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Precipitation variability: spatio-temporal scales and hydrometeorologic extremes
PICO Session

Hourly Temporal Distribution of Wind

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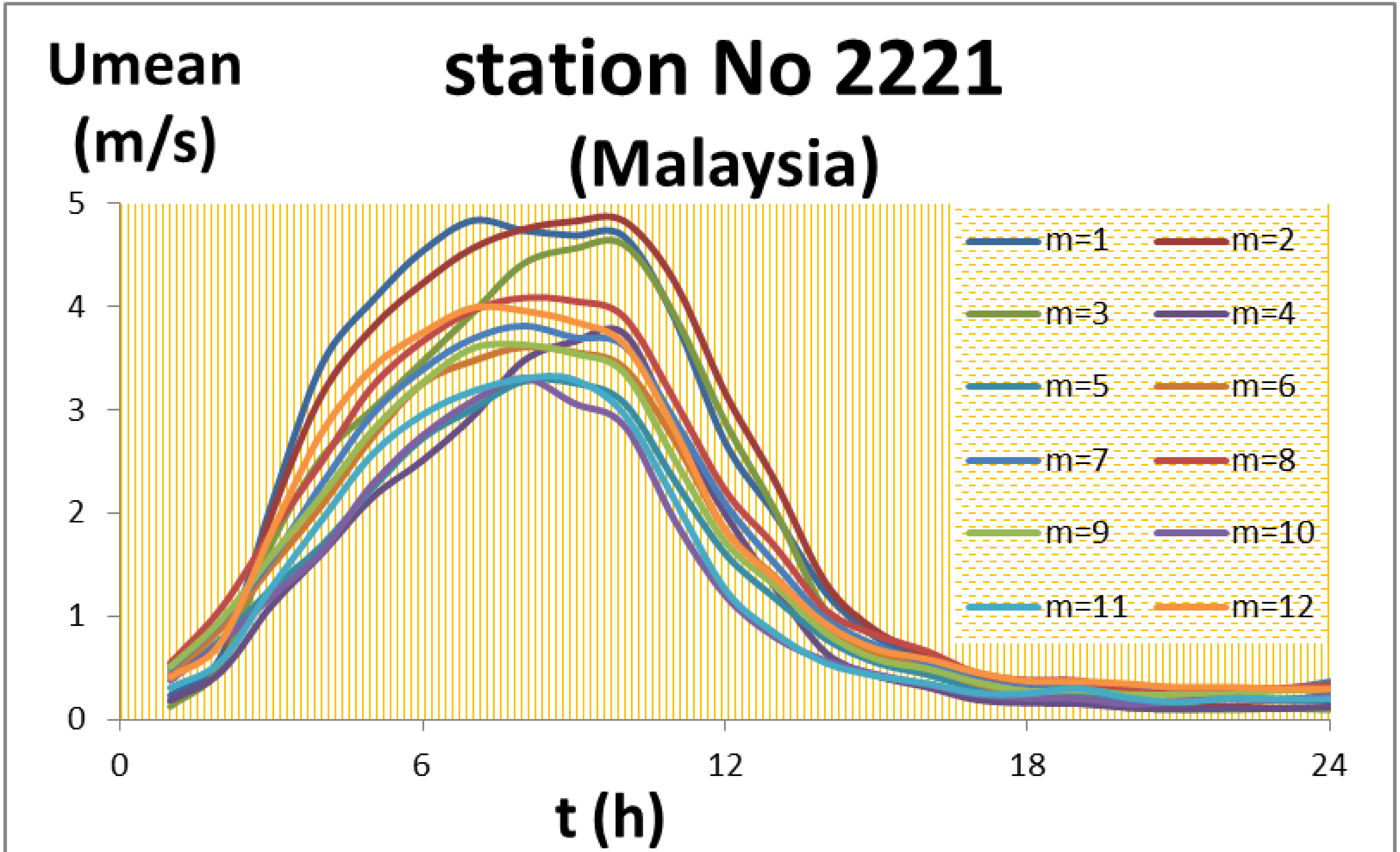
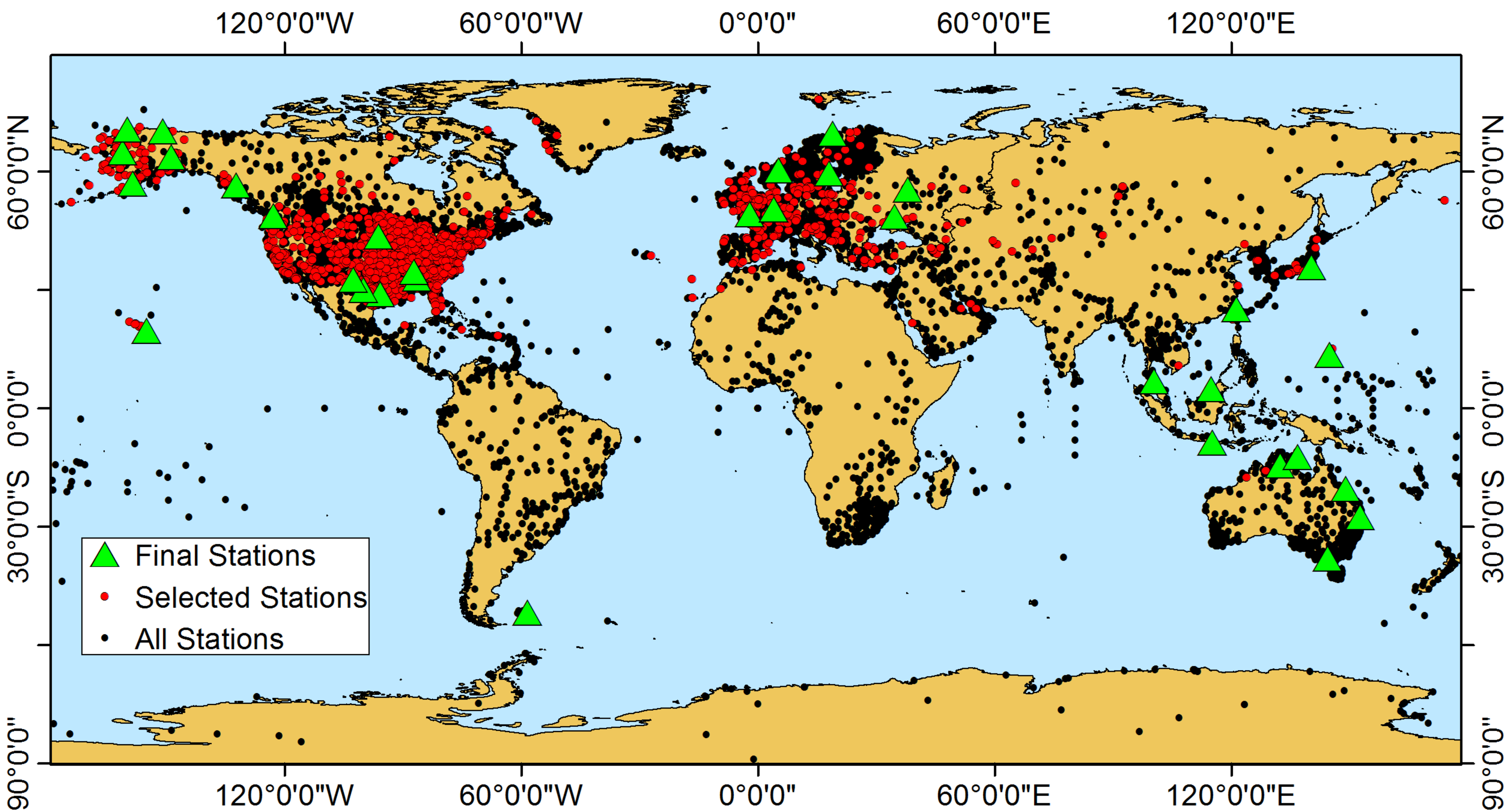
1. Introduction – "**Hourly Temporal Distribution of Wind**"

wind speed → double cyclostationarity → annual and daily cycles.



2. Selected Wind Stations

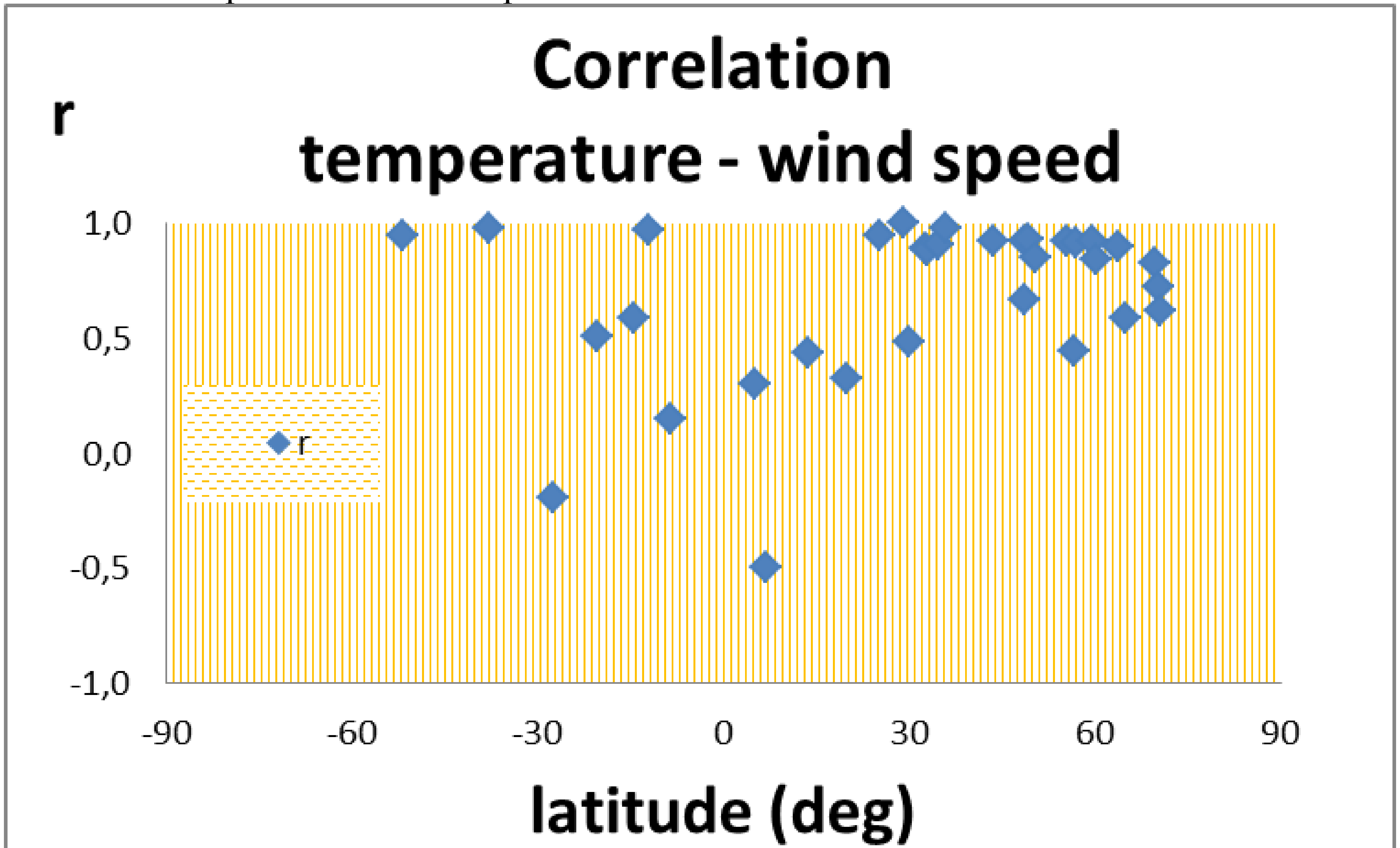
33 stations finally selected → lots of speed measurements



33 of the best stations selected from all around the world (https://www.ncdc.noaa.gov/cdo-web/)

3. Explanation

- ✓ Temperature difference → air-pressure difference → wind (as lake stratification)
- ✓ Temperature fluctuation → wind speed fluctuation
- ✓ Check correlation temperature – wind speed



4. General Concept

Model of double cyclostationarity applied
(Dimitriadis and Koutsoyiannis, 2015):

$$\mu_c = (a_1 \cos(2\pi t/T_h) + a_2)\, \exp(-\cos(2\pi(t-a_0)/T_d)) + a_3 \mu_h$$

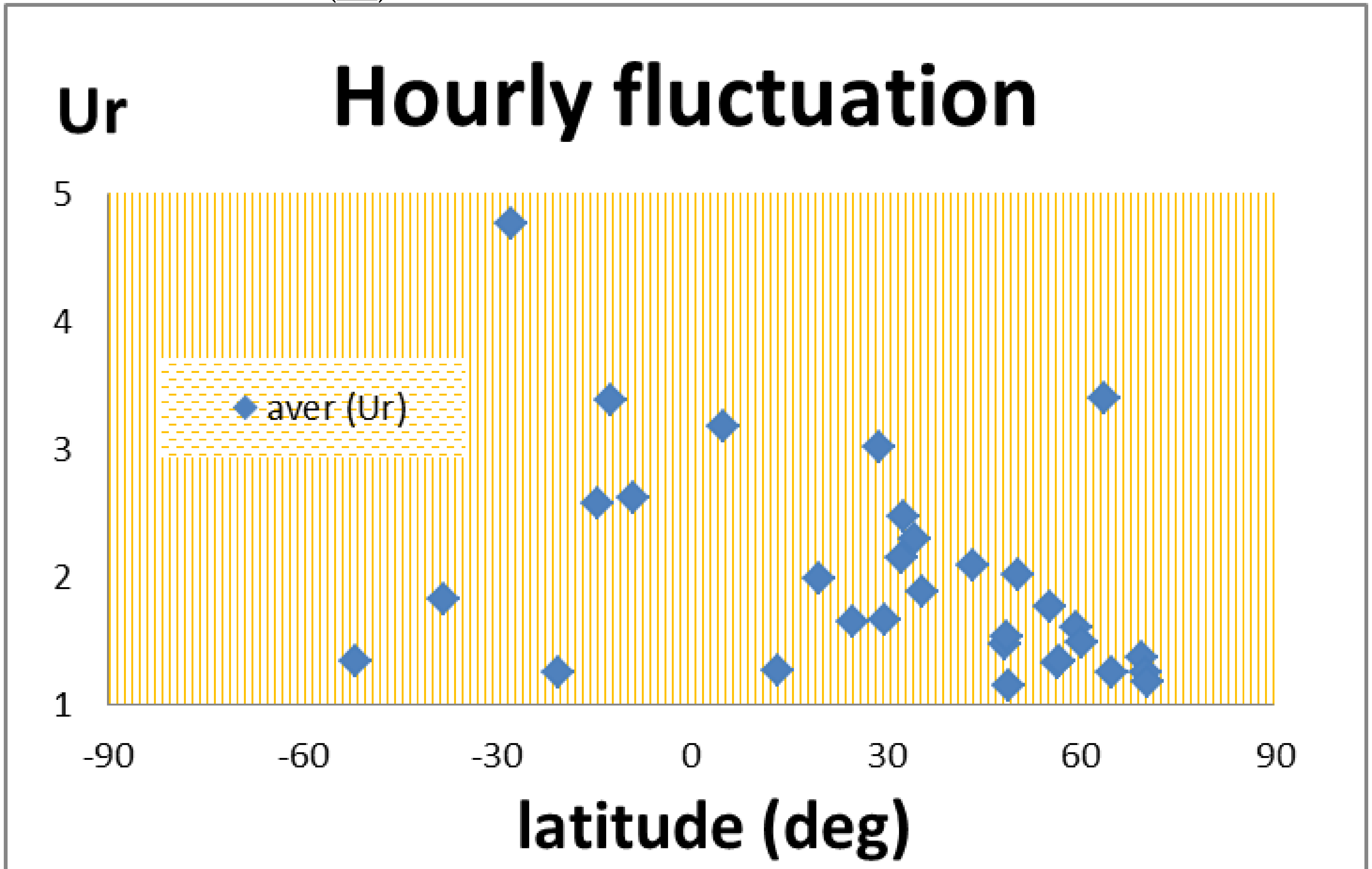
annual cycles daily cycles

where:
μ_c : mean for each variable (for each hour and month)
μ_h : mean for each month.
t : time
T_h = 12 months
T_d = 24 hours
a_0, a_1, a_2: coefficients (m/s)
a_3 : dimensionless coefficient.

5. Measuring the Fluctuation

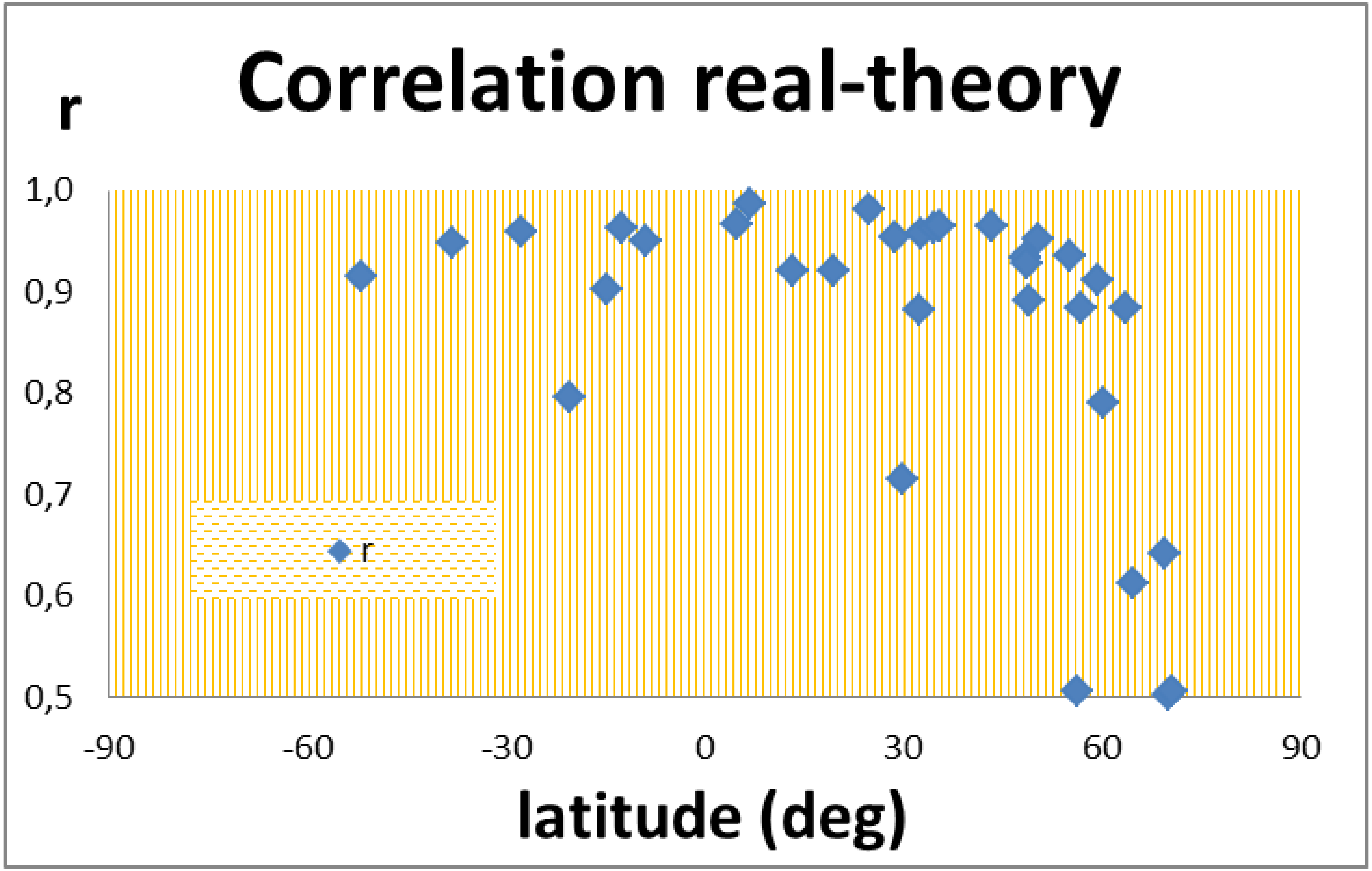
hourly fluctuation of wind → important (?)

✓ check the ratio Umax/Umin (**Ur**)



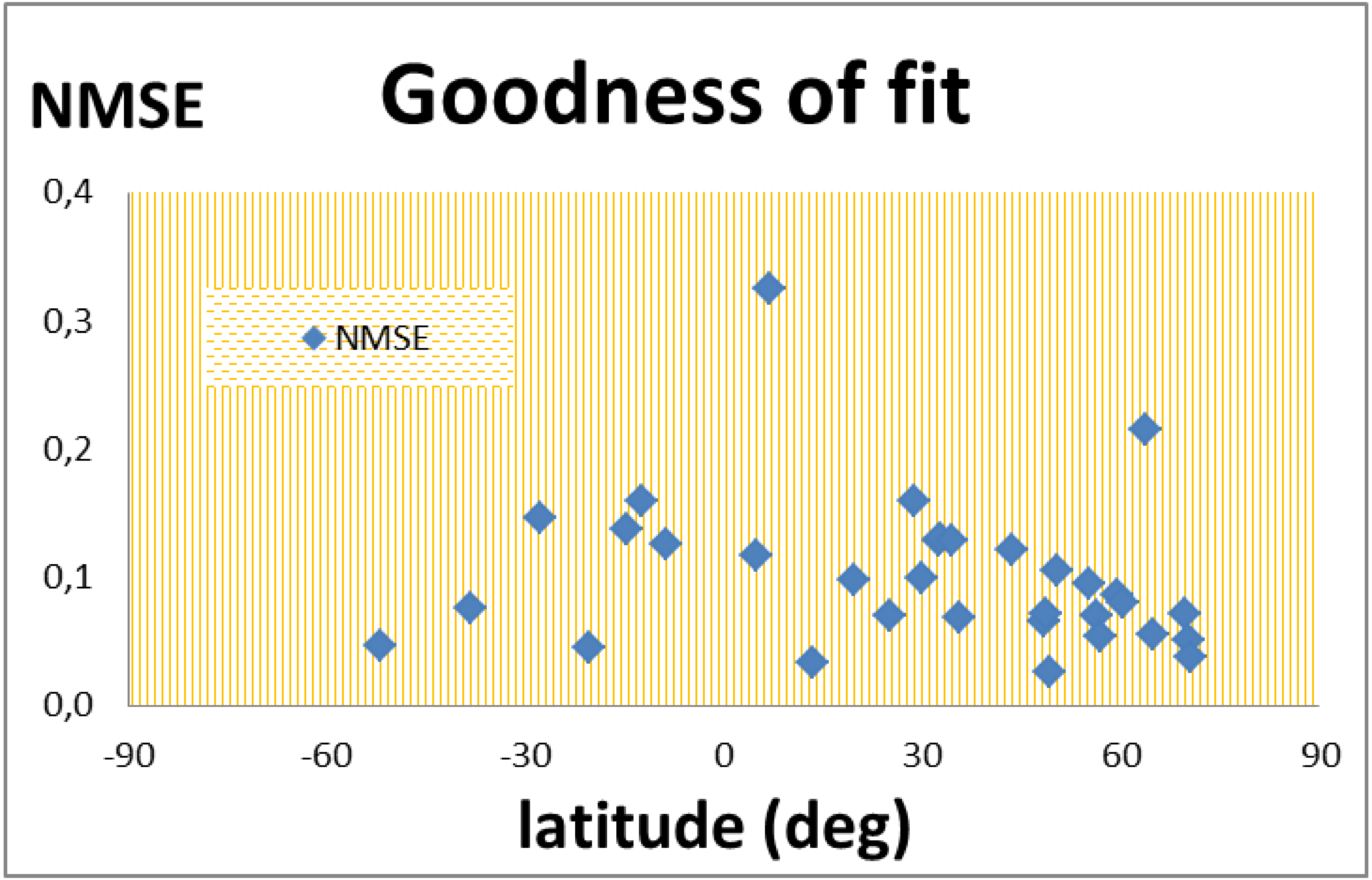
6. Fitting Quality (1)

✓ Check correlation coefficient "r" → close to 1 (?)

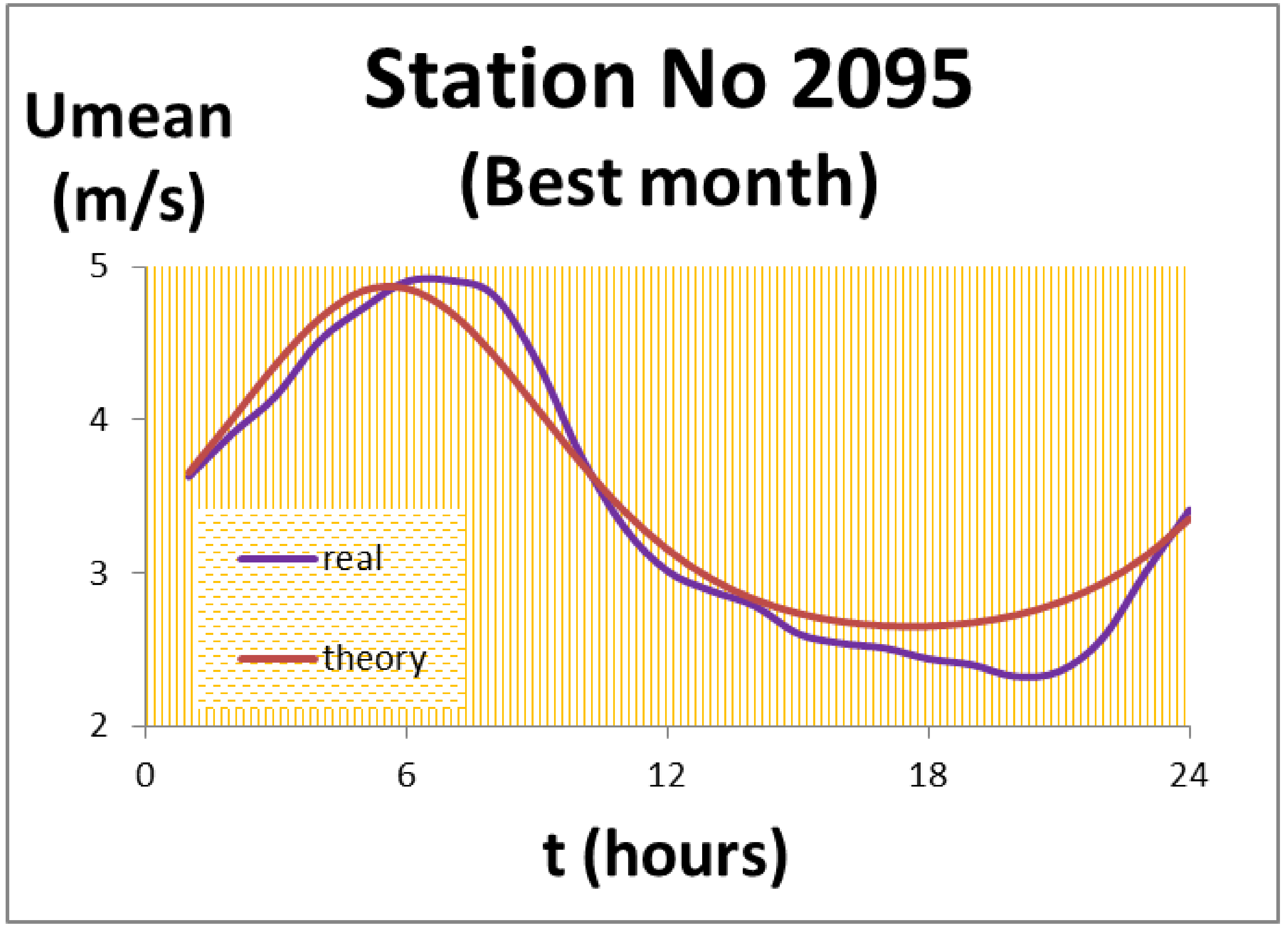


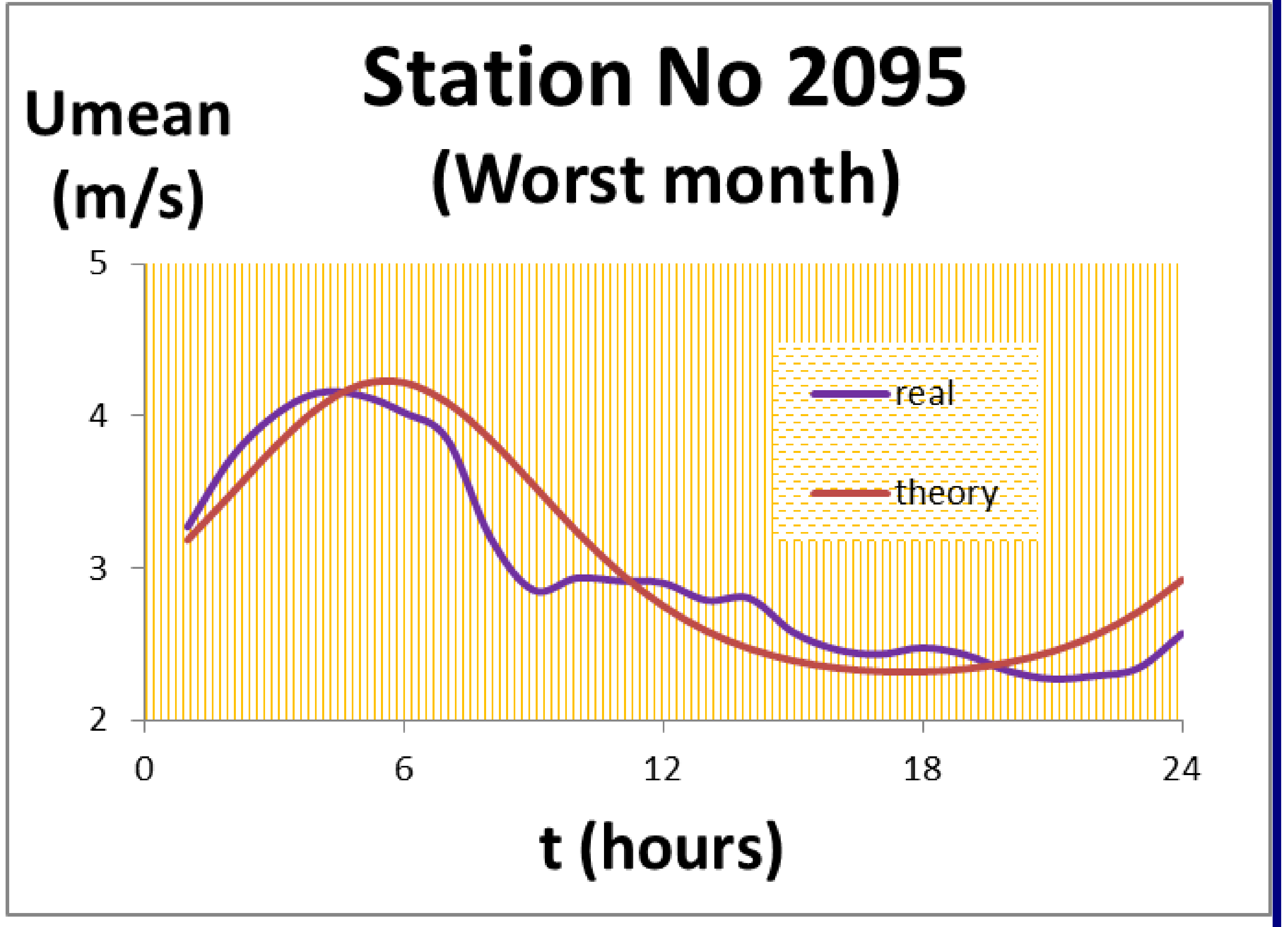
7. Fitting Quality (2)

✓ Check normalised mean square error (NMSE) → close to 0 (?)



8. Fitting Example





THANK YOU FOR YOUR ATTENTION!

For more details and diagrams, please come to the touch screen.

EXTRA INFORMATION

(for the PICO screen)

1. Introduction – **"Hourly Temporal Distribution of Wind"**

Wind speed is a variable of high importance for many aspects, such as estimation of wind energy production.

The subject of this study is the hourly temporal distribution of wind. The hourly scale is ideal for the purposes of energy production.

Wind speed appears to fit in a model of double cyclostationarity (daily and annual cycles).

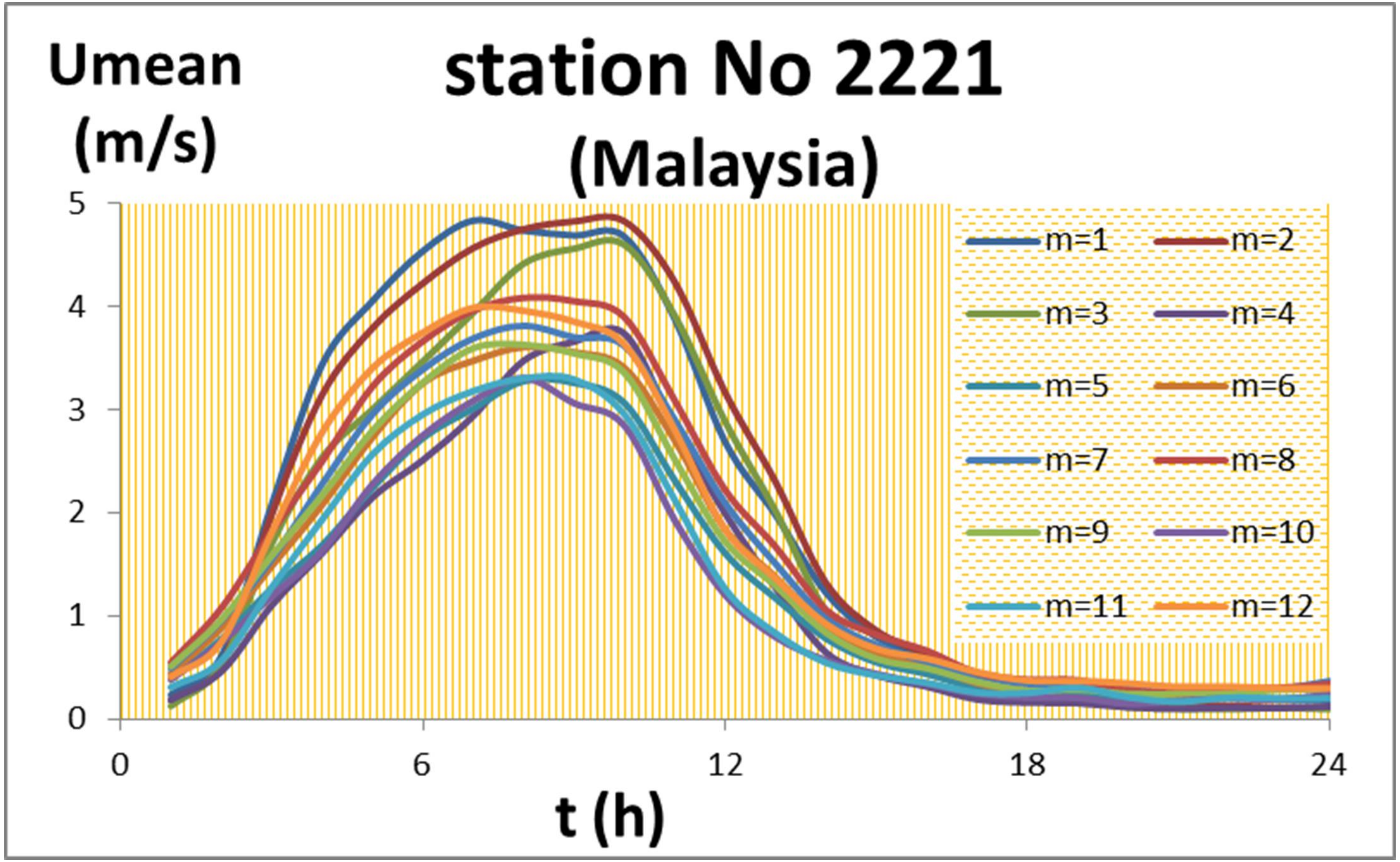


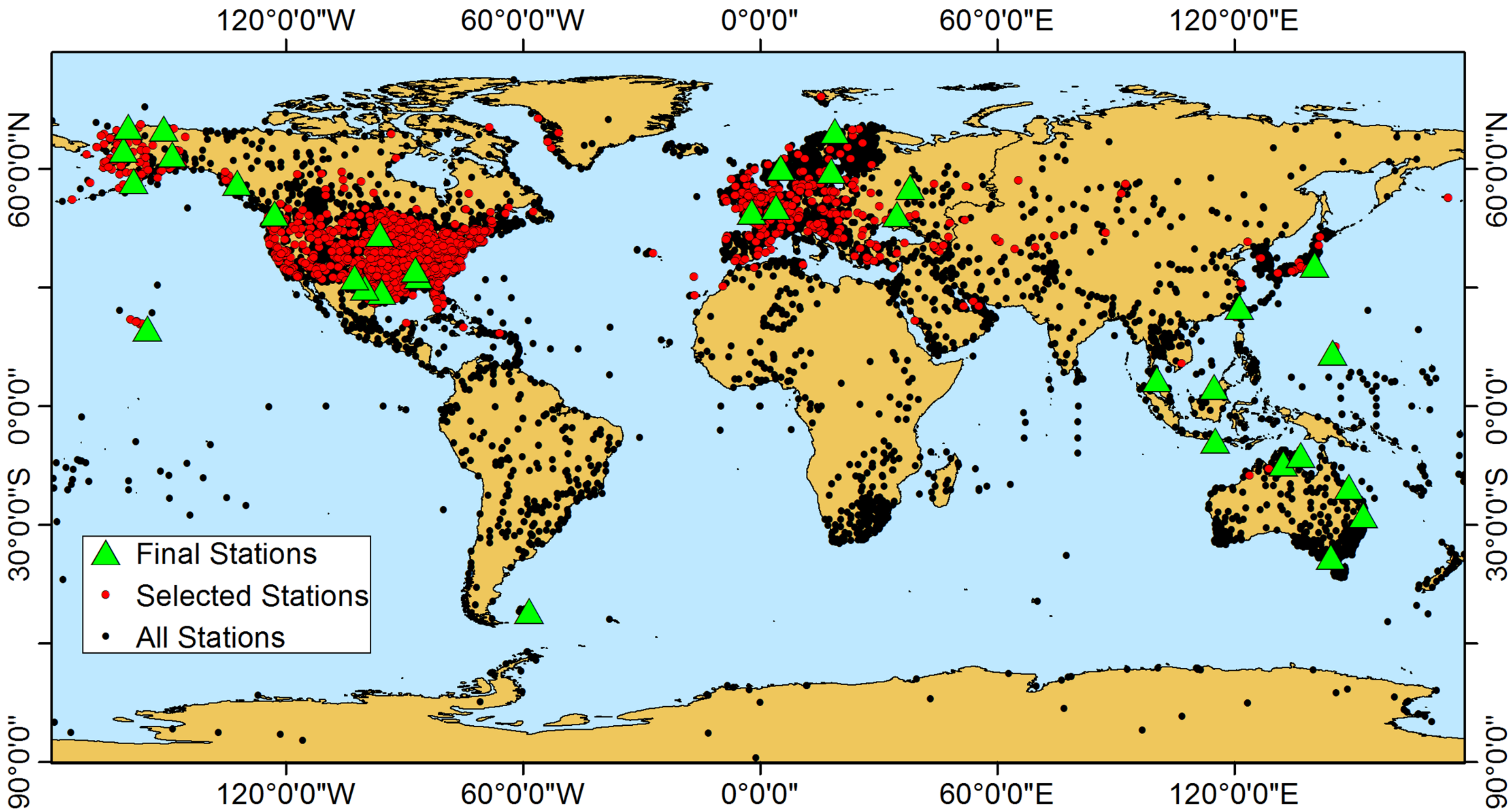
Diagram 1: average hourly distribution of wind speed for each month, for the wind station 2221 in Malaysia.

2. Selection criteria

Data from 7,500 wind stations (**black**) were collected. 1,600 stations of high credibility were selected (**red**)

1) > 100,000 total measurements.
2) > 1 measurement per hour.

Then, 33 stations from all around the world were finally selected (**green**).



Map 1: 33 of the best stations selected from all around the world (https://www.ncdc.noaa.gov/cdo-web/)

3. Explanation

Temperature affects kinetic energy and, as a result, the motion of the air molecules in the microscale. In consequence, it can be assumed that temperature plays an important role in the large-scale, too.

It is known that wind is produced from an air-pressure difference, which is caused by a difference in temperature between two places. The process is similar to thermal stratification in lakes. In a lake, difference in temperature results in difference in density and thus, water motion from one position to another.

As temperature in the atmosphere is not stable during the day in a particular place, it is very possible that temperature differs from place to place, too. This differentiation causes a fluctuation in wind speed. So there might be a physical explanation behind this peak in hourly wind speed.

The correlation between temperature and wind speed is notable, as half of the stations have r>0.85 and over two thirds of them have r>0.5.

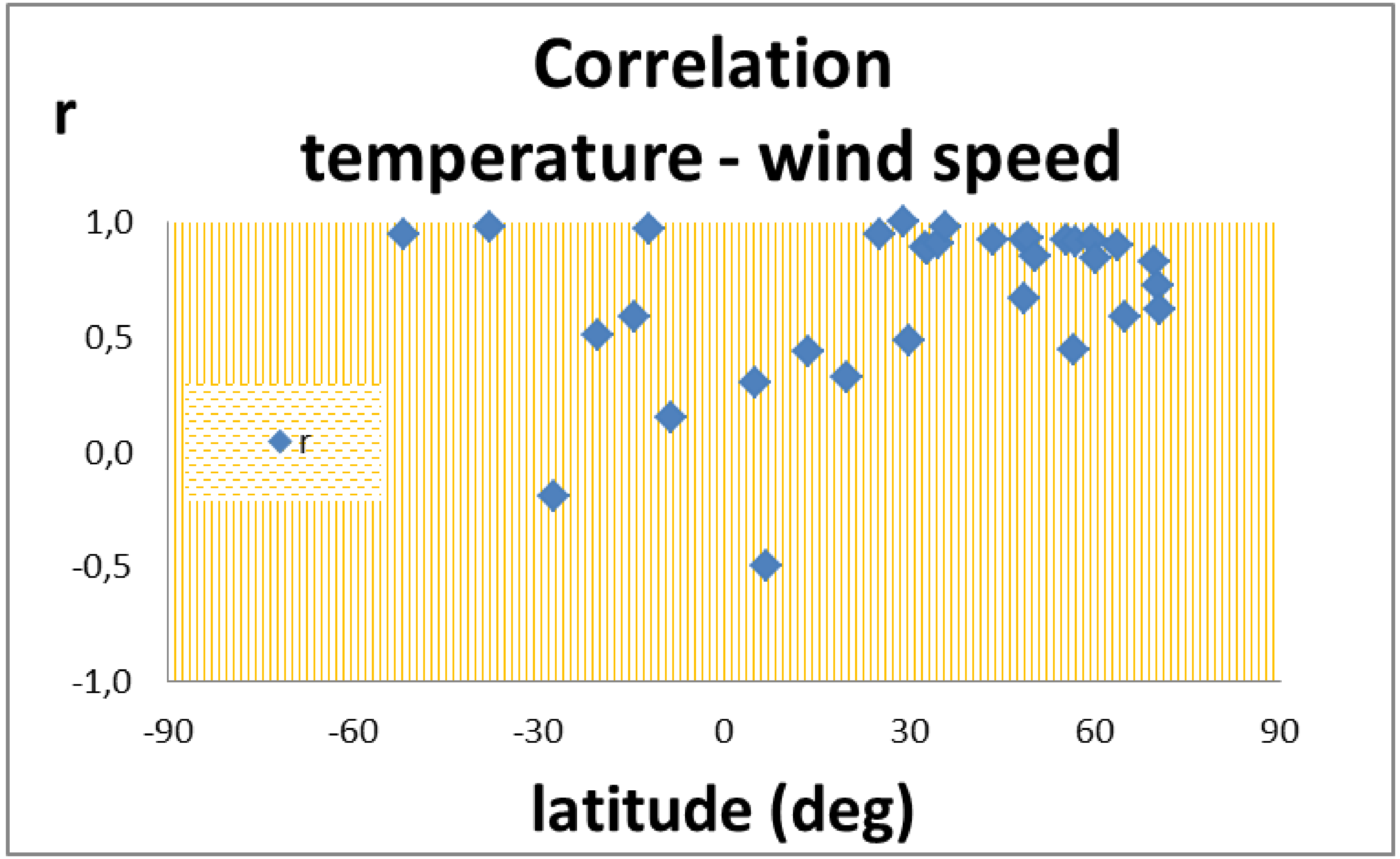


Diagram 2: correlation between temperature and wind speed for all stations

4. General concept (1)

A model of double cyclostationarity was applied (Dimitriadis and Koutsoyiannis, 2015)

$$\mu_c = (a_1 cos(2\pi t/T_h)+a_2)\ exp(-cos(2\pi(t-a_0)/T_d)) + a_3\mu_h$$

Where:

μ_c : mean for each variable (for each hour and month), μ_h : mean for each month.

t : time, T_h = 12 months, T_d = 24 hours

a_0, a_1, a_2: coefficients (m/s), a_3 : dimensionless coefficient.

The way the 4 coefficients influence the final graph is presented in the following 4 diagrams.

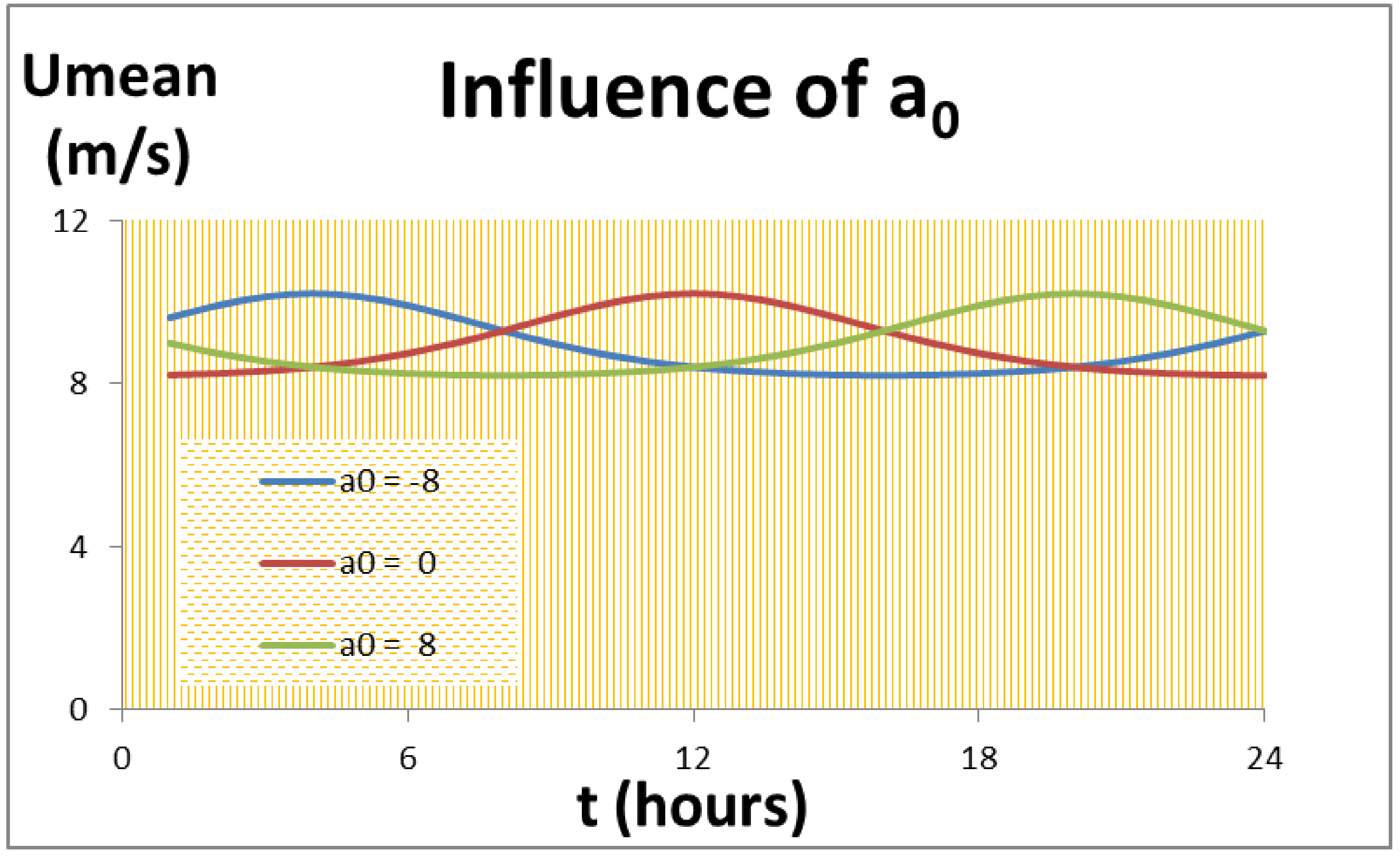


Diagram 3: influence of a_0

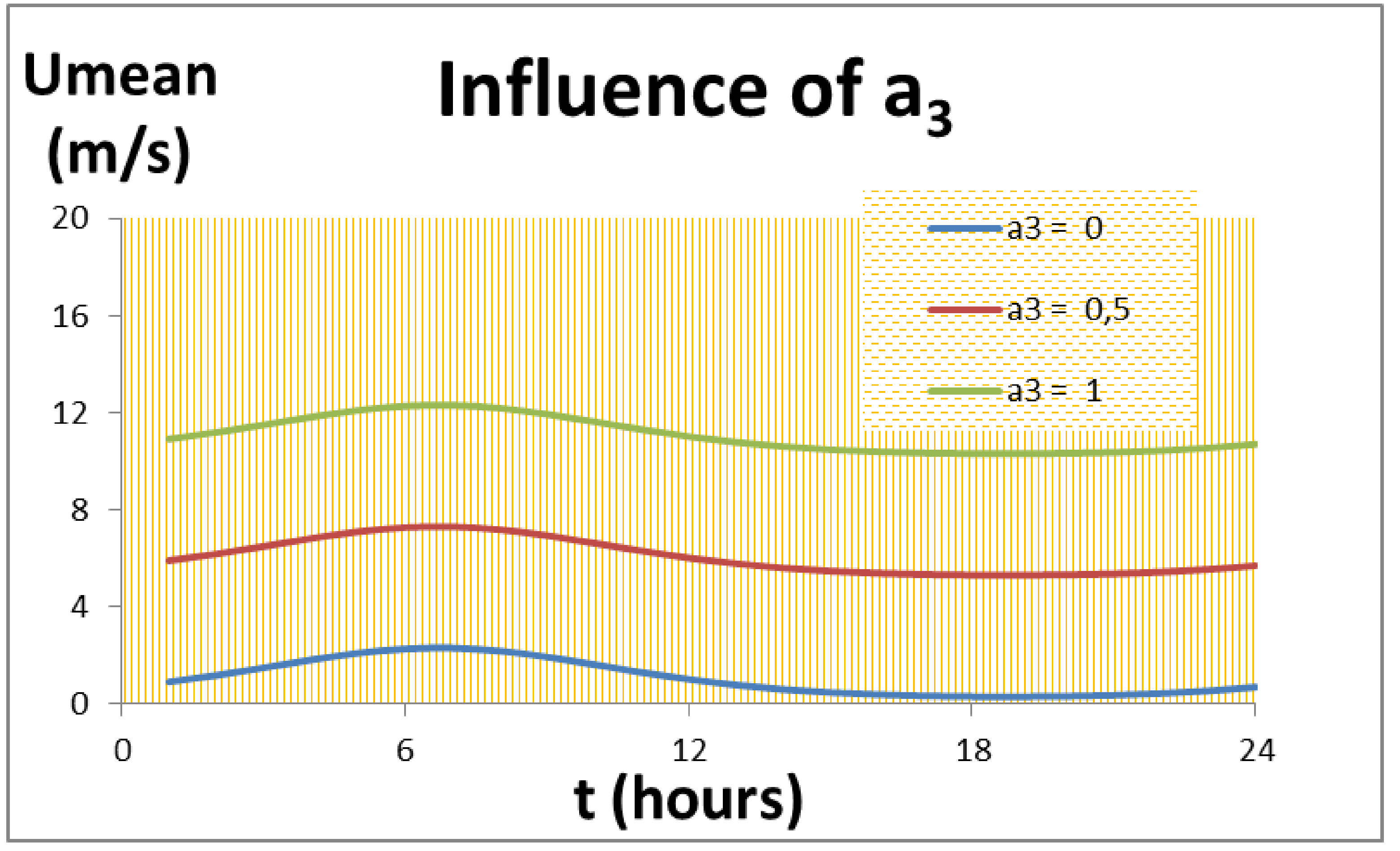


Diagram 4: influence of a_3

4. General concept (2)

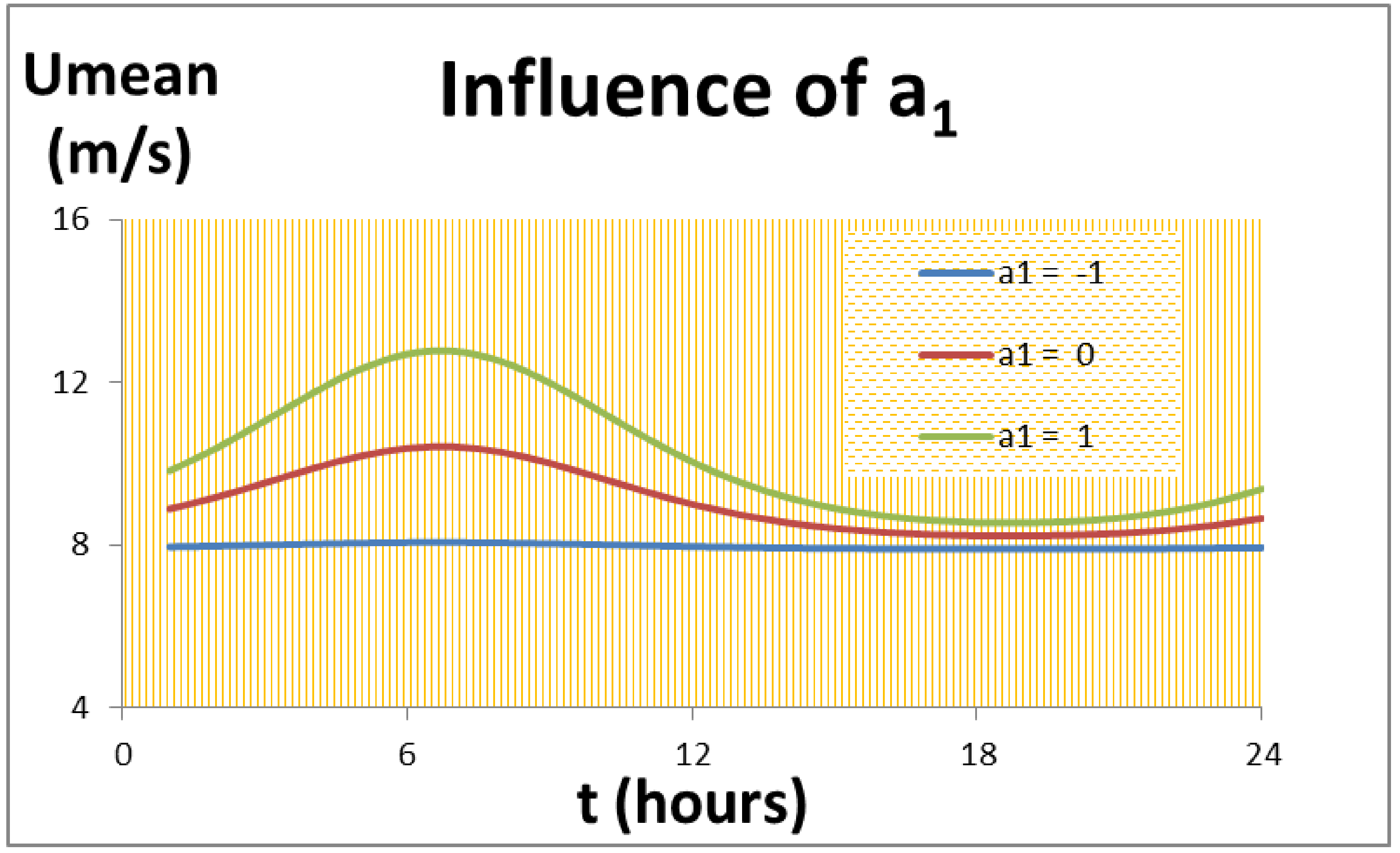


Diagram 5: influence of a_1

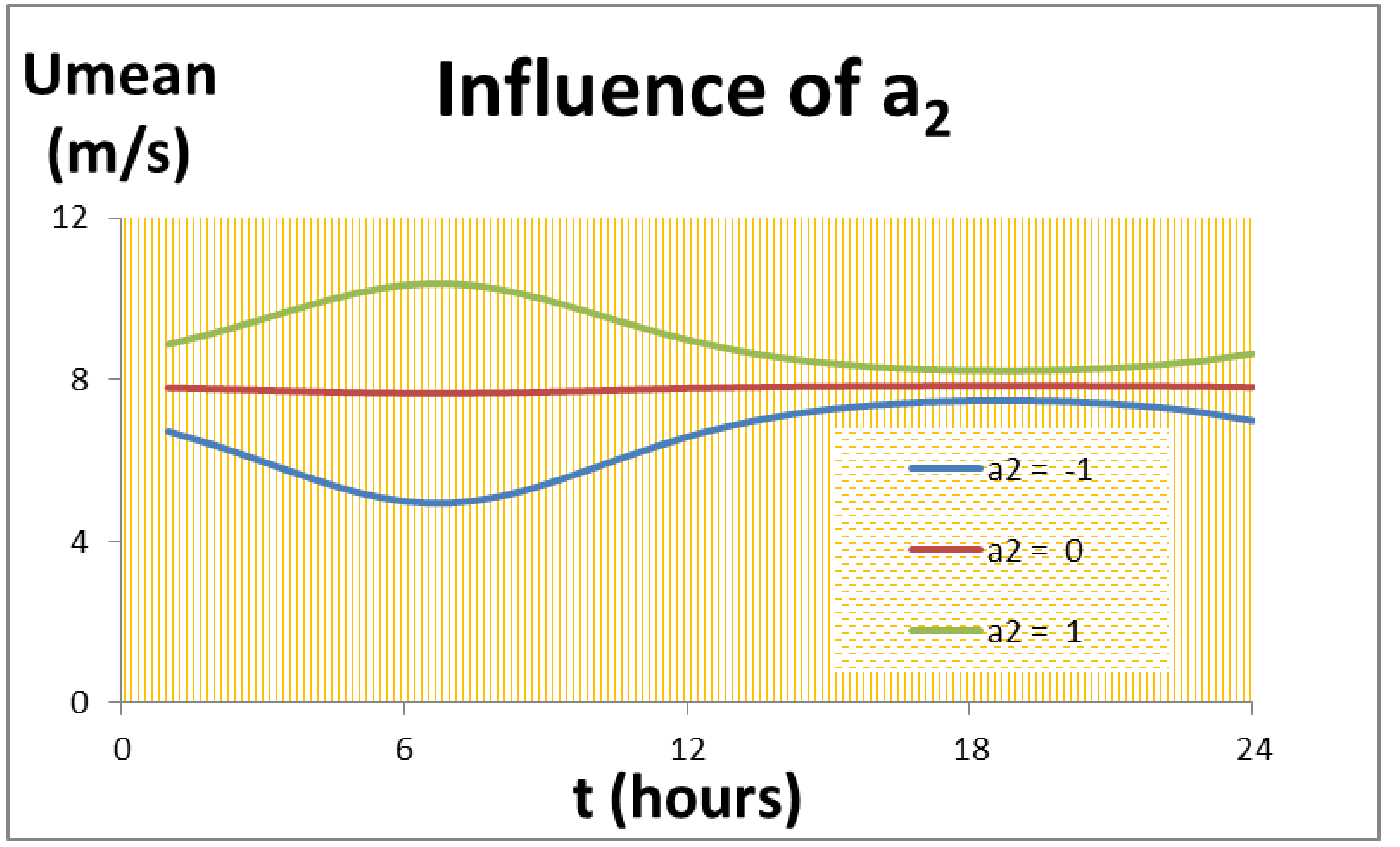


Diagram 6: influence of a_2

Each diagram is made for:
μ_h=10m/s,
as well as for three of the following four values:
a_0=-5.3
a_1=-0.1
a_2=0.94
a_3=0.79

- ❑ a_0 determine the peak hour within the day.
- ❑ a_3 moves the curve up or down.
- ❑ a_1 and a_2 influence the kurtosis and the kind of extreme (high or low value).
- ❑ a_1 is also connected with the monthly cyclostationarity. A high value of a_1 means that wind speed differs importantly from month to month.

5. Measuring the Fluctuation

It should be checked if the ratio Umax/Umin (**Ur**) is great enough in most cases. The average ratio for the 12 months and for all the stations is calculated. Ur is greater than 1.5 in most stations, while sometimes it even exceeds 3.

(However, in stations located northern than +55 degrees and during winter, fluctuation is not very apparent)

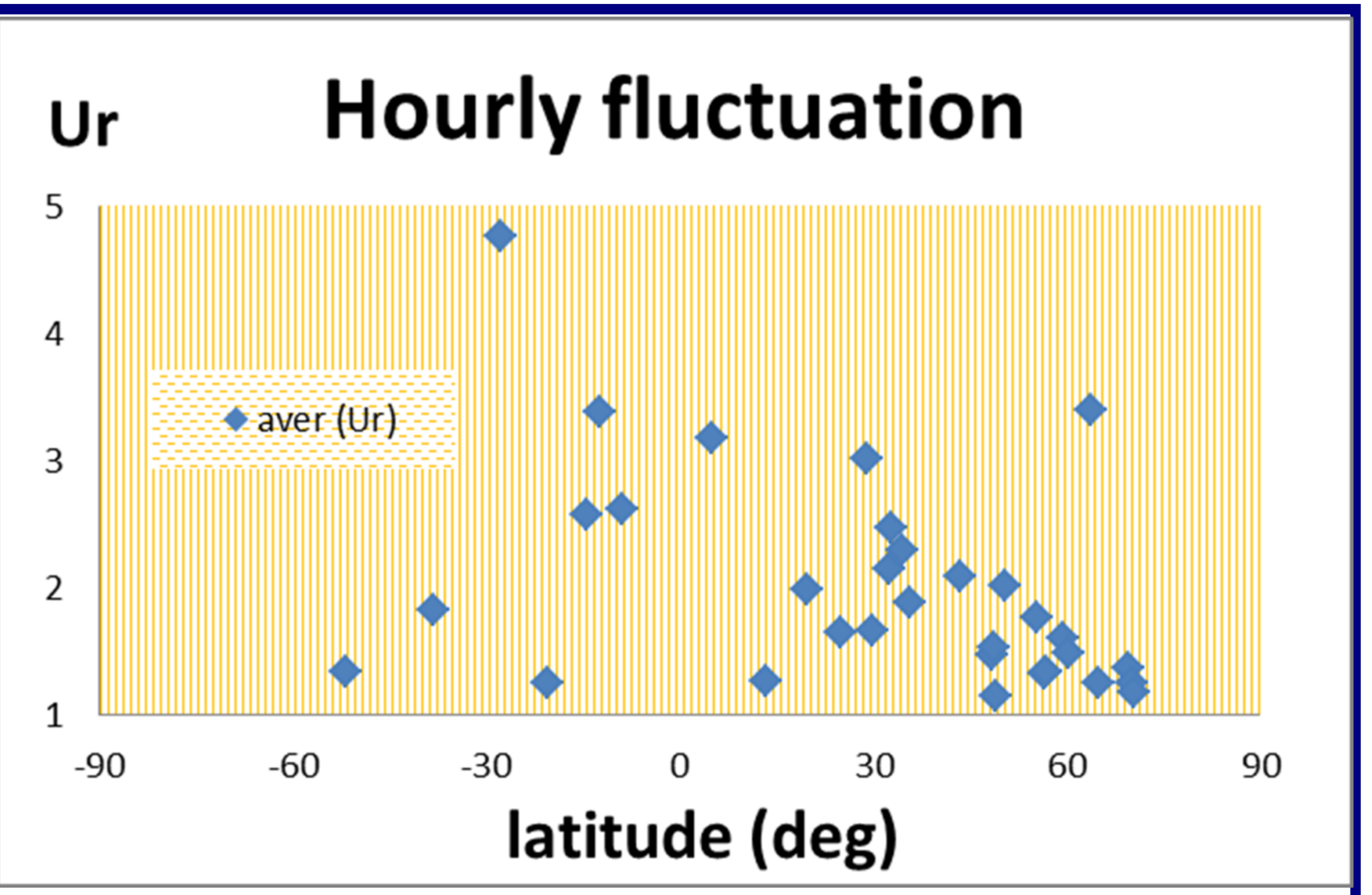


Diagram 7: average ratio Umax/Umin for each station.

6. Fitting quality (1)

The average correlation coefficient r for all months is usually around 0.95.
(However, in the stations located northern than 55 degrees and during winter, the correlation coefficient is underestimated)

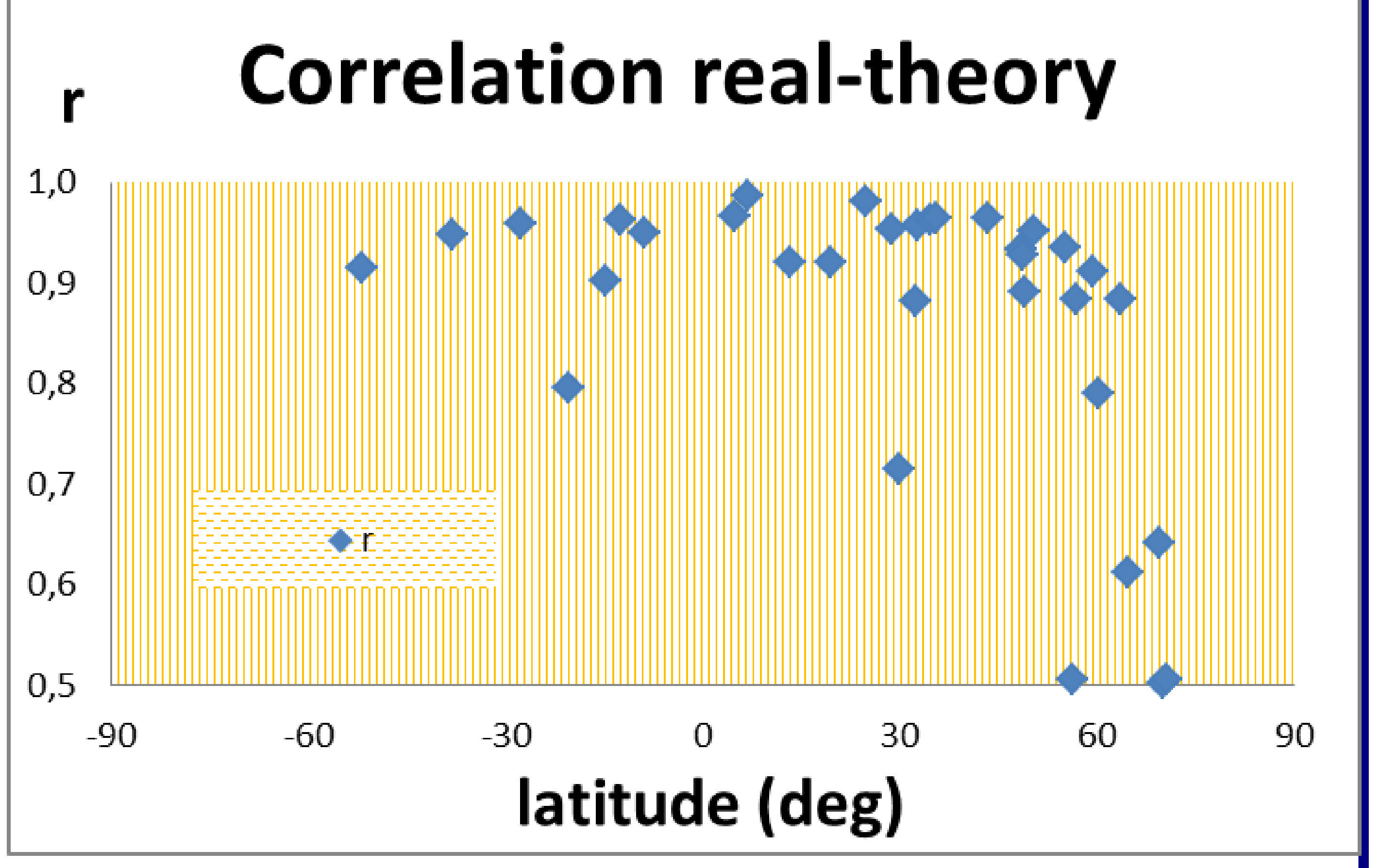
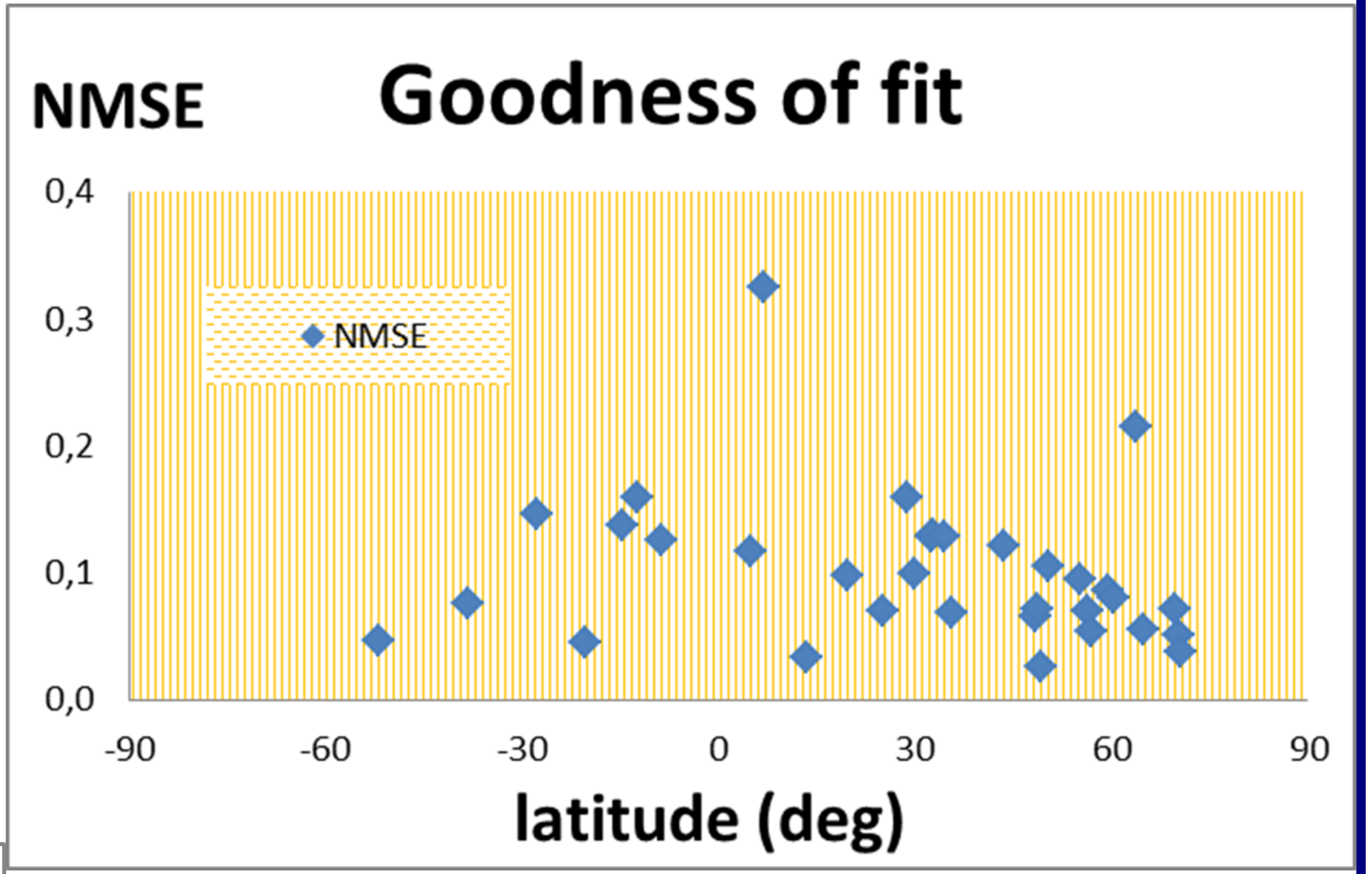


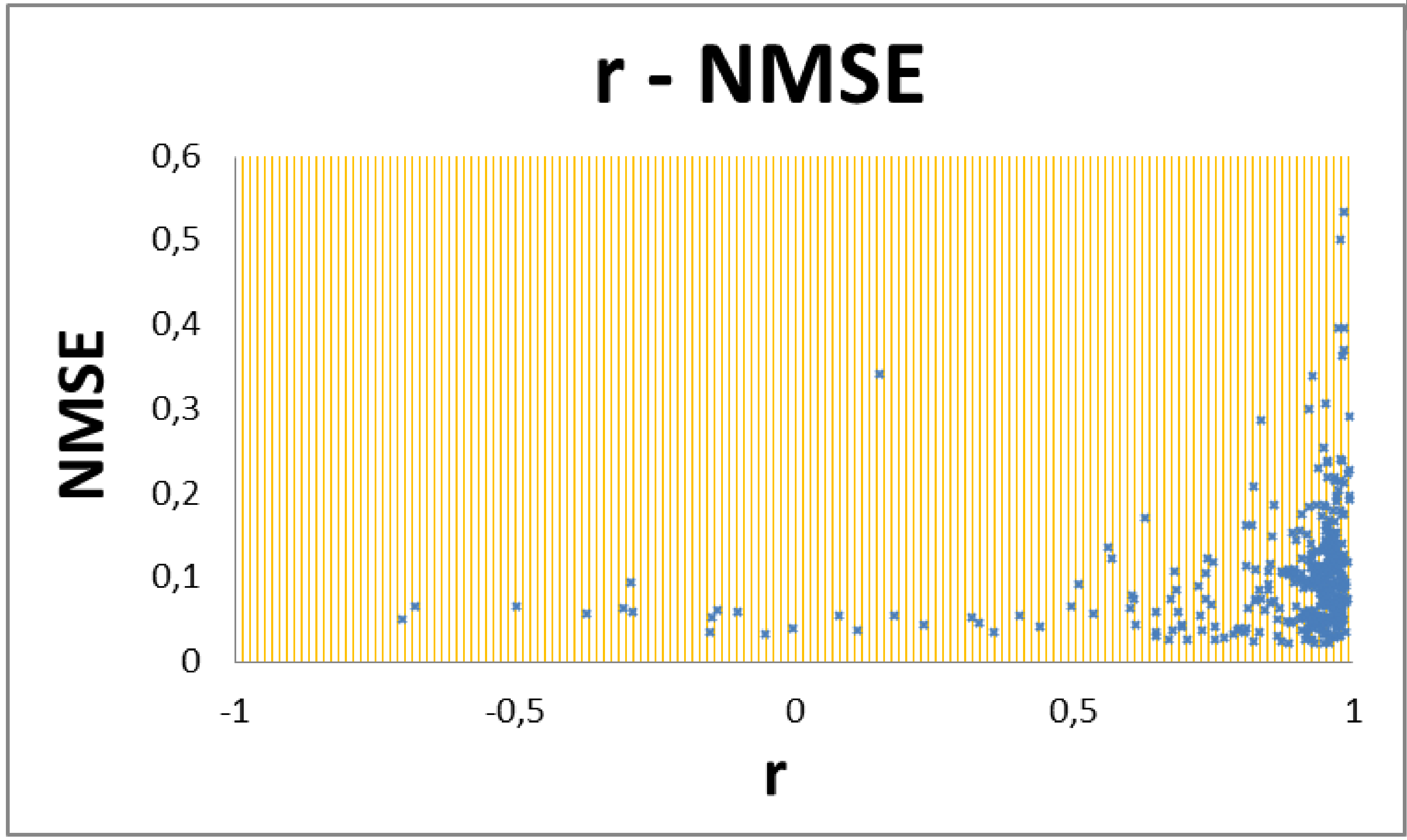
Diagram 8: average correlation coefficient for each station.

6. Fitting quality (2)

As for the Normalised Mean Square Error (NMSE), it is also excellent, being less than 0.20 for almost all cases and generally around 0.1.

Diagram 9 (right): average NMSE for each station.





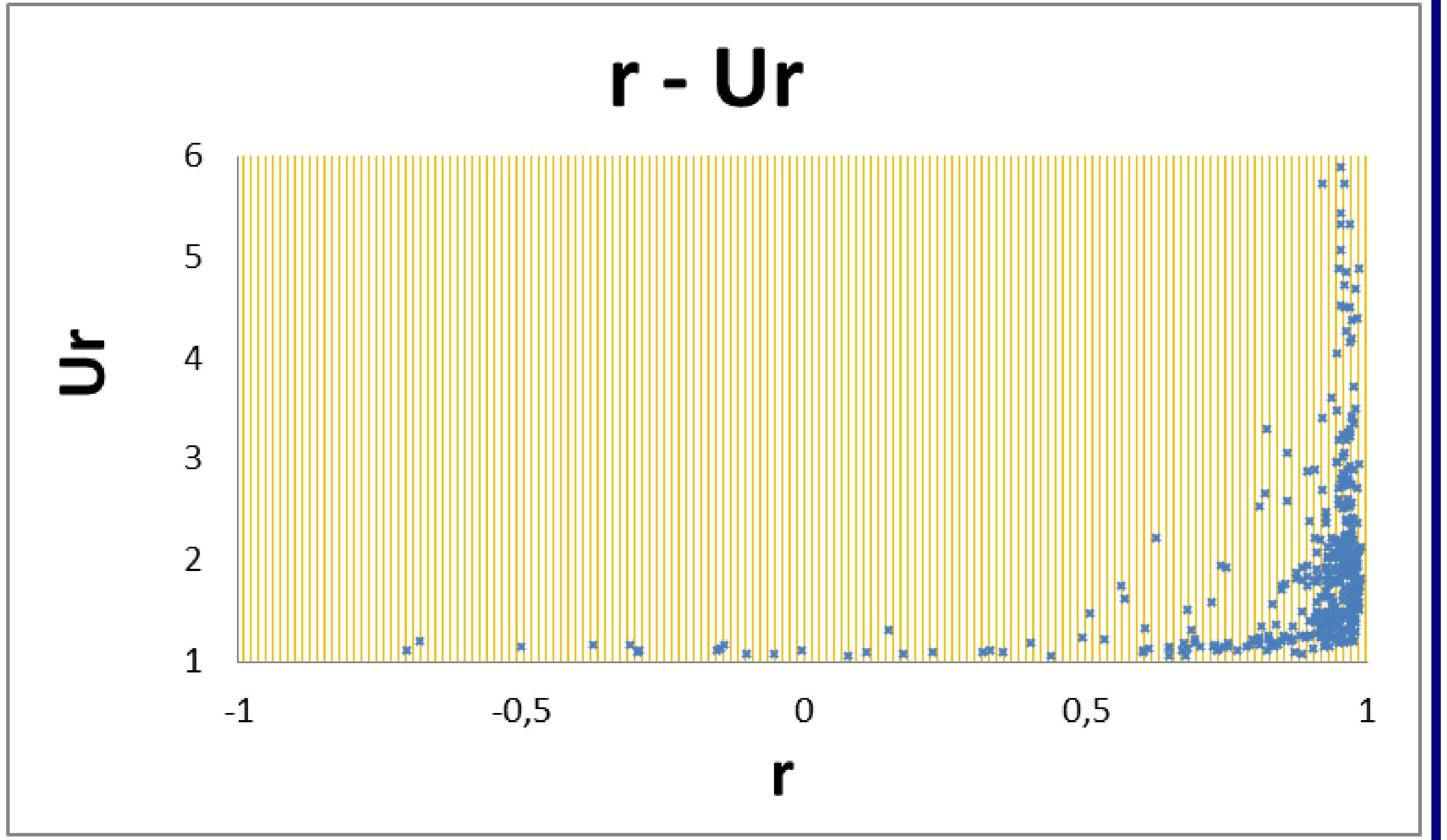
It would be really interesting to correlate NMSE - r for each station and each month.

Generally:

- ✓ When r<0.9, then NMSE<0.15
- ✓ When NMSE>0.15, then r>0.9
- ✓ **Usually, r>0.9 and NMSE<0.2**

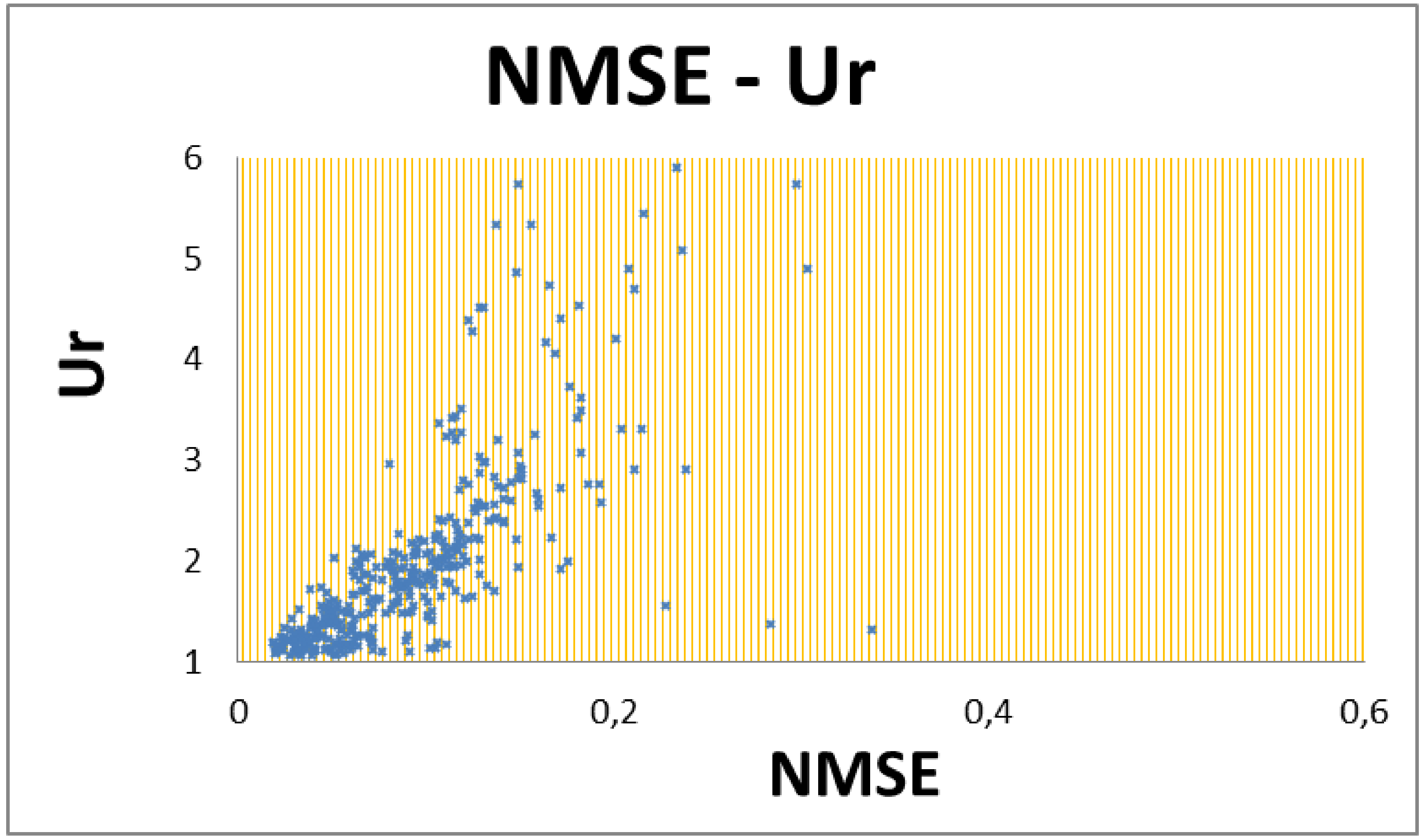
Diagram 10 (left): NMSE in relation with r, for each station and month.

6. Fitting quality (3)



- ✓ When Ur is high, r is always close to 1.
- ✓ When Ur is low, r can sometimes be low.

Diagram 11 (right): r - Ur for each station and each month.



- ✓ When Ur is high, NMSE is generally high.
- ✓ When Ur is low, NMSE is generally low.

Diagram 12 (left): NMSE - Ur for each station and each month.

7. Fitting examples (1)

Three stations are selected to be exposed.

- Station No 1963 : the station with the highest r.
- Station No 634: the station with the lowest NMSE.
- Station No 2221: the station with the highest Ur.

2 diagrams are presented (best and worst month). Each diagram contains 2 graphs:

1) Real distribution.

2) Theoretical curve.

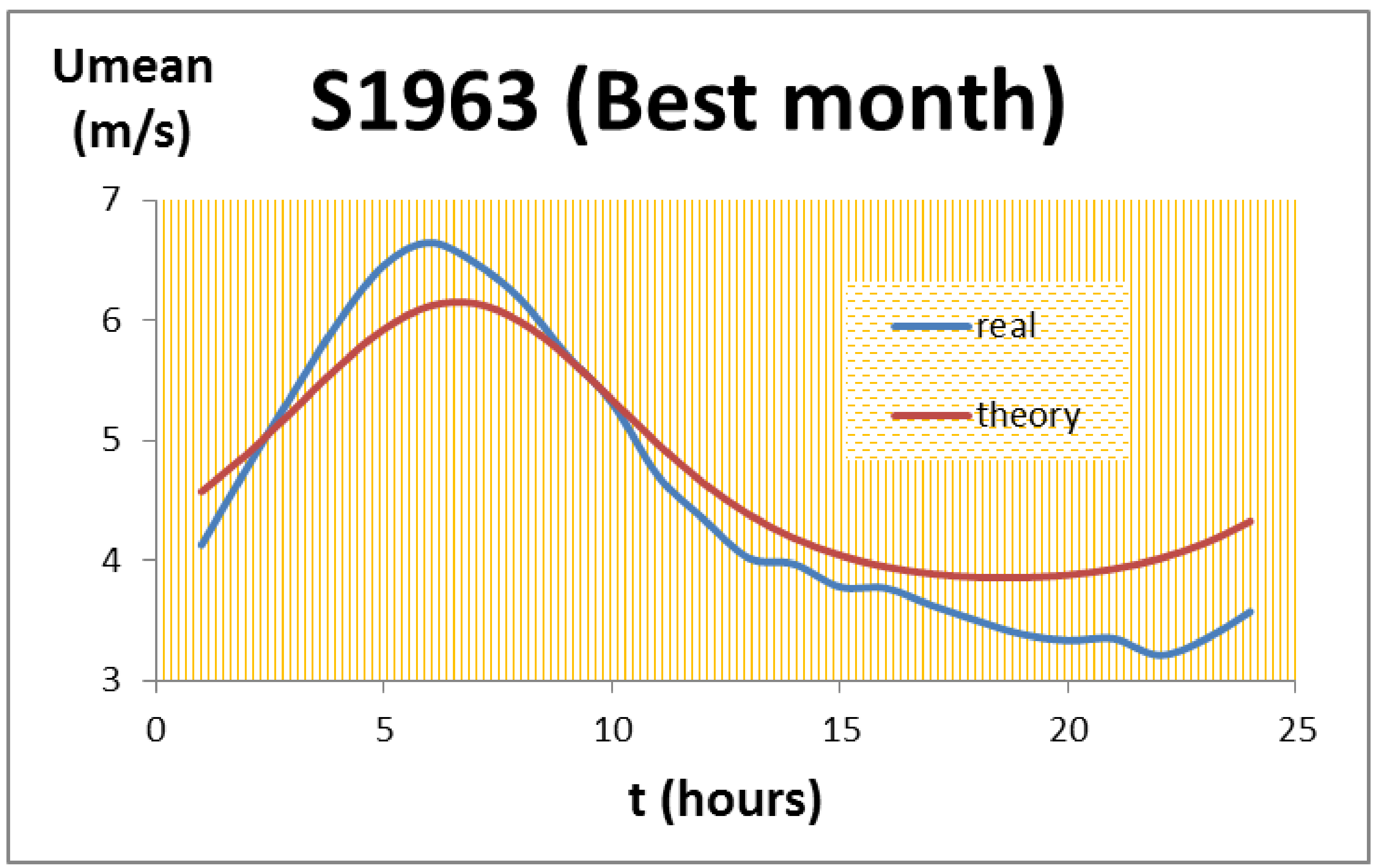


Diagram 13: station 1963 (best month).

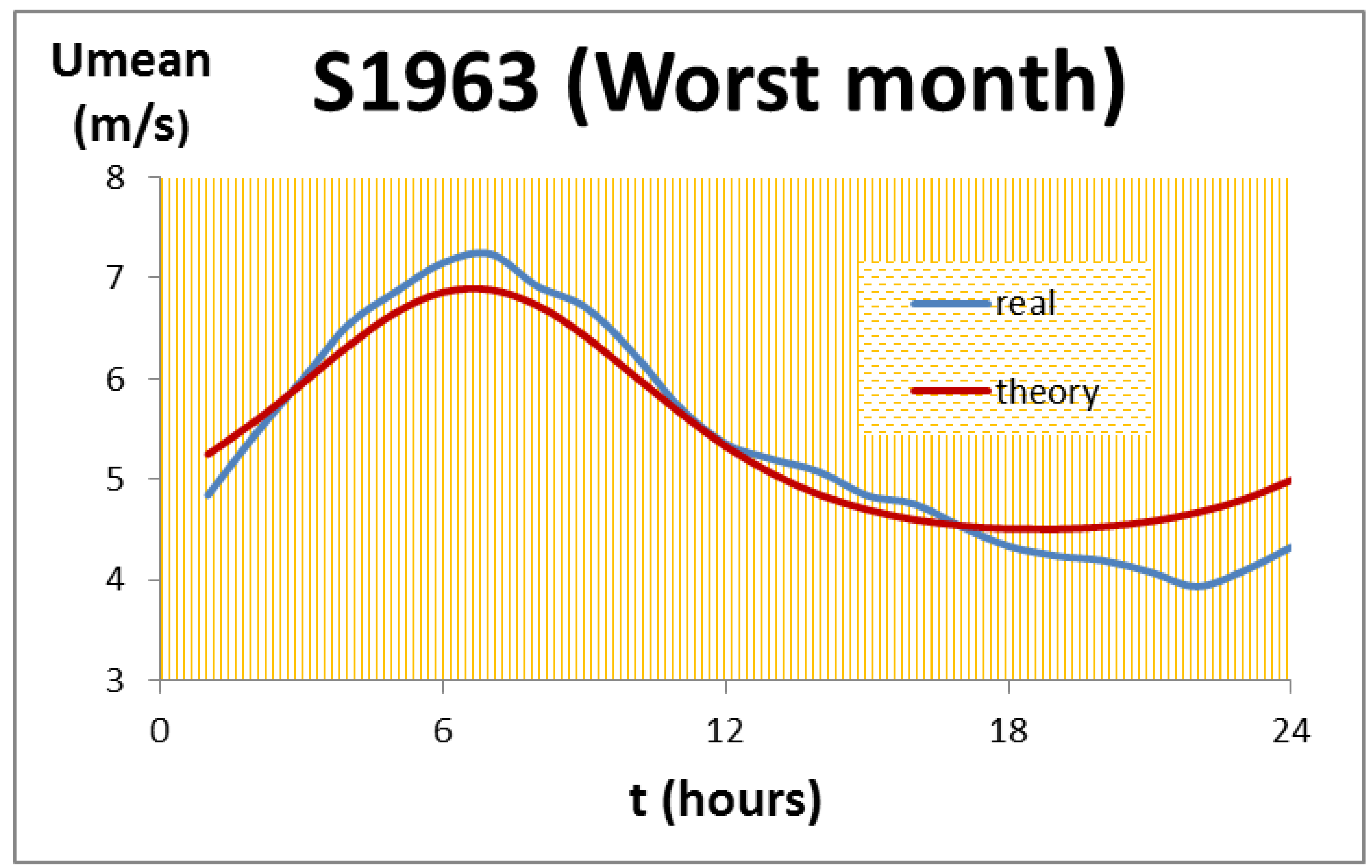


Diagram 14: station 1963 (worst month).

7. Fitting examples (2)

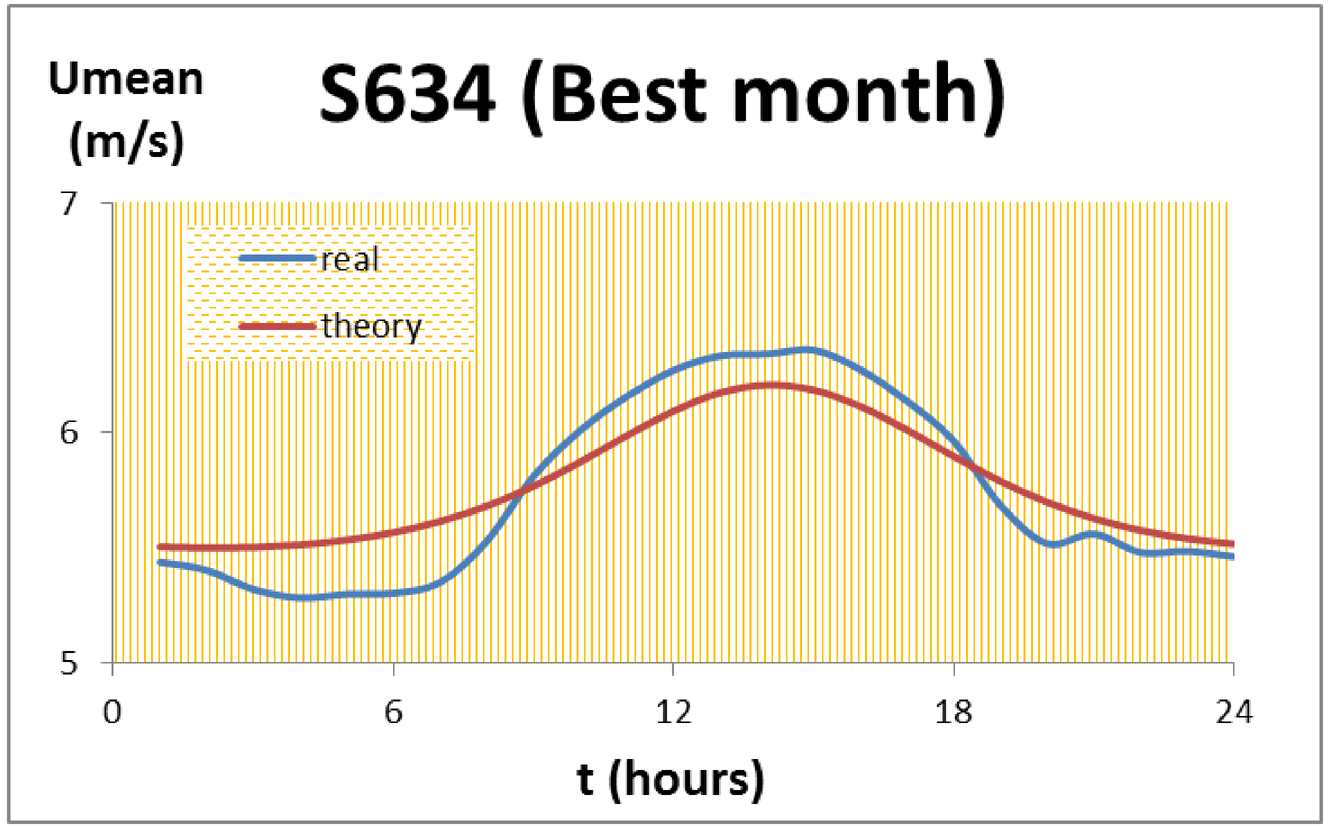


Diagram 15: station 634 (best month).

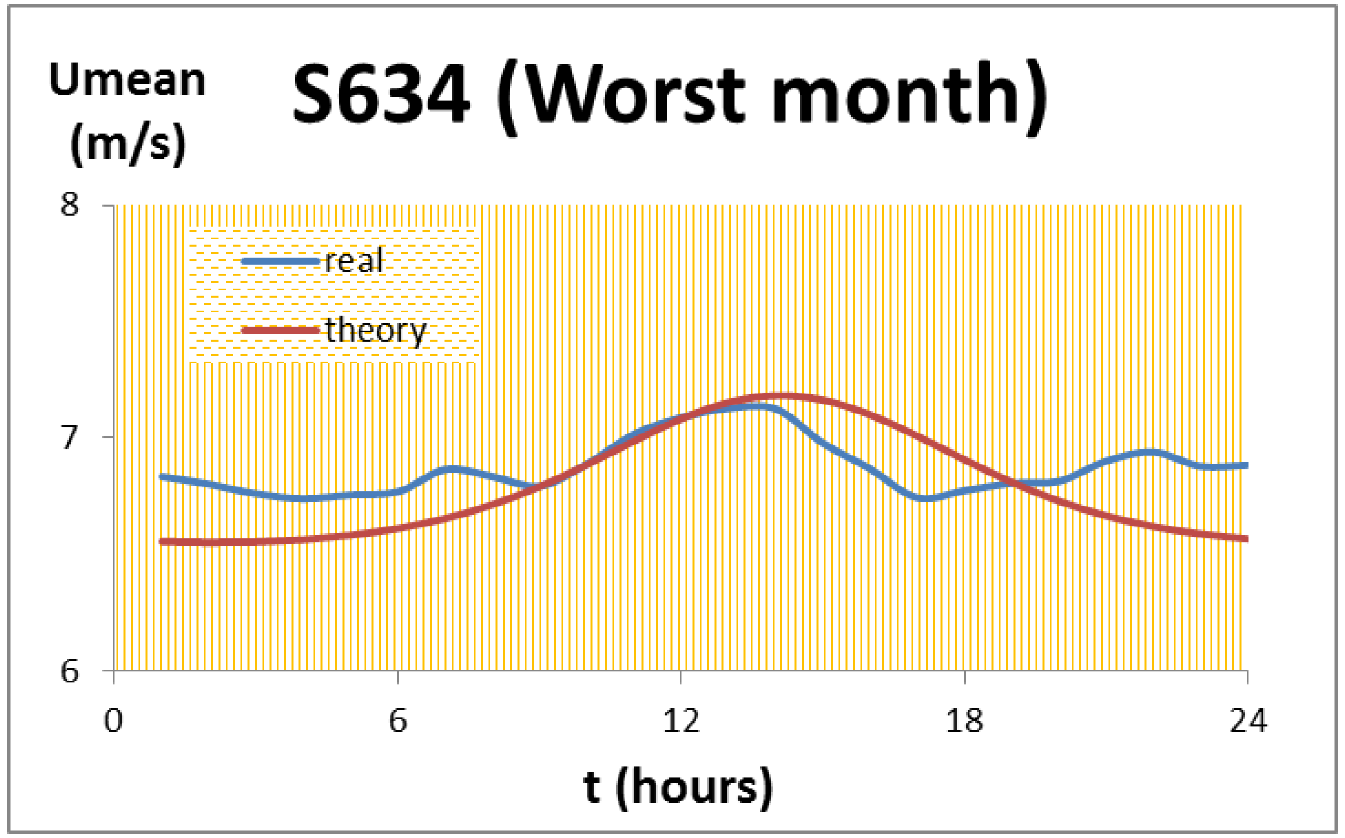


Diagram 16: station 634 (worst month).

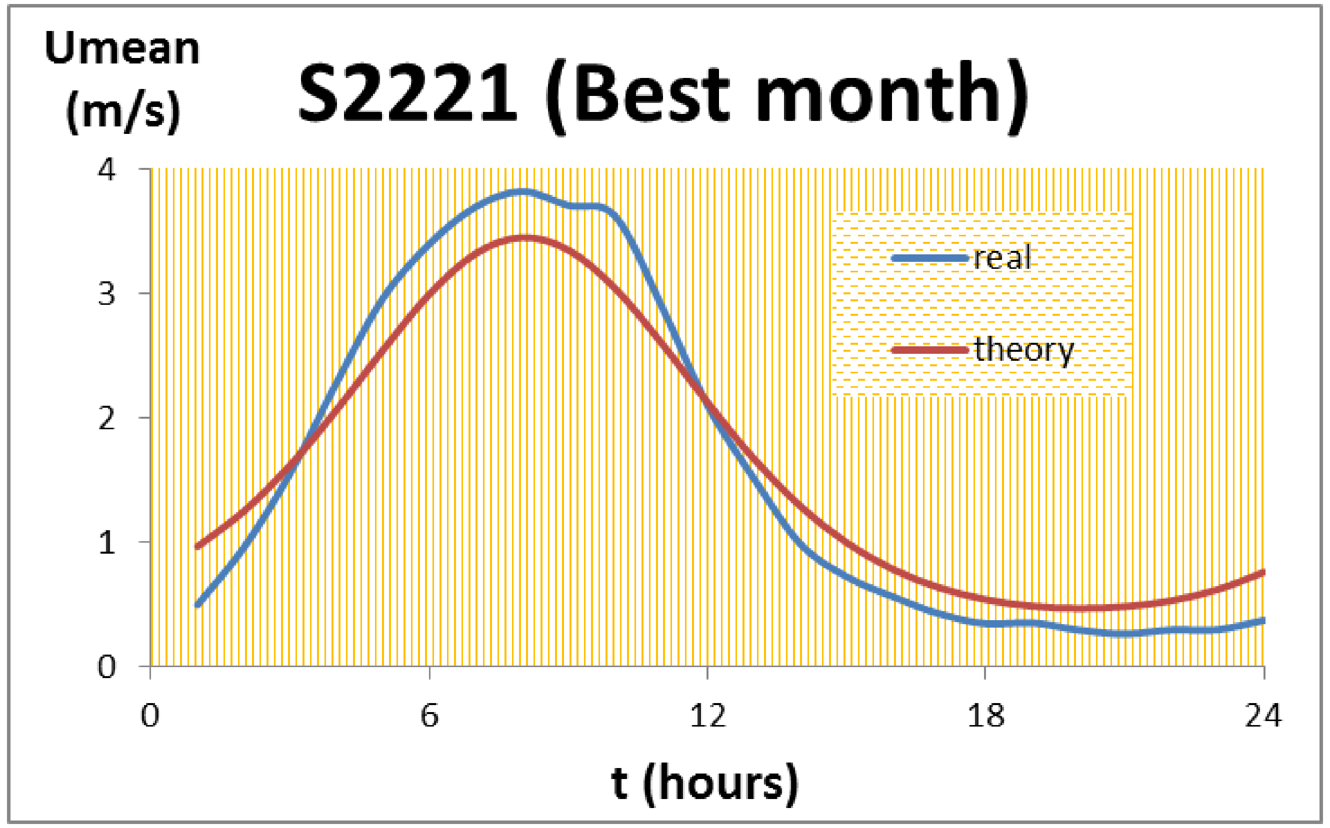


Diagram 17: station 2221 (best month).

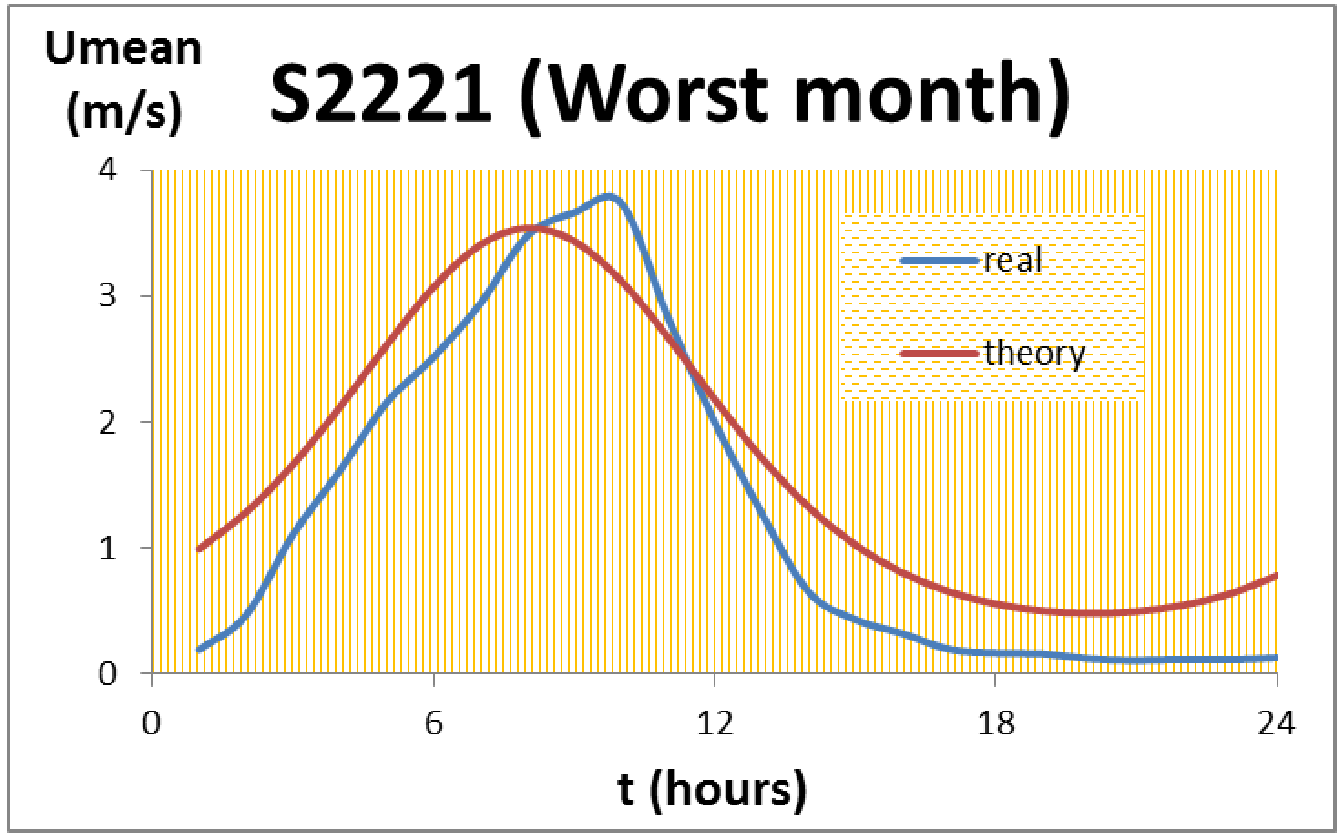


Diagram 18: station 2221 (worst month).

8. General results

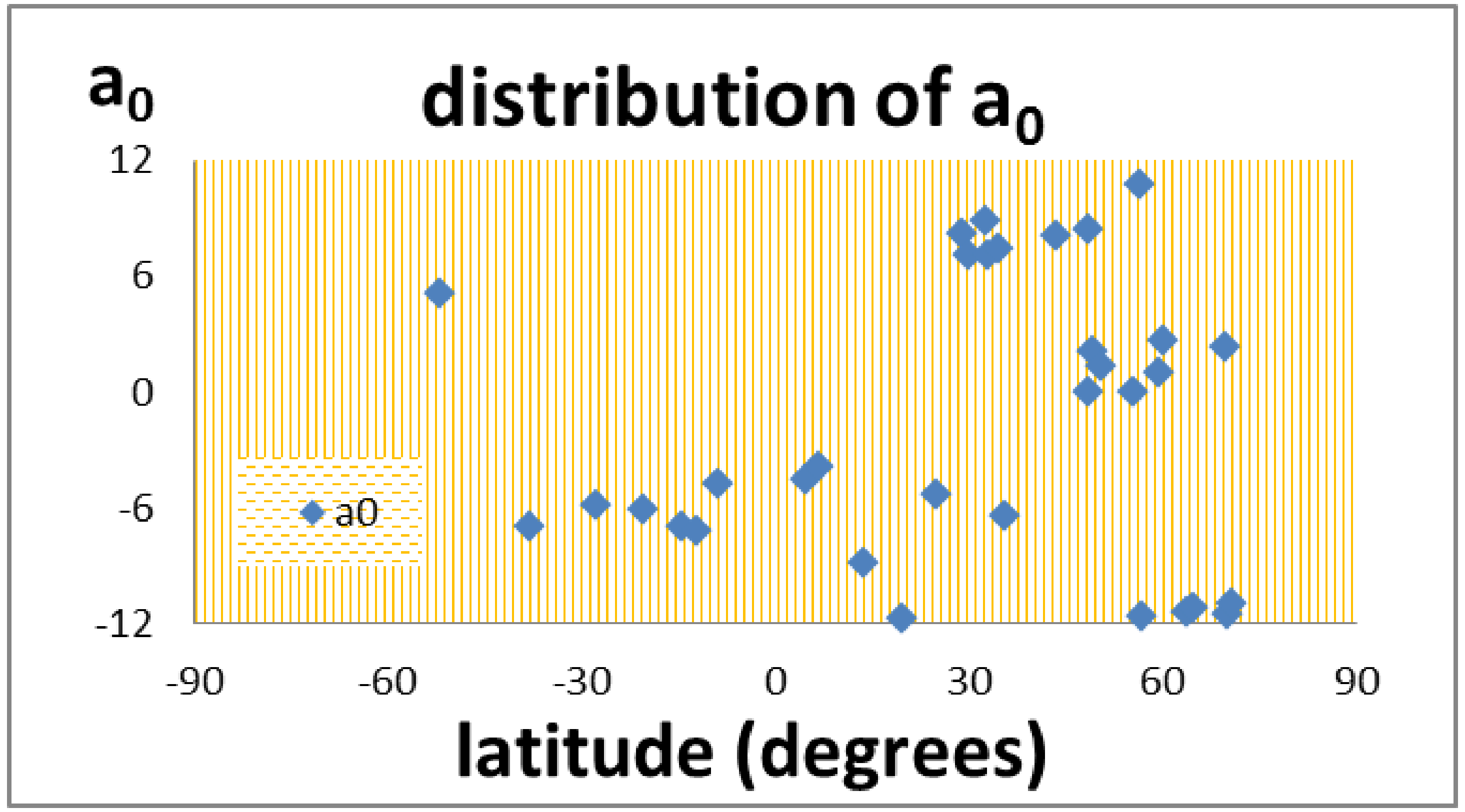


Diagram 19: distribution of coefficient a_0

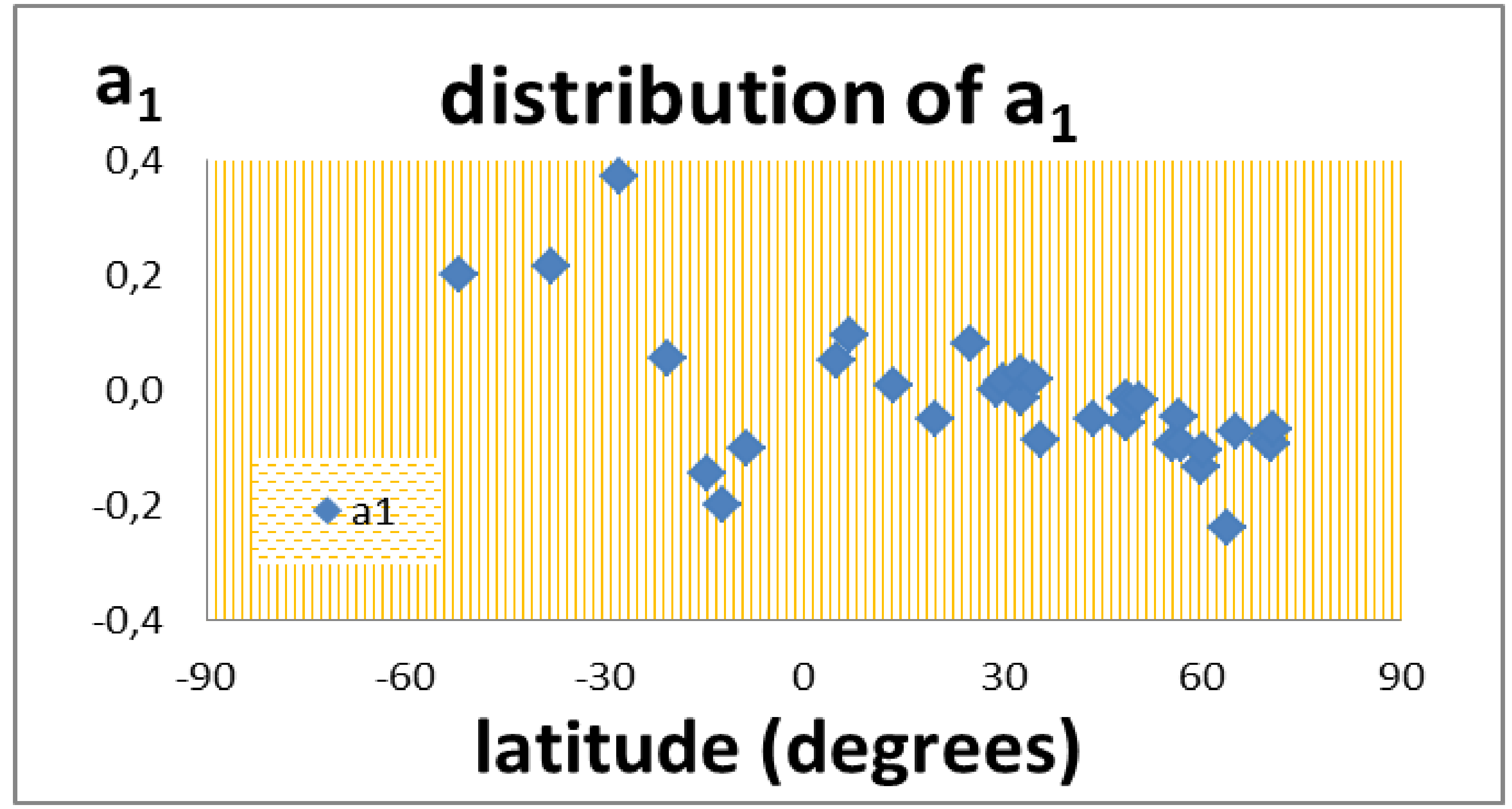


Diagram 20: distribution of coefficient a_1

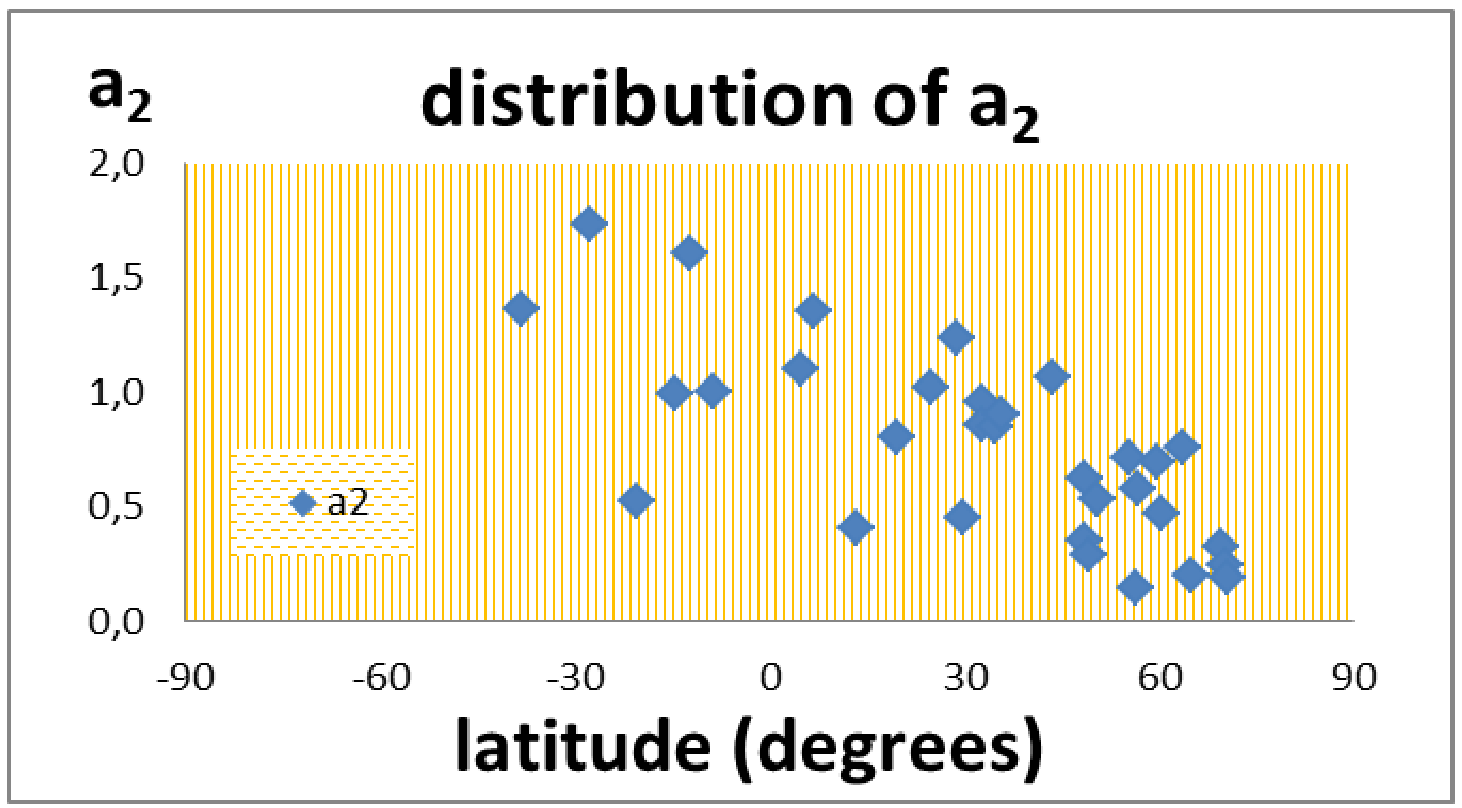


Diagram 21: distribution of coefficient a_2

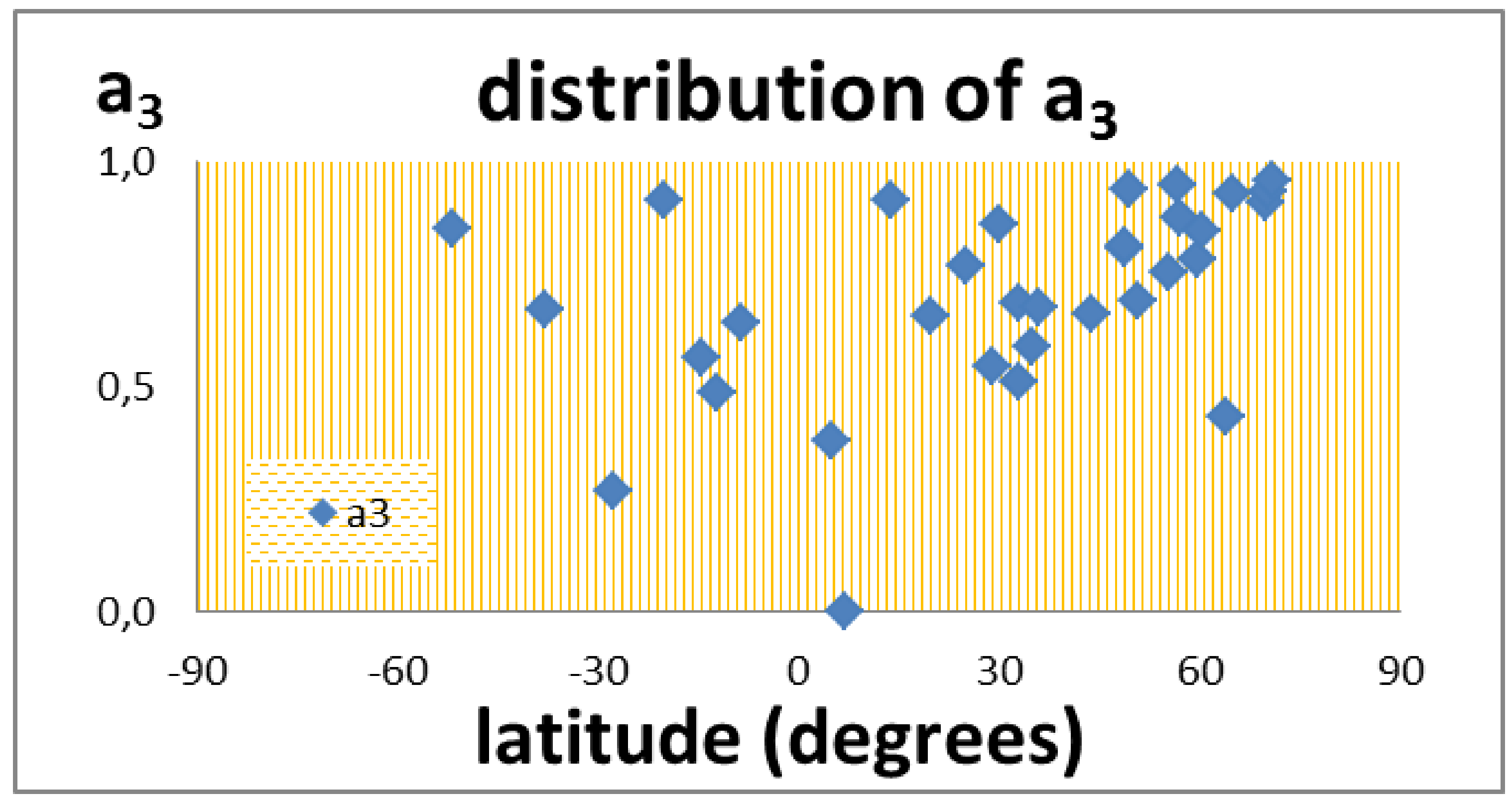


Diagram 22: distribution of coefficient a_3

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