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Wind speed interpolation for hydrological modeling in complex topography area

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Numerical Computations:
Theory and Algorithms
The 2nd International Conference and Summer School

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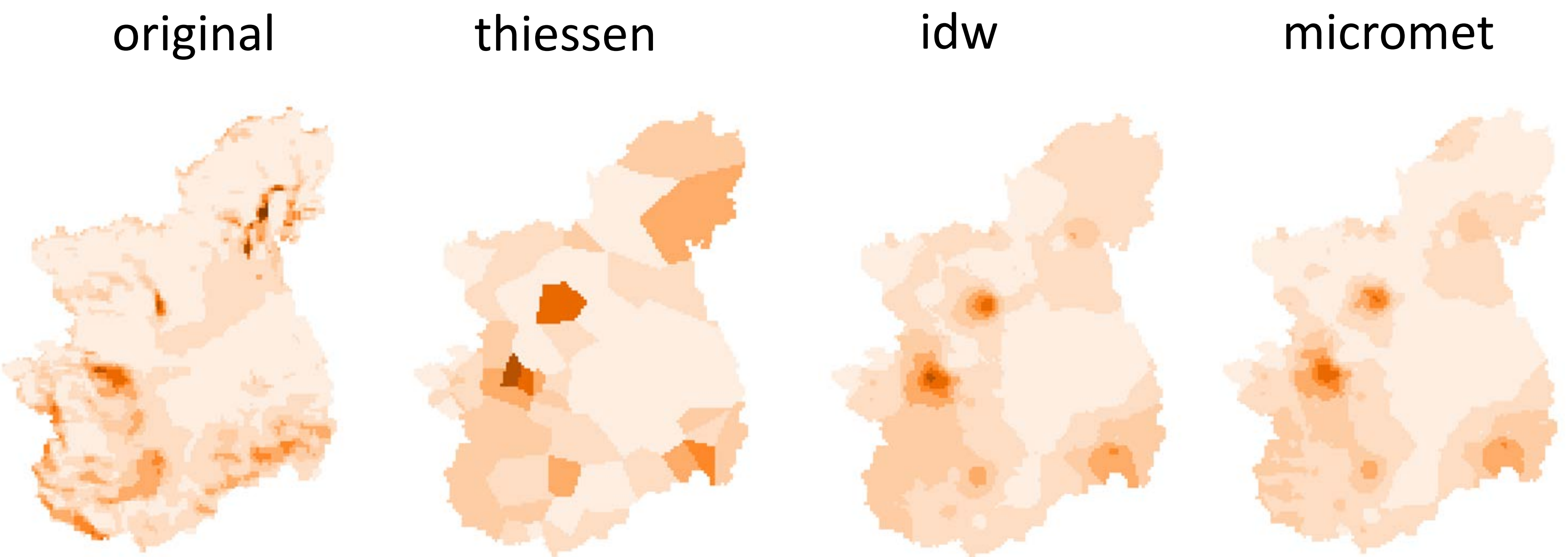
19 – 25 June 2016
Club Med Resort "Napitia"
Pizzo Calabro, Calabria, Italy

OBJECTIVE

Verify a proper method for spatial interpolation of local wind speed measurements in complex topography areas



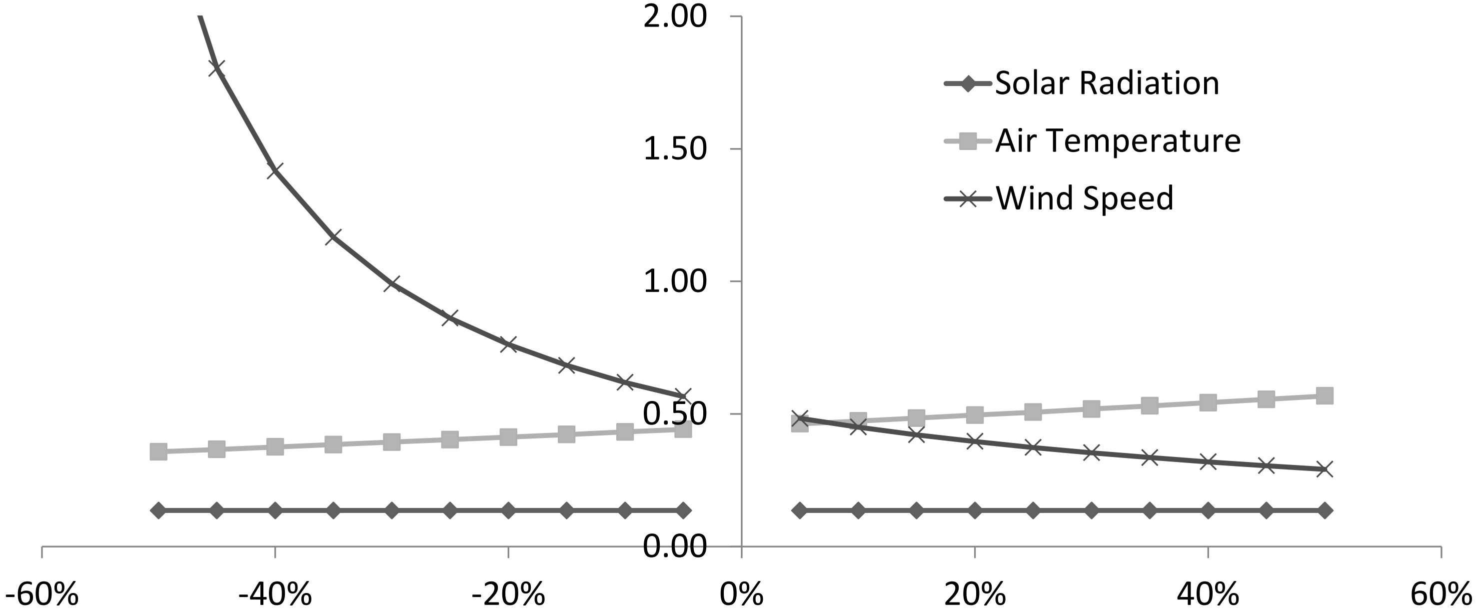
INTRODUCTION

windspeed and evapotranspiration

$$S_{V_i} = \frac{\partial ET_{ref}}{\partial V_i} \cdot \frac{V_i}{ET_{ref}}$$

Sensitivity coefficient

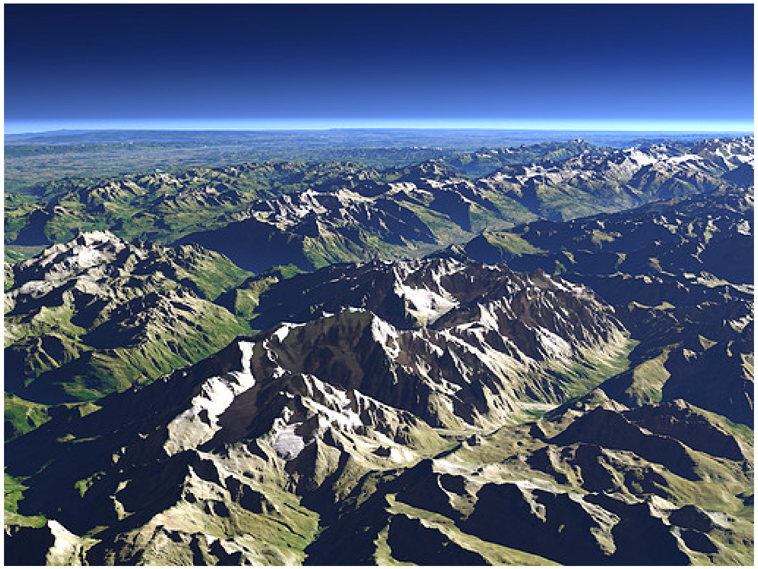
Gong et al., Journal of Hydrology (2006) 329, 620– 629



$$ET_p = \frac{1}{\lambda \rho_w}\left[\frac{\Delta}{\Delta + \gamma\left(1 + \frac{r_c}{r_a}\right)}(R_n - G) + \frac{c_p \rho_a (e_a^* - e_a)}{\left[\Delta + \gamma\left(1 + \frac{r_{c,min}}{r_a}\right)\right] r_a}\right]$$

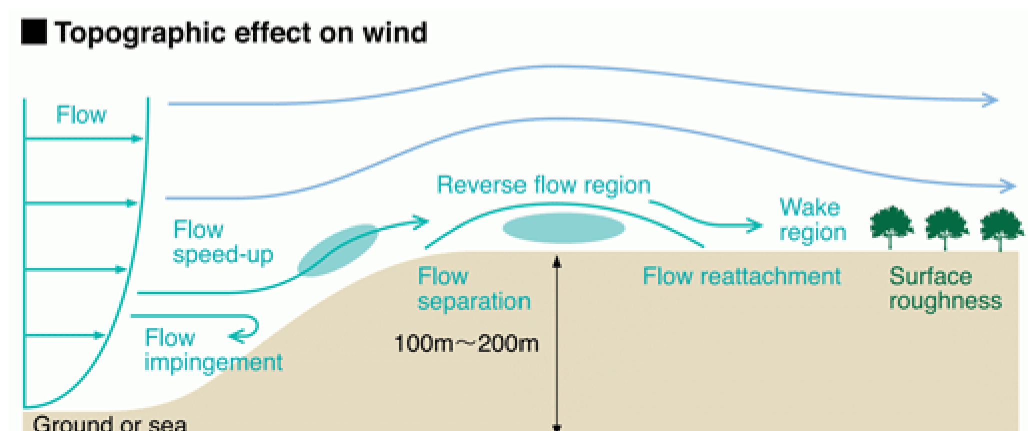
Penman-Monteith

INTRODUCTION
windspeed and complex topography



source: http://earth.imagico.de

View:	Mont Blanc
Location:	Lon 6.564° Lat 45.452°
Altitude:	13 km
Direction:	30°
Camera Angle:	26°



source: http://www.riam-compact.com

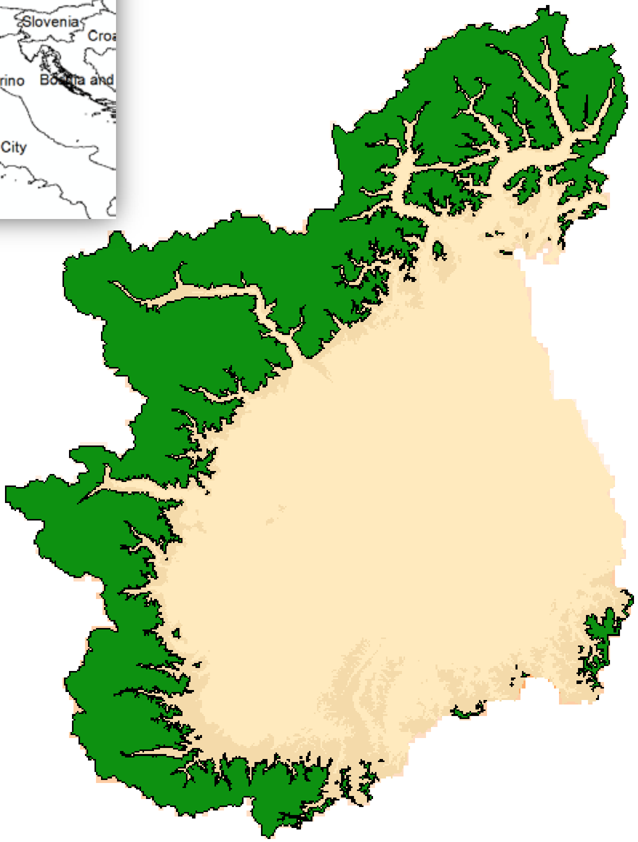
MATERIAL AND METHODS
case study

The upper Po river basin

Total Area: 37200 km^2

MATERIAL AND METHODS

case study

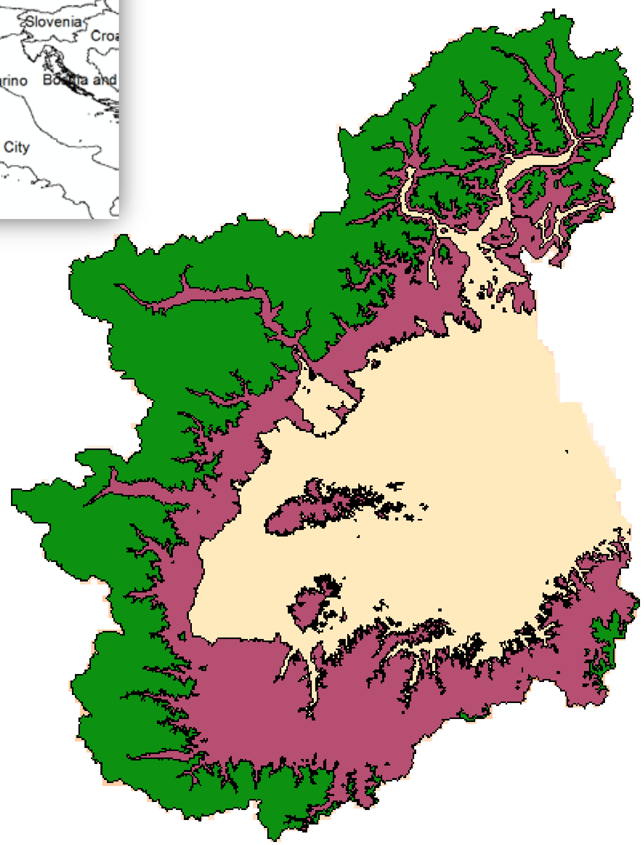


The upper Po river basin

Total Area: 37200 km^2

Area > 1000 m: 13700 km^2, 36.8%

MATERIAL AND METHODS
case study



The upper Po river basin

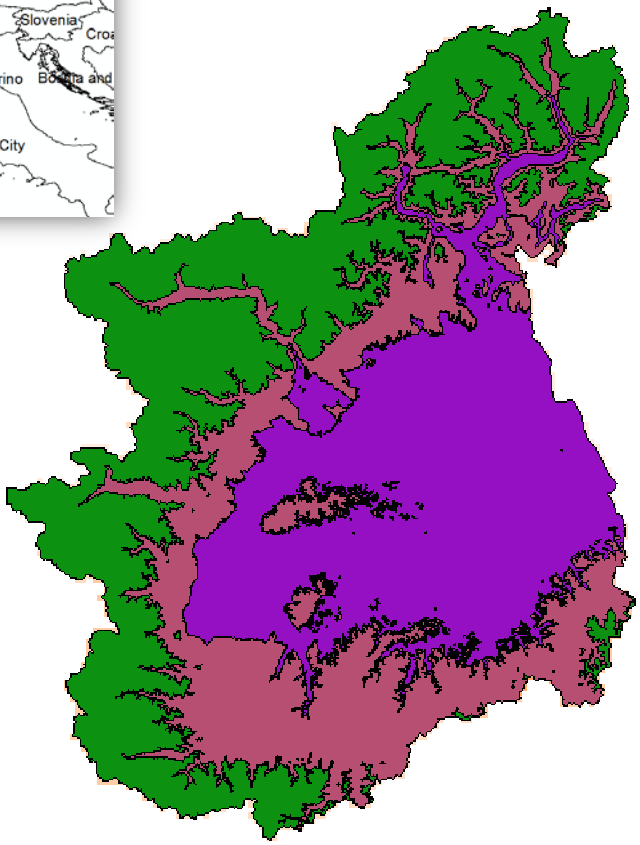
Total Area: 37200 km^2

Area > 1000 m: 13700 km^2, 36.8%

300 m < Area < 1000 m: 10800 km^2, 29%

MATERIAL AND METHODS

case study



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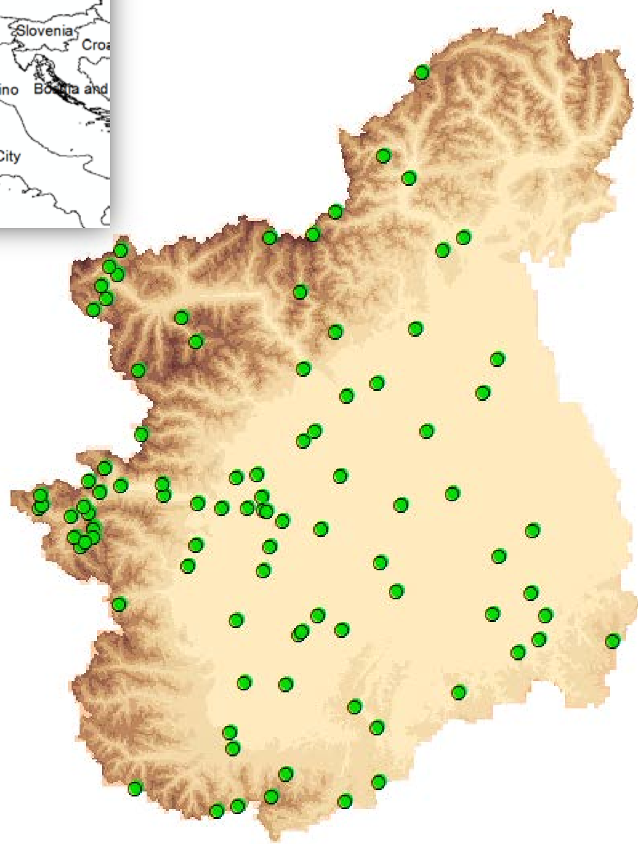
MATERIAL AND METHODS
case study



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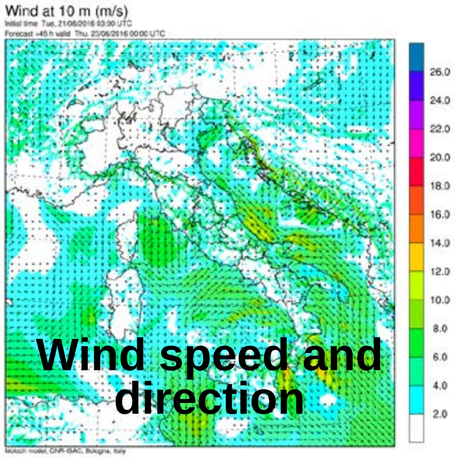
94 stations for wind speed and direction managed by ARPA Piemonte

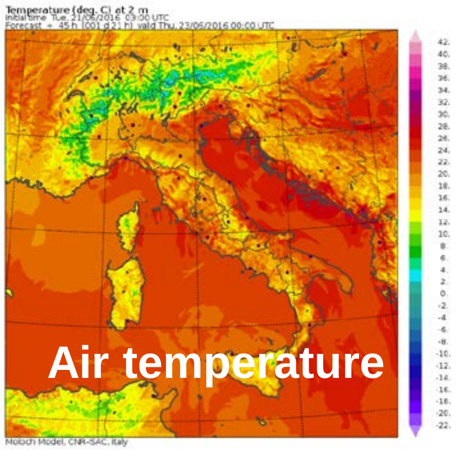
PIEMONTE Arpa Agenzia Regionale per la Protezione Ambientale

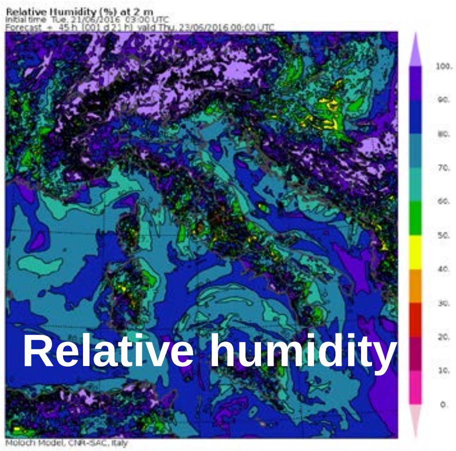
MATERIAL AND METHODS
reference dataset

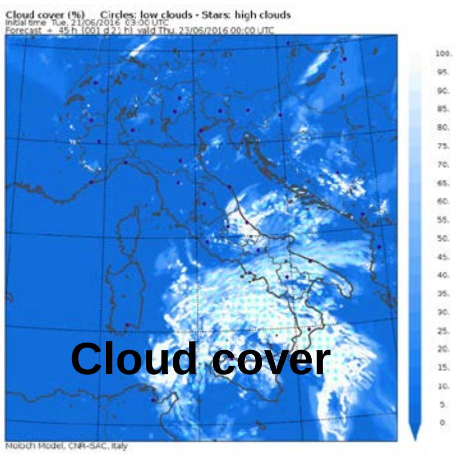
http://www.isac.cnr.it
MOLOCH model 1.5 km resolution

3 months of hourly maps

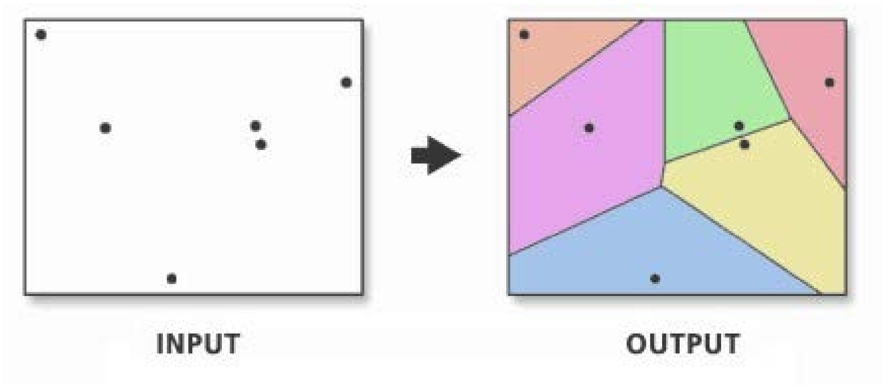


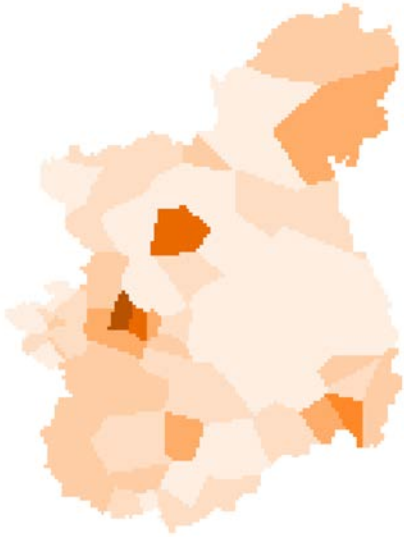




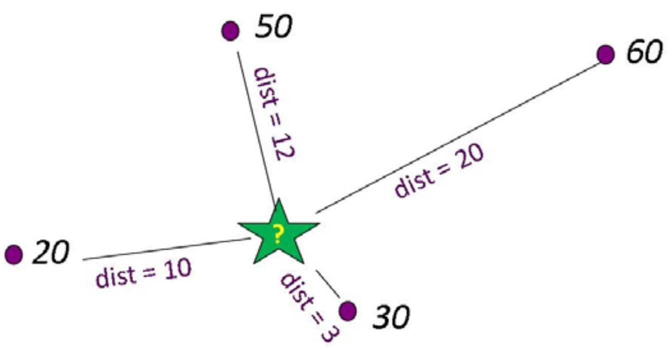


Thiessen polygons (Nearest neighbor)





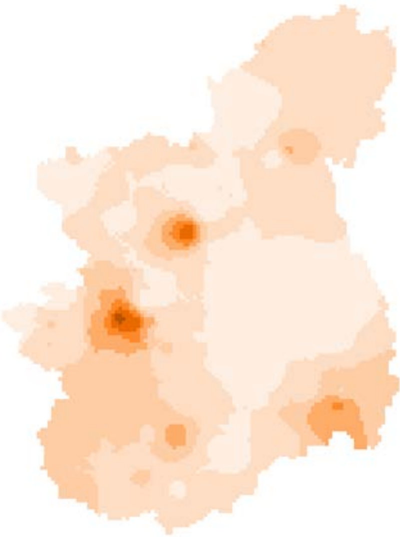
Inverse Distance Weighting (IDW)



$? = \sum Z_i / d^n_{ij} \; / \; \sum 1 / d^n_{ij}$

? = (50/12) + (60/20) + (30/3) + (20/10) / (1/12 + 1/20 + 1/3+ 1/10)

? = 33.8



Micromet (Liston et al., 2006, J. HYDROMETEOROLOGY)

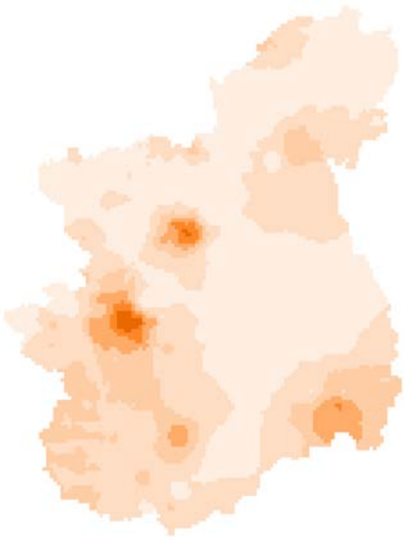
slope weight (0.5)

curvature weight (0.5)

$$W_w = 1 + \gamma_s \Omega_s + \gamma_c \Omega_c$$

slope

curvature



Micromet (Liston et al., 2006, J. HYDROMETEOROLOGY)

1. Wind speed W and direction θ are converted to zonal $\boldsymbol{u}$ and meridional components v:

$$\boldsymbol{u = -W \sin \theta}$$
$$\boldsymbol{v = -W \cos \theta}$$

2. The two components u and v are interpolated using IDW
3. For every cell the u and v components are converted back to wind speed and direction. :

$$\boldsymbol{W = \sqrt{u^2 + v^2}}$$

$$\boldsymbol{\theta = \frac{3\pi}{2} - tan^{-1}\left(\frac{v}{u}\right)}$$

Micromet (Liston et al., 2006, J. HYDROMETEOROLOGY)

4.The topographic curvature Ω_c is computed by defining a length scale η (assume half of wave length of topography) . The curvature is the average of the four local values computed for each of the four cardinal directions, S-N, W-E, SW-NE e NW-SE:

$$\boldsymbol{\Omega_c} = \frac{1}{4}\left[\frac{z - 1/2(z_W + z_E)}{2\eta} + \frac{z - 1/2(z_S + z_N)}{2\eta} + \frac{z - 1/2(z_{SW} + z_{NE})}{2\sqrt{2\eta}} + \frac{z - 1/2(z_{NW} + z_{SE})}{2\sqrt{2\eta}}\right]$$

5.Compute topographic slope in the wind direction Ω_s, where β is the terrain slope and ξ is the aspect

$$\beta = tan^{-1}\left[\left(\frac{\partial z}{\partial x}\right)^2 + \left(\frac{\partial z}{\partial y}\right)^2\right]^{1/2} \quad , \quad \xi = \frac{3\pi}{2} - tan^{-1}\left(\frac{\partial z/\partial y}{\partial z/\partial x}\right)$$

$$\Omega_s = \beta\, cos(\theta - \xi)$$

Micromet (Liston et al., 2006, J. HYDROMETEOROLOGY)

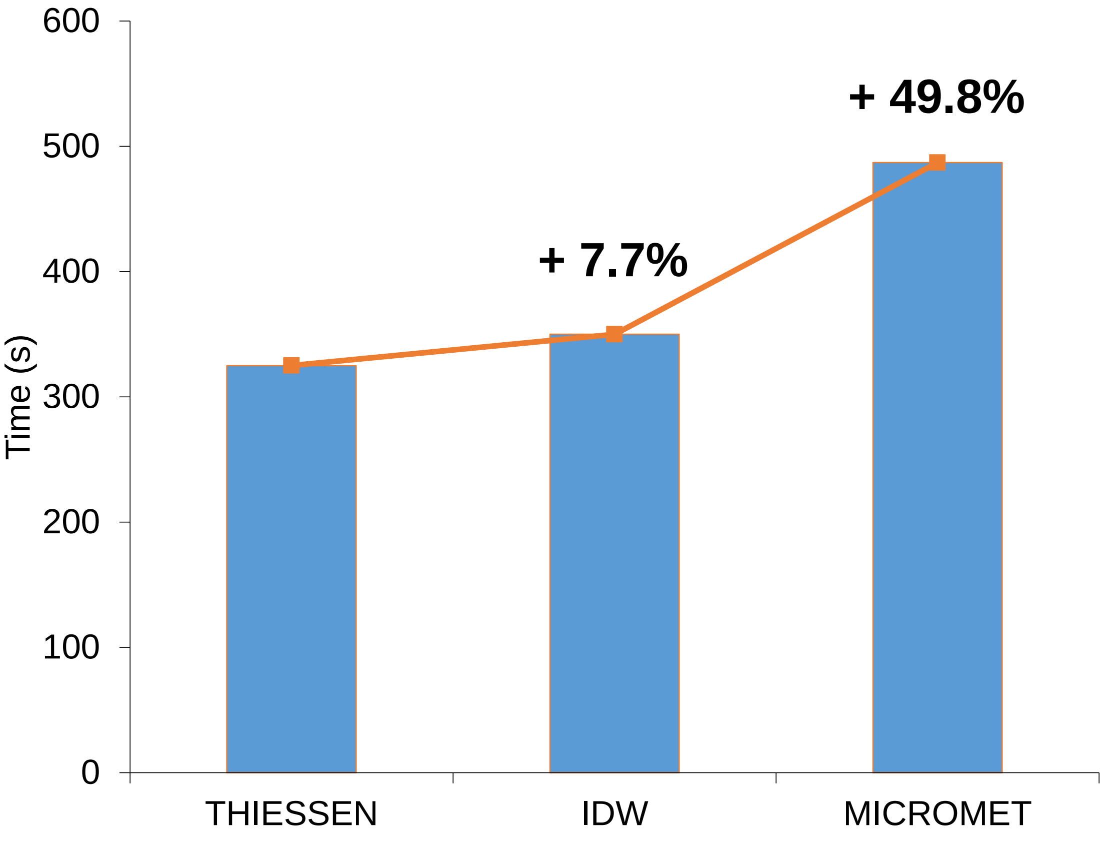
6. The weighting factor to W_w is

$$\boldsymbol{W_w = 1 + \gamma_s \Omega_s + \gamma_c \Omega_c}$$

8. and the final corrected wind speed value W_t is:

$$\boldsymbol{W_t = W_w W}$$

RESULTS
computational time



RESULTS
wind field error

MEAN NRMSE [-]				
	Upper Po	**0-300**	**300-1000**	**> 1000**
Thiessen	0,873	0,447	0,748	1,151
IDW	0,669	0,390	0,595	0,853
MicroMet	0,674	0,414	0,603	0,842

$$NRMSE = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \hat{x}_i)^2}}{\frac{1}{n}\sum_{i=1}^{n}\hat{x}_i}$$

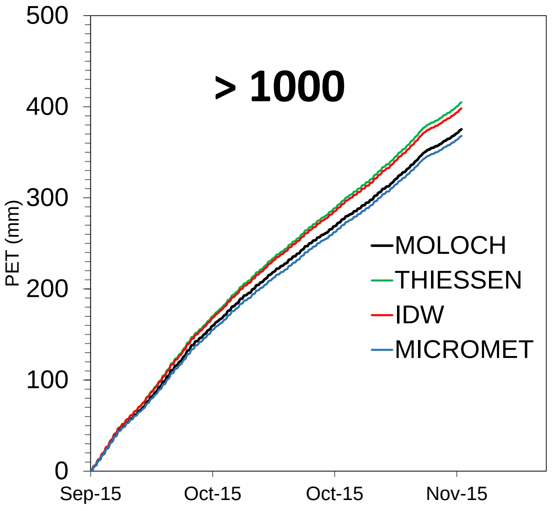
MEAN RBIAS[-]				
	Upper Po	**0-300**	**300-1000**	**> 1000**
Thiessen	0,122	-0,027	0,076	0,290
IDW	0,060	-0,026	0,069	0,161
MicroMet	-0,093	-0,122	-0,104	-0,052

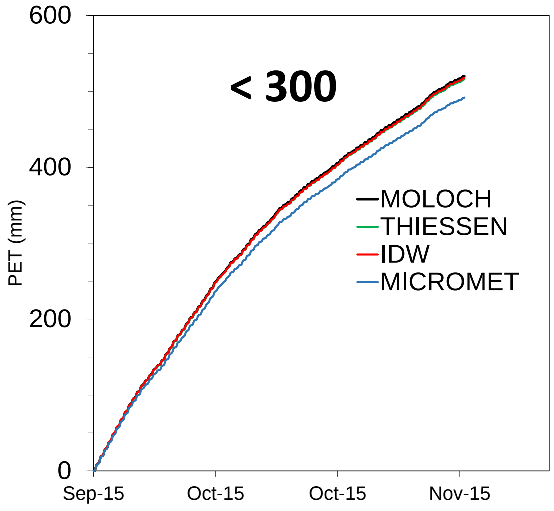
$$RBIAS = \frac{1}{n}\sum_{i=1}^{n}\frac{x_i - \hat{x}_i}{\hat{x}_i}$$

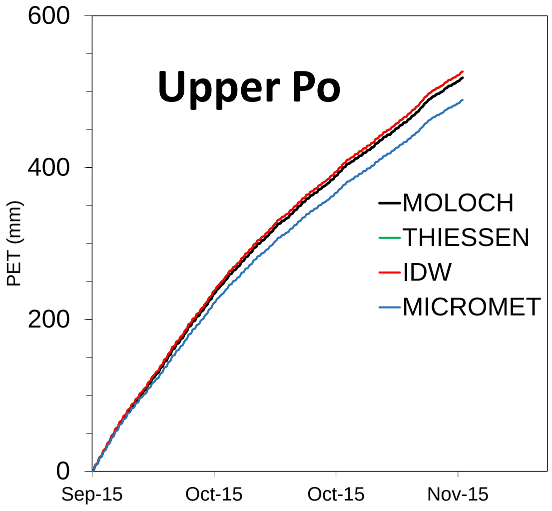
RESULTS

potential evapotranspiration error

ERROR *PET* cumulated [%]				
	Upepr Po	**0-300**	**300-1000**	**> 1000**
Thiessen	1,5%	-0,8%	-1,0%	7,9%
IDS	1,6%	-0,4%	0,2%	6,1%
MicroMet	-5,7%	-5,4%	-8,4%	-2,0%







CONCLUSIONS

1. The Micromet method that interpolates wind data considering topographic feautures requires a computational time that is 50% greater than Thiessen or IDW
2. On wind speed interpolation, the Micromet method presents more accuracy than thiessen or IDW only in high altitude areas, where topography plays an important role. In low altitude areas Thiessen and IDW perform better than Micromet. The Micromet presents a systematic underestimation of wind speed.
3. When wind field is used for estimating potential evapotranspiration, the use of Micromet is justified only on high altitude areas, but a systematic underestimation of evapotranspiration, direct consequence of wind speed underestimation, is present.

THANK YOU FOR YOUR ATTENTION

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