PROGRESS IN SAR SHIP DETECTION AND WAKE ANALYSIS

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OUTLINE

- K-distribution
  - New simple asymptotic approach for large threshold values
  - Parameter estimation difficulties
  - Implications for ship detection
- Ship Wakes
  - Study started at RMC, Kingston using RADARSAT-2 images, AIS, plus other information.
  - Findings and implications for MDA
- See Web site for papers

K-Distribution

- Ships are bright blobs in SAR images
  - Need statistics of clutter background for CFAR
- K-D excellent description of radar clutter
  - Basis is modulated complex Gaussian clutter
- Physical / statistical basis incomplete
  - Modulating distribution assumed gamma
- Modified Bessel functions of 2nd kind.
  - Computational complexity
- Approximation for tail values needed

K-D APPROXIMATION

- Low PFA: interested in tail of distribution
  - Represent pdf as an integral
  - Use steepest descents
- Accurate to better than 0.1% (PFA = 10^{-9})
- Not sensitive to statistics of modulation
  - Implies that K-D has sound physical basis
- Basic code can be implemented in < 18 lines of C# or C++.

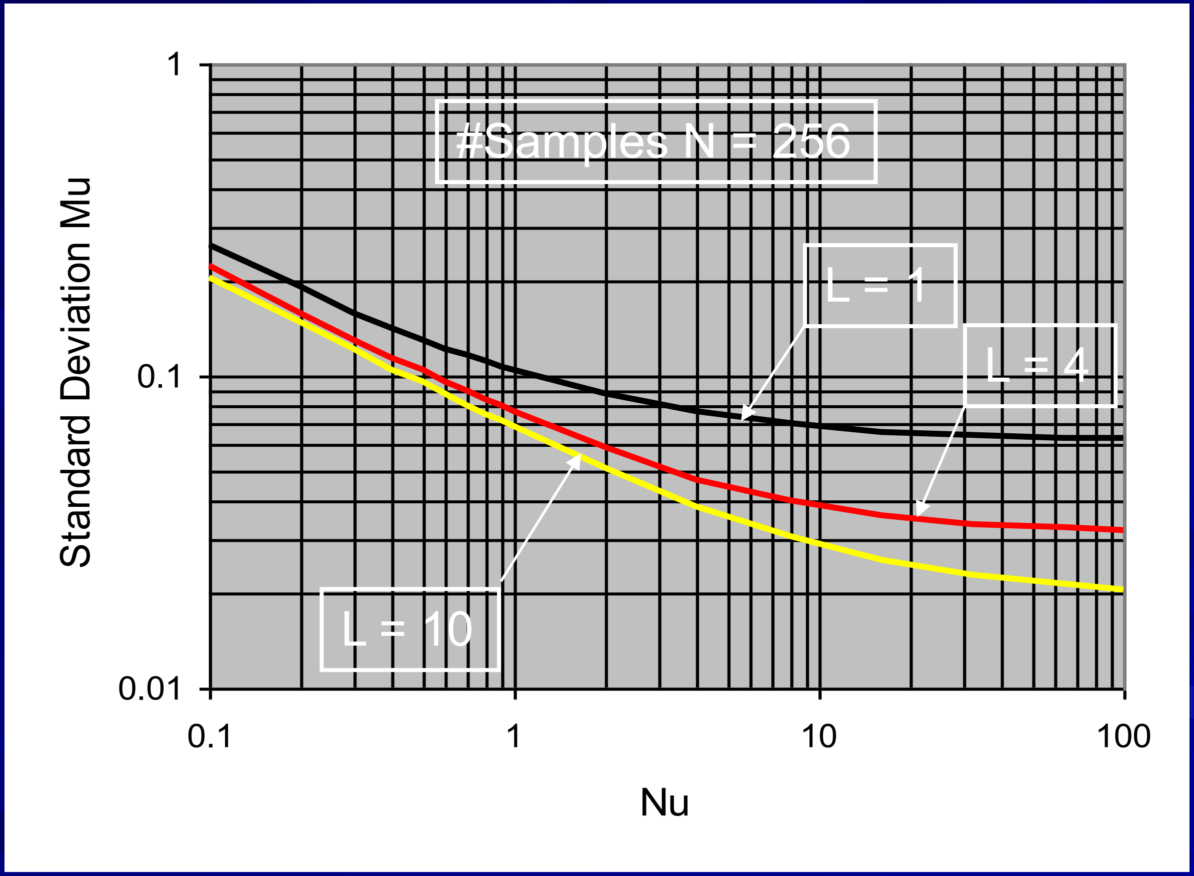
THRESHOLD COMPARISON

LOOKS		L = 1		L = 4	
PFA	ν Smoothness	Accurate	Approx.	Accurate	Approx.
10^{-9}	0.5	214.7	214.8	91.59	91.62
10^{-9}	5.0	47.49	47.50	18.796	18.800
10^{-9}	50.0	24.24	24.24	8.841	8.842
10^{-6}	0.5	95.43	95.55	46.40	46.43
10^{-6}	5.0	25.69	25.70	11.263	11.267
10^{-6}	50.0	15.337	15.338	6.128	6.128

PARAMETER ESTIMATION

- Need to estimate mean and order parameter
  - Number of looks is given
- Can estimate optimal performance
  - Uses Fisher information (Cramer Rao)
- Parameter variance depends on number of independent samples, N
- Need to consider bias
- Note: Parameters need not be integer

OPTIMUM MEAN INTENSITY
Cramer Rao Bound

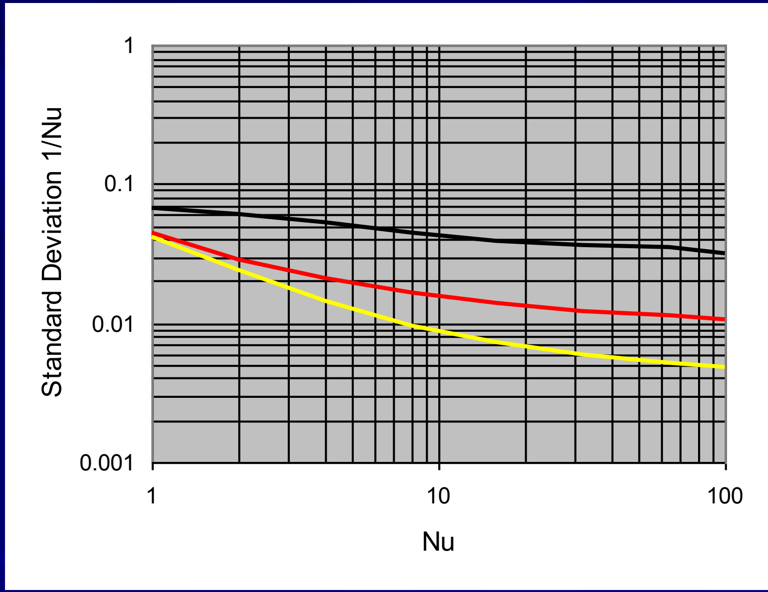


Spiky

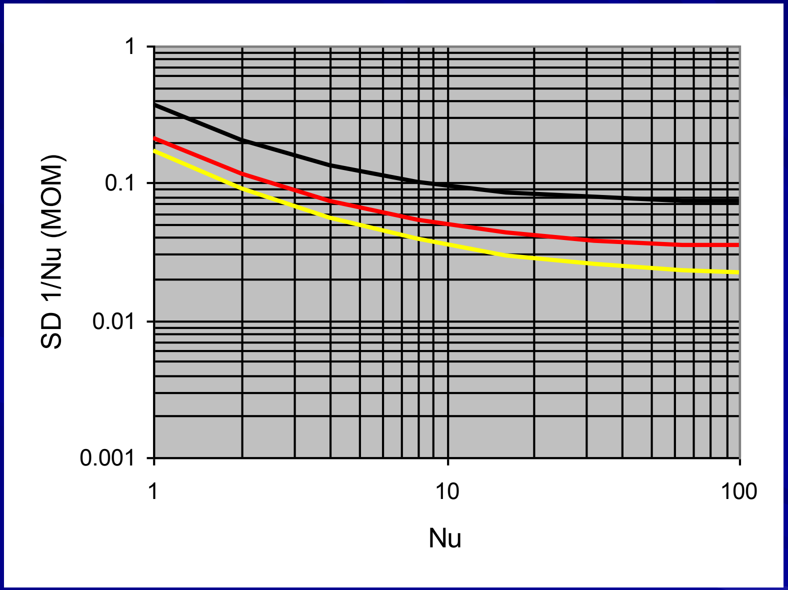
Rayleigh

SDs USING MOM: N = 1000

Optimum

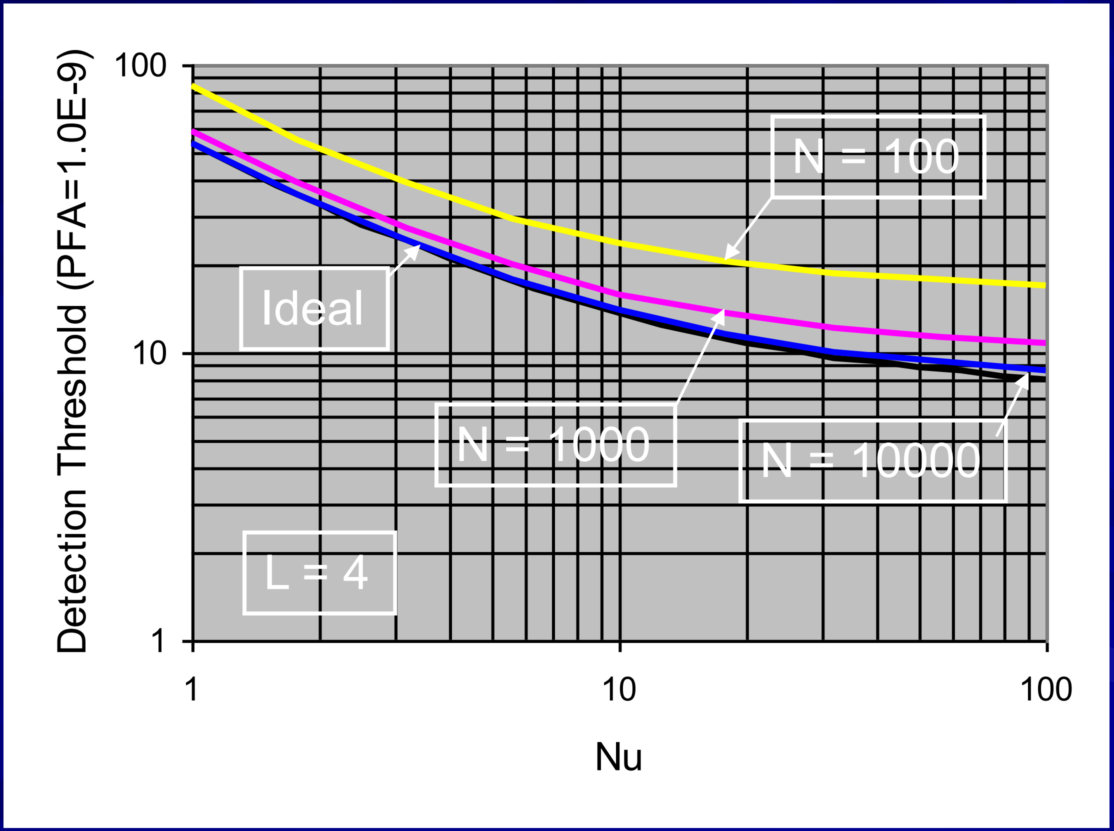


Practical



L = 1 Black; L = 4 Red; L = 10 Yellow

PRACTICAL THRESHOLD



Spiky

Rayleigh

CONCLUSIONS (1)

- K-distribution approximation will reduce computational complexity for ship detection
- Methodology adds support to use of K-distribution
  - Insensitivity to modulating distribution
- Mean of K-distribution can be estimated as usual
- Parameter variance may bias detection thresholds by large factors if N < 1000
  - Very important in spiky clutter
  - Without correction, PFA may increase by orders of magnitude
  - If corrected, probability of ship detection is reduced
  - Adaptive pixel block size (N) is desirable in variable clutter

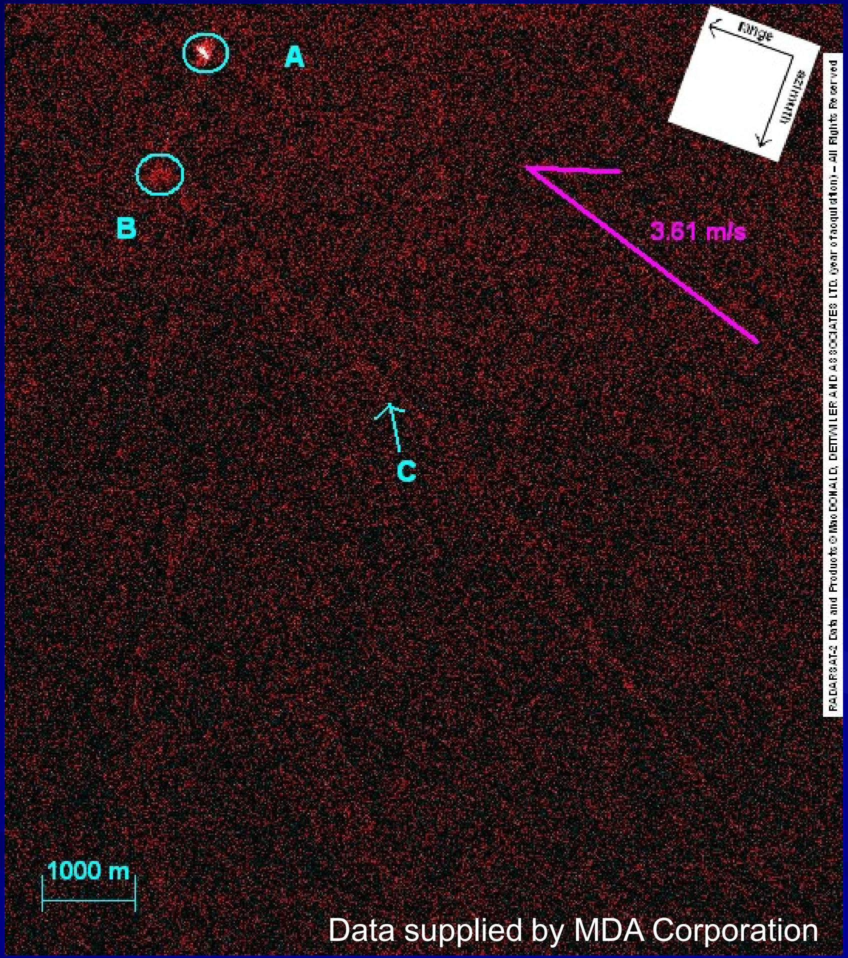
SHIP WAKES

- Turbulent wake study with Dan Roy at RMC
  – RADARSAT-2 images
  – AIS
  – Other ship information about propulsion system (Ship owners, Internet, etc.)
- Analysis (60 ships) includes
  – Twin screws/single screw
  – Left/right handed screws

RMC RESULTS

- Wakes not usually visible when wind speed U > 6 m/s
- Ship speed V is important: if U < 6 m/s && V > 5 m/s, 80% of wakes are visible
- Bright line on side of wake consistent with propeller flows (swirling and axial) and wind direction
  - Wakes from shallow twin screws tend to be visible

RSAT-2: QUEEN OF ALBERNI



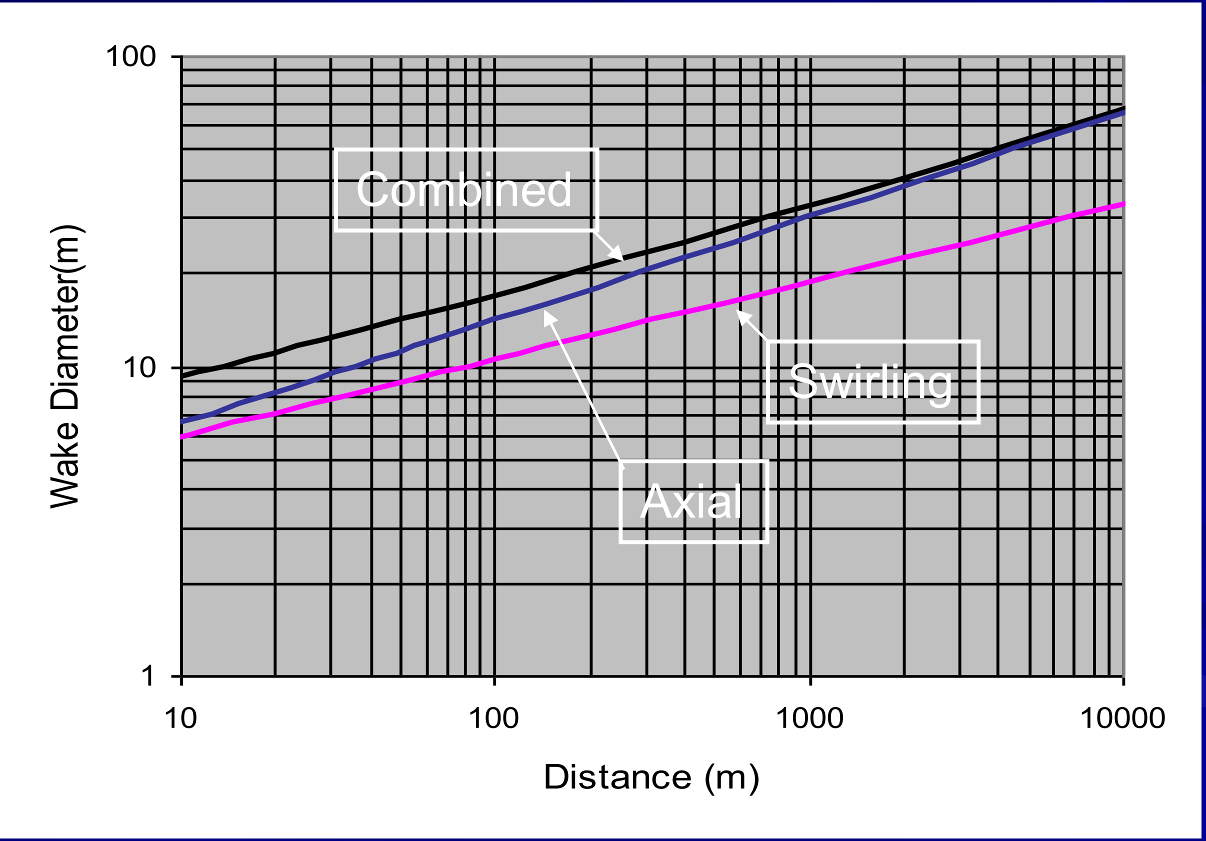
Q of A Parameters

Parameter	
Length (m)	139
Maximum Beam (m)	27.1
Mean Draft (m)	5.5
Maximum Draft (Prop. Tip, m)	5.72
Block Coefficient (estimated)	0.6
Number of Propellers	1
Number of Blades	4
Propeller Shaft Depth (m)	3
Propeller Diameter (m)	5
Propeller Type	CPP
Service Speed (knots)	19
Propeller Speed @ 19 knots (rpm)	~170
Maximum Power (MW)	8.83

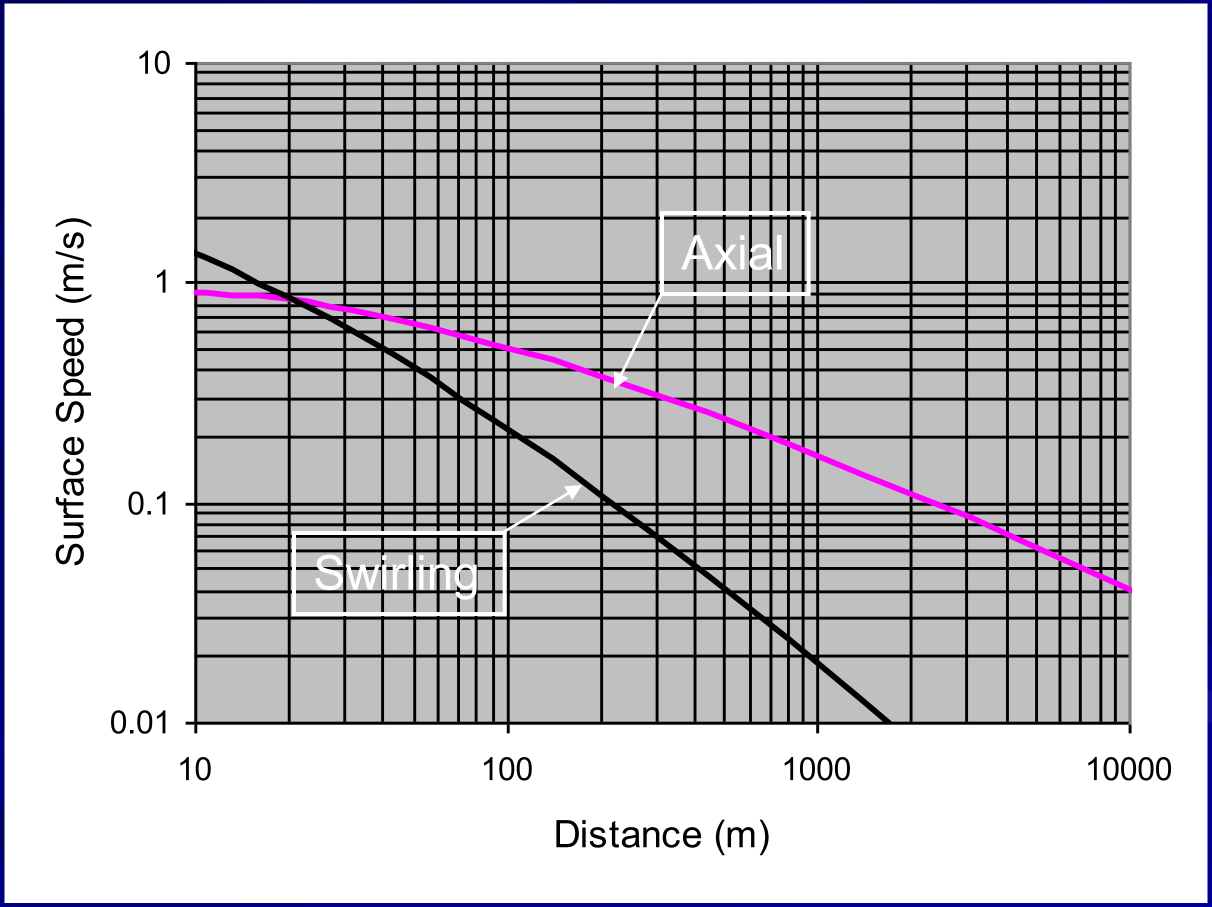
COMBINED SWIRLING AND AXIAL WAKE

- Consider both linear and angular momentum in propeller wake
  - Modify Prandtl's approach to theory
  - Estimate fluid linear and angular momentum using standard engineering methods
- Apply to Queen of Alberni (BC Ferries)

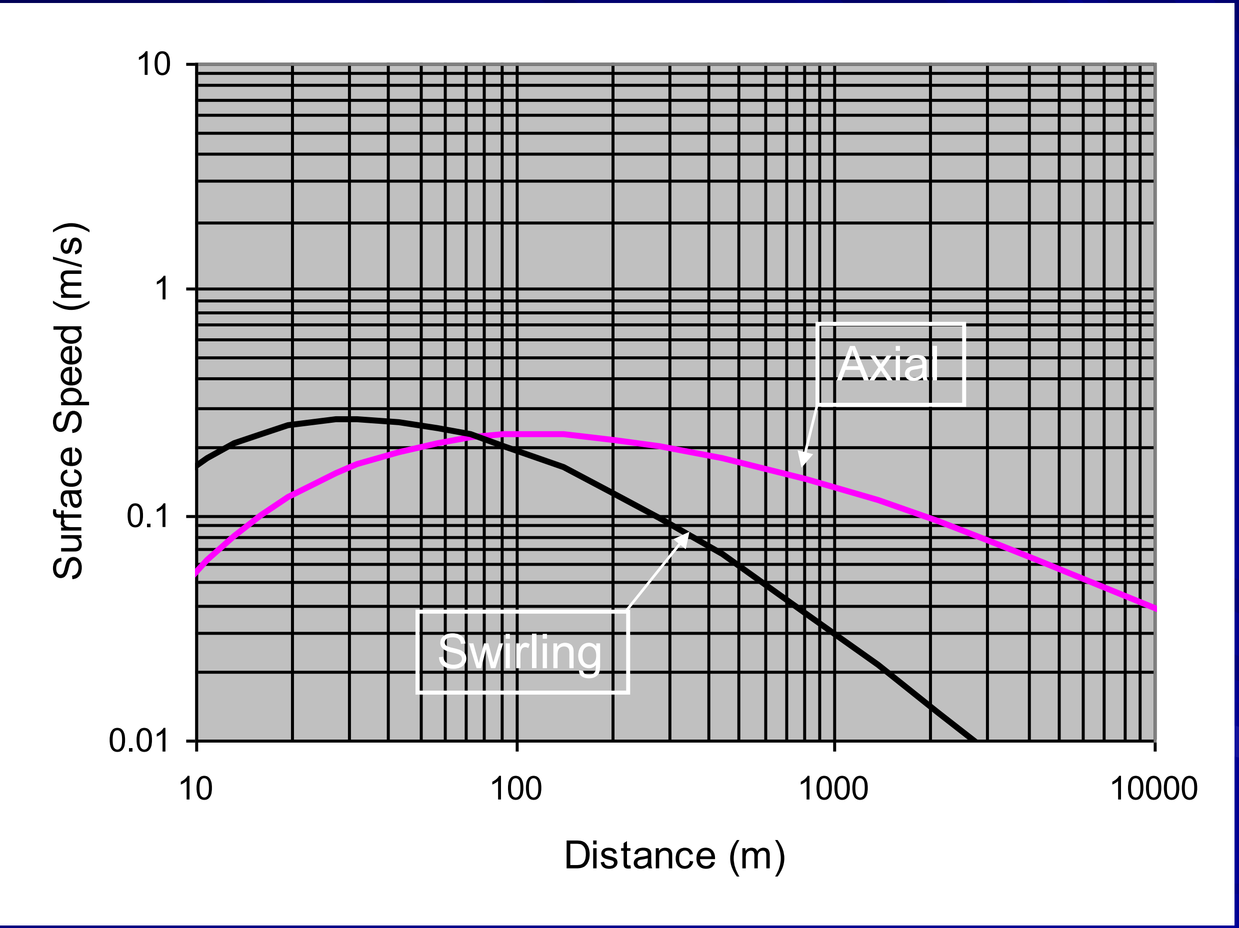
Q of A Wake Diameter



Queen of Alberni Maximum Surface Flow Speed



Deep Screw Case Maximum Flow Speed



CONCLUSIONS (2)

- Surface flows in the turbulent wake can be large compared with Bragg group velocity
  - Expect significant radar wake visibility for long distances
- Swirling component dominates axial flow immediately astern and especially when screws are deep
- Wake characteristics can be used to verify ship
- Note:
  - Hydrodynamic wake width is only one factor in radar wake width. Others are flow speeds, ambient wind and waves, radar effects and geometry.

END

Thank You All!