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高解像度大気海洋結合モデル (MIROC4h) で再現された北西太平洋の低気圧活動
Cyclone activities over northwestern Pacific in the high resolution general circulation climate model (MIROC4h)

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We examine cyclone activities over northwestern Pacific obtained from the Model for Interdisciplinary Research on Climate (MIROC) version 4. The MIROC4h consist five model components (atmosphere, land-surface, river-routine, ocean, and sea-ice subsystems). The spatial resolution in the atmospheric components have T213 spectral truncation (approx. 60 km interval) with 56-layer sigma coordinate below 40 km altitude. To evaluate the effect of air-sea interaction to the cyclone activities, we use three experiments of MIROC4h: (1) control run (fixed external forcing based on observations in 1950, (2) 20th century run (changing external forcing from 1950 to 2007, hereafter 20C3M), and (3) assimilated run with the observed ocean hydrographic data (ODAS, see Ishii and Kimoto, 2009 J. Oceanogr.). More details of the experimental design are documented in Tatebe et al. (JMSJ, in press). Cyclone activities are assessed by 6-hourly history of all cyclones (SLP at cyclone center, date and geographical points of generating, maximum deepening, and dissipating cyclones) by using an objective algorithm for detecting/tracking cyclones developed by Serreze et al. (1993).

Climatological monthly mean conditions of atmospheric and oceanic fields in the two experiments (20C3M and ODAS) show a good agreement with the observed characteristics of that in the Japanese 25-year Reanalysis/Japan Meteorological Agency Climate Data Assimilation System (JRA25/JCDAS). In late spring (Apr, May), however, intensity of the Aleutian low is slightly stronger than that in JRA25. Frequency of rapidly deepening cyclones on Apr-May is twice- or three-times as that in JRA25.

The rapidly deepening cyclones are frequently observed around Japan for cold season (Yoshida and Asuma, 2004 MWR). As noted by Yoshiike and Kawamura (2009 JGR), maximum deepening points of the cyclones tend to concentrate along the Kuroshio-Oyashio Extension during strong winter monsoon period. To examine atmospheric- and oceanic response by changing monsoonal flows, we demonstrate composite analysis of the positive/negative phase of monsoon activities using calculated atmospheric- and oceanic variables in 20C3M and ODAS run. In the strong monsoon period, we can find well-known characteristics both in 20C3M and ODAS experiments: (1) enhanced northerly and northwesterly wind covers over northeast China, East China Sea, Korean Peninsula, and Japan, (2) intensified East Asia jet elongate eastward, and (3) increased latent and sensible heat flux along ocean frontal zone. In cyclone activities (frequency, intensity, geographical distribution of maximum deepening points), however, there are no significant differences between strong and weak monsoon phases. These results suggest that air-sea interaction in MIROC4h is insufficient to change synoptic eddy activities over northwestern Pacific.

キーワード: 大気海洋相互作用, 総観規模擾乱活動
Keywords: air-sea interaction, synoptic scale eddy activity

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2010 年夏における日本の猛暑のメカニズム
Mechanisms of the 2010 summer heat wave in Japan

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Japan experienced an extraordinary heat wave in the summer of 2010 with highest average temperature ever since 1898. This may be linked with the strong positive sea level pressure (SLP) anomaly just to the south of Japan. To identify its cause, a series of atmospheric general circulation model simulations are conducted. Although the tropical Pacific is known as one of the major sources of abnormal weather in Japan, it did not play a significant role during this summer. Rather, the sea surface temperature (SST) anomaly in the tropical Indian and Atlantic Oceans played an important role in forming the positive SLP anomaly. It is suggested that anomalously high SST in the tropical Indian Ocean after the 2009/10 El Nino played a role in inducing an anomalous anticyclone over the northwestern Pacific. On the other hand, the positive SST anomaly in the tropical Atlantic induces more convection and diabatic heating, which in turn, becomes a source of Rossby wave-train along the Asian jet in the upper troposphere that generate positive SLP anomalies around Japan.

キーワード: 大西洋熱帯域, ロスビー波, 異常気象, 亜熱帯ジェット, 猛暑
Keywords: tropical Atlantic Ocean, Rossby wave, abnormal weather, Asian jet, heat wave

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2011 年暖候期に中緯度北太平洋に現れた暖水偏差に対する大気応答の可能性
Possible Atmospheric Response to Prominent Warm SST Anomalies in the Midlatitude North Pacific during Summer/Autumn 2011

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Observational and modeling studies have recently shown that atmospheric response to SST anomalies in the North Pacific subarctic frontal zone (SAFZ) tends to become the strongest and most robust during in midwinter. Although possibility has recently been suggested that warm-season SST anomalies in SAFZ may also force atmospheric anomalies, specific mechanisms how the summertime atmospheric circulation can respond to midlatitude SST are still unsolved. In this study, we focus on prominent warm SST anomalies observed in the North Pacific during the warm season of 2011, to investigate whether and, if any, how the SST anomalies can force stationary atmospheric response through a set of Atmospheric Global Climate Model (AGCM) experiments.

Two types of experiments were conducted with AGCM for Earth Simulator (AFES) with T119 spectral truncation (equivalently ˜125-km grid intervals) and 56 vertical levels. One is what may be called *climatological run*, where the climatological-mean SST was assigned daily as the model lower-boundary condition. The climatological run is compared with *hindcast run*, where warm SST anomalies (stronger than 0.5 K) observed in the warm season 2011 (May through October) were added to the climatological-mean SST assigned to the model. This modification was applied only to the midlatitude North Pacific, so as to keep SST unchanged in any other regions over the globe. The NOAA OISST with a spatial resolution of $0.25^o * 0.25^o$ is used, and the SST climatology is defined for the period 1982-2011. Each of the two runs includes 10 ensemble members each of which was integrated to the end of October 2011 from the initial condition taken from the obsevations for a particular day in the period from 27 March to 5 June. The initial conditions were also used for the verification of our model simulation. Statistically significant differences in the ensemble means between the *hindcast run* and *climatological run* are regarded as a signal of the atmospheric response to the warm SST anomalies observed over the North Pacific in 2011.

AFES is found to well reproduce the tropospheric anticyclonic anomaly as observed over the North Pacific in October. The simulated anticyclonic anomaly should be regarded as a stationary barotropic response that can be attributed to the midlatitude warm SST anomaly over the western North Pacific imposed to the model lower boundary, since the anomalous surface heat flux simulated tends to be upward in September and October. Although the anomalous sensible heat flux changes its sign in late October, the anomalous latent heat flux is stronger and persistently upward. In the model, the barotropic response starts emerging in late September as the climatological westerlies migrating gradually southward come to the vicinity of the SST anomalies as observed. Our model experiments suggest that the anticyclonic anomaly observed in October over the North Pacific and a cyclonic anomaly to its north may be a response to the midlatitude SST anomaly but not merely a remote response to the La Nina event, since the cyclonic anomaly is not included in a canonical anomaly pattern to La Nina derived statistically for October.

Unlike in the observations, the model summertime response is found cyclonic, which may be attributable to the unrealistically weak westerlies over the North Pacific as a model bias. In fact, the westerly jet and the axis of the subtropical anticyclone over the summertime North Pacific tend to be displaced poleward in AFES, and the western portion of the observed SST anomaly is situated under the climatological-mean surface easterlies rather than under the westerlies as observed. Our results imply that the atmospheric responses to midlatitude SST anomalies can be sensitive to relative latitudinal position of the mean westerlies.

キーワード: 大気海洋相互作用, 大気大循環モデル
Keywords: Sea-Air Interaction, General circulation model

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Influence of surface heat fluxes for the secondary cyclone intensification over the South Atlantic Ocean
Influence of surface heat fluxes for the secondary cyclone intensification over the South Atlantic Ocean

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Over the South Atlantic Ocean was found that two kinds of secondary cyclones occur. One kind develops in the western part of the primary system and other in the eastern part. Studies have shown that heat fluxes from the ocean to the atmosphere have an important role in the formation and intensification of cyclonic system. The latent heat flux from the ocean to the atmosphere is like a fuel to cyclonic system through latent heat released from formation of clouds. The sensible heat fluxes can strengthen or weaken the system depending on location. If the sensible heat fluxes heats warm region and cools cold region, it can increase the gradient of temperature enhancing the baroclinicity, and opposite may weaken. In this study we verified the influence of the sensible and latent heat fluxes in the secondary system that developed in April 2010 to the east of the primary system over the South Atlantic Ocean. We performed several numerical simulations by using the Weather Research and Forecasting (WRF) model. The results show that the latent heat flux has a more significant influence on the intensity of the secondary system than the sensible heat flux, which practically does not affect the intensity and location of the secondary system. The absence of latent heat flux delays the development of secondary low pressure center and it weakens both secondary and primary system. Regarding the location, the latent heat flux did not change either primary or secondary system. Therefore, the latent heat flux from the ocean to the atmosphere affects the intensity of the secondary system and delays the development of secondary cyclone more significantly.

キーワード: secondary cyclone, heat flux, South Atlantic, WRF model, extratropical cyclogenesis
Keywords: secondary cyclone, heat flux, South Atlantic, WRF model, extratropical cyclogenesis

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ベーリング海の表面塩分はオホーツク海の中層水温の変化を引き起こせるか？
Does (surface) salinity in the Bering Sea change (intermediate-layer) temperature in the Okhotsk Sea?

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This study suggests a link between the surface salinity in the Bering Sea and intermediate temperature in the Okhotsk Sea, which plays a essential role in the interannual variations in the intermediate overturning over the North Pacific Ocean. On the interannual time scale, the variation in the Okhotsk Sea Intermediate Water (OSIW) temperature lags 5-7 years behind that in the surface salinity in the Bering Sea. Far Eastern Regional Hydrometeorological Agency (FERHRI) extended the hydrographic database in the Okhotsk and Bering Seas by adding the unpublished Russian observation data (FERHRI database). We investigated the mechanism of the link between the Bering and Okhotsk Sea by analyzing the FERHRI database and the atmospheric reanalyses data. The results suggest that the atmospheric circulation manifested as the North Pacific Index strengthens the upwelling of salty water from the subsurface layer and weakens the inflow from the less-saline Alaskan Stream, both of which increases the surface salinity in the Bering Sea. After the more (less) saline surface water is advected southward by the East Kamchatska Current from the Bering Sea, this saltier (fresher) water is supplied to the Okhotsk Sea through the Kuril Straits. More (less) saline surface water eventually contributes to the formation of heavier (lighter) dense shelf water (DSW) in the northern shelf of the Okhotsk. The denser (lighter) DSW increases (decreases) the supply of cold water to OSIW, which make OSIW colder (warmer). The lags among the changes in the surface salinity of the Bering Sea, DSW salinity and OSIW temperature are roughly consistent with the advection durations estimated by using the ocean current velocities.
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Keywords: Bering Sea, Sea of Okhotsk, intermediate overturning, North Pacific Index

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寒候期の黒潮続流域における海面気圧極小と傾圧帯の経年変動
Interannual variations of a local pressure minimum and baroclinicity around the Kuroshio Extension in the cold season

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In the cold season, prevailing advection of a cold/dry continental airmass by the northwesterly monsoonal flow induces strong upward surface turbulent (sensible and latent) heat fluxes in the Kuroshio-Oyashio Extension (KOE) region. A recent study based on the ship-measured ICOADS dataset has shown that a local minimum in the climatological-mean sea-level pressure (SLP) field is collocated with a band of local maxima in the surface heat fluxes along the Kuroshio and its extension. Another recent study has shown through numerical experiments that meridional contrasts in the surface sensible heat flux (SHF) across a prominent oceanic front can act to maintain a surface baroclinic zone within the KOE region. The present study is the first to investigate the interannual variability of SLP minimum (trough) and surface baroclinicity in the KOE region, mainly based on the JRA25 monthly data for a recent 32-year period.

Our analysis reveals that the pressure trough is very likely anchored at 33.75N along the Kuroshio Extension (KE) axis. The trough is situated slightly southward of the heat flux maximum, but their positions vary to some extent interannually. Our additional analysis reveals a statistically significant difference in mean northerly wind speed in between months when the trough axis is located 1.25 deg. south of the heat flux maximum and when their displacement is 2.5 deg. or greater, suggesting the importance of the advective effect by the monsoonal wind.

In wintertime a well-defined surface baroclinic zone marked by the strongest surface air temperature (SAT) gradient forms in the KOE region. Our analysis of interannual variations of the baroclinicity reveals that the latitudinal position of its maximum is collocated with or slightly south of the maximum SHF gradient while situated north of the maximum gradient in the meridional cold advection. This result suggests that the latitudinal position of the baroclinic zone is determined in balance between the heat supply from the ocean and advective effect of the monsoonal wind.

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Ocean mixed layer heat budget east of Japan
Ocean mixed layer heat budget east of Japan

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We investigate the Ocean Mixed Layer (OML) heat budget close to the North Pacific Subarctic Front in an area where the front is quasi-stationary (155^o E). This area is of particular interest because strong air-sea heat exchanges there may affect storm tracks. Also, it is thought to be a formation area of central mode water. The heat budget is computed using satellite SST (AMSRE), altimetry (AVISO) and surface wind data (QuikSCAT). Argo profiling float temperature and salinity data are used to estimate the depth of the mixed layer.

The heat budget seasonal cycle is investigated in two boxes representative of two different regimes of the budget: a deep mixed layer box south of the front where the winter mixed layer depth reaches up to 300 m, and a shallow mixed layer box where winter mixed layer reaches 125 m. In the deep OML box, strong winter cooling mostly due to heat loss to the atmosphere is amplified by Ekman advection and entrainment from below the mixed layer (contributing 30 percent of the cooling). In the shallow OML box, strong cooling by Ekman advection is largely balanced by geostrophic advection due to the front. The effect of this balance on the winter OML water properties linked to Transition Region Mode Water formation are subsequently investigated.

キーワード: North Pacific Subarctic Front, ocean mixed layer, heat budget, observation data, mode water
Keywords: North Pacific Subarctic Front, ocean mixed layer, heat budget, observation data, mode water

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南極におけるインフラサウンド波：気候・環境モニタリングの新指標
Infrasonic Waves in Antarctica: A New Proxy for Climate and Environmental Monitoring

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The Infrasound is defined as sub-audible sound with frequencies ranging from the cut-off frequency of sound (3.21 mHz) to the lowest frequency of the human audible band (20 Hz). This frequency range presents new opportunities for remote sensing of the Earth ’s atmospheric physical environment (Hedlin et al., 2002). There is an emerging body of published results on infrasound waves generated by diverse sources, such as volcanic eruptions, ocean waves, earthquakes, thunders, sprites and airplane passages (Matoza et al, 2007; Garces et al., 2008). For a remarkable example, the 2011 Tohoku-Oki, Japan earthquake (Mw = 9.0) produced unequivocal infrasound signals associated with the large tsunami (Arai et al., 2011). Free oscillations of the Earth from great earthquakes can also affect even the upper atmosphere. Another striking example is given by infrasounic shock waves generated by a large meteorite fall in Japan (Ishihara et al, 2004).

Characteristic features of infrasonic waves associated with environmental changes are clearly identified in Antarctic stations deployed during the International Polar Year (IPY2007-2008). Loading effects from the Southern Ocean are recorded by infrasound sensors deployed at Syowa Stations (SYO; 69S, 39E), in the Lutzow-Holm Bay, East Antarctica. The oceanic effects on infrasound modulated by the presence of sea-ice are examined relating to atmosphere-ocean-cryosphere system. Measurements of these microbaroms are useful tools for characterizing ocean wave climate and global storm intensity, complementing other geophysical measurements. The infrasound data at SYO, moreover, demonstrate unique signals with harmonic over-tones that may be be influenced by local near-surface processes, such as katabatic winds or the ice dynamics. Infrasound observations in Antarctica, consequently, could present unique new proxies for monitoring environmental change as well as temporal climate variations in the southern polar region.

キーワード: infrasound, Antarctica, microbaroms, environmental monitoring, global network, atmosphere-ocean interaction
Keywords: infrasound, Antarctica, microbaroms, environmental monitoring, global network, atmosphere-ocean interaction