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A generalized formulation for downscaling data based on Fourier Transform and inversion: Mathematical rationale and application to the Max-Planck-Institute aerosol climatology data

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ABSTRACT

Occasionally, a need arises to downscale a time series of data from a coarse temporal resolution to a finer one, a typical example being from monthly means to daily means. For this case, daily means derived as such are used as inputs of climatic or atmospheric models so that the model results may exhibit variance on the daily time scale and retain the monthly mean of the original data set without an abrupt change from the end of one month to the beginning of the next. Different methods have been developed which often need assumptions, free parameters and the solution of simultaneous equations. Here we derive a generalized formulation by means of Fourier transform and inversion so that it can be used to directly compute daily means from a series of an arbitrary number of monthly means. The formulation can be used to transform any coarse temporal resolution to a finer one. From the derived results, the original data can be recovered almost identically. As a real application, we use this method to derive the daily counterpart of the MAC-v1 aerosol climatology that provides monthly mean aerosol properties for 18 shortwave bands and 12 longwave bands for the years from 1860 to 2100. The derived daily means are to be used as inputs of the shortwave and longwave algorithms of the NASA GEWEX SRB project.

1. Introduction

As the NASA Global Energy and Water Exchanges (GEWEX) Surface Radiation Budget (SRB) [1,2] is moving toward the next generation of its products, not only are changes being made in its algorithms, new inputs are being made available as well. One of the required input datasets is the Max-Planck-Institute Aerosol Climatology version 1 (MAC-v1, [8]) which provides monthly mean aerosol optical depth, single-scattering albedo and asymmetry-factor for 18 shortwave bands and 13 long-wave bands for the years from 1860 to 2100. The data are produced at the monthly resolution because the modeling background maps for MAC-v1 are based on maps of local monthly ensemble median values available from global AeroCom phase 1 models.

However, the GEWEX SRB algorithms run on a 3-hourly basis. If we replicate the monthly mean value for each of the

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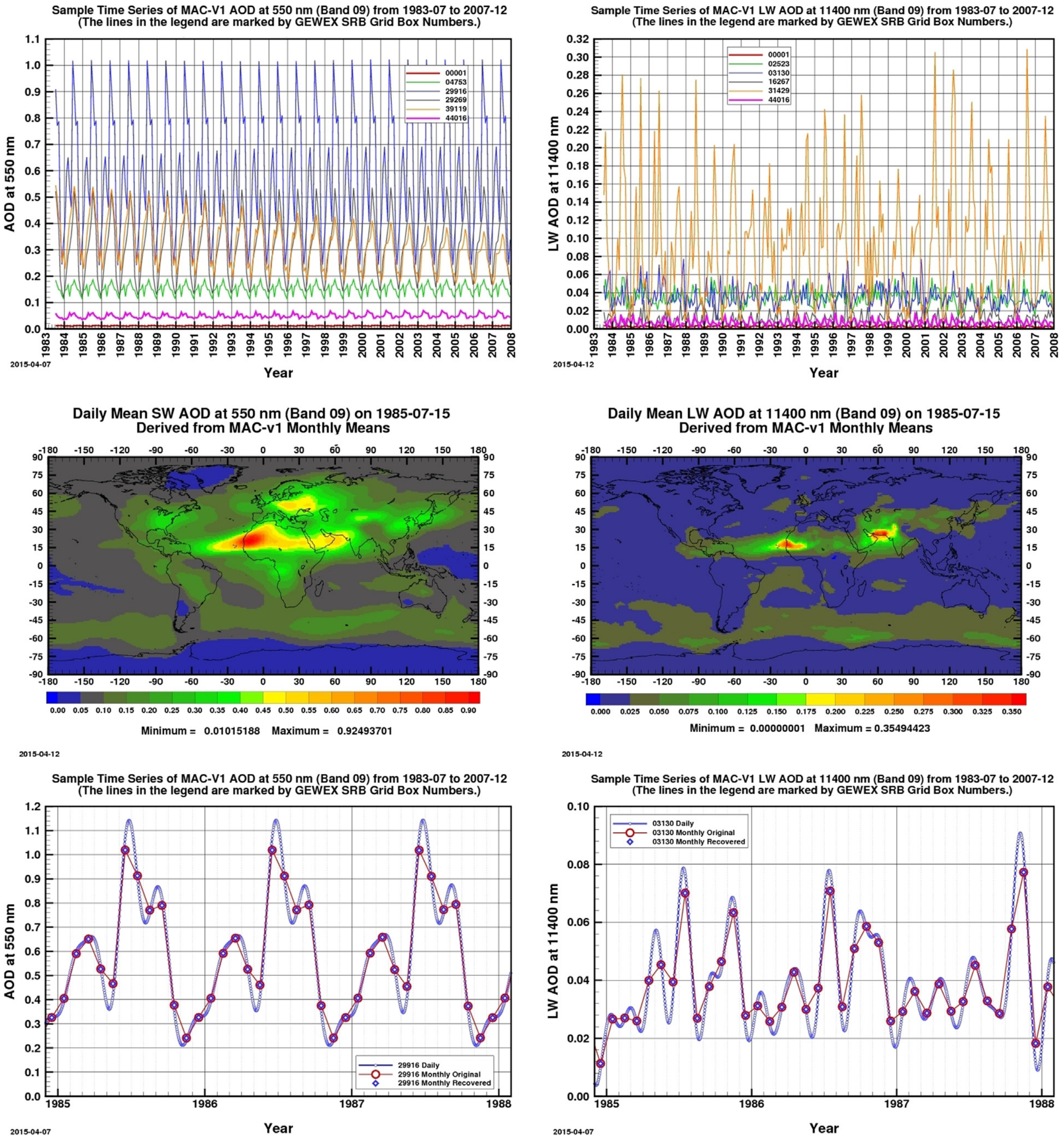

Fig. 1. Sample aerosol optical depth (AOD) results. The left column is for shortwave AOD; the top panel is sample time series of the original MAC-v1 AOD at 550 nm, the middle panel is a sample derived daily mean global field of AOD at 550 nm; the bottom panel shows the derived daily mean time series for a grid box, the recovered monthly as well as the original monthly mean. The right column is the same as the left column except for longwave AOD at 11400 nm. The centers (latitude, longitude) of the grid boxes in the left column are: 00001 (−89.5°, 60.0°), 04753(−50.5°, 49.0°), 29916 (21.5°, −12.5°), 39119(50.5°, 21.0°), 44016 (89.5°, −60.0°), and in the right column are: 00001 (−89.5°, 60.0°), 02523 (−63.5°, −91.0°), 03130 (−59.5°, 43.0°), 16267 (−15.5°, 18.5°), 31429 (26.5°, 60.5°), 44016 (89.5°, −60.0°).

aerosol optical properties for everyday of a month, the results will lack variability on submonthly scales and exhibit abrupt changes from the end of one month to the beginning of the next. For instance, in optical depth, some of those changes in certain locations can be very dramatic as illustrated in Fig. 1. To address these issues, we need to devise a method to recreate the data on a finer time scale. This problem belongs to a class of downscaling problems. While it is impossible to reproduce the reality on scales finer than that of the source data, it is mathematically possible to create submonthly variability that would satisfy two basic requirements: 1.) The submonthly data reproduce the original monthly means, and 2.) the submonthly data is free from abrupt changes as exhibited in the original step-like monthly means.