Observed and Simulated Variability of Ocean Currents on Seasonal and Intra-Monthly Scales

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A set of numerical experiments has been conducted using an ocean general circulation model (OGCM) developed in Hydrometcenter of Russia (*Resnyansky and Zelenko, 1999*). They are aimed at studying the dependence of dynamical characteristics simulated by the model (kinetic energy, vertical structure and temporal variability of ocean currents) on horizontal diffusivity A_H in the equations of heat and salt transport. Finding the dependence of this sort is vital for estimating the relative role of different processes in generating the mean structure and temporal variability of dynamic and hydrographic fields, as well as for tuning the model in order to attain the most possible agreement with observations. In the course of experiments the ability of OGCM to reproduce the structure of temporal variability on seasonal and intra-monthly time scales was also estimated through the comparison with direct current meter records.

To estimate the sensitivity of model results to variations of thermodynamic parameters, three other than that identical model runs have been performed differing only in horizontal diffusivity A_H = 10^3, 10^4 and 10^5 m^2 s^{-1}. In each of the runs the evolution of oceanic fields forced by realistic atmospheric forcing over 24 years was simulated starting from rest with climatological temperature and salinity distributions. The forcing (surface wind stress and heat/fresh water fluxes) was specified using 6-hourly data of NCEP-DEO AMIP-II Reanalysis (*Kanamitsu et al., 2002*) over 1979–2002 in combination with relaxation of the computed near-surface water temperature and salinity values to specified distributions from the WOA-98 atlas assuming relaxation coefficient $c_r^{-1} = 30\ d$. The model integrations were performed in a global domain (excluding the Arctic basin to the north of 77.5° N) on 2°×2° (2°×1° in near equatorial band) grid with 32 level in the vertical.

As an example, a comparison of computed current speeds with current meter records appears in Fig. 1. Here, time series of current speed in the Northwest Pacific over the period from July 1980 to May 1981 are depicted for three depths: in the upper layer ($z = 500$ m), in the main thermocline ($z = 1200\text{m}$) and in deep layer ($z = 4000$ m). As is seen, according to the measurements, the currents strength (mean speed level $\overline{U}$) keeps almost invariant, about 10 cm s^{-1} over a rather broad range of depths. In the model, the mean speed level appears to be underestimated by several times due to, obviously, comparatively course horizontal resolution.

Nonetheless, in the upper layer ($z = 500$ m) the simulations reproduce rather realistically not only general features of the temporal variability on seasonal and intra monthly time scales, but also the most remarkable episodes of the currents temporal changes: almost two-fold intensification in November–December, 1980 and in March–April, 1981; variations with prevailing periods of about two weeks in between these episodes; decreasing intensity to the end of the period considered.

Mutual similarity of observed and computed individual peculiarities weakens with increasing depth ($z = 1200$ m and $z = 4000$ m), though some common features of observed variability remains in model simulations as well. Besides, the impact of A_H variations on the model results, distinctly seen in the upper layer ($z = 500$ m), slackens at these depths. As A_H increases, the mean speed level decreases: from $\overline{U}$ ~ 5 cm s^{-1} with A_H = 10^3 m^2 s^{-1} down to $\overline{U}$ ~ 2 cm s^{-1} with A_H = 10^4 m^2 s^{-1} and $\overline{U}$ ~ 1.5 cm s^{-1} with A_H = 10^3 m^2 s^{-1}. Thus, in the upper part of the A_H variations range considered here the tendency appears for “satiation” of the model response to variations of the parameter. These peculiarities may be evidently explained by enhanced smoothing of the lateral water density gradients in the baroclinic layer with increasing A_H.

Similar “satiety“ may be also noticed in integral dynamic characteristics, such as kinetic energy *KEN* averaged over the World Ocean. Mean levels of *KEN* for A_H =10^3, 10^4 и 10^5 m^2 s^{-1} are 0.25, 0.16 and 0.14 J m^{-3} correspondingly.

Reduction of the similarity with increasing depth may be considered as evidence that in the upper layers the currents variability is determined to a greater degree by the direct response of the ocean to atmospheric forcing (it is specified by “realistic” data in the experiments considered), and with increasing depth the role of internal ocean dynamics rises.

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References

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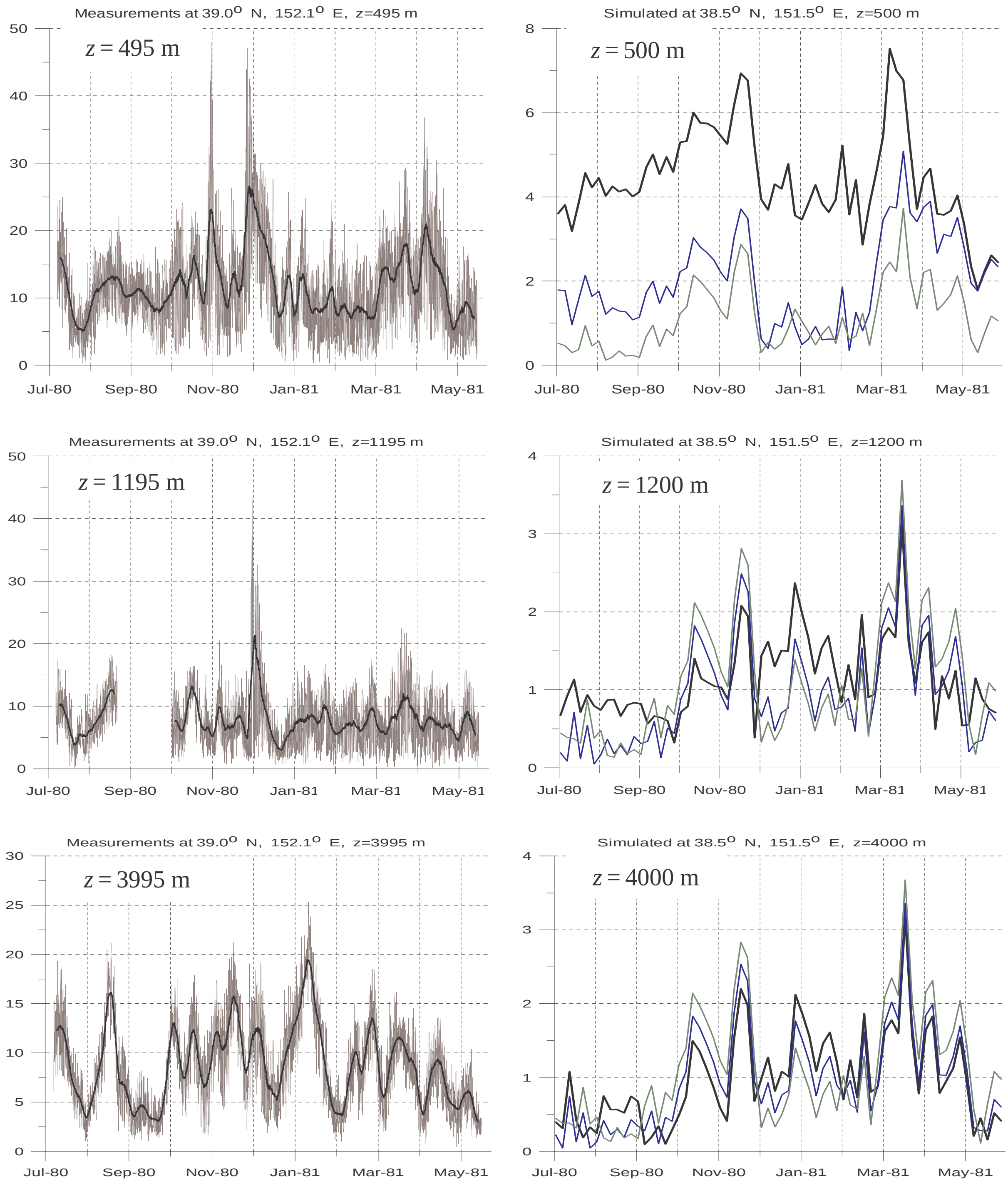

Fig. 1. Measured and simulated July 1980–May 1981 time series of current speed (cm s^{-1}) in the Northwestern Pacific at three different depths: in the upper layer, in the main thermocline and in deep ocean.

Left column – current meter measurements during WESTPAC 1 Experiment (39.0° N, 152.1 E) (*Data from Deep Water Current Meter Moorings, 2002*.). Gray thin line – hourly data, black thick line – 5 days running average.

Right column – OGCM simulations on 2°×2° grid with 6-hourly atmospheric forcing from NCEP-DEO Reanalysis-2 (*Kanamitsu et al., 2002*). Curves in black, in blue, and in green (drawn through data points at 5 days intervals) relate to model runs with horizontal diffusivity $A_H = 10^3$, 10^4 and 10^5 m^2 s^{-1} correspondingly.