STATUS OF SHIP WAKES IN SAR IMAGERY

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**Status Of Ship Wakes In Sar Imagery**

The original document contains color images.
Contribute to Maritime Domain Awareness
- Extraction of Independent Target Parameters
- Confirmation/Validation of other Data (AIS)

Need better Understanding of Ship Wakes

Program of Study started at RMC, Kingston
- RADARSAT-2 Images
- AIS Traffic Pattern Analysis
  - Compare Open Ocean with Lake Ontario/Seaway
RADAR WAKE

- Ship
- Kelvin Arm
- Azimuth Shift
- Turbulent Wake
- Transverse Waves
- Range

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INTERNAL WAVE WAKES

Georgia Strait

Ship

Range

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OPTICAL WAKE

Kelvin Wake Divergent Waves

Turbulent Wake

Vancouver Island Ferry

Kelvin Wake Transverse Waves
Wavelength about 65 m.
OUTLINE

- Information from Wakes
- Gravity Wakes (Deep and Shallow Water)
  - Kelvin
  - Internal
  - Unsteady (Surface and Internal)
- Turbulent Wake
- Surface Scattering
- SAR Effects
WAKE INFORMATION

- Ship Course
- Ship Speed
  - From Wake Offset
  - From Kelvin Transverse Wavelength
- Potential for Information about:
  - Propulsion System
  - Hull Form/Damage
KELVIN WAVELENGTHS

Transverse Wavelength

Wavelength (m)

Ship speed (kts)

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SIMULATED KELVIN WAKE

Point Source

Cusp Waves

Transverse Waves

Divergent Waves
SIMULATED INTERNAL WAKE

Plot of Horizontal Wake Velocity

- Speed = 15 m/s
- Layer Depth = 15 m
- Fractional Density Change = 0.01
REAL AND SIMULATED
UNSTEADY GRAVITY WAKES

- Sinusoidal (or Random) Excitations
- Excitation due to
  - Heave and Pitch
  - Screws (Blade Frequency)
  - Reflection of Ambient Waves from Hull
- Wake Angle may be much Larger/Smaller than Kelvin Angle (39 degrees)
- Wave Crest Patterns can be Novel
UNSTEADY SINUSOIDAL

Omega = ΩU/g; Critical Omega = 0.25

Wake for Omega = 1.0
PROPELLER WAKE

Soloviev et al, 2008
TURBULENT WAKE

- Comprises Random Vortices
- May contain Steady Flows
- Broadens slowly with Distance Astern, \( x \)
- Width, \( b = Cx^{1/n} \)
- Exponent \( 1/n \) depends on Environment and Propulsion
# T-WAKE AND PROPULSION

<table>
<thead>
<tr>
<th>Reciprocal Exponents, $n$</th>
<th></th>
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<tbody>
<tr>
<td>Large linear momentum in wake. Under sail.</td>
<td>3</td>
</tr>
<tr>
<td>Large angular momentum (swirl). Small linear momentum. Single screw.</td>
<td>4</td>
</tr>
<tr>
<td>Negligible mean linear/angular momentum but linear momentum variance high. Under sail at low speed or non-screw propulsion.</td>
<td>≥4</td>
</tr>
<tr>
<td>High swirls. Small mean linear and angular momenta. Two contra-rotating screws.</td>
<td>≥5</td>
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</tbody>
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AMBIENT SEA

Sea State = 4
RADAR SCATTERING

- Bragg Scatter
  - Wright, 1968
- Wave Breaking
- Slope Modulation
- Surface Flows
  - Modify Bragg Waves and Trigger Breaking
- Surfactants
SAR EFFECTS

- Speckle
- Velocity Bunching
- Synthetic Aperture Time (in Ultrafine)
- Often Insufficient Resolution
  - Moire Fringe Effects due to Aliasing
- Bragg Wave Velocities (in Ultrafine)
TRAFFIC FROM AIS

Aug 6th, 2008
6:58LT
CONCLUSIONS

- Wake Theory to be Validated and Completed
  - Basics, Simulations and Visibility
- Inverse Problem Unexplored
- Significant Potential for MDA in Cross-Validation
  - Ship Velocity
  - Low Grade but Valuable Information for Fusion
  - Does not compensate for no AIS Fusion

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