

Interactive comment on “Sand/dust storms over Northeast Asia and associated large-scale circulations in spring 2006” by Y. Q. Yang et al.

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Most frequent SDS in April China had 8 sand/dust storm processes in April 2006, of which 3 were rated as severe SDS processes, 2 SDS processes, and 3 blowing dust process. In the past years since 2000, it was rare to see 2 severe SDS and 1 SDS occur in a short period of 7 days from April 5 to April 11. This leads to a sharply raised frequency of 110% for the occurrence of severe SDS processes over the average of the past years. Heavy dust fall All 19 SDS processes affecting China were accompanied by floating dust. This is especially true to the severe SDS process from Mongolia affecting Beijing area on April 16-18, 2006. According to incomplete figures, Beijing was covered with 330,000 tons of sand-dust, which resulted in a seriously contaminated air marked by grade-5 for air quality.

. [According to the given definitions of SDS process, you first check the synoptic sys-

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tems in the investigation of SDS processes in spring 2000 to 2006. It will be better to present the dominant synoptic systems for SDS in Northeast Asia in spring 2000 to 2006 (or 2003 and 2006) in section 2, because the large scale (synoptic) circulations analyzed in section 3 are directly associated with these dominant synoptic systems for SDS .]

Thanks for the suggestions. We have revised those paragraphs and rephrased as followings: The cold air break out associated with the synoptic systems are occurred frequently in the north of China and its surrounding area. Such the synoptic systems, Mongolia cyclones, north-eastern depression of China are very often occurred in the area. It will provided favorable conditions for SDS process development.

[Section 3. The title "Variations and anomalies of general circulation"; could be more appropriate for the discussion (page 9266, line 6 and 7)]

We have revised this title of section3 and rephrased as "3. Variation and anomalies of general circulation";

Page 9266: line 12, "boundary layer weather systems"; should be deleted. line 19, "seasonal transitional period"; is changed to "seasonal transition";

A circumpolar vortex in the northern hemisphere is a seasonal-scale circulation system, playing an important modulator role in the seasonal transition

Thanks for the suggestions. The "boundary layer weather systems"; has been deleted and "seasonal transitional period"; is to be changed to "seasonal transition";

[In the caption of Fig.1 (page 9278), please substitute "geopotential height"; (geopotential is one word) for "geo-potential"; and add the unit used there.]

Yes, it have been rephrased.

[Page 9267: line 16. the title of section 3.2 should be changed to 'anomalies of mid tropospheric circulations', because the anomalies of circulations in fig. 2 are much more noticeable than the westerly jets there. Synoptically for SDS-events in Northeast Asia, the meridional circulation causing southward cold air break is more important than westerly jet in mid- and lower troposphere there.]

[Fig. 2. Please explain how to calculate the anomalies of wind field in the caption. Are they relative to the mean from year 2000 to 2006 or else?]

Thanks for this suggestion. We have revised the title of section 3.2; given an explanation how to calculate the anomalies of wind field in the caption and rephrased the description of this section as followings:

[In section 2.3, It is presented that 'earlier onset for severe SDS'; in March is one synoptic footprint of SDS processes in spring 2006. But you just give wind field anomalies of April and May in Fig. 2. Why do you not show wind field anomalies in March in Fig. 2? There should be a relationship between anomalies of the mid tropospheric circulations and the earlier onset for severe SDS'; in March, 2006. If not, why?]

Thanks for this suggestion. The circulation results for March have been given in figure 2; and rephrased the description of this section as followings:

The circulation for March, April and May 2003 (Fig. 2b) presents a completely different distribution pattern of 500 hPa field anomaly: 1) the shadow area with a noticeable northward wind field anomaly appeared there. It is mainly consistent with the area of Mongolia, the northern part, the west part, the center part of China and north to the Yangtse River. All these are not in a position to create a condition favorable for the long distance transport as it was in 2006. In this context, of northward current anomaly at the mid-level troposphere, which also covered with the major sand-dust sources of the northeast Asia, makes another reason behind the reduced frequency of sand/dust episodes in 2003.

[In section 3.2, 3.3 and 3.4, you discuss the anomalies of winds and pressure shown in fig. 2, 3 and 4. Please note: these are wind field (or circulation) anomalies, not wind field (or circulation) itself. Please correct the confusions in your discussion (e.g. ‘cyclone circulation’; in line 24 of page 9267 and line 18 of page 9268; ‘northwest jet’; in line 25 of page 9268, ‘northwesterly jet’; in line 20 of page 9258 and ‘southerly jets’; in line 23 of page 9268; et al.). To clearly discuss the anomalies of 500hPa wind fields (or circulations) in section 3.2, it could be more logically that you first describe the mean circulations of 500hPa in spring as a normal year background instead in the first paragraph from line 17 to 22 in page 9267 in the beginning of section 3.2.]

Thanks for this suggestion. The explanation of the anomaly fields in the Fig.2 has been given. In the rephrased manuscript, an anomaly southward meridional circulation in the Fig.2 has been emphasized (shadow area). It means a southward current could be very stronger than those in the average circulation status. and rephrased the description of this section as followings: 3.2 Anomalies of mid-tropospheric circulations Fig.2 is calculated the anomaly fields which are relative to the mean from 1971-2000. In general the anomaly fields can describe what is the mean difference from its average status in the atmospheric circulations. For example, an anomaly southward meridional circulation in the Fig.2 means a southward current could be very stronger than those in the average circulation status. Fig.2a shows a 500hPa wind field anomaly for March (upper chart), April (mid chart) and May (lower chart) 2006. It indicates that in the anomaly wind field, there is a significant southward current occupied about 2/3 part of China area at the mid-level troposphere. From Baikal Lake to all part of China for March (shadow area shows in Fig.2a upper), to northern China, south part of North-east of China and north to the Yangtse River prevailed by a stronger southward current anomaly in April (shadow area shows in Fig.2a mid chart). Also western part of China, center of China and south-western of China was prevailed by the stronger southward current anomaly in May (shadow area shows in Fig.2a lower chart) 2006. The shadow areas in Fig.2a are just consistent with the up-stream area notorious for desertification,

including the Mongolia, north part of China, Hexi Corridor stands. Once sands and stirred and blown up from ground, the mid-level southward abnormal current will be easier to be a powerhouse energizing the long distance transport of sand and dust. As it was mentioned earlier, this abnormal southward current right over a lower reach area made up of the mid and west parts of Mongolia, and an array of deserts in north China, including the Badain Juran Desert, the Kubuqi (Hobq) Desert, and the Onqin Daga sandy land that are sensitive to the sand-dust processes. In this context, the area from north China to the Hexi Corridor, is put under the influence of lower troposphere, which is desirable for an ascending turbulence and blowing sand/dust up from ground.

Section 3.3. Please change the subtitle from “Evolution of momentum field at the lower troposphere” to “Anomalies of momentum field in the lower troposphere”, because the anomalies of spring momentum field in the lower troposphere (but not the evolution) are discussed in this section.

The subtitle 3.3 has been changed as “Anomalies of meridional wind field at the lower troposphere”.

[Please delete the first paragraph of section 3.3 from line 2 to 12 of page 9269, because 1) “perturbation vorticity field (line 2)” is not discussed in this section, 2) “large scale anti-cyclone jets (line 5)” is not indicated in section 3.2, 3) the description and understanding on dynamics between the middle and lower troposphere is not correct and 4) the major factor of onset blowing dust process (the last sentence of this paragraph) is unclear.]

[In fact, the meridional winds are more important factor that triggers up the onset of sand dust process than zonal winds in the lower atmosphere (especially from 850hPa to surface). It is well known that Asian dust storms are caused by cold air break associated with cold fronts with the strong meridional (north) winds sweeping southwards across Northeast Asia. Therefore, please analyze meridional winds in addition to zonal winds for the momentum field in the lower troposphere in section 3.3.]

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Thanks for this important suggestion. We have revised and rephrased the description of this section to emphasize the anomaly southward meridional circulation. And also the figure3 has been changed to show the distribution of 850 hPa meridional wind anomaly in the spring of 2006 and 2003. It is as followings:

As we know, the meridional winds are more important factor that triggers up the onset of sand dust process in the lower atmosphere (especially from 850hPa to surface). It is well known that Asia dust storms are caused by cold air break associated with cold fronts with the strong meridional(south ward) winds sweeping southwards across Northeast Asia. Figure 3 is calculated an anomaly meridional wind field for the spring of 2006 from the average winds by the years of 1971-2000.

It can be seen from the figure 3a that compared with normal year, at the lower troposphere (850hPa), a strong negative anomaly of meridional winds (southward wind anomaly) with an unusually strong wind speed anomalies of 1-2 m/s has recorded in a vast area, ranging from Mongolia to most part of China including western, north and center of China, south part of North-east of China and south of China., High meridional momentum just covered In the major sand source of the northeast Asia mentioned above. It is a favorable condition for triggering up the turbulence movement at the boundary layer, which led to sand blowing and sending a downward transport . This makes an important footprint to explain the increased outbursts of sand/dust storms in 2006.

Figure 3b shows the distribution of 850 hPa meridional wind anomaly in the spring of 2003. It can be seen that major sand effecting area of the northeast Asia, including Mongolia, northwest China, north China, the southern part of northeast China, Korea Peninsula, and south of Japan, have been well covered by the positive anomaly of meridional winds (northward wind anomaly). As we mentioned above, those situation are not a favorable condition for cold air break associated with stronger meridional northward wind anomalies.

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[Section 3.4, It could be more appropriate to change the subtitle from “Abnormal sea level pressure of northeast hemisphere”; to “Evolution of sea level pressure anomalies”; because the evolution of sea level pressure anomalies from winter to spring is analyzed in your discussion in this section.]

we have changed the subtitle from “Abnormal sea level pressure of northeast hemisphere”; to “Evolution of sea level pressure anomalies”;

[Please delete the second paragraph from line 19 to 23 of page 9270, most of which is repeated in the next paragraph.]

The second paragraph from line 19 to 23 of page 9270 in the manuscript has been deleted.

[Page 9271, line 4: 1) “a counter-clockwise manner”; depends the observation positions. Please change it to eastwards (or westwards); 2) “8090 degree”; is a print error. Please correct it.]

Thanks for this suggestion. We have revised and rephrased as follows:

(b) In the spring of 2006, the northern hemisphere had a polar high that moved in a south-eastwards (Fig. 4a). The positive anomaly high center, originally located at the Tamil Peninsular, was shifted to the Bering Strait. At the same time, another positive anomaly high center, originally sat at the Greenland area, moved in the eastwards to the Tamil Peninsular. On the contrary, in the transitional period from winter to spring of 2003, the northern hemisphere had a polar high that did not show an apparent shift, with a noticeably weak positive anomaly center, and limited sphere of influence. Meanwhile, the negative anomaly of the Tamil Peninsular got reinforced.

[You mention a lot of province names in north China in the discussion of section 3. It could be better for non-Chinese readers to give the geographic regions in north China (e.g. northwestern, northeastern or center China) instead of Chinese provinces.]

Thanks for this suggestion. We have revised and rephrased in the corresponding para-

graphs.

[In section 4, conclusion: 1) please emphasize two highlights of this paper are 1) to give a definition of sand dust storm (SDS) process making a new standard of SDS in Northeast Asia and 2) to analyze the large-scale circulations in the atmosphere associated with to the SDS processes in spring of 2000 to 2006, 2) please make the corresponding revisions in the summary, 3) and English grammar and style should be improved.]

Thanks a lot for this suggestion. We have emphasized definition of sand dust storm (SDS) process making a new standard of SDS in Northeast Asia and the large-scale circulations in the atmosphere associated with to the SDS processes in spring of 2000 to 2006, in the summary, and revised and rephrased in the conclusion is as followings:

4. Conclusions Through the discussing in this paper some conclusions can be drawn:

1. A definition of sand storm process as a new standard of sand dust storm (SDS) for Northeast Asia, which groups a number of SDS-events in a period and region according to the synoptic system controlling the SDS-events in Northeast Asia has been given.
2. The evolutions and anomalies of general circulation in the troposphere are analyzed by comparing the spring having most and least occurrence of SDS process in the year 2006 with the year 2003. The results are indicated as followings. (1) In the upper troposphere 100hPa, it is found that, there is a fast developing high-value center in the circumpolar vortices of 2006, which pushes the prevailing circumpolar vortices further to an area close to 52 N. The circumpolar vortices travel southwards, and dominate a large area across the northeast hemisphere for a long duration. The circumpolar vortices of 2003 keep up a stable status with limited motion. So, there are no noticeable variations from February to March, in terms of dominating areas. (2) Comparing with a normal year, the structures of polar circulations over the northern hemisphere are noticeably different at the mid-level troposphere 500hPa in 2006, especially with the year enjoying a reduced frequency of SDS in 2003. It shows that the southward wind anomaly was found in March, April and May 2006. It indicates that

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because of a significant northwestern wind current occupied about 2/3 part of China area at the mid-troposphere 500hPa, once sand stirred and blown up from ground, the mid-level southward abnormal current will be easier to be a powerhouse energizing for long distance transport of sand and dust. This has played an important role in causing frequent attacks of cold air, triggering up the blowing dust and subsequent lower reach transport. The circulation for March, April and May 2003 presents a completely different distribution pattern of 500hPa field anomaly with a noticeable northward wind field anomaly. All these are not in a position to create a condition favorable for the long distance transport as it was in 2006. The some characteristics could be found at lower-level troposphere 850hPa. (3) At the surface, the positive anomaly high center, originally located at the Tamil Peninsular, a key cold air source in the northeast Asia is found in the spring of 2006. It energizes a southward shift of cold air, with a large coverage of the northeast hemisphere, and a long duration, which benefits the high frequency activities of SDS processes. On the contrary, in the transitional period from winter to spring of 2003, polar high in the northern hemisphere did not show an apparent shift, with a noticeably weak positive anomaly center, and limited sphere of influence. It is very important to understanding and studying the footprints of 3D global circulations that affect the SDS system for raising the operational capability of monitoring and early warning of SDS weathers. The effort also benefits an improved understanding of the genesis, development, and long distance transport of sand/dust storms.

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