P5.22

IMPROVEMENTS AND VALIDATION OF THE GAUSSIAN JET MODEL FOR DERIVING ABSOLUTE GEOSTROPHIC VELOCITIES FROM SATELLITE ALTIMETRY

Seungbum KIM and M.A. SAUNDERS*
Satellite Technology Research Center, Korea Advanced Institute of Science and Technology, 373-1 Kusung, Yusung, Taejeon, S. Korea 305-701
* Department of Space and Climate Physics, University College London U.K.
Tel: +82-42-869-8626. Fax: +82-42-861-0064. E-mail: sbkim@krsc.kaist.ac.kr. http://satrec.kaist.ac.kr/~sbkim/

Abstract: Time-mean and absolute geostrophic velocities of the Kuroshio current south of Japan are derived from TOPEX/Poseidon altimeter data using a Gaussian jet model. When compared with simultaneous measurements from a shipboard acoustic Doppler current profiler (ADCP) at two intersection points, the altimetric and ADCP absolute velocities correlate well with the correlation of 0.55 to 0.74. The time-mean velocity is accurate to 1 cm s^{-1} to 5 cm s^{-1}. The errors in the absolute and the mean velocities are similar to those reported previously for other currents. The comparable performance suggests the Gaussian jet model is a promising methodology for determining absolute geostrophic velocities, noting that in this region the Kuroshio does not meander sufficiently, which provides unfavorable environment for the performance of the Gaussian jet model.

1 Introduction

The Kuroshio current is one of the main geostrophic current systems in the North Pacific and is important for ocean circulation and climate: e.g., meridional heat flux, upper ocean temperatures and global-scale teleconnections. Thus significant efforts have been paid to measure its absolute velocity and transport (e.g., Hanawa *et al.* 1996). Numerous methods to measure a current velocity have merits and drawbacks of their own: such as the need of a reference velocity, the geoid or in situ measurements as drawbacks. Among these, the Gaussian jet model for deriving the velocity from satellite altimetry data (Kim and Saunders 2002), is advantageous because it requires none of the drawbacks and is relatively simple. Though the method is limited to regions of strong current meandering, its utility has been widely demonstrated in the measurement of the major current systems in the world ocean: the Gulf Stream (Kelly *et al.* 1991), the Kuroshio Extension (Qiu 1995), and the Antarctic Circumpolar Current (Gille 1994).

Although the performance of the Gaussian jet model has been assessed many times (Joyce *et al.* 1990; Kelly *et al.* 1991; Gille 1994), its accuracy for the Kuroshio current is not available. The Kuroshio to the south of Japan has relatively stable path and in this case the Gaussian jet model may not perform well because it requires strong meandering. In this work, therefore, we aim at deriving the absolute geostrophic of the

Kuroshio current using the altimeter records from TOPEX/Poseidon (T/P) satellites and assess its performance by comparing with in-situ measurements by an acoustic Doppler current profiler (ADCP).

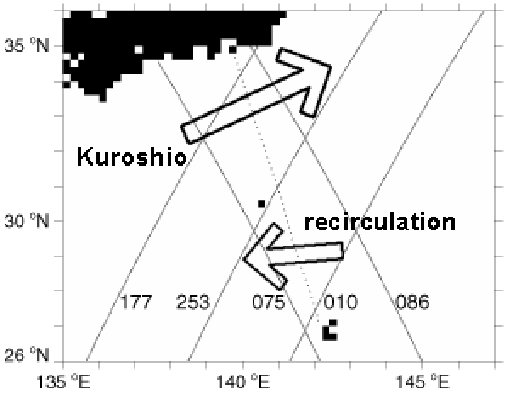

Fig. 1. Ship track for ADCP measurements (sparse dots) and T/P ground tracks (dense dots). The three digit numbers inside the panel indicate the T/P ground track numbers.

2 Data and Method

T/P data preparation

T/P sea surface height (SSH) data used in this study are one-per-second geophysical data records (GDRs) for cycles 001 to 110. Standard editing procedures and corrections as suggested by AVISO are applied. The consequent data are comparable with the GDR version C. To remove the instrument noise, the raw altimeter data are smoothed using a Gaussian filter with a the full width at half-power point (L_{HM}) of 63 km, which is found optimal (Kim and Saunders 2002).

ADCP records

To assess the performance of the Gaussian jet model, we compare the velocity derived from the model with in situ velocity from ADCP observations at three intersection points (Fig. 1). See Hanawa *et al.* (1996), for the full details of the raw data. The area of interest is the entire Northwest Pacific. The time span runs from January 1987 to December 1993 excluding a gap in the altimeter data, from October 1989 until March 1992.

Gaussian Jet Model

In the Gaussian jet model, the time-mean current is reconstructed iteratively from the temporal anomaly using a Gaussian profile for the cross-stream absolute geostrophic velocity at the surface. The Gaussian model is given as (KG)

$$u_s(y,t) = a_1(t)\exp\left[\frac{-(y-a_2(t))^2}{2a_3(t)^2}\right], \qquad (1)$$

where $a_1(t)$ is the peak velocity of the jet, $a_2(t)$ its axis position and $a_3(t)$ its width. u_s denotes an absolute velocity synthesized using a_1, a_2 and a_3. The fundamental idea behind this method is that the velocity anomaly is representative of the absolute velocity in terms of a_2 and a_3 if the jet meanders a distance of order its typical width (Fig. 2). For more details of the implementation and improvement, one may refer to Kim and Saunders (2002).

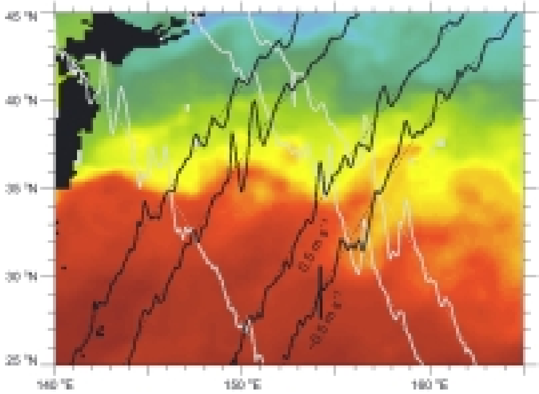

Fig. 2. Velocity anomalies from T/P records superimposed on a simultaneous sea surface temperature image from the ERS-1 satellite.

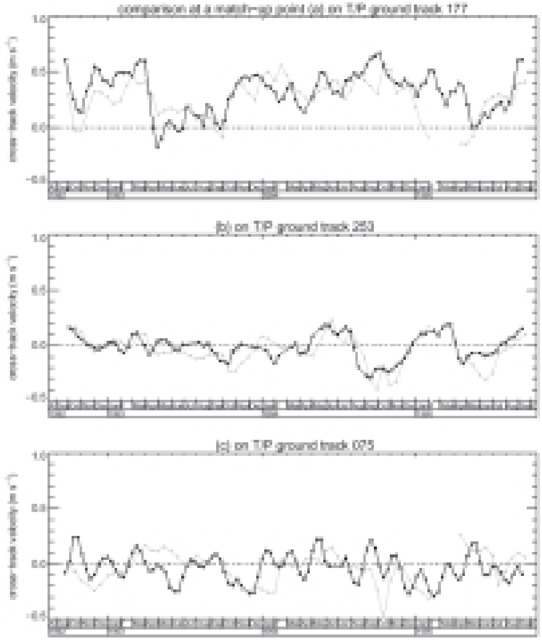

Fig. 3. Comparison of cross-track absolute geostrophic velocities at the intersection points between the Gaussian jet method output (black) and the ADCP measurements (gray).

3 Comparison of the time-mean geostrophic velocity

At the intersection point on ground track 177, the instantaneous velocities correlate reasonably well at the coefficient of 0.55 (Fig. 3a). The velocities around summer 1993 are smaller than those in other periods. Around summer 1993 the Kuroshio takes an offshore path: its axis on the ADCP ship track moves to about 33°N. Thus the Kuroshio velocity at the 34° 10'N intersection point tends to be smaller (Fig. 4a) than normal (Fig. 4b). However, in September 1993, even if the current is on the nearshore path (Fig. 4c), the velocities are small. This is because the current direction is almost parallel to the T/P ground track (Fig. 4c). Some of the large differences between the two velocities are observed during the offshore path: October 1992 and May 1993. In this case the path of the Kuroshio near the intersection point is quite variable (compare Fig. 4a and Fig. 4d).

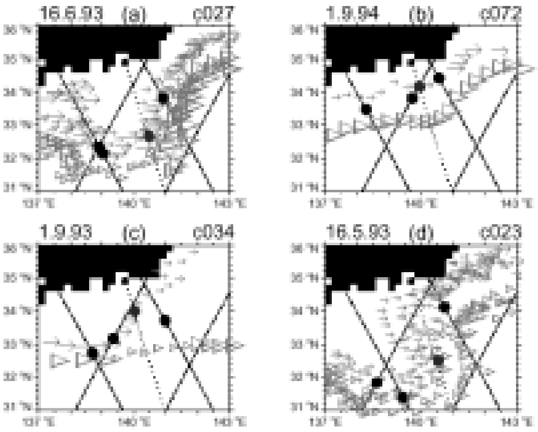

Fig. 4. Positions for the Kuroshio path monitored by the Gaussian jet model and the ADCP records (solid circles) and AVHRR SST frontal positions (arrows and triangles for the north and south walls repectively). The title indicates the dates and the cycle number of T/P altimeter.

The mean difference at the intersection points on the track 177 is 5.4 cm s^{-1}, 15% of the signal (Table 1). The 15% difference is attiributed to the combination of intrinsic errors in the Gaussian jet model, noise in the altimeter records and the consequent deterioration of the model's performance, and insufficient meandering of the Kuroshio to the south of Japan. The insufficient meandering is manifested by the fact that the path of the Kuroshio along T/P ground track 177 has two preferred locations as shown in Fig. 4. This quasi-stability will result in a weak velocity anomaly and, consequently, poor performance of the Gaussian jet model. Gille (1994) and Kim and Saunders (2002) quantify the sizes of these three error terms by simulation and they are estimated to 0.6%, 5.0% and 5.5% of the signal respectively. The quadrature addition of these three sources produces an error budget of 7.5%.

At the intersection points on T/P ground tracks 075 and 253 we may assess the performance of the recirculation model since below ~31°N the flow pattern is dominated by the westward recirculation (Fig. 1). The mean difference ranges from 1.0 cm s^{-1} to 2.9 cm s^{-1} (Table 1) or 7% to 23% of the signal. Such level of difference is very encouraging noting that the recirculation model is just a simple linear one.

4 Summary and discussions

We have derived the absolute geopstrophic velocity from T/P altimeter records and assessed its accuracy for the Kuroshio current and its recirculation to the south of Japan. At two intersection points between ADCP ship track and T/P ground track, the altimetric and ADCP velocities agree well with correlation of 0.56 and 0.71 at > 99 % significance. The mean velocities between the T/P and ADCP derivations at the intersection points differ by 1 cm s^{-1} to 5 cm s^{-1}. These differences are comparable with those for the Gulf Stream. Noting that the insufficient meandering of the Kuroshio would provide unfavorable environment for the performance of the Gaussian jet model, the similar level of performance for the Kuroshio and the Gulf Stream suggests the robustness of the Gaussian jet method. We further found that the simple model for the recirculation is effective. The more complete description of this work and further analysis is available in Kim (2002).

Acknowledgements

The Korean Ministry of Science and Technology (MOST) is acknowledged for supporting this research.

References

Gille, S.T., 1994: Mean sea-surface height of the Antarctic Circumpolar Current from Geosat data - method and application, *J. Geophys. Res.*, **99**, 18 255-18 273.

Hanawa, K., Y. Yoshikawa and T. Taneda, 1996: TOLEX-ADCP monitoring, *Geophys. Res. Lett.*, **23**, 2429-2432.

Joyce, T.M., K.A. Kelly, D.M. Schubert and M.J. Caruso, 1990: Shipboard and altimetric studies of rapid Gulf Stream variability between Cape Cod and Bermuda, *Deep-Sea Res.*, **37**, 897-910.

Kelly, K.A., T.M. Joyce, D.M. Schubert and M.J. Caruso, 1991: The mean sea surface height and geoid along the Geosat subtrack from Burmuda to Cape Cod, *J. Geophys. Res.*, **96**, 12 699-12 709.

Kim, S.B., 2002: Geostrophic Velocities Derived from Satellite Altimetry in the Sea South of Japan, submitted to *J. Korean. Soc. Remote Sens.*

Kim, S.B. and M.A. Saunders, 2002: An improved Gaussian jet model for deriving absolute geostrophic velocity from satellite altimetry, *J. Atmos. Oceanic Tech.,* in press.

Qiu, B., 1995: Variabilities and energetics of the Kuroshio Extension and its recirculation gyre from the first two-year TOPEX data, *J. Phys. Oceanogr.*, **25**, 1827-1842.

Table 1. Errors in the SSH rise across a jet or cross-track velocity determined using the Gaussian jet method. Measures of the differences are given in parenthesis, next to the corresponding percentages (relative to the root-mean-square of the signal). GS, ACC, and KU stand for the Gulf Stream, the Antarctic Circumpolar Current, and the Kuroshio respectively.

Authors	Area	Difference (altimetric – ADCP)		Source of 'truth' data
		Mean	r.m.s.	
Joyce *et al.* (1990)	GS	n/a	48 % (23 cm s^{-1})	ADCP
Kelly *et al.* (1991)	GS	15% (11 cm)	N/a	ADCP
Gille (1994)	ACC	7% (3.0 cm)	N/a	Simulation
This study				
Ground Track 177	KU	15% (5.4 cm s^{-1})	48 % (17.6 cm s^{-1})	ADCP
Ground Track 253	KU	23% (2.9 cm s^{-1})	73 % (9.1 cm s^{-1})	ADCP
Ground Track 075	KU	7% (1.0 cm s^{-1})	133 % (18.8 cm s^{-1})	ADCP