Analisi di sensitività di simulazioni numeriche idealizzate in terreno complesso attraverso variazioni dei parametri superficiali

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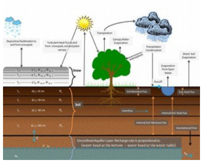
Abstract

A sensitivity analysis has been carried out for different case studies concerning the Noah-mp land surface parametrization in the framework of the Weather Research and Forecasting (WRF) model.
In order to assess the importance of the sensitivity to different parameters, simulations have been performed using an idealized valley geometry, at first comparing different vegetation types and subsequently comparing a homogeneous and an heterogeneous land cover domain.
The sensitivity analysis is performed using the Morris method which allows to evaluate the importance of the different parameters evaluated.
The analysis has been carried out with the aid of the matlab SAFE toolbox, which has been shown in literature to be an efficient tool for Global Sensitivity studies .

Introduction

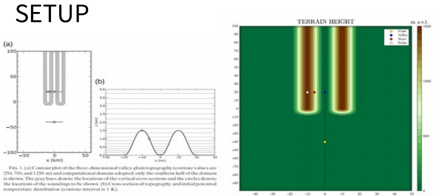
NOAH-MP



PARAMETERS STUDIED:

- HVT: top of canopy
- LAI: leaf area index
- MAXSMC: porosity, saturated value of soil moisture
- Z0MVT: momentum roughness length
- EG: ground emissivity
- ALBSATnir: saturated soil albedo in near-infrared band
- ALBSATvis: saturated soil albedo in visible band

SETUP



Duration:	72 h
Start date:	20/03/2105 06:00:00
Spin-up:	48 h
Area collocation:	LAT: 46° N LON: 11° E
Orientation:	W-E along x axis S-N along y axis
W-E grid points:	100
S-N grid points:	200
Vertical eta_levels :	65
Single W-E cell :	1000 m
Single S-N cell:	1000 m
Single time step:	60 s
W-E lenght:	100 km
S-N lenght:	200 km
Z length:	12 km

Physics:

Micro-physics:	absent
Longwave scheme:	RRTM
Shortwave scheme:	Dudhia
Surface layer scheme:	MYNN
Land surface model:	NOAHMP
Boundary layer scheme:	MYNN 2.5
Slope radiation:	present
Shading effects :	present

Radiative Transfer scheme:
Modified two-streams (NOAHMP)

Boundary conditions:

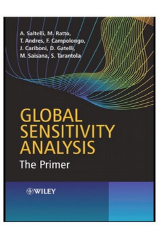
W-E :	symmetric
S-N :	symmetric

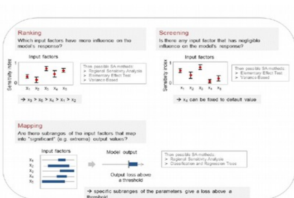
Potential temperature:

$\theta(z) = \theta_s + \Gamma z + \Delta\theta[1 - \exp(-\beta z)]$,

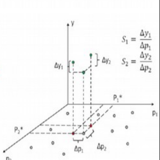
$\theta_s = 280$ K, $\Gamma = 3.2$ K km^{-1}, $\Delta\theta = 5$ K, $\beta = 0.002$ m^{-1}.

SENSITIVITY





- Morris Method OAT derives measures of global sensitivity from a set of local derivatives (Elementary Effects) connecting input perturbations and model output:



$$EE_i = \frac{f(p_i + dp_i) - f(p_i)}{\Delta}, \qquad \mu_i^* = \frac{1}{N}\sum_{j=1}^{N}\left|EE_i^j\right|$$

- Sobol indices derive from decomposing the variance of a scalar model output into variances associated to individual parameters (First order) and parameters interaction (Total order) :

$$V = \sum_{i=1}^{p} V_i + \sum_{i=1}^{p}\sum_{j=i+1}^{p} V_{ij} + \dots + V_{12\dots P}$$

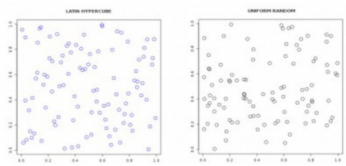
$S_i = V_i / V$, First Order index

$S_{Ti} = 1 - V_{\sim i} / V$. Total Order Index (interactions)

Methodology

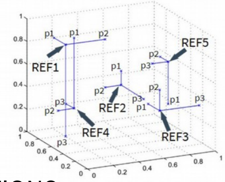
SAMPLING

The chosen method to sample the parameter values is the Latin Hypercube Sampling which combines the strengths of a stratified and random sampling to ensure that all regions of the parameter space are represented in the sample.



DESIGN

A radial design is implemented, which means that a number of reference states are decided beforehand, and all the parameters are perturbed from each of those reference points.



SIMULATIONS

Z0MVT	HVT	MAXSMC	LAI	ALBSATvis	ALBSATnir	EG	
1.19	19.98	0.55	3.10	0.15	0.27	0.85	REF1
1.01	19.98	0.55	3.10	0.15	0.27	0.85	
1.19	27.97	0.55	3.10	0.15	0.27	0.85	
1.19	19.98	0.70	3.10	0.15	0.27	0.85	OAT1
1.19	19.98	0.55	2.16	0.15	0.27	0.85	
1.19	19.98	0.55	3.10	0.07	0.27	0.85	
1.19	19.98	0.55	3.10	0.15	0.40	0.85	
1.19	19.98	0.55	3.10	0.15	0.27	0.97	
0.67	15.42	0.42	2.63	0.08	0.12	0.82	REF2
0.90	15.42	0.42	2.63	0.08	0.12	0.82	
0.67	26.33	0.42	2.63	0.08	0.12	0.82	
0.67	15.42	0.64	2.63	0.08	0.12	0.82	OAT2
0.67	15.42	0.42	2.47	0.08	0.12	0.82	
0.67	15.42	0.42	2.63	0.24	0.12	0.82	

7 PARAMETERS (k=7)

10 REFERENC STATES (r=10)

In a single complete set of simulations (REF+OAT) each parameter has one perturbed value (p=1) and k unperturbed values

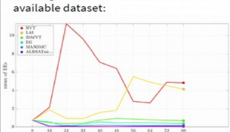
EACH SET HAS: k+p runs

TOTAL RUNS r(k+p)=80

POST-PROCESS

Convergence analysis of μ(EE)

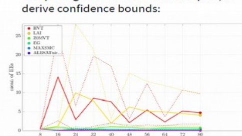
Repeat computations using a decreasing number of samples to assess if convergence was reached within the available dataset:



μ(EE) calculated 10 times from 8 runs to 80 runs (each time adding 8 runs)

Bootstrap method for confidence bounds

Repeat convergence analysis using bootstrapping (i.e. resampling and then computing over random sub-samples) to derive confidence bounds:



Number of bootstraps: 100000

Results

The different vegetation types considered clusters into two different kinds of behaviours (Figure 1) which display velocity differences up to 2.5 m/s in the first part of the day for both slope and valley winds and dampen out when the solar forcing fades.
Differences in temperatures are most relevant over the slope in the katabatic phase.
The heterogeneous case study (Figure 2) shows that local differences of the same order of magnitude of the mean values of wind and temperature can arise.

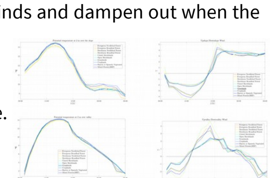


Figure 1: daily time series of a) slope temperature; b) slope wind; c) valley temperature; d) along-valley wind;

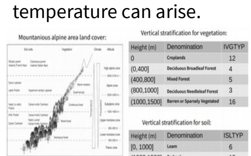


Figure 2: the heterogeneous land-cover configuration used to schematize a tipical Alpine valley

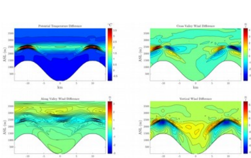


Figure 3: difference between homogeneous and heterogeneous scenario for temperature and velocities in all the 3 directions

Figure 4 shows different phases of the daily valley circulation to highlight the spatial distribution of the variations in u,v,w induced by the perturbation of HVT and LAI. Differences involves the ridge plumes, the slope flows and the inner valley boundary layer height. The ranking of the parameters studied with the Morris method is showed in Figure 5.

OUTPUT RESPONSE CROSS-SECTIONS

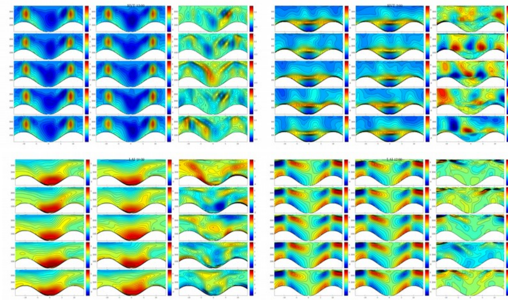


Figure 4: Each of the four panels show as first column the reference states output, as second column the output with the perturbed parameter and as third column the difference between the two representing the elementary perturbation of the output. Top left: perturbation of w by change in HVT; top right: perturbation of v by change in HVT; bottom left: perturbation of v by change in LAI; bottom right: perturbation of u by change in LAI.

SCREENING

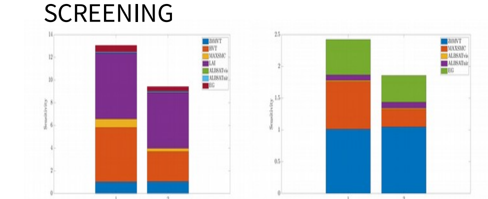


Figure 5: a) the stackedbars show the 2 most prominent parameters b) plotting the remaining parameters allows to detect the less influent ones

Conclusions

Based on the nature of the method and the results gathered until now, we can use the Morris method as a screening tool to assess the following:

- Which parameters are non-influential
- Which parameters are the most influential
- Which parameters cannot be considered non-influential in some of the scenario considered

Future directions

- Extensions of the work could be centered around these topics:
  - A higher number of simulations would reduce uncertainty
  - A higher number of parameters would include more interactions but also more realism to the scenarios
  - Different ranges of values would allow a mapping analysis and permit comparison with other works
  - Different kinds of variables involved (latent heat flux, sensible heat flux etc.) would focus to more general subprocesses like heat exchange
- Implementation of a hybrid methodology (screening phase with Morris - ranking phase with Sobol) could be tried to gain more quantitative results
- Differences in parameters spatial distribution inside the simulation domain would test out the findings provided by this study in a more realistic scenario

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