Regional climate forcing and response from black carbon and dust in snow: a preliminary study on Central Italy

P. Tuccella[1,2], E. Raparelli[2,3], F. Bruschi[4], D. Cappelletti[4], V. Colaiuda[5,2], A. Lombardi[2], F. S. Marzano[2,3], L. Menut[6], M. Pecci[7], G. Pitari[1], R. Lidori[2], B. Tomassetti[2]

[1]Department of Physical and Chemical Science, University of L'Aquila, L'Aquila, Italy
[2]Center of Excellence in Telesensing of Environment and Model Prediction of Severe Events (CETEMPS), University of L'Aquila, L'Aquila, Italy
[3]Department Information Engineering, Electronics and Telecommunications, Sapienza Università di Roma, Rome, Italy
[4]Dipartimento di Chimica, Biologia e Biotecnologie, Università degli Studi di Perugia, Perugia, Italy
[5]Abruzzo Region Civil Protection Agency
[6]Laboratoire de Météorologie Dynamique, IPSL, CNRS/Ecole Polytechnique/Sorbonne Université/Ecole Normale, Supérieure, Palaiseau CEDEX, France
[7]Italian Glaciological Committee

paolo.tuccella@univaq.it

INTRODUCTION

Black carbon (BC) and soil dust (SD) are radiation-absorbing aerosol particles. Once deposited on the snow surface by dry and wet deposition, they increase the amount of solar radiation absorbed by snowpack, by lowering the snow albedo. This results in an enhancement of the melting rate and regional temperatures, with consequences on snow duration, runoff and water supplies. Moreover, large amount of BC or SD in the snow could decrease the stability of the snowpack, with consequent potential increase of the probability for avalanche formation. In this work, we reported on preliminary results about the impact of BC and SD on seasonal snow, obtained from the development of a treatment of snow darkening effect from BC and SD in the snow within the meteorology-chemistry coupled online WRF-CHIMERE model. The work is a preliminary step for an intensive evaluation on the Central Apennines.

MODEL DEVELOPMENT

In this work, the effect of BC and SD on snow albedo was simulated with the WRF-CHIMERE model. WRF-CHIMERE is a meteorological-chemistry coupled online model which includes a treatment for aerosol direct and indirect effects (Briant et al., 2017; Tuccella et al., 2019; Menut et al., 2021). Snow on the ground was simulated with the NOAH-MP land surface model already included in WRF. NOAH-MP includes a three layers snowpack model. BC-snow and SD-snow were calculated implementing a progonostic treatment in the model. BC and SD were added in the snow surface starting from the deposition fluxes simulated by CHIMERE. Their transport by melting water in the layers below the surface was parameterized as in Flanner et al. (2007). The effect of snowfall on BC and SD on snow surface was also taken into account. A parameterization for snow albedo based on snow-layer ageing was added in the model. Snow grain radius was calculated with a growth model including the dry and wet metamorphisms, and the effect from refreezing. Finally, the snow albedo and its perturbation from BC and SD was calculated according to Dang et al. (2015), as in Tuccella et al. (2021).

MODEL SETUP

WRF-CHIMERE was run from November 2020 to April 2021 with a grid resolution of 9 km in the domain shown in Fig. 1. WRF was driven by ECMWF analysis at 0.10°, while climatological aerosols are used as boundary conditions for CHIMERE.

RESULTS

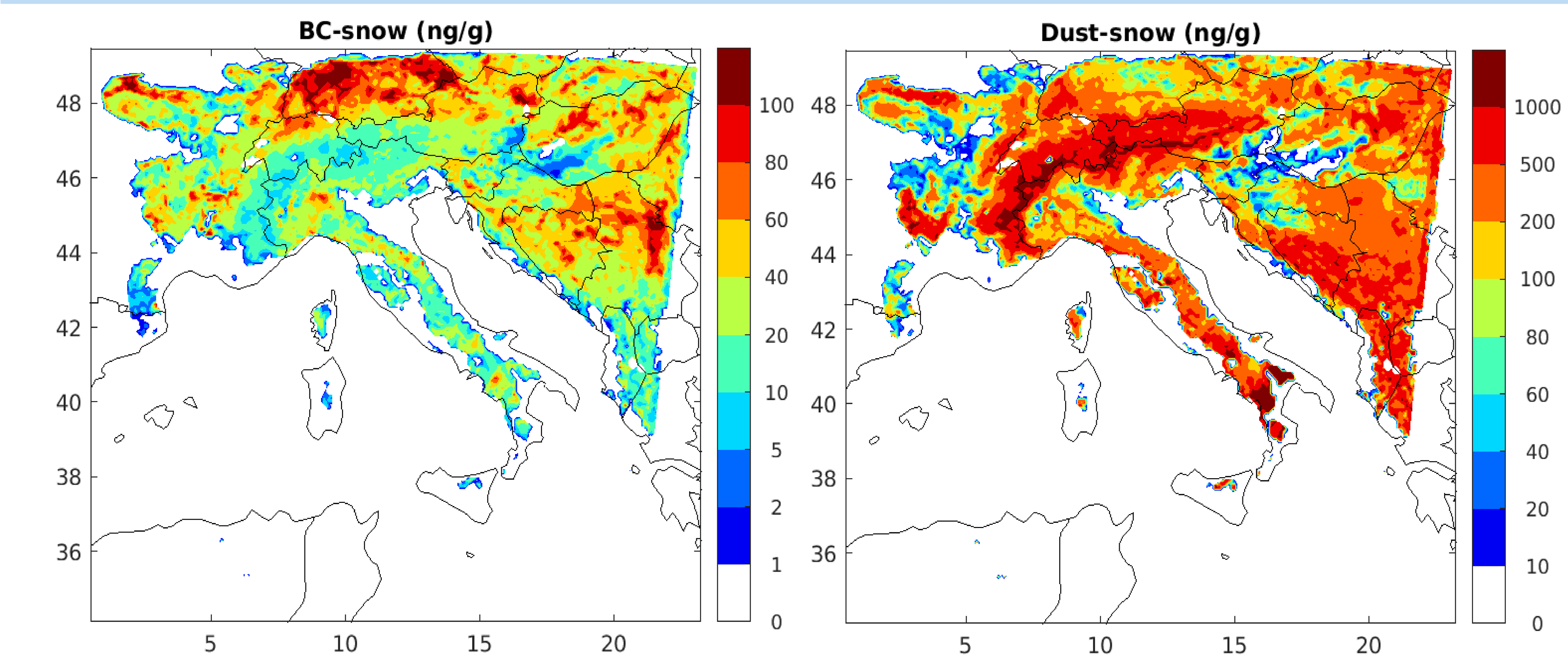

Figure 1. BC (left) and SD (right) mixing ratio simulated by WRF-CHIMERE.

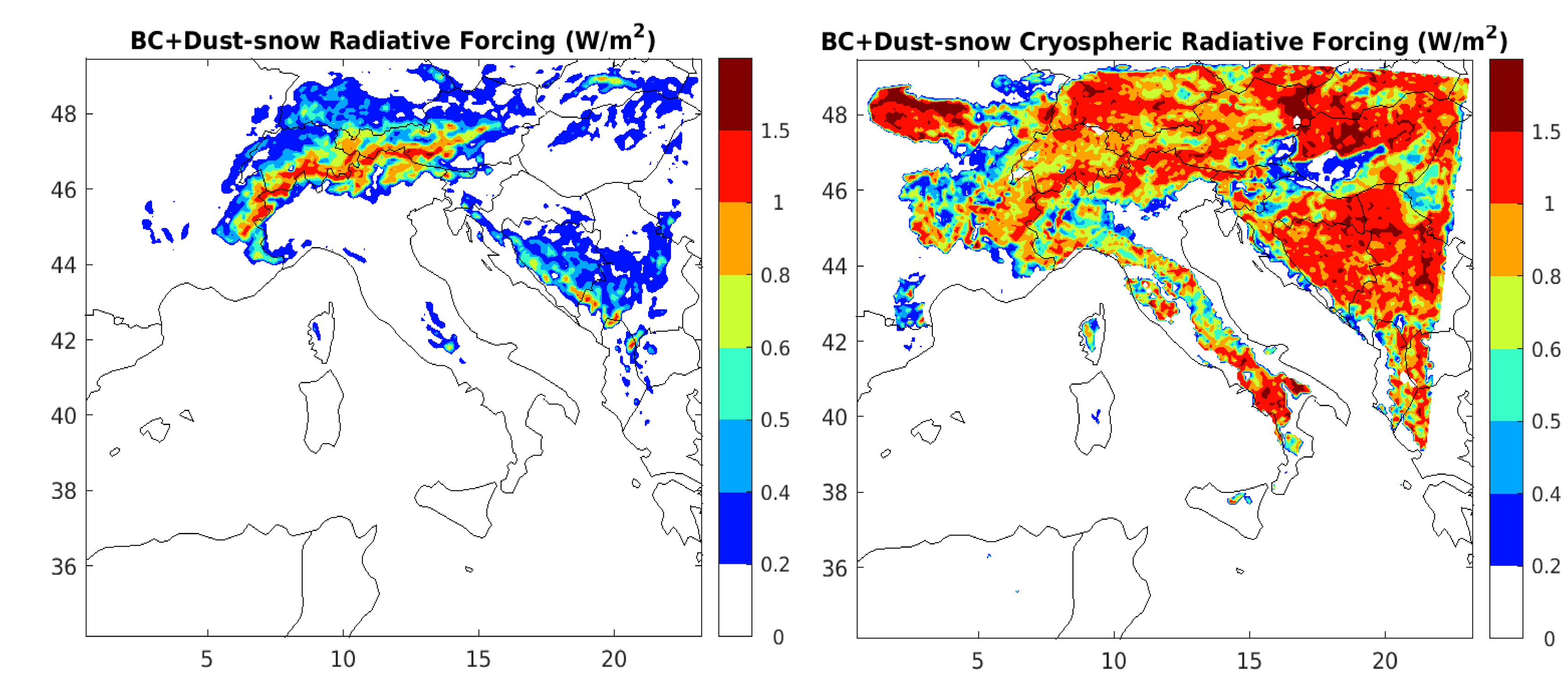

Figure 2. Radiative forcing at surface (left) and cryospheric radiative forcing (right) from BC and soil dust in the snow.

Fig. 1 shows the average BC and SD mixing ratio in the seasonal snow predicted by WRF-CHIMERE. According to our model, in Western Alps the BC concentrations was 5-20 ng/g, while in Central Alps BC mixing ratio was up to 20-40 ng/g. The highest BC-snow content was predicted in Eastern Alps with values up to 40-60 ng/g. BC-snow was up to 40-60 ng/g in Northern Apennines, while in Central Apennines the average values were 10-20 ng/g. The same values were calculated in Southern Appenines. The largest values of SD-snow were larger than 1000 ng/g accross the Alps, while they were of several hundreds of ng/g on the Apennines.

Fig. 2 shows the radiative forcing (RF) and cryosphere radiative forcing (CRF) from BC and SD in snow. RF is the true climate forcing as defined by IPCC, while CRF is the mean increase in energy absorbed by snowpack.

FURTHER DEVELOPMENTS

Snowpack physical properties, BC and SD mixing ratio in the snow predicted by WRF-CHIMERE will be evaluated in Central Apennines with in-situ measurements.

References
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