Influence of High-latitude Dust on Aerosol Concentrations and Deposition in the Arctic

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Motivation

- Dust emission in E3SMv1 is parameterized following Zender et al. (2003), referred to as **Z03**. It uses a fixed soil erodibility map for dust generation. However, soil erodibility could change over time due to the changing climate states and/or land use land over changes.

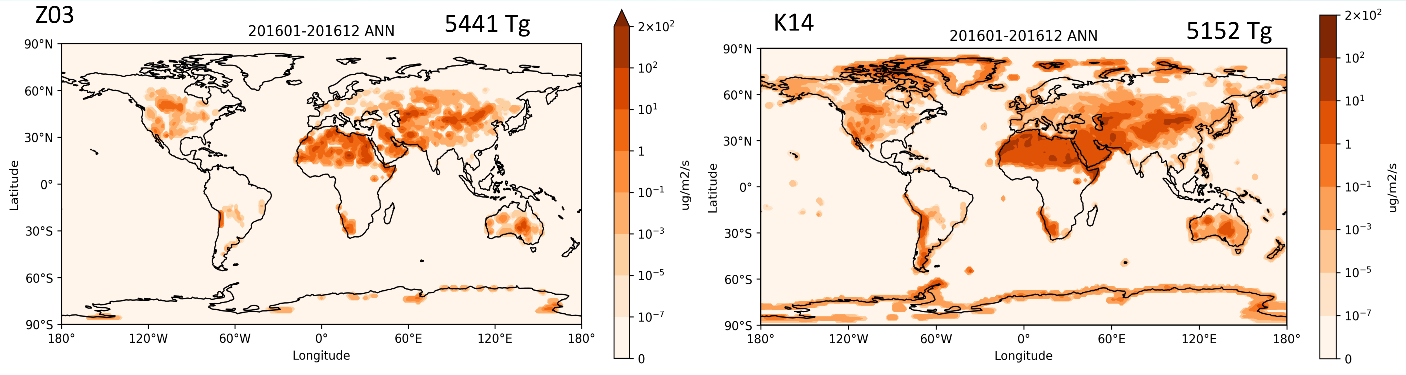
- We implemented a new dust emission scheme (Kok et al., 2014; referred to as **K14**) to the V2 model. **The new scheme calculates soil erodibility online based on the soil moisture and fractional areas of bare ground (vegetation and snow cover) predicted by the land model**.

- This poster examines impact of the High-Latitude Dust (HLD) on aerosols and aerosol deposition in the Arctic, by comparing the two emission schemes in E3SM v1 and v2.

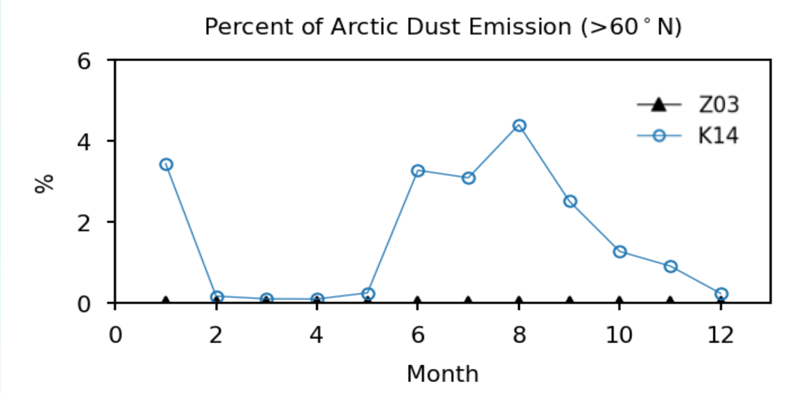
- The HLD has the potential to significantly influence glaciation of Arctic low-level clouds, snow albedo, and iron supply to the adjacent ocean.

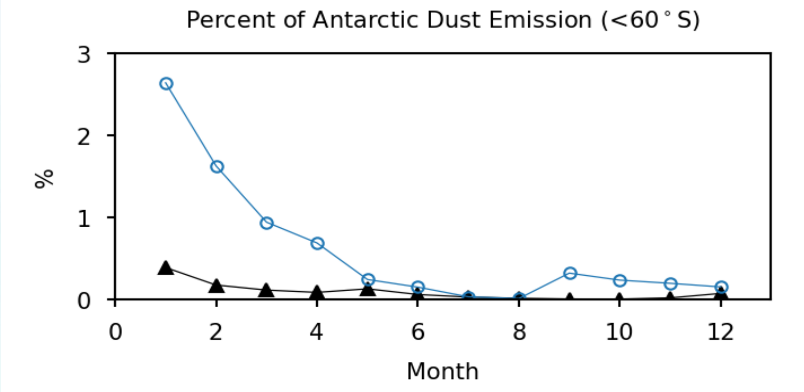
The new scheme (K14) predicts similar global dust emissions to Z03, but they differ largely in high latitudes

Spatial Distribution of Dust Emission Fluxes



Monthly Variations of Dust Emissions



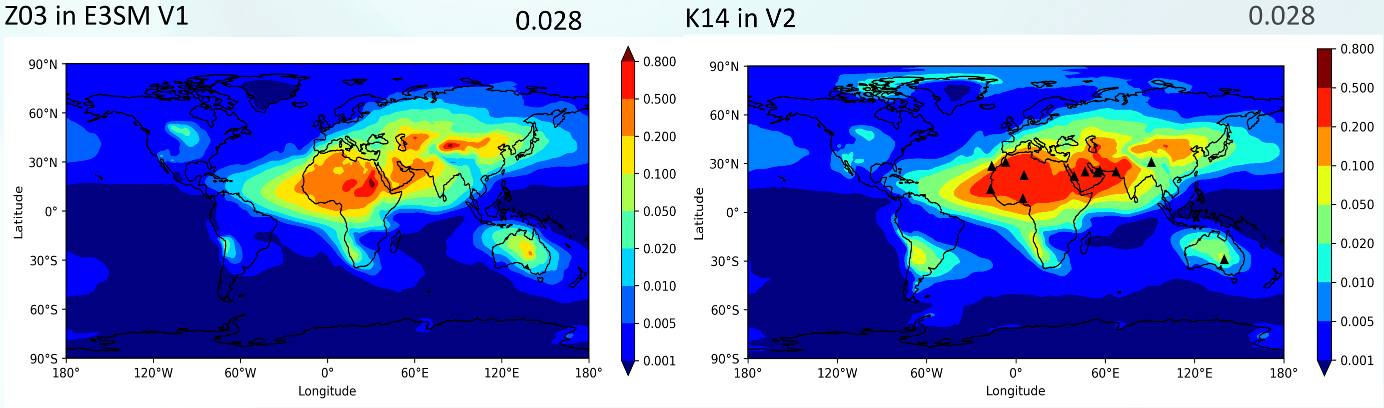


Distinctive season cycle in HLD emissions is simulated with K14

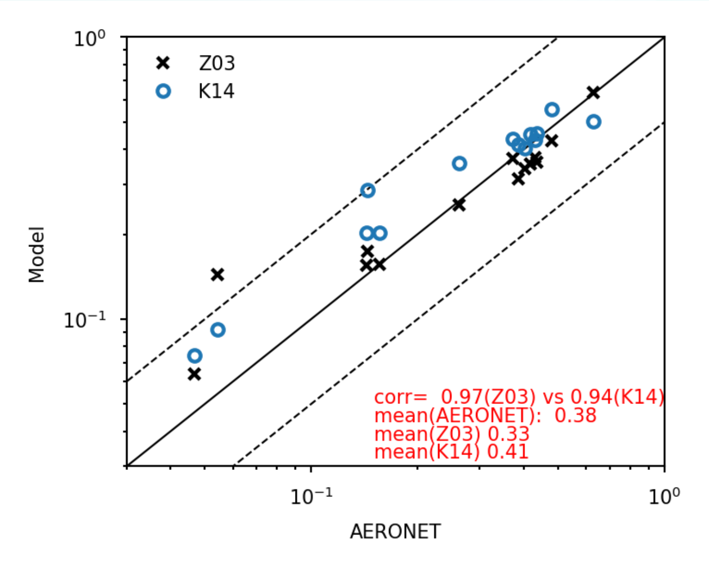
- The total global dust emissions are similar between the two schemes: 5441 Tg (Z03) vs 5152 Tg (K14)
- Compared to Z03, K14 predicts larger dusty areas and smaller spatial gradient in low and mid latitudes
- Large abundances of high-latitude dust (HLD) are predicted with K14: on the yearly basis, HLD contributes to ~5% of global total dust emissions. In contrary, very little HLD is given by Z03

The differences in the predicted dust between K14 and Z03 are small in low and mid latitudes

Spatial Distribution of Dust Aerosol Optical Depth (AOD)



Comparison of the modeled and AERONET (obs.) AOD

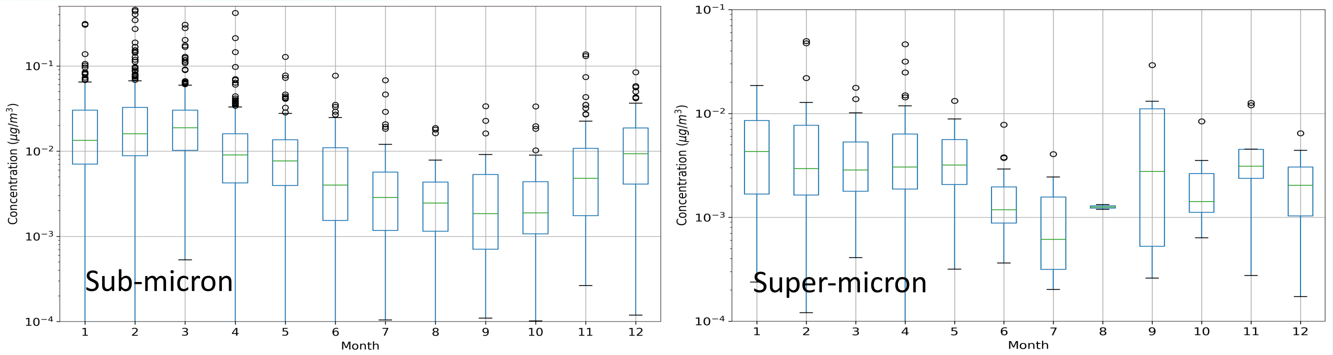


- The simulated annual and global mean dust AOD is 0.028 by Z03 and K14, close to the observationally-based estimate at 0.03.
- The differences in dust AOD between the two schemes are small in low and mid latitudes (except for South America).
- K14 predicts higher dust AOD in Arctic, consistent with the increased HLD emissions, while the AOD differences in Antarctic are small.

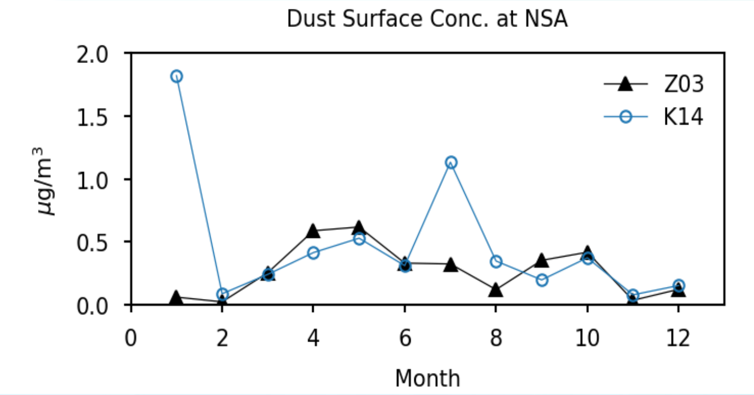
Both schemes simulate AOD reasonably well at the selected AERONET sites in the dusty regions (black triangles in the middle map)

K14 improves in simulating the seasonality depicted in the Arctic dust observations

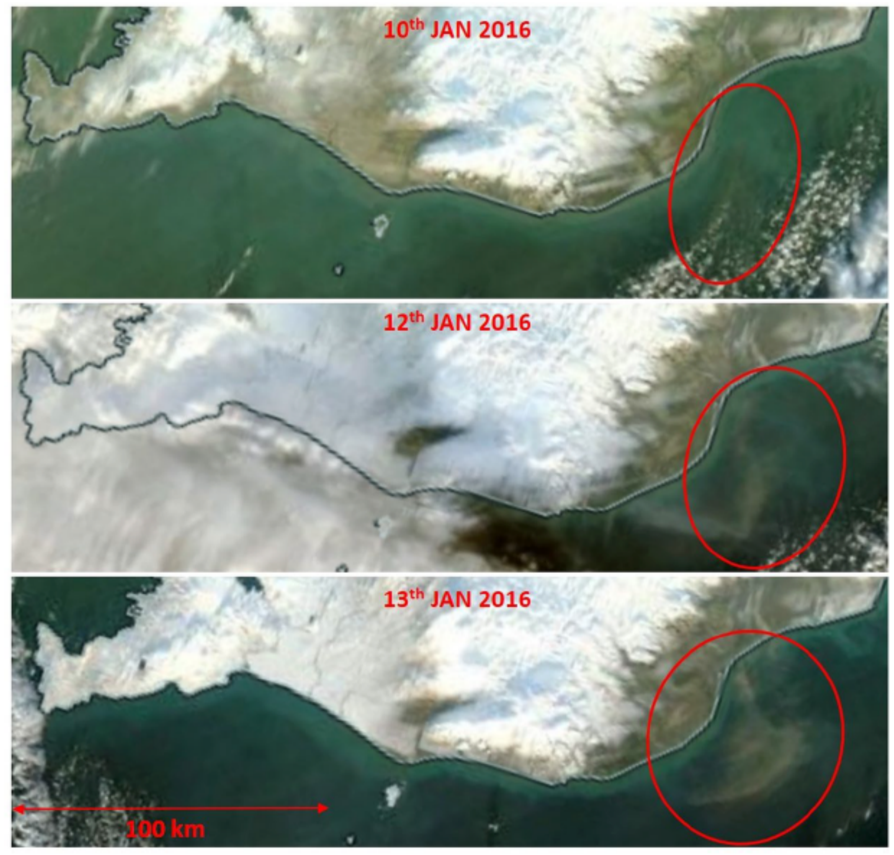
Observations of Non-sea salt Ca at Barrow, Alaska – a proxy for Dust



(Above) The surface data shows a major peak in winter (Jan-Mar) and a secondary peak in fall (Sep) due to the super-micron dust



(Left) K14 predicts a strong seasonal cycle in dust surface concentrations, and agree better with the long-term surface data at NSA (Barrow, Alaska) by capturing the major peak in winter



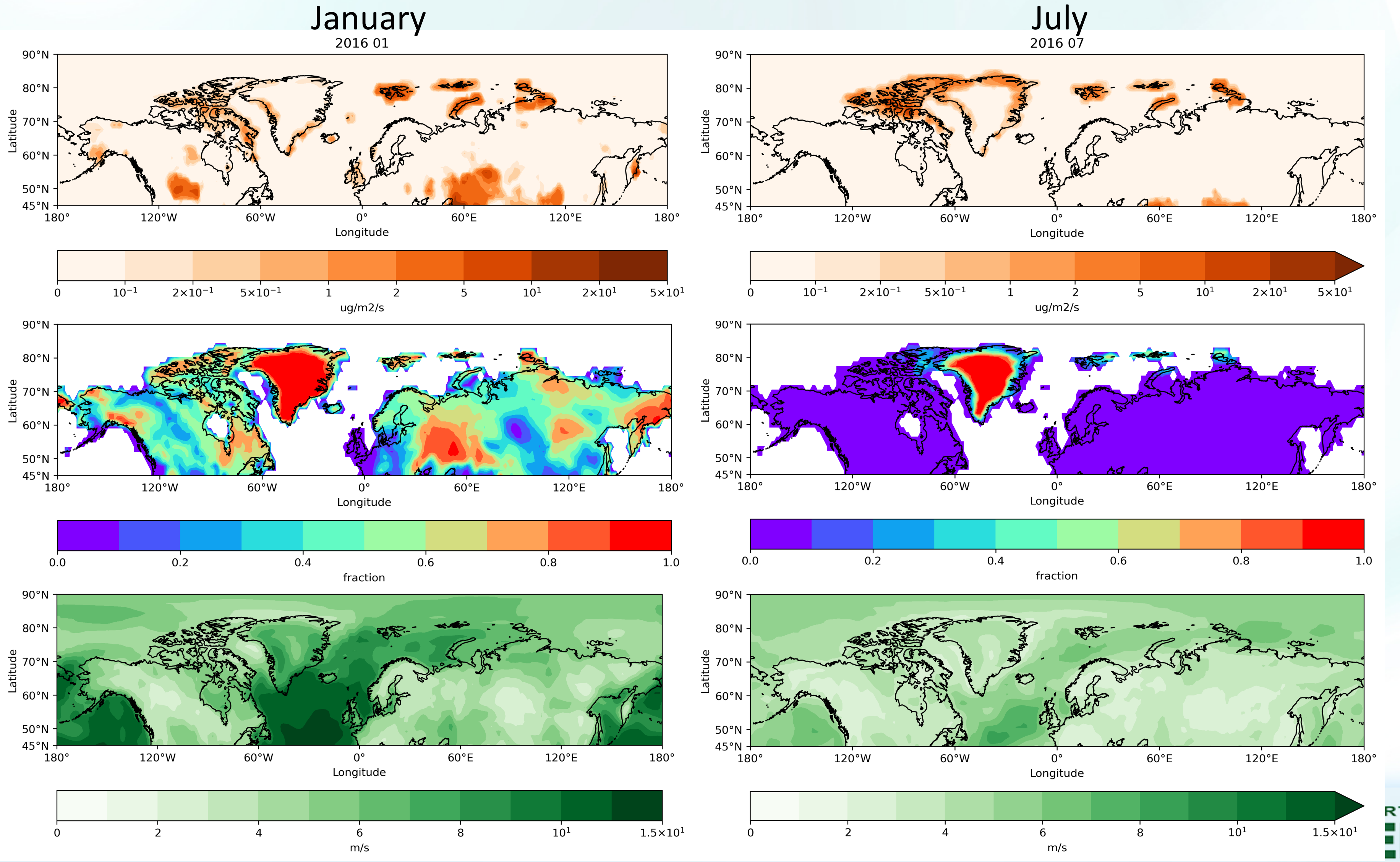
(Above) MODIS satellite images show dust plumes (red circle) emitted from the southern Iceland glacial outwash plains in January 2016 (Dagsson-Waldhauserova et al., 2019)

Winter HLD emissions are driven by high winds in subarctic, while the summer HLD occurs in Arctic over snow-free land

HLD Emission

Snow cover

Surface winds



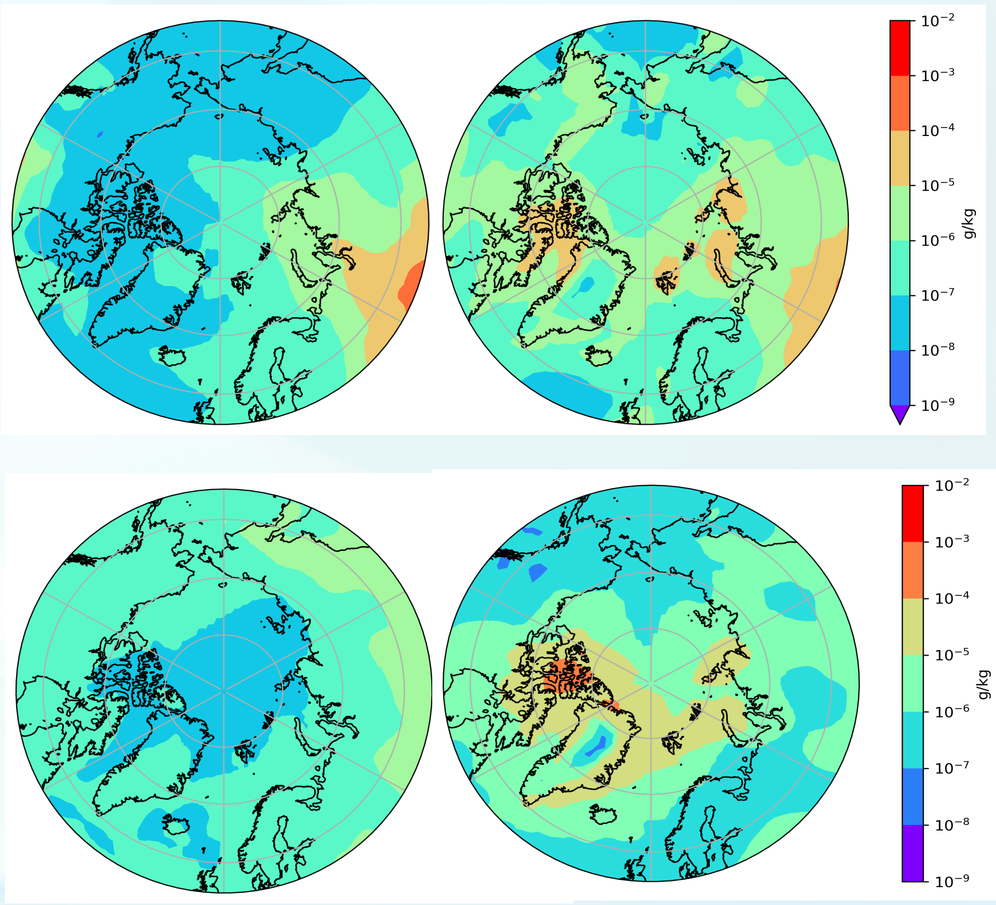
The new dust scheme K14 predicts higher dust surface concentrations and deposition in Arctic by several folds

Dust Surface Concentration

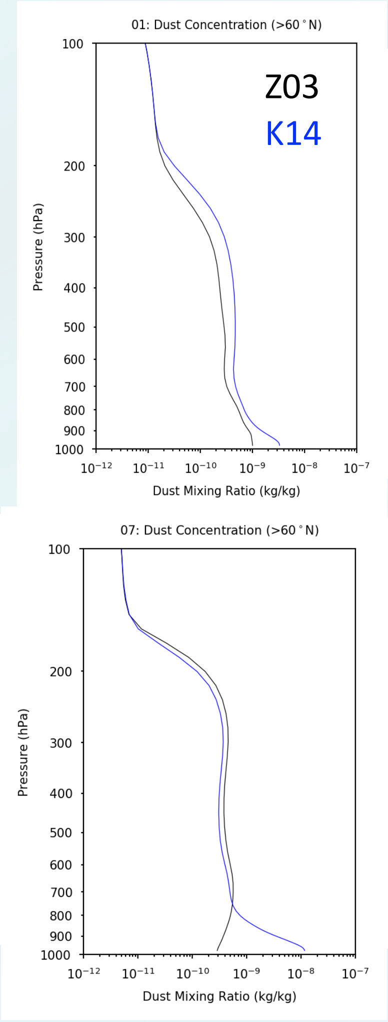
Z03 (V1) K14 (V2)

January

July

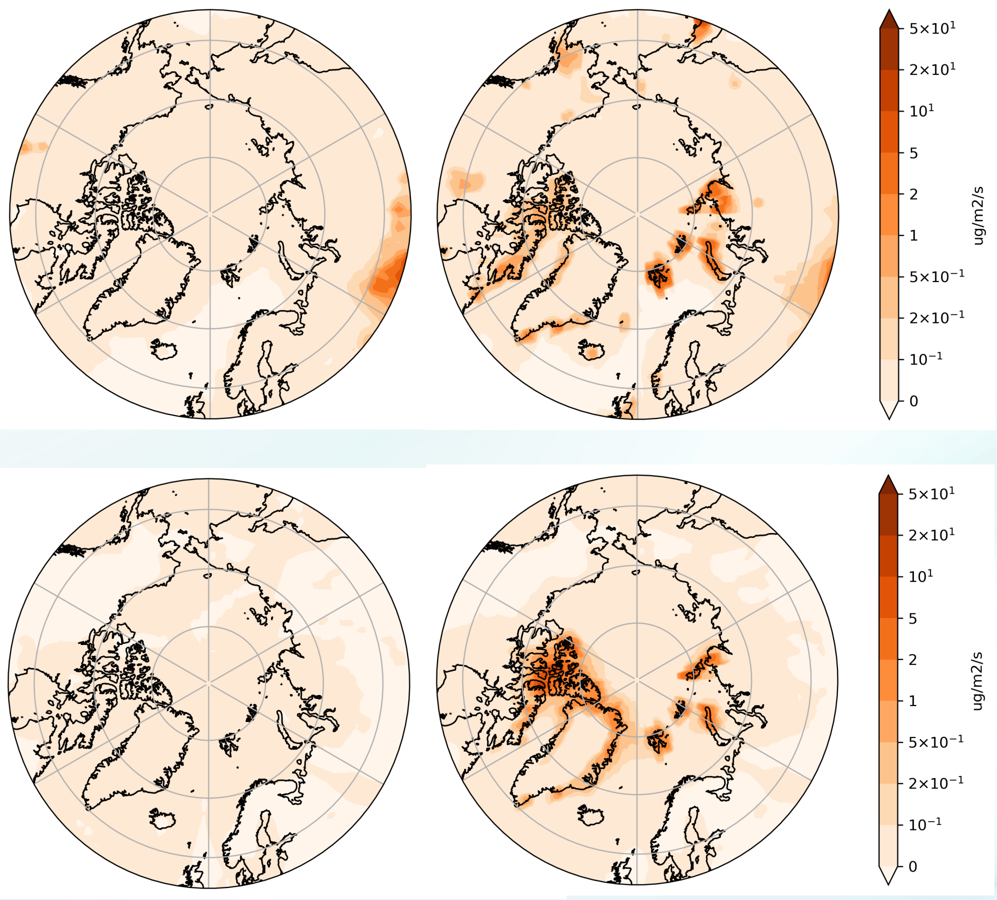


Vertical Profile



Deposition

Z03 (V1) K14 (V2)



E3SM Energy Exascale Earth System Model

U.S. DEPARTMENT OF ENERGY

Summary

- We implemented and examined a new dust emission scheme (K14) in V2 that has a stronger dependency than V1 (Z03) on the time-varying land surface properties such as predicted snow and vegetation cover and wind.
- In the modern-day condition, K14 is constrained by satellite observations and performs similar to Z03 in low and mid latitudes. However, there are substantial increase of High-Latitude Dust (HLD) with K14, contributing to 5% annual global dust emissions, with larger seasonal and regional differences.
- We have showed that K14 is able to simulate the observed cold winter dust events in sub-Arctic, associated with strong winds. This has been postulated as an important INP source for Arctic mixed-phase clouds.
- We also showed that the seasonal change of snow cover is the driver of the summer/fall Arctic dust emissions, which enhance the deposition of ‘black’ dust on land and iron supply to the ocean.