Characterization of Saharan dust episodes over central Italy

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Saharan dust episodes can be observed over Mediterranean region several times a year, affecting PM10 concentration. In particular, Italian peninsula can be affected by Saharan dust outbreaks, which can contribute to the exceedance of limit values for PM10 concentration. For this reason, it is mandatory to identify the quantitative amount of relevant mineral dust events. Several methods and techniques have been proposed to identify and quantify the amount of mineral dust to PM10 concentration, using both experimental techniques and numerical models. In this work a joined use of measurements and numerical models has been applied, in order to provide a complete characterization of Saharan dust outbreaks, from meteorological, dynamical and quantification point of view in Tuscany (Central Italy) during spring-summer 2014.

THE CASE STUDY

During 2014, a field campaign was conducted, in the framework of the PATOS project, to study the composition and sources of PM10 in two sampling sites in Tuscany (Fig.2): Livorno-La Pira (on the cost) and Pistoia-Montale. Daily samples were collected for one year every even day and analyzed by different techniques to obtain a complete chemical characterization (elements, ions and carbon fractions).

Hourly fine (<2.5 μm) and course (2.5-10 μm) aerosol samples were collected by a Streaker sampler for a shorter period and hourly elemental concentrations were obtained by PIXE.

From these datasets, the soil dust component was estimated using the sum of oxides algorithm:

$$[\text{soil dust}] = 1.15 \times ([Al_2O_3]+[SiO_2]+[K_2O]+[CaO]+[TiO_2]+[Fe_2O_3]) =$$
$$= 1.15 \times (1.89\,[Al] + 2.14\,[Si] + 1.67\,[Ti] + 1.90\,[Al])$$

where the Na-Mg contribution is taken into account by the 1.15 factor and the contribution of K, Ca and Fe, due to anthropogenic enrichments of these elements, is calculated using the Al concentration and typical ratios of these elements to Al in soil dust composition. Note that this estimate of the soil dust component includes both long range transported Saharan dust as well as local resuspended mineral dust.

Fig.1 – The PIXE setup at the INFN-LABEC laboratory allows very sensitive and rapid (1 minute/sample) measurements of all the main crustal elements, thus making this technique a very effective tool to assess the actual impact of Saharan dust episodes.

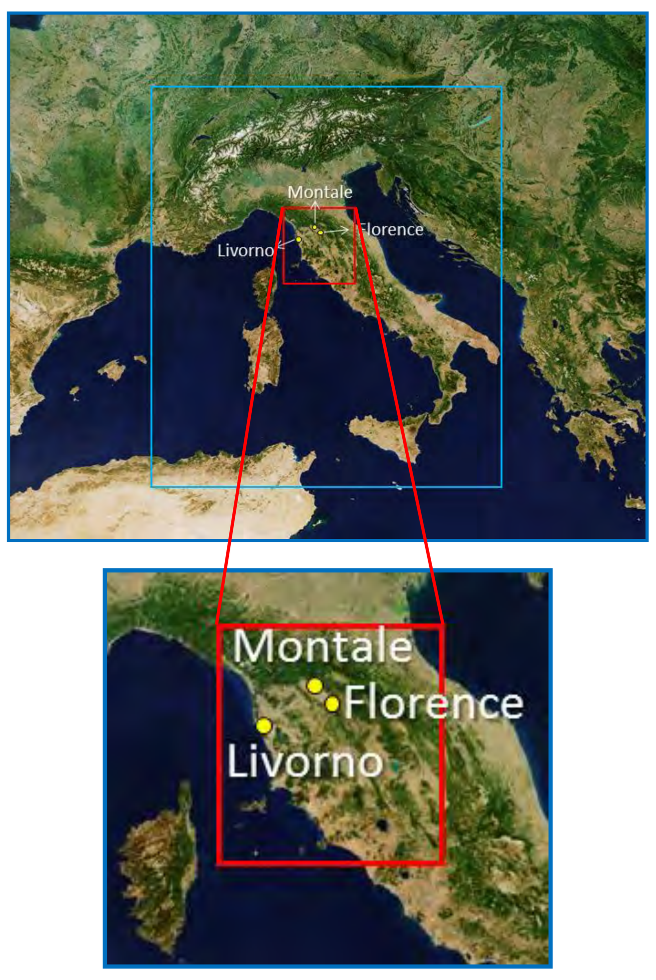

Fig.2 – Domains of the modelling system (blue WRF and red CAMx) and localization of the sampling sites.

METEOROLOGICAL ANALYSIS

Saharan dust transport can reach our regions, especially during a particular synoptic situation: a quite deep trough involving the Atlantic coast of Europe and a high pressure system on the Eastern part of Mediterranean regions. If the gradient between them is strong enough, a south-easterly flow will establish, and it can be able to transport dust towards northern Italy and even central part of Europe. For example, this synoptic situation occurred during 22nd-23rd of May 2014 (as shown in Fig.3); during 24th of May the precipitation contributed to the final evolution of the dust episode.

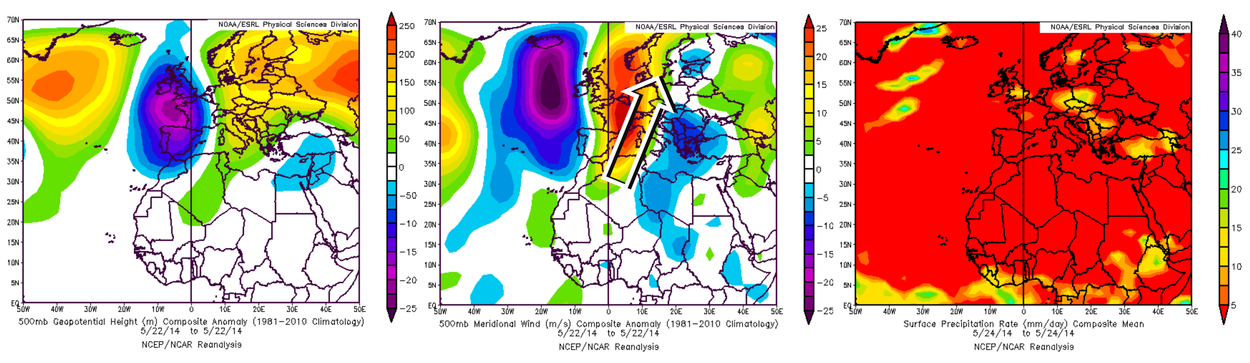

Fig.3 – 500 mb geopotential height anomaly for 22 May (left), 500 mb meridional wind component anomaly for 22 May (center) and surface precipitation rate for 24 May 2014.

THE MODELLING SYSTEM

Numerical models approach is able to characterize Saharan dust outbreaks.

In particular the SPARTA model chain, developed by LaMMA Consortium, as designated by Tuscany Regional Government, can estimate the dust concentrations, among the other main atmospheric pollutants. This modelling system is able to provide a 3D description of the dynamic evolution of the dust episode.

SPARTA is based on the meteorological model WRF-ARW and on the chemical model CAMx, using CHIMERE boundary conditions. This system is running both in forecast and analysis modes (Fig. 4).

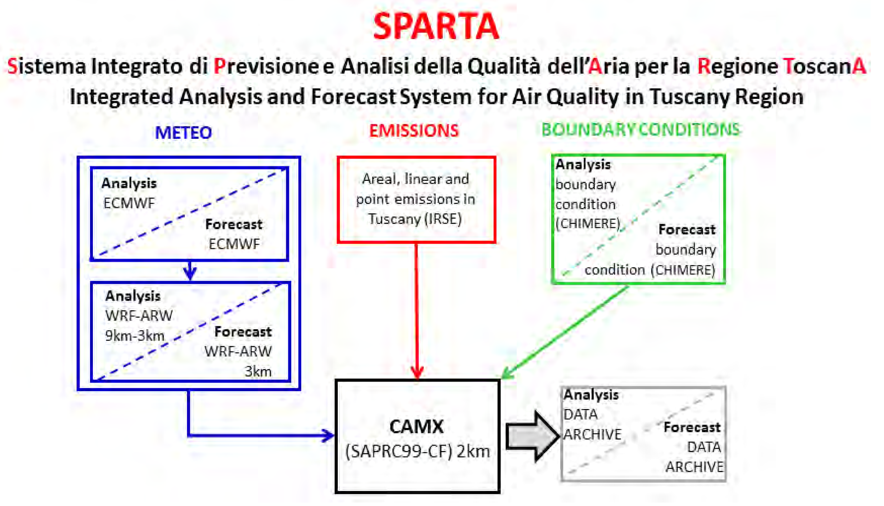

Fig.4 – Scheme of the SPARTA modelling system

RESULTS

Time Series

The time series of the daily simulated dust concentration at the ground level are compared with the mineral dust contribution to PM10 obtained by the measurements, in Livorno and Montale.

In Fig. 5, the comparison between daily measurements, on alternate days, and modelling estimates, during the period 1st April – 30th September 2014 is shown. Since the measurements contain also the local dust contribute, a qualitative comparison shows that the model simulation properly identifies the occurred dust episodes. The 22nd-23rd May episode is completely analyzed providing also a meteorological analysis (Fig.3) and the model cross sections (Fig.7). During the July episode a sampling was made on hourly basis (Fig. 6). The comparison between simulations and hourly measurements reveals a good agreement, properly detecting the episode, especially in the coastal site.

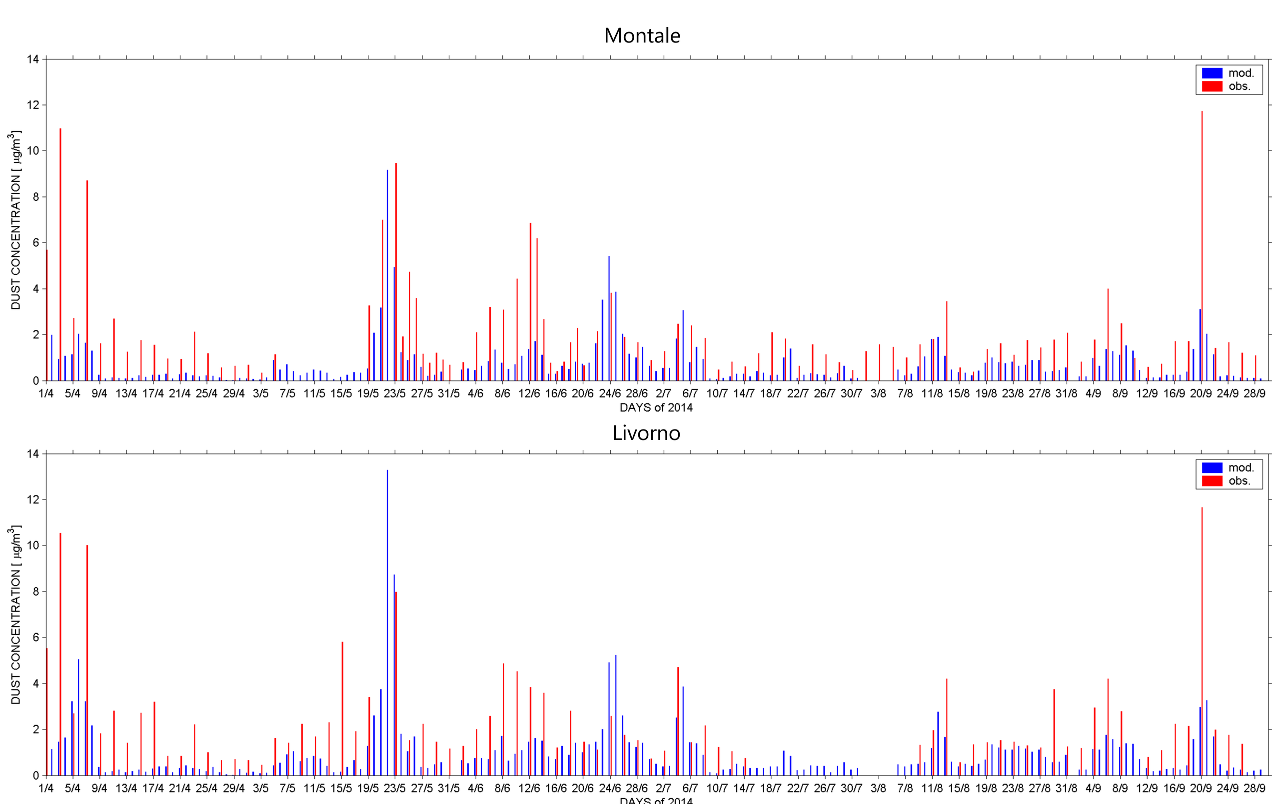

Fig. 5 - Daily dust concentration of Montale (top) and Livorno (bottom): modelled (blue bars) and measurements (red bars).

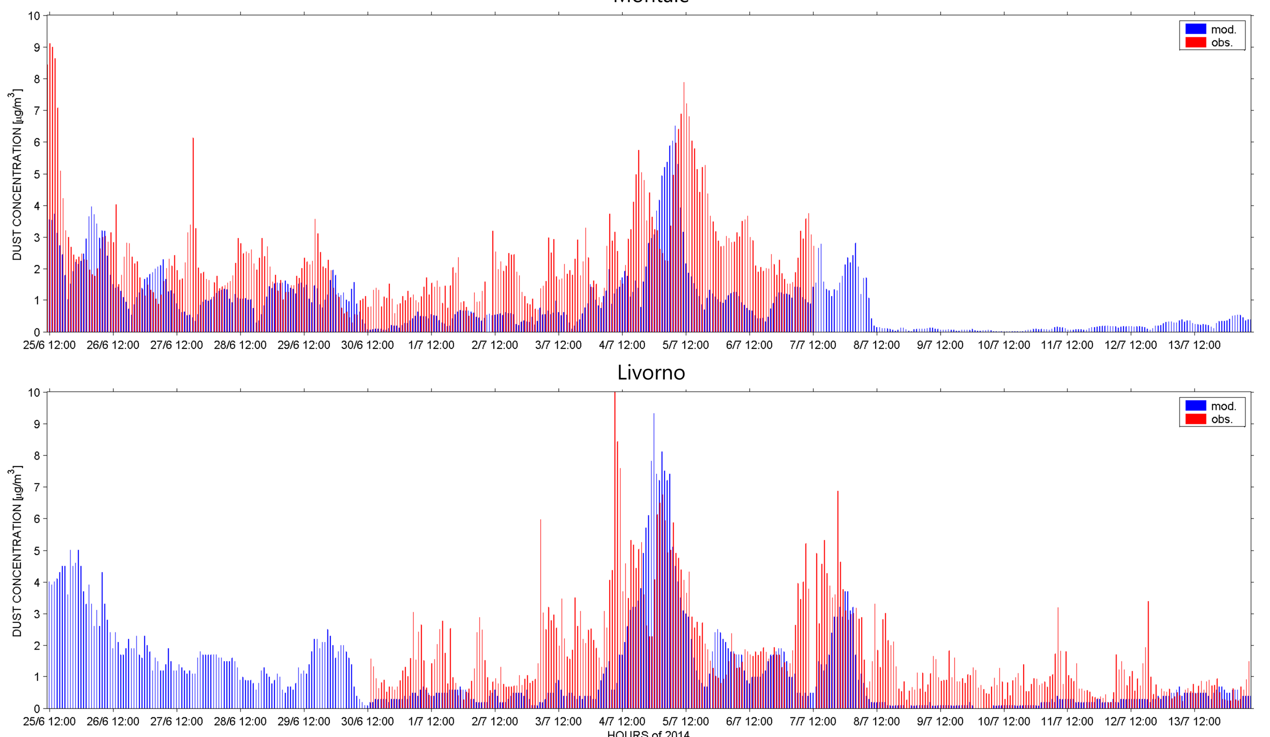

Fig. 6 – Hourly dust concentration of Montale (top) and Livorno (bottom): modelled (blue bars) and measurements (red bars), during the period from 25th June to 14th July 2014.

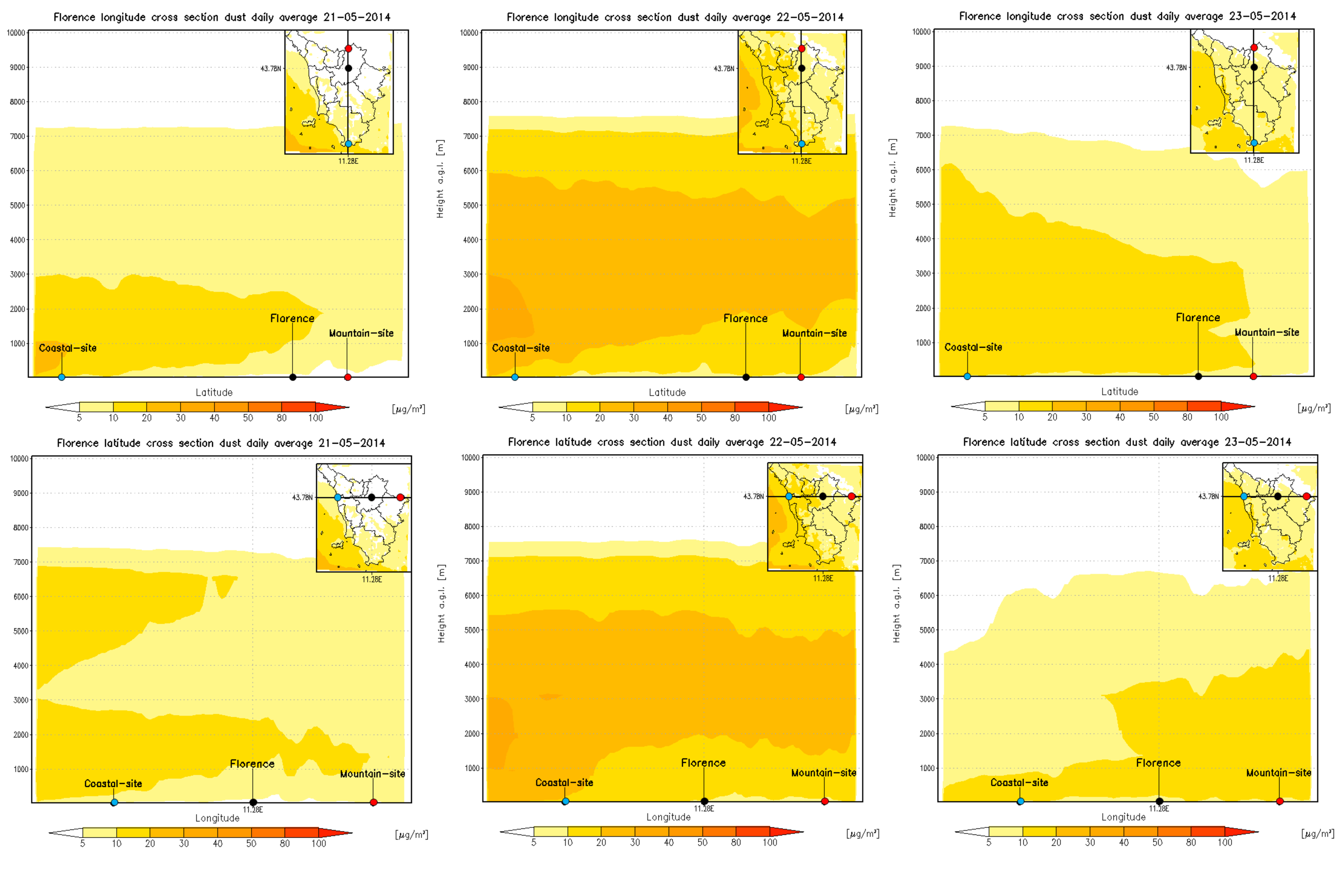

Fig. 7 - Dust concentration cross section along Florence longitude (top) and latitude (bottom) for the 21st, 22nd and 23rd May 2014

Cross sections

The cross sections of the mean daily dust concentration relative to Florence longitude (Fig.7-top) and latitude (Fig. 7-bottom) provide detailed information on the vertical distribution of dust concentration, on the deposition at the ground level and its timing evolution.

The analyzed episode starts on 21st May and ends on 23rd May, reaching its max during 22nd May 2014.

The dust flux comes from South (Fig.7-top) and the vertical distribution shows the dynamical evolution of the analyzed outbreak, with higher concentrations in the upper part of the atmosphere during the beginning of the event and a consequent boundary layer involvement.

To note the role of boundary layer in the different localizations of the domain: coast, inner flatland and mountain.

CONCLUSIONS

The joined use of measurements and numerical modelling shows a good agreement in the description of the dust episodes. Measurements provide the identification and quantification of the events, while the modelling approach provides a detailed description of the 3-dimensional evolution of the Saharan episodes, furthermore it can be used in forecast mode.

As an example, in Fig. 8 is shown a particular event occurring on 1st of March 2018, properly reproduce by SPARTA operational forecast system: after the snow event involving most of the Italian peninsula a Saharan dust episode occurred.

As future development, a more continuous interaction between numerical modelling approaches and specific in situ measurements could improve both research fields.

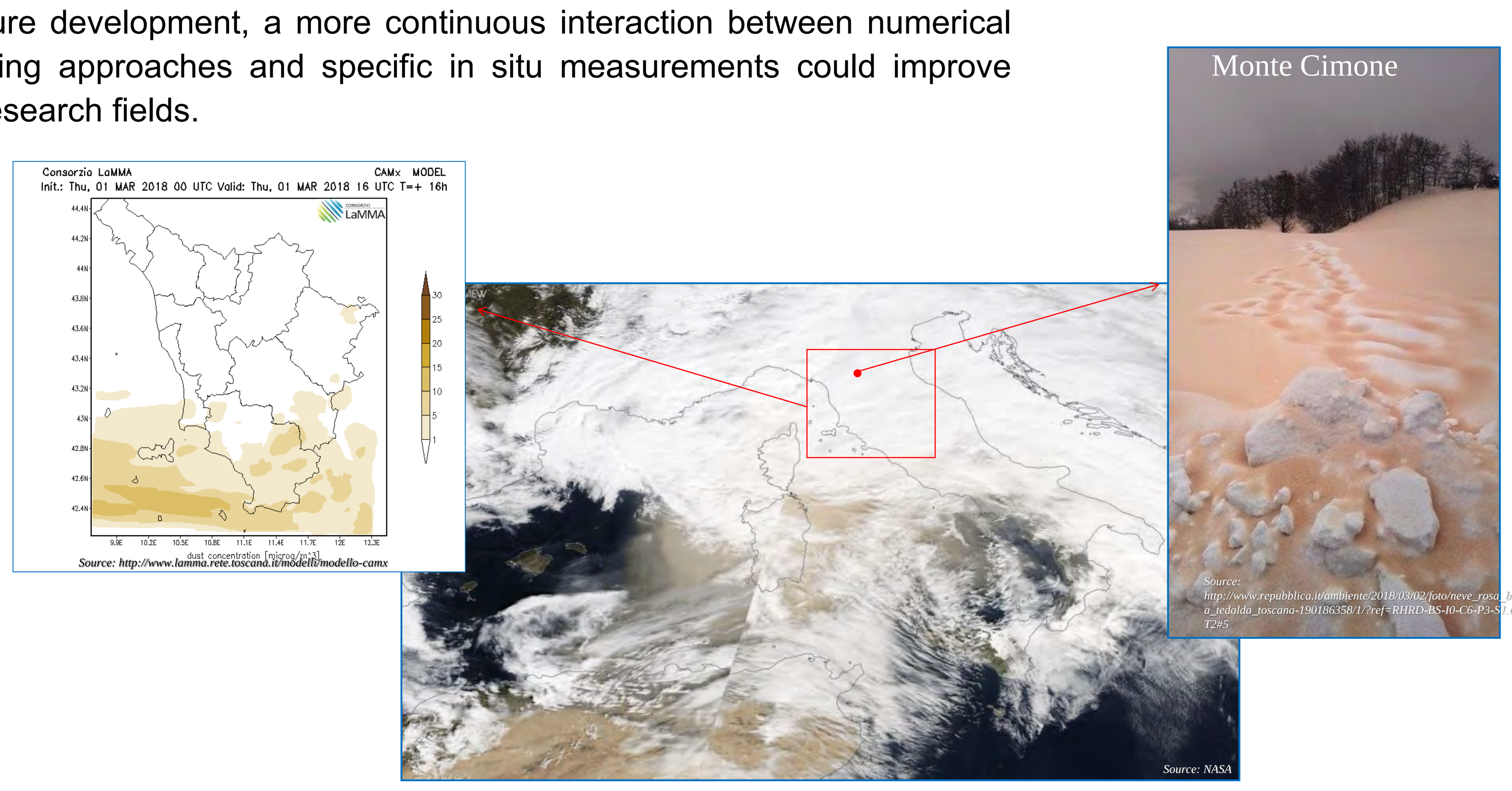

Fig. 8 – NASA satellite image (center) of dust outbreak occurring in 1st March 2018 after the snow event involving Italy; on the left the dust forecast out coming from SPARTA model system (LaMMA Consortium); on the right a suggestive picture od this particular event.