Research of forcing sources causing the blocking high related to the Okhotsk high

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1. INTRODUCTION

The Okhotsk high is important for the summer weather in Japan, because the intensity of the high influences the Baiu front (Wang and Yasunari 1994) and the development of the high has caused the cold summer in Japan (Ninomiya and Mizuno 1985). Investigating the cause of the occurrence and the development of the Okhotsk high will be connected to the forecasting skill and to the mitigation of the cold summer. Various studies on the mechanism and the formulation process of the Okhotsk high have been conducted from 1990s to 2000s.

Tachibana *et al.* (2004), who analyzed the monthly mean data in July, has pointed out that there are two types of the Okhotsk high; One has a barotropic structure related to the Rossby wave over Siberia, and the other has a baroclinic structure related to the SST over the Northern Pacific. They reported that the baroclinic Okhotsk high causes the cold summer in Japan.

Nakamura and Fukamachi (2004) reported that the surface Okhotsk high is accompanied with the blocking high over the Far Eastern Siberia and investigated a composite analysis about anomalous events in July. They found that a stationary Rossby wave packet, propagated from anticyclonic anomalies over northern Europe, is stagnated over the Far East. The Okhotsk high related to the Rossby wave corresponds with the barotropic high investigated by Tachibana *et al.* (2004). However, Nakamura and Fukaachi (2004) and Sato and Takahashi (2007) have suggested rather different opinion on the barotropic Okhotsk high investigated by Tachibana *et al.* (2004). They pointed out that the Okhotsk high is not completely barotropic but has a particular baroclinic structure, which has a baroclinic structure at low-level and a barotropic structure at middle and upper-level, and provides the cold advection to low-level (hereafter, the Okhotsk high related to the Rossby wave is called “the quasi-baroclinic Okhotsk high”.)

On the other hand, Sato and Takahashi (2007) presented that kinetic energy conversion from the basic field to the anomaly field contributes to the formation of the upper blocking high. The predominant vorticity forcing or Rossby wave propagation with a specific phase is not always accompanied with the anticyclonic anomaly over Siberia. Maeda *et al.* (2006) suggested that the numerical forecast of the Okhotsk high has a great uncertainty because a fake Okhotsk high can be formed after a few days from the error included in the initial values.

Thus, there are some discrepancies on the structure, the influence, and the mechanism. The purpose of this study is to revisit the different opinions on the cause of the Okhotsk high, and to reexamine what is the forcing source of the blocking high which is related to the surface Okhotsk high over the Far Eastern Siberia. We hope that the study would contribute to the advancement of the forecast skill.

2. DATA and METHOD

The data used in this study are reanalysis of JRA-25 (Japanese 25-year Reanalysis) and JCDAS (JMA CDAS). (Hereafter, “JRA-25” is referred to both the datasets.) The analysis period is from 1979 to 2008. The horizontal resolution is $1.25^\circ \times 1.25^\circ$. Almost all precedent studies on the Okhotsk high used NCEP/NCAR reanalysis data. Figure 1 shows snapshots of the geopotential height at 1000 hPa at 000 UTC on 25 July 2003, compared for NCEP/NCAR and JRA-25. When the contours of 200 m and 140 m are compared, it is found that JRA-25 can describe the Okhotsk high in more detail than NCEP/NCAR, because JRA-25 has a finer horizontal resolution than NCEP/NCAR.

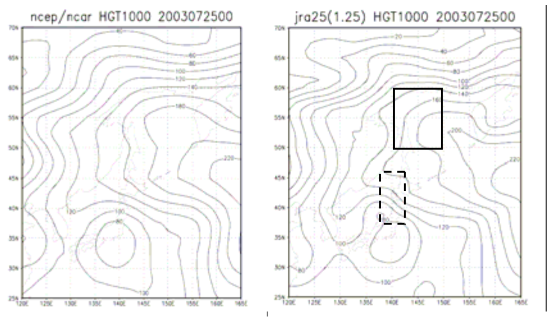

Fig.1. 1000hPa weather maps (solid lines for every 20gpm) based on the NCEP/NCAR reanalysis (left) and JRA-25 reanalysis (right) for 0000UTC, 25 July 1993. Each square is the area used for OHI and Northern Japan temperature.

We introduce an index of OHI for the intensity of the Okhotsk high based on 1000 hPa geopotential height applied with the 7-day low-pass-filtering. OHI is defined as the standardized maximum value of anomalies observed within 50° -60° N, 140° -150° E area for daily July data at every year. Figure 2 shows the time series of OHI during 30 years. In order to consider the developing cases for 30 years, peak days of the daily maximum value of OHI are searched in July for every year and are defined as the developed Okhotsk high. We analyzed the circulation field and the energy flow for each case. All data sets were applied with the 7days low-pass-filter.

3. RESULTS

First, we examined the relationship between the surface Okhotsk high and the temperature in the northern Japan (see Fig. 2). The index of the temperature is averaged within the defined area. The correlation coefficient between the two is not so high. But the OHI tends to show a greatly high value when the temperature index shows the cold anomaly. We analyzed the propagation of a quasi-stationary Rossby wave by the wave activity flux over the Far

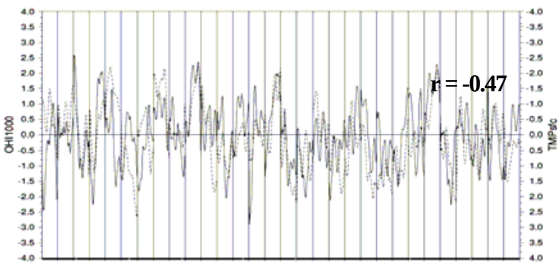

Fig.2. The time series of the OHI (solid line) and Surface temperature (broken line) standardized in July from 1979 to 2008.

East for every year. As a result, the propagation routes can be sorted into three patterns. One of patterns of the propagating flux and wave trains is from the ancicyclonic anomaly over the northern Europe to the ancicyclonic anomaly over the Far Eastern Siberia as in Nakamura and Fukamachi (2004). The Second pattern is from the cyclonic anomaly over the Eurasian Continent as explained by Wang and Yasunari (1994) and by Wakabayashi and

Kawamura (2004). The final pattern shows no propagation of the flux.

Most cases of high OHI for the pattern 1 were observed with the noticeable wave activity flux (for example; 1981, 82, 88, 93, 03.) We compared years of the first pattern (WAF) with years of the third pattern (No-WAF). We show that WAF years

WAF **No-WAF**

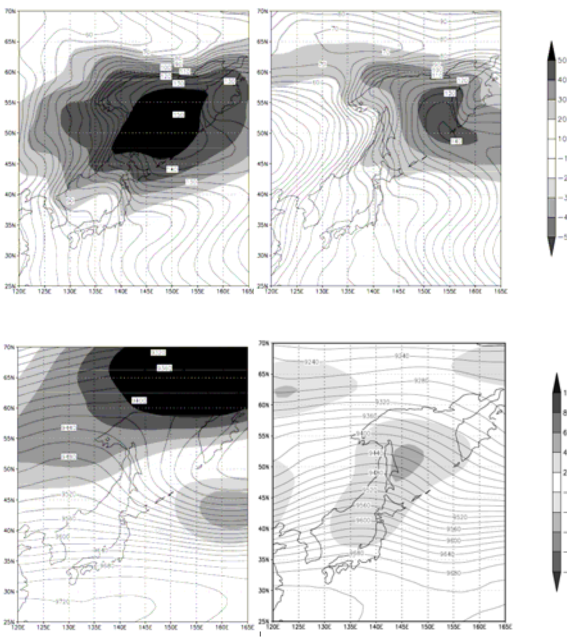

Fig.3. (a) and (c); 1000hPa and 300 hPa geopotential height composited for the peak times of WAF yers. (shade for the anomaly)., (b) and (d); The same as (a) and (c) for No-WAF years.

and No-WAF years do not differ much in the surface high (see Fig. 3(a) and (b)), but the anticyclonic anomaly on upper-level rotates clockwise and exists to the northwest of the center of the surface high for WAF years (Fig. 3(c)). On the other hand, it exists to north or northeast for No-WAF years (not shown in Fig. 3(d)).

Next, Figure 4 shows the WAF and EP-Flux for each case. The case for 2003 represents WAF years showing that the flux propagates from the anticyclonic anomaly over the Northern Europe to balotropic anticyclonic anomaly over the Far East (Fig. 4(a)). But, the case for 1983 representes No-WAF years, showing that the propagated flux breakes in the cyclonic anomaly over the central Siberia and the

2003 **1983**

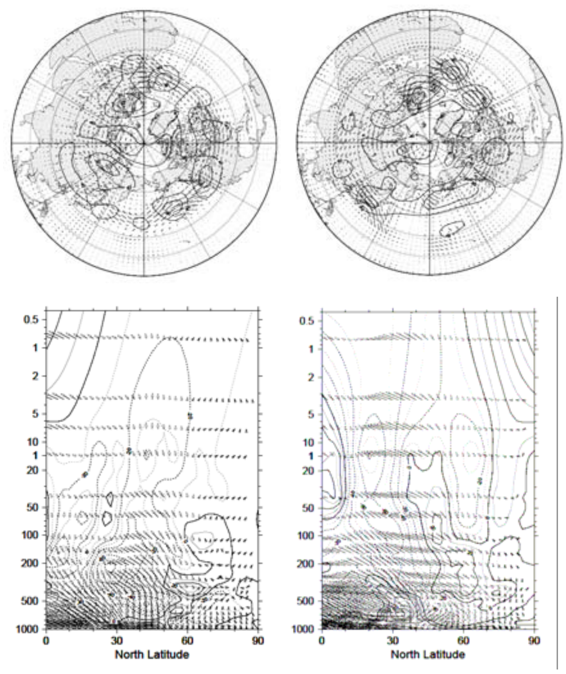

Fig.4. (a); The wave activity flux and the barotropic component for 0000UTC, 19 July 2003 (for 5 day befor the peak day)., (c); E-P flux and its divergence for 0000UTC, 18-24 July 2003., (b) and (d); The same as (a) and (c) for 000UTC , 13 July 1983.

balotropic anticyclonic anomaly over the Far East does not exist (not shown in Fig. 4.(b)). Instead, the E-P flux converges at middle and low-level around 55° N. This refers most cases of the No-WAF year (Fig. 4.(d)). Thus, westely momentum can be deprived only from the middle and low-level for the No-WAF year.

4. CONCLUSION and DISCUSSION

A number of strong Okhotsk high might be caused by the propagation of the quasi-stationary Rossby wave as suggested by Nakamura and Fukamachi (2004). This result does not accord with Tachibana *et al.* (2004). But, Tachibana et al. (2005) also insisted the effect of liner-superposition of the baroclinic and the quasi-baroclinic Okhotsk high. So we need to consider it. On the other hand, there are cases of the Okhotsk high developed although the Rossby wave does not propagate. There is a possibility that the cold frontal jet is reduced only at the low-level by the removal of the westerly momentum.

In any case, the blocking in summertime has been resolved less than that in wintertime. We should analyze further by focusing mainly on the vorticity source and the propagation of the quasi-stationary Rossby waves and on the intensification of the jet. The hindcast-experiment will be needed for finding the forcing area of the Rossby waves.

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