SeaSonde Radial Velocity Processing
December 31, 2007

SeaSonde radial processing involves three steps: first, radar cross spectra are analyzed using direction-finding methods to give radial files; second, these files are merged over time; third, as an option, the merged files can then be interpolated and smoothed.

(1) PROCESSING OF RADAR CROSS SPECTRA

Radial velocities and their spatial uncertainties are derived from SeaSonde radar-echo spectrum spectra using methods described by Lipa et. al.[1]. The voltage cross spectra are analyzed to obtain the directions of arrival of the signal for each value of the radial velocity and for all range cells. This typically produces several (N_s) velocity values for a given range and azimuth, ranging from $v_{\min}$ to $v_{\max}$. These values are averaged to give the output radial velocity value v_{mean} and the standard deviation $\sigma_{spatial}$ is calculated.

Output values from this processing step are radial files containing the parameters $P = v_{mean}, \sigma_{spatial}, N_s, v_{\max}, v_{\min}$ for the corresponding azimuth angles and for all ranges. We refer to the last 4 parameters of P as 'spatial quality factors'.

(2) **MERGING OF RADIAL FILES OVER TIME**

Typically seven successive radial files are merged to provide additional stability and to produce an estimate of temporal standard deviation. A time series containing N_t times is formed of the parameters P at each range and azimuth angle. To produce an output value in the merged file, the number of time points must exceed the minimum value set in ***Analysis options Line 1 Parameter 2.***

There are two user-selectable options for merging:

(a) Median filter: Analysis options Line 13 Parameter 1 Either = 0 OR =1

We calculate the median value v_{mean}^{med} of velocity v_{mean} over the time series. This defines the corresponding spatial quality factors. The temporal standard deviation σ_{temp}^{med} is calculated (i.e. the standard deviation of v_{mean}^{med}).

(b) Averaging : Analysis options Line 13 Parameter 1 = 2

The average value of the parameters P is calculated over the time series to give: $v_{mean}^{av}, \sigma_{templ}^{av}, N_s^{av}, v_{\max}^{av}, v_{\min}^{av}$. The temporal standard deviation σ_{templ}^{av} is calculated (i.e. the standard deviation of v_{mean}^{av}).

These procedures are repeated for all azimuth angles and ranges.

Output Parameters

Merged radial files contain the parameters

$$Q = \left[v_{mean}^{med}, \sigma_{spatial}^{med}, N_s^{med}, v_{\max}^{med}, v_{\min}^{med}, N_t, \sigma_{temp}^{med} \right] or \left[v_{mean}^{av}, \sigma_{spatial}^{av}, N_s^{av}, v_{\max}^{av}, v_{\min}^{av}, N_t, \sigma_{temp}^{av} \right]$$

for all ranges and calculated azimuth angles. We refer to the last 2 parameters of Q as 'temporal quality factors'.

(3) **SPATIAL INTERPOLATION/ SMOOTHING OF MERGED RADIAL FILES**

This is optional. If no further processing is desired, set
Analysis options Line 1 Parameter 3 = 0

However it may be desirable to reduce gaps in the angular coverage and eliminate wild velocities. Before further processing, azimuth angles in *Q* that are over land (as defined by ***angseg.sav***) are eliminated, resulting in a set of merged radials for each range cell and water segment containing velocities, angles
$v(i),\ \theta(i),\ i = 1,2.....,n$.

The degree of interpolation and smoothing is controlled be parameters set in
Header line 19 parameter 4: Width of Gaussian smoothing function W
parameter 5:Width of segment used for smoothing θ_{seg}
parameter 6: Velocity threshold v_{thresh}
parameter 7:Allowable angular gap θ_{gap}
Header line 22 parameter 1: Bearing resolution $\Delta\theta$

There are two user-selectable options:
(a) Gaussian smoothing and interpolation over angle:
Analysis options Line 1 Parameter 3 =1
The following steps are carried out.

(i) A set of angles $\alpha(j),\ j = 1,2.....,m$ is defined to cover the water segment with angular resolution $\Delta\theta$.

(ii) For a given angle, we define a surrounding angular segment *A* of width θ_{seg} **,** from $\alpha(j) - \Delta\theta_{seg}/2$ to $\alpha(j) + \Delta\theta_{seg}/2$ and identify the set of merged radials that fall within this segment.

(iii) Wild vectors are eliminated by calculating the median velocity of the merged radials $v(i)$ that fall within the segment *A*, and eliminating radials that differ from the median by more than the threshold velocity value v_{thresh}**.** This defines a reduced set of merged radials with velocities and azimuth angles that we write as $v_{seg}(i),\ \theta_{seg}(i),\ i = 1,2.....,n$. Defining the median velocity as $v_{seg}^{med}(j)$, we have:

$$\left| v_{seg}(i) - v_{seg}^{med}(j) \right| < v_{thresh}$$

(iv) The smoothed/interpolated radial velocity at angle $\alpha(j)$ is calculated by smearing the velocities using a Guassian window as follows:

$$v_{smooth}(j) = \frac{\sum_{i=1}^{n} v_{seg}(i) e^{-(\theta(i)-\alpha(j))^2/2W^2}}{\sum_{i=1}^{n} e^{-(\theta(i)-\alpha(j))^2/2W^2}}$$

The sums are taken over terms for which the difference between the angle $\theta(i)$ and $\alpha(j)$ is less than the limiting value θ_{gap}.

(v) A similar calculation is carried out for the temporal quality factors. However the meaning of the spatial quality factors is destroyed by the smoothing process and these quantities are set to 999.

(vi) This procedure is repeated for all the m values of $\alpha(j)$ that cover the water segment.

(b) Linear interpolation over angle:
Analysis options Line 1 Parameter 3 =2

With this option, a linear interpolation in angle is performed over gaps around each range cell that are less than the limiting value θ_{gap}. For values $v(i),\ \theta(i)$ and $v(i+1),\ \theta(i+1)$ from the merged set Q such that:

$$\Delta\theta < \theta(i+1) - \theta(i) \le \theta_{gap}$$

velocities at the intermediate angles are obtained by linear interpolation, e.g. at angle ϑ such that:

$$\theta(i) < \vartheta \le \theta(i+1)$$

the velocity is calculated to be:

$$v_{\mathrm{int}erp} = v(i) + \frac{(\vartheta - \theta(i))(v(i+1) - v(i))}{\theta(i+1) - \theta(i)}$$

A similar calculation is carried out for the temporal quality factors. The spatial quality factors are set to 999 for interpolated angles. This procedure is repeated wherever there is an azimuthal gap.