HF-Radar Network
Near-Real Time Ocean Surface Current Mapping

The HF-Radar Network (HFRNet) acquires surface ocean radial velocities measured by HF-Radar through a distributed network and processes the data to produce synoptic maps of surface currents in near-real time throughout coastal waters of the United States. Accurate and reliable surface currents are critically dependent upon the continued development of quality control (QC) metrics implemented at various stages of processing. Radial data is quality controlled during each of three main processing stages:

1) On-site at the Radar installation during production of georeferenced radial velocities with bearing determination from raw signal voltages
2) Upon acquisition of radial data by HFRNet Portals
3) During processing for production of synoptic surface current maps

Current QC and surface current processing algorithms in the HFRNet are documented below along with work in progress aimed at delivering the next generation of QC metrics.

On-Site Radial Velocity QC

Radial velocities derived from surface ocean backscatter of HF-Radar are dependent upon the quality of Doppler spectra formed from the reflected energy. Prior to estimating radial velocities, the manufacturer's software performs quality control on the Doppler spectra to ensure they are of suitable quality for velocity estimates. The internal software parameters used to determine whether spectra are acceptable have been empirically derived and refined over twenty years of research, development and user feedback. These tests include, but are not limited to:

- Noise floor detection and computation
- First order Bragg peak detection and measurement (Doppler frequency limits of first order are determined in CODAR systems)
- Second order peak detection and measurement
- Individual spectrum signal to noise ratio (SNR) computation for the first and second order peak
- First to second order ratio measurement

Doppler spectra that do not meet these criteria are rejected and radial velocities are not produced from them. Since these processes influence the production of radial velocities they are inherently part of the quality control process for surface currents.

HFRNet Portal QC

Radial data QC is performed upon file acquisition by HF-Radar Network (HFRNet) Portals and consists of basic file integrity and consistency tests. Any given radial file must pass all QC tests before being placed in the object ring buffer (ORB) for distribution

in the network. Performing basic QC on files upon acquisition prevents incomplete files from entering the network and allows downstream quality control to focus on specific tests such as radial velocity uncertainty. The specific tests performed on radial velocity files upon acquisition by a Portal are described below. Radial files failing to meet these criteria are not placed on the ORB for distribution.

File Format Independent Tests
All radial files, regardless of format, must have a timestamp consistent with the current date or a past date, not a date in the future. This test was established in order to protect against occasional files with timestamps from the far future (i.e. year 2040). Currently, all radial files acquired by HFRNet Portals report the data timestamp in the filename. The filename timestamp must not be any more than 72 hours in the future relative to the Portals' system time.

CODAR Range-Bin Format Tests
Range-bin format files are converted to LLUV format before distribution through the ORB. Several QC tests are performed upon converting the file including:

- The file name timestamp must match the timestamp reported within the file
- Files must contain radial data (bearing, velocity & uncertainty)
- As a minimum, the following metadata must be defined:
    - Site code (obtained from filename)
    - Timestamp (obtained from filename)
    - Site coordinates (reported within file)
    - Antenna pattern type (measured or idealized, obtained from filename)
    - Timezone (UTC or GMT only accepted, reported within file)

LLUV Format Tests
Before placing LLUV format files on the ORB the following tests are performed:

- The file name timestamp must match the timestamp reported within the file
- Radial data tables (Lat., Lon., U, V, …) must not be empty
- Radial data table columns stated must match the number of columns reported for each row (a useful test for catching partial or corrupted files)
- The site location must be within range:
    $-180 \le Longitude \le 180$
    $-90 \le Latitude \le 90$
- As a minimum, the following metadata must be defined:
    - Filetype (LLUV)
    - Site code
    - Timestamp
    - Site coordinates
    - Antenna pattern type (measured or idealized)
    - Timezone (UTC or GMT only accepted)

Surface Current Processing

Once radial data arrives at an HFRNet Node it is available for integration with other radial velocity measurements from neighboring sites through surface current mapping. The HF-Radar Network's primary proto-operational product is the generation of real-time velocities (RTV) which are ocean surface currents mapped from radial component measurements. There are three general steps in producing RTVs:

1) Radial data QC
2) Surface current mapping
3) Resolved surface current QC

Radial Velocity QC

Questionable radial velocity measurements are removed prior to mapping surface currents in order to reduce error. Two criteria must be met in order for a radial measurement to be used in deriving RTV solutions. The radial velocity must be (a) below the maximum radial magnitude threshold and (b) located over water. The maximum radial magnitude threshold represents the maximum reasonable radial magnitude for the given domain. This maximum radial threshold is 1 m/s for the West Coast of the United States and 3 m/s for the East/Gulf Coast. Landmasking of radial solutions is performed using polygons derived from the World Vector Shoreline database collected by the National Geospatial Intelligence Agency and obtained from the National Geophysical Data Center (http://rimmer.ngdc.noaa.gov/mgg/coast/getcoast.html).

Surface Current Mapping

Surface currents are mapped onto regional grids based on equidistant cylindrical projections with resolutions of 500m, 1km, 2km and 6km. Regional grids have been developed for the West Coast of the United States, the Gulf of Alaska and the Gulf/East Coast of the United States. In order to reduce the solution space, grid points over land and near the coast (within ½ km) are removed.

Surface currents are derived using a least squares fit to radial velocities (following Gurgel, 1994) within a pre-defined distance from each grid point. Radials must come from at least two different sites and there must be at least three radials available in order to produce a velocity estimate for a given grid point. The search radius around each gridpoint is approximately 30% greater than the grid resolution. Actual search radii for each grid resolution defined are given below:

Grid Resolution (km)	Search Radius (km)
0.5	0.75
1	1.5
2	3
6	10

The contribution of each site's radials to solutions for a given resolution are currently determined solely by the site's operating frequency. Sites operating near 25 MHz and higher contribute to solutions at 1 km resolution, 12 MHz and higher sites contribute to

solutions at 2 km resolution and all sites contribute to solutions at 6 km resolution. Site selection for each resolution will eventually be determined by the radial range resolution instead of operating frequency.

RTV QC
Surface currents derived from integrated radial velocity measurements must not exceed the following thresholds:

1) Maximum total speed threshold
2) Maximum Geometric Dilution of Precision (GDOP) threshold

Like the maximum radial speed threshold, the maximum total speed threshold represents the maximum reasonable surface velocity for the given domain. The maximum total speed threshold is 1 m/s for the West Coast of the United States and 3 m/s for the East/Gulf Coast domain.

GDOP is a scalar representing the contribution of the radial (bearing) geometry to uncertainty in velocity at a given gridpoint. Higher GDOP values indicate larger covariances associated with the least square's fit used in obtaining the solution. The GDOP maximum threshold is 10 for all domains. However, near-real time applications such as web display apply a more conservative maximum threshold of 1.25 to RTV solutions.

Active Developments in Quality Control
A variety of MUSIC algorithm decision metrics will be collected and statistically analyzed for Quality Control purposes. These QC metrics include (but are not limited to):

1. Signal to noise ratio (SNR) for each antenna
2. Cross spectra covariance matrix eigenvalues
3. Single and Dual angle solution
    a. Direction of Arrival (DOA) metrics (magnitude)
    b. Direction of Arrival (DOA) function widths (3 dB)
    c. Signal amplitude matrices

Distributions for all QC metrics will be generated, and first and second order moments will be determined and continuously maintained. When radial solutions have QC metrics that fall below a threshold (e.g., the mean value minus three standard deviations), they will be flagged as having low quality. An overall quality metric for each radial will be computed, for example, on a scale of 0-5. A metric of 0 would indicate low values of all metrics listed above and poor quality; a score of 5 would indicate high values of all metrics and good quality. The overall quality metric for each radial solution will be displayed in conjunction with the radial output. Users will be able to view plots of radial quality metrics over the observation area of the HF RADAR. This will indicated spatial areas with low quality solutions.

In the future, the overall quality metrics can be passed on with the radial solutions to the total current vector algorithm, and poor quality radial data can be filtered out before the total current vectors are computed.