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Dust Emission from Crusted Surfaces

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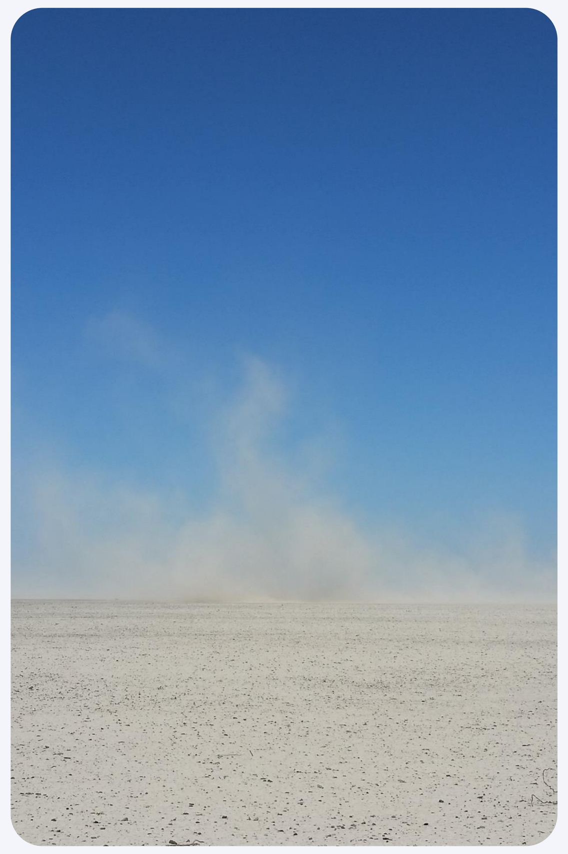

Fig. 1: Dust plume, Lordsburg Playa, NM, USA, 20 Oct 2016. Photo: M. Klose

Motivation:

- Crusted surfaces, e.g. ephemeral lakes, are known as efficient dust sources (e.g. ***Fig. 1***)
- The surface condition on crusted surfaces is often heterogeneous and particle supply is limited.
- Sediment entrainment under such conditions is not well understood and the applicability of existing dust emission schemes is not well tested.

Objectives:

- *Investigate the **variability of sediment entrainment** from crusted surfaces using detailed field data*
- *Test the **applicability of a state-of-the-art dust emission scheme** to represent dust emission from a crusted surface*

Field Data:

- Detailed field measurements have been conducted in spring and fall 2016 (cf. ***Fig. 2***) at different locations in NM, USA (*Klose et al.*, 2018, in prep.) including
  - Sampling of loose erodible material (LEM) using a new sampling system (*Klose et al.*, 2017)
  - Sampling of surface crust
  - Meteorological measurements
  - Measurement of sediment transported in saltation using samplers and optical sensors
  - Measurement of sediment transported in suspension using laser-based aerosol monitors
  - Laser-based particle-size analysis of the collected physical samples
- SANTRI^{TM} platforms (*Etyemezian et al.*, 2017a, 2017b) were deployed for some events to obtain detailed saltation measurements.
- Here, we focus on Site C for which the most complete data set is available for Spring 2016. The site has sandy soil and a weak carbonaceous crust.

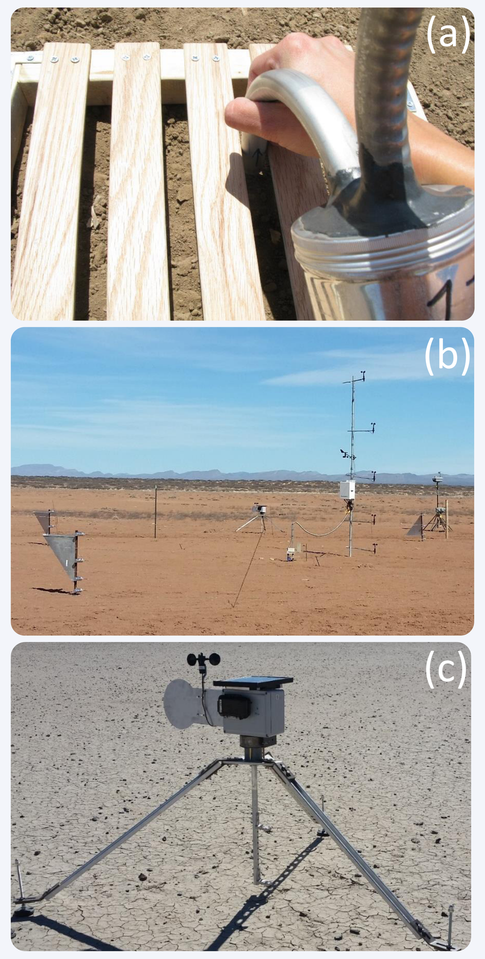

Fig. 2: Photographs showing (a) LEM sampling, (b) a measurement site containing instrumentation to measure meteorological and sediment transport quantities, and (c) a SANTRI measurement platform.

Particle-size distribution – Model input

- Samples of the top ~1-cm soil layer are commonly used to obtain particle-size distributions (PSDs) for use in models. These PSDs might not be suitable to represent the particle population exerted to wind forces.
- Samples of soil crust and loose erodible material (LEM) were taken and allow for testing of the effect of PSD on model performance.
- ***Fig. 3*** shows a comparison of the different PSDs used here. The PSDs of LEM and crust highlight the differences of the surface sediment components.

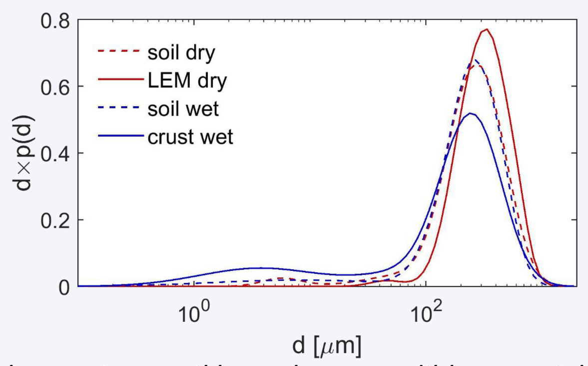

Fig. 3: Particle-size distributions of the top 1-cm soil layer, loose erodible material, and soil crust analyzed in wet/dry dispersion and used as model input.

Sediment transport – Field measurements

- Comparison of the saltation flux, Q [g m^{-2} s^{-1}], estimated using Kawamura (1964) with that obtained from SANTRI measurements showed that Q was overestimated by 3 orders of magnitude. This was expected, because surface crusting limits particle supply. (***Fig. 4***).

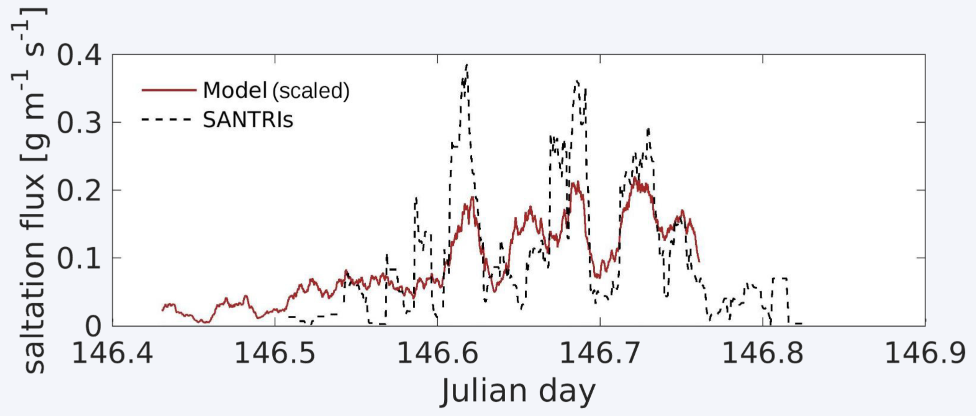

Fig. 4: Saltation flux, Q [g m^{-1} s^{-1}], obtained from SANTRI measurements (black dashed line) and estimated based on Kawamura (1964) and scaled by 1/1000 (red line) for a dust event on 25 April 2016.

- ***Fig. 5*** shows averaged 1-min saltation counts and dust emission flux, F [mg m-2 s-1], in relation to wind maxima, u_{max} [m s^{-1}], for 6 events in Spring 2016 on Site C.
- F was much weaker on 14 and 22 March compared to 12 March despite a larger number of saltation counts. This was possibly caused by the strong previous event on 12 March, which had visually eroded the surface.
- On 23 March, dust emissions were again strong, most likely due to a change in wind direction by ~70°, thereby exposing different surface areas to saltation.
- On 25 and 26 April, dust emissions remained strong with a shallower increase of F with u_{max} on 26 April.
- Note that Wenglor records showed gaps due to clogging of the laser window and Wenglor saltation counts therefore need to be interpreted with caution.
- Little rainfall occurred in April 2016.

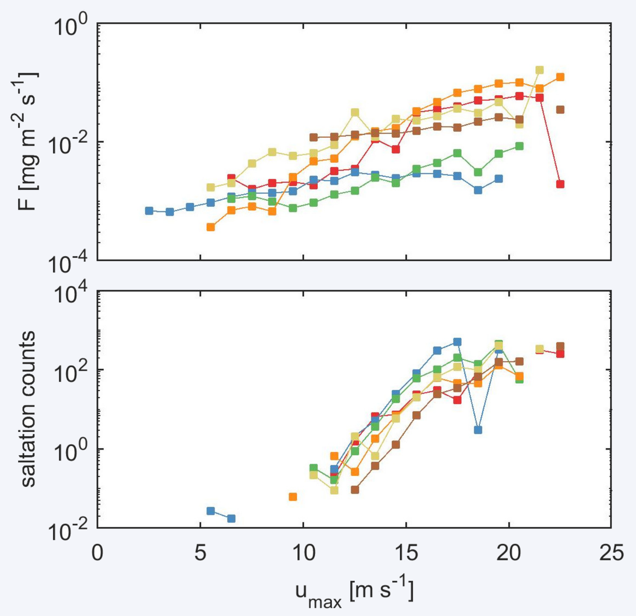

Fig. 5: (a) Dust emission flux, F [mg m^{-1} s^{-1}], obtained from DustTrak measurements and (b) Wenglor® saltation counts versus 1-min wind speed maxima (4.8m height) for 6 events in Spring 2016 on Site C.

Dust Emission Scheme:

- The parameterization from *Shao* (2004) estimates size-resolved dust emission based on the soil volume removed through saltation impacts.
- Key parameters of the scheme are (*Shao et al.*, 2011)
  - c_y proportionality parameter
  - κ measure for aggregate stability (less stable for larger κ)
  - P soil plastic pressure [N m^{-2}]; affects volume removal ("bombardment") efficiency
- *Shao et al.* (2011) achieved very good results for their study site (a sand surface) using $c_y = 5.7 \times 10^{-5}$, $\kappa = 0.5$, and $P = 20250$ N m^{-2}.
- The scheme uses minimally and fully-dispersed PSDs to mimic the parent soil PSDs under, respectively, no and maximum (mechanical) dispersion.
- We use $Q_{Kawamura}$/1000 in combination with the dust emission scheme as suggested by comparison of modeled and measured saltation flux (***Fig. 3***). We note that by using a constant scaling factor, we ignore a possible between-event variability.

References
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Dust emission flux – Model and observations

- The parameters c_y, κ, and P were adapted to achieve a 'best fit'-combination.
- When using soil PSD, modeled dust emission fluxes underestimated the extremes, i.e. small fluxes were overestimated and large fluxes were underestimated (not shown).
- Representing the minimally and fully dispersed PSDs with LEM and crust PSDs instead of soil PSDs (***Fig. 3***) led to improved and very good agreement between model and observations in most cases (***Fig. 6***). This suggests crust abrasion through saltation bombardment as the dominant emission mechanism.
- Individual peaks were not captured by the model. The reason is likely heterogeneity of dust emission on the site, which also limits the applicability of the gradient method for dust flux calculation.
- On 14 March observed dust emission fluxes peaked earlier than predicted. However, observed Wenglor saltation counts (not shown) indicated peak saltation activity at around 17:20 LST, consistent with the model results.
- Very good agreement can be achieved using a consistent set of parameters (***Fig.6***) that reflects the insights obtained from observations:
  - Soft crust leading to small P (*Rice et al.*, 1997)
  - Reduced dust emission efficiency on 14 and 22 March, recovery on 23 March
  - Somewhat weaker aggregate stability on 25 April, possibly due to antecedent rainfall and corresponding surface renewal.

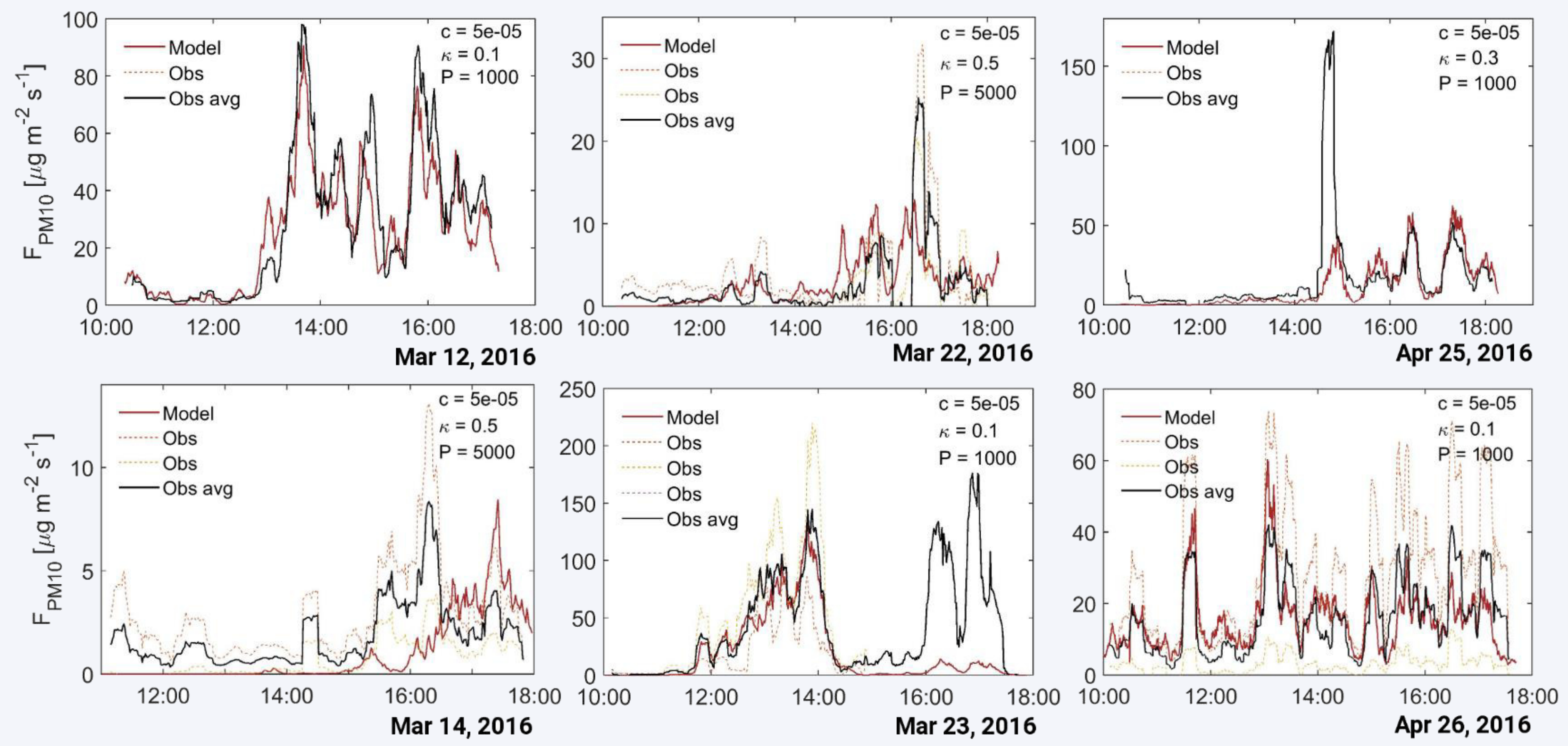

Fig. 6: Dust emission flux, F [g m^{-2} s^{-1}], obtained using the S04 scheme (red line) with optimized parameters and estimated from dust concentration measurements using the gradient method (individual instrument pairs as available – dashed colored lines; average – red line) for 6 dust events in Spring 2016 on Site C.

Conclusions

- The dust emission scheme from *Shao* (2004) is able to reproduce dust emission from a crusted surface, if accurate input is provided, in particular for the
  - particle-size distributions of the sediment available for saltation and dust emission
  - saltation flux
- Changes of dust emission efficiency are consistent between observations and best-fit model parameters.
- Comparison with other crusted locations is needed to generalize the results.

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