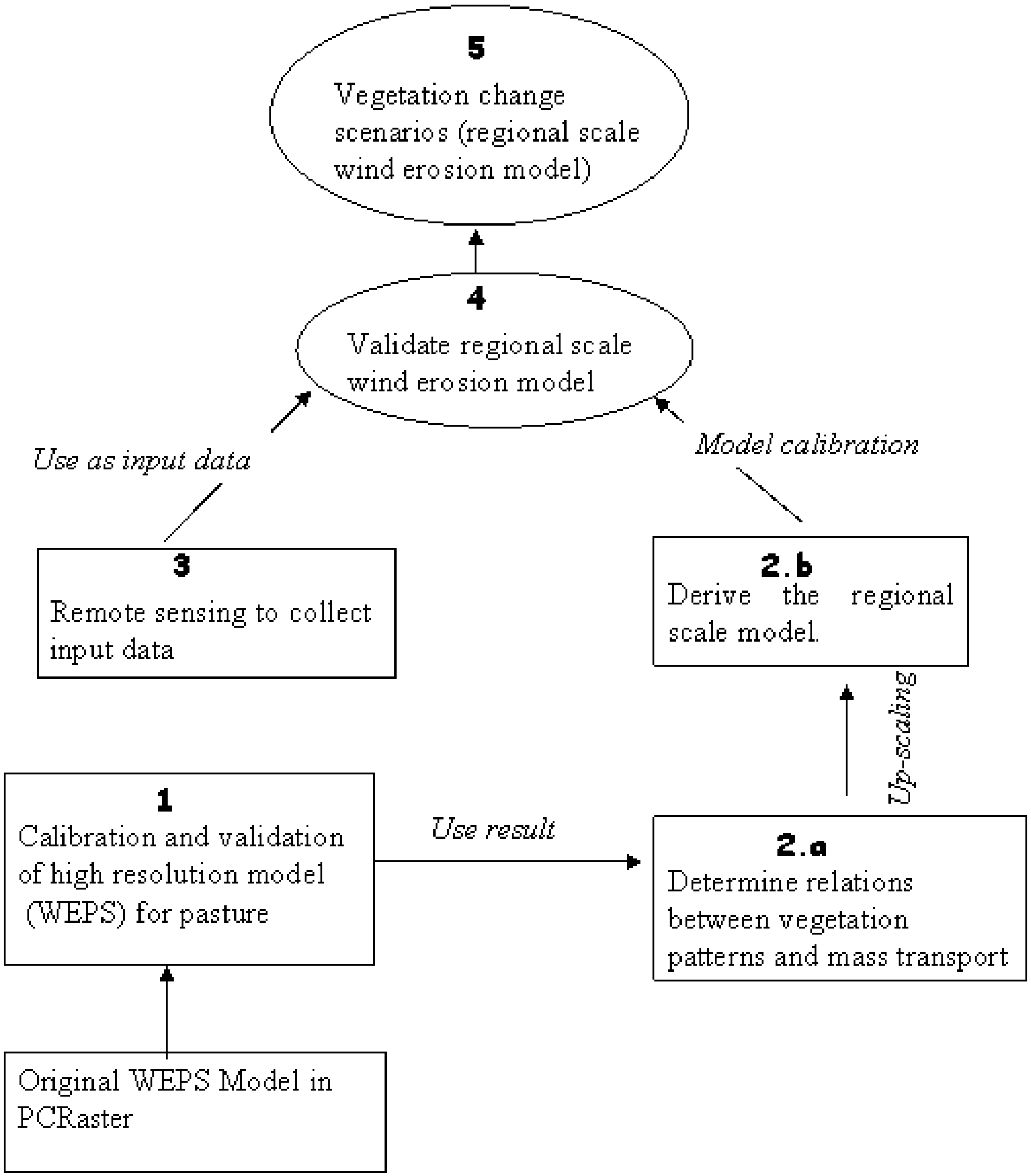
- The submodel simulates the decrease in crop residue biomass due to microbial activity.
- The decomposition process is modeled as a first order reaction with
  - temperature and
  - moisture

  as driving variables.

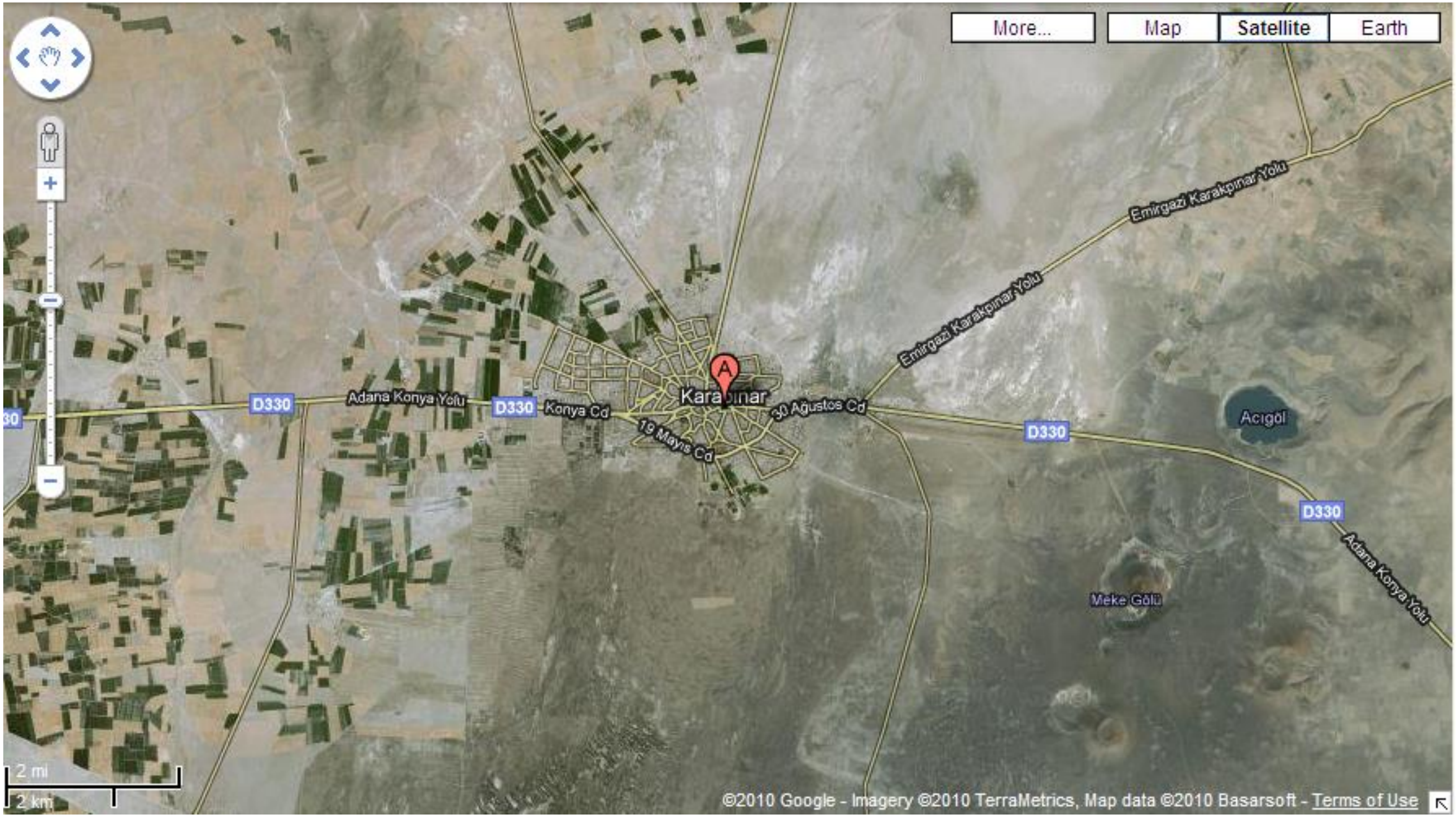
WEPS, simulation geometries



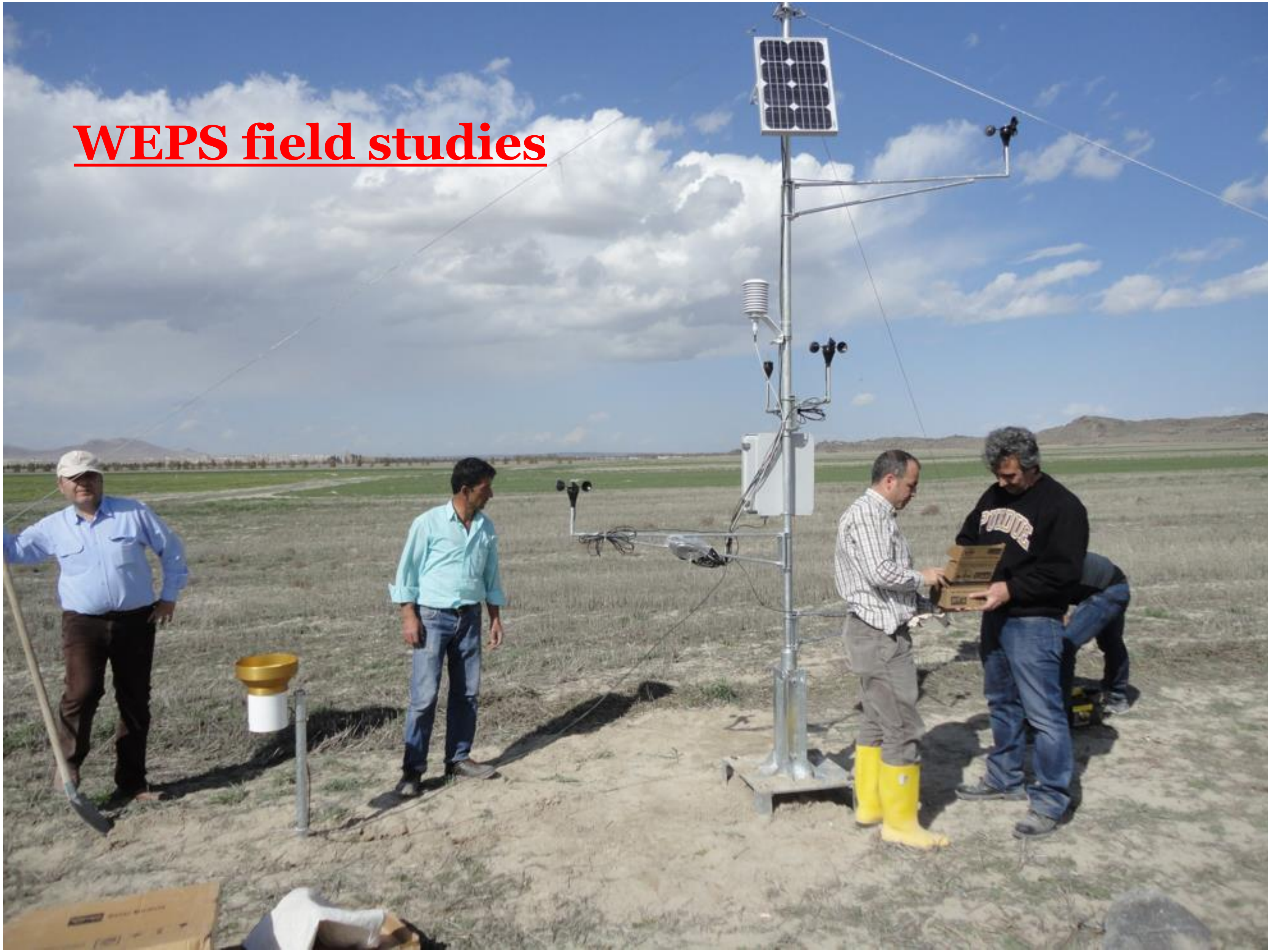
WEPS upscaling



WEPS, field studies



WEPS field studies



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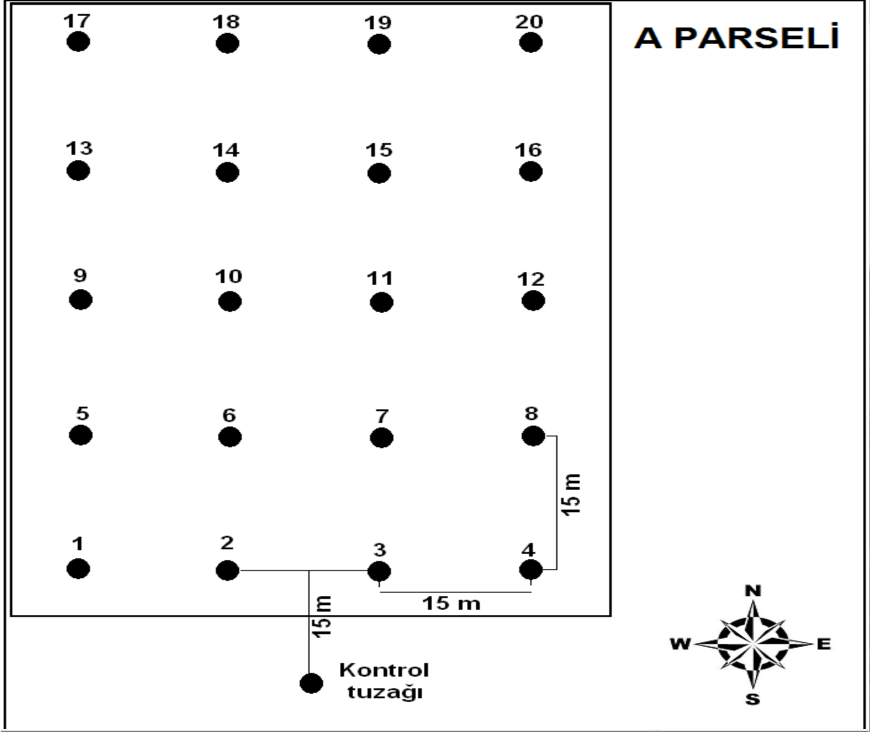
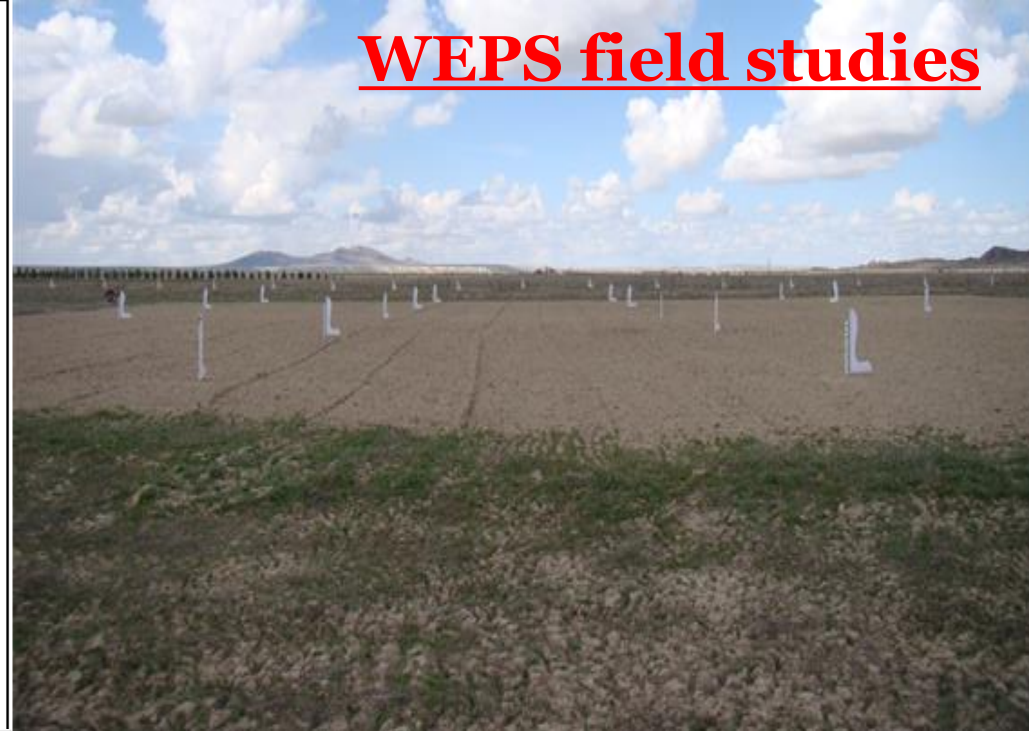
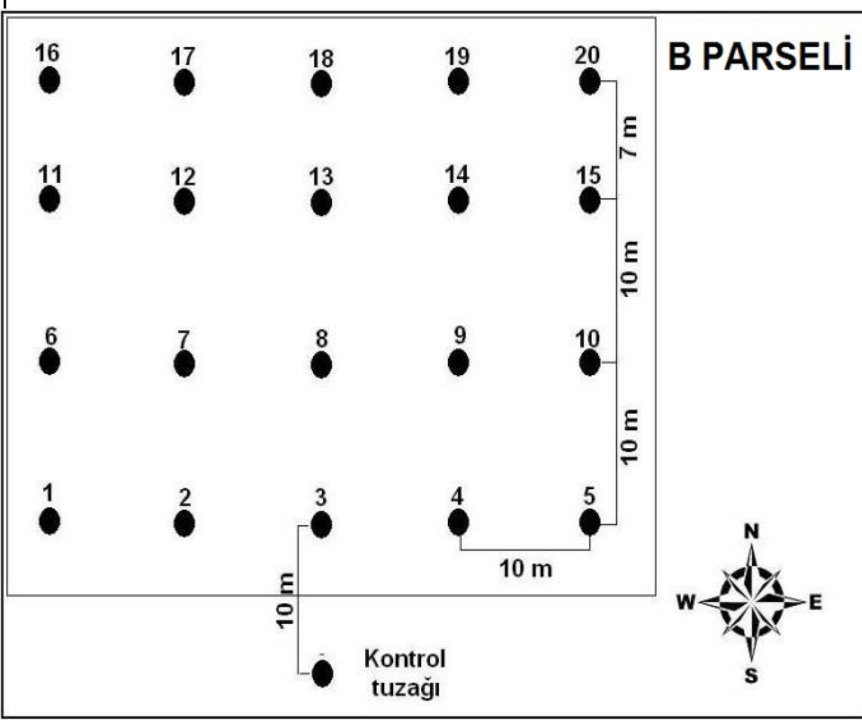
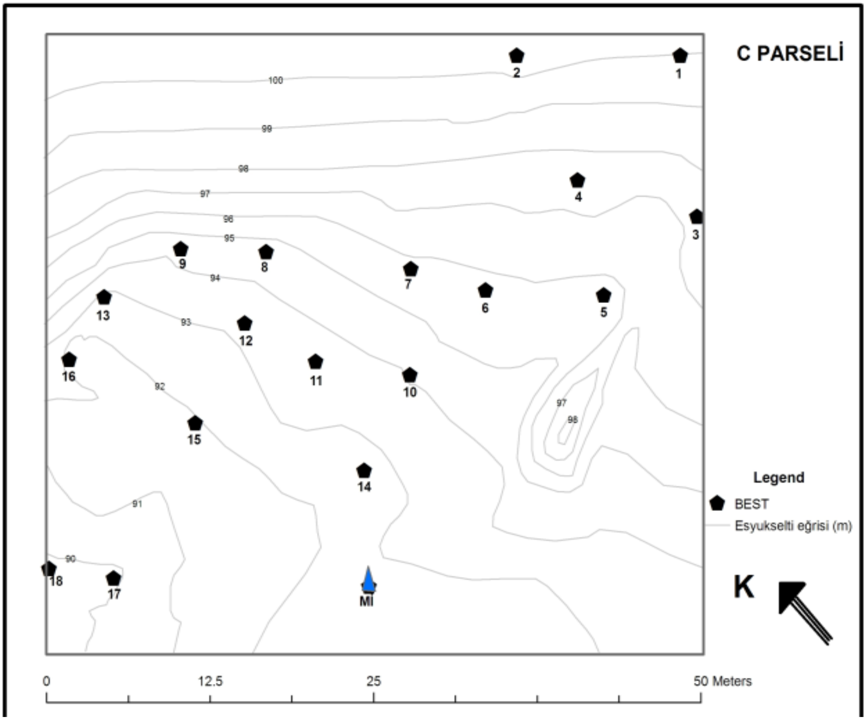
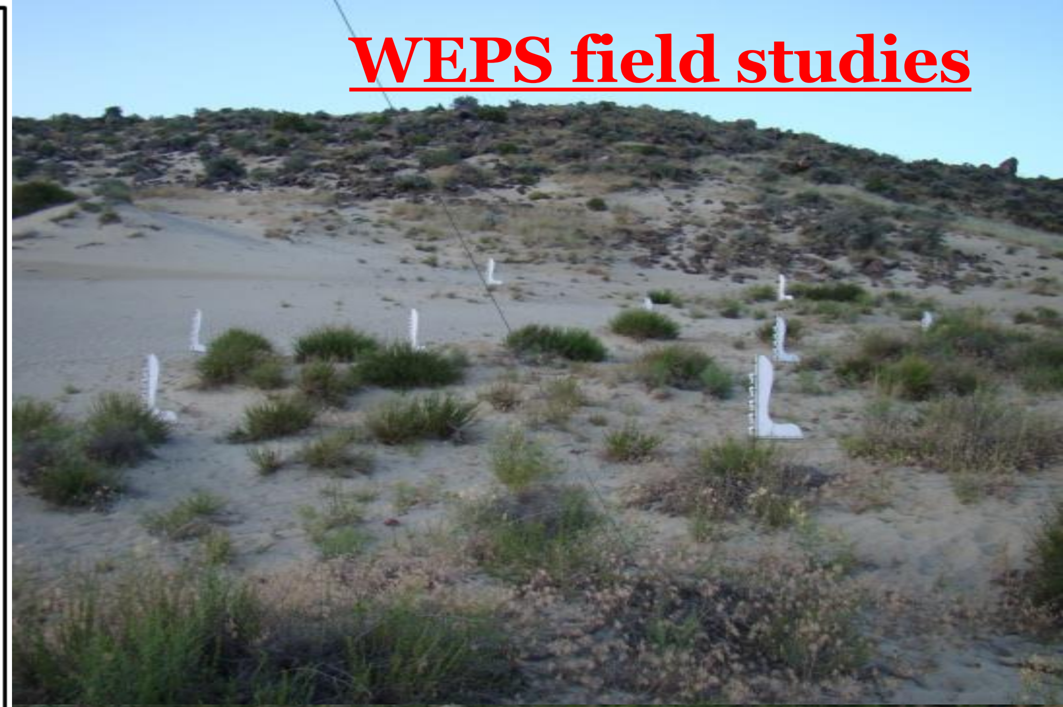


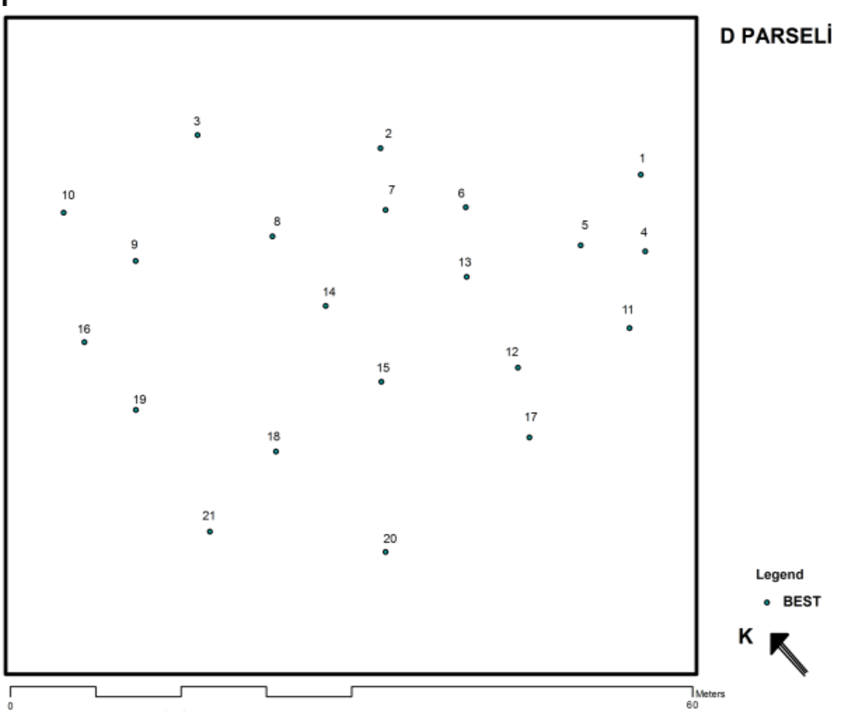




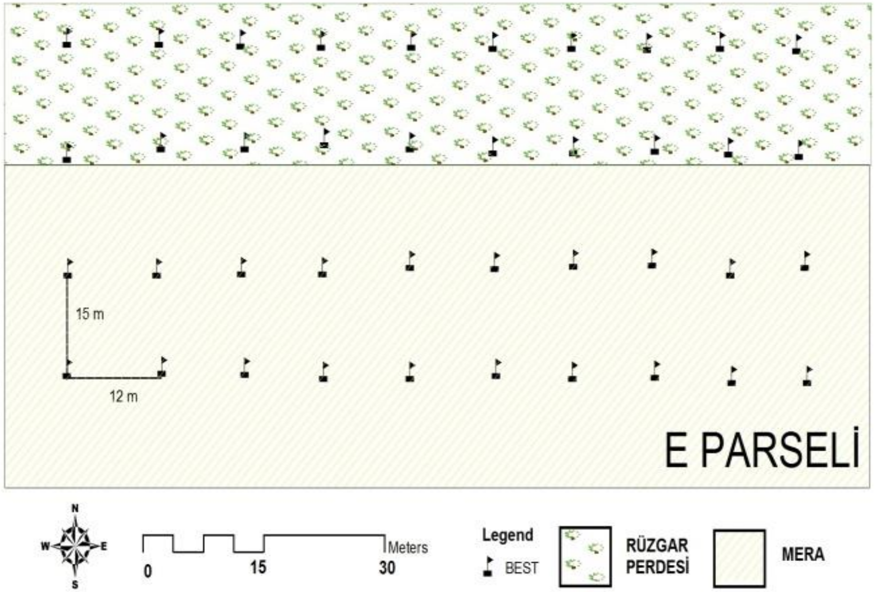
WEPS field studies

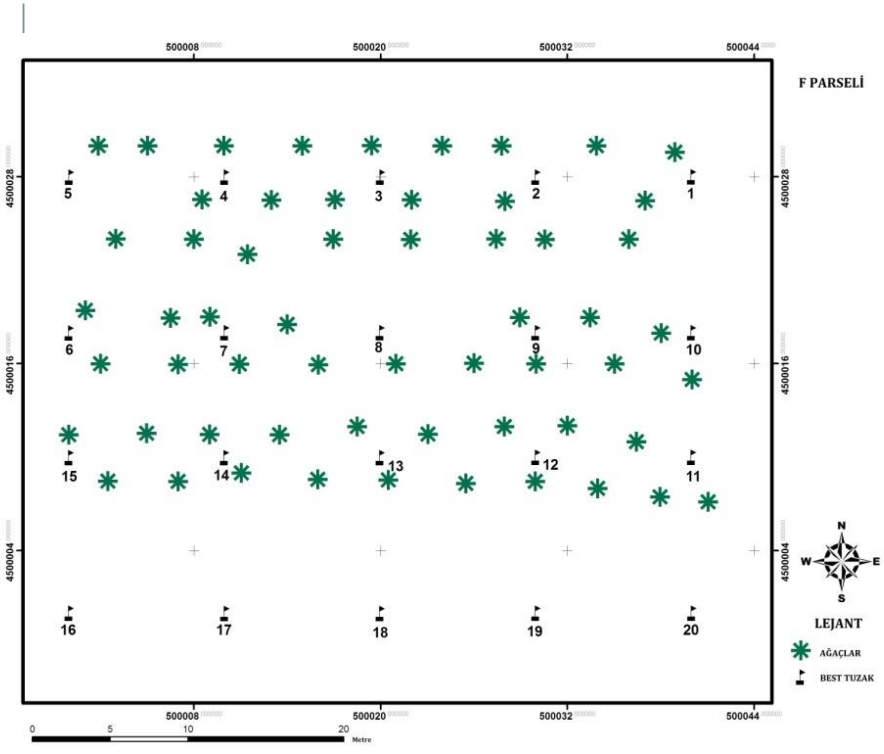






WEPS field studies





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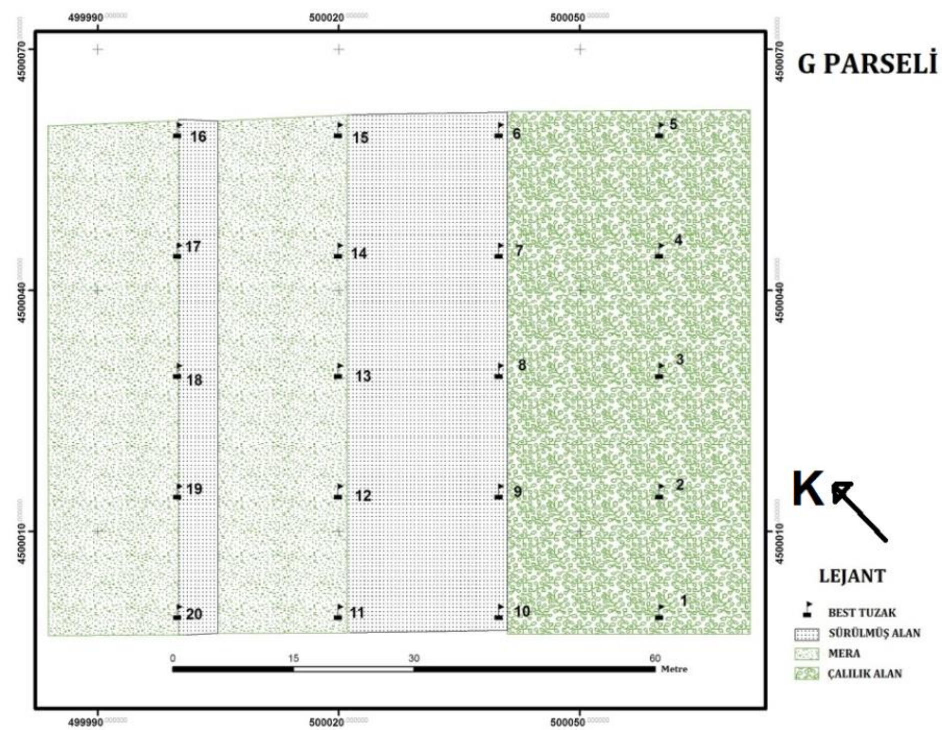


WEPS upscaling

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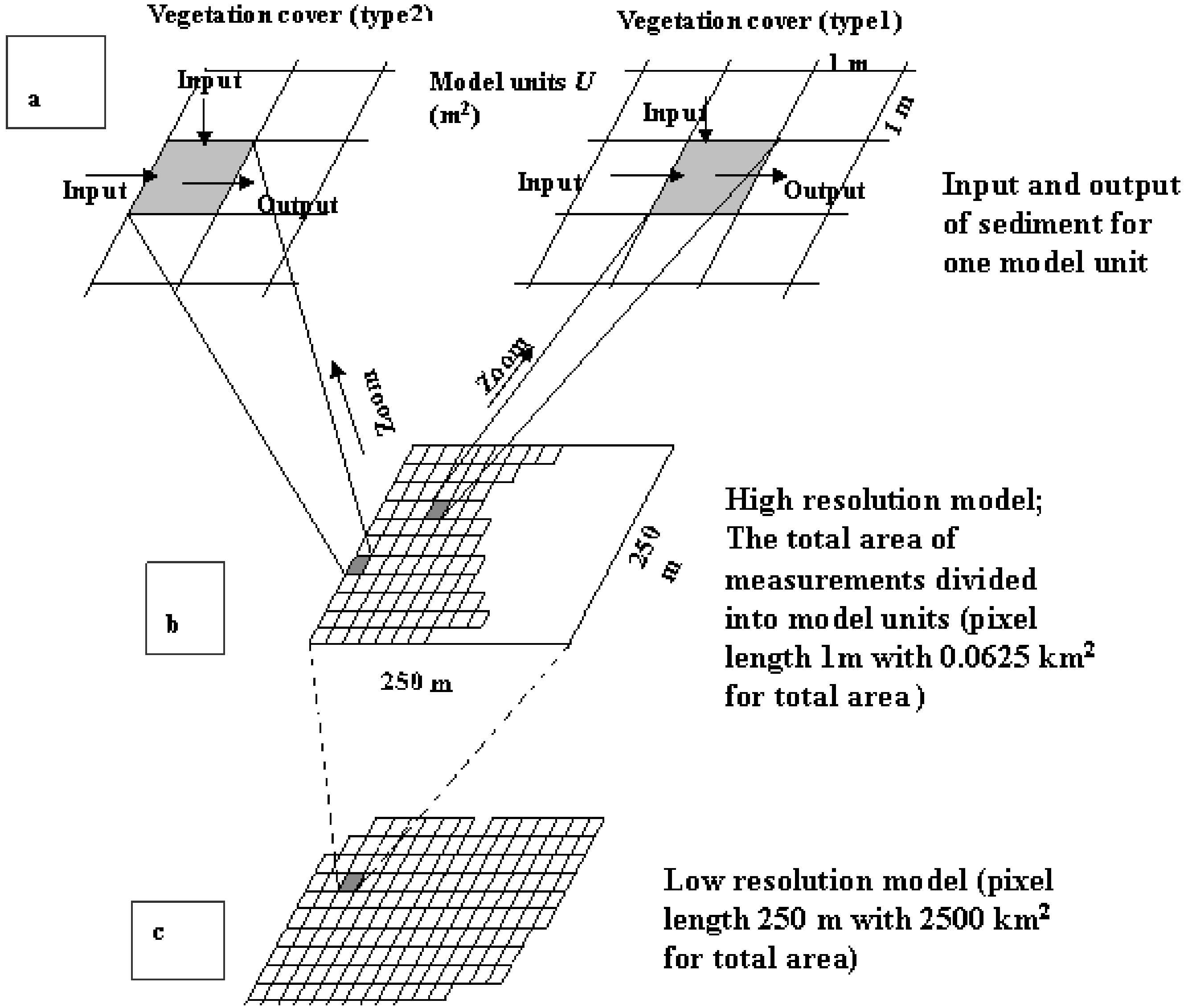
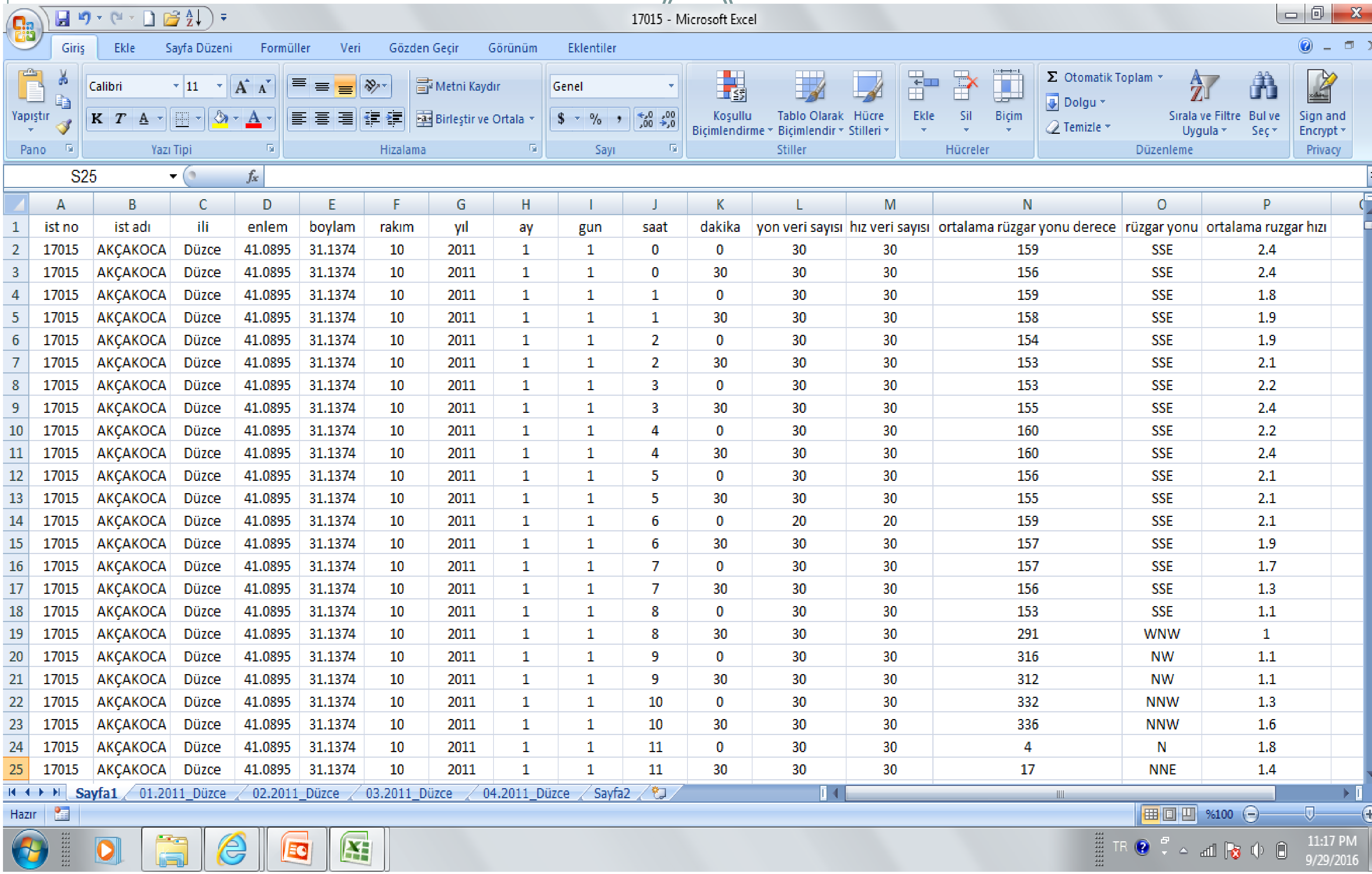


Submodels: Weather

Compact database → historical monthly summaries of wind speed and wind direction

- We have used ***historical statistical information about most meteorological variables*** and use stochastic techniques to determine likelihood of various levels of those variables."
- *Source: WEPS-technical document, 1996* (WINDGEN/ WEPS)

Step 1: Wind data collecting and processing between 2005 - 2016 years from 451 (397 worked out) meterological stations from Turkish State Meteorological Service



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17015	AKÇAKOCA	Düzce	41.0895	31.1374	10	2011	1	1	0	0	30	30	159	SSE	2.4
17015	AKÇAKOCA	Düzce	41.0895	31.1374	10	2011	1	1	0	30	30	30	156	SSE	2.4
17015	AKÇAKOCA	Düzce	41.0895	31.1374	10	2011	1	1	1	0	30	30	159	SSE	1.8
17015	AKÇAKOCA	Düzce	41.0895	31.1374	10	2011	1	1	1	30	30	30	158	SSE	1.9
17015	AKÇAKOCA	Düzce	41.0895	31.1374	10	2011	1	1	2	0	30	30	154	SSE	1.9
17015	AKÇAKOCA	Düzce	41.0895	31.1374	10	2011	1	1	2	30	30	30	153	SSE	2.1
17015	AKÇAKOCA	Düzce	41.0895	31.1374	10	2011	1	1	3	0	30	30	153	SSE	2.2
17015	AKÇAKOCA	Düzce	41.0895	31.1374	10	2011	1	1	3	30	30	30	155	SSE	2.4
17015	AKÇAKOCA	Düzce	41.0895	31.1374	10	2011	1	1	4	0	30	30	160	SSE	2.2
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17015	AKÇAKOCA	Düzce	41.0895	31.1374	10	2011	1	1	8	30	30	30	291	WNW	1
17015	AKÇAKOCA	Düzce	41.0895	31.1374	10	2011	1	1	9	0	30	30	316	NW	1.1
17015	AKÇAKOCA	Düzce	41.0895	31.1374	10	2011	1	1	9	30	30	30	312	NW	1.1
17015	AKÇAKOCA	Düzce	41.0895	31.1374	10	2011	1	1	10	0	30	30	332	NNW	1.3
17015	AKÇAKOCA	Düzce	41.0895	31.1374	10	2011	1	1	10	30	30	30	336	NNW	1.6
17015	AKÇAKOCA	Düzce	41.0895	31.1374	10	2011	1	1	11	0	30	30	4	N	1.8
17015	AKÇAKOCA	Düzce	41.0895	31.1374	10	2011	1	1	11	30	30	30	17	NNE	1.4

Step 2: Preparing "joint wind speed/direction frequency by month" tables to calculate scale and shape parameters of the Weibull distribution function for each of the 16 cardinal wind directions by month

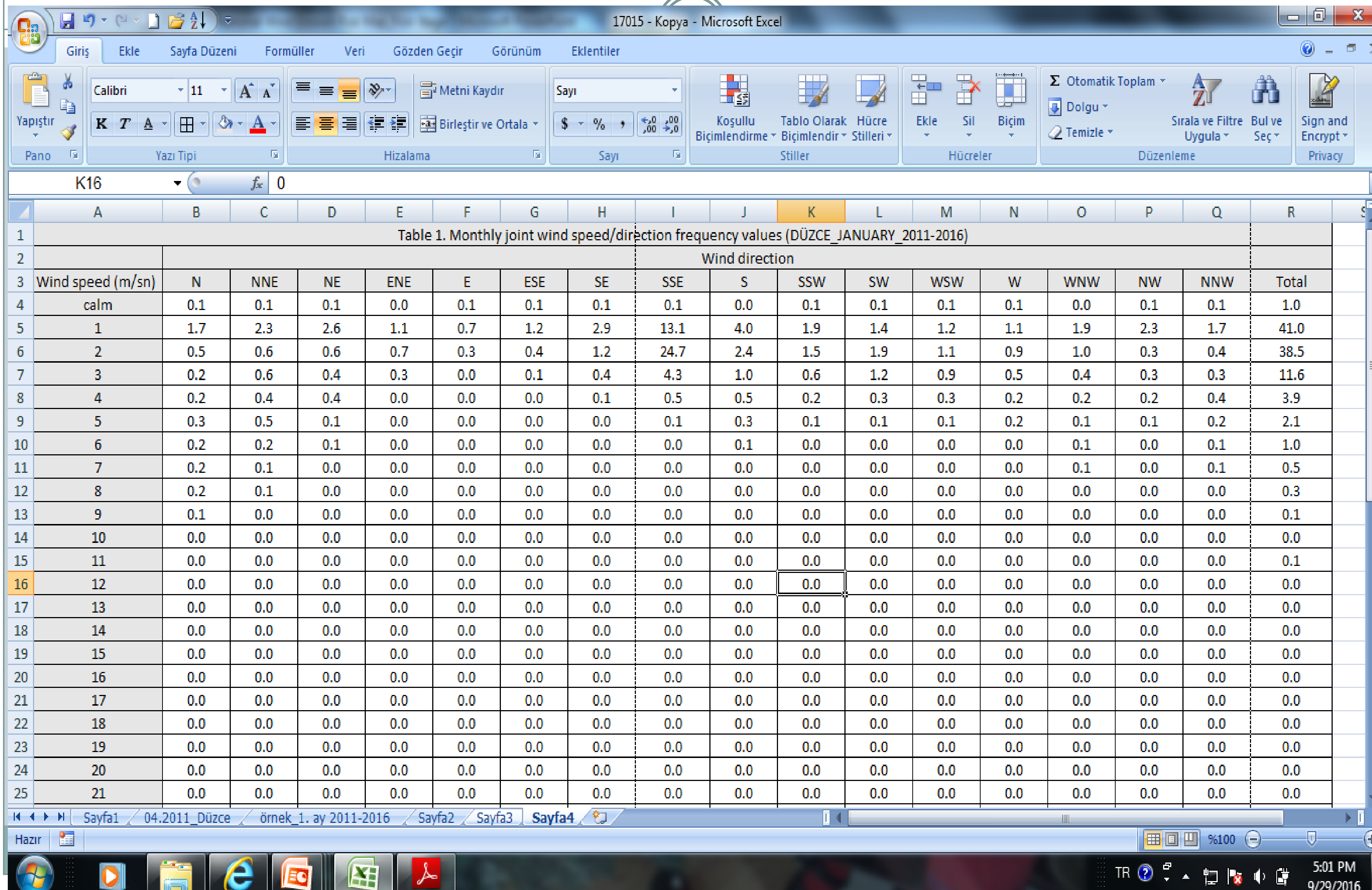


Table 1. Monthly joint wind speed/direction frequency values (DÜZCE_JANUARY_2011-2016)

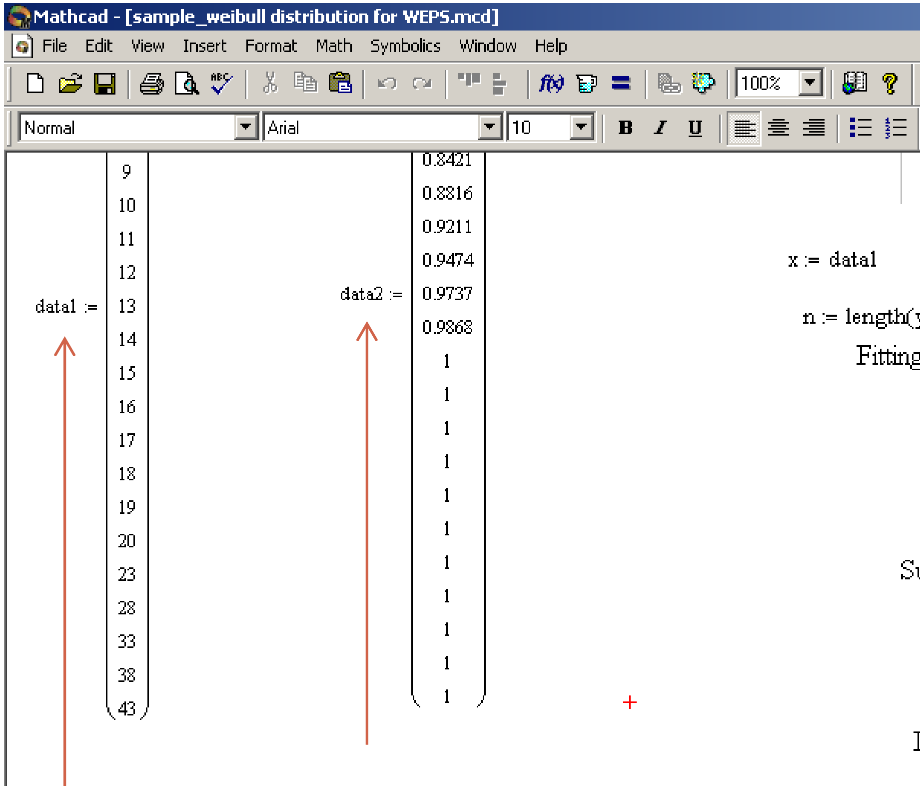
Wind speed (m/sn)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
	Wind direction																
calm	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.1	1.0
1	1.7	2.3	2.6	1.1	0.7	1.2	2.9	13.1	4.0	1.9	1.4	1.2	1.1	1.9	2.3	1.7	41.0
2	0.5	0.6	0.6	0.7	0.3	0.4	1.2	24.7	2.4	1.5	1.9	1.1	0.9	1.0	0.3	0.4	38.5
3	0.2	0.6	0.4	0.3	0.0	0.1	0.4	4.3	1.0	0.6	1.2	0.9	0.5	0.4	0.3	0.3	11.6
4	0.2	0.4	0.4	0.0	0.0	0.0	0.1	0.5	0.5	0.2	0.3	0.3	0.2	0.2	0.2	0.4	3.9
5	0.3	0.5	0.1	0.0	0.0	0.0	0.0	0.1	0.3	0.1	0.1	0.1	0.2	0.1	0.1	0.2	2.1
6	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.1	1.0
7	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.5
8	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Step 3: The calm periods were eliminated, and the frequency of wind in each speed group was normalized to give a total of 1.0 for each of the 16 cardinal directions, and cumulative frequency values were calculated

Normalized cumulative frequency values

Wind Speed	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm	Total
	Wind Direction																	
1	0.46	0.41	0.48	0.57	0.71	0.68	0.54	0.21	0.48	0.50	0.36	0.28	0.44	0.54	0.69	0.61		
2	0.64	0.56	0.67	0.81	0.93	0.95	0.89	0.79	0.78	0.85	0.71	0.65	0.67	0.80	0.82	0.76		
3	0.69	0.65	0.78	0.95	1.00	0.98	0.98	0.99	0.88	0.93	0.87	0.86	0.87	0.90	0.90	0.83		
4	0.74	0.75	0.87	0.99	1.00	1.00	0.99	1.00	0.94	0.99	0.96	0.97	0.93	0.94	0.97	0.91		
5	0.78	0.83	0.91	1.00	1.00	1.00	1.00	1.00	0.97	0.99	0.98	0.99	0.98	0.98	0.99	0.94		
6	0.85	0.88	0.95	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.99	0.98	0.99	0.95		
7	0.90	0.93	0.97	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.99	0.99	1.00	0.97		
8	0.94	0.95	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	0.98		
9	0.96	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99		
10	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
13	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
15	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
16	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
17	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
18	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
19	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		

Step 4: Modeling wind speed distribution with Weibull approach and obtaining both scale and shape parameters of distributions for future wind speed/direction estimations



Wind speed classes

Cumulative frequency distribution

$x := \text{data1} \qquad y := \text{data2}$

$n := \text{length}(y) - 1 \qquad n = 24$

Fitting function F (Weibull density with unknown parameters):

$$F(x,c,k) := 1 - \exp\left[-\left(\frac{x}{c}\right)^k\right]$$

← ***Weibull equation***

$i := 1 .. n$

Sum of squares to be minimized:

$$SSE(c,k) := \sum_i \left(y_i - F(x_i,c,k)\right)^2$$

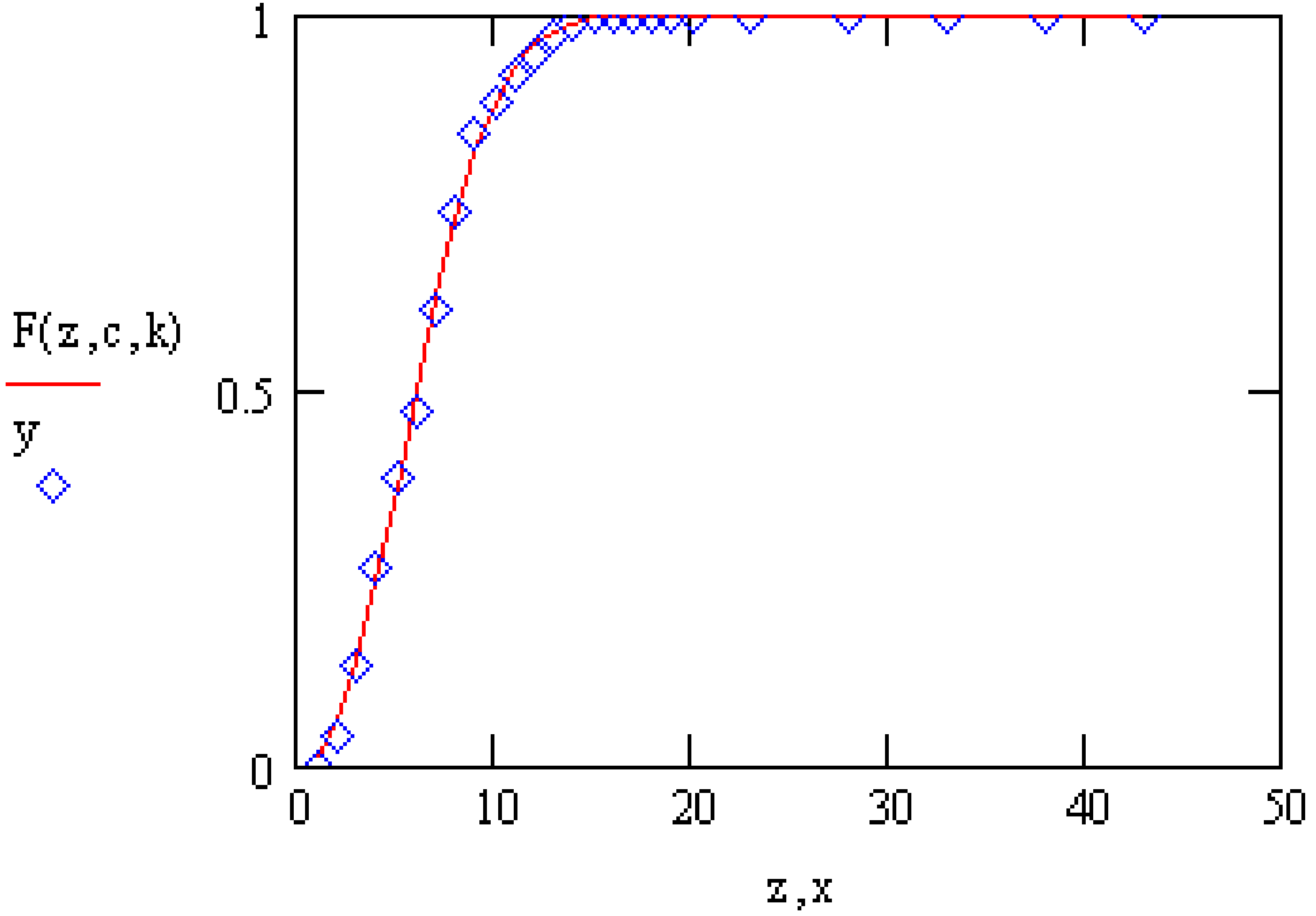
Initial guess for parameters:

$c := 0.8 \qquad k := 1$

Given $\qquad SSE(c,k) = 0$

Parameters for best fit: $\begin{pmatrix} c \\ k \end{pmatrix} := \text{Minerr}(c,k)$

Step 5: Cumulative wind direction/speed graphs were prepared for 16 cardinal directions and 12 months for each meteorological station



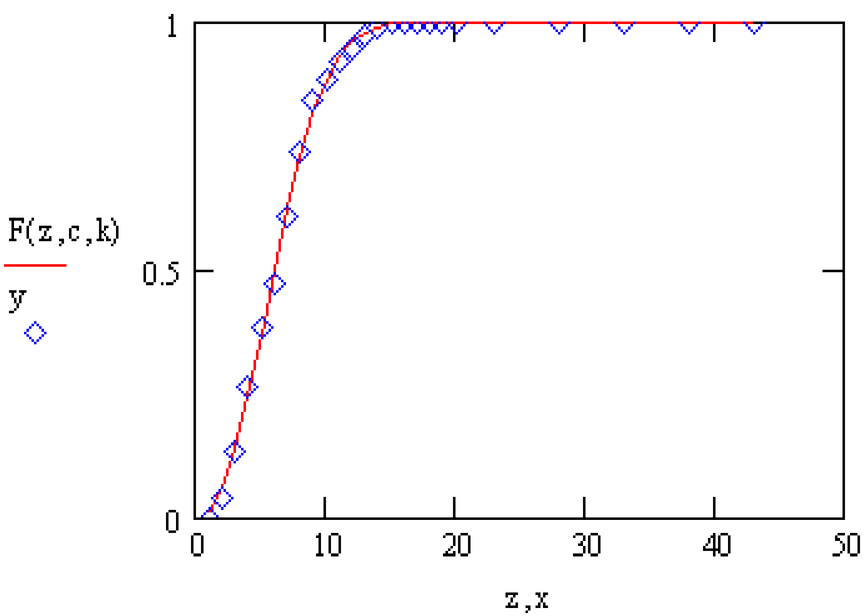
Parameters for best fit: $\begin{pmatrix} c \\ k \end{pmatrix} := \mathrm{Minerr}(c,k)$

Other statistics: $Syy := \sum_i \left(y_i - \mathrm{mean}(y)\right)^2$ $R^2(c,k) := 1 - \frac{SSE(c,k)}{Syy}$

$SSE(c,k) = 0.0027$ $R^2(c,k) = 0.999$ $c = 7.1$ ***Scale parameter***

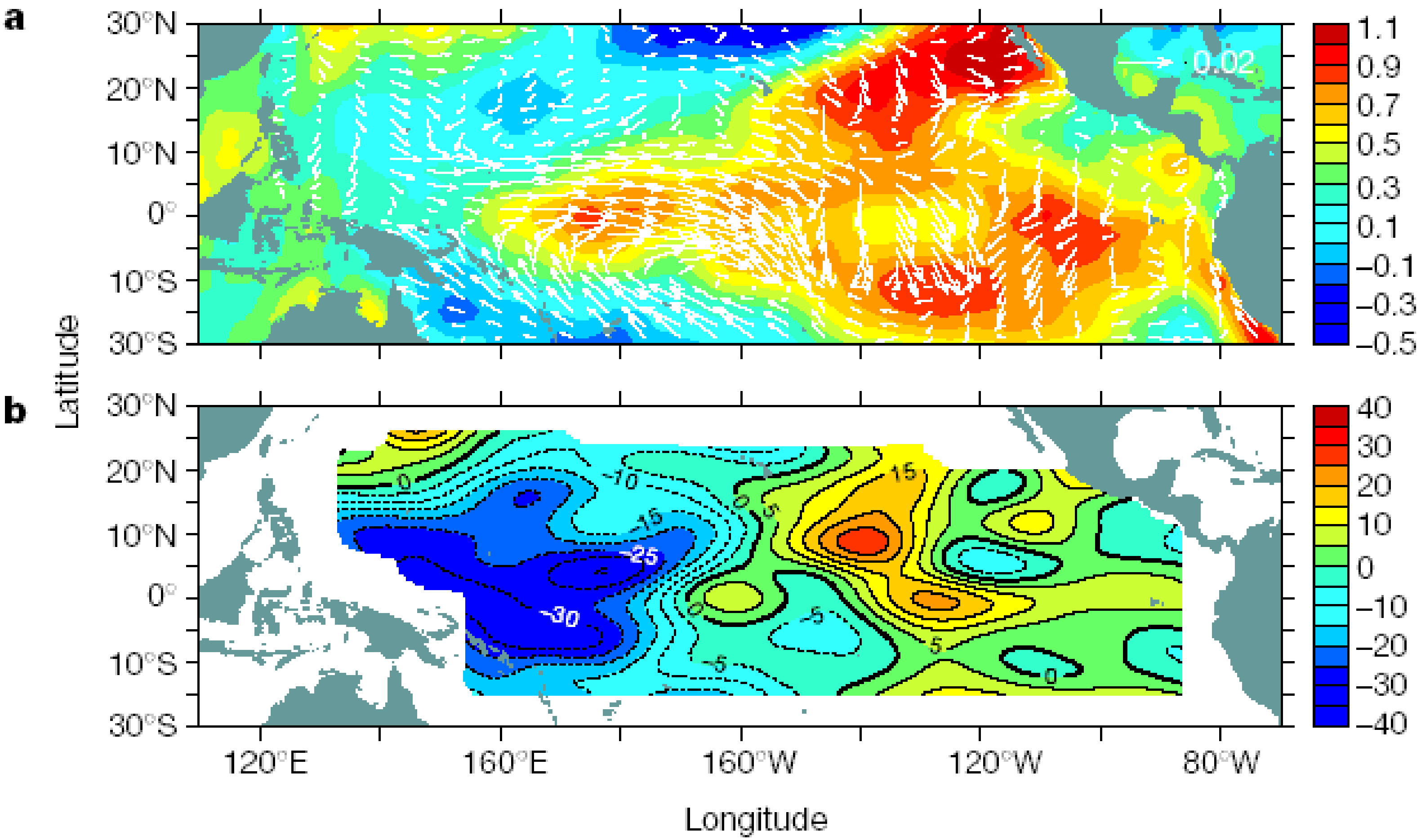
$k = 2.225$ ***Shape parameter***

16 cardinal directions
12 months
451 met. stations



Mean squared error (this would be zero if a true solution existed):

$\frac{SSE(c,k)}{n-2} = 1.249 \times 10^{-4}$



Ultimate goals of the performing this project are firstly to produce the Wind Erosion Risk Map all over the country and secondly to determine the potential wind erosion risk areas to apply effective management measurements in these areas.

Thank you for your attention