Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

ACG05-01 Room:202 Time:May 25 14:15-14:45

Quasi-stationary Jets in the North Pacific Subarctic Frontal Zone: Formation Mechanisms and Roles in the Salt Transport

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The subarctic frontal zone (SAFZ) in the North Pacific is the boundary between the wind-driven subtropical gyre and the subpolar gyre. Recently, it was found that quasi-stationary jets (QSJs) originating in the Kuroshio Extension advect warm and saline water to the SAFZ. The Kuroshio water encounters the subarctic water, forming a thermohaline front in-between (Isoguchi et al., 2006; Wagawa et al., 2014). The QSJs are pathways of the saline water from the subtropical gyre to the subpolar gyre. We found in a numerical experiment that ocean surface salinity in the subpolar gyre varies when the basin-scale wind changes. The salt transport changes through the QSJs is likely responsible for this surface salinity change. A part of the saline water via the QSJ should be advected finally to the Sea of Okhotsk and affect ventilation of the intermediate layer of the North Pacific.

The QSJ's position is remarkably stationary. The jet tends to be located over the eastern flank of a topographic mound off the Kamchatska-Japan Trench, although it is as high as 500 m in the deep Pacific Ocean of a total depth of 5500 m. In this study, characteristic curves of the baroclinic Rossby waves, derived from the ocean reanalysis data provided by the Japan Coastal Ocean Prediction Experiment (JCOPE), are used to discuss the formation of the QSJ. The phase speed of the baroclinic Rossby waves is affected by the barotropic flow (Nishigaki and Mitsudera, 2010), particularly in the high latitudes where β is small and stratification is weak. Because of this baroclinic-phase-speed dependence on the barotropic flow, the surface baroclinic jet can be affected by the topography although its height is so low. Here we show that a characteristic curve originating in the subtropical gyre and that originating in the subpolar gyre meet at the location where the QSJ is present. This is a hyperbolic point of the characteristics, so-called the Rossby repeller. A surface baroclinic jet is formed along the characteristics that diverge from the hyperbolic point, because the pycnocline displacement varies discontinuously across these diverging characteristics. The barotropic flow over the low topographic mound is particularly important because the baroclinic Rossby waves in the subpolar gyre propagate southwestward along the characteristics, deformed by the barotropic flow over the mound, toward the hyperbolic point where they meet the barroclinic Rossby waves in the subtropical gyre. Formation mechanisms will be discussed further by numerical experiments using a simple two-layer model.

Keywords: Subarctic frontal zone, baroclinic Rossby-wave characteristics, barotropic flow generation

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ACG05-02 Room:202 Time:May 25 14:45-15:00

Seasonality in sea surface salinity and relating sea surface variables

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With accumulation of salinity observational data by Argo floats, it becomes possible to investigate salinity variability on seasonal to interannual time scales. While we know that there is strong seasonality in sea surface temperature (SST), seasonality in sea surface salinity (SSS) is not known well. Based on gridded Argo and other observational data and atmospheric reanalysis data, we examine global distribution of SSS seasonality using 12-month lagged auto-correlation map. In contrast to SST, which shows clear seasonality except for the tropical oceans especially in the Pacific, seasonality of SSS is not clear in large part of the global ocean except for tropics in the eastern Atlantic, the eastern Pacific, and the western Indian Oceans. Meanwhile the distribution depends on data products to some extent. Consistent with the limited seasonality, forcing field for SSS, i.e., precipitation-evaporation, Ekman transport, and geostrophic current fields also show limited seasonality except for the tropical oceans.

Keywords: Sea surface salinity, seasonality, Argo observation

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ACG05-03 Room:202 Time:May 25 15:00-15:30

Recent trends in the upper ocean salinity for the tropical Indo-Pacific and decadal shift in mid-1990s

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As an indicator of the global hydrological cycle, ocean salinity is an essential factor in the large scale climate variability (Schmitt, 2008, Oceanography). The sea surface salinity (SSS) in the global ocean can be well reflected in the pattern of air-sea freshwater flux, the evaporation and precipitation (Yu et al., 2007, JC). Previous studies revealed that the western tropical Pacific (WTP) was freshening since 1950s, as the most significant salinity change over the global ocean (e.g. Boyer et al., 2005, GRL; Cravatte et al., 2009, CD). It resulted from an increase of global hydrological cycle in a global warming scenario, constrained by the Clausius-Clapeyron relationship (Held and Soden, 2006, JC). However, a remarkable hiatus of the global warming has occurred since the beginning of the 21th century (Meehl et al., 2011, Nature Climate Change), which is tied to a strengthening Pacific trade winds and sea surface temperature (SST) cooling in the eastern equatorial Pacific (e.g. Tokinaga et al., 2012, Nature; Kosaka and Xie, 2013, Nature; England et al., 2014, NCC).

Argo profiles provide unprecedented salinity observations in global coverage. Robust SSS trends are found in the tropical Indo-Pacific, recorded in Argo since 2004 but started from mid-1990s in reconstructed salinity dataset. The analysis of atmospheric fields reveal that the intensification of the Walker Circulation is the cause of SSS trends. It enhances the precipitation over the Marinetime Continent and adjacent ocean and reduces precipitation over the central tropical Pacific, resulting in WTP salty and SCS-SETIO fresh. From a view of longer time scale, the present salinity trends start a few years before the Global Warming Hiatus, which terminate the trends since 1970s, and implying a dominated decadal shift in the tropical Indo-Pacific in mid-1990s

Keywords: salinity, decadal shift, tropical Indo-Pacific, Global Warming Hiatus, Argo float, Walker Circulation

Japan Geoscience Union Meeting 2015
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ACG05-04 Room:202 Time:May 25 15:30-15:45

Impact of relaxation of sea surface salinity towards an interannually variable salinity to the Pacific in the OFES

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To explore the impact of relaxation of sea surface salinity (SSS) towards an observational interannually variable salinity to the Pacific in the OFES, we have conducted a new experiment (ARGO run), in which SSS is strongly relaxed to monthly mean SSS observed by the Argo. We have compared this output with that obtained from an operational experiment (CLIM run), in which SSS is relaxed to monthly mean climatological SSS of the WOA98. The integration period of the ARGO run is 2005-2013, and that of the CLIM run is 1950-2013. Their horizontal resolutions are 0.1x0.1 degrees, and both are driven by monthly mean wind stress of the NCEP reanalysis 1.

The regions where the interannually variable SSS plays significant role are detected by evaluating the ratios of standard deviation of monthly anomalies of salinity around 25 sigma theta isopycnal surface between ARGO run/CLIM run. In the Pacific, the large fluctuations are found in the subtropical mode water (STMW), where the standard deviation is increased three-fold, and in the South Western Tropical Pacific region, where the deviation is increased two-fold. In this presentation, we will describe the features of the salinity response in the STMW.

Relationship between the salinity anomaly in the STMW and the SSS and the salinity anomaly in the isopycnal surface are suggested by time-lag correlation analysis. It is found that there are two main factors for the interannual variability: the one is SSS change in the STMW formation region, and the other is westward propagating isopycnal spiciness signal. Twenty month ago SSS change in the formation region is highly correlated with the salinity variability in the STMW (R=0.83). At this time, the spiciness signal associated with the STMW salinity variability locates at 40 degrees to the east, and their correlation coefficient is also high (R=0.81). Although the integration period of 9 years is perhaps not enough for the lag correlation analysis, we note that these results are consistent with an analysis of tracking of water masses.

Keywords: Sea surface salinity, Mode water, Interannual variability, OFES model, Argo, Spiciness

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ACG05-05 Room:202 Time:May 25 15:45-16:00

Improvements to a global ocean data assimilation system through the incorporation of Aquarius surface salinity data

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The Aquarius/Satelite de Aplicaciones Cientificas (SAC)-D satellite, an L-band passive radar system has been providing global maps of sea surface salinity (SSS) since 25 August 2011. In parallel with the ongoing satellite observations, assiduous efforts for reducing measurement errors have been made along with detailed validation campaigns. As a result, there are multiple possibilities for new science. For example, the new SSS field obtained on completion of a few annual cycles of Aquarius measurements will support detailed climate studies and should greatly improve our understanding of the ocean freshwater cycle.

In order to enhance the description of oceanic processes by using Aquarius SSS data we make use of a data assimilation approach, which has the advantage of providing four-dimensional analysis fields incorporating the limited observational data within the framework of established dynamical models. Hence, we aim to merge Aquarius data into the global ocean data assimilation system developed in the Meteorological Research Institute and then assess its impacts on the upper-ocean field.

Positive effects by incorporating the Aquarius data can be seen in several regions in the global ocean, although uncertainty in the Aquarius data is expected to be large in some regions. Around the Indonesian maritime continent, the Aquarius data assimilation reduces the SSS biases that may arise due to the use of excess precipitation in the atmospheric reanalyses. Comparison with buoy data lends support to the use of the Aquarius data in this region, although the land fractions involved (0.02) are above the more severe level used for the open ocean (e.g., 0.0005). In other regions with large effects, model biases in the SSS field due to the defects in both the forcing field and the model (resolution and parameterizations) reported in previous studies are reduced by the Aquarius data assimilation. Furthermore, other parameters such as subsurface temperature are affected by the new data through the water-mass formation processes. These results indicate the importance of Aquarius data in deriving improved representations of the global ocean from dynamical models.

Previous studies pointed out that Argo and Aquarius data are highly complementary, with Argo data vital for analyzing and correcting biases in Aquarius data and Aquarius data able to resolve temporal and spatial SSS variability missed by Argo. Our results are consistent with this view and demonstrate a route through to a possible integration of these data sources by using data assimilation methods. It is demonstrated that the improved representation in the SSS variability can influence other variables in the upper ocean. This can be attributed to the both background error covariances and dynamical processes (e.g., strong vertical mixing in the surface mixed layer and subduction from it). Although further studies for validating and reducing the errors in Aquarius data are required, these results underline their great importance for describing and predicting the global climate.

Keywords: sea surface salinity, Aquarius, data assimilation, ocean estimatation, maritime continent, stratification

Japan Geoscience Union Meeting 2015
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ACG05-06 Room:202 Time:May 25 16:15-16:45

Observations of spiciness anomaly propagation in the North and South Pacific

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Subduction and propagation of density-compensated (warm/salty or cool/fresh) temperature and salinity water-mass perturbations on isopycnals, referred to as spiciness anomalies, from the mid-latitude region to the equatorial region have been hypothesized to play an important role in decadal variability in the Pacific region. Recent increase of Argo profiles reveals propagation of spiciness anomalies on isopycnals from both the North and South Pacific to the equatorial Pacific on decadal timescales. In this talk we review our and previous studies that reported propagation of spiciness signals, and examine attenuation of spiciness anomalies on isopycnals for the period 2003?2014. It is revealed that spiciness anomalies in the South Pacific are diffused vertically in the course of the propagation, but still propagate equatorward. In addition, we also discuss the influence of anomalous advection across horizontal salinity gradient over isopycnals on spiciness anomaly generation.

Keywords: spiciness, subduction, Argo float, decadal variability, Pacific Ocean

Japan Geoscience Union Meeting 2015
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ACG05-07 Room:202 Time:May 25 16:45-17:00

Global characterization of decadal-scale upper ocean heat content variability

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Upper ocean heat content (OHC) is at the heart of natural climate variability on interannual-to-decadal time scales, providing climate memory and the source of decadal prediction skill. Regional expressions of the OHC variability such as its generation and propagation are, however, not fully explored. We here present a global analysis of interannual-to-decadal OHC variability based on an observed subsurface temperature and salinity analysis dataset. Detrended, non-seasonal temperature anomalies are first decomposed into two parts –(1) temperature anomalies that are associated with density anomalies and (2) temperature anomalies that are density-compensated with salinity–by projecting the temperature anomalies on three dimensional density gradients, and then vertically integrated for 100-400m depth range to obtain the each component of OHC anomalies. The former component follows Rossby wave dynamics while the latter behaves as passive tracers subject to advection by background mean flows, distinct underlying mechanisms that are useful in characterizing the OHC variability.

Global variance analysis shows that the density component of OHC variability is large in all the world WBC regions, presumably due to vertical displacement of the thermocline that responds to the basin-wide wind stress variability. On the other hand, the spiciness component is large with the ratio to the total OHC variability exceeding 0.7 in subpolar regions where the mean spiciness gradients are particularly large. These results are consistent with a hypothesis proposed in our previous study that the mean spiciness gradients and axial displacement of subpolar WBCs can be a source of regional OHC anomalies, suggesting the importance of spiciness and hence an active role of salinity in interannual-to-decadal scale OHC variability.

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ACG05-08 Room:202 Time:May 25 17:00-17:30

Impacts of regional mixing on the temperature and salinity structures of the tropical Pacific Ocean

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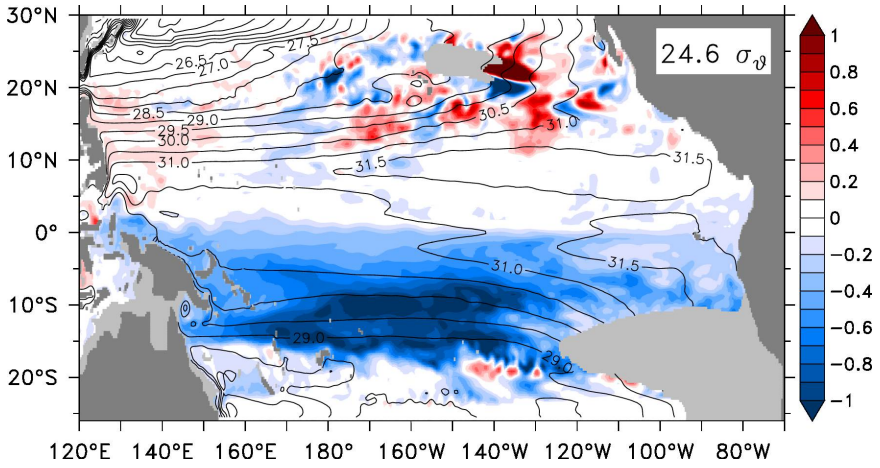
We investigate the sensitivity of numerical-model solutions to regional changes in vertical diffusion. Specifically, we vary the background diffusion coefficient, κ_b, within spatially distinct subregions of the tropical Pacific, assess the impacts of those changes, and diagnose the processes that account for them.

Solutions respond to a diffusion anomaly, κ_b, in three ways. Initially, there is a fast response (several months), due to the interaction of rapidly-propagating, barotropic and gravity waves with eddies and other mesoscale features. It is followed by a local response (roughly one year), the initial growth and spatial pattern of which can be explained by one-dimensional (vertical) diffusion. At this stage, temperature and salinity anomalies are generated that are either associated with a change in density ("dynamical" anomalies) or without one ("spiciness" anomalies). In a final adjustment stage, the dynamical and spiciness anomalies spread to remote regions by radiation of Rossby and Kelvin waves and by advection, respectively.

In near-equilibrium solutions, dynamical anomalies are generally much larger in the latitude band of the forcing, but the impact of off-equatorial forcing by κ_b on the equatorial temperature structure is still significant. Spiciness anomalies spread equatorward within the pycnocline, where they are carried to the equator as part of the subsurface branch of the Pacific Subtropical Cells, and spiciness also extends to the equator via western-boundary currents; they are also carried to the Indian Ocean via the Indonesian Throughflow. Forcing near and at the equator generates strong dynamical anomalies, and sometimes additional spiciness anomalies, at pycnocline depths. The total response of the equatorial temperature and salinity structures to κ_b in various regions depends on the strength and spatial pattern of the generation of each signal within the forcing region as well as on the processes of its spreading to the equator.

Keywords: spiciness anomalies, ocean general circulation model, Subtropical Cells



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ACG05-09 Room:202 Time:May 25 17:30-17:45

IOD associated interannual variability of the sea surface salinity in the tropical Indian Ocean

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Based on Argo and satellite sea surface salinity (SSS) data, we analyze the variability of salinity and its related ocean dynamics in the tropical Indian Ocean (IO). The results show significant interannual variability of SSS associated with the Indian Ocean Dipole (IOD) mode in the equatorial IO. Satellite well captures the SSS variations and generally provides SSS maps with higher space-time resolution, particularly in the regions where Argo floats are sparse. The salinity anomalies are mainly due to the adjustment of the tropical circulation, which is strengthen (weakened) by equatorial current anomaly and ocean gyre in the southern IO during negative (positive) IOD event. We find a SSS dipole in the southern IO through the analysis of ten-year Argo SSS data. The SSS anomalies near the equatorial region and that in the southern region is opposite. The SSS dipole is mainly associated with strong Indian Ocean dipole (IOD) events, especially which occurred with El Nino Southern Oscillation (ENSO). The equatorial current and precipitation anomalies associated with IOD dominate the SSS anomalies in the northern and southern parts of the dipole respectively. Ocean Rossby wave associated with ENSO contribute to the maintenance of the SSS dipole.

Keywords: sea surface salinity, interannual variability, SSS dipole, IOD, Rossby wave, tropical ocean circulation

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ACG05-10 Room:202 Time:May 25 17:45-18:00

The impact of spiciness on El Nino

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We investigate the modulation of ENSO location and amplitude by spiciness anomalies in the tropical thermocline. First, Argo observations constrain the size of observed spiciness anomalies. Realistic perturbations are then used to investigate the impact on an intermediate El Nino model. This shows that spiciness anomalies can increase the thermocline feedback and thus enhance the Bjerknes feedback and ENSO amplitudes. Experiments with coupled general circulation model are conducted to investigate the impact on the character of El Nino.

Keywords: air-sea interaction, el nino, salinity