

Surface wind and erosion in the Sahel within **CAVIARS**

Climate Agriculture and Vegetation Impacts on Aeolian eRosion in the Sahel



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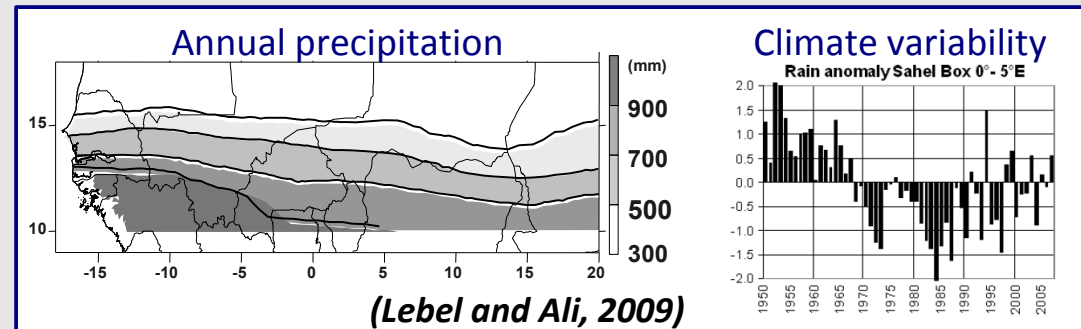
Background

sharp meridional gradient of rainfall

100 to 600 mm /year , semi-arid to arid

Multi-decadal climatic variability

1950-1970 : wetter, 1970-1985 : drought



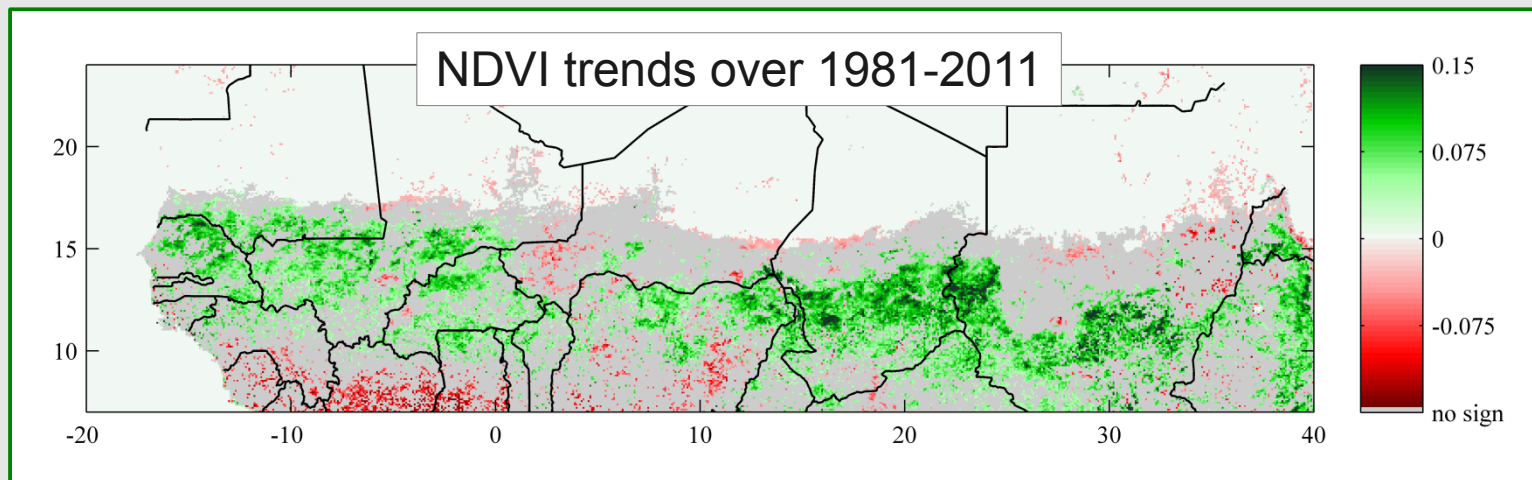
Low vegetation cover, strong annual Dynamics

Sharp decrease during drought decades

long term variability linked to Precipitation (Olson et al., 2005)



A recent greening from satellite data, consistent with in-situ data (Dardel et al. 2014)

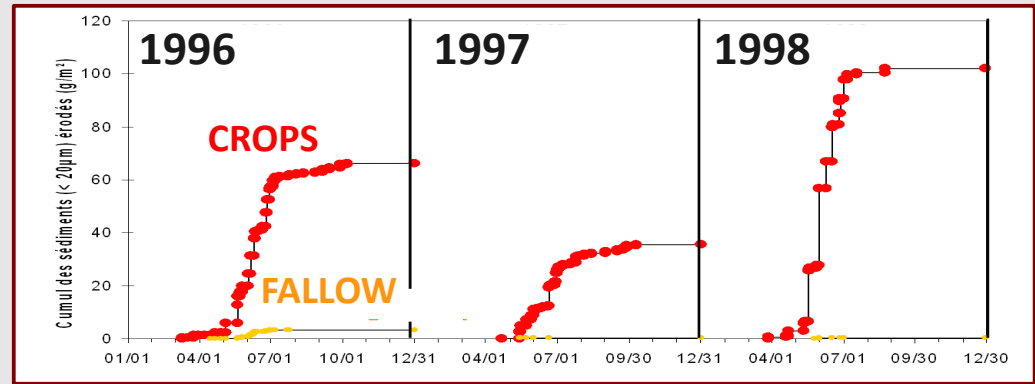


Background

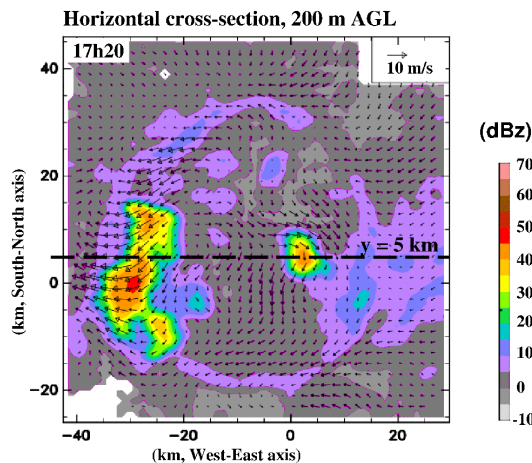
increase of aeolian erosion, coupled with change in precipitation magnitude of recent activity higher than prior to the 70's 80's droughts (*Dumay et al. 2002*)

erosion mostly observed over bare soil crops, prior to rain during convective events (*Rajot 2001*)

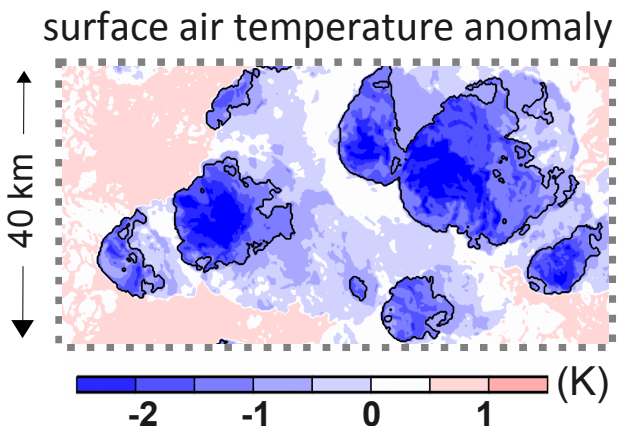
A tendency for more crops and less natural vegetation and pastures (*Hiernaux and Turner 2002*: + 1% à 3% per year, 17 years)



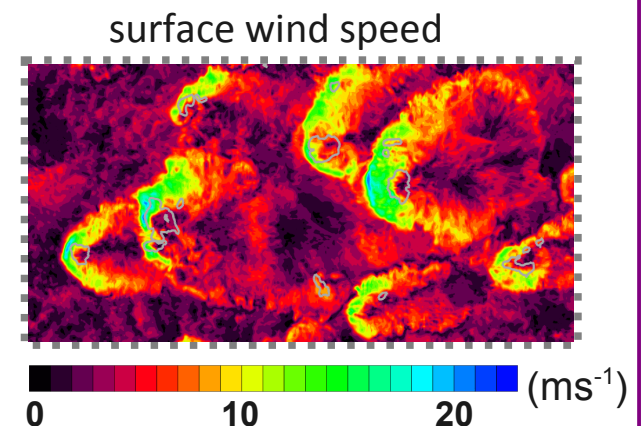
Importance of deep convection, convectively-generated cold pools for erosion
Marsham et al. (2008, 2011), Heinold et al. (2013)



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



Large Eddy Simulation $dx = 200$ m (case study of Couvreur et al. 2012)



The CAVIARS project

Objective Documenting changes in aeolian erosion linked to climatic changes and modifications of land use & land cover during the last 50 years

Strategy Development of a regional integrative modelling tool to quantifies the different drivers of changes in erosion (land use, aridity...)

Validation with data available over the recent past

Assessment of the model performance over the last decades (hindcast)

Combined/coupled simulations of vegetation and erosion

Erosion: DPM

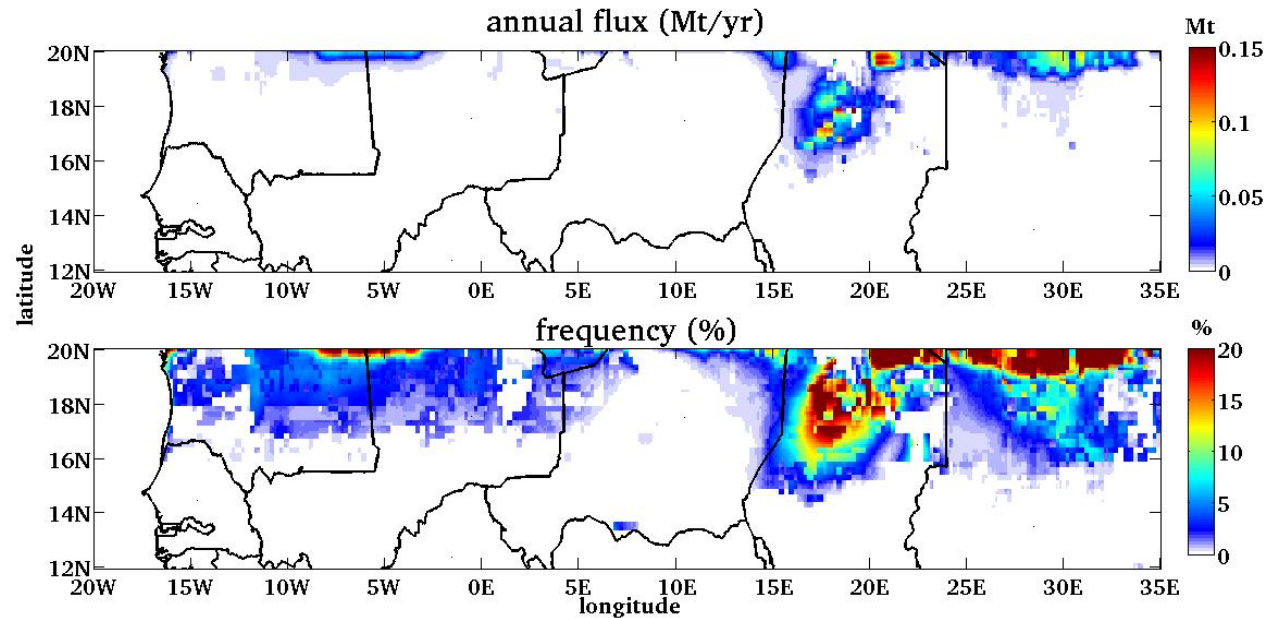
Natural vegetation: STEP

Crops : SARAH

10°N - 18°N , 20°W - 20°E

Dx = Dy = 25 km

*duration: 5-year periods
within [1960,2010]*



(Pierre et al., 2012) , assuming natural vegetation

Special care to input data, improved and/or sensitivity tests

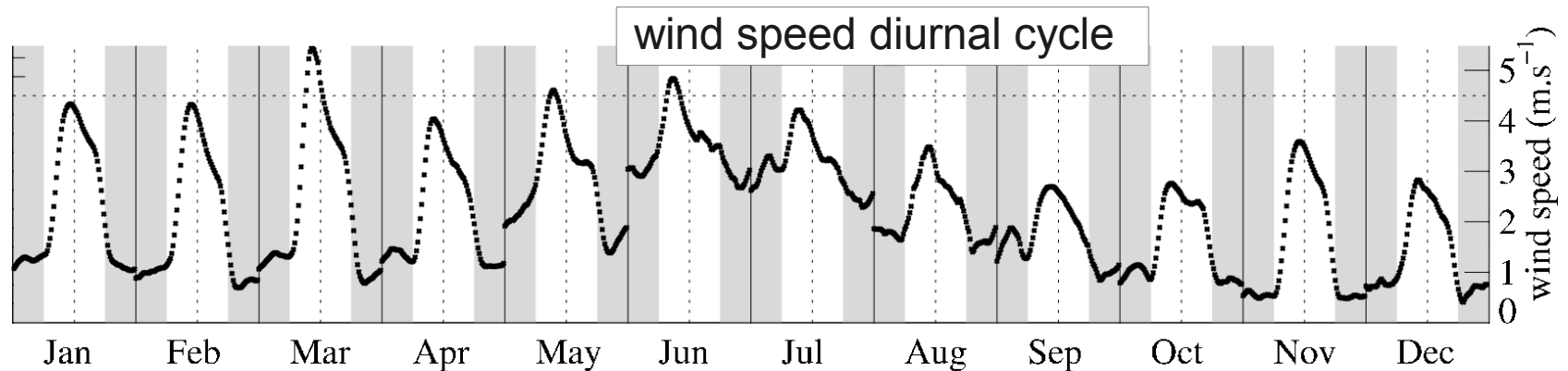
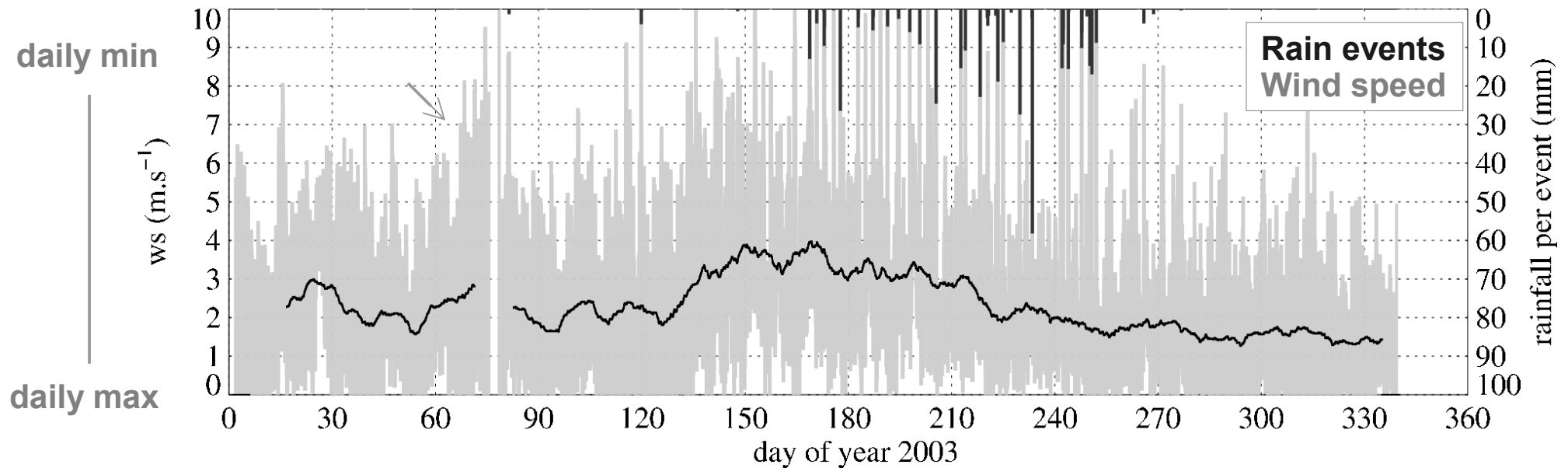
Soil and surface databases (texture, size distribution, roughness...), land use, land cover

*Meteorology: precipitation, temperature, humidity, incoming radiation, **surface wind***

$$\text{Erosion} \sim U^3 (1 + U_t / U) (1 - U_t^2 / U^2)$$

Important characteristics of the surface wind in the Sahel

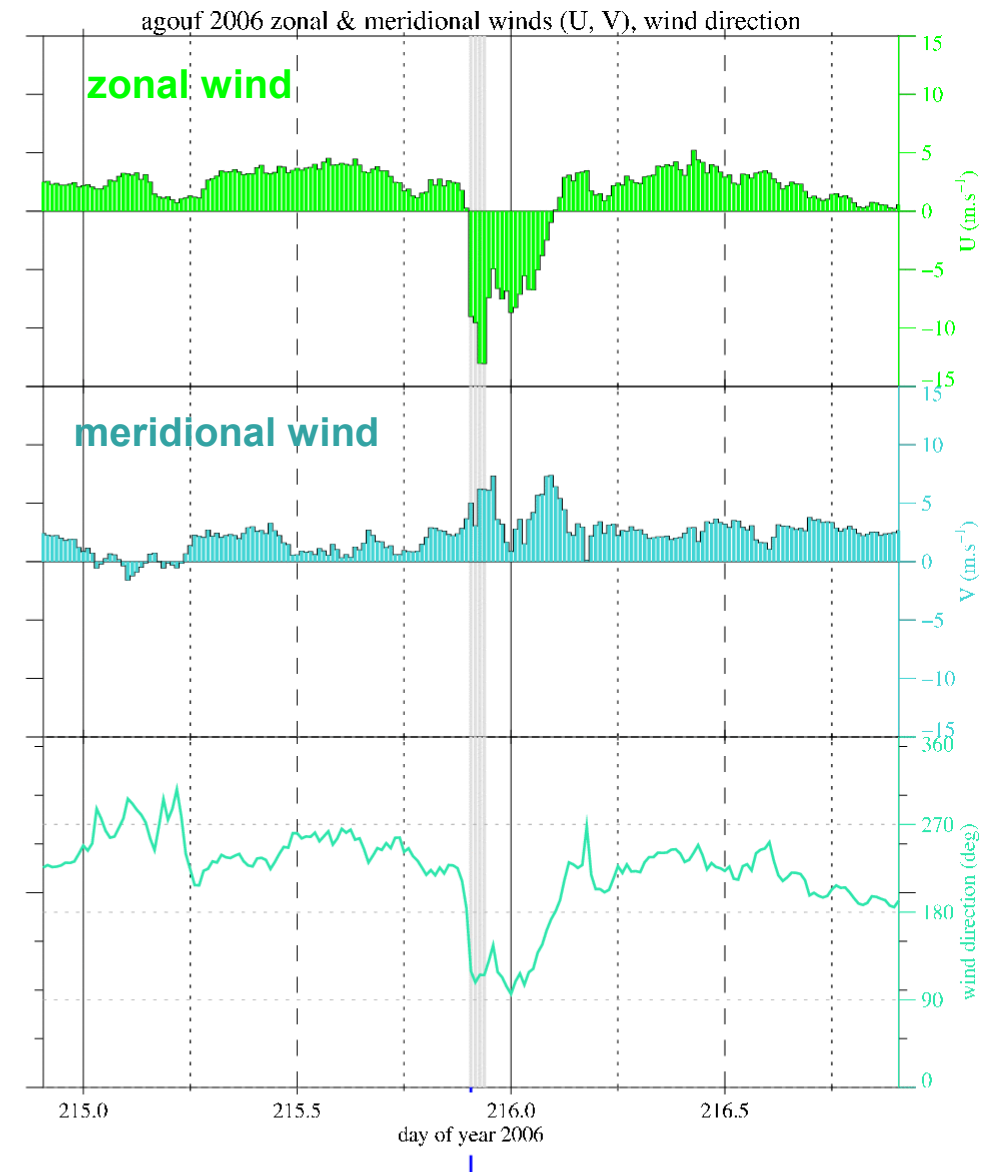
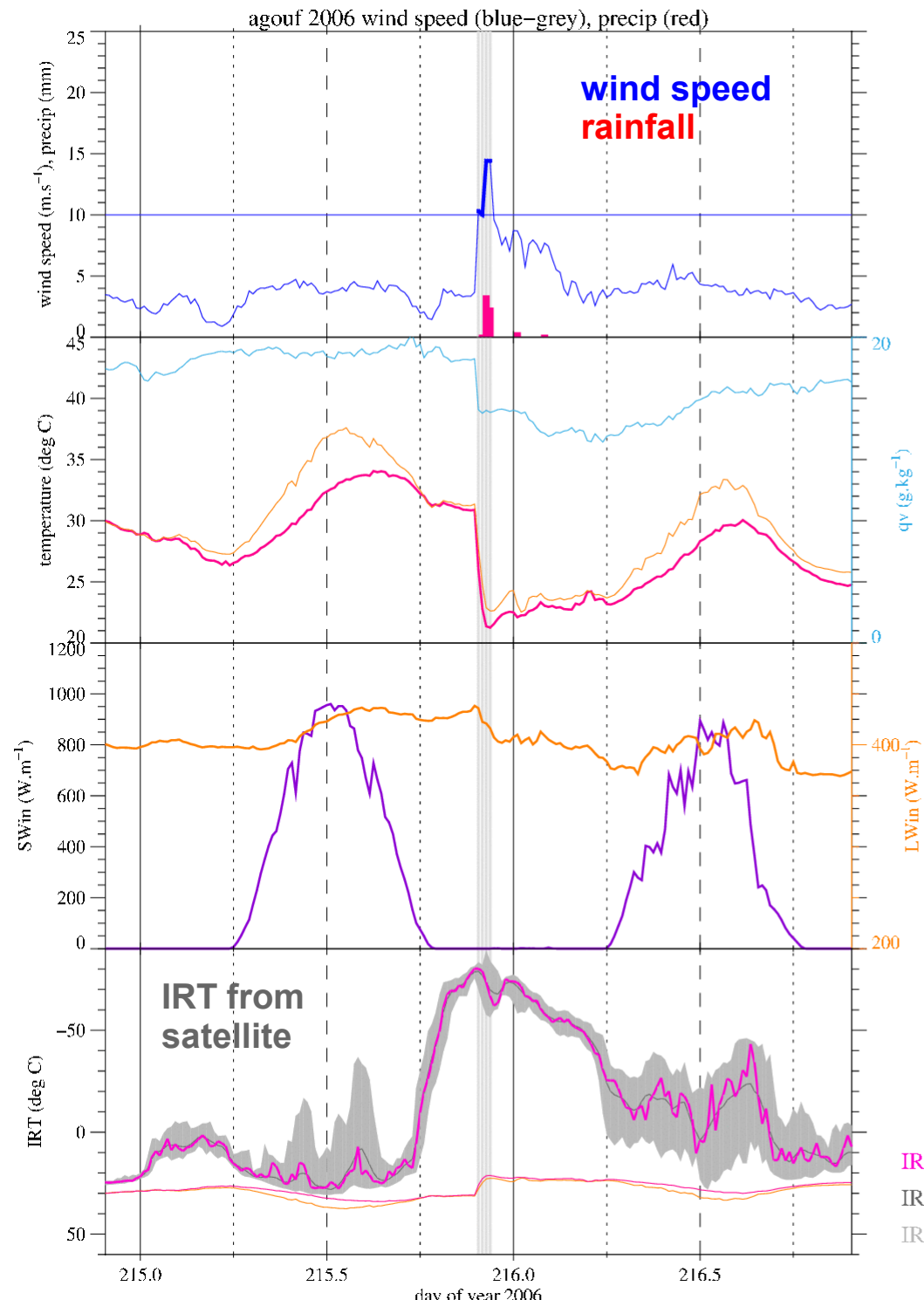
Agoufou, Mali (1.5°W, 15.3°N) local data , automatic weather station



Guichard et al. J. Hydrology (2009)

*Strong wind gusts associated with rainfall
morning maximum (mixing of low level nocturnal jet)
weak nocturnal wind outside of the monsoon season (dry air)*

Zoom on a typical example of convective event as seen locally in the Sahel



vertical grey lines : occurrences of wind speed $> 10 \text{ m s}^{-1}$

IRT above agouf

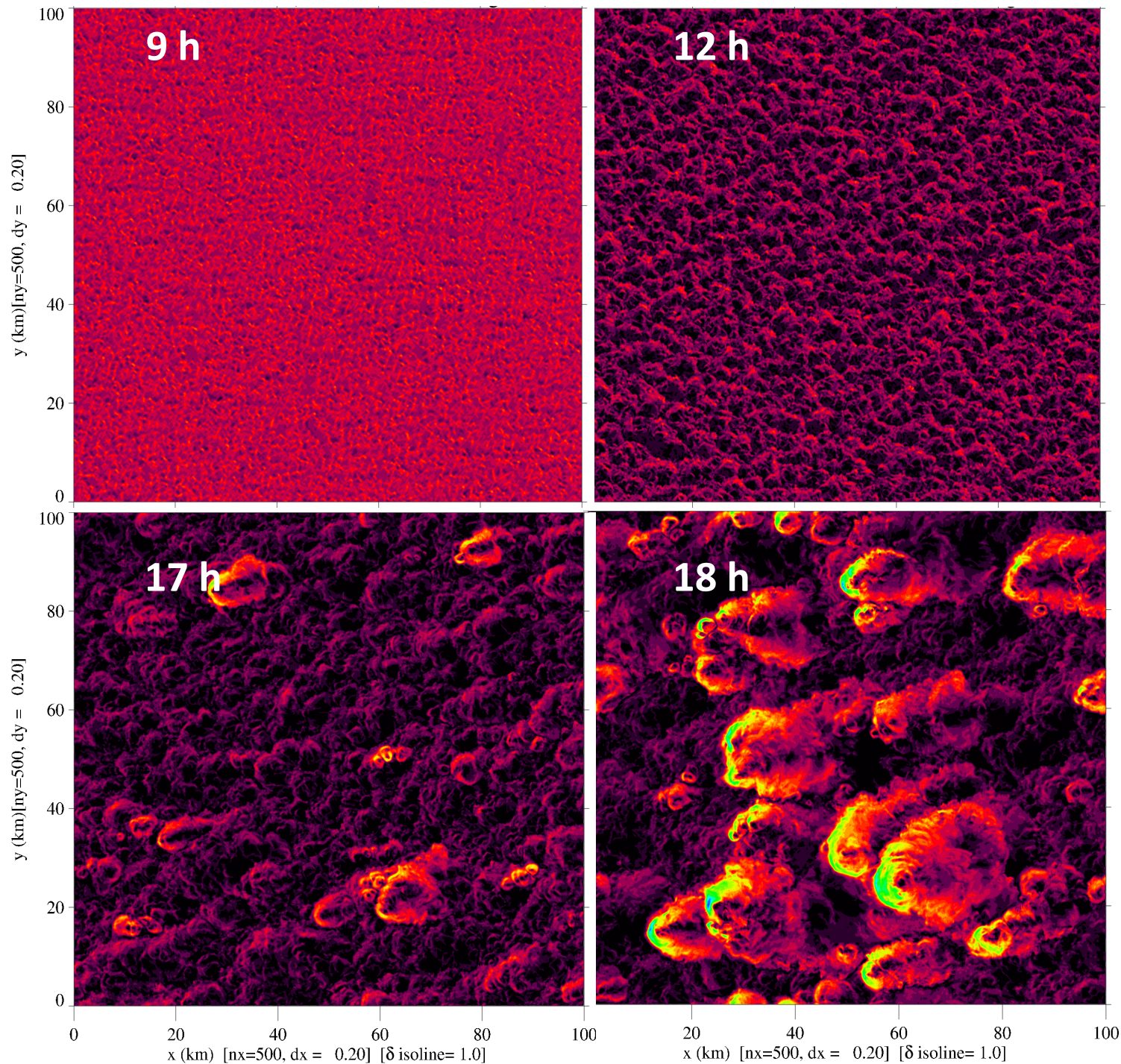
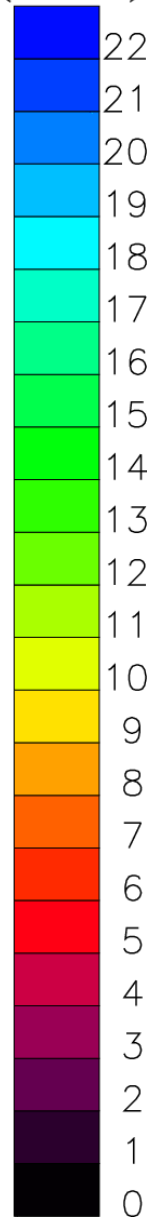
IRT 50 km x 50 km centred on agouf pixel: average

IRT 50 km x 50 km centred on agouf pixel: min and max

Most strong wind events involve rainfall (different from the Sahara)

Zoom on an example of convective event as simulated with LES

(m.s⁻¹)

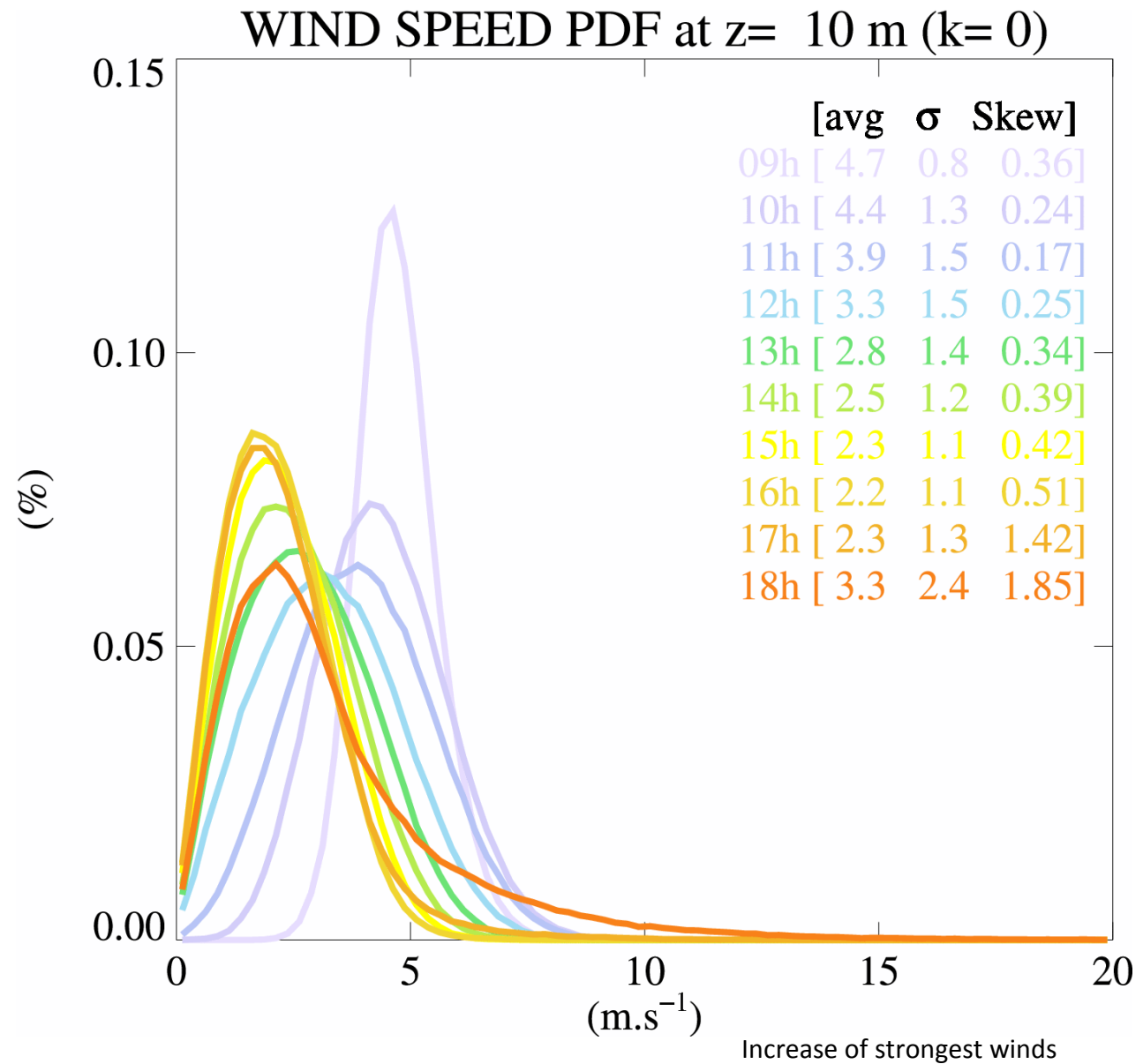
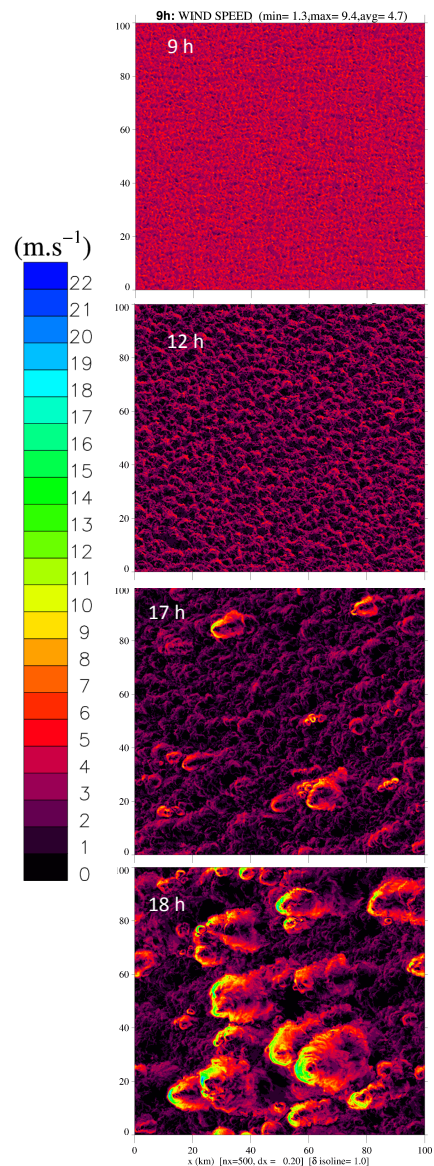


Daytime
growth
of the
convective
boundary
layer

Mean wind
speed
weakens

Cold pools
spreading
at the surface
with
strong winds
at
their
leading edges

Zoom on an example of convective event as simulated with LES



Wind fields for aeolian erosion models

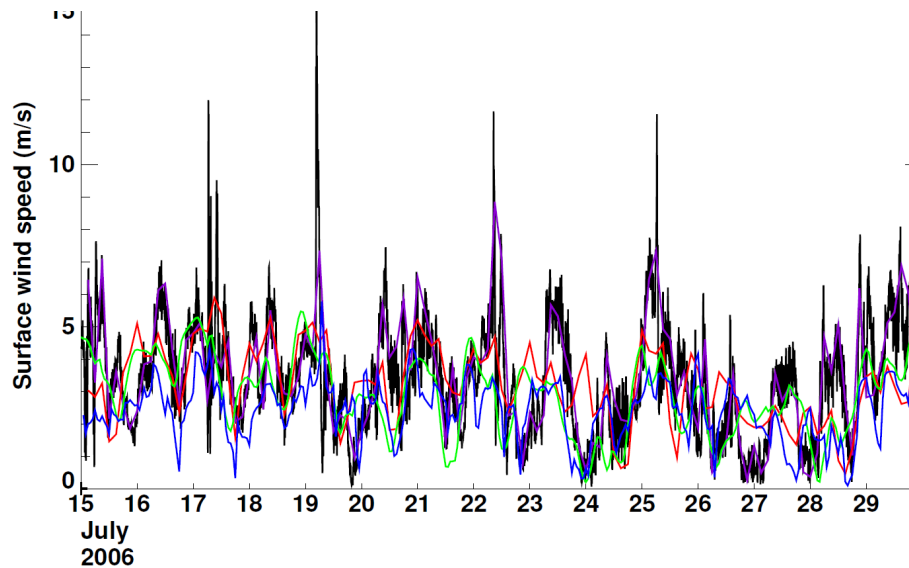
Large area, back in the past: meteorological reanalyses

time sampling $\sim 3\text{h}$, $dx \sim 50\text{-}200\text{ km}$

broad climatology, even if some accuracy issues (models very sensitive to the chosen reanalyse)

no parametrization of gusts associated with deep convection

(ERA-Interim: diagnostic gust but for DRY convection), anyway too coarse in time and space



Observations (5 min avg)
Observations (3h-sampled of 15 min-avg)
ERA-Interim (dt=3h-sampled)
MERRA (dt=1h)
NCEP-CFSR (dt=1h)

delicate comparison, but some robust differences

Largerone et al. (2014) & poster EGU2014-13244

Various attempts to provide a better formulation of wind speed and gust

→ *Several empirical formulations of gusts* (Nakamura et al. 1996 and several others)

involve strength of cold pool, shear, rainfall (not for erosion purpose)

→ *Redelsperger et al. (2000)* mostly for surface sensible and latent heat flux purpose

→ *Cakmur (2004)* specifically for dust emission in climate models

a limitation to R00 & C04 based on knowledge of deep convection over tropical ocean, very moist environment, weaker downdraughts than over land (different controls & balances)

Approach improvement of reanalyses ERA-Interim wind fields

keep it simple, no use of -fragile- output from convective param., PDF, suited for the Sahel

1) Analysis of **AWS data**, wind measured with 2D and 3D sonic and cup anemometers

5 sites in the Sahel, each with several years of data of each type, dt :1 to 5 min

(re)discovered some issues with cup anemometers in convective situations

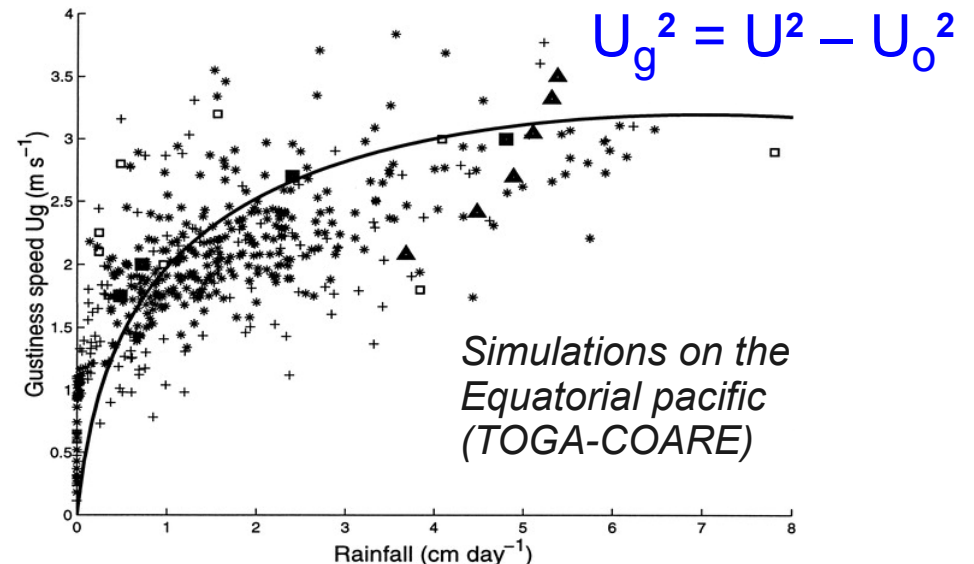
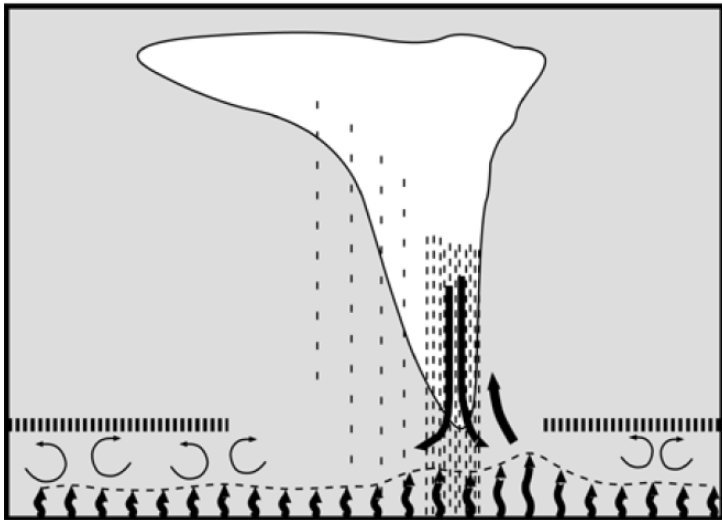
2) Use **results from explicit simulations** of Sahelian deep convective events

dx = 200 m to 5 km

*models/runs :MesoNH, AROME, **CASCADE UK** (Marshall et al. 2011 and others)*

➡ to formulate **empirical statistical relationships** between gust winds & convection
use of precipitation, estimate of the strength of downdraughts, DCAPE, shear...

U_g = gustiness = $f(\text{rain})$, $f(M_{\text{conv,down}})$...



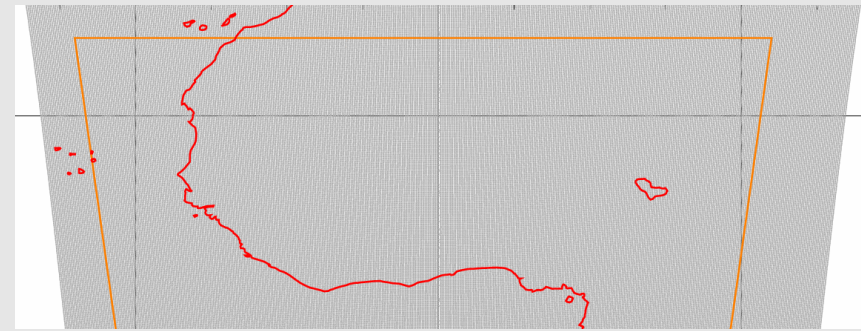
Redelsperger et al. (2000)

A few preliminary results

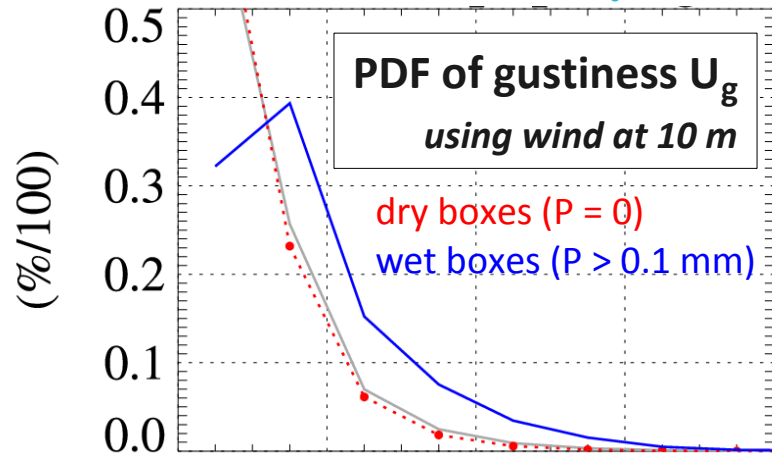
Monsoon season [10°W-10°E , 10°N-20°N]

time sampling = 1 h

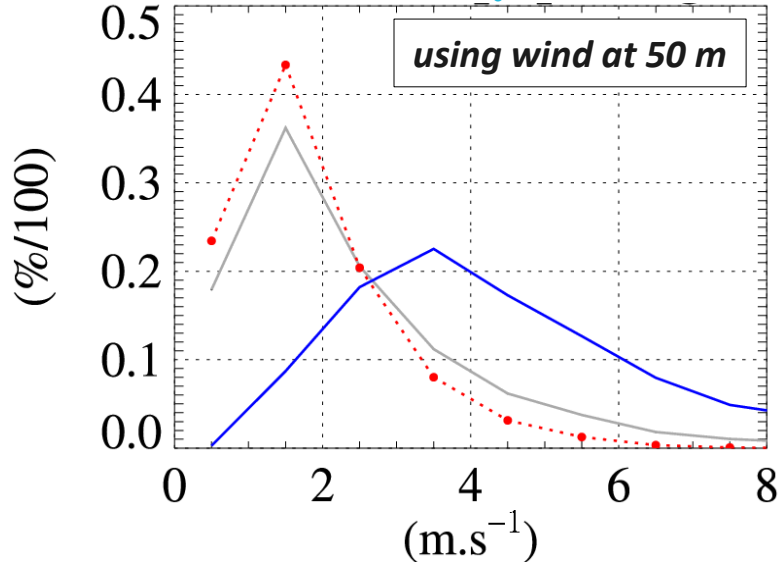
boxes $A_i \sim 100 \text{ km} \times 100 \text{ km}$: compute $U_g (A_i, t)$



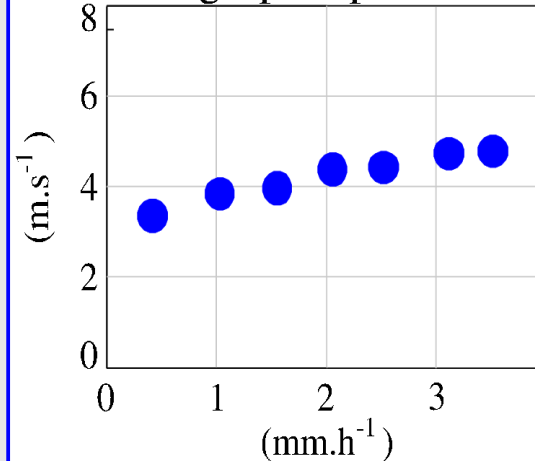
CASCADE: 40 days



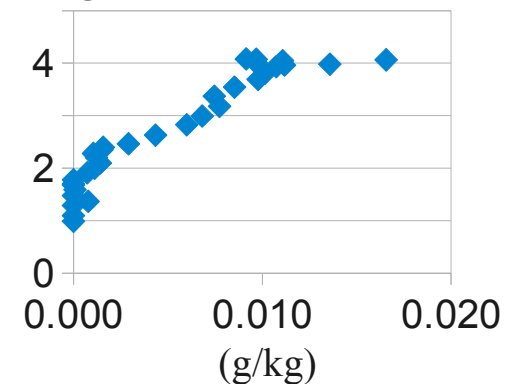
AROME: 6 days , $dx=4 \text{ km}$



U_g f precipitation



U_g f surface rain water



caution

substantial scatter (exploration of DCAPE, shear)
quantitative differences among models

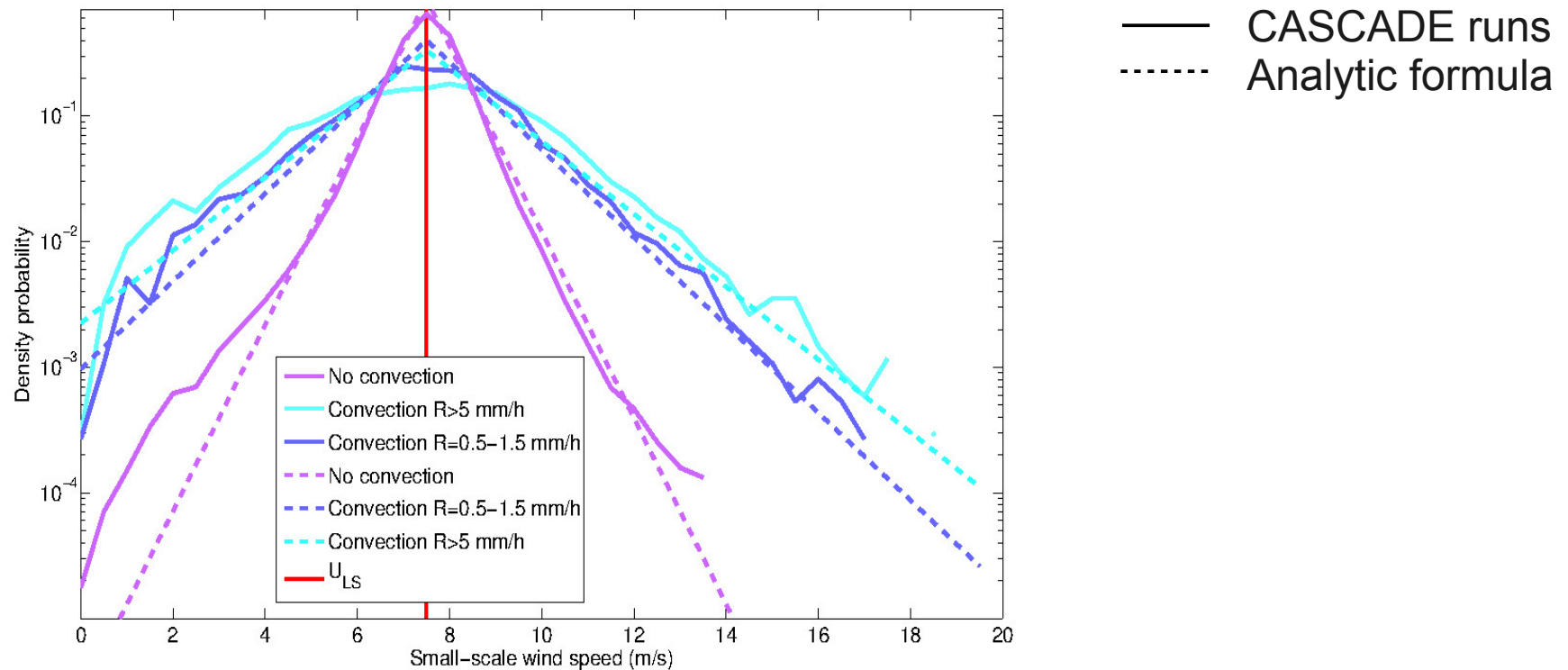
still, in the Sahel (south of 16°N at least),
rainfall appears as informative at 1st order
(consistent with local and MIT data)

most gust cases occur close to where rain is falling

both models generate convectively-driven gust winds, as opposed to models with convective parametrizations which do not display any - consistent with previous CASCADE studies

A few preliminary results

parametrizing wind speed PDF



source: Largeron

$$f(u, \sigma_*, \mu_*) = \frac{\sqrt{2}}{2\sigma_*} \exp\left(-\frac{\sqrt{2}|u - \mu_*|}{\sigma_*}\right)$$

$$\mu_* = U_{LS}$$

$$\sigma_* = A \cdot U_{LS}^\alpha$$

with A & $\alpha = f(\text{rainfall})$

Summary

CAVIARS aims at documenting changes in aeolian erosion in the Sahel linked to climatic changes & modifications of land use & land cover during the last 50 years via the development and use of a regional integrative modelling tool to quantifies the different drivers of changes in erosion (land use, aridity, climate...)

Not fully coupled tool, on purpose : erosion model with a combined dynamic vegetation (natural and crops) but without coupling with the atmosphere

Hincast approach, with assessment of the model performance (use of AMMA data)
Importance of - work on - the input datasets, among which **surface wind speed**

Need to improve surface wind speeds that are used in this type of study

Meteorological reanalyses not well suited for this purpose (*Largerion et al. 2014*)

lacking gust winds induced by convectively-generated cold pools that appear critical for erosion

Use of convection-permitting and large eddy simulations to build a parametrization of subgrid-scale wind fields (scale : 80 km x 80 km 'pixel') - CASCADE, AROME, MesoNH
In the Sahel, rainfall appears informative, but need to refine the parametrization (DCAPE, wind shear...) - *work in progress*

Exploitation of local datasets (large database), understanding and model evaluation

*More to come before the end of **CAVIARS**, in the next 3 years*

5-min average surface wind speed

