Summary

Coordinated orbit planning of multiple altimetric satellites is expected to lead to significant improvements in resolution and accuracy of sea surface height (SSH) and surface geostrophic velocity fields. This investigation evaluates three methods of velocity estimation which are currently in use, or which have recently been proposed with random noise in mind, for several single and two satellite configurations, in the Gulf Stream (GS) region. Sea surface height measurements are simulated using the output of the 1/10° resolution Los Alamos model of the North Atlantic [4]. Velocities are then evaluated from perfect measurements, as well as from measurements to which realistic instrument noise and orbit errors have been added, and compared with the original model velocities. Two cases identify velocity uncertainties associated with sampling and data errors, respectively.

![Figure 1: Ground track patterns for (a) T/P and JASON tandem mission with interleaved tracks (configuration prepared by the science working team) and (b) T/P and JASON tandem mission with orbit plane offset by 9.25° (proposed for velocity determination along ground tracks [3], overlaid on a map of kinetic energy in the GS region.](image)

![Figure 2: Accuracy of geostrophic velocities resulting from application of the "parallel track" method [3] to configuration (C) in the GS region (3°–3°N 60°–40°W) as a function of track separation (deg). Velocity error variances are expressed as a percentage of the local signal variance. The error budgets consist of three contributions, denoted in the figure by its magnitude in cm. The first number represents the random instrument noise which was removed here by averaging smoothing (100 km cut-off); the second number represents the amplitude of a once-per-rev or bit error, which introduces a bias between two separate tracks; and the third number represents a parameterization of additional errors such as due to track displacements in the presence of a cross track mean sea surface slope. Figure 3 suggests that: (1) Orbit errors have a significant impact on velocity errors; (2) very small track separations are undesirable since the effect of data errors is amplified; (3) even for orbit errors of 3 cm useful velocity estimates can still be obtained; (4) Velocity errors are insensitive to data error for larger track separations and become dominated by sampling errors, and a T/P + JASON combination, with and without data errors, orbit errors for T/P, JASON and ERS were 2, 2 and 4 cm respectively. In conclusion: (1) Velocity accuracies in the GS region are not very much impacted by data errors; (2) accuracies obtained from the T/P and JASON combination are slightly lower than for the T/P + JASON combination; (3) Averaging in both components is comparable; (4) Velocity accuracies are slightly lower than those obtained from parallel track and crossover methods for identical error budgets when averaged over the GS region.

![Figure 3: Accuracy of velocities estimated at crossings in the GS region as a function of smoothing span for the T/P, JASON, and GEOSAT missions. The smoothing span is defined as the distance over which the along track SSH slope is estimated. Estimates are given for both noise free measurements and for measurements incorporating realistic noise estimates for the other two missions (2, 3 and 4 cm respectively). Conclusions from Figure 2: (1) Even in the absence of data errors, velocity accuracies are limited by sampling errors resulting from the non-synchronization of the two flights, introducing a temporal interpolation error; and (2) Both orbit inclination and repeat period affect this error contribution, leading to relatively lower accuracies for GEOSAT and ERS; (3) At the GS latitude, the V component is more poorly determined than the U component.](image)

![Figure 4: Accuracy of velocity estimates determined from optimally interpolated SSH maps as a function of the smoothing span for both T/P + JASON interleaved tandem mission, and a T/P + ERS combination with and without data errors, orbit errors for T/P, JASON and ERS were 2, 2 and 4 cm respectively. In conclusion: (1) Velocity accuracies in the GS region are not very much impacted by data errors; (2) Accuracies obtained from the T/P + ERS combination are slightly lower than for the T/P + JASON combination; (3) Averaging in both components is comparable; (4) Velocity accuracies are slightly lower than those obtained from parallel track and crossover methods for identical error budgets when averaged over the GS region.](image)

![Figure 5: A comparison of the < u'v' > and < u'v' > terms of the Reynolds stress tensor, along and across the Gulf Stream core respectively, obtained from parallel track (squares) and interleaving configurations, in the latter case obtained with both the crossover (stars) and optimal interpolation (circles) methods. The dotted line represents the model truth.](image)

![Figure 6: Velocity vector obtained from crossover and parallel track procedures along a ground track across the Gulf Stream. The model velocity is shown in blue, and estimates from simulated data with errors are shown in red. The given velocities were obtained by applying the parallel track method to an interleaved configuration.](image)

![Figure 7: Velocity error variance ellipses resulting from application of the PT, XQ, and Q methods to parallel track and interleaving T/P + JASON tandem configurations respectively for measurements including data errors, overlaid on the mean sea surface height, identifying the mean location of the Gulf Stream.](image)