Towards an Improved Representation of Meteorological Processes in Models of Mineral Dust Emission

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INTRODUCTION

- Mineral dust is a key player in the Earth system with important ramifications on radiation, clouds, atmospheric chemistry, biogeochemical cycles and human health.
- Satellite observations of aerosol optical thickness are the main constraints on the dust cycle.
- Emission and deposition are poorly observed and understood, and must be "tuned".
- Emission is highly sensitive to the tail end of the near-surface wind-speed distribution.
- Small discrepancies between analysis products / modelling strategies lead to massive differences in dust emission.

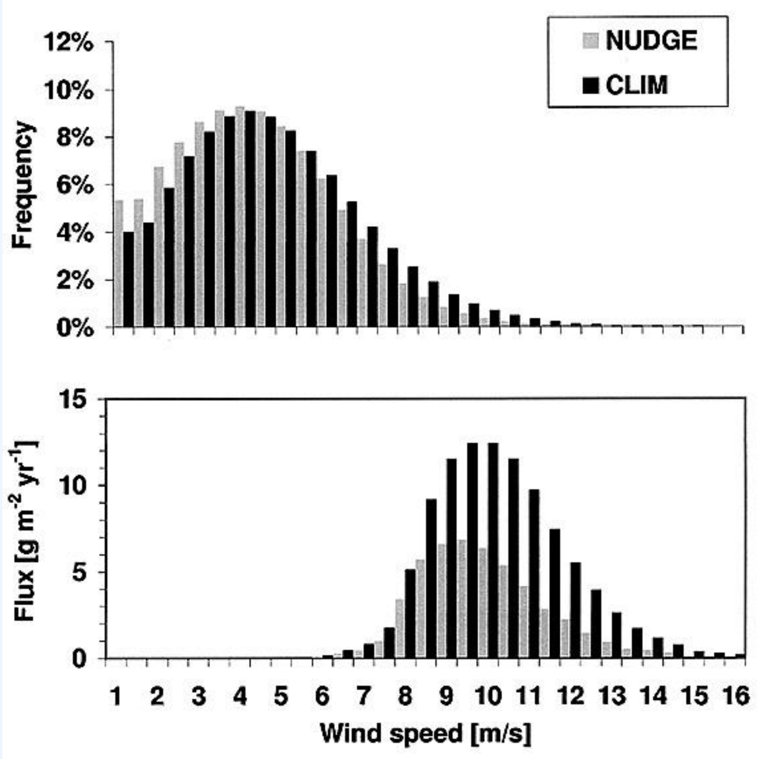


FIG. 1: Frequency distribution of grid cell mean winds (top) and corresponding distribution of the global dust flux as a function of wind speed (bottom) in the ECHAM4 used as a climate model and nudged to ERA-15 re-analysis, respectively (from Timmreck & Schulz 2004).

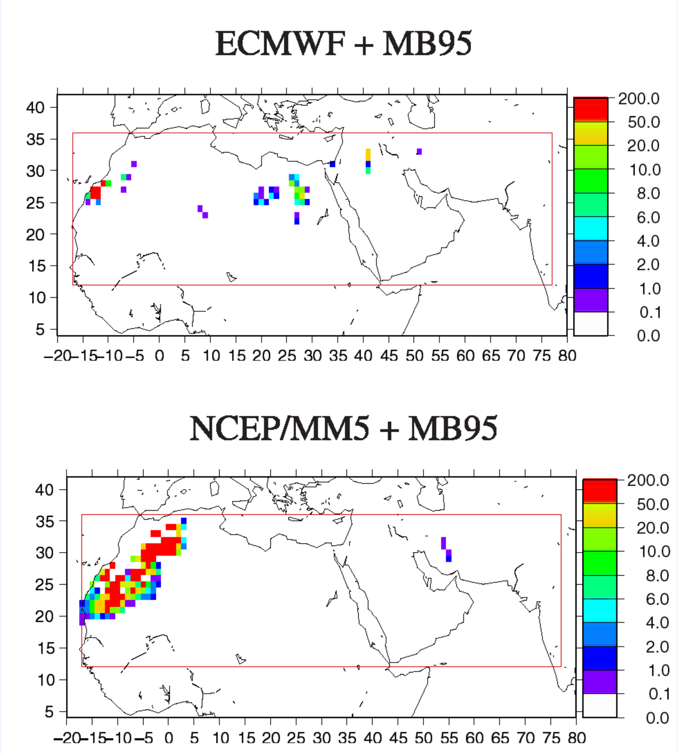


FIG. 2: Dust emission flux maps for 12 UTC 20 February 2004 using the Marticorena & Bergametti (1995) dust emission scheme, and ECMWF (top) and NCEP data (bottom) as meteorological forcings (from Menut 2008).

- There is an urgent need to better understand meteorological processes crucial for dust emissions and their representation in numerical dust models.
- This is the main objective of a new European Research Council Starting Grant project at the University of Leeds.

LOW-LEVEL JETS

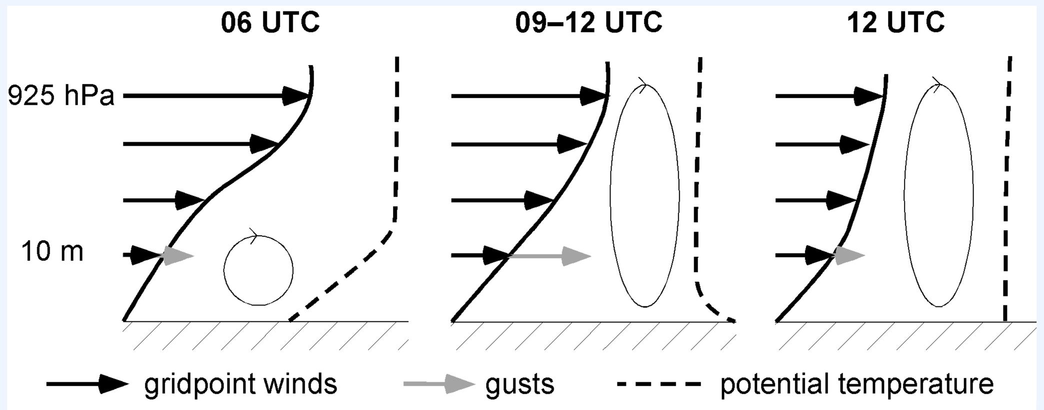


FIG. 3: Schematic depiction of typical changes in low-level wind, gusts, potential temperature and turbulence in the West African heat low region. (from Knippertz 2008).

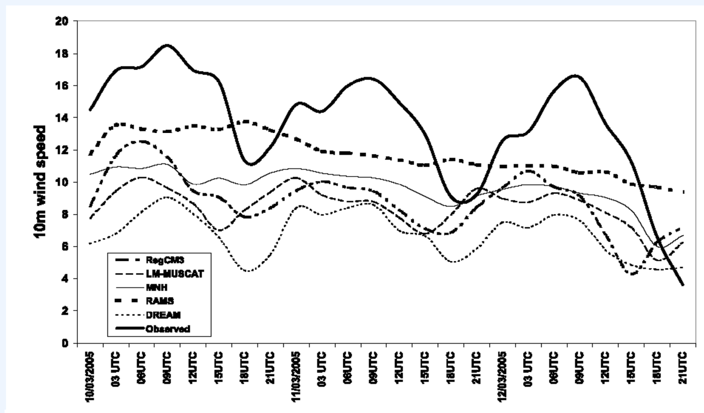


FIG. 4: The diurnal cycle in wind speed over the Bodélé Depression in observations and five regional models (from Todd et al. 2008).

- Intense low-level jets form over desert regions due to an inertial oscillation in the layer above the nighttime surface inversion (Fig. 3).
- Downward mixing of momentum during the build-up of the planetary boundary layer in the morning creates peak wind speeds and dust emission.
- This process is largely underrepresented by numerical models (Fig. 4).

HABOOBS

FIG. 5: Example of a haboob. The dust-filled cold pool is usually ~1.5 km deep and runs ahead of the parent storm.

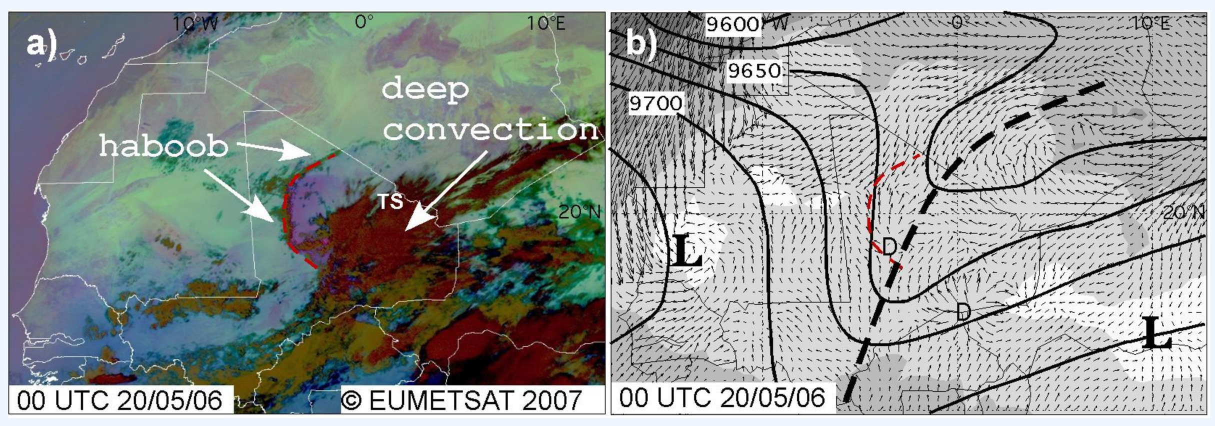
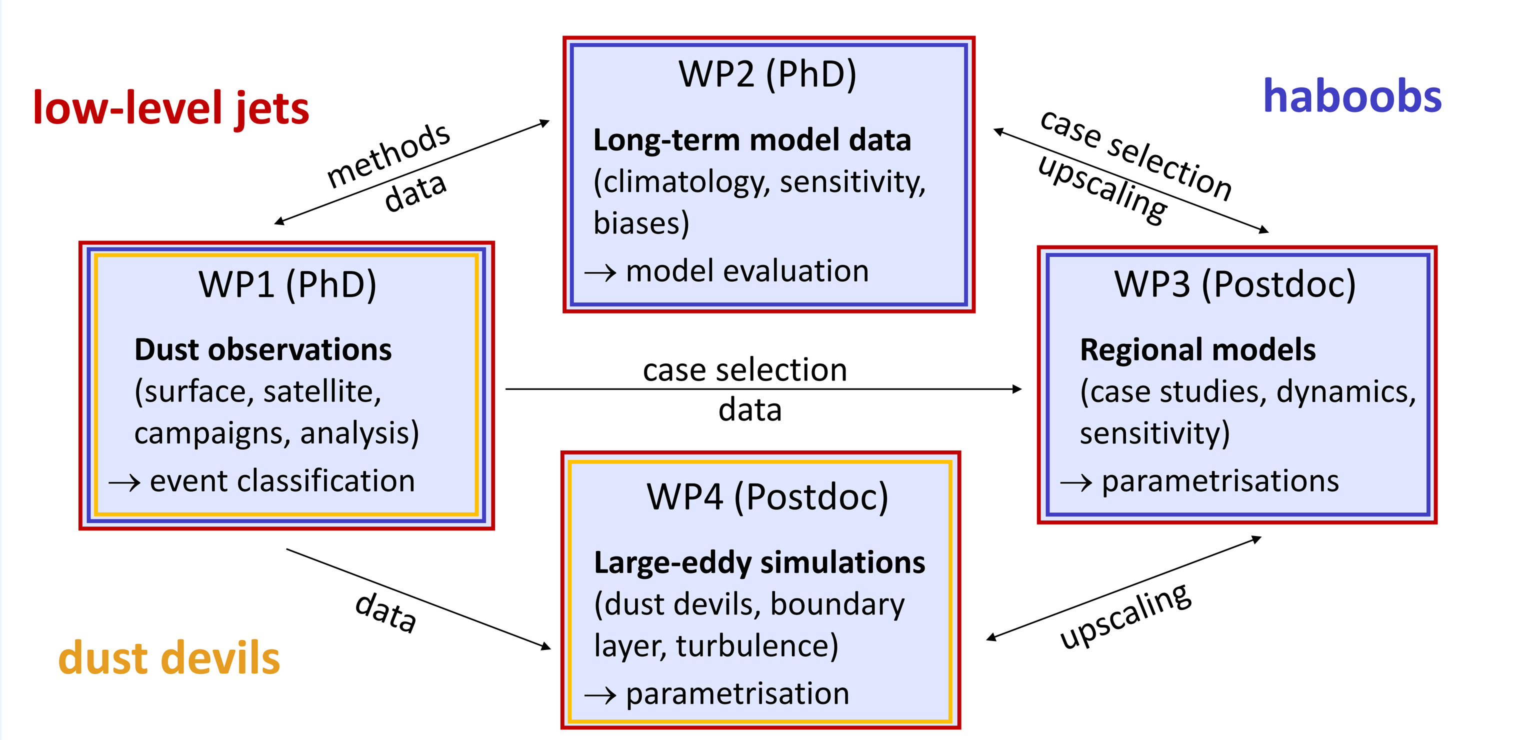


FIG. 6: Meteosat Second Generation dust product (magenta = dust, dark red = cold, thick high-level clouds ; brown = thick mid-level clouds) and ECMWF analysis showing geopotential height at 300 hPa (thick lines every 25 gpm), mean sea level pressure (grey shaded) and wind vectors on the lowest model level. The haboob clearly visible in the satellite data is absent in the analysis *(from Knippertz et al. 2009).*

- Haboob dust storms (Fig. 5) form at the leading edge of cold pools generated through evaporating precipitation.
- Haboobs occur in connection with organized convection, mostly at the southern and northern fringes of the Sahara.
- Haboobs are difficult to observe due to cloud contamination of satellite products.
- Convection schemes struggle to represent the mesoscale organization and therefore the peak winds (Fig. 6).

THE "DESERT STORMS" PROJECT



- €1.4M funding from ERC over 2010–2015
- Integral approach: combines a wide range of observations, models and methods
- New approach: model evaluation and assessment on process level
- Ultimate aim: identify optimal model configurations and develop parametrisations for 3 key processes

- Possible interactions with **AeroCom**:
  – provide event classification
  – obtain data for model evaluation (if possible hourly)
  – provide parametrisations for test in given model
  – obtain feedback on performance

DUST DEVILS

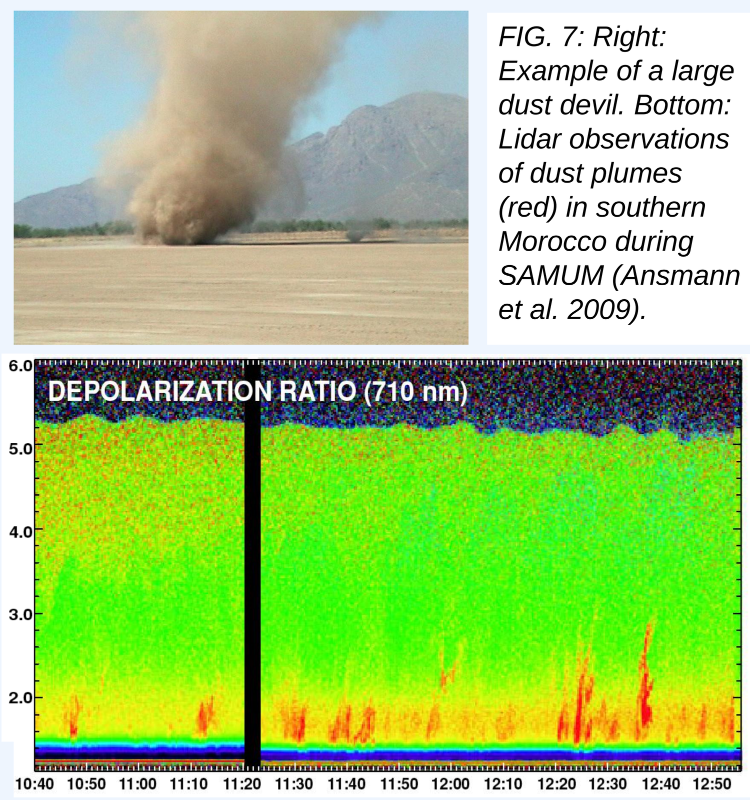


FIG. 7: Right: Example of a large dust devil. Bottom: Lidar observations of dust plumes (red) in southern Morocco during SAMUM (Ansmann et al. 2009).

- Rotating dust devils and non-rotating dusty plumes form in active dry-convective desert boundary layers.
- Typical scales are diameters of 10–100m and lifetimes of minutes.
- Their effects are not represented in dust models at all.
- Rough estimates based on field observations suggest a contribution to the global dust emission of up to 35% (Koch & Renno 2005).

CONCLUSIONS

- Estimates of dust emission are highly uncertain, largely due to problems with the representation of peak wind speeds in numerical models.
- The key meteorological phenomena that cause these uncertainties are nocturnal low-level jets, moist convective cold pools and dry convective mixing processes in the daytime planetary boundary layer.
- The ERC-funded "Desert Storms" project at the University of Leeds aims at deepening our physical understanding of these processes, which should ultimately lead to model improvements through more adequate model configuration and/or parametrisations.
- The project seeks interactions with the AeroCom community through exchange of data and tests of new parametrisations in AeroCom models.

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