DIFFERENCES in SURFACE WIND SPEED between OBSERVATIONS , REANALYSES and CLIMATE MODELS : Why do they matter for DUST EMISSION SIMULATIONS in the SAHEL?

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CONTEXT AND OBJECTIVES

► Surface wind field is a major driver of dust emission in the Sahel

► Strong dust emission associated with convective rain events in this region (Rajot 2001, Marsham et al. 2011, Pierre et al. 201X...)

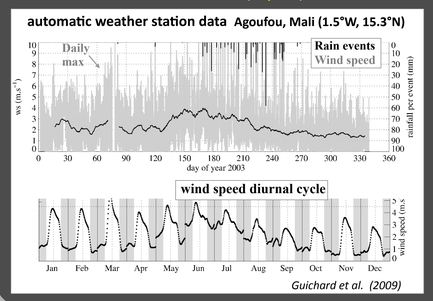
► Analyse the capabilities and weaknesses of surface wind fields provided by atmospheric models (reanalyses, CMIP5 climate models) for the simulation of dust emission in the Sahel

► Design a parametrisation of convectively-induced modifications of the surface wind (gustiness and mesoscale distribution)

MAJOR FEATURES OF THE SURFACE WIND IN THE SAHEL

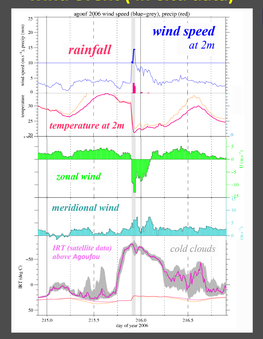
Strongest wind gusts associated with rainfall events
Fine space and time scale processes (mesoscale)
morning maximum (mixing of low level nocturnal jet)
weak nocturnal wind in winter (dry air)

automatic weather station data Agoufou, Mali (1.5°W, 15.3°N)



Guichard et al. (2009)

A typical example of very strong wind event (in-situ data)

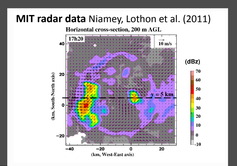


Many similarities with composite over more than 200 cases

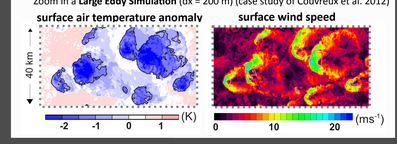
More than 90% of the highest wind events (> 10m.s-1) are associated with rainfall in the Sahel

These strong wind gusts are generated by convectively-driven cold pools spreading at the surface

MIT radar data Niamey, Lothon et al. (2011)

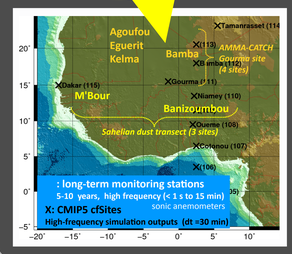


Zoom in a **Large Eddy Simulation** (dx = 200 m) (case study of Couvreux et al. 2012)

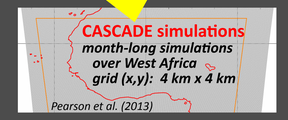


DATA AND METHOD

evaluation of models with data fromSahelian sites
local comparisons
closest grid points

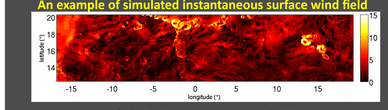


design of a parametrization based on
- guided by - results from '*convective cold-pool resolving*' simulations and framed by data



Pearson et al. (2013)

An example of simulated instantaneous surface wind field



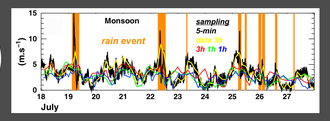
Also use of AROME simulations and LES over smaller domains and/or duration (not shown)

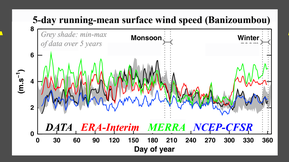
EVALUATION OF SURFACE WIND SPEED IN METEOROLOGICAL RE-ANALYSES

Major errors in surface wind speed provided by reanalyses meteorological reanalyses at sub-synoptic scales (Largeron et al. 2015)

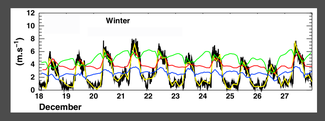
gust winds associated with rain events

Data
ERA-Interim
MERRA
NCEP-CFSR



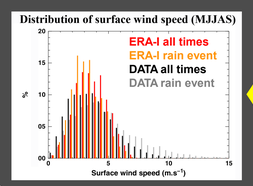


diurnal cycle (with impact on the annual cycle)



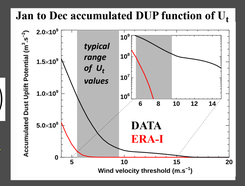
Reanalyses provide reasonable estimates of synoptic and intraseasonal fluctuations but miss strong gust winds

Not simply a sampling issue (even if 3h is really coarse)
More fundamentally, there is no representation of wind gusts associated with parametrized deep convection in these products (structural issue)



ERA-I misses the highest wind speeds associated with convective rain events

$$DUP = u^3\left(1+\frac{U_t}{U}\right)\left(1-\frac{U_t^2}{U^2}\right)$$



As a result, dust emission is likely to be largely underestimated

SURFACE WIND SPEED IN CMIP5 CLIMATE SIMULATIONS

Distributions *vary more among models than along latitude*

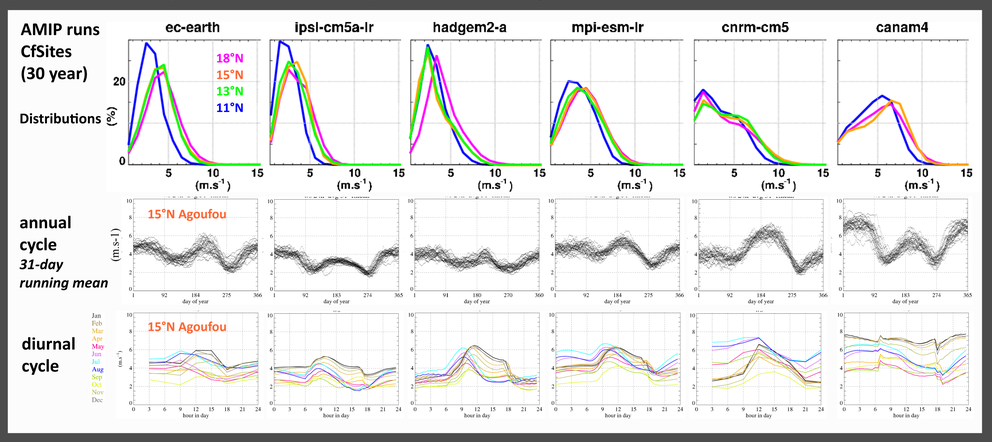
Annual cycle*: an increase of the wind speed during the monsoon in most simulations, as opposed to a decrease in observations*

Diurnal cycle*: some qualitative 'functional' agreement; e.g. morning maximum, weaker nighttime wind speeds in winter*

► *In some models, a shift in the timing of the morning maximum from winter to summer that is not supported by observations*

► *Possibly a lack of consistency of the time steps between radiative computations for different processes in some models*

As reanalyses, climate models do not simulate convective gust winds. This is a structural problem: convective wind gusts correspond to a mesoscale phenomenon which is not parametrized. Besides, there are also other substantial differences and biases



PARAMETRIZATION OF CONVECTIVELY-GENERATED SUFFACE WIND SPEED

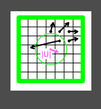
Statistical empirical approach in the same spirit as Redelsperger et al. (2000) but for the Sahel (semi-arid, over land), not the tropical atmosphere over the ocean

use **CASCADE simulations** to sample **numerous convective rain events** analysed as a function of wind speed and other atmospheric parameters (DCAPE...)

1) parametrization of **gustiness U_g** $U_g^2 = \langle \|\tilde{U}\| \rangle^2 - \|\langle \tilde{U} \rangle\|^2$

(1°x1°)-mean wind speed ≠ speed of (1°x1°)-mean wind vector $\overline{U}$

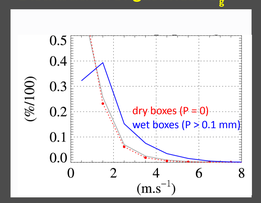
U_g = f(rainfall, $|\overline{U}|$)



2) Parametrization of a **mesoscale distribution of convective wind speeds**

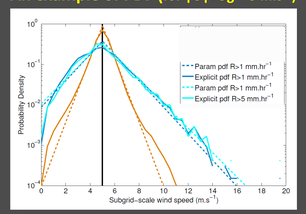
Laplace (not Weibull) PDF $f(u,\sigma,\mu) = \frac{\sqrt{2}}{2\sigma}\exp\left(-\frac{\sqrt{2}|u-\mu|}{\sigma}\right)$ with coeff. f(rainfall, $|\overline{U}|$)

Distribution of gustiness U_g



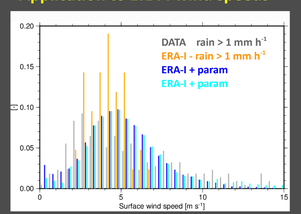
CASCADE runs correctly simulate an enhancement of U_g during rain events

An example of PDF (for |U|+Ug = 5 m.s-1)



The parametrization captures the broadening of the wind speed distribution during rain events

Application to ERA-I wind speeds



More occurrence of strong winds with the parametrization, though less than observed

PERSPECTIVES

► **Further explore the sensitivity of surface wind field to atmospheric parameters to refine the parametrization**

► **Test of the parametrization at local scale (Agoufou, Banizoumbou)**

► **Use ECMWF surface wind modified with parametrization for dust emission simulations**

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