Sensitivity of Near-Inertial Internal Waves to Spatial Interpolations of Wind Stress in Ocean Generation Circulation Models

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Abstract

The oceanic near-inertial internal waves (NIWs) have been extensively studied using ocean general circulation models (OGCMs). Currently most OGCMs use the bilinear or bicubic interpolation to interpolate wind stress onto models' surface grids. In this study, we examine the influences of bilinear and bicubic interpolations on the wavenumber and frequency spectra of wind stress and on the simulated NIWs in the ocean. It is demonstrated that both the bilinear and bicubic interpolations are equivalent to spatial low-pass filters with the former leading to more significant loss of wind stress variance at high wavenumbers. When coarse (e.g., 2°) wind stress is used to force OGCMs, the bilinear and bicubic interpolations significantly damp the wavenumber spectrum of wind stress at mesoscales, leading to decreased near-inertial wind stress variance. Using the bilinear (bicubic) interpolation could weaken the near-inertial wind work by $\sim 43\%$ (22%) in the subtropical region (10°N - 30°N) and by $\sim 16\%$ (4%) at the midlatitudes (30°N - 50°N).

We propose a new interpolation method, i.e., the bi-*sinc*-function interpolation, which is able to retain all the wind stress variance within the Nyquist wavenumber. Compared to the bilinear and bicubic interpolations, the bi-*sinc*-function interpolation improves the simulations of NIWs and should be incorporated into OGCMs especially when coarse wind stress is used.

Keywords: Near-Inertial Internal Waves, Wind Stress, Spatial Interpolation, Ocean General Circulation Models

1. Introduction

Near-inertial internal waves (Garret, 2001), referred to as NIWs henceforth, form a pronounced peak in the ocean current frequency spectrum, containing half of the kinetic energy and a substantial portion of the shear in the internal wave field (Ferrari and Wunsch, 2009). They are of central importance to a variety of ocean processes, including the mixed layer deepening (Greatbatch, 1984; Price et al., 1986; Jochum et al., 2013), phytoplankton dispersion (Franks, 1995) and mesoscale eddy dissipation (Polzin, 2010). In addition, they are thought to provide an energy source for abyssal diapycnal mixing which affects uptake of heat and carbon by the oceans as well as climate changes (Munk and Wunsch, 1998; Wunsch and Ferrari, 2004; Jing and Wu, 2014). Due to the important role of NIWs in the climate system, they have been extensively studied using ocean general circulation models (OGCMs) forced by reanalysis wind products (Nagasawa et al., 2000; Furuichi et al., 2008; Rath et al., 2013 and 2014; Rimac et al., 2013; Simmons and Alford, 2012; Zhai et al., 2005, 2007 and 2009) or coupled to atmosphere general circulation models (AGCMs) (Komori et al., 2008; Jochum et al., 2013).

As a natural resonant frequency of fluids on a rotating planet, NIWs are efficiently forced by wind stress in the near-inertial frequency band (Pollard and Millard, 1970; Alford, 2003; Rath et al., 2013). The near-inertial wind stress is generated by atmospheric processes from mesoscales (e.g., fronts and tropical cyclones) to synoptic scales (e.g., midlatitude storms). Previous numerical studies revealed the sensitivity of simulated NIW strength in OGCMs to the horizontal

resolution of wind forcing, pointing out the important role of mesoscale wind stress in powering NIWs (Jiang et al., 2005; Rimac et al., 2013). So far the horizontal resolution of AGCMs is typically coarser than 1° , which is not able to resolve all the mesoscale wind stress variability and underestimates the near-inertial wind work. Furthermore, as the horizontal resolution of OGCMs has been pushed to $O(0.1^\circ)$ to resolve mesoscale oceanic eddies, a spatial interpolation is required to interpolate the coarse wind stress derived from AGCMs onto the much finer grids of OGCMs. The bilinear and bicubic interpolations are two built-in options for most OGCMs and AGCMs. On one hand, the bicubic interpolation seems to be a better choice for interpolating wind stress in the sense that it produces continuous wind stress curl, which plays an essential role in the quasi-geostrophic dynamics. On the other hand, using the bilinear interpolation is not unusual in previous NIW-modelling studies (e.g., Nagasawa et al., 2000; Furuichi et al., 2008; Rimac et al., 2013). So far it remains unclear how these interpolation methods may affect the simulation of NIWs.

Recently, Jing et al. (2015) applied a *sinc*-function interpolation to the time domain and found significant improvement in the simulated NIWs compared to the linear interpolation. In this study, we generalize the *sinc*-function interpolation to the two-dimensional spatial domain and propose a bi-*sinc*-function interpolation method (referred to as the bisinc interpolation henceforth). The performance of bisinc interpolation in simulating NIWs is analyzed and compared to those of bilinear and bicubic interpolations. The paper is organized as follows. The numerical model configurations are introduced in Section 2. In Section 3, we compare the bilinear,

bicubic and bisinc interpolations especially their influences on the horizontal wavenumber spectrum and frequency spectrum of wind stress. Simulations of NIWs using different interpolations are presented in Section 4. Discussion is provided in Section 5 followed by conclusions. Comparisons of computational cost among different interpolations are provided in Appendix A.

2. Model configurations

A coupled regional climate model (CRCM) developed at Texas A&M University is used to study NIWs in the North Pacific. It includes the Weather Research and Forecasting (WRF) Model (Leung et al., 2006) as the atmospheric component and the Regional Ocean Modelling System (ROMS) (Moore et al., 2004; Shchepetkin and McWilliams, 2005) as the oceanic component. The CRCM is configured with ROMS and WRF both at $\sim 0.1^\circ$ horizontal resolution and thus is able to resolve mesoscale wind stress. The model domain covers the entire North Pacific with the WRF domain slightly larger than the ROMS domain (Fig. 1). The ROMS shares the same grids with WRF in the overlapped domain to avoid mismatch between land- and ocean-surface heat fluxes. The open boundaries of the ocean are forced by 5-day average Simple Ocean Data Assimilation (SODA) dataset. The 6-hourly National Centers for Environmental Prediction (NCEP) reanalysis data are used as the initial and boundary conditions for the atmosphere. In the CRCM simulation, WRF and ROMS are coupled every hour which is sufficiently fine to resolve wind stress variance in the near-inertial band.

The numerical simulations consist of five experiments. In the first experiment

(E-Control), NIWs are simulated using the CRCM. The simulation is initialized on October 1, 2002 from a 6-year ROMS spin-up simulation (1997-2002) and integrated for one year. The period 2002-2003 is chosen as it is a relatively neutral year for both the El Niño Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) which modulate the activities of midlatitude storms and tropical cyclones (Camargo and Sobel, 2005; Chang and Fu, 2002). This facilitates the comparisons of the simulated NIW strength to the climatological mean derived from the surface drifters (Chaigneau et al., 2008; Elipot and Lumpkin, 2008).

The remaining four experiments (E-Linear, E-Cubic, E-Sinc, and E-Smooth) are the ROMS-only simulations with the hourly air-sea heat and momentum fluxes obtained from the E-Control. The starting date of these experiments is October 1, 2002 with the same initial and boundary conditions as those of E-Control. To examine the effects of different interpolation methods on the simulated NIWs, the $0.1^\circ \times 0.1^\circ$ wind stress derived from E-Control is first smoothed using a $2^\circ \times 2^\circ$ moving average and then subsampled onto $2^\circ \times 2^\circ$ grids (referred to as the 2° wind stress henceforth). The $2^\circ \times 2^\circ$ box is used here because it is comparable to the horizontal resolution of some widely used reanalysis wind products such as the NCEP and CORE-II (Coordinated Ocean-Ice Reference Experiments II) datasets. Finally, the 2° wind stress is interpolated back onto the original $0.1^\circ \times 0.1^\circ$ grids to force the ROMS using the bilinear interpolation for E-Linear, bicubic interpolation for E-Cubic, and bisinc interpolation for E-Sinc.

The difference of NIWs in E-Control from those in E-Linear, E-Cubic, and

E-Sinc comes from two aspects. First, the $2^\circ \times 2^\circ$ moving average filters out part of the mesoscale wind stress variability, reducing the near-inertial wind stress variance. Second, the interpolations may lead to further reduction of mesoscale wind stress variability and cause additional loss of near-inertial wind stress variance. To isolate the influence of interpolations on the simulated NIWs, we perform a ROMS-only simulation forced by the $2^\circ \times 2^\circ$ moving averaged wind stress without subsampling and interpolations (referred to as E-Smooth). Performance of different interpolation methods in simulating NIWs can be evaluated based on the comparisons of E-Linear, E-Cubic, and E-Sinc to E-Smooth.

3. The influence of spatial interpolations on the wavenumber and frequency spectra of wind stress

Let $\tau(i, j)$ represent the zonal or meridional wind stress component with a grid size of Δx and Δy in the zonal and meridional direction, respectively. Introduce the

zero-padding wind stress $\tilde{\tau}(\frac{i}{M}, \frac{j}{N})$:

$$\tilde{\tau}(\frac{i}{M}, \frac{j}{N}) = \begin{cases} \tau(\frac{i}{M}, \frac{j}{N}), & \frac{i}{M}, \frac{j}{N} \in \mathbb{Z} \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

where M and N are any positive integer and $\mathbb{Z}$ denotes the integer set. The interpolation of $\tau(i, j)$ onto finer grids with a grid size of $\Delta x/M$ and $\Delta y/N$ can be expressed by the 2-D convolution formula:

$$\tau_{\text{int}}(\frac{i}{M}, \frac{j}{N}) = \sum_{p=-\infty}^{\infty} \sum_{q=-\infty}^{\infty} \tilde{\tau}(\frac{i-p}{M}, \frac{j-q}{N}) g(\frac{p}{M}, \frac{q}{N}) \quad (2)$$

where g is called the impulse response function uniquely determined by the

interpolation method (Bracewell, 1965). Introduce the wavenumber response function:

$$R(k_H) = \frac{\Phi_{\text{int}}^{\tau}(k_H)}{\Phi^{\tau}(k_H)} \quad (3)$$

where $k_H = \sqrt{k^2 + l^2}$ is the magnitude of horizontal wavenumber, Φ_{int}^{τ} and Φ^{τ} are the horizontal wavenumber spectra for τ_{int} and τ respectively. R measures the influence of interpolations in the horizontal wavenumber space. According to the 2-D convolution theorem, $R(k_H) = \frac{1}{2\pi} \int_0^{2\pi} |G(k_H \cos \alpha, k_H \sin \alpha)|^2 d\alpha$ for an isotropic wind stress field where $G(k, l)$ is the 2-D Fourier transform of $g(\frac{i}{M}, \frac{j}{N})$ and $\alpha = \arctan(l/k)$ is the azimuth of horizontal wavenumber.

The impulse response function for the bilinear interpolation is (Fig. 2a):

$$g_L(x, y) = g_L(x)g_L(y) \quad (4)$$

where

$$g_L(x) = \begin{cases} 1 - |x|, & |x| < 1 \\ 0, & \text{otherwise} \end{cases} \quad (5)$$

Its Fourier transform is

$$G_L(k, l) = \text{sinc}^2\left(\frac{k\Delta x}{2\pi}\right) \text{sinc}^2\left(\frac{l\Delta y}{2\pi}\right) \quad (6)$$

where $\text{sinc}(x) = \sin(\pi x)/(\pi x)$.

The impulse response function for the bicubic interpolation is (Fig. 2b):

$$g_C(x, y) = g_C(x)g_C(y) \quad (7)$$

where

$$g_C(x) = \begin{cases} 1.5|x|^3 - 2.5|x|^2 + 1, & |x| \leq 1 \\ -0.5|x|^3 + 2.5|x|^2 - 4|x| + 2, & 1 < |x| < 2 \\ 0, & \text{otherwise} \end{cases} \quad (8)$$

Its Fourier transform is

$$G_C(k, l) = [3\text{sinc}^4(\frac{k\Delta x}{2\pi}) - 2\text{sinc}^2(\frac{k\Delta x}{2\pi})\text{sinc}(\frac{k\Delta x}{\pi})][3\text{sinc}^4(\frac{l\Delta y}{2\pi}) - 2\text{sinc}^2(\frac{l\Delta y}{2\pi})\text{sinc}(\frac{l\Delta y}{\pi})] \quad (9)$$

Now introduce the bisinc interpolation with the impulse response function defined as (Fig. 2c):

$$g_S(x, y) = g_S(x)g_S(y) \quad (10)$$

where

$$g_S(x) = \text{sinc}(x) \quad (11)$$

Its Fourier transform is

$$G_S(k, l) = \begin{cases} 1, & -k_N < k < k_N, -l_N < l < l_N \\ 0, & \text{otherwise} \end{cases} \quad (12)$$

where $k_N = \pi/\Delta x$ and $l_N = \pi/\Delta y$ are the zonal and meridional Nyquist wavenumbers, respectively.

Fig. 2 visualizes the impulse response functions for different interpolations. In contrast to the bilinear and bicubic interpolations, the bisinc interpolation is nonlocal in the physical space, as evidenced by the checkerboard in the far field (Fig. 2c). Therefore, the bisinc interpolation on any grid point is not merely based on its surrounding neighborhood but the whole domain. It should be noted that the magnitude of $\text{sinc}(x)$ decreases as x^{-1} asymptotically, suggesting that g_S can be approximated as zero in practice for i and j larger than some critical value i_c and j_c .

Here the critical value is chosen as $i_c = 20M$ and $j_c = 20N$. Sensitivity tests suggest that the wavenumber spectrum of the bisincly interpolated wind stress exhibits little variation (<5%) for further increasing the value of i_c and j_c .

Fig. 3 compares the horizontal wavenumber spectra of wind stress in E-Linear, E-Cubic, and E-Sinc to that of the 2° wind stress. Consistent with Eqs. (6) and (9), the bilinear and bicubic interpolations are equivalent to low-pass filters in space, leading to significant reduction of wind stress variance at mesoscales (Fig. 3b). The reduction is more evident for the bilinear interpolation than the bicubic interpolation. The spectral value at 0.001, 0.002, and 0.003 cpkm¹ is respectively attenuated by 13%, 43% and 73% for the bilinear interpolation but only by 1%, 18% and 56% for the bicubic interpolation. Unlike the bilinear and bicubic interpolations, the bisinc interpolation retains all the wind stress variance within the Nyquist wavenumber (Fig. 3b). The wavenumber spectra between E-Sinc and the 2° wind stress differ by less than 5%.

The different interpolation methods do not only influence the horizontal wavenumber spectrum of wind stress but also its frequency spectrum (Fig. 4 and 5). It should be noted that the near-inertial wind stress at the midlatitudes (30°N-50°N) is primarily generated by synoptic storms while tropical cyclones dominate the near-inertial wind stress variance in the subtropical region (10°N-30°N). As the horizontal scale of tropical cyclones is significantly smaller than midlatitude synoptic storms, influences of different interpolation methods on the frequency spectrum of

¹ 1 cpkm is equal to 1 cycle per kilometer.

wind stress may differ from one region to another. In view of this region sensitivity, we examine the influences of the different interpolation methods in the subtropical region and at the midlatitudes separately.

In the subtropical region where the mesoscale wind stress (i.e., tropical cyclones) makes dominant contribution to the near-inertial wind stress variance, different interpolations have pronounced influences on the frequency spectrum of wind stress. As the bilinear and bicubic interpolations filter out part of the mesoscale variability, they significantly reduce the wind stress variance at inertial and higher frequencies (Fig. 4b). The wind stress variance between $0.9-1.1 f$ is reduced by 24% for the bicubic interpolation and by 48% for the bilinear interpolation, compared to that in E-Smooth. The elevated reduction for the bilinear interpolation compared to the bicubic interpolation is a result of more significant damping of mesoscale wind stress variability by the bilinear interpolation (Fig. 3b). In contrast, as the bisinc interpolation retains all the wind stress variance within the Nyquist wavenumber, the frequency spectrum of wind stress in E-Sinc is close to that in E-Smooth with a discrepancy less than 5% (Fig. 4b).

At the midlatitudes, the frequency spectra of wind stress are still damped by the bilinear and bicubic interpolations while the bisinc interpolation retains the wind stress variance at all the frequencies (Fig. 5). The wind stress variance between $0.9-1.1 f$ is reduced by 24% for the bilinear interpolation and by 8% for the bicubic interpolation, compared to that in E-Smooth. It should be noted that the reduction of near-inertial wind stress variance by the bilinear and bicubic interpolations is less

significant at the midlatitudes than in the subtropical region. This is because the midlatitude near-inertial wind stress is primarily generated by synoptic storms.

4. Results

In this section, we examine the influence of different interpolation methods on the NIW simulations using the CRCM configured over the North Pacific. Details on computing the near-inertial currents are provided in Appendix B. The surface near-inertial currents in E-Control (Fig. 6a) show good agreements with the observations (Chaigneau et al., 2008; Elipot and Lumpkin, 2008). In E-Control, the mean near-inertial current amplitude over the North Pacific is 12.3 cm s^{-1} , comparable to 11.5 cm s^{-1} obtained from the observations of surface drifters (Chaigneau et al., 2008). The most energetic near-inertial currents are found around 43°N collocated with the midlatitude storm tracks. The zonal-mean near-inertial current variance there reaches up to $55 \text{ cm}^2\text{s}^{-2}$ and is close to the observed value $\sim 50 \text{ cm}^2\text{s}^{-2}$ (Elipot and Lumpkin, 2008). Strong NIWs are also found in the tropical and subtropical western Pacific and in the tropical eastern Pacific, which is also consistent with the observations (Chaigneau et al., 2008). The former is mainly furnished by the tropical cyclones (Fig. 6b) while the latter might be due to the intermittent winds jets of Central America (Chelton et al., 2000).

The spatial patterns of near-inertial wind work W_I in E-Smooth and in E-Control agree well with each other (Fig. 6b and 7a). But the magnitude is systematically weaker in E-Smooth than E-control since the $2^\circ \times 2^\circ$ moving average filters out part of the mesoscale wind stress variability, reducing the near-inertial wind

stress variance. To evaluate the performance of different interpolations in NIW simulations, we use E-Smooth as a benchmark and compare the simulated W_I in E-Smooth to those in E-Linear, E-Cubic, and E-Sinc, respectively.

All the interpolations yield correct spatial patterns of W_I . In particular, the pronounced W_I associated with storm tracks and tropical cyclones is well reproduced regardless of the different interpolations (Fig. 7). However, the magnitude of W_I in E-Linear and E-Cubic is systematically weaker than that in E-Smooth (Fig. 7 and 8). The annual mean W_I integrated over the entire North Pacific in E-Smooth is 0.14 TW. But the values are reduced to 0.10 TW and 0.12 W in E-Linear and E-Cubic, respectively. The reduced W_I in E-Linear and E-Cubic is consistent with the loss of near-inertial wind stress variance by the bilinear and bicubic interpolations (Fig. 4 and 5). In contrast, as the bisinc interpolation retains all the near-inertial wind stress variance, W_I in E-Smooth and E-Sinc agree well with each other (Fig. 7 and 8). The discrepancy is less than 10% at all the latitudes.

The influences of different interpolations on W_I are latitude-dependent with more pronounced influences in the subtropical region than at the midlatitudes (Fig. 8). This is mainly because the tropical cyclones make the dominant contribution to the near-inertial wind work in the subtropical region while the midlatitude near-inertial wind work is primarily injected by synoptic storms. The tropical cyclones have a smaller horizontal scale compared to midlatitude synoptic storms, making the near-inertial wind stress variance more sensitive to the interpolation methods in the subtropical region than at the midlatitudes (Fig. 4 and 5). To further confirm this point,

we examine the influences of interpolation methods on the near-inertial wind work in the regions affected by tropical cyclones (130°E-150°E, 15°N-24°N) and midlatitude synoptic storms (33°N-47°N, 155°E-175°W), separately. For the region affected by tropical cyclones, the analysis is focused on the summer time (April 2003-September 2003) when most of the tropical cyclones occur. In contrast, the winter time (October 2002-March 2003) is considered for the storm track region since this is the season associated with the strongest synoptic storms.

In the region affected by tropical cyclones, the mean W_I in E-Sinc is 8.1 mW m⁻², close to the value 8.2 mW m⁻² in E-Smooth (Table 1). In contrast, the mean W_I is reduced by 43% in E-Linear and 22% in E-Cubic. The reduced near-inertial wind work by the bilinear and bicubic interpolations significantly weakens the oceanic NIWs. The mean near-inertial kinetic energy KE_I integrated over the upper 1000 m is 4.2 kJ m⁻² and 4.1 kJ m⁻² in E-Sinc and E-Smooth, respectively. But the value decreases to 2.8 kJ m⁻² in E-Linear and 3.6 kJ m⁻² in E-Cubic.

In the region under the storm track, W_I in E-Sinc agrees well with that in E-Smooth (Table 2). The mean W_I in E-Sinc is about 5.2 mW m⁻², close to the value 5.1 mW m⁻² in E-Smooth. The bilinear and bicubic interpolations still underestimate the near-inertial wind work. But the underestimation is less evident compared to that in the region affected by tropical cyclones. The mean W_I in E-Linear (E-Cubic) is 4.3 (4.9) mW m⁻², only 16% (4%) smaller than that in E-Smooth. Due to the reduced near-inertial wind work by the bilinear and bicubic interpolations, the simulated NIWs in E-Linear and E-Cubic are slightly weaker than those in E-Sinc and E-Smooth. The

mean KE_I in both E-Sinc and E-Smooth are around 3.4 kJ m^{-2} . But the value decreases to 2.9 kJ m^{-2} and 3.3 kJ m^{-2} in E-Linear and E-Cubic, respectively.

5. Discussion

It should be noted that the simulated near-inertial wind work based on the 2° wind stress is always weaker than that in E-Control regardless of the various interpolations (Fig. 8). This is because part of the near-inertial wind stress variance comes from the subgrid-scale ($<4^\circ$) features, which cannot be recovered by any kind of interpolation. To get an accurate simulation of NIWs, it is thus necessary to force OGCMs with high-resolution wind stress resolving all the mesoscale variability. Fortunately, wind stress products with a horizontal resolution $\leq 0.5^\circ$ have already become available due to the rapidly increased computational power in the past ten years (e.g., the Climate Forecast System Reanalysis and European Centre for Medium-Range Weather Forecasts datasets) and are suggested to be used in the future studies of NIW modelling.

6. Conclusions

In this study, we examine the influences of the different spatial interpolations of wind stress on the simulated near-inertial wind work and oceanic NIWs in OGCMs. Three interpolation methods are considered: the bilinear, bicubic, and bisinc interpolations. Comparisons among these three interpolation methods are summarized as follows:

- (1) The bilinear and bicubic interpolations are equivalent to spatial low-pass filters, but the former results in more significant loss of wind stress variance at high

wavenumbers.

- (2) When coarse (e.g., 2° in this study) wind stress is used to force OGCMs, the mesoscale wind stress variability is significantly damped by the bilinear and bicubic interpolations, leading to decreased wind stress variance at inertial and higher frequencies. Using the bilinear (bicubic) interpolation could weaken the near-inertial wind work by $\sim 43\%$ (22%) in the subtropical region and by $\sim 16\%$ (4%) at the midlatitudes.
- (3) The proposed bisinc interpolation conserves the wavenumber and frequency spectra of wind stress, leading to improved simulation of near-inertial wind work and oceanic NIWs. It is a better interpolation method than the bilinear and bicubic interpolations and should be used in OGCMs.

Appendix A

For our model domain, performing one bilinear, bicubic, and bisinc interpolation consumes around 0.48, 0.68, and 1.42 CPU core seconds, respectively. Therefore, the improved performance of bisinc function in simulating NIWs is at the cost of increased computational burden.

However, the increased computational cost associated with the bisinc interpolation is negligible compared to the total computational cost for running the model. In our model simulations, the OGCM obtains the wind stress every hour. For a one-year simulation, this requires 8760 times of interpolations of wind stress, which costs less than 3.5 CPU core hours in total for the bisinc interpolation. In contrast, integrating the model for one year requires around 30000 CPU core hours for the ROMS-only simulation and 160000 CPU core hours for the coupled simulation.

Appendix B

In this study, the near-inertial current (u_I, v_I) and wind stress $(\tau_{x,I}, \tau_{y,I})$ are retained by high-pass filtering the horizontal velocity with a cutoff frequency of $0.8f$ where f is the local Coriolis frequency (Furuichi et al., 2008). The near-inertial wind work is computed as $W_I = u_I \tau_{x,I} + v_I \tau_{y,I}$. The near-inertial kinetic energy integrated in the upper 1000 m is computed as $KE_I = \int_0^{1000} \frac{\rho_0}{2} (u_I^2 + v_I^2) dz$ where $\rho_0 = 1025 \text{ kg m}^{-3}$ is the reference sea water density.

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Figure Caption

Fig. 1 CRCM computation domain in the North Pacific: the outer frame outlines the WRF computational region and the inner frame outlines the ROMS computational region.

Fig. 2 The impulse response function for the (a) bilinear, (b) bicubic, and (c) bisinc function interpolation.

Fig. 3 (a) The horizontal wavenumber spectrum of the original 0.1° wind stress (grey dashed) and the smoothed and subsampled 2° wind stress (black solid). (b) The ratio of horizontal wavenumber spectrum computed from the bilinearly (blue), bicubicly (green), and bisincly (red) interpolated wind stress to that derived from the 2° wind stress. The cyan, blackish green, and orange dashed lines denote the values evaluated from Eq. (6), (9) and (12), respectively. All the wavenumber spectra are computed from the entire model domain and averaged over the entire simulation period.

Fig. 4 (a) The frequency spectra of the wind stress in E-Control (grey dashed) and E-Smooth (black solid). (b) The ratio of wind stress frequency spectra in E-Linear (blue), E-Cubic (green), and E-Sinc (red) to that in E-Smooth. All the frequency spectra are first computed on individual grid points during April 2003-September 2003 and then spatially averaged within the region 130°E - 150°E , 15°N - 24°N .

Fig. 5 Similar to Fig. 4 but for the region 155°E-175°W, 33°N-47°N during October 2002-March 2003.

Fig. 6 The annual mean (a) near-inertial wind work (W m^{-2}) and (b) surface near-inertial current amplitude (m s^{-1}) simulated in E-Control

Fig. 7 The annual mean near-inertial wind work (W m^{-2}) in (a) E-Smooth, (b) E-Linear, (c) E-Cubic, and (d) E-Sinc.

Fig. 8 (a) The latitudinal distribution of zonally averaged annual mean near-inertial wind work in E-Control (grey), E-Smooth (black), E-Linear (blue), E-Cubic (green), and E-Sinc (red).

Table 1 The mean near-inertial wind work W_I and near-inertial kinetic energy KE_I integrated in the upper 1000 m within 15°N-24°N, 130°E-150°E during April 2003-September 2003.

	E-Smooth	E-Linear	E-Cubic	E-Sinc
W_I (mW m ⁻²)	8.2	4.7	6.4	8.1
KE_I (kJ m ⁻²)	4.1	2.8	3.6	4.2

Table 2 Similar to Table 1 but for the mean values within 33°N-47°N, 155°E-175°W during October 2002-March 2003.

	E-Smooth	E-Linear	E-Cubic	E-Sinc
W_I (mW m ⁻²)	5.1	4.3	4.9	5.2
KE_I (kJ m ⁻²)	3.4	2.9	3.3	3.4