Towards an offline parameterization of convective dust storms

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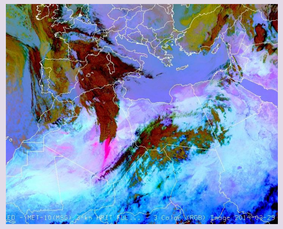
I. Context – mineral dust in West Africa

West African desert areas: Sahara and Sahel

- **First source of mineral dust** (half of worldwide emissions) with possible long-range transport and remote impact on weather as well as on human health
- **Several uncertainties** in these areas due to lacking direct observations and difficult satellite observations and complex modelling of wind gusts responsible for dust emission

Dust outbreak over the Sahara (pink) that reached Europe in early April 2014



Meteosat-10 Dust RGB 1600 UTC 29 March 2014

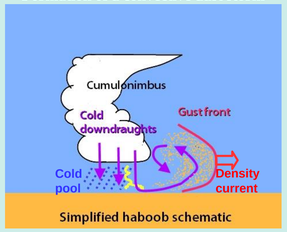
The ERC project Desert Storms (KIT/University of Leeds) aims at a better understanding the weather processes involved in the emission of mineral dust over West Africa

II. Focus – convective dust storms

Classical „sand storms“, also called haboobs

- **Created by convective downdrafts** driven by evaporation of precipitation with a cold pool propagating quickly and a gust front lifting dust ahead
- **Absent from global models** which do not resolve convection and from statistical parameterizations of subgrid-scale winds

Formation of a convective dust storm



http://www.weathercast.co.uk

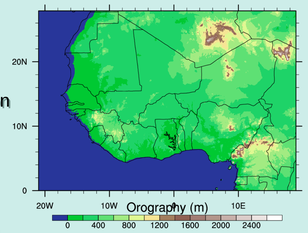
We suggest a physical offline parameterization of wind gusts based on the downdraft mass flux in a convection scheme

III. Data – the Cascade project

Unified Model simulations for West Africa

- Summer 2006 (June-October) **at different resolutions:** dx=4/12km with explicit convection dx=12/40km with parameterized convection
- Contribution of **convective dust storms** to total dust emission reaching 40% in the 4-km explicit run but lacking in the parameterized runs *(Marsham et al. 2011, Heinold et al. 2013)*

Domain of the 4-km Cascade run



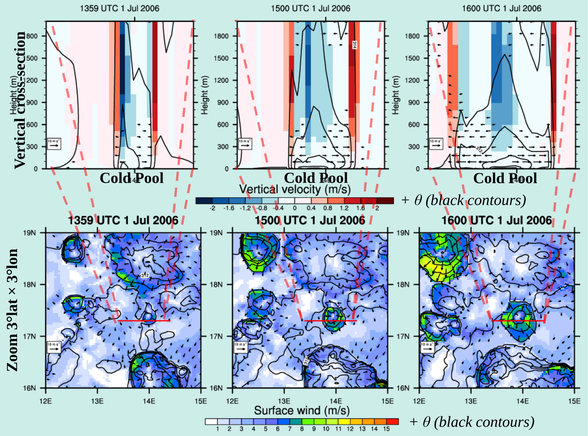
The Cascade project contains an ideal set of simulations for developing an offline parameterization of convective dust storms

IV. Overview – comparison of model runs

4-km run with **explicit convection**

- Explicit vertical motions are solved with the model primitive equations and show strong up- and downdrafts in organized convective systems
- The strong convective downdrafts create cold pools at low levels which quickly propagate radially with a front of wind gusts ahead

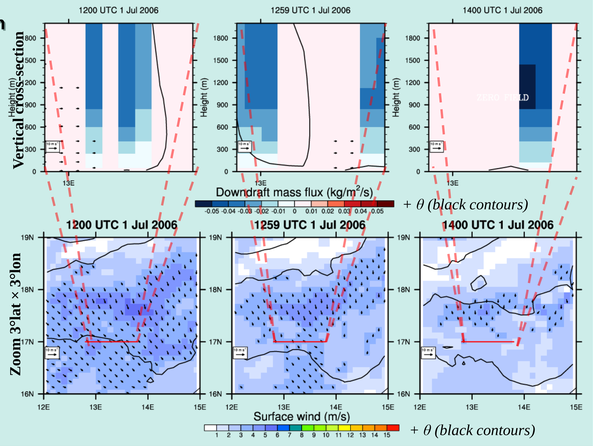
Runs with explicit convection capture the propagating gust fronts typical of convective dust storms



12-km run with **parameterized convection**

- Vertical mass fluxes are estimated with the subgrid convection scheme in each horizontal grid cell independent of the neighboring cells
- The subgrid convection scheme lacks the formation and propagation of cold pools and related wind gusts

Runs with parameterized convection lack the crucial physical processes to develop convective dust storms



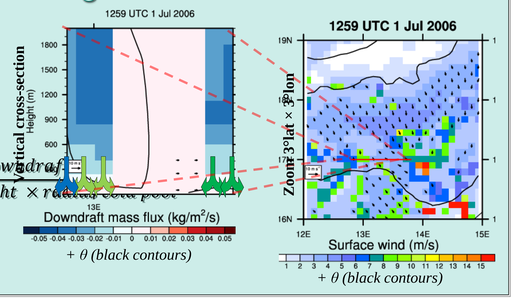
V. Method – parameterization of wind gusts

Parameterization based on *Cakmur et al. (2004)*

- The downdraft mass flux disperses radially in a cylindrical cold pool with constant size
- Surface winds are parameterized as

$$wind \propto \frac{downdraft}{height \times radius\ cold\ pool}$$

Strong downdrafts generate wind gusts that can reach (unrealistic) high values



VI. Preliminary results - statistics of dust uplift

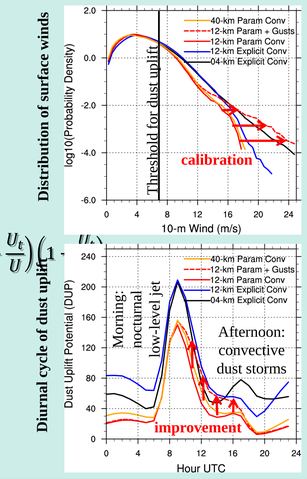
Statistics for June-July in the Sahara

- The parameterization of wind gusts is applied offline to the 12-km run with parameterized convection and calibrated with the tail of distribution of surface winds in the 4-km run
- The wind factor for the uplift of dust is evaluated with the Dust Uplift Potential

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

with U the surface wind and U_t the threshold for dust uplift *(Marsham et al. 2011)*

The parameterization of wind gusts allows for dust uplift in the afternoon and simulates the contribution of convective dust storms (but too early)



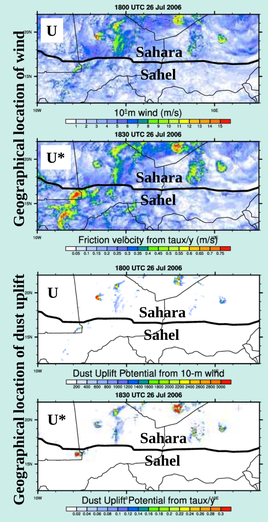
VII. Discussion – sensitivity to surface winds

The friction velocity U* is the actual surface wind and is physically relevant to compute dust uplift but often the 10-m wind U is available only.

Here we compare U and U* in the 4-km run:

- Both U and U* reveal high winds (in green-red) related to convective dust storms in the Sahara but only U* shows such structures in the Sahel where the surface roughness length z_0 is higher
- U and U* create dust uplift in the Sahara mostly: the threshold for dust uplift U^*_t increases with z_0 *(Marticorena and Bergametti 1995)* and prevents dust uplift in the Sahel; the threshold in U is taken as uniform U_t=7m/s *(Marsham et al. 2011)*

The dust uplift obtained with the 10-m wind u and with the friction velocity u* agree well on the contributions of Sahel and Sahara (but disagree on particular features)



VIII. Conclusions and perspectives

We suggest a physical parameterization of wind gusts for convective dust storms
First tests with a set of model runs for Summer 2006 deliver promising results
The parameterization will be applied to different datasets over extended periods

KIT – University of the State of Baden-Wuerttemberg and National Research Center of the Helmholtz Association

Acknowledgment
This work is funded by ERC grant 257543 *Desert Storms*

European Research Council

Further reading

Marticorena and Bergametti (1995) Modeling the atmospheric dust cycle: 1.Design of a soil-derived dust emission scheme. *Journal of Geophysical Research: Atmospheres* 100(D8): 16 415–16 430
Cakmur et al. (2004) Incorporating the effect of small-scale circulations upon dust emission in an atmospheric general circulation model. *Journal of Geophysical Research: Atmospheres (1984–2012)* 109(D7),
Marsham et al. (2011) The importance of the representation of deep convection for modeled dust-generating winds over West Africa during summer. *Geophysical Research Letters* 38(16)
Heinold et al. (2013) The role of deep convection and nocturnal low-level jets for dust emission in summertime West Africa: Estimates from convection-permitting simulations. *Journal of Geophysical Research: Atmospheres* 118(10): 4385–4400

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