School of Earth & Environment
FACULTY OF ENVIRONMENT

UNIVERSITY OF LEEDS

Investigating Peak-wind Generating Mechanisms Driving Dust Emissions in West Africa

B. Heinold, P. Knippertz, S. Fiedler, J. H. Marsham*, and I. Tegen$

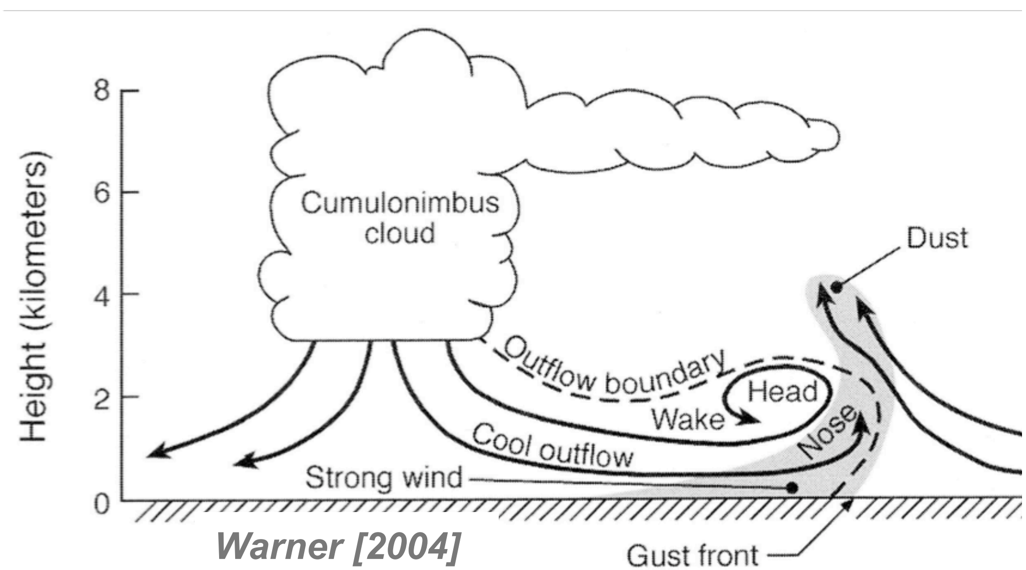
*National Centre for Atmospheric Science, University of Leeds, UK
$Leibniz Institute for Tropospheric Research, Leipzig, Germany

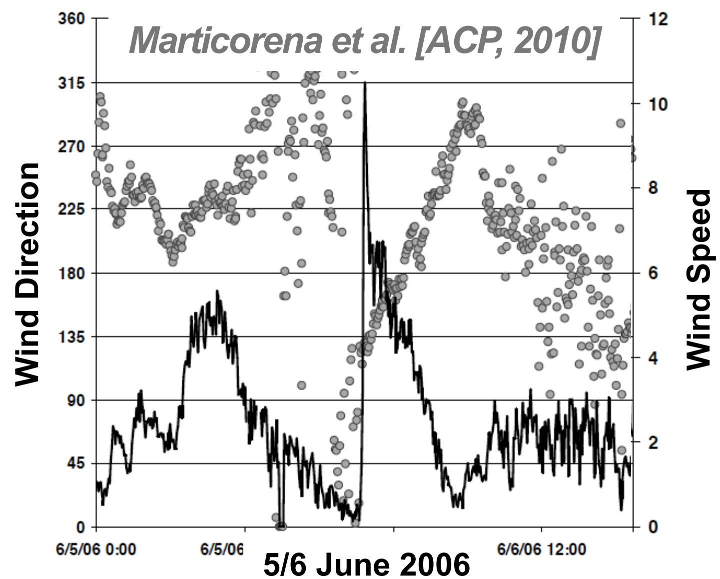
AMMA 2012, Toulouse, 05 July 2012

Motivation

UNIVERSITY OF LEEDS

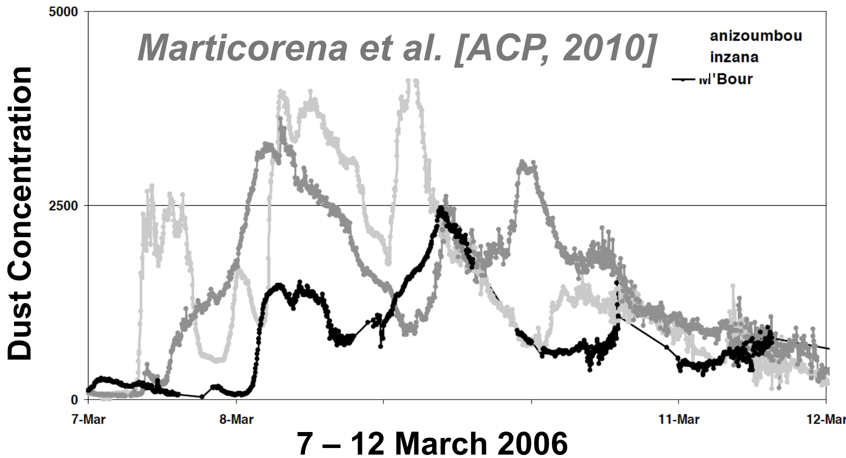
Khartoum/Sudan, 29 April 2007 (Source: http://anthropoasis.free.fr)



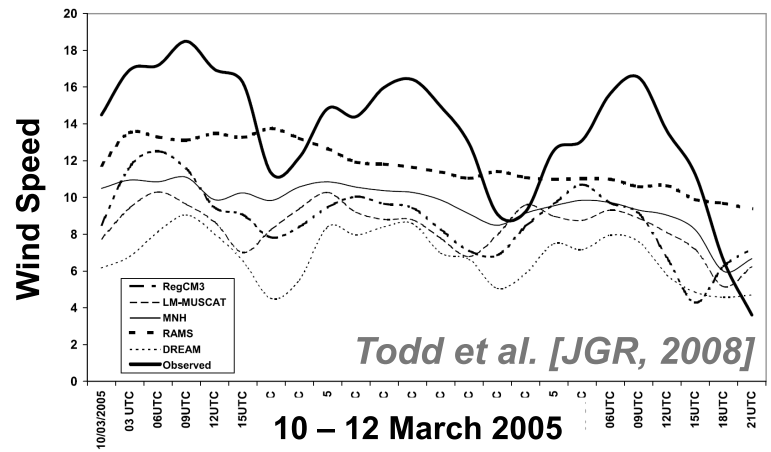


Nocturnal Low-Level-Jet (NLLJ)

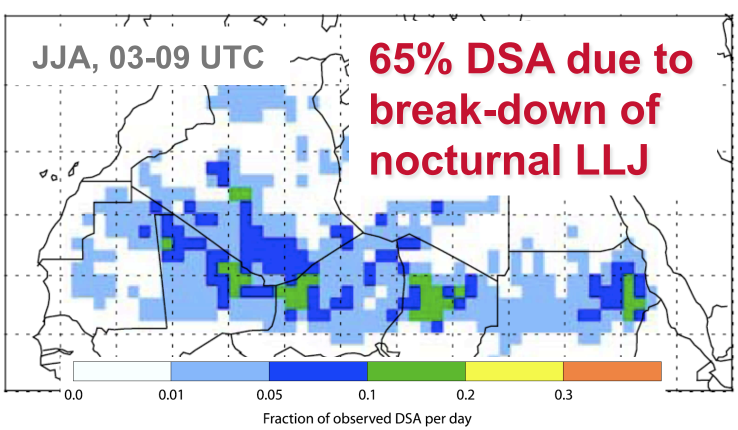
AMMA/Sahel

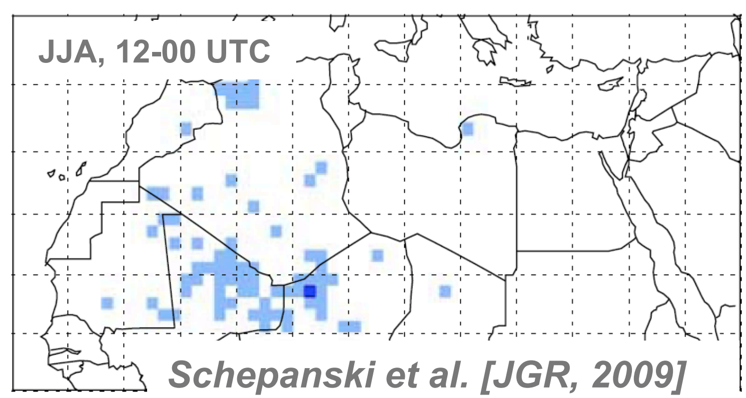


Bodélé LLJ



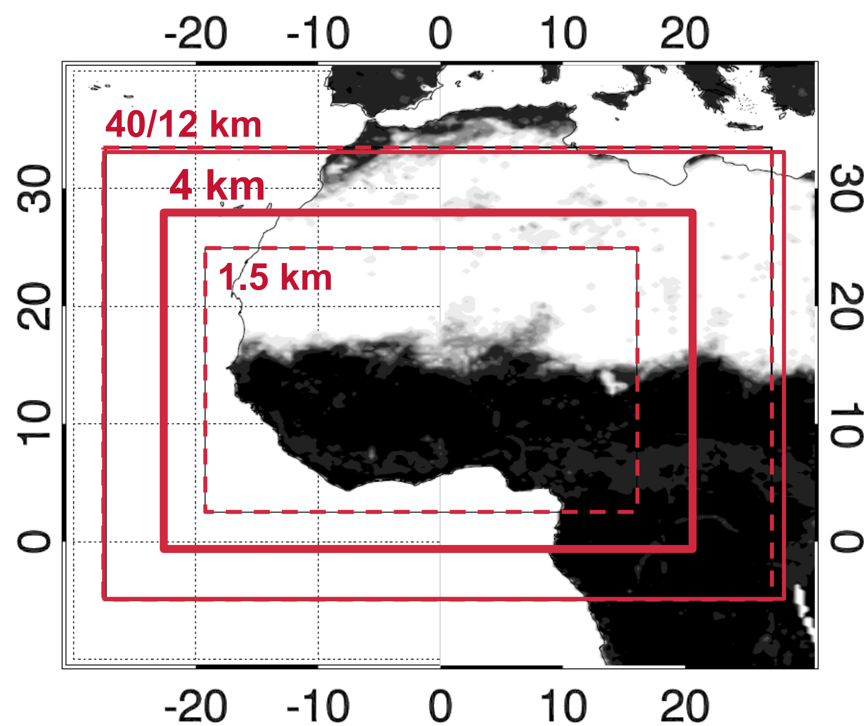
Dust Source Activation (DSA) over North Africa based on Meteosat IR Dust Index





Cascade Project Simulation

- First convection-permitting simulations covering West Africa
- UK MetOffice Unified Model (UM), version 7.1
- Horizontal grid spacing: 40, 12, **4 km** and 1.5 km
- Modelled period: 25 Jul – 2 Sep 2006
- Initial and boundary conditions: ECMWF 25-km forecast
- Previous 10-day study by Marsham et al. [GRL, 2011]



Marsham et al. [GRL, 2011]

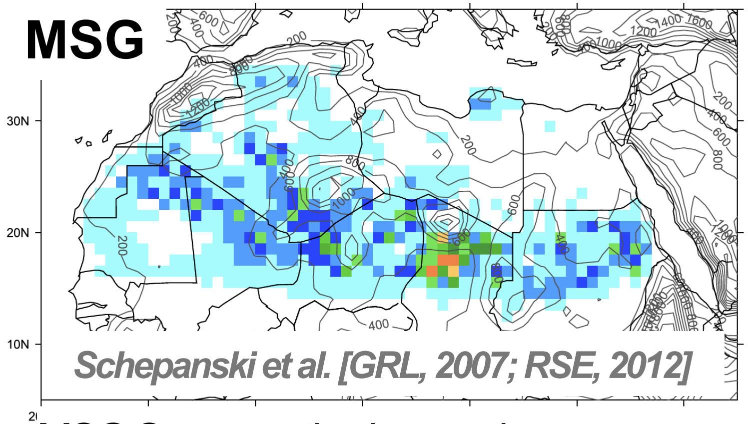
Dust Emission Scheme (DES)

UNIVERSITY OF LEEDS

Offline version of DES Tegen et al. (2002; 2004)

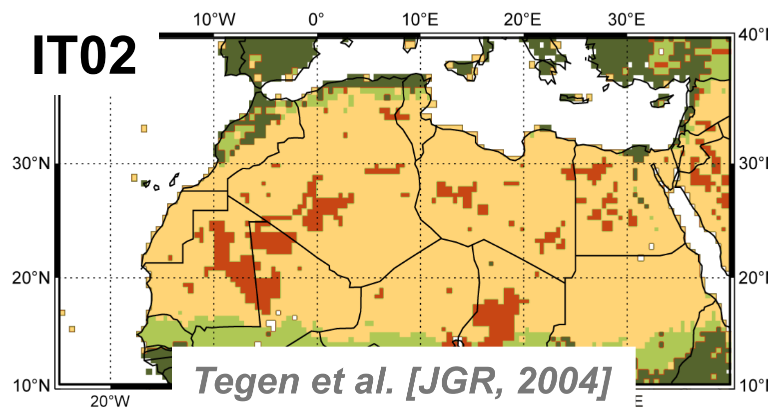
- 3 different land surface parameterisations

MSG



MSG Source activation mask

IT02



Potential Sources =Orographic depressions

BL08

...ical Parameters of the Dry Soil Size Distributions for Soils of the North of Africa [*Marticorena et al.*, 1997a]: Median ...), Standard Deviation (σi), and Mass Fraction (Pi)

	Population 1			Population 2			Population 3		
Typology	Dmed1, μm	σ1	P1, (%)	Dmed2, μm	σ2	P2, %	Dmed3, μm	σ3	P3, %
Silty fine sand (SFS)	210	1.8	62.5	125	1.6	37.5	...	...	...
Medium sand (MS)	690	1.6	80	210	1.8	20	...	...	...
Coarse sand (CS)	690	1.6	100	...	...	...	...	...	...
Coarse medium sand (CMS)	690	1.6	90	210	1.8	10	...	...	...
Fine sand (FS)	210	1.8	100	...	...	...	...	...	...
Silty medium sand (SMS)	125	1.6	37.5	210	1.8	31.25	690	1.6	31.25
Moderately salty silt (SEM)	520	1.5	80	125	1.6	20	...	...	...
Highly salty silt (SEF)	520	1.5	92	125	1.6	8	...	...	...
Salt waste (SW)	125	1.6	50	520	1.5	50	...	...	...
[illegible]	[illegible]	[illegible]	100	...	...	...	...	...	...
[illegible]	[illegible]	[illegible]	50	520	1.5	40	125	1.6	10
Silty coarse sand (SCS)	690	1.6	60	125	1.6	40	...	...	...

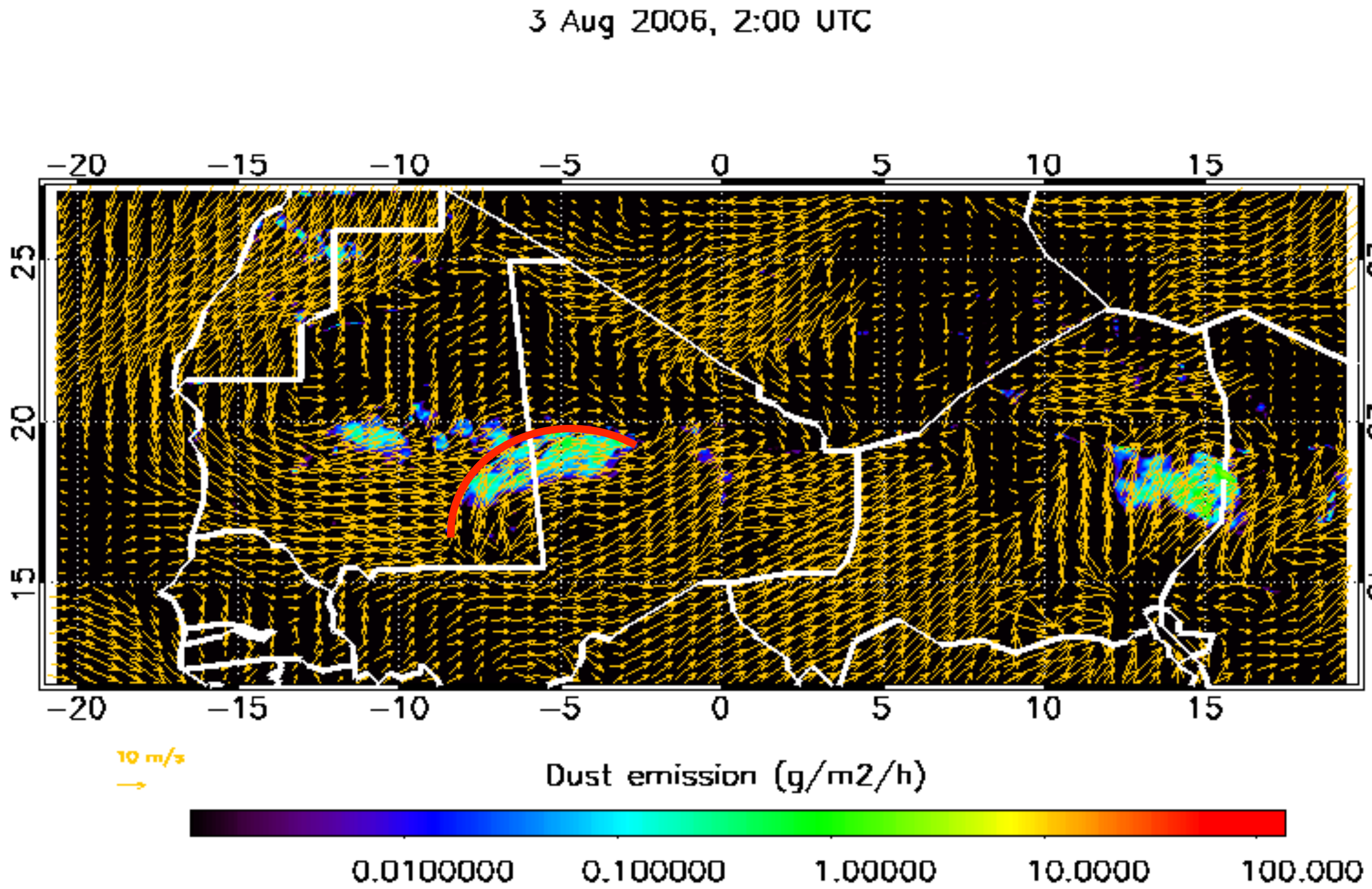
Detailed soil data base

Laurent et al. [JGR, 2008]

Modelled Dust Emission

UNIVERSITY OF LEEDS

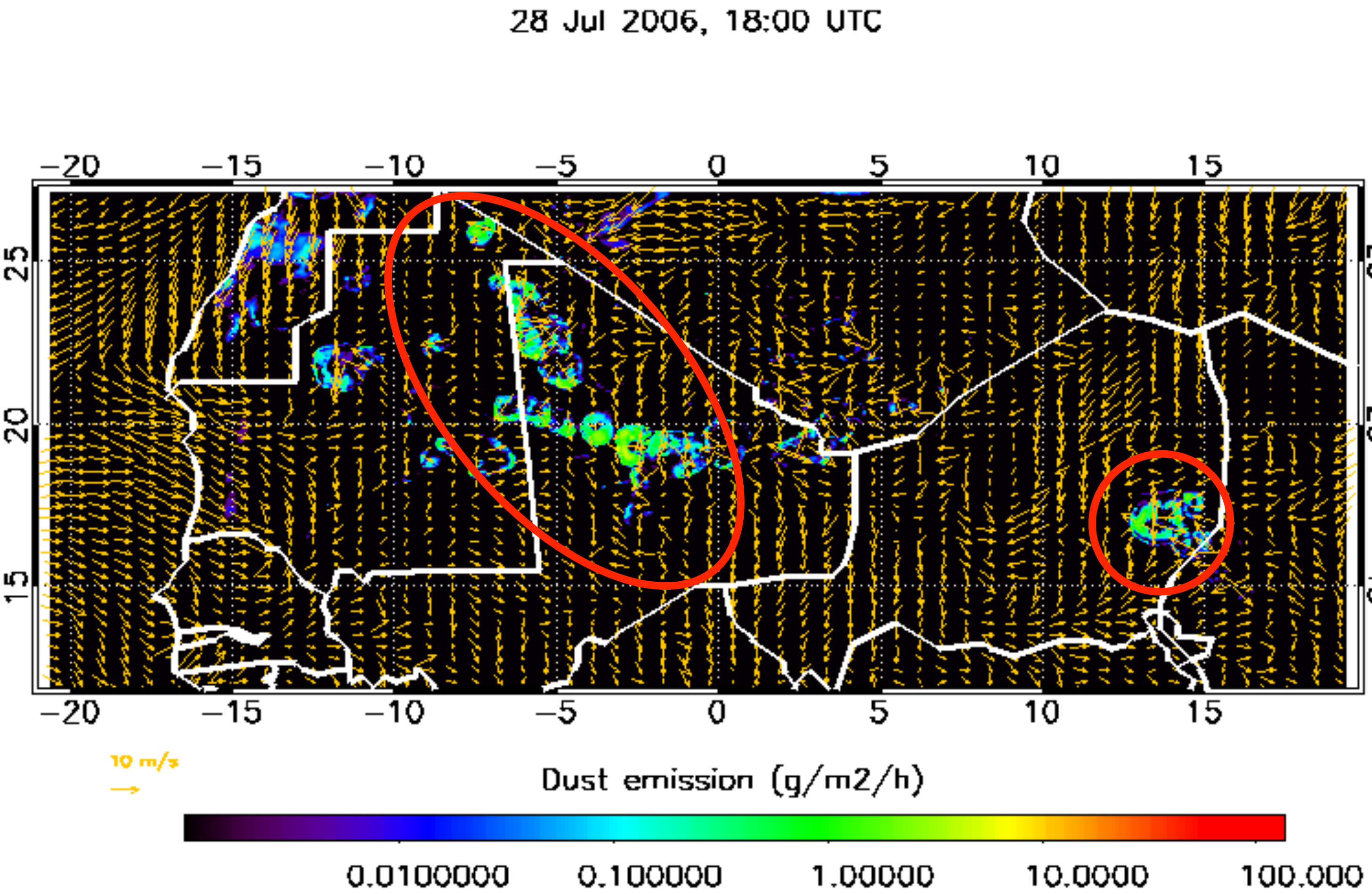
Haboobs



Modelled Dust Emission

UNIVERSITY OF LEEDS

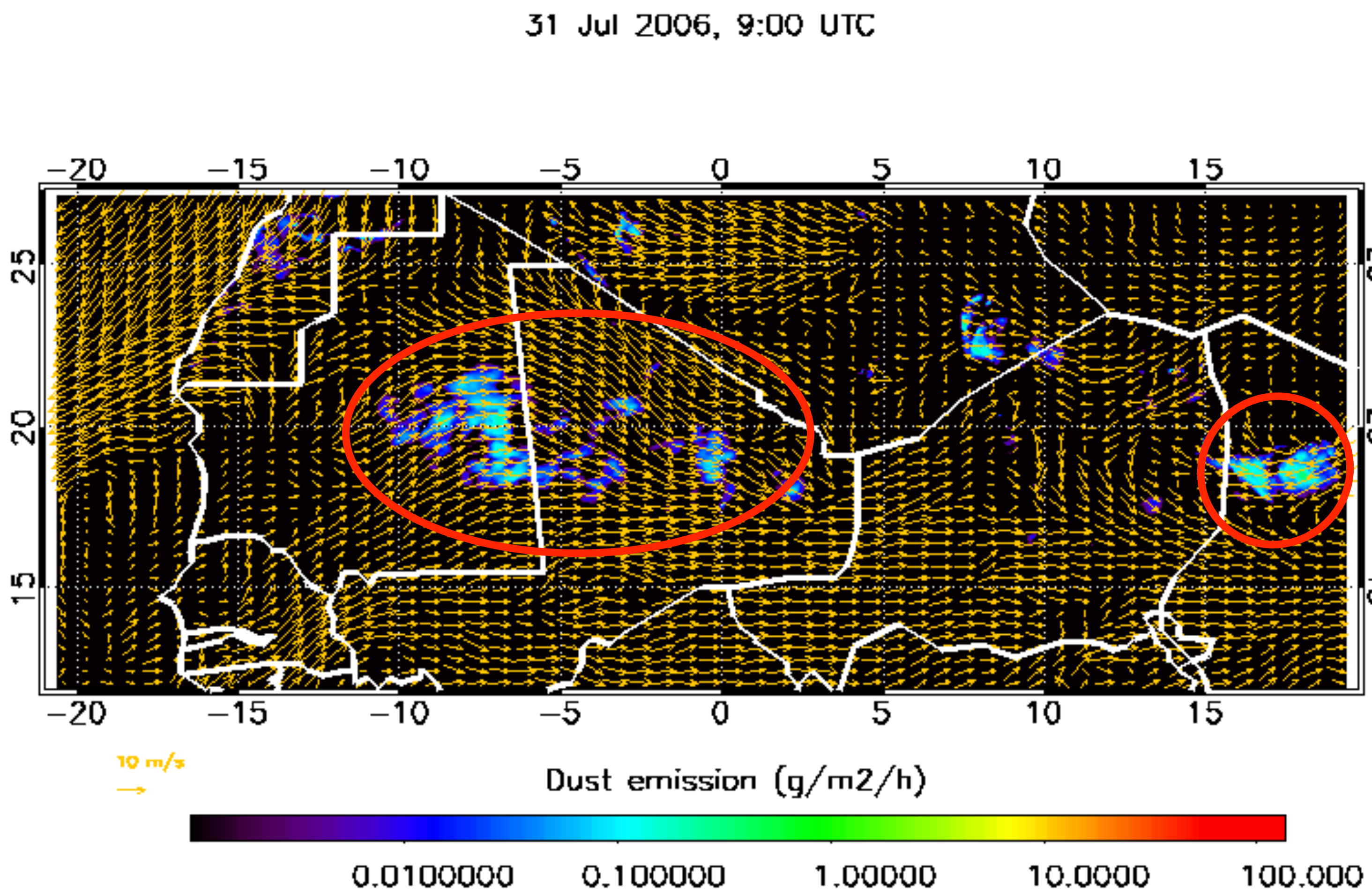
Microburst-like Events



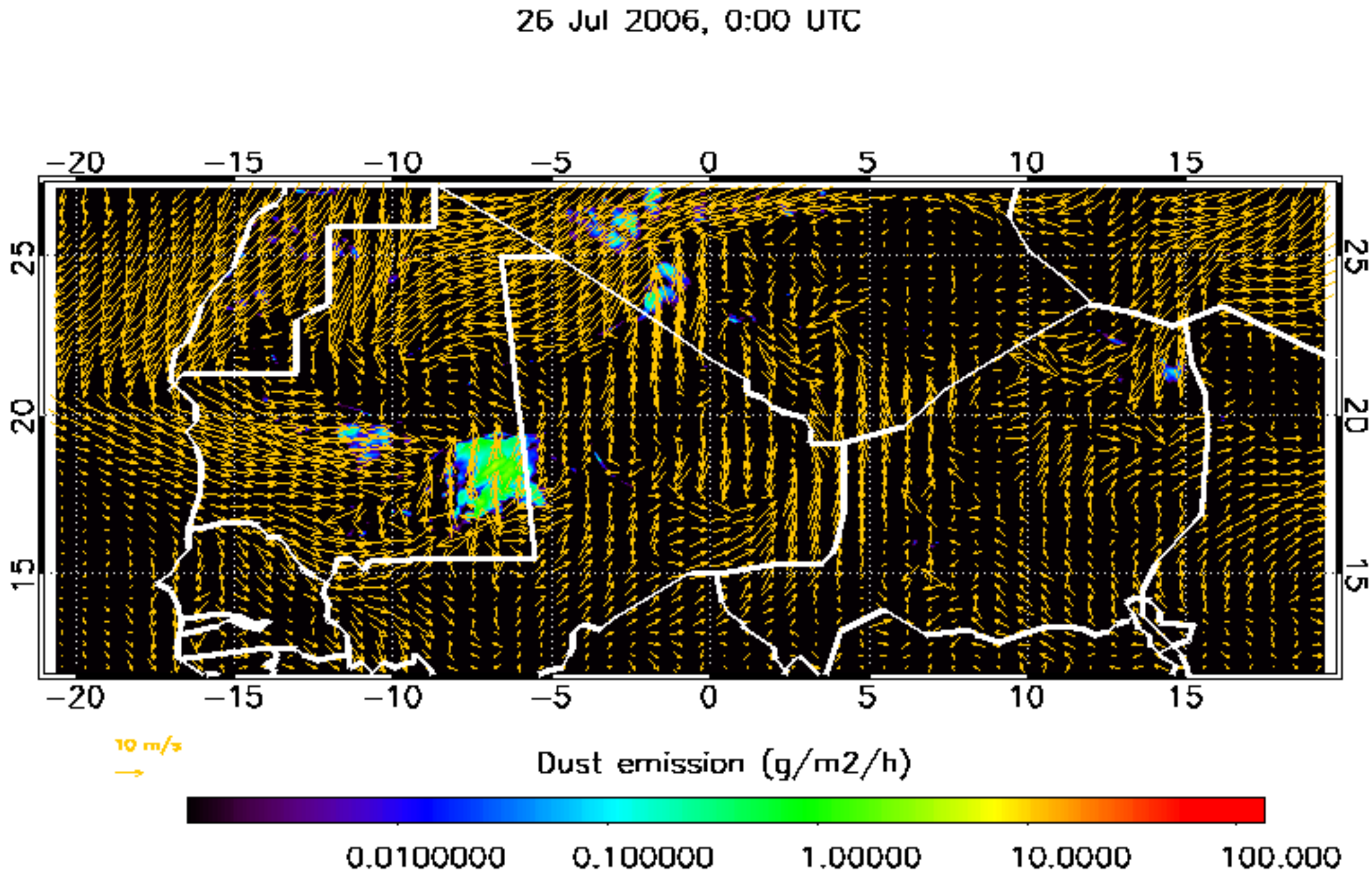
Modelled Dust Emission

UNIVERSITY OF LEEDS

Break-down of NLLJs



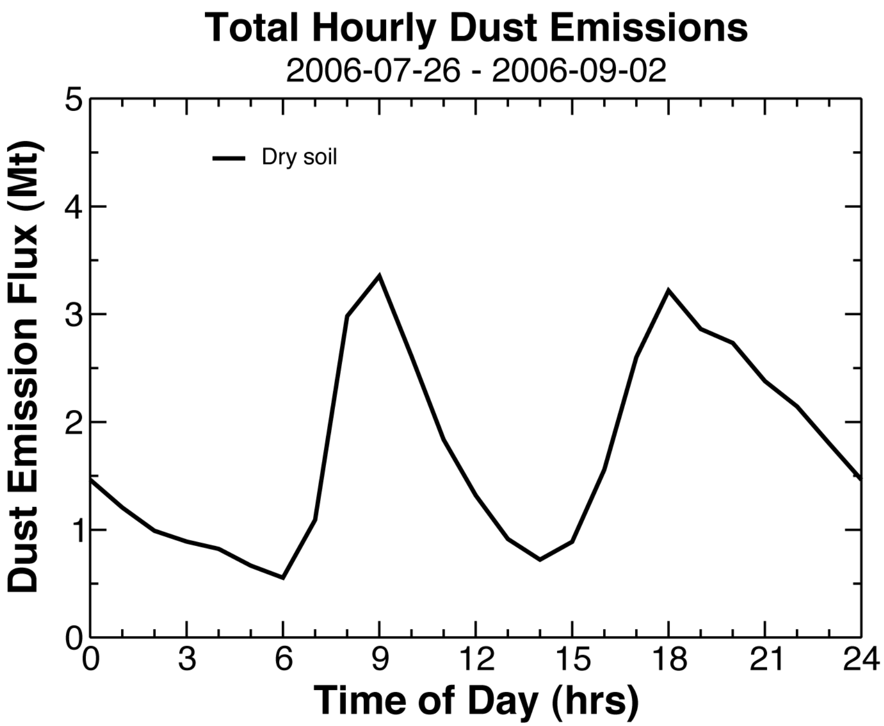
Modelled Dust Emission

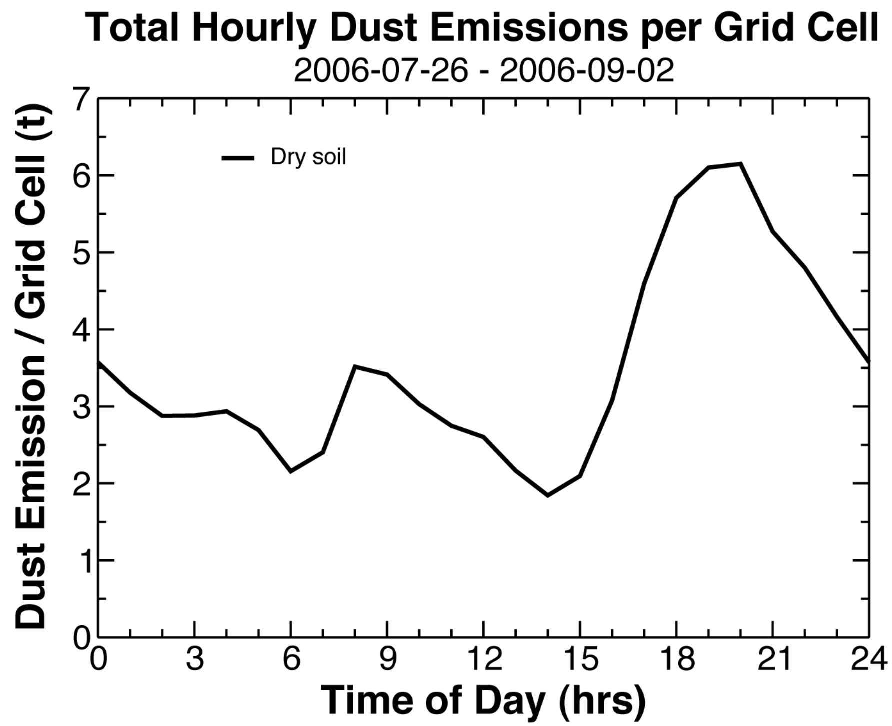


Role of Moist Convection & NLLJs

UNIVERSITY OF LEEDS

Daily Cycle of Dust Emission



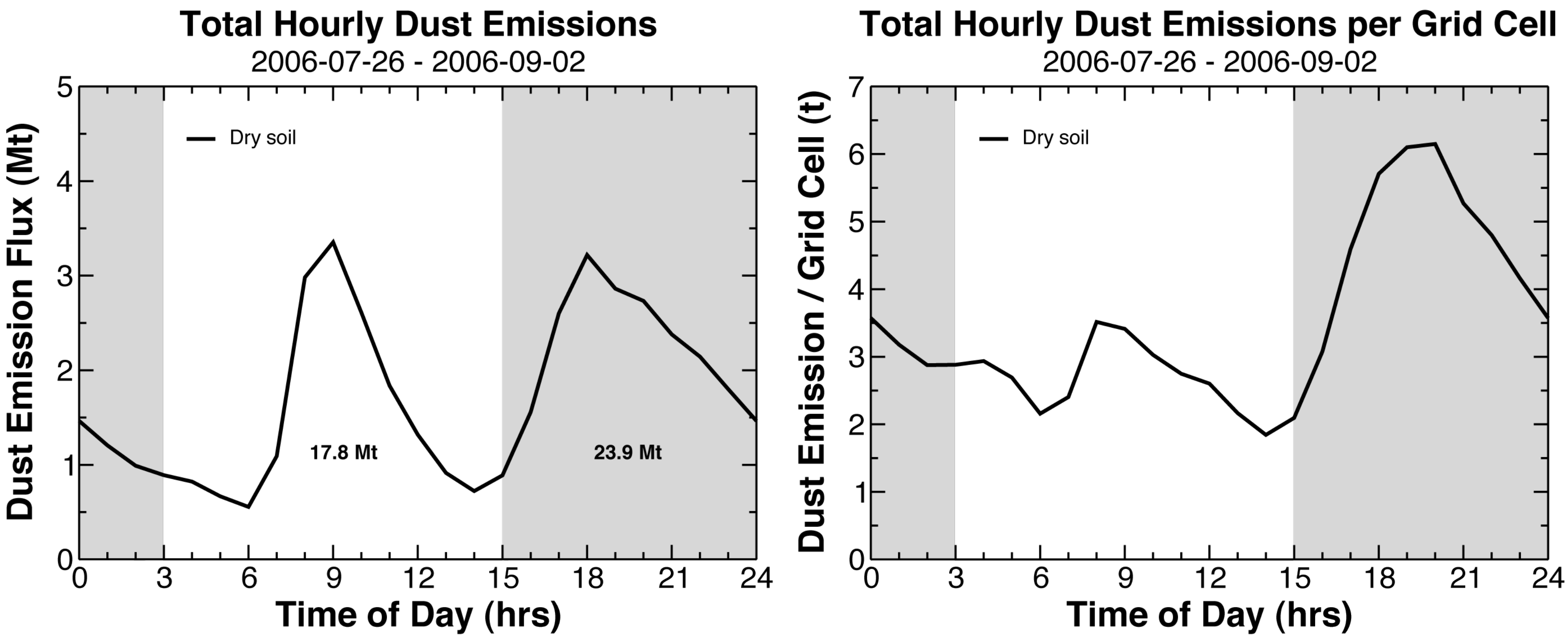


- Analysis by time of day suggests slightly higher dust emissions due to moist convective cold pools (haboobs and microburst-like events)
- Cold pools are highly efficient in dust source activation compared to LLJs

Role of Moist Convection & NLLJs

UNIVERSITY OF LEEDS

Daily Cycle of Dust Emission

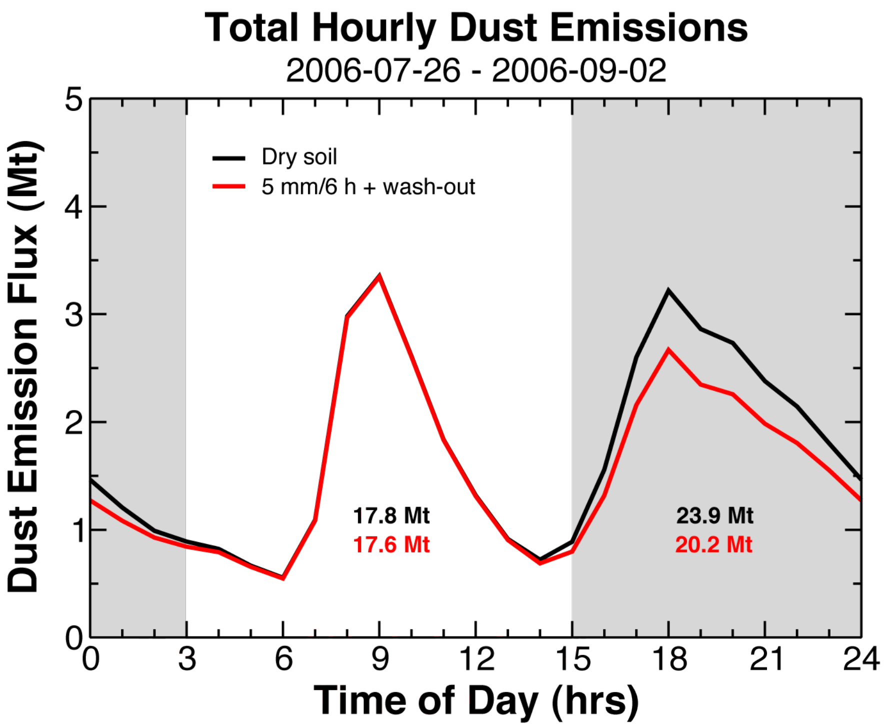


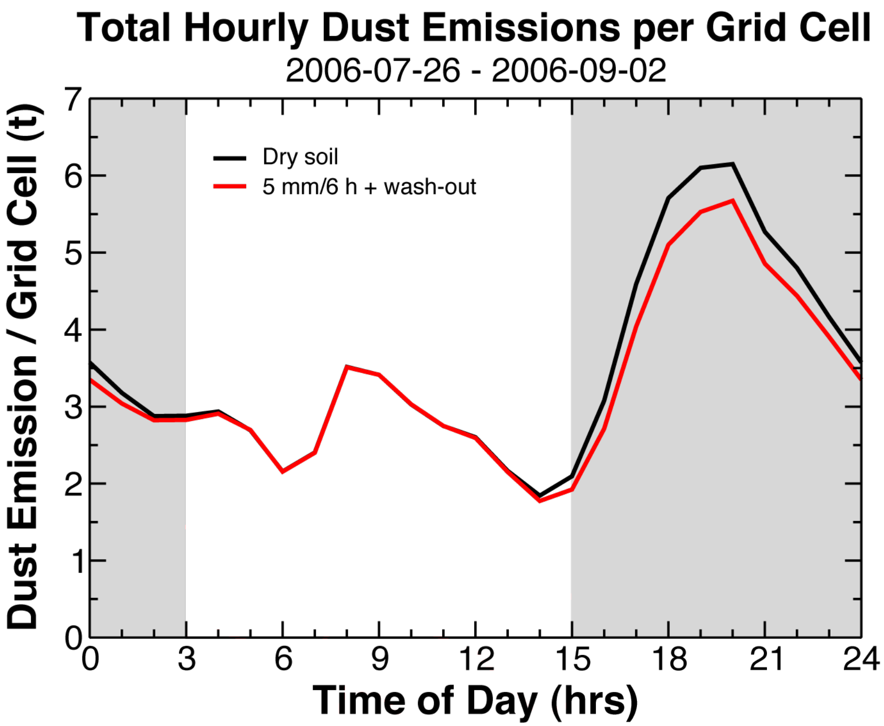
- > 50% of dust emissions occur from afternoon to night, which are supposed to be due to convective cold pools (haboobs and microbursts)
- Cold pools are highly efficient in dust source activation compared to LLJs

Role of Moist Convection & NLLJs

UNIVERSITY OF LEEDS

Daily Cycle of Dust Emission



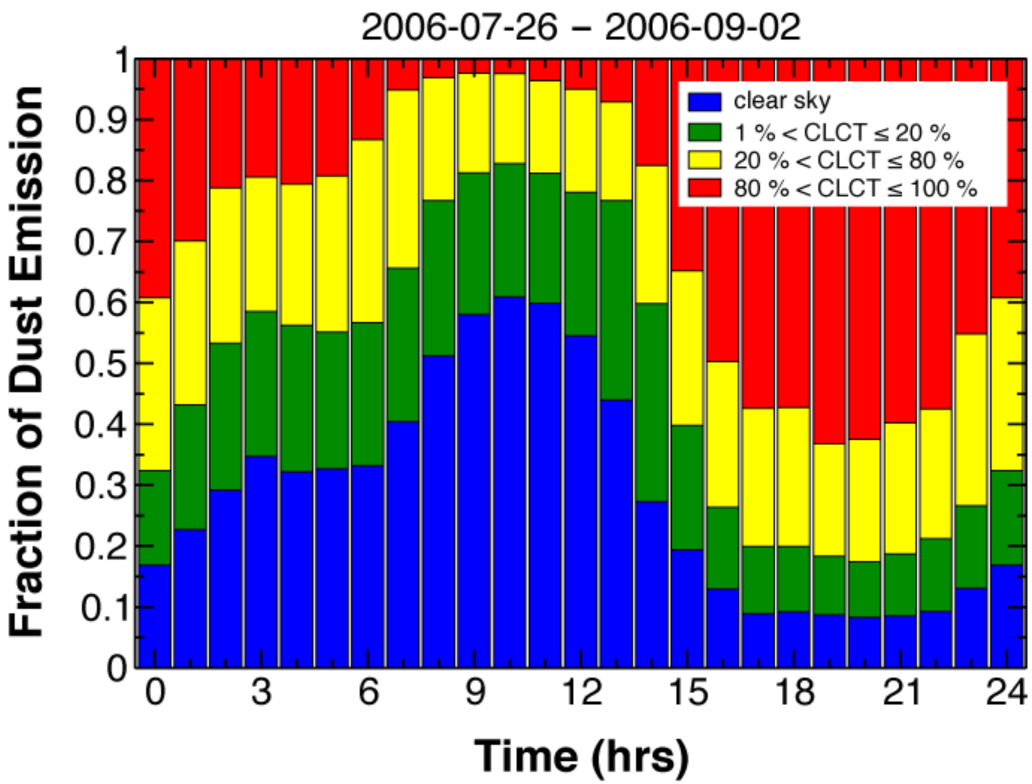


- > 50% of dust emissions occur from afternoon to night, which are supposed to be due to convective cold pools (haboobs and microbursts)
- Cold pools are highly efficient in dust source activation compared to LLJs

Role of Moist Convection & LLJs

UNIVERSITY OF LEEDS

Dust Emission vs. Cloud Cover

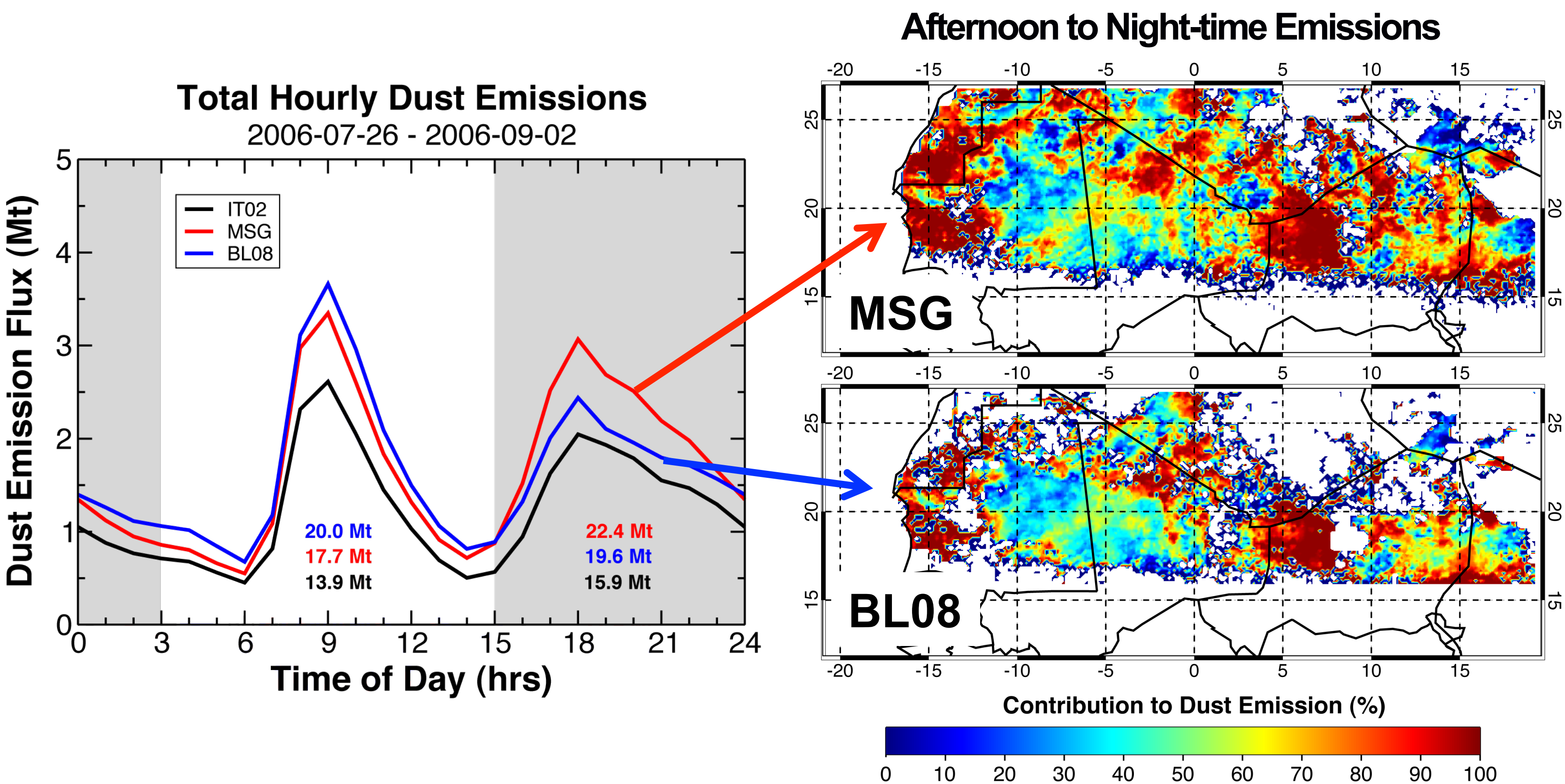


- 80% of moist convective dust events are at least partly obscured by clouds
- Satellite retrievals are likely biased towards NLLJ-induced dust emissions

Sensitivity Study

UNIVERSITY OF LEEDS

Sensitivity to Surface Characteristics

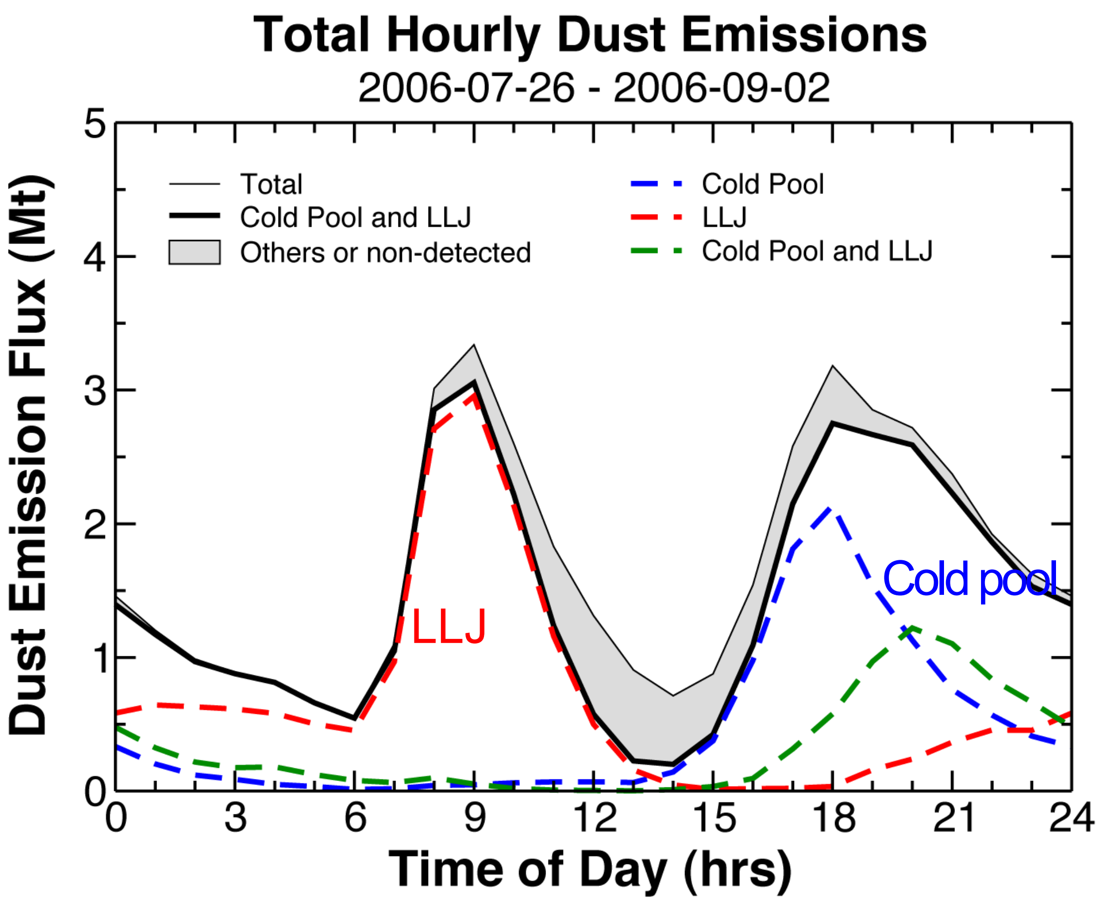


- Different DES favour different source regions and meteorological drivers

Quantification of Key Processes

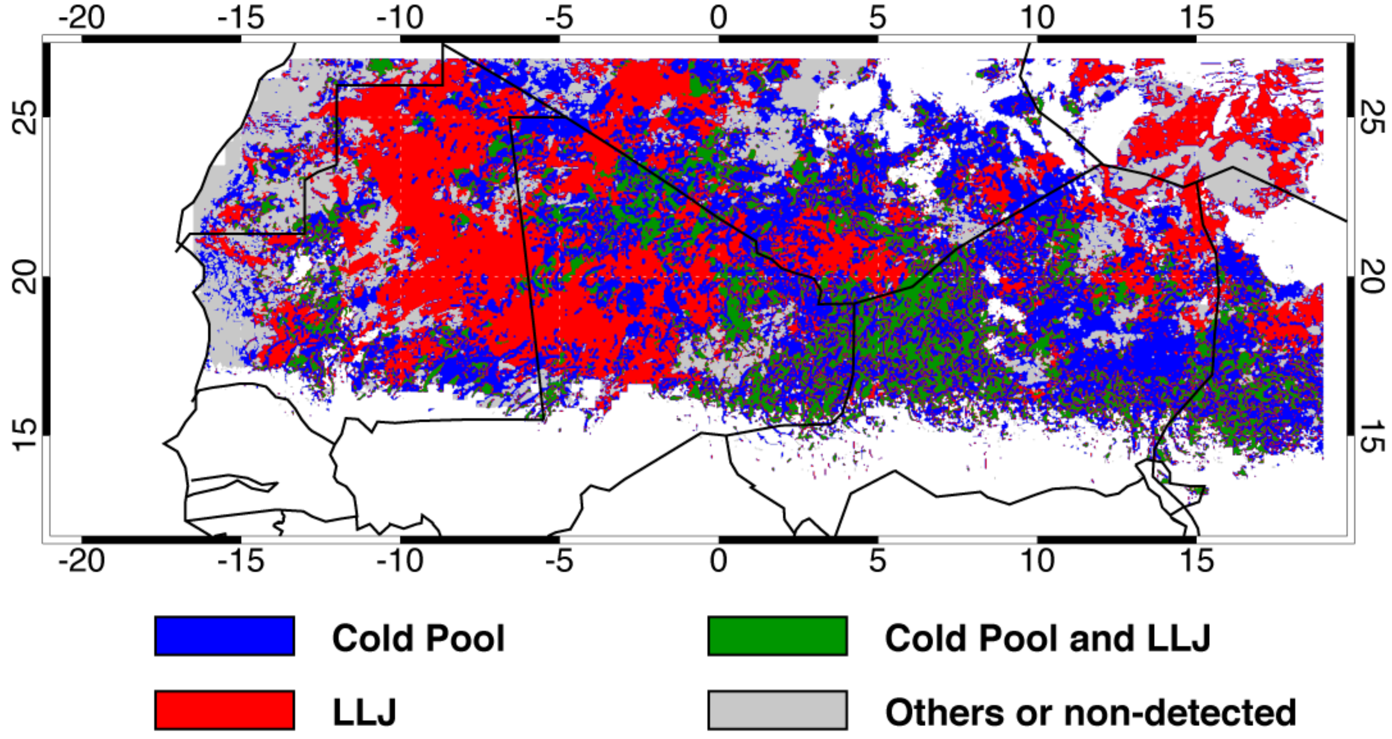
UNIVERSITY OF LEEDS

Objective Detection of Cold Pools and NLLJs



- Detection of cold-pool and NLLJ-related dust emission using objective algorithms
- NLLJs : 40%
- Cold pools: 27%
- Other processes and missed detection: 14%
- Problem: Ambiguity during evening and night-time hours (19%)

Hot Spots of Meteorological Drivers of Dust Emission



Summary

UNIVERSITY OF LEEDS

- Moist convective cold pools and break-down of nocturnal low-level jets are key meteorological processes of desert dust mobilization
- Assessing their contribution to the Saharan dust production through observations and modelling is still challenging
- First convection-permitting, continental-scale Cascade simulations are used for offline dust emission computations over summertime W-Africa
- Time-of-day analysis: 53% afternoon-night emissions supposed to be related to the more efficient moist convective events
- Detection method: 27% and 40% contribution by cold pools and NLLJ, respectively, but 19% ambiguous detections
- Tests with different dust schemes show sensitivity of each NLLJ and cold-pool induced dust mobilisation to land surface characteristics

Acknowledgements

UNIVERSITY OF LEEDS

We would like to thank:

Cascade modellers for providing the UM data,

Nick Dixon (University of Leeds) for managing UM data and support,

Benoit Laurent (LISA Paris) for providing soil data and DES development.

erc

Detection Algorithms

UNIVERSITY OF LEEDS

Nocturnal LLJs

- New objective detection algorithm for low-level jets
- Based on criteria for static stability and vertical wind shear
- **Poster Po.8B.13 S. Fiedler et al.**

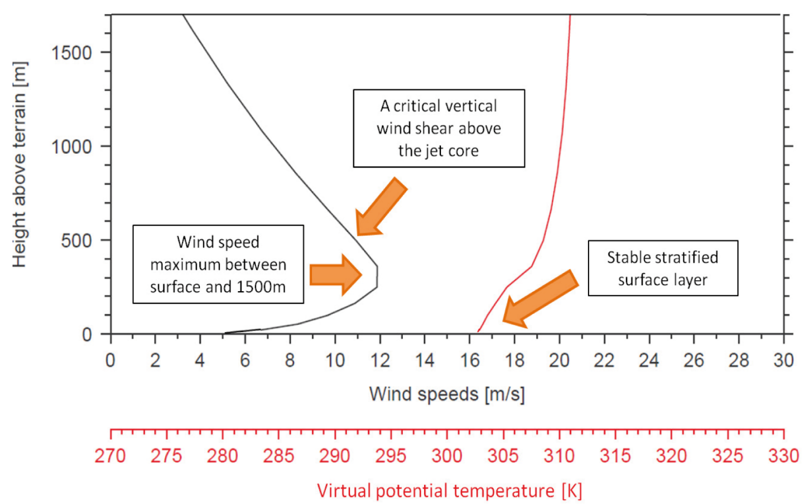
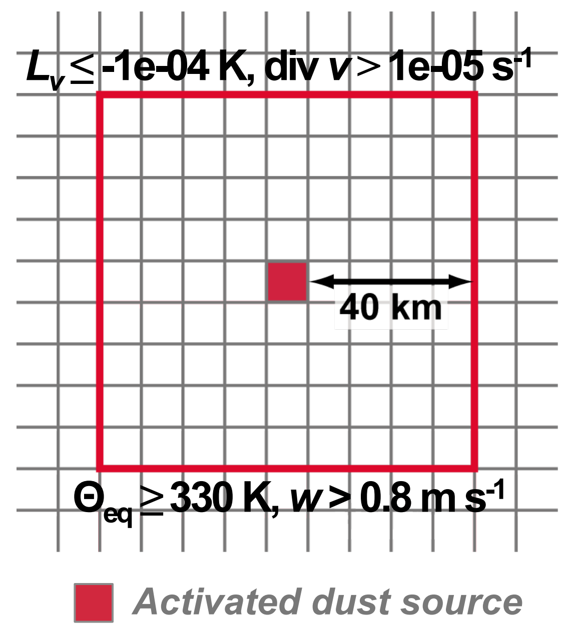


Figure: S. Fiedler

Convective Cold Pools

- Detection of cold-pool-related dust emissions
- Testing multiple thresholds within 40 km radius



Dust Emission Scheme (DES)

UNIVERSITY OF LEEDS

Offline version of DES Tegen et al. (2002; 2004)

- Dust emission depend on:
  - Surface wind speed (UM)
  - Vegetation cover and type (external data set)
  - Surface roughness (external data set)
  - Soil texture (external data set)
  - Soil moisture, snow cover (UM)
- Dust emission flux:

$$F = \alpha \cdot A_{eff} \cdot G \cdot (1 - A_{snow}) \cdot I_{\theta}$$

$$G = \frac{\rho_a}{g} \cdot u_*^3 \cdot \sum_i [(1 + \frac{u_{*tri}}{u_*})(1 - \frac{u_{tr,i}^2}{u_*^2}) \cdot s_i] \qquad \text{for} \quad u_* \geq u_{*tr}$$

Cascade Project

- UK NERC-funded consortium (Walker Inst., U. Reading, U. Leeds, U. East Anglia, MetOffice, NCAS, BADC)
- Investigation of organisation of tropical convection at different time and length scales
- Satellite observations and high-resolution regional modelling over West Africa and Indian Ocean / West Pacific
- Funding period: 2008 – 2012
- http://climate.ncas.ac.uk/Cascade

NATURAL ENVIRONMENT RESEARCH COUNCIL

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL
Walker INSTITUTE
University of Reading
UEA University of East Anglia
Met Office
British Atmospheric Data Centre