Numerical Simulation of the Wind Stress Effect on ALOS PALSAR Images of Far Wakes of Ships

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Introduction

• Studies of remote sensing and hydrodynamics of ship wake are important for ship detection, oceanic safety, and fishing and pollution control.
• Hydrodynamics of far wakes of ships are not well known.
• Environmental conditions (wind, waves, stratification, surfactants, currents, etc.) and factors from a ship (structure of ship, speed and direction of ship, bubbles, etc.) make complexities of ship wake hydrodynamics.
• This study is aimed at numerical simulation of the wind effect on the ship wake visibility in SAR images
Structure of Ship Wake

Adapted from Hennings et al., 1999
CFD Fluent

- Computational fluid dynamics (CFD) software
- Non-hydrostatic model
- Broad physical model capabilities – flow, turbulence, heat transfer, reactions, etc.
- Used with meshing software (i.e. Gambit)
- Post processor – plots, contours, pathlines, animations, etc.
- Detached eddy simulation (DES) is used for all models for this study
Model based on ship hull and propeller models made by Dr. Shin Hyung Rhee (Dept. of Naval Architecture & Ocean engineering, Seoul National University)
Grid scheme for far wake

- 1,875,000 cells – top cell = 1cm, longitudinal (x) increment = 0.5m, lateral (Y) increment = 0.2m
- Periodic boundary for longitudinal direction
- Pressure inlet & outlet in laterally when wind force applied
Initial condition

Three wind cases – no wind, weak wind (4.0 m/s), and stronger wind (8.5 m/s)
Result (no wind)

Cross section

Top view

Longitudinal (along the wake) velocity (m/s)
Result (weak wind - 4 m/s)

Cross section

Top view

Longitudinal (along the wake) velocity (m/s)
Result (stronger wind – 8.5 m/s)

Cross section

Top view

Longitudinal (along the wake) velocity (m/s)
No wind (t = 200s) – top view

Polarization: HH
Frequency: 9.65 GHz
Incidence angle: 35 degs

Ship-wake model (SW 3.2.0) of A. Fujimura (NSU) and radar imaging algorithm (M4S 3.2.0) of R. Romeiser (UM)
Weak wind (t = 200s) – top view

Ship-wake model (SW 3 2.0) of A. Fujimura (NSU) and radar imaging algorithm (M4S 3.2.0) of R. Romeiser (UM)
Stronger wind ($t = 200s$) – top view

8.5 m/s wind

Ship-wake model (SW 3 2.0) of A. Fujimura (NSU) and radar imaging algorithm (M4S 3.2.0) of R. Romeiser (UM)
Simulating PALSAR image

- Frequency: 1.27 GHz
- Polarization: HH
- Incidence angle: 35 degrees
- Time: 200s

Ship-wake model (SW 3.2.0) of A. Fujimura (NSU) and radar imaging algorithm (M4S 3.2.0) of R. Romeiser (UM)
Wind 6 m/s

Radar look

Incidence angle 34.3 deg
Conclusion

• A hydrodynamic model of far wakes of ships in combination with a radar imaging algorithms has been able to reproduce the effect of wind on the wake structure in PALSAR images.

• Upwind side (convergence zone) of the turbulent wake in simulated SAR images appears to be bright, while downwind side (divergence zone) of that appears to be dark.

• The model results are qualitatively consistent with the images of ship wakes from ALOS PALSAR.
Future works

- More information of ship (size, forward speed, shape, number of screws, etc.), and other factors (bubbles, waves, stratification, surfactants, currents, etc.) will be needed for more realistic model and understanding hydrodynamics of far wakes of ships.
- The new approach developed in this work can be useful for simulation of other fine scale features on the sea surface (sharp frontal interfaces, freshwater plumes, etc.) and their interpretation in high-resolution SAR images.
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