Subgrid treatment of surface wind speeds and wind-driven aerosol emissions in CAM5

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Motivation

- Subgrid variability (**SGV**) of surface wind speed is often neglected in global aerosol-climate models with coarse resolutions
- This can lead to resolution-dependence of simulated wind-driven emissions of aerosols and their precursors, and influence the estimate of both natural and anthropogenic aerosols' climate effect.
- It is important to quantify the impact and parameterize SGV.

Summary

- SGV is parameterized a function of "GCM" grid-mean quantities.
- Contribution from moist convective eddies dominates the surface wind speed SGV over the oceans. It is harder to parameterize SGV over land, since the subgrid variation of surface elevation plays an important role. Using monthly mean SGV from ECMWF and a Weibull PDF already helps to reduce the error in dust emission estimate.
- A SGV parameterization based on findings in this study has been developed and is being tested in CAM5.

Data and Method

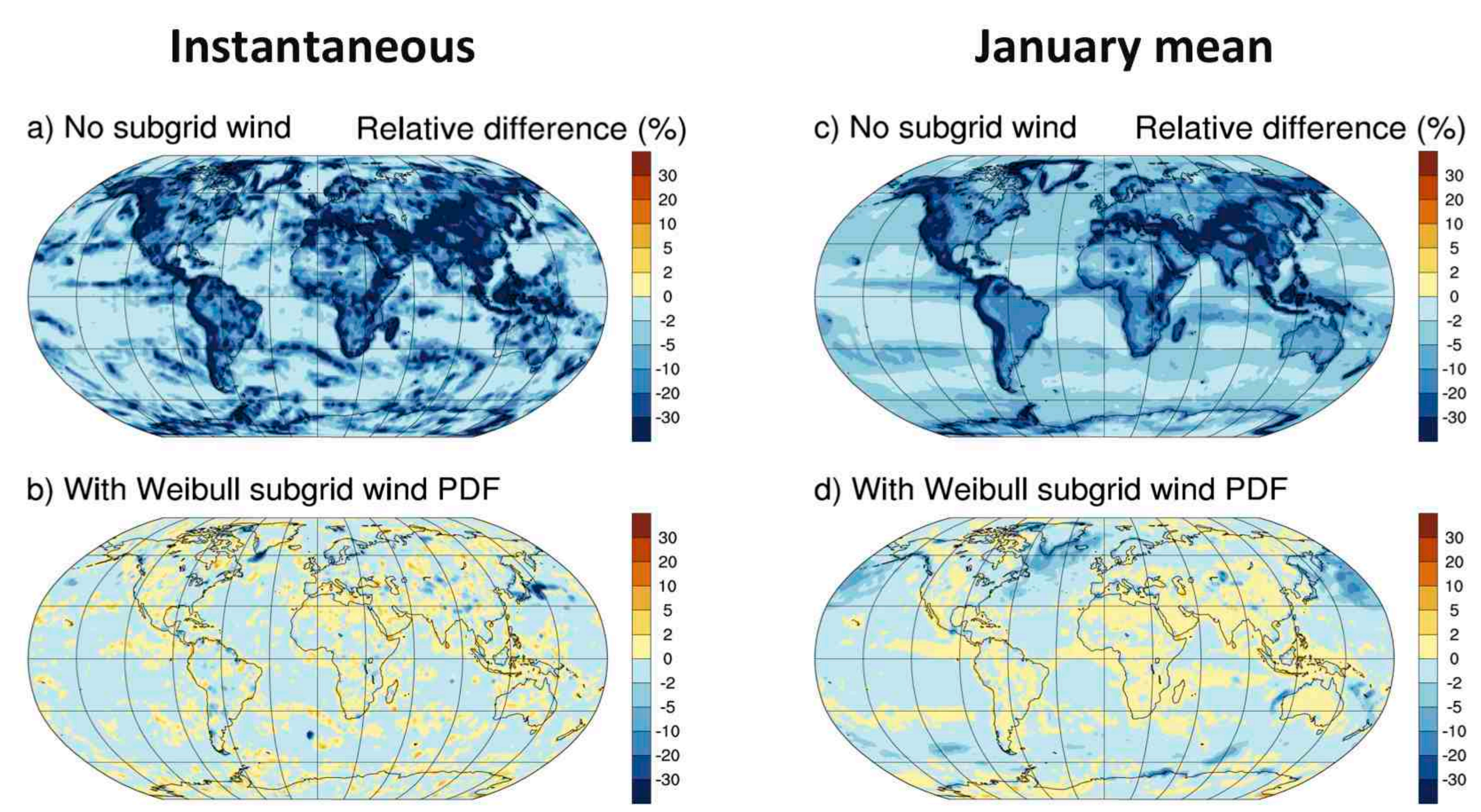
- High-resolution meteorological fields from ECMWF global analysis (~15 km) and regional WRF simulations (from 75km down to < 1km)
- Analyze subgrid variation of surface wind speed and represent the PDF using the Weibull distribution:

$$f(x;\alpha,\beta) = \begin{cases} \frac{\alpha}{\beta^{\alpha}} x^{\alpha-1} e^{-(x/\beta)^{\alpha}} & x \geq 0 \\ 0 & x < 0 \end{cases}$$

x : a random variable (wind speed)
α : shape parameter
β : scale parameter

- Parameterize subgrid variability of surface wind speed as a function of various "GCM" grid-mean quantities as recommended in previous studies (see "implementation in CAM5" for details)

Potential Impact of SGV on Sea Salt and Dust Emissions



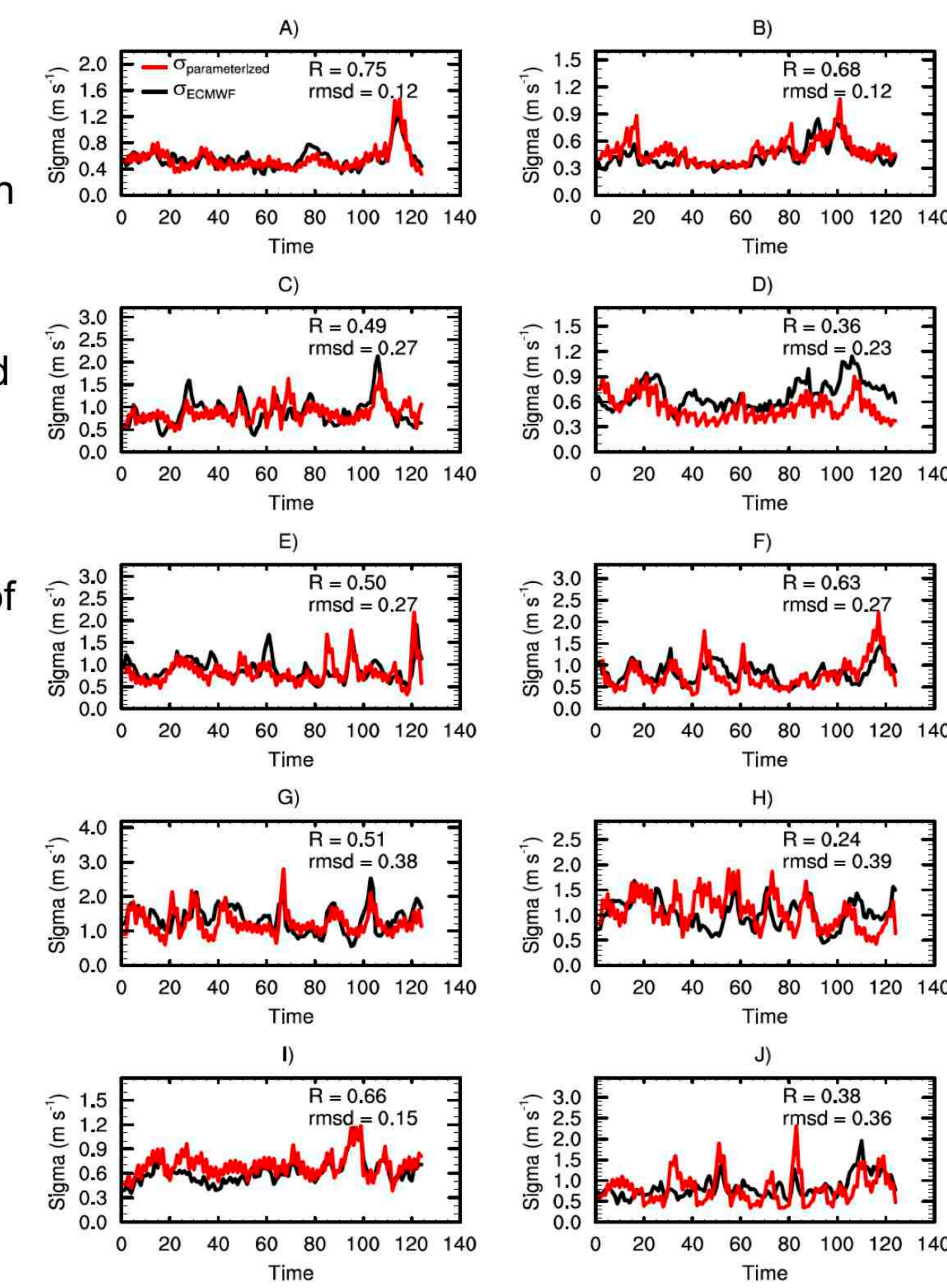
Panels a) and c) show the relative difference between the cubed grid-mean (2°) wind speeds ($U_{10m,mean}$^3) and the mean cubed wind speeds calculated from data on 0.14° grids ($U_{10m}^{3}_{mean}$). Panels b) and d) shows the relative difference between the Weibull-PDF estimated mean cubed wind speeds and that calculated from the 0.14° data. Left panels show the instantaneous fields at 2011-01-01 0:00GMT. Right panels show the monthly mean fields for Jan 2011. Sea salt emission in CAM5 is linearly dependent on U_{10m}^3.41. Dust emission calculation is more complicated and here we use the cubed wind as an approximation.

Evaluation of the Parameterized SGV over Ocean

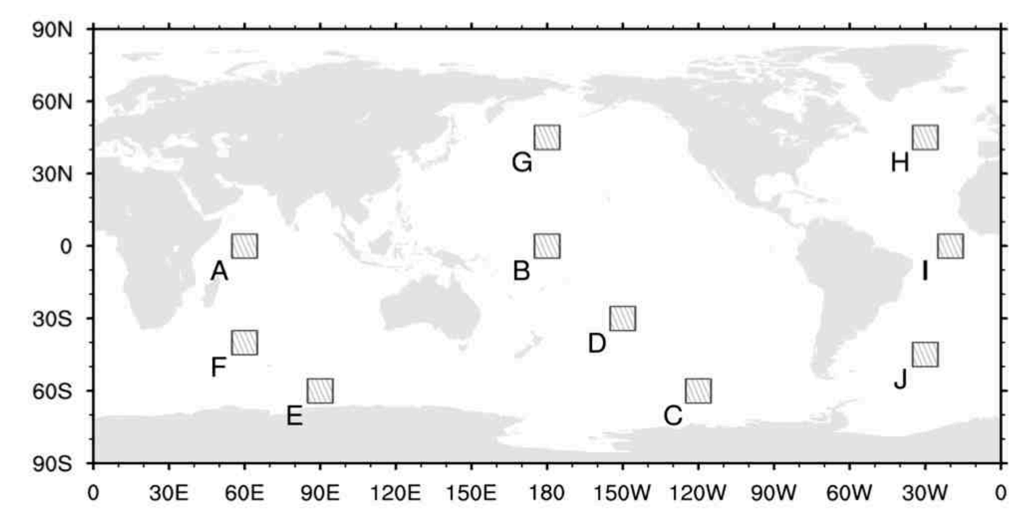
ECMWF analysis SGV
Calculate the subgrid standard deviation of wind speeds at 10m from the 15-km resolution ECMWF analysis over 2° "GCM" grid boxes

Parameterized SGV
Average 15 km analysis data to 2° "GCM" grid boxes. Apply SGV parameterization that involves grid box mean precipitation, surface heat flux, and PBL height.

Plotted values (every 6 hours) are averages of 2° SGV's over 10° areas in January 2011.



Ten 10°x10° regions



Implementation in CAM5

- CAM5 predicts the grid mean wind speed at 10m.
- Subgrid standard deviation of the wind speed = F (grid mean turbulence kinetic energy, surface heat flux, PBL height, precipitation, surface elevation inhomogeneity).
- Weibull distribution is constructed based on the mean and subgrid standard deviation.
- Emission is calculated by integrating the source function over the Weibull wind PDF.
- Offline CLM is used for testing the subgrid impact on dust emission.

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