Large-scale fluctuations of sea level and winds in the southeast Pacific sector of the Southern Ocean

Denis L. Volkov1 and Victor Zlotnicki2
1Joint Institute for Regional Earth System Science and Engineering, University of California Los Angeles (denis.volkov@jpl.nasa.gov)
2Jet Propulsion Laboratory, California Institute of Technology

1. Overview

The southeast Pacific sector of the Southern Ocean plays an important role in regulating the climate of Antarctica. This is the region where the Antarctic Circumpolar Current (ACC) reaches its southernmost latitude, and where the biggest source of the Antarctic Intermediate Water (AAIW) formation is located. Satellite observations of low-pass filtered (with 1-year running mean) sea surface height (SSH) from October 1992 to January 2013 have revealed a large-scale pattern of the interannual/interdecadal variability. The positive (negative) phase is associated with higher (lower) than average sea level west of the South America and lower (higher) than average sea level over the ACC and south of it. Similar pattern of the interannual variability has also been observed in sea surface temperature (SST) data (not shown). We show that the observed variability of SSH is related to wind forcing over the region, and to Pacific Decadal Oscillation suggesting the importance of large scale teleconnections. The wind strengthens/weakens the convergence/divergence zones that is reflected in the SSH variability. The coupled empirical orthogonal functions analysis of an ocean data synthesis product shows that the observed variability of SSH and wind stress is correlated with subsurface salinity distribution and can possibly be indicative of the Antarctic Intermediate Water formation rates. This is an ongoing work that is aimed to establish relationship between the interannual changes in SSH, the ACC frontal locations, winds, and the AAIW formation rates.

3. Sea Surface Height variability

4. Relation to wind forcing

The first coupled EOF mode of SSH and wind stress components: (A and D) – spatial patterns of SSH, (B and E) – spatial patterns of τx and τy (C and F) – time series of expansion coefficients for SSH (blue), τx and τy (red). This mode explains 68% and 45% of the covariance of SSH and τx, and SSH and τy respectively. In contrast to the individual EOF analysis, the coupled EOFs identify the modes of behavior in which sea level and wind stress are strongly coupled. The first coupled mode of variability between SSH and wind stress can be described as a strengthening and weakening of westerly and easterly (near Antarctica) winds, which is accompanied by fluctuations in SSH possibly related to convergence and divergence of Ekman transport. Note that the maximum SSH variability occurs around the convergence anomaly zone at 45°S and the divergence anomaly zone at 65°S. This statistical relationship suggests that the interannual variability of SSH in the region is wind-driven and barotropic in nature.

5. Large-scale sea level, winds, and salinity in ECCO2

The ECCO2 salinity section averaged between 80°W and 100°W (A) and (B) T-S diagrams at 42°S for the 1992-1994 (blue), 1999-2001 (red), and 2008-2010 (green) averaging time intervals. ECCO2 produces AAIW seen as a salinity minimum at about 700 m depth. The salinity at the core of the AAIW in 1999-2001 was lower than in 1992-1994 and in 2008-2010.

6. Summary and Outlook

- 18 years of satellite altimetry observations have revealed a large-scale pattern of interannual/interdecadal variability of sea level; this variability is related to wind forcing possibly through wind-induced convergence/divergence (barotropic sea level variability); the correlation with PDO suggests the importance of large-scale teleconnections
- The analysis of the ECCO2 model output shows that the vertical distribution of salinity is strongly coupled to sea level and wind stress; convergence/divergence of Ekman transport west of the Drake Passage corresponds to an decrease/increase of salinity in the surface layer and in the core of the AAIW

Next steps:
- Quantify the formation of the AAIW in the ECCO2 model and analyze its relationship to wind forcing
- Investigate the relationship between the ACC frontal locations and the AAIW formation

2. Data

- Sea Surface Height: satellite altimetry observations, processed by SSALTO/DUACS, distributed by AVISO with support from CNES
- Monthly wind stress and sea surface temperature: ERA-Interim reanalysis, provided by the European Center for Medium Range Weather Forecast (ECMWF)
- Climate indices: Antarctic Oscillation index provided by the NOAA Climate Predictions Center, Pacific Decadal Oscillation index provided by JISAO (University of Washington)
- ECCO ocean data synthesis product: temperature, salinity, and wind stress.

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