Convective dust storms during Saharan dust outbreak on Northern Adriatic

Boris Mifka[1], Maja Telisman Prtenjak[2]

[1]Department of Physics, Univeristy of Rijeka, *boris.mifka@phy.uniri.hr*

[2]Department of Geophysics, Faculty of Science, University of Zagreb

Introduction

Airborne mineral dust affects the climate by modifying radiation budget, formation of clouds and marine biogeochemical cycles. The Saharan dust outbreak in September 2015 was simulated with WRF-Chem model. Two major sources of dust in Algeria and Tunisia were detected. The temporal evolution of mean dust emission at sources shows strong morning peaks typical for Nocturnal Low Level Jet (NLLJ) breakdowns. The simulations results are in good agreement with AERONET stations AOD and PM_{10} at 10 Italian and Croatian air quality stations. However, due to North African Sandstorm Survey (NASCube) observations, the Haboob activity were present and possibly affecting the dust emissions. The objective is to investigate the dominant contribution to dust emission between NLLJ and Haboobs.

Model's setup

First experiment, including whole chemistry was conducted to explain PM_{10} (Fig. 1) increase on Northern Adriatic, and second to estimate impact of NLLJ and Haboobs on dust emissions in North Africa:

- **EXP_50**: WRF-Chem with MOZART-GOCART chemistry. Grid: $50 \times 50\ km^2$ and 50 vertical levels,
- **EXP_27**: WRF-Chem with dust only. Grid: $27 \times 27\ km^2$ and 49 vertical levels with 25 levels below 1 km. Nested domain: $9 \times 9\ km^2$ (Figure 1).

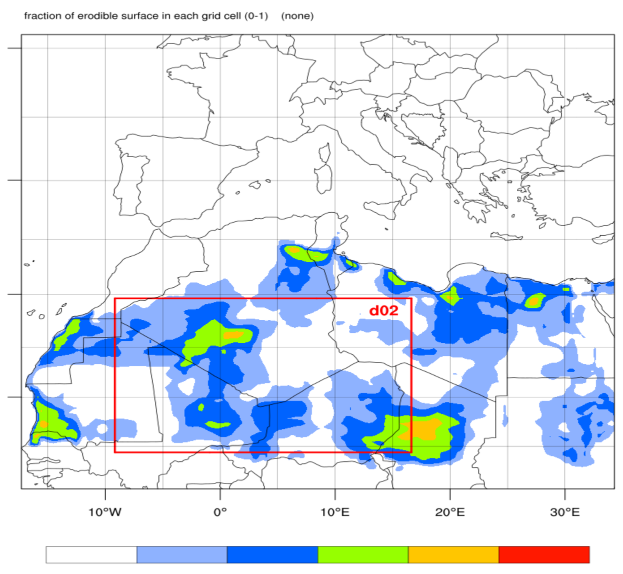

Figure 1: EXP_27 domains with fraction of erodible surface.

Option	**WRF-Chem**
Period	7.09-22.09. 2015. (3 days spinup)
Meteo B.C.	ECMWF Operational analysis $0.141° \times 0.141°$, 26 vert. levels
Chem B.C	MOZART-4 (EXP_50), no dust B.C.
Emissions	Edgar-HTAP at $0.1° \times 0.1°$
Physics	PBL (and surface layer): MYNN, Noah LSM, Microphysics: Morrison 2 m. Cumulus Convection: Grell 3D, Radiation:(RRTMG, lw and sw)
Dust	Ginoux: $F_p \propto u_{10}^2(u_{10m} - u)$, emission if $u > u_{threshold}$ over erodible surface
FDDA	For T,q, u and v fields except in PBL nudging coefficient= $3 \times 10^{-4} s^{-1}$

Other Haboob activity

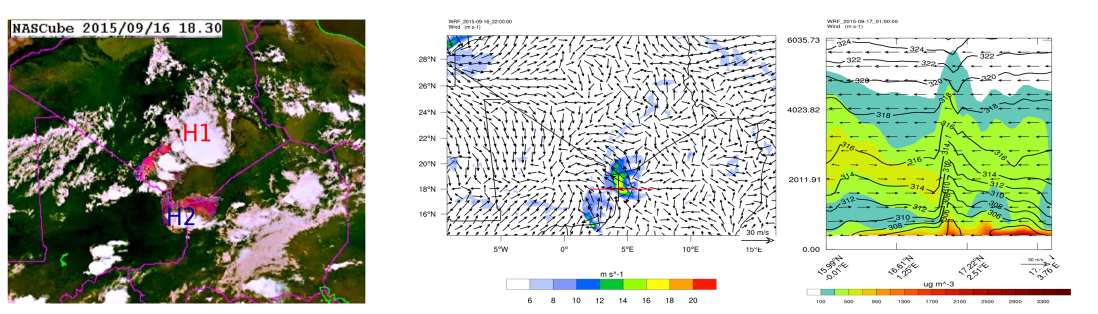

Figure 5: EXP_27 Haboob on 16.9.15: a) NaS-Cube thermal anomaly and visible product, b) wind field at 18 UTC, c) vertical cross section of zonal and vertical wind, Θ_v and dust concetration 17.09 at 01 UTC.

NLLJ development

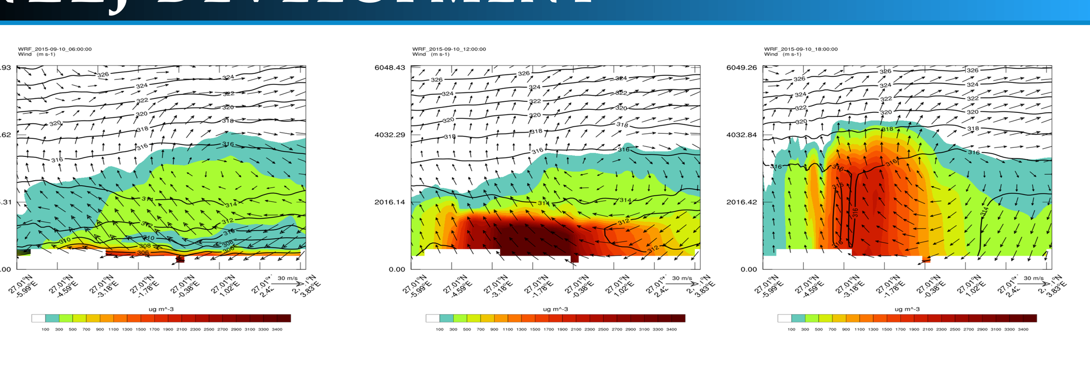

Figure 6: As in Fig. 3c at 06, 12 and 18 UTC.

Results

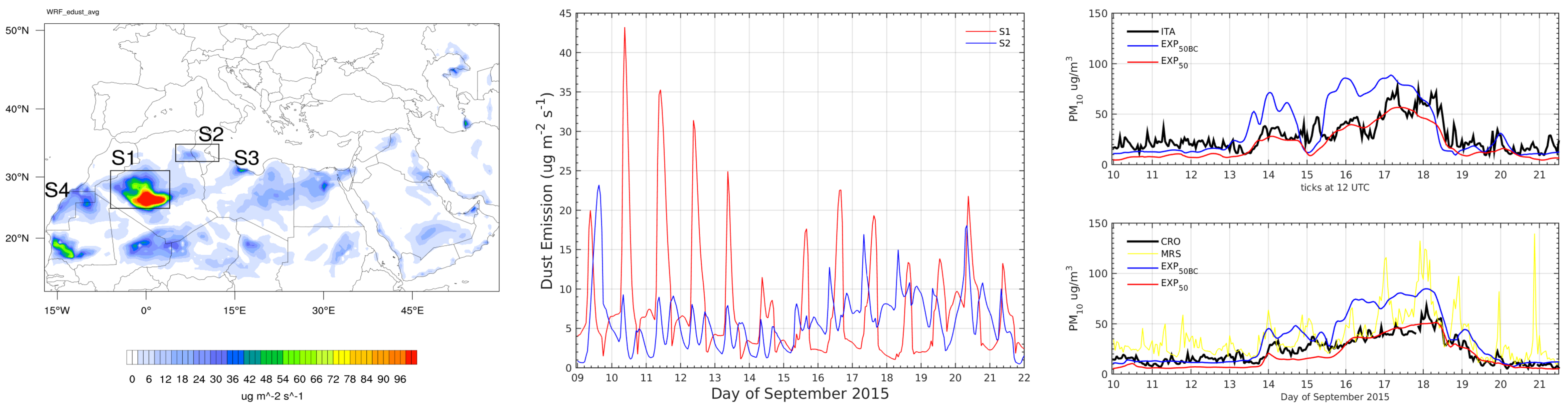

Figure 2: EXP_50: a) total dust emissions temporal average from September 11 to 22, b) temporal evolution of dust emissions at S1 and S2, c) spatial hourly PM_{10} average at 6 Italian and 2 Croatian stations and WRF-Chem.

Using HYSPLIT trajectories (not shown), two dust sources (S1,S2) were identified (Fig. 2a) to affect PM_{10} increase at Northern Adriatic stations (Fig. 2c). Dust concentrations are overestimated when dust boundary conditions are applied, and model does not reproduce the variability at local station (MRS) which is known to be affected by local activity. Source's dust emission peaks (Fig. 2b) occur at 09-10 UTC which is typical for NLLJ morning breakdown. Vertical wind speed profile and temperature inversion (Fig 3c) indicate NLLJ presence until morning hours. At 09 UTC the vertical gradient of Θ_v and jet core weakens, while surface wind speed increases (Fig. 3a). The emitted dust is lifted up to 4 km in following hours while the concentration is reduced, due to diurnal PBL development (Fig. 6).

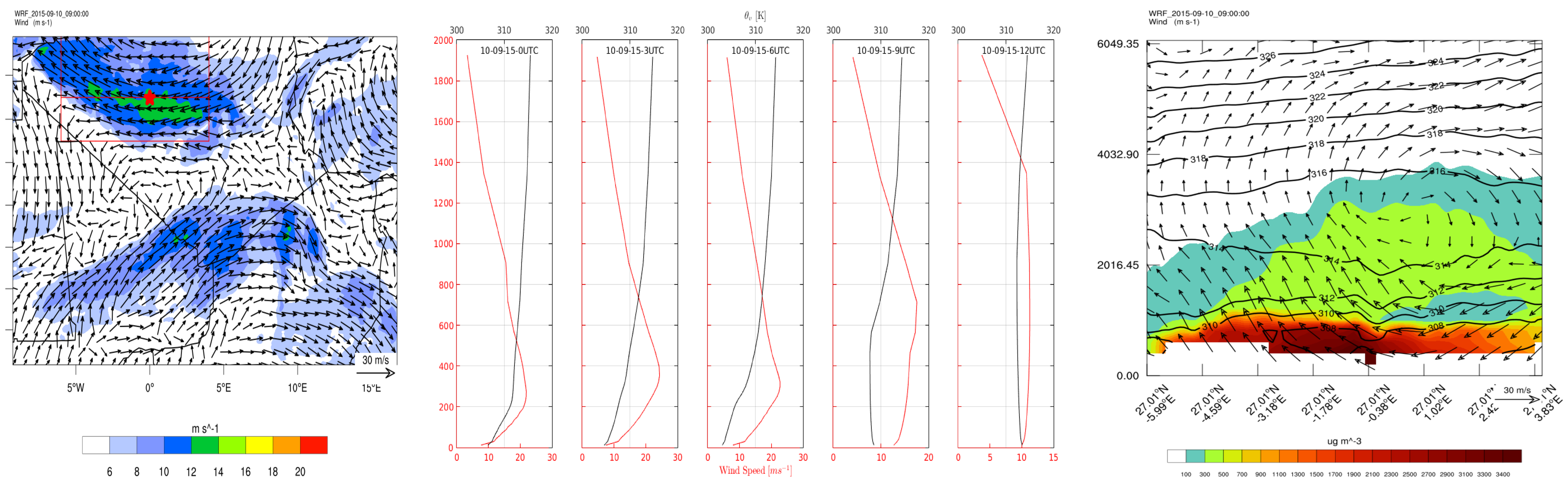

Figure 3: EXP_27 on 10.9.15: a) wind speed and vectors at 09 UTC, b) NLLJ vertical profiles at red star on map (a) from 00 to 12 UTC, c) vertical cross section of Θ_v, horizontal wind and total dust concentration at 09 UTC.

Radial cold pools form convective down drafts (Haboobs) can lift the significant amounts of dust on their fronts. Using NASCube project Visible and Thermal Anomaly product, the Haboob on Algerian-Mali border was detected on 11.9.15. at 00 UTC possibly affecting the dust transport. The model captures the convection initiation, but misses the entire development (Fig 4). Significant Haboobs on wider Algerian area were spotted 16.09-18.09., but probably have not affected the transport on Northern Adriatic due to shift in synoptic patterns. Habbob H2 (Fig. 5) observed on 16.9 at 18 UTC is captured well with model, while H2 is missing.

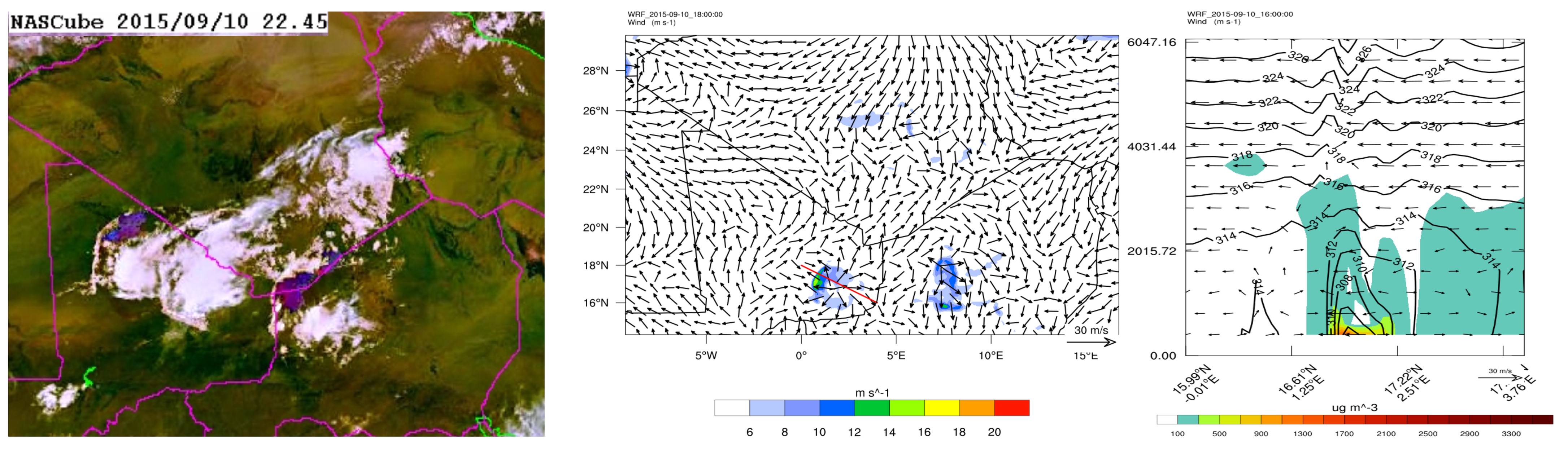

Figure 4: EXP_27 (d02) Haboob on 10.9.15: a) NaS-Cube Visible and Thermal Anomaly product, b) wind field at 18 UTC, c) vertical cross section of zonal and vertical wind, Θ_v and dust concetration at 16 UTC.

Discussion

Simulations using EXP_50 setup provides reasonable agreement with measured AERONET AOD (not shown) and PM_{10} at Northern Adriatic stations (Fig. 2c). The question arises upon the dominance of two dust emitting mechanisms: NLLJ breakdown and convective dust storms. Several conclusions from the study can be withdrawn:

- fine grid resolution is required to simulate Haboob, while NLLJ is well captured on coarse grid,
- over dominant sources, no presence of Haboobs was observed, and strongest Haboobs were outside transport to N. Adriatic period, while NLLJ breakdown occurs daily,
- Haboobs in model are frequently collocated, or missing, while initiation time is represented better.

It is hard to estimate the effect of dust advection towards the S1 and S2 from other regions and other emission processes including convective storms. Despite the uncertainty of Haboob simulations on fine grid, and its impact on dust emission, the EXP_50 simulations profs that robust result depends mostly on NLLJ mechanism and not on individual convection storms.

Further Work

Since the dominant mechanism for dust emission in this case study was found to be NLLJ breakdown, the future work would be to chose the Haboob impacted dust outbreak on Northern Adriatic. Also, the results, especially in vertical need to be evaluated against some reanalysis data, since the radio-sounding profiles are not available at S1 and S2. The most important will be to improve the model's physical setup for proper simulation of Haboob events.