SPECIAL PROJECT FINAL REPORT

Project Title:	Mineral Aerosol Impacts to Sub-seasonal to Seasonal Predictability (MASP)
Computer Project Account:	SPRSNICK
Start Year - End Year :	2017- 2019.
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Other Researchers (Name/Affiliation):	N/A

Summary of project objectives

The objective of this special project was to explore effects of atmosphere-dust aerosol interactions using the global NMMB model integrated with the dust aerosol model DREAM. The major focus of the project was examining effects of the aerosol within the period of 3-4 weeks.

Summary of problems encountered

It took longer time than considered to embed the DREAM dust model component into the global NMMB atmospheric model structure. The major problem was to modify the original pre-processing NCEP/NMMB system to the ECMWF computer environment; we finally managed to make the whole NMMB-DREAM structure functional. Total use of storage and HP computer facilities was less than planned.

Experience with the Special Project framework

The ECMWF administrative guidance was excellent. We sincerely thank for all support from the responsible staff.

Summary of results

Dust aerosol is an efficient ice nuclei important for heterogeneous cloud glaciations even in regions distant from desert sources. A new generation of ice nucleation parameterizations including dust as ice nucleation agent opens the way towards a more accurate treatment of cold cloud formation in atmospheric models. Using such parameterizations, we have coupled a regional dust-atmospheric modeling system capable to predict dust-induced ice nucleation in real-time. Moreover, these indirect dust effects might improve the accuracy of the numerical weather prediction; it also might positively affect prolongation of the predictability of modes. Aerosol acting as ice nucleating particles (n_{IN}) enhances the heterogeneous glaciation of cloud water making it to freeze earlier and at higher temperatures than otherwise. Insoluble particles such as dust and biological particles are known as the best ice nuclei. It has been in the scientific publications that the dominant ice nucleation (IN) is heterogeneous immersion process in 94% of the collected samples. During IN process, only a small number of dust particles, a few in a standard liter, is sufficient to trigger the cloud glaciations process at temperatures lower than -20°C. Since dust with small concentrations is easily lifted to the mid and upper troposphere, cold clouds formed due to dust can be found at locations distant from dust deserts.

Exploiting these findings, we have recently developed a coupled regional real-time forecasting atmosphere-dust forecasting system (Nickovic et al., 2016), which predicts n_{IN} affected by dust as a model online variable. Such new component represents a step towards operational cold clouds prediction and associated precipitation. To our knowledge, this is the first time that all ingredients needed for cold cloud formation by dust are predicted in operational mode within one modeling system. Immersion and deposition modes of freezing are assumed to be dominant for ice formation process.

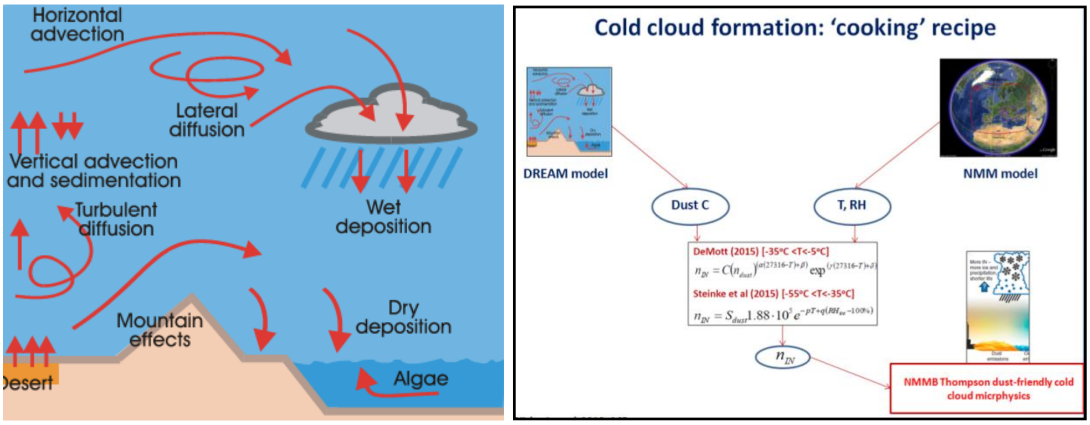

Fig. 1. Left: DREAM mode conceptual figure. Right: Conceptual scheme of integrating dust and atmospheric model components.

In this Special project, we achieved the following two objectives: we The major results are addressed to the following several aspects.

- we transited the ice nucleation (IN) parameterization from the regional to the global version of the atmospheric model driver NMMB
- we perform a series of experiments to test the accuracy of IN calculation in different numerical experiments
- We tested the indirect effects of mineral dust in the atmosphere using the parameterization for number of ice nucleating dust particles (#INP) (DeMott et al, 2015; Steinke et al, 2015; Nickovic et al, 2016). This parameterization has been included in the global atmospheric-dust modeling system.
- We performied one-month model simulation of #INP (April 2018).

Comparison of the model #INP against SEVIRI/MSG observation of Ice Water Path (IWP) has been performed and shown in Figure 2. All the major observed cold cloud patterns have been reasonably well predicted by the NMMB-DREAM model.

We have also established daily comparisons of IN calculation over the European-African region against the SEVIRI/MSG observation of Ice Water Path at 12:00 which are available at http://www.seevccc.rs/?p=8. Below are some examples shown (Fig.2.):

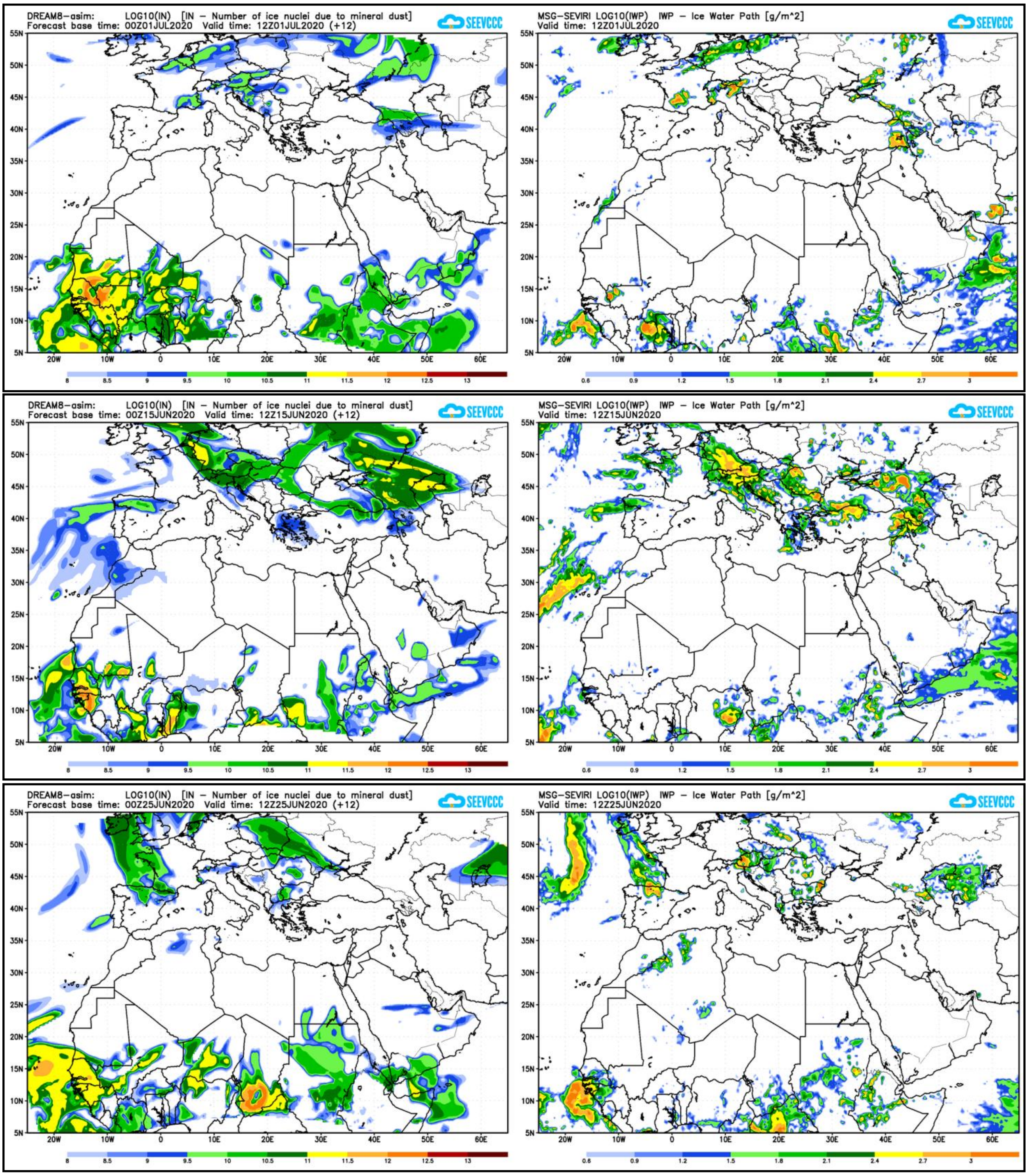

Fig. 2. A selection of examples in which are routinely compared DREAM IN prediction against the SEVIRI/MSG IPW

After transiting the IN parameterization to the ~50-km global version of NMMB model, we performed a series of one-month model runs. The model had a cold dust start, performing 'warming up' of the concentration field within first 2-3 days of the model run. The wet depositing is also not included for the time being, but it will be done in the next project period. The major DREAM dust patterns has been generally well reproduced when compared against the global CAMS April 2018 dust analysis (Figure 3) and against regional DREAM SDS-WAS prediction; Here, maps for 14 April has been shown when the major dust storm has passed the Crete island bringing extreme surface dust concentrations.

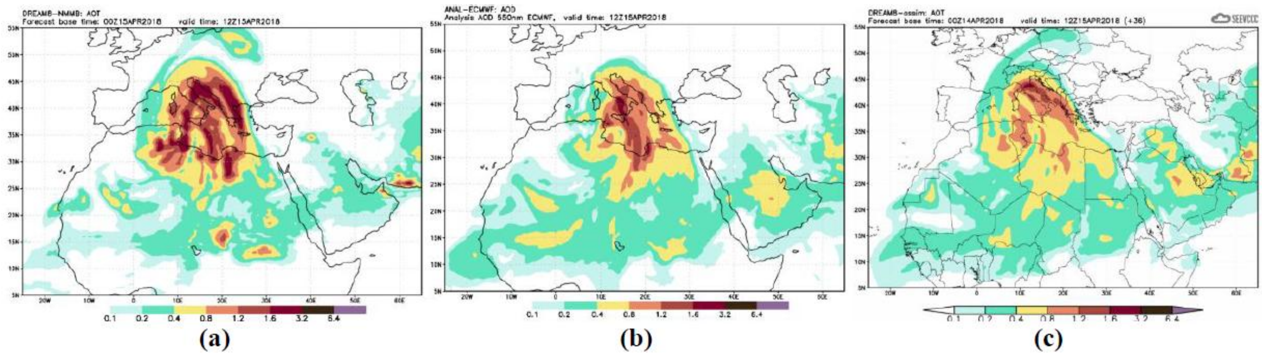

Figure 3. Dust Aerosol Optical Depth AOD: (a) regional section of the DREAM-NMMB global prediction. (b) Global CAMS dust analysis. (c) RHMSS operational regional dust model forecast

Another numerical test we performed was addressed to the Australian dust storm event in January 2020. The simulation was part of WMO SDS-WAS initiative to include dust impacts to high latitudes in its research agenda.

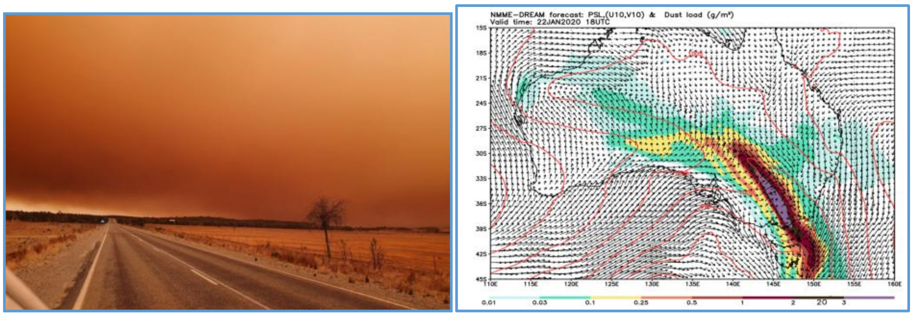

Fig. 4. Left: Australian landscape in the middle of the 22 January dust storm. Right: Predicted vertical dust load over Australia at 18:00UTC 22 January 2020

Dust was moving fast southward. Our model simulation showed that the dust was transporting on 24 January to the Antarctica region, covering a large sector of the eastern continent coastline (Fig.4). The model also predicted that a fraction of dust would have the role of ice nuclei in the formation of cold clouds. The simulated ice cloud formed by dust compared well with the NASA observation of the ice cloud phase over the Antarctic region (Fig.5). The experiment has been performed having in mind the fact that there are numerous processes in which aerosol plays a significant role at high latitudes. Dust, in particular, changes snow/ice albedo and melting rates, affects the marine productivity, alters microbial dynamics in glaciers and causes indirect (cloud formation) and direct (solar radiation) effects. The numerical experiment conducted demonstrates the potential of modeling and observational facilities to better understand why climate change is happening so fast in the high latitudes.

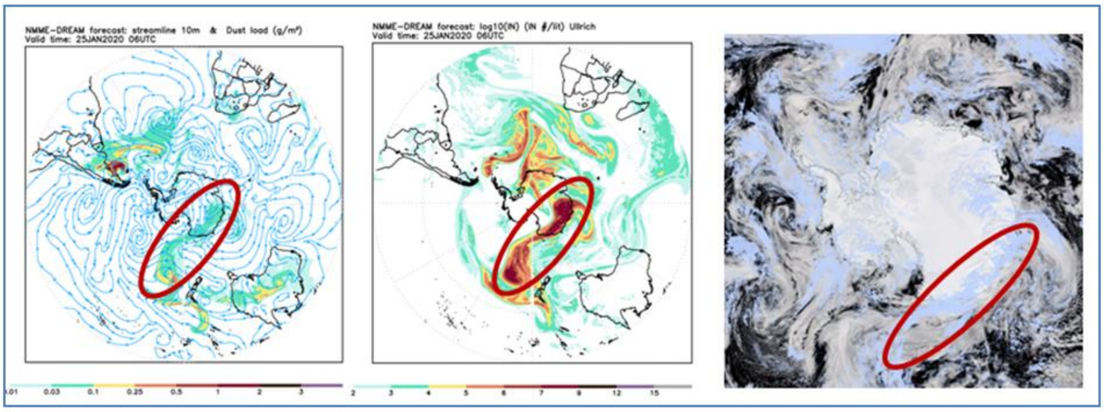

Fig. 5 Australian dust arrived to Antarctica on 25 January 2020. Left - predicted dust vertical load (g/m^3); Central - predicted Log10 [number of dust ice nuclei/liter]; Right - NASA satellite ice cloud phase

In summary, thanks to the computer resources provided by ECMWF, most of objectives of the Special project have been performed. However, because there was partial lack of human resources in the research modeling group in RHMSS, we did not arrange to test the 2-way dust-atmosphere mode version and therefore to test if such model setup permits possible extension of the model predictability.

List of publications/reports from the project with complete references

DeMott, P. J., Prenni, A. J., McMeeking, G. R., Sullivan, R. C., Petters, M. D., Tobo, Y., Niemand, M., Möhler, O., Snider, J. R., Wang, Z., and Kreidenweis, S. M.: Integrating laboratory and field data to quantify the immersion freezing ice nucleation activity of mineral dust particles, Atmos. Chem. Phys., 15, 393-409, doi:10.5194/acp-15-393-2015, 2015.

Nickovic, S., Cvetkovic, B., Madonna, F., Rosoldi, M., Pejanovic, G., Petkovic, S., and Nikolic, J.: Cloud ice caused by atmospheric mineral dust – Part 1: Parameterization of ice nuclei concentration in the NMME-DREAM model, Atmos. Chem. Phys., 16, 11367-11378, https://doi.org/10.5194/acp-16-11367-2016, 2016.

Steinke, I., Hoose, C., Möhler, O., Connolly, P., and Leisner, T.: A new temperature- and humidity-dependent surface site density approach for deposition ice nucleation, Atmos. Chem. Phys., 15, 3703-3717, doi:10.5194/acp-15-3703-2015, 2015.

Future plans

RHMSS considers a possible new application for an extension of the project