Ocean Science Symposium 2015, Busan

Session 1:
Western Boundary Currents (WBCs) : dynamics and variability

The first day

26-Oct-2015, 13:50 – 15:30

Invited speaker :

8 years observing flow into the Solomon Sea

William Kessler [1], Russ Davis [2] and Jeff Sherman [2]

[1] NOAA/Pacific Marine Environmental Laboratory
[2] Scripps Institution of Oceanography

Abstract

Gliders have been used to make regular coast to coast sections across the Solomon Sea since 2007, a total of 66 complete sections measuring temperature, salinity, and absolute velocity. These sections confirm earlier ideas that two distinct sources feed the Solomon Sea: Subtropical water in the main thermocline arrives from the eastern subtropics, and a deeper mass subducted near New Zealand arrives as a subsurface western boundary current. Annual and interannual transport variability have similar magnitude (about plusminus 7Sv; most of the annual cycle occurs in the shallow subtropical inflow, while lower-frequency signals arrive in the western boundary current. ENSO-timescale variability lags equatorial ENSO indices by about 3 months, due to the travel time of Rossby waves from their central Pacific generation region.

A linear (Rossby wave/Godfrey Island Rule) analysis accounts for much of the variability, and suggests that the decades-long increase in equatorial trade winds is producing a longterm decrease in Solomon Sea transport, by about 3.5Sv/decade.

Corresponding E-mail : william.s.kessler@noaa.gov

East Australian Current dynamics: past variability and future change

Neil J. Holbrook and Eric C.J. Oliver

Institute for Marine and Antarctic Studies
ARC Centre of Excellence for Climate System Science, University of Tasmania, Hobart, Tasmania 7001, Australia

Abstract

The dynamics underpinning the interannual to decadal variability and multi-decadal trend in East Australian Current (EAC) transports are not necessarily straightforward. For example, the modest but nevertheless significant El Nino – Southern Oscillation (ENSO) signals in sea level at Australia's east coast and temperatures in the Tasman Sea are dynamically interesting, since our primary dynamical understanding of ENSO in Australia's oceanic domain is due to equatorial and coastal wave dynamics that connects the western tropical Pacific with Australia's west (and not east) coast via the Indonesian Throughflow. Further, it has been argued that the observed multi-decadal warming in the southwest Tasman Sea is due to a 'spin-up' of the South Pacific Gyre. However, the relationship between atmospheric forcing, 'spin-up', and East Australian Current (EAC) transport response, is also not completely obvious. In this presentation, we review and discuss some of our recent findings underpinning multi-year and multi-decadal changes in EAC transports and sea surface temperatures. In particular, we examine the dynamic roles of Rossby waves and mesoscale eddies on historical and projected future changes in the EAC. Projected changes in the EAC Extension through the 2060s will be discussed based on dynamically downscaled results from the eddy-resolving Ocean Forecasting Australia Model (OFAM) forced by output from the CSIROMk3.5 climate model under the A1B emissions scenario. We find that the transport in the EAC Extension is projected to further increase, at the expense of the Tasman Front, due largely to complex and somewhat surprising changes in the eddy field characteristics and distribution. We show that these projected eddy changes are likely to play an important role in the distribution of sea surface temperature extremes in the future – with the extreme warming centre located further south and closer to Tasmania's east coast than the mean warming centre.

Corresponding E-mail : neil.holbrook@utas.edu.au

Seasonal Variation of the Pacific North/South Equatorial Current Bifurcation

Zhaohui Chen and Lixin Wu

Physical Oceanography Laboratory, Ocean University of China

Abstract

The seasonal variation of the Pacific North/South Equatorial Current (NEC/SEC) bifurcation off the Philippine/Australian coast is investigated. It is shown that the seasonal cycles of the NEC/SEC bifurcation are generally analogous to each other, both of which shift synchronously back and forth seasonally and arrive at their southernmost positions in boreal late spring and early summer. In terms of their south–north migration, it is shown that the annual range of SEC bifurcation is twice as large as its counterpart in the North Pacific. This difference is mainly attributed to the seasonally-varying wind forcing around the Australian coast, while it is almost absent in the NEC bifurcation case. Without considering the alongshore winds, we propose a simple bifurcation model under the framework of linear Rossby wave dynamics. It is found that the seasonal NEC/SEC bifurcation latitude is predominantly determined by the spatial pattern of the wind and baroclinic Rossby wave propagation. This model explains the roles of local/remote wind forcing and baroclinic adjustment in the south–north migration and peak seasons of the bifurcation latitude.

Corresponding E-mail : chenzhaohui@ouc.edu.cn

Low frequency variability of the South Pacific Subtropical Gyre as seen from satellite altimetry and Argo

Linlin Zhang, Tangdong Qu and Dunxin Hu

LZ,DH: Institute of Oceanology, Chinese Academy of Sciences, China
LZ,TQ: International Pacific Research Center, SOEST, University of Hawaii at Manoa, USA

Abstract

Low frequency variability of the South Pacific subtropical gyre is investigated using satellite altimeter and Argo data. In most of the region studied, both sea surface height and steric height exhibit a linearly increasing trend, with its largest amplitude in the western part of the basin. Analysis of the Argo data reveals that the steric height increase north of 30°S is primarily caused by variations in the upper 500 m, while the steric height increase south of 30°S is determined by variations in the whole depths from the sea surface to 1800 m, with contributions from below 1000 m accounting for about 50% of the total variance. Most of the steric height increase is due to thermal expansion, except below 1000 m where haline contraction is of comparable magnitude with thermal expansion. Correspondingly, the South Pacific subtropical gyre has strengthened in the past decade. Within the latitude range between 10° and 35°S, transport of the gyre circulation increased by 20-30% in the upper 1000 m and by 10-30% in the deeper layers from 2004 to 2013. Further analysis shows that these variations are closely related to the Southern Annular Mode and Pacific Decadal Oscillation.

Corresponding E-mail : zhanglinlin@qdio.ac.cn

Ocean currents and water masses observed along 135E in the northwestern Pacific Ocean

Dongchull Jeon

Korea Institute of Ocean Science & Technology, Ansan, Korea

Abstract

Oceanic currents have been measured at the 3 moored buoy monitoring systems approximately along 135E in the tropical-to-subtropical northwestern Pacific Ocean for up to eight years. Long-term variability of the oceanic currents and the water masses along the cruise tracks have been analyzed. Background sea surface temperature has been increased up to 1.0 degree for the last 33 years at the warm pool of the western Pacific. The subsurface zonal currents from 300 ~ 2,000 meters in depth flow eastwards (at 17N and at 14N along 135E), defined as the North Equatorial Undercurrent (NEUC), which is opposite to the westward-flowing surface currents (NEC). The NEUC on the density range of 26.6-27.6 sigma-t has three cores approx. at 9.5N, 13N, and at 17N; the vertical range of the three cores are from 300m, 400m, and 500m at their upper boundary depths, respectively, down to approx. 2,000m at the lower boundary. The zonal current system in the northwestern Pacific seems to vary dependent upon the dynamic results between the surface currents (NEC and STCC) and the subsurface current (NEUC) by large-scale wind stress pattern and local geostrophic balance with the continuity at the western boundary. The dominant period of the meridional components of the currents is about 60 days, related with meso-scale eddy activities, which seem to add the driving force to STCC, apart from the western boundary.

Corresponding E-mail : dcjeon@kiost.ac

Seasonal and interannual variations of the Kuroshio's near-surface circulation in the East China Sea

Peng Qi and Lei Cao

Institute of Oceanology, Chinese Academy of Sciences, China

Abstract

The spatial and temporal near-surface variability along the Kuroshio current in the East China Sea (ECS) are studied based on original velocity measurements at 15 m depth from Surface Velocity Program (SVP) drifters, geostrophic velocity anomalies (GVA) computed from the demeaned AVISO (Archiving, Validation, and Interpretation of Satellite Oceanographic data) and ageostrophic Ekman currents derived from the Cross-Calibrated Multi-Platform(CCMP) surface winds provided by the NASA PO.DAAC. Seasonal fluctuations of the flow path, axis, width, along-stream and shoreward transport of the ECS Kuroshio main stream are investigated using the near-surface climatological residual currents derived from 30 h running mean of the measured SVP drifter trajectories. It is found that the entire ECS Kuroshio main stream has basically larger velocity, bigger width and less intrusion onto the southern shelf of the ECS in summer than in other three seasons; while the strongest intrusion occurs in spring rather than in fall and/or winter. Interannual variations of the intrusion onto the southern shelf of the ECS are analyzed using a 19-year (1993–2011) monthly mean time series of 15 m depth geostrophic current derived by combing the AVISO-GVA with the mean geostrophic velocity field, which is derived by subtracting the AVISO-GVA and the ageostrophic Ekman current from the measured residual current field. Significant 2- to 4-year oscillations are found, which are associated with El-Nino and La Nina events.

Corresponding E-mail : pqi@qdio.ac.cn

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Session 1:
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26-Oct-2015, 15:45– 17:25

Invited speaker :

A New Paradigm for the North Pacific Subthermocline Low-Latitude Western Boundary Current System

Bo Qiu, Shuiming Chen, Daniel Rudnick and Yuji Kashino

University of Hawaii, Manoa, US

Abstract

Subthermocline western boundary circulation along the low-latitude North Pacific Ocean (2-25N) is investigated by using profiling float and historical CTD/XCTD data and by analyzing an eddy-resolving global OGCM output. In contrast to the existing paradigm depicting it as a reversed pattern of the wind-driven circulation above the ventilated thermocline (i.e., depth < 26.8 sigma_theta), the subthermocline western boundary circulation is found to comprise two components governed by distinct dynamical processes.

For meridional scales shorter than 400km, the boundary flows along the Philippine coast exhibit convergent patterns near 7N, 10N, 13N, and 18N, respectively. These short-scale boundary flows are driven by the subthermocline eastward zonal jets that exist coherently across the interior North Pacific basin and are generated by the triad instability of wind-forced annual baroclinic Rossby waves. For meridional scales longer than 400km, a time-mean Mindanao Undercurrent (MUC) is observed from 6N to 13N together with another northward-flowing boundary flow beneath the Kuroshio from 16N to 24N. Rather than remote eddy forcing from the interior Pacific Ocean, both of these broad-scale subthermocline boundary flows are induced by baroclinic instability of the overlying wind-driven western boundary currents, the Mindanao Current and Kuroshio.

Corresponding E-mail : bo@soest.hawaii.edu

Seasonal variability of the Mindanao Current determined using mooring observations from 2010 to 2014

Fujun Wang

Key Laboratory of Ocean Circulation and Waves, Institute of Oceanology, Chinese Academy of Sciences, Qingdao, China

Abstract

A subsurface mooring was deployed east of Mindanao Island at 8°N, 127°3′E from December 2010 to August 2014 to collect direct measurements of the Mindanao Current (MC). The Acoustic Doppler Current Profiler (ADCP) fixed on the main float showed that the MC is a strong and stable southward flow with a standard deviation of less than 21 cm s-1 in the upper 500 m. The core flow occurs between depths of 50 and 100 m, with a maximum mean speed of 78 cm s-1 at 100 m. The MC has a maximum velocity during boreal summer (June) and a minimum velocity during autumn (October).

The Asian monsoon intensifies the wind-driven sea surface height anomaly east of Mindanao Island, and the resulting sharp slope induces meridional flow with large variability. Rossby waves and the boundary effect weaken the contribution of wind, stabilizing flow in the MC. The MC is determined by the zonal gradient of the SSHa rather than by the SSHa itself, suggesting an inconsistency between the Mindanao Eddy (ME) and MC. The semiannual ME signal plays an important role in the seasonal variability of the MC.

Corresponding E-mail : fujunwang@qdio.ac.cn

Intraseasonal variability of subthermocline current east of Mindanao

Qingye Wang

The Institute of Oceanology, Chinese Academy of Sciences (IOCAS)

Abstract

The intraseasonal variability (ISV) of the subthermocline current east of Mindanao was characterized and was explained as the activity of subthermocline eddies using mooring observations at 8N, 127.03E and a high-resolution numerical model. Mooring observations show that the ISV of the observed current east of Mindanao is significantly intensified below the thermocline. The ISV amplitude of zonal subthermocline current is comparable with that of the meridional current. The comparisons between observed and modeled current vector illustrate subthermocline eddies can cause the ISV of the subthermocline current east of Mindanao. Furthermore we identified and tracked all eddies at a depth of 400-800 m in 2000-2011 using the horizontal velocity outputs. Trajectories and propagation vector field of the eddies at a depth of 400-800 m show that the ISV of the subthermocline current was caused by the subthermocline eddies from three different pathways. The subthermocline eddies propagating along approximately 10N–11N contributed more to the ISV of the subthermocline current east of Mindanao than did those eddies propagating westward along 8N or northwestward from the New Guinea coast.

Corresponding E-mail : wangqy@qdio.ac.cn

Interannual to decadal variability of the upper-ocean heat content in the western North Pacific and its relationship to oceanic and atmospheric variability

Hanna Na

Faculty of Science, Hokkaido University, Sapporo, Japan

Abstract

Upper-ocean thermal variation in the western part of the North Pacific (NP) is mainly driven by ocean dynamics and transport (i.e., western boundary current variability), different from the eastern NP where surface heat flux forcing would be a major source of the variability. This study examines the oceanic 3-dimensional thermal structures and variability of the western NP on the interannual to decadal time scale and discusses their relationship to oceanic and atmospheric variability by analyzing observation and reanalysis data. It is shown that an overall cooling trend for 45 years (1964–2008) in the Kuroshio Extension (KE) and Subarctic Frontal Zone (SAFZ) region is associated with the meridional shift of the KE and SAFZ on interannual time scales with a decadal phase shift in the early 1980s (KE-SAFZ mode). It appears that, however, the decadal changes in KE strength are not extended to the SAFZ, contributing to non-coherent variability between them (KE mode). The KE-SAFZ mode exhibits significant maximal correlation with the Pacific Decadal Oscillation at half-year lag, implying that it is a relatively fast response to the large-scale wind-stress curl forcing in the North Pacific and is potentially associated with the propagation of barotropic signal to the western boundary current system. The KE mode appears to be related to the North Pacific Gyre Oscillation by about a 3-year lag, suggesting a delayed response to the atmospheric forcing in the North Pacific via baroclinic Rossby wave propagation.

Corresponding E-mail : hna@mail.sci.hokudai.ac.jp

Decadal variability of the Kuroshio Extension jet and its relation to coastal sea level along Japan

Yoshi N. Sasaki

Faculty of Science, Hokkaido University, Sapporo, Japan

Abstract

This study examines decadal variability of the Kuroshio Extension (KE) jet and its relation to coastal sea level along Japan using satellite and coastal sea-level data. The first mode of singular value decomposition analysis between sea level anomalies in the western North Pacific and coastal sea levels of Japan reveals that northward (southward) shifts of the KE jet accompany the coastal sea level rise (fall) in the early 2000s and 2010 (in the late 1990s and the late 2000s). The shifts of the KE jet result from wind induced signals in the eastern North Pacific, which is propagated westward along the jet axis as a jet-trapped Rossby wave. During the propagation, the meridional scale of the SLAs gradually narrows, and their amplitude increases. Consistently, the resulting sea level fluctuation along the Japan coast is quite large in the regions that are under the direct influence of the jet-trapped Rossby waves. Our results suggest that a large part of recent sea level rise in the KE region and along the coast of Japan can be explained by wind-driven circulation changes.

Corresponding E-mail : sasakiyo@mail.sci.hokudai.ac.jp

Epoch-dependency of upper ocean heat storage rate with ocean advection in the Kuroshio-Oyashio Extension region

Gyundo Pak[1], Young-Hyang Park[2], Frédéric Vivier[3], Kyung-Il Chang[1]

[1] SEES, Seoul National University, Seoul, South Korea
[2] LOCEAN/DMPA, Muséum National d'Histoire Naturelle, Paris, France
[3] LOCEAN/IPSL, Université Paris VI, Paris, France

Abstract

The western boundary of the North Pacific including Kuroshio-Oyashio Extension (KOE) region is characterized by strong air-sea interactions through vigorous oceanic heat release to the atmosphere especially in the boreal winter. Although the ocean influences the atmosphere through sea surface temperature (SST) variability, it has been suggested that the upper ocean heat content is a better climate predictor than SST for the ocean's feedback to the atmosphere. In this study, heat storage rate (HSR) in the upper 400 m is investigated to understand the dynamics of its temporal variability from the 30-year-long outputs of high-resolution (1/12°) ocean general circulation model integrated by Mercator Ocean, France. Most of the seasonal to interannual HSR variability is explained by combination of oceanic horizontal heat advection and net surface heat flux, with a negligible contribution from subsurface processes. The seasonal HSR is mostly explained by net surface heat flux. Over the whole period of analysis, the interannual variability of annual-mean HSR as well as summer HSR mainly arises from horizontal heat advection in the KOE region. In stark contrast to this, the dominant contributor to the interannual variability of the winter HSR depends critically on the period. The horizontal heat advection dominates in the 1990s when the East Asian winter monsoon (EAWM) was significantly weakened, while the net surface heat flux was rather better correlated with HSR during the strong EAWM epochs in the 1980s and since the mid-2000s. This epoch-dependent importance of ocean advection for winter HSR (thus SST) in the KOE region is consistent with the recent observational evidence in the literature.

Corresponding E-mail : gdpak@curl.snu.ac.kr