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Some discussions on Arctic vortex

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Abstract The Arctic vortex is a persistent large-scale cyclonic circulation in the middle and upper troposphere and the stratosphere. Its activity and variation control the semi-permanent active centers of Pan-Arctic and the short-time cyclone activity in the subarctic areas. Its strength variation, which directly relates to the atmosphere, ocean, sea ice and ecosystem of the Arctic, can affect the lower atmospheric circulation, the weather of subarctic area and even the weather of middle latitude areas. The 2003 Chinese Second Arctic Research Expedition experienced the transition of the stratosphereic circulation from a warm anticyclone to a cold cyclone during the ending period of Arctic summertime, a typical establishing process of the polar vortex circulation. The impact of the polar vortex variation on the low-level circulation has been investigated by some scientists through studying the coupling mechanisms of the stratosphere and troposphere. The impact of the Stratospheric Sudden Warming (SFW) events on the polar vortex variation was drawing people's great attention in the fifties of the last century. The Arctic Oscillation (AO), relating to the variation of the Arctic vortex, has been used to study the impact of the Arctic vortex on climate change. The recent Arctic vortex studies are simply reviewed and some discussions on the Arctic vertex are given in the paper. Some different views and questions are also discussed.

Key words Arctic, Polar Vortex, Arctic Oscillation, Stratosphere and Troposphere, Climate Change

1 Introduction

The Arctic plays a key role in the global energy budget. The earth-atmosphere system gains the energy from solar shortwave radiation and returns the energy to the space by long-wave radiation. On average, the gained net energy from the area whose latitude is lower than 40° is almost the same as the lost net energy from the area whose latitude is higher than 40°. Both the Arctic and the Antarctic are heat sinks, the energy is transferred from the lower latitude to the higher latitude and both of the earth's polar regions by atmospheric and oceanic circulation system. The Arctic climate shows the signal of fast change, which draws people's great attention (Johannessen *et al.* 1996, Walsh *et al.* 1996, Thompson and Wallace 1998). During the observation period (the ending period of the Arctic summertime) on Chukchi Sea, the team of the Second Chinese Arctic Research Expedition (Zhang 2004) experienced the transition of Arctic middle and upper stratosphere from a warm anticyclonic circulation to a cold cyclonic circulation. This typical case that the polar vortex began to form in the Arctic On Sep. 5, 2003 arouses our research interest in the Arctic vortex. The word of "polar vortex" appeared in some meteorological text books long time ago (Meteorological Division 1976; Qiu 1985), and in the sixties of last century, some Chinese meteorologists had already done some prominent research work (Tao 1964). Since then the related research work has been stopped for a long time due to short of the data and limitation of observing conditions. The studies on the polar vortex evolution, the relationship between polar vortex variation of the Arctic stratosphere and the lower tropospheric circulation, their relationship with the ocean-air interface flux, sea ice and ocean, pan-Arctic circulation and mid-latitude circulation, the influence mechanism of the polar vortex and the Arctic change on climate, have drawn the attention of some international projects, such as SEARCH (Morison *et al.* 2001), SHEBA (Uttal *et al.* 2002) and SPARC (1998), however these studies are still very poor in China. There are already some published articles and books on the study of the relationship between polar vortex variation and the climate of China (Yu *et al.* 2005; Gong *et al* 2004; Zhao 1999), but there are very little studies on the physical process and mechanism. Though the polar vortex area index, the polar vortex strength index and polar vortex center position have been used as one of the indexes for mid-term and long-term weather forecast and short-term climate prediction in some operational departments, large part of these studies and applications are still on the stage of "seeking index and finding correlation", the studies on the physical mechanisms and processes still need to be emphasized and strengthened.

Whereas there are still some often confused concepts on polar vortex and some prejudice on polar research in academy, some discussions on the polar vortex will be introduced firstly in section 2; the polar vortex variation and its impacts on lower-level circulation are discussed in section 3; the influence mechanism of the polar vortex strength variation on the climate is discussed in section 4; the conclusions and discussions are given in section 5.

2 Arctic vortex

As the main role of the pan-polar atmospheric circulation, the polar vortex is a persistent large-scale whirl circulation in the middle and upper troposphere and stratosphere and centered on the two poles of the earth. The center of Arctic vortex usually deflects from the Arctic center, and the circulation pattern is usually asymmetric. Comparing with the Arctic vortex, the center of Antarctic vortex is closer to the polar center and its circulation pattern is much closer to symmetric ones (Xie and Fan 1991). There are similar descriptions on the averaged horizontal circulation pattern and seasonal variation of polar vortex in some meteorological and synoptic text books long time ago. But up to the present, there are very little descriptions and discussions on the instant circulation patterns and characteristics of polar vortex.

From Sep. 3rd to Sep. 13th, 2003, the period of Xuelong investigation vessel entering the Chukchi Sea of the Arctic and carrying out the Second Chinese Arctic Research Expedition (Zhang 2004), is the typical transition period of the Arctic middle and upper stratosphere from a warm anticyclone to a cold cyclone, the period of a typical wintertime polar vortex circulation establishing The center of polar vortex stayed stably in the area of Chukchi Sea during this period The center strength of the vortex began to strengthen since Sep 3rd, the minimum geopotential height was 16072 geopotential meters on 100 hPa height, on Sep 8th, the center geopotential height decreased to 15951 geopotential meters and began to increase slowly thereafter Fig 1 shows the geopotential height and air temperature fields from NCEP reanalysis data on Sep 8 th In order to clearly show the daily circulation variation, a 5-day running averaging method is used here and the same method is used on following figures The geopotential height of polar vortex center shown on Fig 1 is a little bit higher than the one without smoothing treatment, which represents the characteristic of the Arctic middle and lower stratosphere during this period: it was controlled by a warm low pressure on the layer from 200 hPa to 50hPa, the position of low pressure center is almost the same as the warm center, deflecting from the Arctic center and located on the Chukchi Sea And it was controlled by the cold and low pressure for the layers lower than 300 hPa Fig 2 shows the geopotential height and air temperature of Sep 8th on 500 hPa, which represents the characteristic of the Arctic middle and upper tropospheric circulation during this period The position of cold center is almost the same as the low pressure center, which is located on the Chukchi Sea It should be paid attention that the polar vortex shown on the synoptic charts from 500 hPa to 300 hPa clearly shows that the Arctic circulation field has some relationship with the north branch jets of tropospheric long-wave system. From the distribution of isotherm and isopotential on the synoptic charts of constant pressure surface, it can be seen that the Arctic vortex is highly barotropic and it is clearly different to the strong baroclinic mesoscale polar low. This typical polar vortex circulation extends from the stratosphere not only to the middle and upper troposphere, but also to the sea surface As shown on above figures, the geopotential field of 1000 hPa in Fig 3 obviously shows that a strong large-scale low pressure circulation controls the whole Chukchi Sea, the adjacent east Siberia Sea, the Beaufort Sea and their northern Arctic ocean The center positions of each layer are almost the same During the period of second Chinese Arctic science expedition, the remote sensing image of FY-1D received by the SEASPACE on "*Xuelong*" vessel (Fig 4) clearly showed that the lower layer eddy cloud in the polar vortex circulation controlling above Arctic ocean areas was developing strongly at that time The center of cloud eddy deflected only 208km to the west of the eddy center of 500 hPa potential field at 00: 00UTS of Sep 10th The scale of this type of cloud system, strongly developing cloud eddy center, and the corresponding tropospheric and stratospheric circulation, all demonstrate that the cloud on Fig 4 is different from the cloud system of normal cyclone or the polar low.

During this period the polar vortex upward till the upper stratosphere was still controlled by the cyclonic circulation, but a cold center appeared clearly in the polar vortex region Fig 5 shows the geopotential height and air temperature of Sep 8th on 10 hPa synoptic chart, which clearly displays the difference of the thermal structure comparing with the layers under 10 hPa As returning to the middle of August, the whole Arctic even the pan-Arctic was still covered by strong anticyclone on the middle and upper Arctic stratosphere The geopotential height and air temperature of 10 hPa on Aug 16th, 2003, shown on Fig 6, clearly demonstrates that a strong warm anticyclone was controlling the whole Arctic and its center is close to the Arctic center The circulation pattern is highly symmetric, which is very similar to the averaged summer circulation pattern of the Arctic middle and upper stratosphere. Thereafter the anticyclone strength of middle and upper stratosphere decreases and the air temperature becomes cold gradually. By Sep. 5th, a cold cyclonic vortex located at the Arctic center formed rapidly. Around the vortex are the regions of high pressure. During this period, the lower Arctic stratosphere still maintained a warm cyclonic circulation, and the vertical structure of the Arctic circulation can be summarized as: the troposphere was a cold vortex, the lower stratosphere was a warm cyclonic circulation; a large warm anticyclonic circulation maintained in the middle and upper stratosphere till the last ten days of August (Fig. 6) and it became a cold cyclonic circulation after Sep.

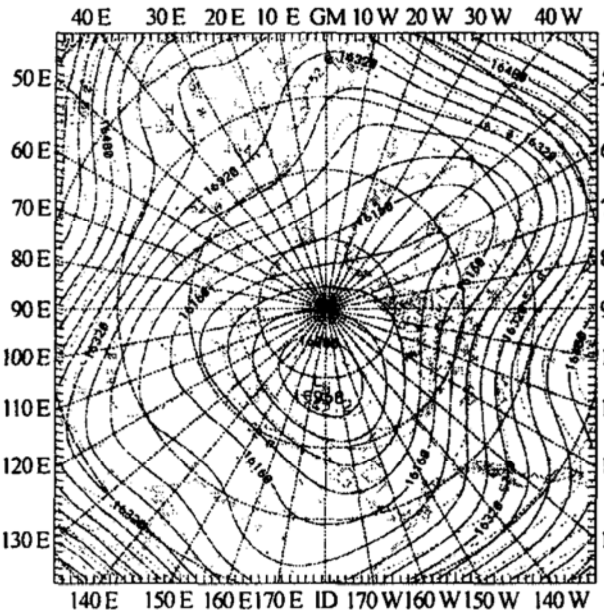

Fig. 1 100 hPa analysis fields of geopotential height (solid line) and air temperature (dashed line) at Sep. 8, 2003, 00:00 UTS. L and H denote low pressure and high pressure center of the geopotential height field, cold and warm center of temperature field, respectively

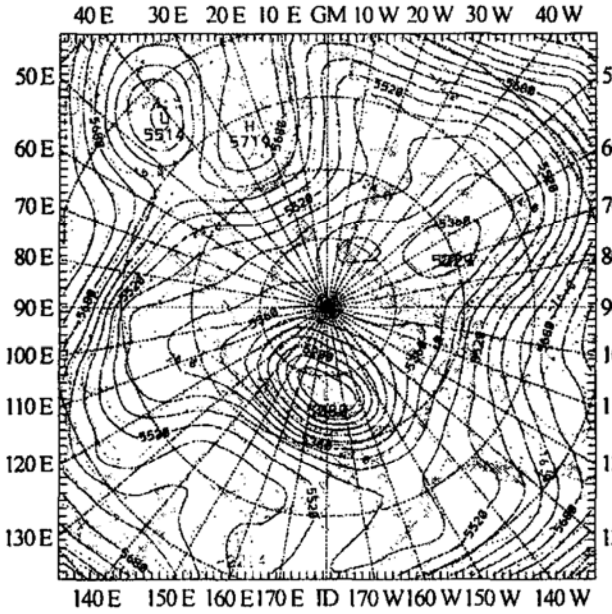

Fig. 2 Same as Fig. 1, but for 500 hPa

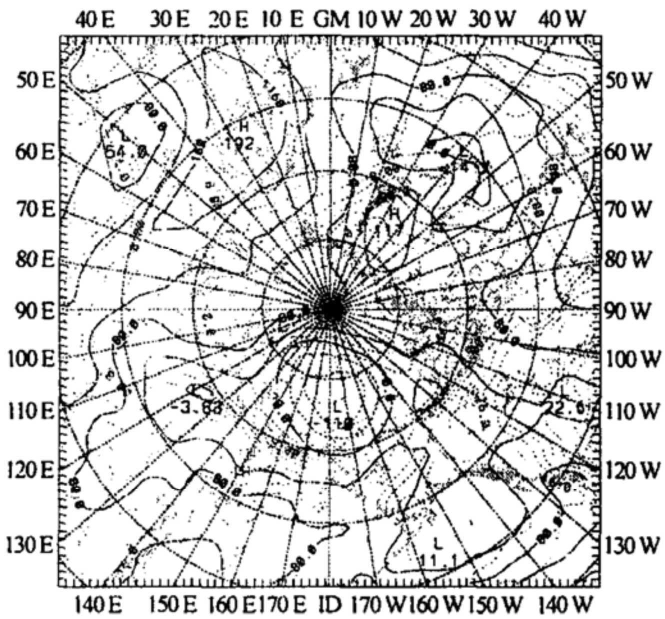

Fig. 3 Same as Fig. 1, but for 1000 hPa

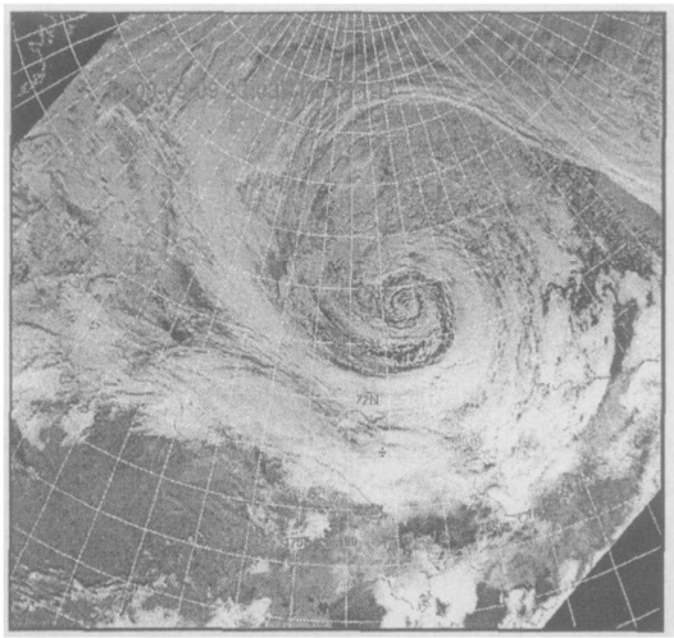

Fig. 4 FY-1D satellite remote sensing image for Sep. 9, 2003 UTC 23:03

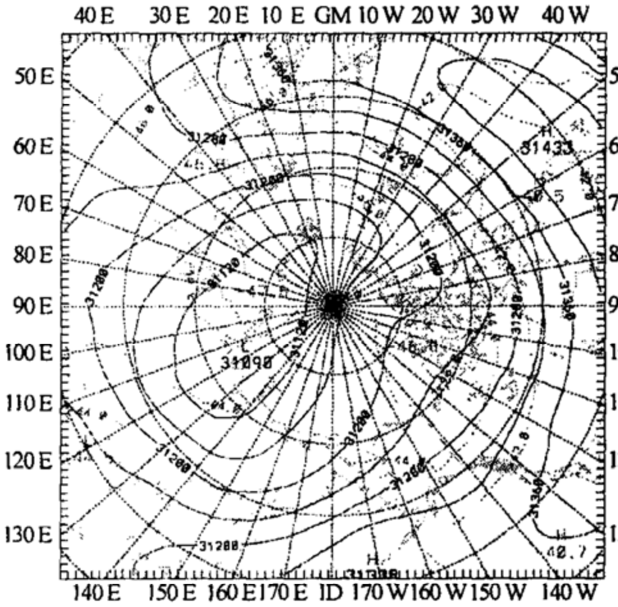

Fig 5 Same as Fig 1, but for 10 hPa

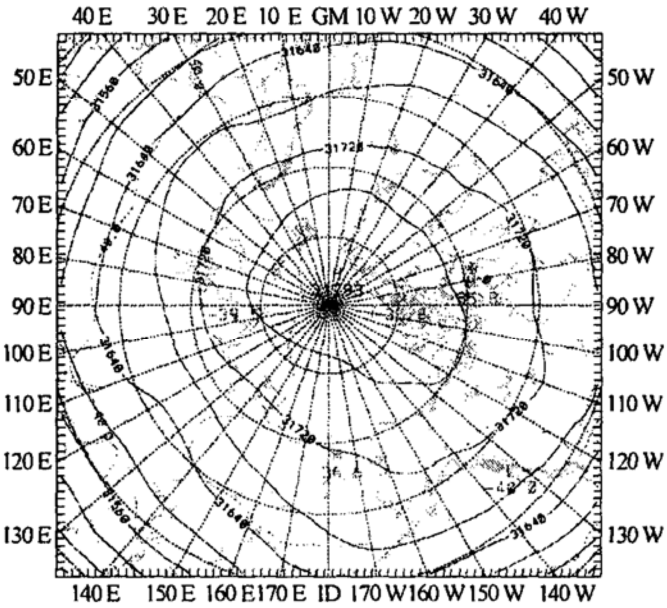

Fig 6 Same as Fig 5, but for Aug 16, 2003

5th (Fig 5). Ac- cording to the data statistic, Qiu (1985) pointed out that the high latitude circulation on 20 km height (corresponding to 50 hPa) begins to become cyclonic circulation from anticyclonic circulation during the last ten days of August, and the transition of the higher layer (60 km or so) circulation begins usually in the first ten days of September. Black *et al.* (2006) use NCEP/NCAR daily-averaged reanalysis data to study the stratospheric zonal wind transition. They set 10 hPa 70°N zonal-mean zonal wind 0 value as a threshold to composite 47 stratospheric final cooling (SFC) events from 1958 to 2004. The average date of Northern Hemisphere SFC onset is Aug 29 and its interannual variation is 4 days.

The polar vortex is often confused with the polar low or the polar cyclone, such as in "Vocabulary for Atmospheric Science (1994)", the polar vortex is confused with polar low. In the "International Meteorologic Dictionary" (WMO 1992) the polar vortex is defined as the large-scale cyclonic circulation in the middle, upper troposphere and stratosphere, and the polar low is defined as the small and shallow low pressure forming on the high latitude ocean, which means that the polar low is the synoptic system of lower troposphere. Fig 7 shows the satellite remote sensing image of the outbreak of the polar low down the Norway and Denmark coast. The eddy cloud on Fig 7 has clear eye-like structure as the one on Fig 4, but they represent different scales and different type circulation system on pan-Arctic area. Summarizing the descriptions above, the polar vortex is a large-scale persistent vortex circulation covering the whole Arctic middle and upper troposphere and the stratosphere, it can extends to the sea surface when it is strongly developing, the polar low is sub-synoptic scale system occurring on the troposphere of pan-Arctic areas, making it more clear, the polar low is α-scale or β-scale eddy which is much smaller than the polar vortex, and the polar low is highly baroclinic and its maximum horizontal scale is only several hundred kilometers, the Arctic cyclone is the tropospheric cyclonic circulation which forms and develops on the Arctic ocean in wintertime, its scale normally is 1000km to 2000km, larger than the Arctic low but usually smaller than the polar vortex. Sometimes these traveling tropospheric weather systems may relate to the activity of semi-persistent low centers. The semi-persistent active centers of the northern hemisphere, such as Aleutian low and Icelandic low, are the statistical characteristic of a serial of moving cyclones moving close to the area of active centers, decelerating and strengthening in sub-Arctic areas.

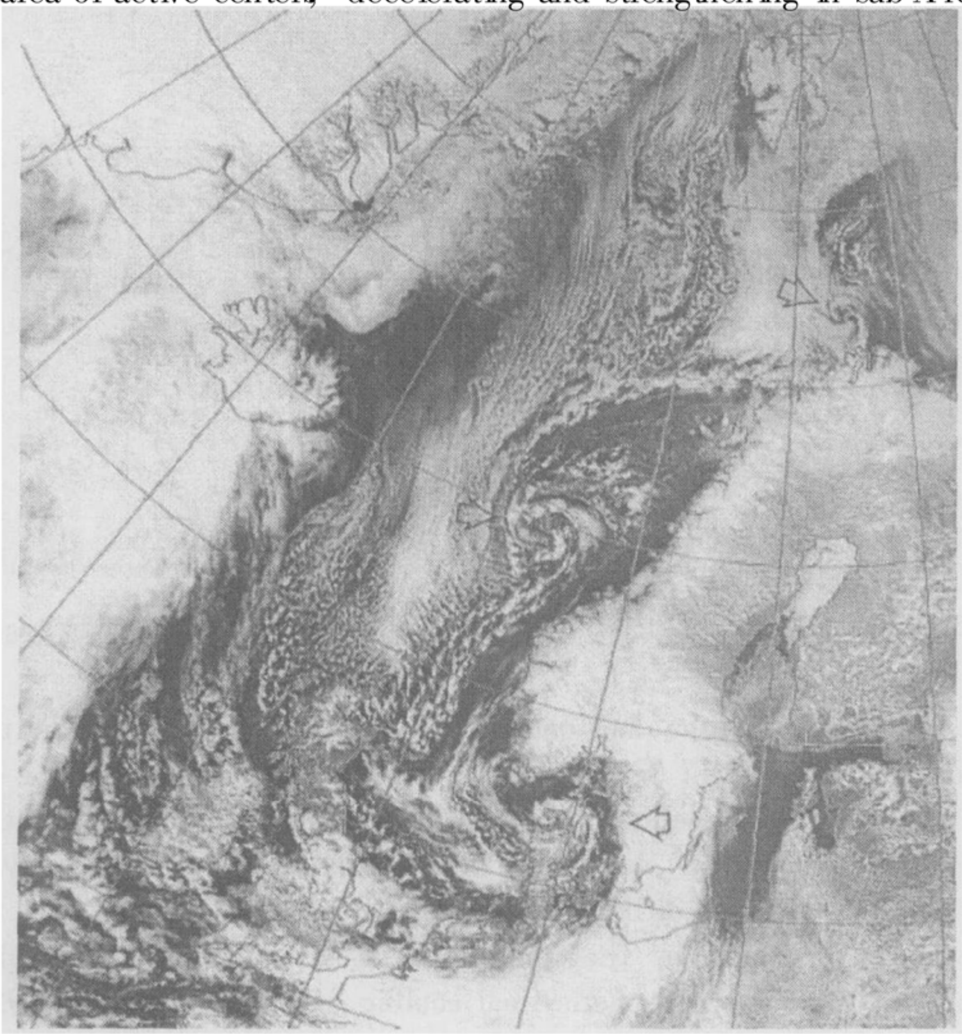

Fig. 7 A visible wavelength satellite image of an outbreak of polar low down the coast of Norway and Denmark. The eddy cloud systems of three polar lows are, respectively, indicated by arrows at North Cape, Norwegian Sea (65°N), and over Denmark. (after Rasmussen and Turner 2003)

On average the lower troposphere underneath the Arctic vortex is the high pressure or ridge; the polar low or polar cyclone is seldom underneath the polar vortex center, but often exists in the periphery of the polar vortex. As shown on Fig. 1 to Fig. 3, from the lower troposphere to stratosphere all are large cyclonic circulations and their center positions on each layers seldom appear on the same location. The vertical structure and its evolution of this polar vortex will be discussed in detail in the other papers.

3 Polar vortex variation and its impact on lower atmospheric circulation

It was pointed out by observations (Thompson *et al.*, 1996; Baldwin and Dunkerton 1999; Perlwitz *et al.* 2003) that the stratospheric polar vortex strength variation can affect the tropospheric circulation, and the temporal scale of the strength variation is more than several weeks, but tropospheric weather situation variation takes only several days. The strong stratospheric circulation variation firstly occurs on the 50km height, thereafter descends to the lower troposphere with an anomaly tropospheric weather system appearing (Baldwin and Dunkerton 2001). It has been noticed that the variation of polar vortex is correlative to the outbreak of strong cold air in the northern hemisphere. When polar vortex is strong, the westerly belt sinks to the earth surface and carries large amount of warm and humid air from the ocean to the land. These correlations and the stratospheric sign can be used for numerical forecast of tropospheric weather system. Investigating the mechanisms of stratosphere affecting the troposphere and including these mechanisms in the numerical simulation will help understand the climate evolution well and serve the weather forecast (Baldwin *et al.* 2001, 2003).

The annular mode (AM) can represent the characteristic of the polar vortex strength well. Baldwin and Dunkerton (2001) got the daily variation of annular mode on 26 isobaric surfaces between 1000 hPa and 0.316 hPa from November to next April from NCEP's 1000 hPa to 10 hPa analysis data from 1958 to 1999, the Tiros' operational vertical sounding data including the layers till 1 hPa from 1979 to 1993 and the British Meteorologic Bureau data including the layers till 0.316 hPa from 1993 to 1999. AM provides better measurement for vertical coupling than latitudinal averaging field, such as u (Baldwin and Dunkerton 2001). The value of stratospheric AM is the measurement of the polar vortex strength, whereas the behaviors of near surface AM are called Arctic Oscillation (AO) (Thompson and Wallace 1998; Baldwin and Dunkerton 1999) and North Atlantic Oscillation (NAO) (Wallace 2000). It affects short-term climate change with the temporal scale of several weeks to several ten-days. During the winter the AM signal of northern hemisphere extends from the stratosphere to the surface, which shows the modulation on the strength and the structure of the polar vortex (Black *et al.* 2002). The AM variations of northern hemisphere with time on different heights during the winter of 1998 to 1999 clearly show that the larger anomaly firstly appears on the upper and middle stratosphere and extends downward thereafter, the temporal scale of AM evolution in troposphere is very short and when AM is changing in troposphere, it is evidently different comparing with its changing in stratosphere. In other winters from 1958 to 1999, some positive and negative anomalies often extend to the surface, but not all the processes behaves in this way. Usually only the strongest positive and negative anomalies relate to the surface, and the weak anomalies maintain in the stratosphere. Baldwin and Dunkerton (2001) use the average of large negative anomaly and large positive anomaly as the measurement of the AM on 10 hPa height. Its daily value is highly correlative to the u of 60°N on 10 hPa height (0.95). Its positive value represents the strong vortex with clear structure, whereas the large negative value represents the weak vortex with unclear structure (Gillleff *et al.* 2001).

The dates when the value of AM on 10 hPa is smaller than the critical value -3.0 and larger than the critical value 1.5 are defined as weak and strong "vortex event" respectively, which signals the establishment of large anomaly of stratospheric circulation. In order to investigate the tropospheric evolution after the polar vortex event, the extending period after the formation of stratospheric anomaly is further defined as "vortex regime" (Thompson *et al.* 2001).

Though there are many studies on the statistical correlation of circulation anomalies between the stratosphere and troposphere and the relationship of the circulation anomalies with the AM of northern hemisphere in seasonal scale (Baldwin *et al.* 1999, 2003), the mechanism controlling the interaction between the stratosphere and troposphere must be further studied in order to diagnose the dynamic process causing the daily variation of AM in detail. Early in the sixties of last century, the Chinese scholars already paid attentions to the above studies and got some noticeable results (Sun *et al.* 1964). Song and Robinson (2004) proposed a "downward control with eddy feedback" hypothesis to explain the mechanism of stratospheric influence on the troposphere: the anomalous stratospheric planetary wave driving transmits the forcing to the surface by secondary circulation. Instead of a weak and downward decaying modification of tropospheric wind, the response to this forcing signal in the troposphere is amplified and modified by eddy feedback. Subsequent model test experiment shows that the forcing of tropospheric response is dominated by that due to tropospheric eddies, consistent with the hypothesis and Kushner and Polvani's results (2004). However, the experiment also shows the tropospheric response depends strongly on the state and dynamics of stratosphere, which is different from the hypothesis. Hence, the realistic downward influence process must be more complicated than the hypothesis. More observational analysis and modeling of stratosphere-troposphere coupling could contribute to the deep understanding of this mechanism.

The possible mechanisms of the stratosphere affecting the troposphere include: (1) the propagation of planetary wave (Perlwitz and Harnik 2003); (2) the interaction between the wave and the zonal flow (Christiansen 1999); (3) remote response to the adjustment of the troposphere potential vorticity (Baldwin and Dunkerton 1999; Hartley *et al.* 1998); (4) downward control (Haynes *et al.* 1991) and (5) the amplification of intrinsic mode (Robinson 1991). However, until now, it is still not clear that which of the mechanisms is dominant for this downward influence process.

Many studies use a general circulation model (GCM) to simulate the tropospheric response on stratospheric perturbation and investigate the sensitivity of the surface climate to the stratospheric polar vortex variation (Polvani and Kushner 2002; Norton 2003). However, most of them focus on the dynamic mechanism, not the thermal effect.

4 The influence mechanism of polar vortex strength variation on climate

The synoptic analysis clearly uncovered that the establishment, maintenance and destruction of polar vortex on middle and upper troposphere and stratosphere closely relate to the adjustment and the seasonal variation of atmospheric circulation. In the sixties of last century Tao (1964) pointed out the characteristic of the seasonal atmospheric circulation variation in lower stratosphere during the periods from wintertime to summertime and from summertime to wintertime and its close relationship with Arctic circulation. The stratospheric sudden warming not only closely relates to the polar vortex splitting and the circulation adjustment of polar stratosphere, but also considerably relates to the stratospheric blocking high on high latitude (Limpasuvan *et al.* 2004). Since discovered by Scherhag (1952) in the fifties of last century, large amount of observing data, especially the radiative data from the satellite remote sensing, the analysis of atmospheric dynamics and the numerical simulations all represent the significance of the sudden warming for the studies of polar vortex variation and the relationship between polar stratosphere and troposphere (Chen 1962; Murakami *et al.* 1963). Since the sixties and the seventies of last century, the energetics (Murakami *et al.* 1963; Miller *et al.* 1972) has been widely applied to study the transportation and transform of averaged effective potential energy, averaged kinetic energy, effective eddy potential energy, eddy kinetic energy, and the effects of radiative heating and cooling in the intermediate layer, stratosphere and troposphere. Since the super long-wave of the troposphere transfers superabundant energy upward for stratospheric sudden warming, inversely the troposphere of polar and high latitude regions accepts more radiative energy from the stratosphere and causes the warming effect of the troposphere and the earth surface. The variation of troposphere circulation caused by this feedback mechanism further affects the polar weather and even the weather of middle latitude areas.

The AM and AO can represent the characteristic of the polar vortex strength variation well, their varying tendency shows the strength variation of Arctic vortex and signals the variation of Arctic atmosphere, ocean, sea ice and ecological environment, and hence it has been uncovered that the annual variation of the Arctic sea ice closely relate to the seasonal strength of AO (Belchansky *et al.* 2004). People used to call the complex future change of the pan-Arctic areas as Unaami which is Esquimau and means "tomorrow", the relationship between Unaami and AO and how to closely relate Unaami to the climate change through AO now have become a subject that is causing people's great attention and is listed as one of the research focuses under SEARCH project (Morison *et al.* 2000). Since AO is the main mode of the Arctic atmospheric variation, it is reasonable to consider the AO as an important component of climate change. It can be concluded that the appearance of increasing tendency of the AO is consistent with greenhouse effect, which means this tendency is related with the lower layer atmosphere heating and higher layer atmosphere cooling. There are still many questions on how AO is driven. Somebody proposes that the sea surface itself can drive the AO due to the warming effect of CO_2 (Fyfe *et al.* 1999), but the simulations (Yamazaki and Shinya 1999) and the observations (Baldwin *et al.* 1999) by other people suggest that the stratosphere is the key for the AO change.

About the influence of the Arctic variation on the climate, people have paid more attention to the important effects of the feedback mechanism of the atmosphere cloud variation and the ice cover evolution at the ocean-air interface in the whole climate system. Sea ice is the underlying surface with maximum temporal and spatial variation in the two polar areas and it has unique function in the global climate. The ice and snow covers can change the reflection rate of the earth surface and change the shortwave absorbability of the underlying surface and the energy exchange between the ocean and the atmosphere. The feedback mechanism between ice and reflection rate is the key factor of large-scale feedback in the climate system, and it is also the important topic on studying the physical process of energy budget on the air-ice-ocean interfaces in SHEBA (Surface Heat Budget of the Arctic Ocean) project (Perovich *et al.* 1999; Curry *et al.* 1995). The cloud amount variation directly affects the absorbability of long-wave radiation and the cloud-radiation feedback strengthens the Arctic heating through some mechanisms. These are not only the focuses of studying physical processes in SHEBA project, but also the keys of large-scale climate research (Curry *et al.* 1996). The feedback effect of the fresh water cycle of the Arctic Ocean and its impact on subpolar ocean circulation cause the large-scale global feedback which affects the global thermohaline current, and further affect the long-term global climate change (Polyakov *et al.* 1999; Steele and Boyal 1998). In addition, the stratospheric polar vortex likes a chemical reaction vessel, the concentrations of vapor, nitrogen oxides (NO_x) and ozone (O_3) entering the polar vortex through the polar vortex wall dramatically drop, but the concentration of chlorine monoxide (ClO) increases dramatically, which result in more and more radiative cooling in polar regions. The low temperature and the catalysis of Cl make the O_3 becomes even lesser, especially there appears a hole of O_3 in the Antarctic. This feedback function of lower stratospheric chemical components noticeably affects the maintenance and splitting of the polar vortex (Waugh *et al.* 1999). The destruction and maintenance of the polar vortex, the variation of its strength and it influence mechanism on the climate are getting more and more people's attention.

The Chinese researchers analyses the relationship of the strength change of the Arctic vortex with the East Asia atmospheric circulation and Chinese climate by using the synoptic and statistic methods and have gotten noticeable results (Wu and Wang 2002; Yu *et al.* 2005). Gong (2003) analyzed the impact of AO on the Chinese winter climate through large amount of data and uncovered that the AO index has some applicable value on Chinese long-term and middle-term weather forecast and climate prediction. Yu Yongqiang (2005) also investigated the relationship between the AM of southern hemisphere in springtime and the precipitation of China in summertime.

5 Summary and discussions

The Arctic vortex is an important atmospheric circulation system of the Arctic middle and upper troposphere and above, its activity has significant impact on the AO, NAO and the northern hemispheric and even the global atmospheric circulation, its activity also directly affects the weather and the climate of China.

The strength variation of polar vortex can cause climate change, control the Arctic atmosphere, ocean, sea ice and ecologic environment, affect the low-level atmospheric circulation and the weather of subarctic and even the middle latitude areas. The cloud formation and the variation of cloud amount in polar troposphere and even in polar stratosphere, the concentration variations of atmosphere chemical components in lower stratosphere, the formation and melting of sea ice on the ocean-air interface, the transportation and variation of fresh water in the ocean, their feedback mechanisms, and the coupling mechanism between the troposphere and the stratosphere all are the key physical processes of climate system. These have become the key science topics in some current climate research projects, such as SEARCH, SHEBA and SPARC. The scientists are trying through studying these topics to learn the physical process of signal transferring downward and signal magnification of the stratospheric polar vortex variation, how this physical process affects the pan-polar circulation, even forming the sub-polar extreme weather system, and how the lower atmosphere and ocean drive the upper atmosphere variation through the flux exchange at the air-ice-ocean interfaces and these feedback mechanisms. The polar expedition and in situ observations provide the key data for polar synoptic analysis and energy diagnosis analysis and provide important parameters for developing air-ice-ocean coupling model.

The 2003 Chinese Second Arctic Research Expedition experienced the transition of the stratosphere circulation from a warm anticyclone to a cold cyclone during the ending period of Arctic summertime, a typical establishing process of the polar vortex circulation, which fires our interest of studying the transform mechanism of the polar vortex. The relationship of the circulation transform of this middle and upper stratospheric and the polar vortex establishment with lower tropospheric circulation, ocean-air interface fluxes, the variation of sea ice and ocean arouses our more interest. The Arctic exploration and the establishment of Chinese Arctic station provide our country the observing condition for studying above problems. Further studying this case can also provide the basis for enacting the plan of future Arctic science exploration.

Though the influences of Arctic and polar vortex on Chinese climate have been paid significant attention in our country and the researchers have got noticeable achievements on them, and in some operational departments the polar vortex area, polar vortex strength index and polar vortex center position even have been used as one of indexes for middle-term and long-term weather forecast and shore-term climate prediction (Zhao 1999), it should be paid attention that the most parts of these studies are analyzing the correlations of AO index, polar vortex area, polar vortex strength index with Chinese weather and climate, and seldom studying the physical processes and mechanisms. It is the fact that recently the analysis on these physical processes from the view of atmospheric physics is very little. Though Arctic vortex has been discussed long time ago among scholars, it is often confused with polar low and lower atmospheric cyclone. And the studies on the physical processes of polar vortex variation and its impact mechanism on climate have got widely international attention, but there are no many studies on it in China, it should be strengthened on the mechanism studies of the impact of polar vortex variation on the East Asia circulation and Chinese climate. In conclusion the studies on these problems are very limited and have not got enough attentions in the academic community. In order to develop and improve the ability of long-term and middle-term weather forecast and short-term climate prediction of our country, the mechanism studies must be strengthened and we cannot only stop on seeking indexes and solving correlations. And we should put enough attention on analyzing the reasonability of two poles' circulation simulation in developing global climate coupling model.

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