THE VISUALIZATION METHOD OF THE 3D CONCENTRATION DISTRIBUTION OF ASIAN DUST IN THE GOOGLE EARTH

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ABSTRACT:

The Asian dust (called "Kosa" in Japan) transported from desert areas in the northern China often covers over East Asia in the late winter and spring seasons. In this study, first of all, for dust events observed at various places in Japan on April 1, 2007 and March 21, 2010, the long-range transport simulation of Asian dust from desert areas in the northern China to Japan is carried out. Next, the method for representing 3D dust clouds by means of the image overlay functionality provided in the Google Earth is described. Since it is very difficult to display 3D dust clouds along the curvature of the Earth on the global scale, the 3D dust cloud distributed at the altitude of about 6300m was divided into many thin layers, each of which is the same thickness. After each of layers was transformed to the image layer, each image layer was displayed at the appropriate altitude in the Google Earth. Thus obtained image layers were displayed every an hour in the Google Earth. Finally, it is shown that 3D Asian dust clouds generated by the method described in this study are represented as smooth 3D cloud objects even if we looked at Asian dust clouds transversely in the Google Earth.

1. INTRODUCTION

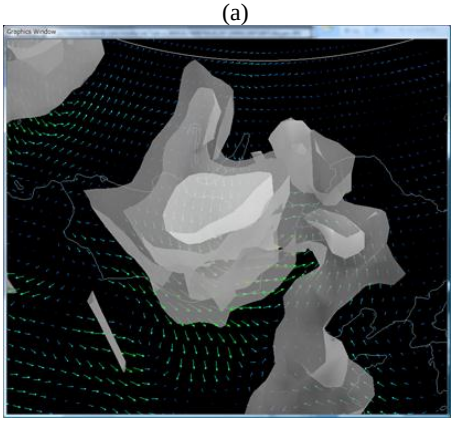
The Asian dust transported widely from desert areas in the northern China often covers over East Asia in the late winter and spring seasons. Fine dust particles will have harmful influence on our health. It is, therefore, important to see the extent and movement of Asian dust clouds over East Asia. In order to find out the source region and mass flux of sand dusts transported to Japan from arid areas in the northern China, we have carried out the long-range 3-dimensional transport simulation of Asian dust clouds and displayed the computed concentration distribution of dust clouds in a map system (Kusaka, 2009, 2003, 2011). In order to see the movement of dust clouds 3-dimensionally in the Google Earth, we transformed the file format of 3D dust clouds generated by the long-range transport simulation into the COLLADA file format such as the DAE format. However, it is very difficult to represent 3D dust clouds that are successfully placed along the curvature of the Earth on the global scale in the Google Earth.
In this study, a method for visualizing 3D Asian dust clouds in the Google Earth is described, and the time variation of the 3D concentration distribution of Asian dust clouds derived from the long-range transport simulation is also shown in the Google Earth. We computed the 3D concentration distribution of dust clouds over East Asia in cases of dust events observed in Japan on April 1 to 2, 2007 and March 21, 2010. We first transform the file format of 3D concentration distribution of Asian dust clouds obtained from the transport simulation into the VRML format with the wrl file extension. After that, we read them in terms of the 3dsMAX software and then divided 3D Asian dust clouds distributed at the altitude of about 6000m into many thin layers and displayed each of layers at the appropriate altitude in the Google Earth. Thus obtained image layers are displayed every an hour in the Google Earth. In order to animate the movement of 3D Asian dust clouds in the Google Earth, we also developed the software for automatically generating the KML script file and the image folder in which images corresponding to each layer of 3D dust clouds are saved. As a result, it is shown that 3D Asian dust clouds created in the present study are recognized as smooth 3D objects even if we zoom in the Google Earth.

2. LONG-RANGE TRANSPORT SIMULATION OF ASIAN DUST

In order to obtain the time variation of the 3D concentration distribution of Asian dust clouds for East Asia, we need to solve the 3-dimensional diffusion equation. We used the Aria regional package (Aria Technologies 2007) developed by Aria Technologies, France to carry out the long-range transport simulation of the Asian dust. The Aria regional package consists of the operational meteorological software based on MM5 and the continental Eulerian dispersion software using the CHEMERE multi-scale model. The Aria regional program allows us to compute the diffusion and depletion of Asian dust using US-NCEP GRIB data. The most important and difficult problem for the transport simulation of the Asian dust is to determine initial conditions such as source regions, the released time and mass flux of the sand dust.
We have reported how we determine initial conditions to solve the 3D diffusion equation (Kusaka 2003, 2009). That method was also used in this study. The source region estimated for dust events observed at various places in Japan on April 1 and 2, 2007 was located near (44.03, 111.60) at the latitude-longitude coordinates. The released time was about 00:00 on March 30, 2007 In addition, to check how dust particles rise with the ascending current near the estimated source region, we visualized the 3-dimensional flow of wind using the graphic package, savi3D, provided in the Aria regional package. Fig.1 shows surfaces with the same velocity at the altitude of 1000hPa to 750hPa near the source region. In Fig.1(a) and 1(b), isosurfaces with values of 10, 20, 25, 30m/s are shown in 4 gray scales. The brighter region corresponds to the higher velocity.

We can see from Fig.1 that sand dust particles were carried upward by the swirling wind flow over the source region.

(a)



(b)

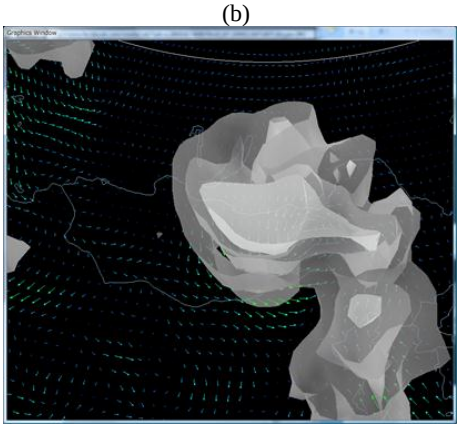


Fig.1 Flow of wind over the source region and isosurfaces of velocities of 10, 20, 25, 30 m/s. (a) shows equi-velocity surfaces at 2007.3.30 06:00 and (b) shows those at 2007.3.30 12:00.

We estimated the released region of the sand dust observed in Japan on March 21, 2010 in the same way as the case of dust event of April 1, 2007. As a result, it was found that sand dust particles were released at the Badainjaran desert from 3:00 to 12:00 on March 19.

In order to estimate the released mass flux of sand dust particles at the estimated source region, we used the transport simulation software (Aria Technologies 2007) to compute the 3-dimensional concentration distribution of Asian dust. The results of the long-range transport simulation of Asian dust are easily visualized and analyzed, by using the savi3D graphic package given in Aria regional package. We determined the released mass flux such that the computed concentration of Asian dust is nearly equal to the concentration of Suspended Particulate Matter (SPM) measured at various measurement places in Japan. The concentration of the SPM is measured every one hour at more than 2000 measurement spots in Japan. We acquired SPM data from Atmospheric Environmental Regional Observation System (AEROS) in Japan and estimated the concentration of SPM and the arrival time of Asian dust clouds at various places in Japan. In the case of dust event observed in Japan on April 1, 2007, the evaluation results are shown in our paper (Kusaka 2011). It was found that the concentration of Asian dust obtained from the simulation almost corresponds to that of SPM measured at several places in Japan. In the case of dust event on March 21, 2010, the evaluation results for the arrival time and the concentration of Asian dust at 7 Prefectures in Japan are shown in Table 1. We can see from Table 1 that the long-range transport simulation of Asian dust provides good results. Fig.2 shows the concentration distribution of Asian dust at 21:00 on March 20, 2010 obtained from the long-range transport simulation using the estimated mass flux at the source region. In Fig. 2, Asian dust clouds with the concentration of 0.6 mg/m^3 and topographical features in the East Asia are shown.

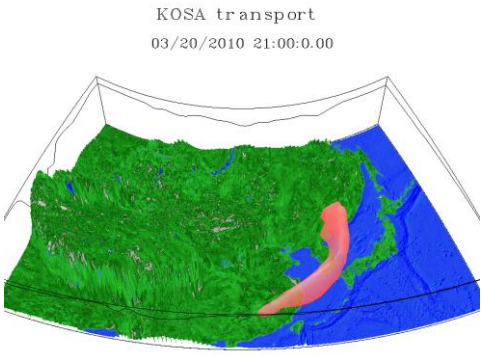


Fig.2 Dust clouds with the concentration larger than 0.6mg/m^3 at 21:00 on March 20, 2010

Table 1 Evaluation results for the arival time and the concentration of Asian dust (mg/m^3)

	SPM		Evaluation	
	Arival time	Concentration	Arival time	Concentration
Nagasaki	2010.3.20 22:00	0.6	○	○
Fukuoka	2010.3.20 23:00	0.6	○	○
Kumamoto	2010.3.21 0:00	0.6	2010.3.20 23:00	○
Hyogo	2010.3.21 3:30	0.3	○	○
Kyoto	2010.3.21 5:00	0.3	○	○
Ishikawa	2010.3.21 3:30	0.4	○	○
Akita	2010.3.21 5:00	0.2	2010.3.21 6:00	○

3. ANIMATION OF 3D ASIAN DUST CLOUDS IN THE GOOGLE EARTH

The long-range transport simulation software given by Aria regional package allows us to generate image files of the concentration distribution of Asian dust as shown in Fig.2. By using these images of Asian dust clouds, we have made an animation of the concentration distribution of Asian dust in the Google Earth (Kusaka 2009, 2011) to open the movement of the simulated Asian dust clouds to the public. In this case, the dust cloud is represented as the image and so we can clearly see the movement and extent of Asian dust clouds in the Google Earth. However, we are not able to see the widely spread dust cloud covering the sky. It is expected that we represent the Asian dust cloud 3-dimensionally in the Google Earth as if we would look at the dust cloud covering the sky from the ground surface.

3.1 Generation of 3D Asian Dust Clouds

The savi3D software allows us to output files of 3D dust clouds in the MeRAF file format based on the netCDF (Network Common Data Form) format. However, it is difficult to process them by means of the typical CG and image processing software. The software for transforming dust clouds with the MeRAF

format to those with VRML file format (.wrl) is also provided in the Aria regional package. We used the file transform software to output dust cloud files with the extension wrl.
After that, they were read into the CG software, 3dsMAX, and were transformed to the dae format that is associated with COLLADA. It is possible to display the 3D dust cloud with the dae file format in the Google Earth, but as shown in Fig.3, the dust cloud is not successfully placed along the curvature of the Earth because it is represented in the xyz orthogonal coordinate system. We will need another method to represent 3D dust clouds on the global scale in the Google Earth.

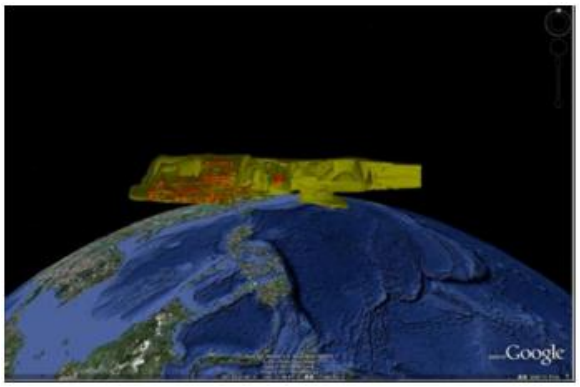


Fig.3 Asian dust cloud with dae format represented in the Google Earth

3.2 A method for Displaying 3D Dust Clouds in the Google Earth

The Google Earth provides the capability to easily display the image over the existing terrain. We use the image overlay functionality provided in the Google Earth to display dust clouds 3-dimensionally. To do that, we need to slice the 3D dust cloud thin. We first read the 3D dust cloud with the wrl file format in the 3dsMAX and divide the 3D cloud distributed at the altitude of about 6300m into 10 layers, each of which is the same thickness. This was done by the boolean operation between the 3D cloud and the box of a rectangular parallelepiped with the thickness of 630m. We made the rendering of the extracted layer of the 3D cloud and saved it as the png image. The image of a layer made by such operations is shown in Fig.4.

Fig.4 The image of the sliced one layer (High concentration areas in a layer are shown by the thick color.)

3.3 Animation of 3D Dust Clouds

We use 120 files output in every an hour by the long-range transport simulation from 00:00 on March 19 to 23:00 on March 23, 2010 to make an animation of 3D Asian dust clouds in the Google Earth. As described in the section 3.2, we need to generate many images for displaying even one dust cloud 3-dimensionally. Therefore, a software system for describing the KML (Keyhole Markup Language) script for the animation of 3D dust clouds was produced by using the VBScript. This software system consists of two components. One component produces the KML script file for the image overlay used in representing a 3D dust cloud, and the other produces the KML script for the animation of 3D dust clouds. In the KML script for the animation, the start time and end time, the name of KML file for the image overlay in each of 3D dust clouds are described. The name of KML file for the image overlay is referred in the <NetworkLink> tag. If the start time, the number of 3D dust clouds for the animation, the number of slicing a 3D dust cloud and the number of images inserted between layers are input in this software system, the KML script file and the image folder in which images for the animation are saved are generated automatically. In this case, the end time for the animation is computed from the number of 3D dust clouds for the animation because we have files output in every an hour from the long-range transport simulation. We can animate 3D Asian dust clouds over East Asia in the Google Earth by this KML file. Figs.5 and 6 show images of Asian dust clouds at 00:00 on March 20, 2010 and at 8:00 on March 20, 2010, respectively. Figs.7 and 8 show Asian dust clouds in case that we looked at Asian dust clouds transversely. Fig.9 shows Asian dust cloud covering the sky in the case that we are in the dust cloud. In Figs.5 to 8, the concentration of dust cloud is higher than 0.1mg/m3. As seen from Figs.7 and 8, 3D Asian dust clouds generated by the method described above are represented as smooth 3D cloud objects. The animation of 3D dust clouds generated for dust events observed in Japan on April 1, 2007 was also carried out. As a result, it was shown that it is possible to make the 3D representation of Asian dust clouds in the Google Earth as if we would look at the dust cloud covering the sky from the ground surface.

4. CONCLUSIONS

We estimated the released region and mass flux of Asian dust in cases of "Kosa" phenomena observed in Japan on April 1, 2007 and March 21, 2010 to carry out the long-range transport simulation of Asian dust. from March 19 to 23, 2010. In order to evaluate results of the transport simulation of Asian dust clouds, the concentration of Asian dust clouds was compared with that of SPM measured at various places in Japan. As a result, it was found that the long-range transport simulation of Asian dust clouds provided good results.
A new method for displaying the 3D concentration distribution of Asian dust clouds in the Google Earth was proposed. We divided the 3D dust cloud distributed at the altitude of about 6300m into 10 layers, each of which is the same thickness. Each layer was transformed to the image by using the Max script given in the 3dsMAX software. After that, we used the image overlay functionality provided in the Google Earth to display Asian dust clouds 3-dimensionally. The animation of 3D Asian dust clouds in the Google Earth was made, by using the software system we produced for describing the KML script for the animation of 3D dust clouds. As a result, it was found that 3D Asian dust clouds generated by the method described in this

study are represented as smooth 3D cloud objects even if we looked at Asian dust clouds transversely in the Google Earth.

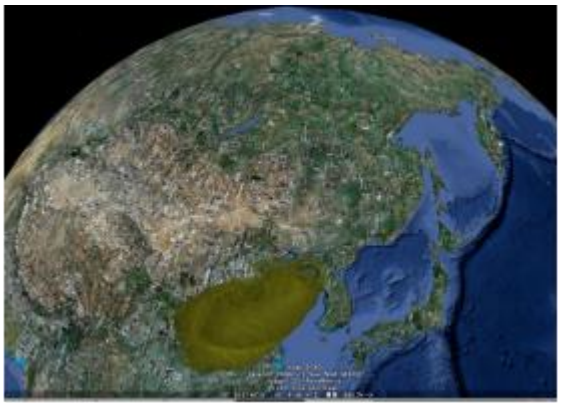


Fig. 5 Asian dust cloud at 00:00 on March 20, 2010

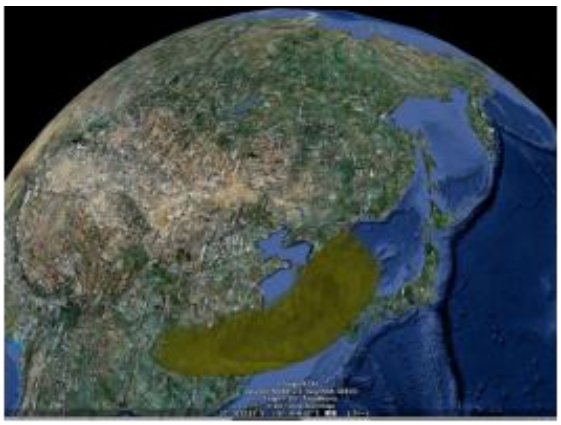


Fig.6 Asian dust cloud at 08:00 on March 20, 2010

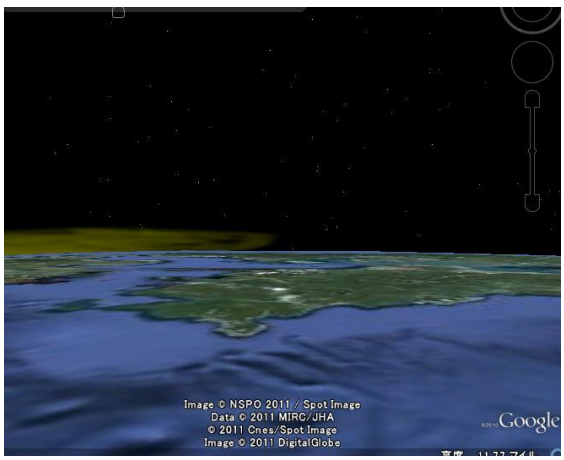


Fig. 7 Asian dust cloud at 03:00 on March 20, 2010 when we looked at the Google Earth in the transverse direction.

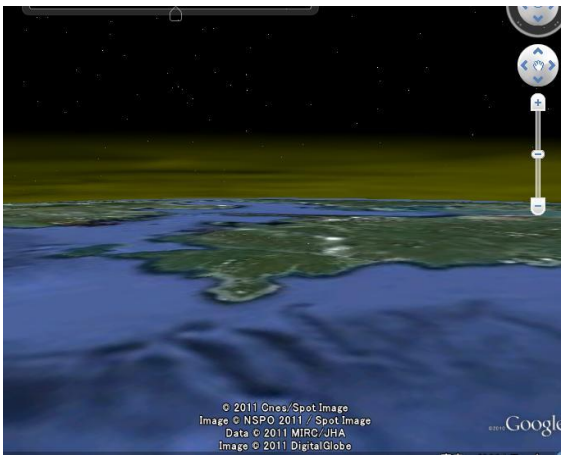


Fig.8 Asian dust cloud at 10:00 on March 20, 2010 when we looked at the Google Earth in the transverse direction.

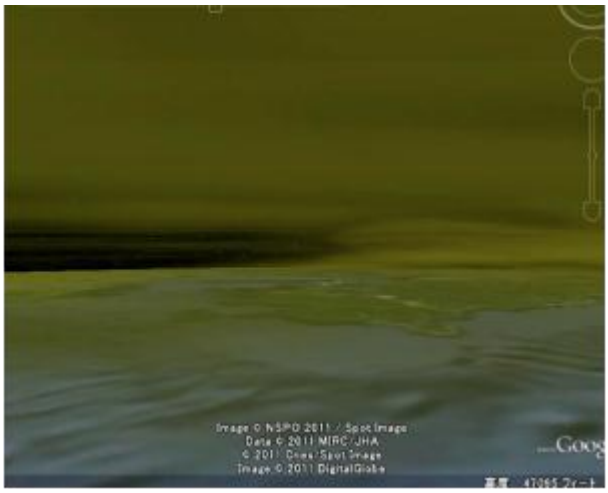


Fig. 9 Asian dust cloud covering the sky in the case that we are in the dust cloud

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