

# Inter-decadal modulations in the dynamic state of the Kuroshio Extension system: 1905-2016

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The Kuroshio Extension is an eastward-flowing, inertial jet in the subtropical western North Pacific after the Kuroshio separates from the coast of Japan. Being the extension of a wind-driven western boundary current, the KE has long been recognized as a turbulent current system rich in large-amplitude meanders and energetic mesoscale eddies. An important feature emerging from the past 25-yr satellite altimeter measurements is that the KE system exhibits clearly-defined decadal modulations between a stable and an unstable dynamic state. The decadal-modulating KE dynamic state exerts a great impact on the regional sea surface temperature, heat content and water mass properties. By clarifying the relationship and physical processes between the basin-scale wind forcing and the KE dynamic state over the altimeter era, we hindcast the KE dynamic state going back to 1905 with the use of ECMWF reanalysis wind stress product. It is found that the low-frequency KE variability modulated in the past century in connection with the mid-1920s, mid-1940s, and mid-1970s' climatic regime shifts in the Aleutian Low pressure system. In addition to the modulations in KE's response to the external wind forcing, the midlatitude ocean's feedback to the overlying atmosphere appeared to have differed within the epochs of the different 20th century regimes.

Keywords: Kuroshio Extension, decadal variability, air-sea interaction

## Influence of the Kuroshio Extension and Oyashio fronts on the atmosphere as revealed in the JRA-55 family

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Impact of midlatitude frontal SST gradients on the overlying atmosphere are assessed through comparison between two products of a new Japanese reanalysis (JRA55). One of them is a product called JRA55C in which in-situ observational data have been assimilated in a forecast system with horizontal resolution of ~60km and the COBE SST data with 1-degree resolution is prescribed. The other is an additional product (JRA55CHS) with MGDSST data with a quarter-degree resolution, which can resolve the frontal-scale SST structures. The comparison reveals substantial differences in midlatitude atmospheric processes around the western boundary currents and associated SST fronts. As a typical example, wintertime atmospheric response to variability of the Kuroshio Extension (KE) is examined. The Kuroshio Extension fluctuates between its stable and unstable regimes on (quasi) decadal time scale. In its unstable regime, eastward transport of the KE decreases, and its path tends to be more meandering compared to its stable regime. As in satellite observations, enhancement of cloudiness and precipitation in the mixed-water region east of Japan during the unstable regime of KE relative to its stable regime is represented well in JRA55CHS but not in JRA55C product. The enhancement results from augmented heat/moisture release from the warmer ocean with more active warm-core eddies in unstable KE regimes. This oceanic thermal forcing onto the atmosphere is manifested as positive correlation in anomalies between SST and heat/moisture release, which is represented only in the high-resolution MGDSST but not in the COBE SST. Distinct differences in upward motion and diabatic heating ratio represented in these products are not limited within the atmospheric boundary layer, suggesting the significant impact of the oceanic forcing on the atmospheric circulation in free atmosphere.

## Interannual modulations of the influence of North Pacific oceanic fronts on the atmosphere as revealed in the JRA-55 family

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Influence of frontal SST anomalies associated with North Pacific subarctic frontal zone on the overlying atmosphere are investigated through comparison between two sub-products of a new Japanese reanalysis for the global atmosphere (JRA-55). In one sub-product, JRA-55C, all the observational data but satellite data are assimilated on horizontal resolution of  $\sim 60\text{km}$  with COBE SST data on 1-degree resolution prescribed over 55 years. The other sub-product, JRA-55CHS, is the same as JRA-55C, but with MGDSST data on a quarter-degree resolution only over 28 recent years.

Atmospheric response to SST anomaly associated with meridional displacement of oceanic frontal zone is investigated as an interannual modulations of the influence of North Pacific oceanic fronts. In JRA-55CHS, SST anomaly is much better collocated with anomalous heat/moisture release in October. Enhancement of convective precipitation over warm SST anomalies is larger and so is area-averaged precipitation anomaly in JRA-55CHS. Anomalous upward motion and convective heating are also enhanced over the warm SST anomaly, not only within the atmospheric boundary layer but also in free troposphere. These results suggest that assimilating high-resolution SST data has a certain impact for global atmospheric reanalysis.

キーワード：海洋前線、大気海洋相互作用、北西太平洋、大気再解析

Keywords: Oceanic front, Air-Sea interaction, western North Pacific, Atmospheric Reanalysis

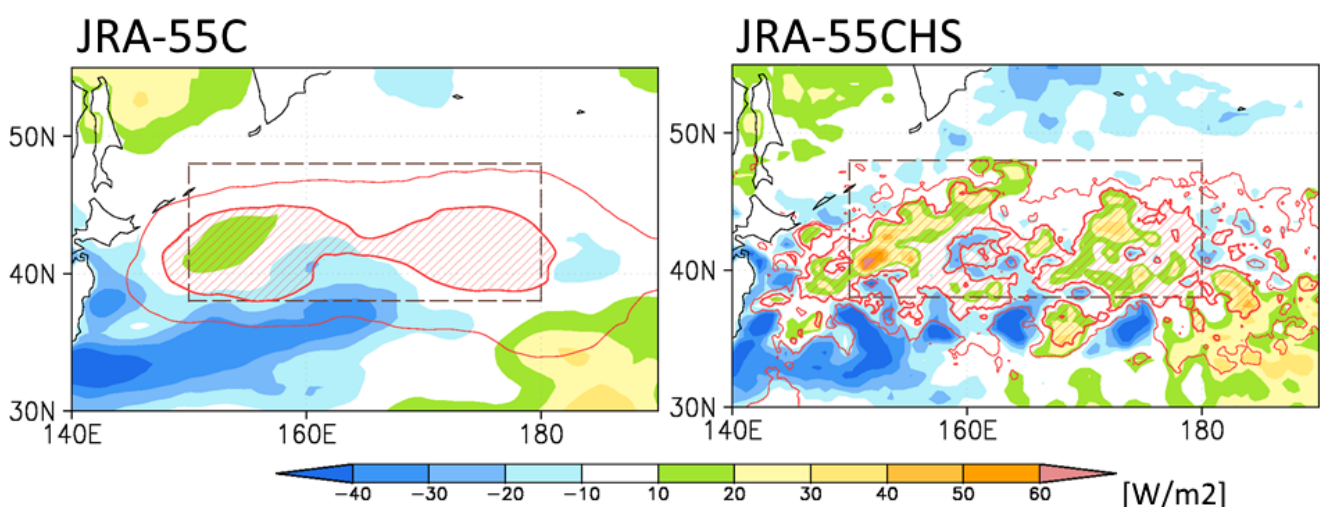


Fig. Anomalous SST (red contours for +0.8K, red hatches for +1.4K) and net turbulent heat flux (color as indicated) in October

## Effects of the North Pacific subtropical front on the Baiu/Meiyu rainband in a 60-km AGCM

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Atmospheric effects of the North Pacific subtropical sea surface temperature (SST) front (STF) on the Baiu/Meiyu rainband in late May are investigated using an atmospheric reanalysis and atmospheric general circulation model (AGCM) experiments. The Baiu/Meiyu rainband in the reanalysis is tilted to the northeast with minimum rainfall along the STF, consistent with satellite observations. The reanalysis data and two AGCM experiments based on high-resolution SST and spatially smoothed SST fields identify three effects of the STF. The first is ocean evaporation, which provides a large amount of moisture for the rainband, because of high SST in the STF region. The second is transient eddies, which induce the weak rainfall along the STF. Subsynoptic-scale lows that develop in the atmospheric baroclinic zone anchored by the STF, together with a synoptic high in the main storm track, bring about strong northeasterly winds, which carry dry air to the north of the STF and cause the eddy moisture divergence and the weak rainfall. The third is the mean cyclonic circulation, which forms over the STF and is associated with the intensified subtropical jet in the middle and lower troposphere. The mean cyclonic circulation intensifies the mean moisture convergence by convergent flows and advection, causing the rainband to tilt northeastward. The mechanism of the mean cyclonic circulation is discussed.

Keywords: SST front, Rainband

## Response of the early summer (baiu) rain to interannual sea surface temperature variability in the East China Sea

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The East China Sea is the region where deep atmospheric response to warm western boundary currents is the strongest along with the Gulf Stream region. Atmospheric response, especially response of early summer (baiu) rain, to interannual variability of sea surface temperature (SST) front associated with the Kuroshio in the East China Sea is examined using by observational data and regional atmospheric model simulation. It is revealed from observational data that the strong (weak) SST front is accompanied by the heavy precipitation and large cloud liquid water over the northern East China Sea and south of Japan. The heavy precipitation is likely associated with the strengthening of storm activity over the SST front. These observational results are confirmed by the regional atmospheric model simulation. That is, when the SST front is intensified (reduced) by adding negative (positive) SST anomalies over the continental shelf, the storm activity is intensified (weakened) over the SST front. Because the interannual variability of the SST front intensity is largely governed by SST anomalies over the continental shelf, and because these SST anomalies persist at least from a month earlier, the results in the present study imply potential predictability of precipitation over south of Japan in early summer.

キーワード：梅雨前線、黒潮、東シナ海

Keywords: Baiu rainband, Kuroshio, East China Sea

## 中緯度の海上下層雲の雲頂高度と海霧発生頻度を決める環境場

### The Cloud Top Heights of Marine Low Clouds and the Frequency of Marine Fog over Mid-Latitudes, and their Controlling Environment

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海上の下層雲の雲量は、海面水温と大気中層の温度から実質的に決定される対流圏下層の安定度によって大きく左右される一方で、下層雲量は日射の遮断を通じて海面水温に影響を与える。つまり、海上の下層雲と海洋の間には強い相互作用があると言える。

亜熱帯海上の下層雲はよく研究されてきているが、中緯度海上の下層雲については、研究はあまり進んでいない。雲量についての研究は多少あるものの、雲頂高度については皆無と言ってよい。そこで、本研究では、CALIPSO衛星観測データから作成された九州大学雲マスクデータを使い、中緯度の海上下層雲の雲頂高度を詳しく調べた。こうした全球規模の雲頂高度の解明は、CALIPSO衛星データの登場によって初めて可能となったものである。

本発表では、中緯度の海上下層雲の雲頂高度と霧発生頻度の観測的特徴を包括的に概観する。中緯度の海上下層雲の雲頂高度の季節変化が明らかにされると共に、北半球と南半球における雲頂高度の季節変化の違いも示される。霧の発生頻度は、北太平洋や北西大西洋では明瞭な季節変化を示す一方、南大洋では霧の発生頻度は季節によらずほぼ一定であった。さらに、これらの特徴をもたらす、SSTを含む気象場について調査した。その結果、海上下層雲の雲頂高度と大気安定度指数、また、霧の発生頻度といくつかの地表面気象要素（地上気温と海面水温の温度差など）の間に高い相関があることが明らかとなった(Fig.1)。

キーワード：中緯度、海上下層雲、海霧

Keywords: mid latitude, marine low clouds, marine fog

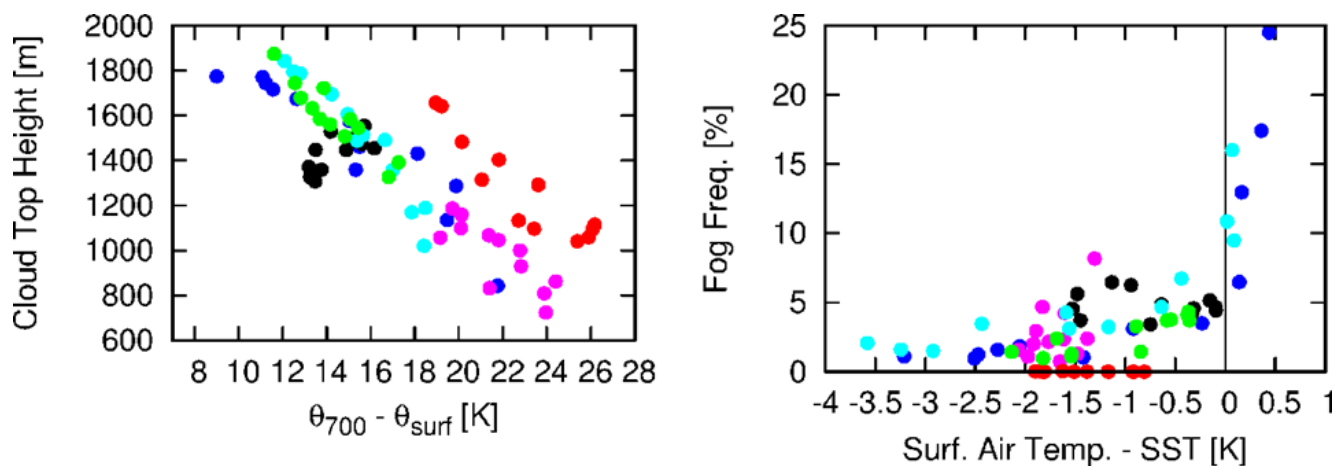


Fig. 1. The relationship between cloud top height and a potential temperature difference  $\theta_{700} - \theta_{\text{surf}}$  (left), and the relationship between fog frequency and temperature difference between the surface air and the sea surface (right). Areas investigated in the present study: the North Pacific (blue), the Southern Ocean (black), the northwest Atlantic (light blue), the northeast Atlantic (green), off California (pink), and off Peru (orange).

## The influence of the Gulf Stream on wintertime European blocking and North Atlantic jet

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The influence of Gulf Stream over the North Atlantic and Europe sector are investigated by analyzing NCEP-CFSR dataset and conducting a pair of 20-year integrations of 50-km grid-spacing AGCM (AFES). For the boundary condition, observed SSTs are used for control experiment (CNTL) and spatially smoothed SST for the other experiment (SMTH) over the Gulf Stream region. Between these experiments, substantial differences are found in European blocking and in North Atlantic eddy driven jet. For both phenomena, CNTL reproduces better the observed features than SMTH, which misses some of essential features of each phenomenon. This indicates that the realistic SSTs and high-resolution atmospheric models are important in reproducing these phenomena, including cold spells, long-lasting low surface air-temperature condition, resulted from European blockings. In the presentation, we will show that how these phenomena are related to meridional heat flux of the lower atmosphere and other atmospheric processes. Also, we would like to introduce HighResMIP in CMIP6, because HighResMIP can provide us very-near-future opportunities for the first time to investigate consistencies of mid-latitude atmospheric responses to the oceanic fronts and eddies are consistent among numerical. How robust consistencies we can find for what phenomena will affect our future trajectories of mid-latitude air-sea interaction studies.

キーワード：高解像度モデル、渦熱輸送、降水加熱

Keywords: high-resolution model, eddy heat flux, precipitation heating



## To what extent do oceanic frontal zones affect mid-latitude weather and climate?

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This talk introduces the mechanism of “Thermal Damping and Strengthening” and discusses why understanding this process is key to determining the influence of oceanic frontal zones, such as the Gulf Stream and the Kuroshio Extension, on mid-latitude weather and climate. Specifically, we argue this mechanism is key because it is the interaction of oceanic frontal zones with individual atmospheric fronts that is primarily responsible for the local as well as basin-scale ocean-to-atmosphere feedback in the seasonal mean and longer time scale. As a result, it is suggested that the influence of these oceanic frontal zones on climate can only be properly realised in general circulation models of sufficiently high resolution (i.e. horizontal grid size of 25km or less). The current implications for both general circulation models and reanalysis datasets are also addressed.

Keywords: Frontal air-sea interaction, Mid-latitude climate variability

## Links of wintertime climate variability in Eurasia to ocean temperature anomalies in the preceding seasons

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Several recent studies indicate that wintertime extreme weather events and climate variability over Eurasia are related to anomalies of sea ice cover in the Barents Sea region even though casual mechanisms behind this relation remain uncertain. Here we will first review our previous investigations of this problem, based on a regression analysis between oceanic observations and atmospheric (NCEP/NCAR) reanalysis for the period 1982-2006, which show that: (i) a large fraction (70% of the variance explained) of the total sea ice cover variability in the Barents and Greenland Seas in winter is related to Atlantic water temperature (AWT) anomalies at the entrance to the Barents Sea in the preceding summer, (ii) these local AWT anomalies are representative of, at least, a regional mode of subsurface ocean temperature anomalies which reemerge on the surface in the following autumn-to-winter season, (iii) these anomalies affect not only the sea ice cover but, consequently, also the local atmospheric conditions up to the tropopause level in the Barents Sea region, (iv) they influence also the large-scale atmospheric circulation in the Northern Hemisphere extratropics by perturbing the storm tracks. The large-scale surface air temperature anomalies related to warm AWT anomalies form a kind of the “warm Arctic-cold Eurasia” pattern with a negative lobe in the latitude band of a significant reduction of the upper-tropospheric storm track activity and lower-tropospheric poleward transient eddy heat flux. This pattern is uncorrelated with the corresponding anomalies related to the North Atlantic Oscillation, which increases the potential for seasonal prediction of wintertime climate variability in middle latitudes based on summer AWT anomalies. Finally, we will present some preliminary results on the robustness of the proposed scenario based on a statistical analysis of links between wintertime surface atmospheric variability in Eurasia (data from the ERA-Interim reanalysis) to the sea surface temperature in the Barents Sea and North Atlantic during preceding seasons in whole era of satellite observations (1979-2016).

# Tripole precipitation pattern and SST variations linked with extreme zonal activities of the western Pacific subtropical high

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Using the daily variables of NCEP reanalysis 1 from 1981 to 2014, this study first constructs a new index to describe the western Pacific subtropical high (WPSH) zonal activities by the normalized relative vorticity (RV) series averaged over a three-dimensional (3D) core domain (112.5°–142.5°E, 10°–30°N, 925–500 hPa). Its horizontal scope is referred to as core region. Ten positive and six negative extreme episodes lasting from 10 to 17 days were identified based on the new index. They demonstrated prominent variabilities in intraseasonal and interannual timescales. Composite results show a tripole precipitation pattern with a wet (dry) zone over the tropical western Pacific (TWP) separating two dry (wet) zones in the meridional direction. The northern one covers the mei-yu belt while the southern one extends along the tropical Indian Ocean (TIO) and the Maritime Continent (MC). The activities of WPSH and monsoon trough form the height anomalies over the core region, while its northern height anomalies are due to the westerly trough in middle latitudes. Further, the three systems exert joint effects on the tripole dry-wet pattern.

Within the biweekly evolution of positive composite, a weaker WPSH displays first an eastward and then a westward track. Negative composite indicates that a stronger WPSH first retreats eastward, then strides westward, and finally moves northeastward during around two weeks. The sea surface temperature (SST) anomalies over TIO and TWP are crucial for the extreme WPSH episodes. Concretely, the SST anomalies over TIO largely influence the overall intensity and location of WPSH and are especially important in the early stages of WPSH episodes. Locally, the SST anomalies over the core region are passive responses of atmospheric forcing in the early stages of WPSH episodes and then exert effect on the WPSH in their later stage.

Keywords: western Pacific subtropical high, extreme episode, relative vorticity, geopotential height, precipitation, sea surface temperature

## Role of mixed layer depth in surface frontogenesis of the Kuroshio Extension region: Interannual variability

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Using the JRA-55 reanalysis data and Argo observation dataset from 2004 to 2015, we examine how meridional variations in the mixed layer depth across the sea surface temperature (SST) front in the Kuroshio Extension region affects the surface frontogenesis. A mixed layer heat budget analysis shows that the surface heat flux term generally strengthens the SST front despite the stronger net surface heat loss on the equatorward side, because the surface mixed layer is much deeper on the equatorward side, and the SST is less sensitive to the surface heat flux.

キーワード：黒潮続流、海面水温、混合層厚、海面熱フラックス

Keywords: Kuroshio Extension, sea surface temperature front, mixed layer depth, surface heat flux

## Frontogenesis in the Agulhas Return Current region simulated by a high-resolution CGCM

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Detailed mechanisms for frontogenesis/frontolysis of the sea surface temperature (SST) front in the Agulhas Return Current (ARC) region in the southwestern Indian Ocean are investigated using outputs from a high-resolution coupled general circulation model (CGCM), the Community Earth System Model (CESM; Small et al. 2014), which has good skill in simulating the main features of the SST front and mixed layer depth in the ARC region. The SST front is maintained throughout the year due to approximate balance between frontolysis by surface heat flux and frontogenesis by horizontal advection. Although a southward (northward) cross-isotherm flow on the northern (southern) side of the front is weaker than a strong eastward along-isotherm current in the frontal region, this cross-isotherm confluent flow advects warmer (cooler) temperature toward the SST front north (south) of the front and acts as the dominant frontogenesis mechanism. In addition, stronger (weaker) frontogenesis in austral summer (winter) is attributed to the stronger (weaker) cross-isotherm confluence, which may be linked to seasonal variations of the Agulhas Current, ARC, and Antarctic Circumpolar Current.

On the other hand, the contribution from entrainment is relatively small, because frontolysis by larger (smaller) entrainment velocity on the northern (southern) side opposes frontogenesis by less (more) effective cooling associated with a thicker (thinner) mixed layer and smaller (larger) temperature difference between the mixed layer and entrained water in the northern (southern) region.

キーワード：水温前線の強化・緩和過程、アガラス反転流、高解像度大気海洋結合モデル、水平移流、エントレインメント

Keywords: frontogenesis/frontolysis, Agulhas Return Current, high-resolution coupled general circulation model, horizontal advection, entrainment

## Effect of SST in the Sea of Japan on the Winter Cyclones

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**Introduction:** Zhao et al. (2016, JGR) showed that the extratropical cyclone passage results in a localized surface cooling along the subpolar front in the winter Sea of Japan (Fig. 1) because of the cold-air outbreaks associated with the cyclones. It is reasonable that the SST alters atmospheric processes and, thus, a two-way coupling process may occur between SST (hence, the front) and the following cyclones which passing near the Sea of Japan, although the detailed process remains unclear. Using the WRF model Version 3.7.1 (WRFV3), we attempt to uncover such potential effect of the SST altered by the previous cyclones on the following ones during winter in the Sea of Japan.

**Methods:** We used the cyclone deepening rate as the indicator, and we chose 0.1 Bergeron as the criterion. Any cyclone, with CDR changed over Bergeron and last over 6 hours, would be regarded as “Affected”. There are 26 cyclones simulated in this study.

**Results:** According to our results, there were nearly one-fourth of cyclones remains unchanged, while others were largely modified. Analyses showed the cold air invasion over the Sea of Japan may be the key to make the cyclones sensitive or insensitive. When the northwesterlies located over the Sea of Japan, the atmosphere above became cold and unstable. A strong low-level baroclinic zone was found at the southern region of Japanese archipelago. With such situation, cyclones generate and pass through a southern path, over the Kuroshio region and Sea of Japan. The colder SST could therefore affect the cyclones aloft easily. When the northwesterlies located over the Okhotsk Sea, the atmosphere over the Sea of Japan was relatively warmer and more stable. Cyclones mainly generated over the continent where the colder SST of the Sea of Japan could hardly affect.

As for the “Affected” cyclones, Yamamoto (2013) suggested a weakening effect of the cold Sea of Japan on the cyclogenesis. However, we found, in this study, half of simulated cyclones was found to be intensified, i.e. CDR was increased over 0.1 Bergeron. Only 6 cyclones were weakened as Yamamoto (2013) suggested. Furthermo, the time series of the central SLP showed the intensified cyclones had an oscillated response. Such oscillation clearly indicated the existence of another effect of the cold Sea of Japan on the extratropical cyclones, and further results and analyses will be showed during the Meeting.

キーワード：温帯低気圧、低気圧活動、大気海洋相互作用

Keywords: Extratropical cyclone, cyclone activity, Air-Sea interaction

# 北西太平洋上で急発達する低気圧に伴う寒冷コンベアベルトと降水分布 Precipitation distributions and cold conveyor belt associated with rapidly developing cyclone over the northwestern Pacific Ocean

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北太平洋上で急発達する低気圧に伴った降水分布について、寒冷コンベアベルトが海面から受ける影響の大きさを分類し、解析を行った。寒冷コンベアベルトが海面から受ける影響の大きさは、低気圧北半円の2m高度温度と海面水温の差 ( $\Delta T \equiv T_{2m} - SST$ ) を指標にし、洋上で急発達する低気圧の事例を A:  $\Delta T > -2$  (気温が高い/海面水温が低い)、B:  $-4 < \Delta T < -2$ 、C:  $\Delta T < -4$  (気温が低い/海面水温が高い) の3つに分類した。どの低気圧も発達するにつれてコンマ状の降水域に変形した。Aの低気圧は南北に伸びた降水分布で、暖域が低気圧の東側に南北に伸びて広く分布していた。Cの低気圧は低気圧中心周辺に比較的円形に広がった降水分布であり、低気圧の北側では気温と海面水温との差が大きいためより海面の影響を受けている。また、Cの低気圧は黒潮続流上に集中していて、最大発達率は他の分類に比べ小さいものが多かった。Cの低気圧は大気側の大きなスケールの傾圧性ではなく、主に海面からの潜熱フラックスによって発達が促されたと予想される。

# Impact of SST on heavy precipitation events over Japan during summer

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The previous studies have pointed out the role of sea surface temperature (SST) over the Japan Sea on winter precipitation on the downwind side under the northwesterly East Asian winter monsoon. However, the role of SST over the Japan Sea on precipitation during summer is not well understood. The heavy precipitation event occurred over the northern main island of Japan in early-August, 2013. The unusual precipitation seems to be associated with the significant moisture flux over the Japan Sea where the sea surface temperature was warmer than the normal. Here, the impact of SST warming over the Japan Sea on the heavy precipitation event is examined using a regional atmospheric model. In one experiment, the actual SST is prescribed as a lower boundary condition, while the climatological mean SST is given in another experiment. The simulated precipitation amount associated with the heavy rainfall event in the former experiment is more than that in the latter experiment, associated with the increased moisture flux. In addition, it is found that the heavy rainfall tends to occur near the coast when the SST is higher than the normal. The results suggest a potential impact of SST on severe precipitation events even during summer. The role of SST on other precipitation events are also discussed.

Keywords: Sea Surface Temperature, Precipitation, Japan Sea



## 北太平洋海洋前線付近での初夏SST偏差の持続と関連する大気海洋循環 Persistence of the sea surface temperature anomalies near the North Pacific oceanic front in early summer and the associated atmospheric and oceanic circulations

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This work examines the persistence of sea surface temperature (SST) anomalies in the early summer (June and July) along the North Pacific oceanic front and the associated atmospheric and oceanic circulations. Dividing the region of this oceanic front into two, i.e., the western(160°E-170°W, 35°-45°N) and the eastern(170°-140°W, 35°-45°N) parts, the discussion is enhanced through the comparison of anomalous circulations in these two regions. In the west, the early summer SST anomalies exhibit strong persistence from spring to fall. In the east, the persistence is rapidly weakened in fall.

The western SST anomalies have feedback with the lower stratus during summer, which enhances the persistence from spring to fall. On the other hand, the eastern SST anomalies decrease the amplitude by fall due to damping by surface heat flux. In addition, the sea water temperature (SWT) anomalies show significant differences in the depth profiles between the two regions. In the west, the SWT anomalies keep the strong persistence from the surface to at least 300m depth below the seasonal thermocline, while the persistence is weakened near the surface shallower than 25m by fall in the east, although the persistence is strong until winter in the deeper depth in the east. The eastern SWT anomalies in this deep depth reemerge near the surface with strong vertical convective mixing from fall to winter.

キーワード：北太平洋海洋前線、夏季SST偏差の持続

Keywords: the North Pacific oceanic front, persistence of summer SST anomalies

## Influences of sea surface temperature on a heavy rainfall event over Shimane in late August 2013

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Shimane in western Japan suffered from heavy rainfall in late August 2013. This heavy precipitation is associated with a seasonal rain front and warm humid airflow over the Tsushima warm current. Although sea surface temperature (SST) distribution is considered to be important for the heavy precipitation, SST analysis data sets with high spatial resolution currently available have certain uncertainties because of differences in observations used and analysis procedures for the datasets. To investigate influences of SST on the heavy precipitation event and its sensitivity to SST datasets, we have conducted hindcast experiments with the weather research and forecasting (WRF) model with 3-km horizontal resolution with five different SST data as its lower-boundary condition. The experiments can reproduce heavy precipitation, though somewhat underestimated. The experiments have confirmed that the experiments with warmer SST data along the Tsushima current tend to reproduce the stronger precipitation. Since differences in evaporation and near-surface equivalent potential temperature are sensitive to the SST distribution, moisture supply, low-level stability and resulted precipitation can be modified by uncertainties in SST estimations. Therefore, the present study implies that quantitatively more accurate forecasts of heavy precipitations require more reliable SST distribution.

キーワード：海面水温、豪雨、大気海洋相互作用、対馬海流

Keywords: sea surface temperature, heavy rainfall, air-sea interaction, Tsushima current

## The role of midlatitude oceanic front in the formation of the climatological-mean atmospheric circulation

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We have performed a set of 15-member ensemble experiments using an atmospheric general circulation model (AGCM) to evaluate the role of midlatitude oceanic fronts in forming the climatological-mean atmospheric circulation. The first set of experiments (CNTL) is forced with satellite-observed sea surface temperature (SST) while the second set (SMTH) is with smoothed SST in which steep meridional gradient of SST associated with confluence of warm subtropical and cool subarctic current is largely reduced. Difference between the two experiments (CNTL-SMTH) highlights the role of frontal SST gradient. Namely, resolving the SST front in the mid-latitude North Pacific leads to enhancement of northward eddy heat flux by transient eddies around the latitudes of the SST front. It also leads to weakening of westerlies just to south of the climatological subtropical jet, while enhancement of the westerlies to the north of it in the mid to upper troposphere. Tropospheric geopotential height response to the frontal SST gradient is characterized by a meridional dipole of negative and positive anomalies over the Sea of Okhotsk and over the midlatitude western North Pacific, respectively, which resembles the Western Pacific (WP) pattern. In association with the WP-like pattern, the polar stratospheric temperature is elevated. Resolving SST front over the North Atlantic shows similar atmospheric responses to that over the North Pacific.

キーワード：海洋フロント、中緯度大気海洋相互作用

Keywords: oceanic front, midlatitude air-sea interaction

## Effects of the Pacific high and the Tibetan high on occurrence of drought and cool summer in northern Japan

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Meteorological disasters, including drought, cool summer, and heavy rain, have a serious effect on the crop yields in Japan. In this study, the connections between occurrence of agro-meteorological disasters in northern Japan and pressure and temperature fields in the tropospheric and lower stratospheric circulation over East Asia are examined. Based on the monthly air temperature for northern Japan, hot summer years and cool summer years in northern Japan are extracted from the 35-year (1980-2014) sample. To investigate the connection between the hot/cool summer in northern Japan and atmospheric circulation over East Asia in summer, composite differences (hot summer years minus cool summer years) of several variables such as geopotential height, temperature, and vertical p-velocity are calculated. In addition, the statistical significance of these composite differences is evaluated using Welch's t test. The analysis showed high pressure anomalies over northern Japan in the troposphere and lower stratosphere. This indicates that both the North Pacific high and the Tibetan high tend to extend to northern Japan during the hot summer years. On the other hand, cool summer in northern Japan seems to be associated with the weakening of these highs. Additionally, we show the meridional circulation and rainfall distribution in hot/cool summer years.

キーワード：干ばつ、冷夏、チベット高気圧、北太平洋高気圧

Keywords: drought, cool summer, Tibetan high, North Pacific high