# CURRENTS AND TIDES OBSERVED IN THE KOREA-TSUSHIMA STRAIT

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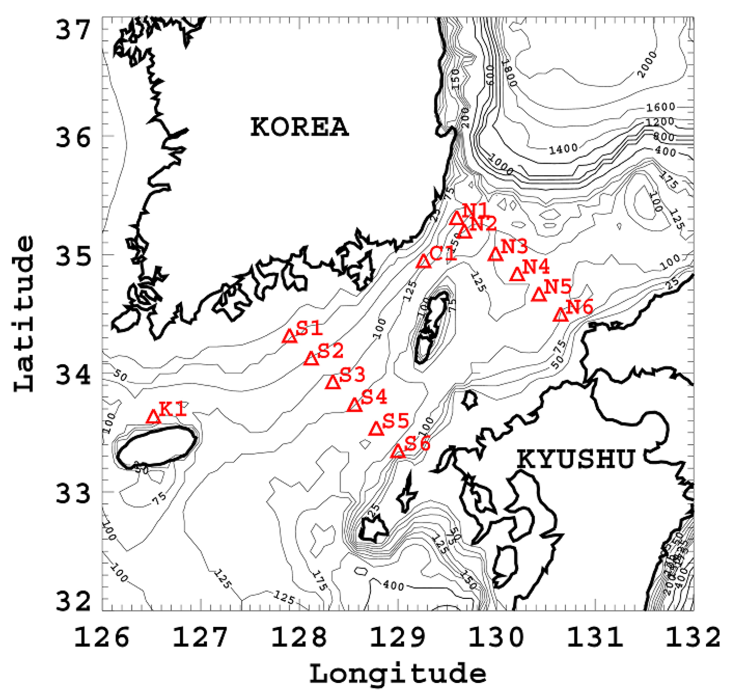
ABSTRACT

Current measurements over nearly a year are made in the Korea-Tsushima Strait for the first time. Twelve bottom-mounted acoustic Doppler current profilers returned high quality current profile measurements along lines located northeast and southwest of Tsushima Island at depths ranging from 59 to 142 m, for the time period between May 1999 and March 2000. The two sections show markedly different mean flow regimes. A high velocity current core was found to exist along the southwestern section along the western slope of the strait for the entire recording period. Tsushima Island disrupted the current flow towards the northeast to such an extent that a counter current commonly existed in the island shadow. The northeastern section is marked by strong spatial variability but in the mean consists of two streams, one on each side of the strait. Non-tidal currents exceeding 70 cm/s were found which were embedded in total currents exceeding 120 cm/s. Tidal currents are responsible for about 25% of the eddy kinetic energy in the near surface layer, they account for more than 50% of the eddy kinetic energy at mid depths and about 70% near the bottom. Current descriptions and statistics are presented to describe the three-dimensional current field.

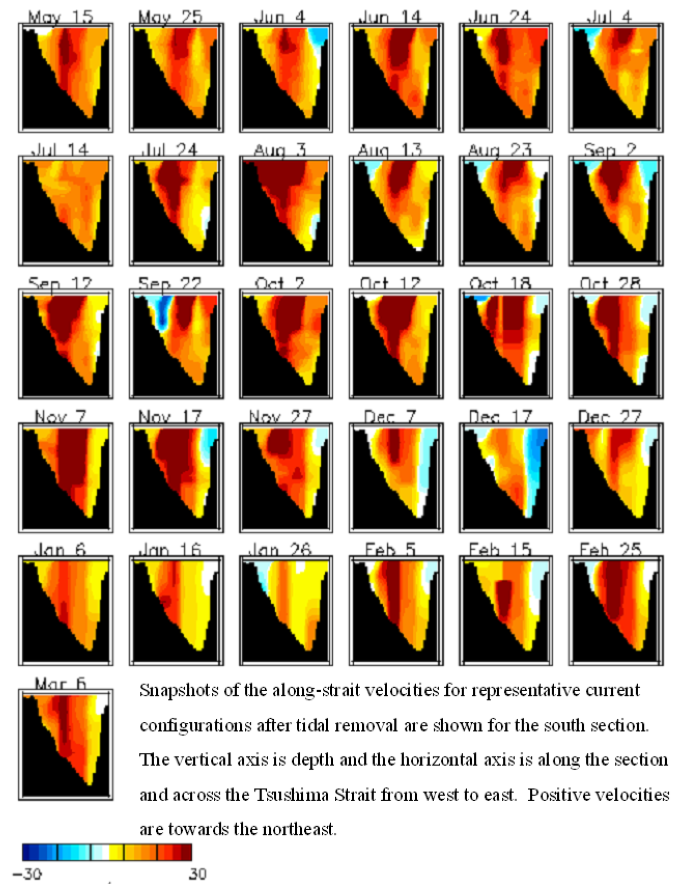
## OBJECTIVES

- What are the dominant low frequency currents?
- How do currents vary spatially and seasonally?
- What is the current transport through the Korea Strait?
- What are the dominant tides in terms of tidal heights and tidal velocities?
- What is the contribution of the tidal currents to the total mean kinetic energy?
- Are the tide charts for the Korea-Tsushima Strait accurate?

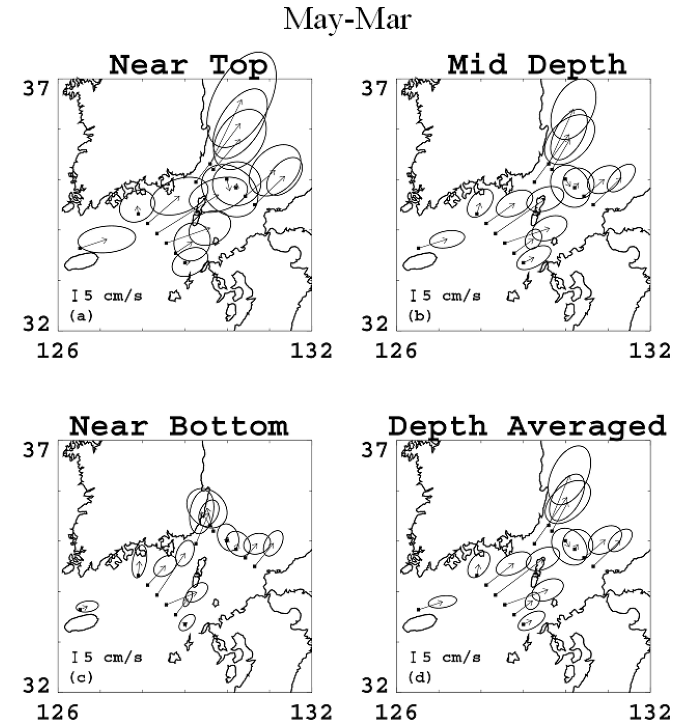
| Mooring | Lat | Lon | Start Day | End Day | Top Bin | Bottom Bin | Bin Size | Water Depth |
|---|---|---|---|---|---|---|---|---|
| S1 | 34.32 | 127.90 | 130 | 289 | 5 | 53 | 2 | 59 |
| | | | 290 | 437 | 6 | 55 | 1 | |
| S2 | 34.13 | 128.12 | 129 | 289 | 7 | 83 | 2 | 89 |
| | | | 290 | 436 | 7 | 83 | 2 | |
| S3 | 33.93 | 128.34 | 129 | 288 | 11 | 103 | 4 | 113 |
| | | | 290 | 438 | 11 | 103 | 4 | |
| S4 | 33.74 | 128.56 | 128 | 287 | 9 | 97 | 4 | 107 |
| | | | 288 | 438 | 9 | 97 | 4 | |
| S5 | 33.54 | 128.78 | 128 | 287 | 19 | 143 | 4 | 152 |
| S6 | 33.35 | 129.00 | 129 | 286 | 9 | 105 | 4 | 115 |
| | | | 288 | 438 | 9 | 105 | 4 | |
| C1 | 34.95 | 129.26 | 292 | 444 | 7 | 97 | 2 | 103 |
| K1 | 33.64 | 126.52 | 62 | 356 | 6 | 114 | 4 | 124 |
| N1 | 35.31 | 129.60 | 293 | 440 | 9 | 113 | 4 | 119 |
| N2 | 35.20 | 129.67 | 125 | 282 | 25 | 137 | 4 | 142 |
| | | | 285 | 441 | 24 | 132 | 4 | |
| N3 | 35.01 | 129.99 | 126 | 283 | 13 | 125 | 4 | 132 |
| | | | 285 | 441 | 11 | 123 | 4 | |
| N4 | 34.84 | 130.21 | 126 | 283 | 13 | 117 | 4 | 127 |
| | | | 285 | 441 | 13 | 117 | 4 | |
| N5 | 34.67 | 130.43 | 127 | 284 | 16 | 120 | 4 | 130 |
| | | | 285 | 442 | 11 | 119 | 4 | |
| N6 | 34.50 | 130.65 | 127 | 284 | 12 | 108 | 4 | 118 |
| | | | 286 | 442 | 12 | 108 | 4 | |



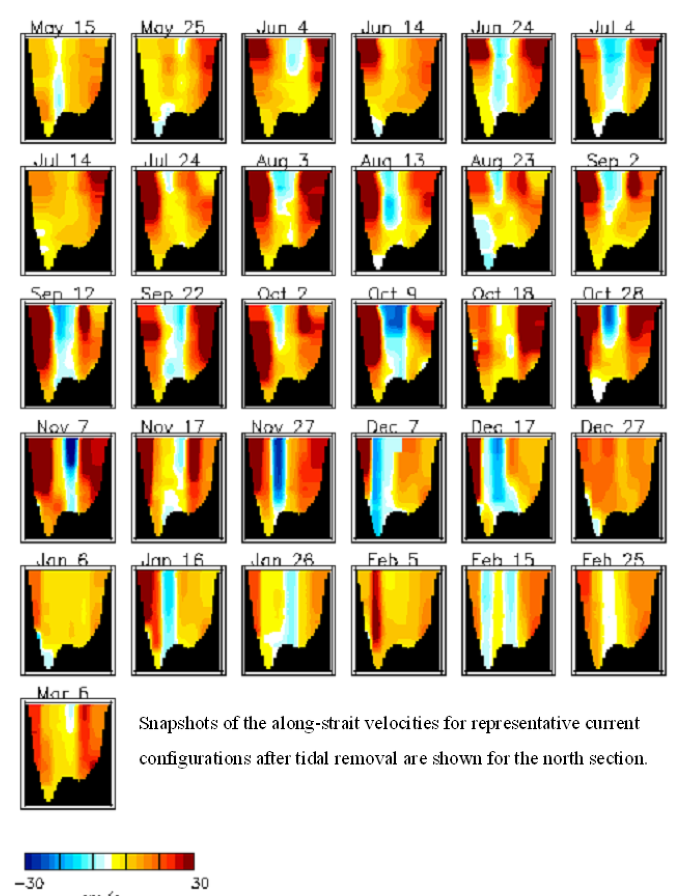

ADCP mooring locations and bathymetry. Depths are in meters.



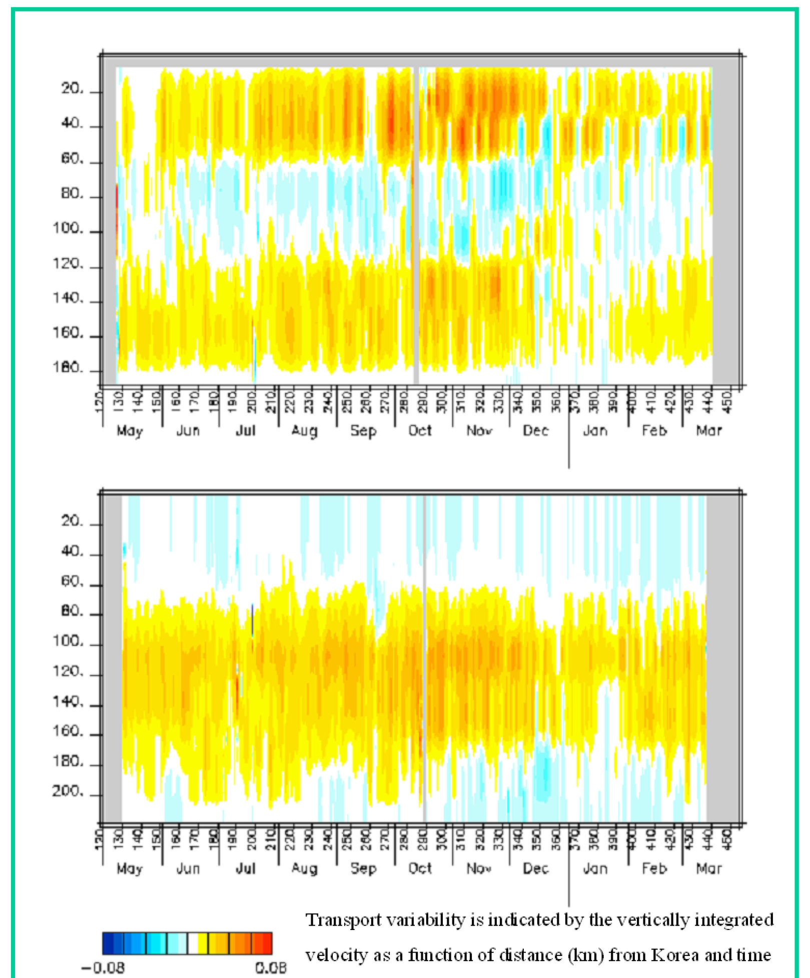
Snapshots of the along-strait velocities for representative current configurations after tidal removal are shown for the south section. The vertical axis is depth and the horizontal axis is along the section and across the Tsushima Strait from west to east. Positive velocities are towards the northeast.



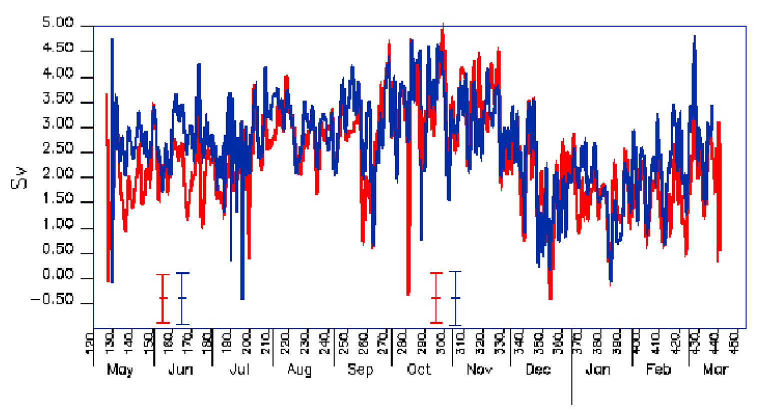

Mean currents near the surface (top velocity bin) (a) for mid-depth currents (middle velocity bin) (b) for near-bottom currents (bottom velocity bin) (c) and for depth-averaged currents (d) and their corresponding standard deviation ellipses after tide removal are shown for the eleven month period (May 1999 through October 2000).



Snapshots of the along-strait velocities for representative current configurations after tidal removal are shown for the north section.



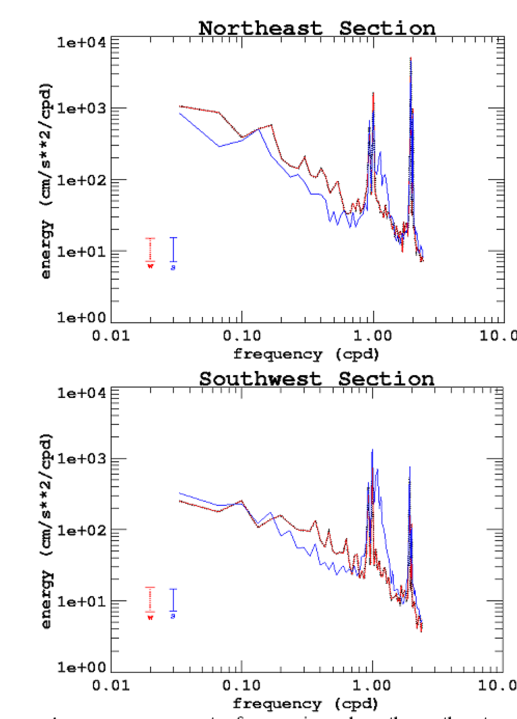
Transport variability is indicated by the vertically integrated velocity as a function of distance (km) from Korea and time for the northeastern section (top) and southwestern section (bottom).



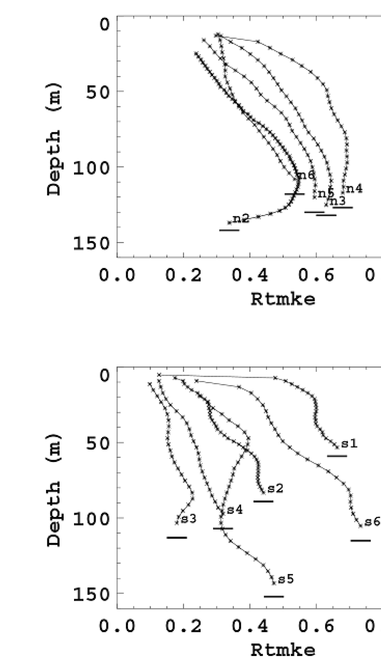
Total transport estimates for the southwestern section (blue) and northeastern section (red) are shown as a function of time. The corresponding time-averaged transports are 2.7 Sv and 2.3 Sv. The RMS transport error estimate is shown in the lower left by the confidence intervals. These error estimates are time-invariant.

Table 2. Monthly Mean Transport (Sv) (1999 – 2000)

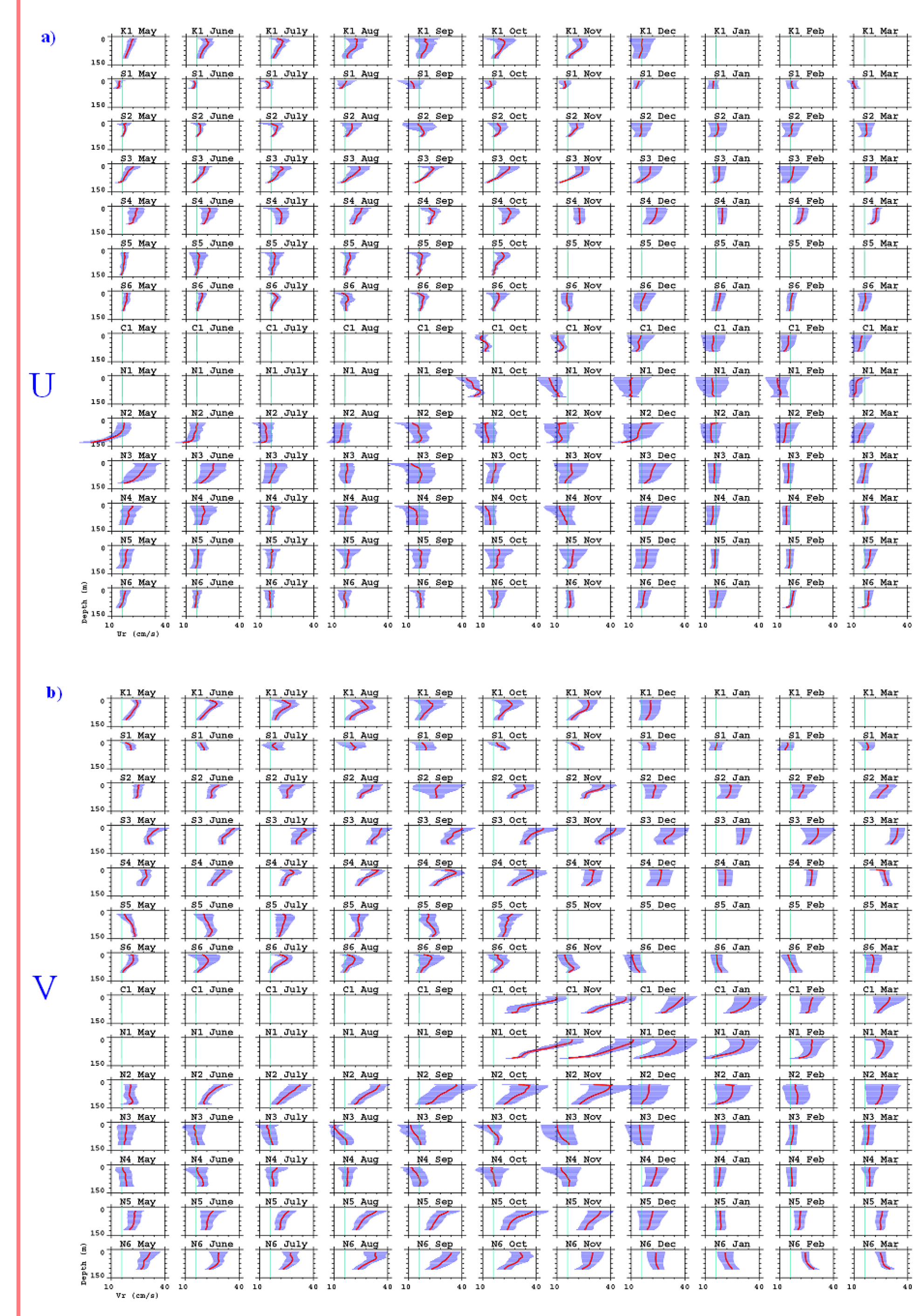
| | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Avg | σ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N Line | 1.9 | 2.1 | 2.3 | 2.9 | 2.8 | 3.2 | 3.3 | 1.9 | 1.6 | 1.6 | 2.3 | 2.3 | 0.62 |
| S Line | 2.7 | 2.8 | 2.8 | 3.0 | 3.1 | 3.5 | 3.1 | 1.8 | 1.7 | 2.2 | 2.8 | 2.7 | 0.55 |



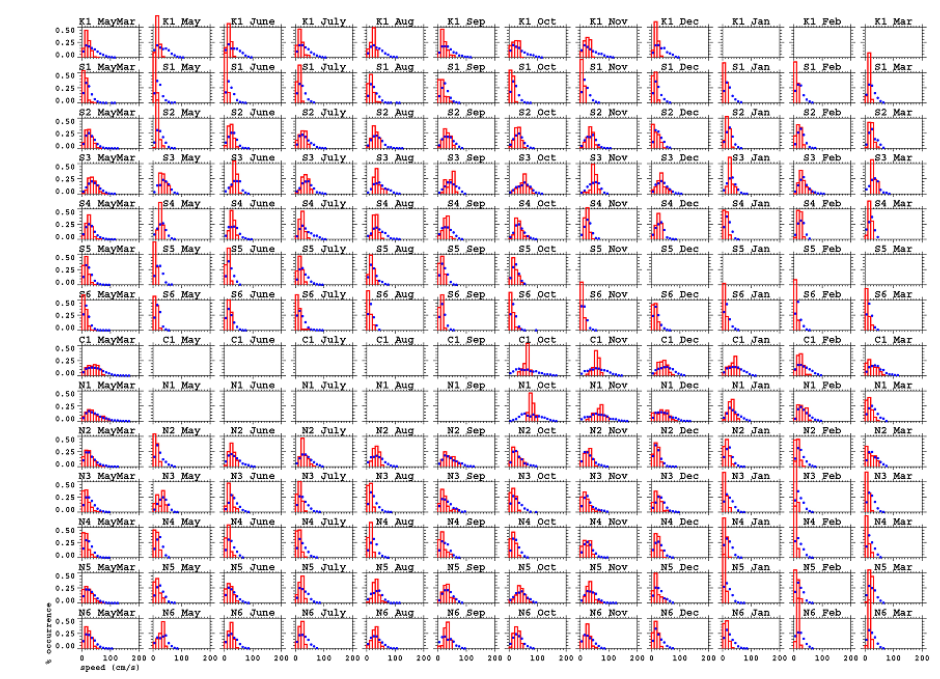

Average energy spectra for moorings along the northeast and southwest sections for summer (solid line) and winter (dashed line).



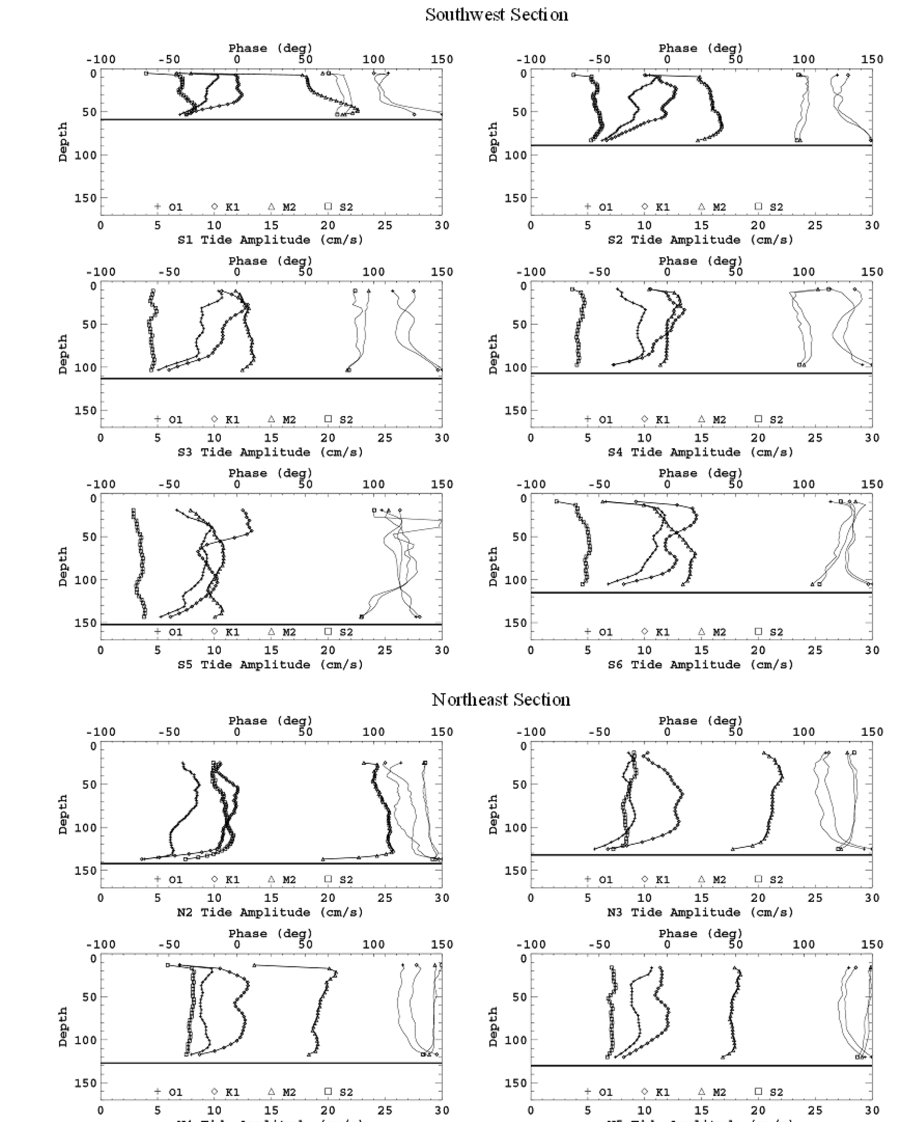

Contribution of tidal currents to the total mean kinetic energy.

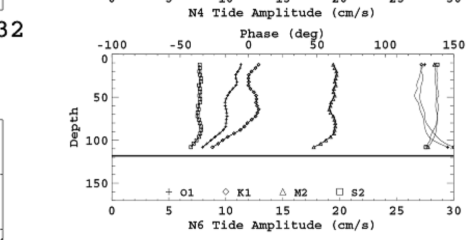


a) Monthly mean velocity profiles (red line) and standard deviation (horizontal blue lines) for u velocity components where u is across Strait (approximately parallel to the north and south sections). The zero velocity is indicated by the light vertical green line. b) As in a) but for the v velocity component where v is along Strait (approximately normal to the south and north sections).

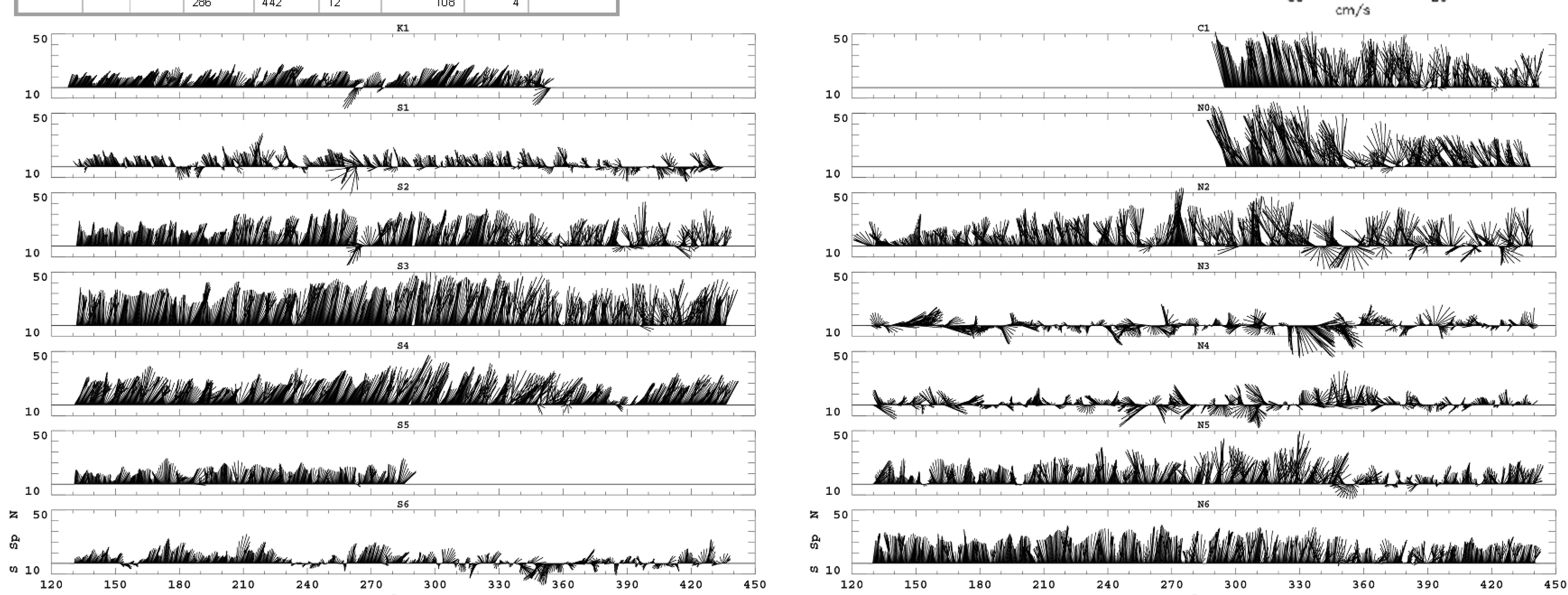


Overall and monthly near-surface speed histograms. Vertical red bars indicate the frequency of current observations occurring within 10 cm/s velocity bins after tides have been removed. Blue dots indicate the frequency of current observations which include tidal currents.

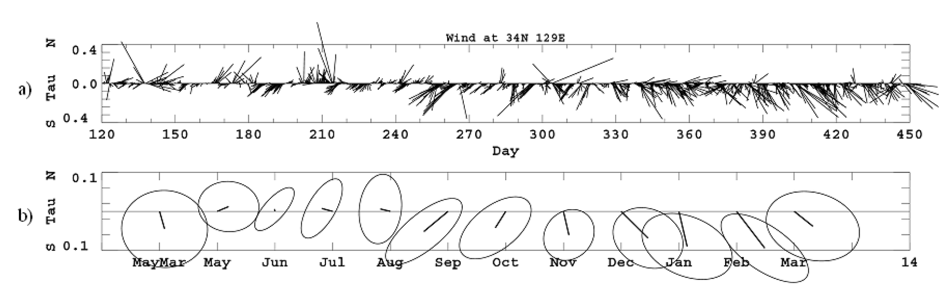


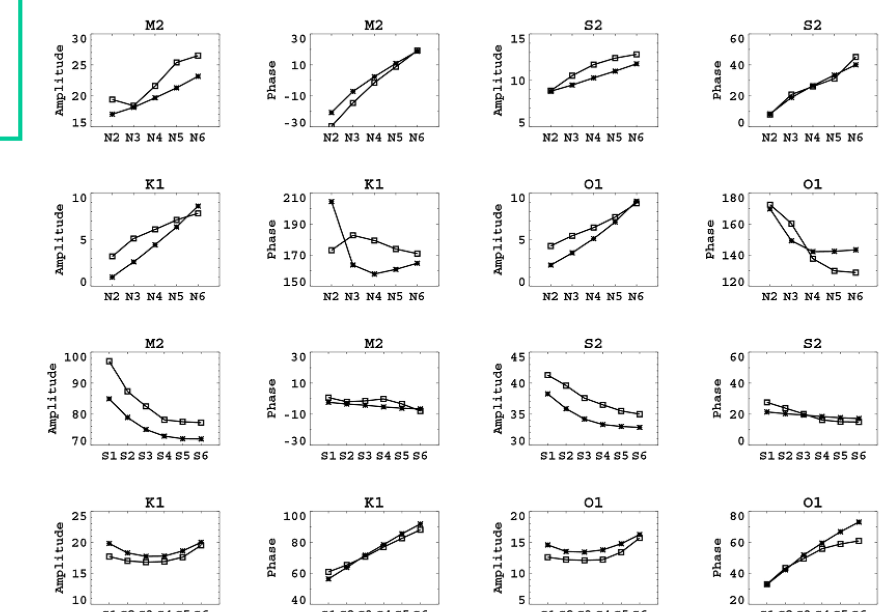
Amplitudes of the individual tidal constituents M2, S2, K1, and O1) corresponding to the magnitudes of the major axes of the tidal ellipses. Each computed tidal velocity is marked by an identifying symbol. Corresponding local inclination angles are given by the thin lines marked by symbols at the ends. The bold horizontal line indicates bottom depth.



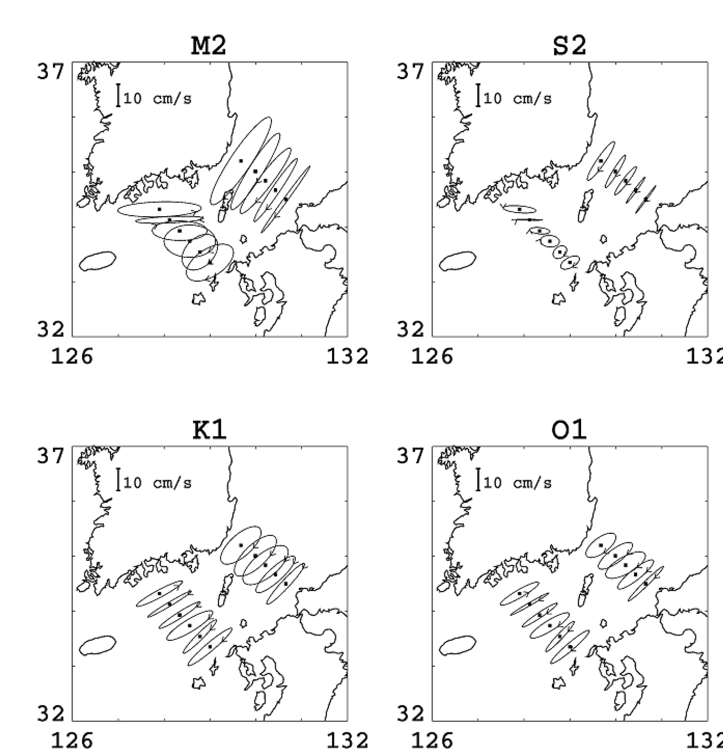
Vector stick diagrams of current velocities for ADCPs. The currents have been vertically averaged for each ADCP. Tides have been removed using a low-pass filter with a 40-hour cutoff frequency. X-axis units are in days beginning in 1999.



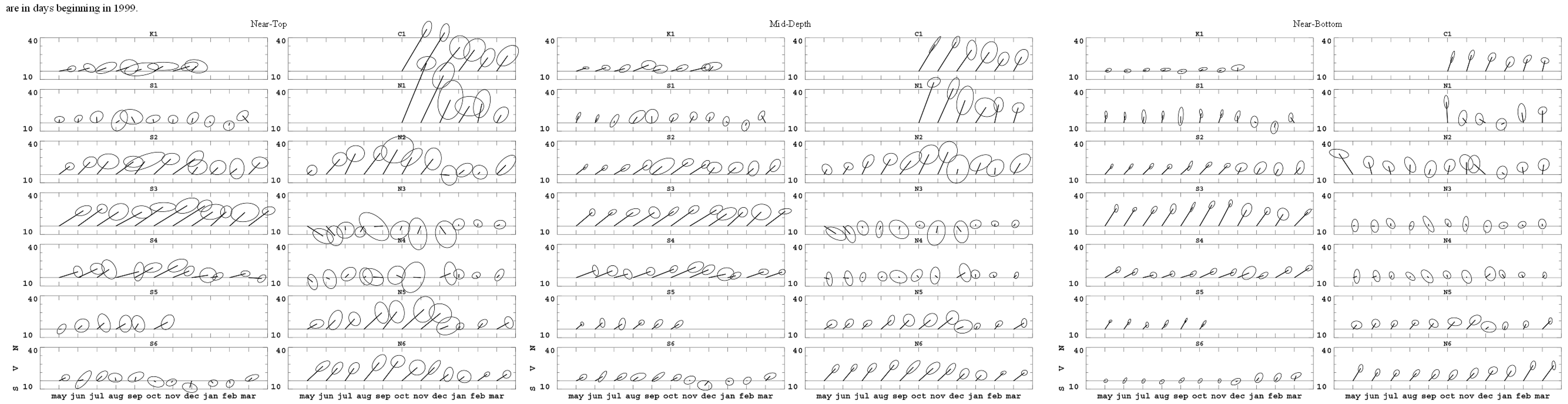

a) Vector stick diagram of wind stress from NOGAPS for one-degree grid square centered at 34N, 129E. Wind vectors are at six-hour intervals. X-axis units are in days beginning in 1999. b) Corresponding monthly mean wind-stress vectors with standard deviation ellipses. Mean winds from May 1999 through March 2000 are denoted by MayMar.



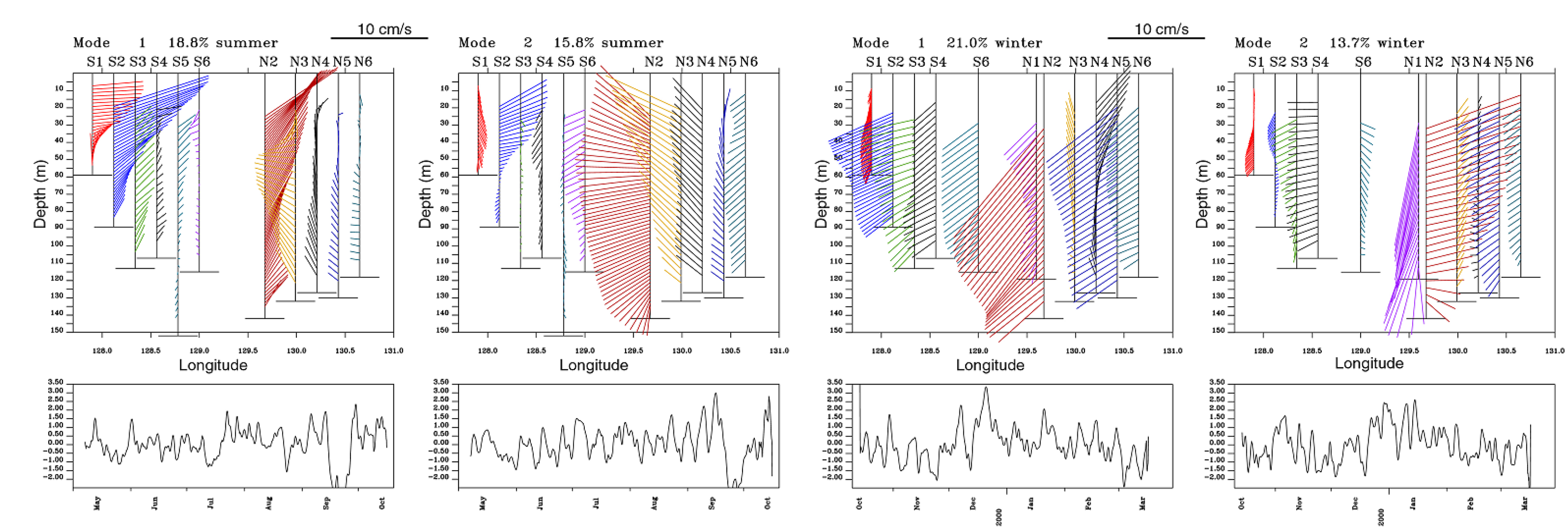
Tide chart tidal amplitudes (cm) and Greenwich phases (squares) from (Odamaki, et.al. 1989) are compared with computed amplitudes and phases (asterisks) from pressure gauge moorings deployed along lines northeast (N2 – N6) and southwest (S1 – S6) of Tsushima Island.




Tide current ellipses with sense of rotation arrows




Monthly time series of mean current vectors and their corresponding standard deviation ellipses for near-top velocity bin, mid-depth and near-bottom levels.




EOF analyses of the moorings along the northeast and southwest sections for a) Mode 1 summer, b) Mode 2 summer, c) Mode 1 winter, and d) Mode 2 winter. North is up along the y-axis and east is to the right along the x-axis. The vectors in the upper panels are scaled in time by the time series in the lower panels, and reverse direction on sign change by the time series. The vector velocity scale is indicated by the bar at the top of the figure. Horizontal bars at the bottom of each profile correspond to bottom depths.

## SUMMARY AND CONCLUSIONS

- A highly persistent main velocity core of along-strait flow lies along the bathymetric slope on the western side of the Strait.
- Downstream of Tsushima the core splits into two distinct cores separated by a region of zero mean current and high variability.
- Strongest currents, just off Korea, are over 100 cm/s but are 170 cm/s if tides are included.
- Southwestern flows occur near coasts and in the lee of Tsushima.
- Mean transport is 2.7 Sv and is minimum in January and maximum in October.
- Seasonal flows are more pronounced northeast of Tsushima than to the southwest, and are less pronounced with depth.
- Eight tidal constituents account for about 88% and 70% of the height variability along southwest and northeast lines in the Strait.
- Charted values of the main tidal constituents are high and need adjustment.
- M2 and S2 are the dominant tidal heights and M2 or K1 dominate tidal currents.
- Tidal currents account for half the total mean kinetic energy.
- The contribution of tidal currents to the total velocity field generally increases with depth.
- Main tidal constituents exhibit varying degrees of depth dependence, largest in the near-surface and near-bottom layers.
- Vertically averaged tidal velocities may not be representative of tidal flows.