# Observational evidence for propagation of decadal spiciness anomalies in the North Pacific

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## 1. Motivation

Much attention has paid been to propagation signals from the mid-latitude Pacific to the equatorial Pacific through the oceanic subduction pathway due to its potential role in decadal variability in the Pacific [Gu and Philander, 1997]. Two mechanisms for propagation of subducted signals

1. higher mode of baroclinic Rossby wave
   – pressure (thickness) anomaly
2. passive advection by current
   – **spiciness (density compensated) anomaly**
   – Ta $(x, y, \sigma_\theta, t)$ = T $(x, y, \sigma_\theta, t)$ – Tclm $(x, y, \sigma_\theta)$

However, propagation of spiciness anomalies (warm/salty or cool/fresh) has not been observed yet due to limitations in salinity observations. Recent advent of the Argo network of drifting buoys allows, for the first time, the basin-wide description of spiciness signals in the North Pacific.

## 2. Data and Mean State

Argo profiles for the period 2001–2008 are linearly interpolated to isopycnal surfaces, and are spatially interpolated by a variational interpolation technique that minimizes the misfit between the irregularly distributed original data and the interpolated fields. Most 3° × 3° bins contain at least 50 profiles (**Fig. 1a**).

The depths of 25< $\sigma_\theta$ <25.5 kg m$^{-3}$ isopycnals (**Fig. 1b**) that connect the subtropical and tropical Pacific are characterized by a bowl shape. The water subducted east of 160°W between 30°N and 40°N flows southward and then turns westward to the western boundary.

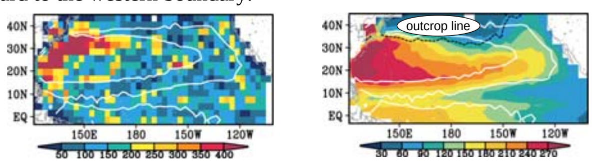


**Fig. 1** (a) Total number of the Argo profile and long-term mean of (b) depth (m) from Argo observations averaged over 25 < $\sigma_\theta$ < 25.5 kg m$^{-3}$ isopycnals for the period 2001–2008. White contours denote 1.6 and 3.4 m$^2$ s$^{-2}$ isopleths of the Montgomery potential.

## 3. Propagation of spiciness anomalies

A cool/fresh spiciness anomaly appears in the eastern subtropics at 120°W–150°W in 2003–2004 (**Fig. 2**). This spiciness anomaly migrates southwestward, and arrives in the western tropics in 2008. Also, two warm/salty anomalies are observed to propagate along the same path from 2003 to 2005, and after 2005.

The propagation speed of the spiciness anomalies matches mean advection speeds. The particle positions advected by the mean geostrophic velocity on the isopycnals coincide with the cool/fresh spiciness anomaly from 2004 to 2007 (**Figs. 2–3**).

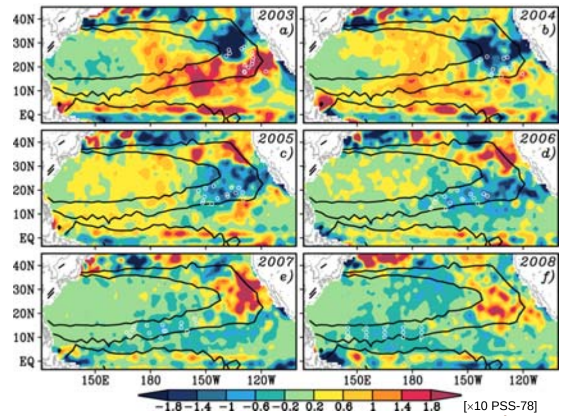


**Fig. 2** Annual mean salinity anomalies averaged over 25< $\sigma_\theta$ <25.5 kg m$^{-3}$ isopycnals. Contours denote 1.6 and 3.4 m$^2$ s$^{-2}$ mean Montgomery potential isopleths. Circles indicate water parcels positions calculated from the mean velocity fields.

The spiciness anomalies are modified along their path, with amplitude gradually decreasing with time (**Fig. 4**). The amplitude of the salinity anomaly decreases by about 70% from about 0.15 PSS-78 in 2004 to about 0.043 PSS-78 in 2008. One possible process for the attenuation is temporal variability of velocity fields, which acts to diffuse spiciness anomalies from the mean path. Indeed, a part of the cool/fresh anomaly overshoots the path to the shadow zone in the eastern Pacific around 5°N–10°N (**Figs. 2 and 5**).

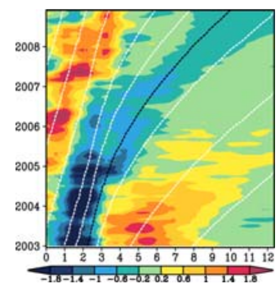

**Fig. 3** Time-distance diagram of the salinity anomaly along the subduction path. Horizontal axis is the distance (×10$^3$ km) from the outcrop line. White and black lines indicate the trajectory advected by the mean velocity.

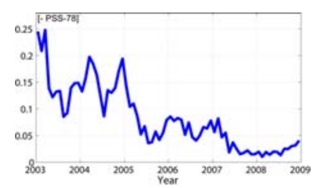


**Fig. 4** Salinity anomaly averaged over the particle positions shown in Fig. 2.

## 4. Summary

The unprecedented temporal and spatial coverage of Argo observations allows observational analysis of the basin-wide, coherent propagation of spiciness anomalies from the eastern subtropics to the western tropics. Their propagation path and speed are in good agreement with advection by the mean geostrophic current. Our results indicate that Argo observations are a powerful tool for understanding subducted signals.

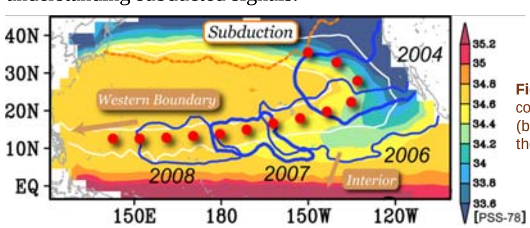


**Fig. 5** Propagation of the cool/fresh spiciness anomaly (blue contours). Color denotes the long-term mean salinity.

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