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Numerical Study on Polarimetric SAR Imaging Response to Ocean Current

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1. Introduction

Ocean surface current (OSC) is one of the key marine dynamic elements which dominates the global circulation of carbon and heat. By modulating ocean surface topography and roughness, the ocean currents could be characterized on synthetic aperture radar (SAR) images. In this study, we aim to numerically investigate the polarimetric SAR imaging responses to two-dimensional ocean surfaces with currents and waves. The well-developed radar imaging model (RIM) is employed to conduct the numerical simulations under various frequencies, incidence angles, wind speeds and full polarizations. The current surface with a typical internal wave phenomenon generated by the MITgcm numerical mode is used, which has resolution of about 1/200° in longitude direction and 1/60° in latitude direction. Current modulation of wave spectrum is considered in the KHCC03 spectrum.

2. Methodology

A. Modulation of ocean wave spectrum by various factors

$$B(\boldsymbol{\kappa}) = B_0(\boldsymbol{\kappa})\left[1+\int T(\boldsymbol{\kappa},\mathbf{K})\exp\left[i(\mathbf{K}\cdot\mathbf{x}-\Omega t)\right]d\mathbf{K}\right]$$

Current-modulated Spectrum; Background Spectrum; comprehensive modulation transfer function

dimensionless relaxation time

$$T(\boldsymbol{\kappa},\mathbf{K}) = \frac{\tau}{1+i\cdot r}\left[\frac{m_\kappa^{ij}\hat{u}_{i,j}}{\omega}+\hat{\beta}+\frac{\hat{I}_{sw}+\hat{I}_{pc}}{B}\right]$$

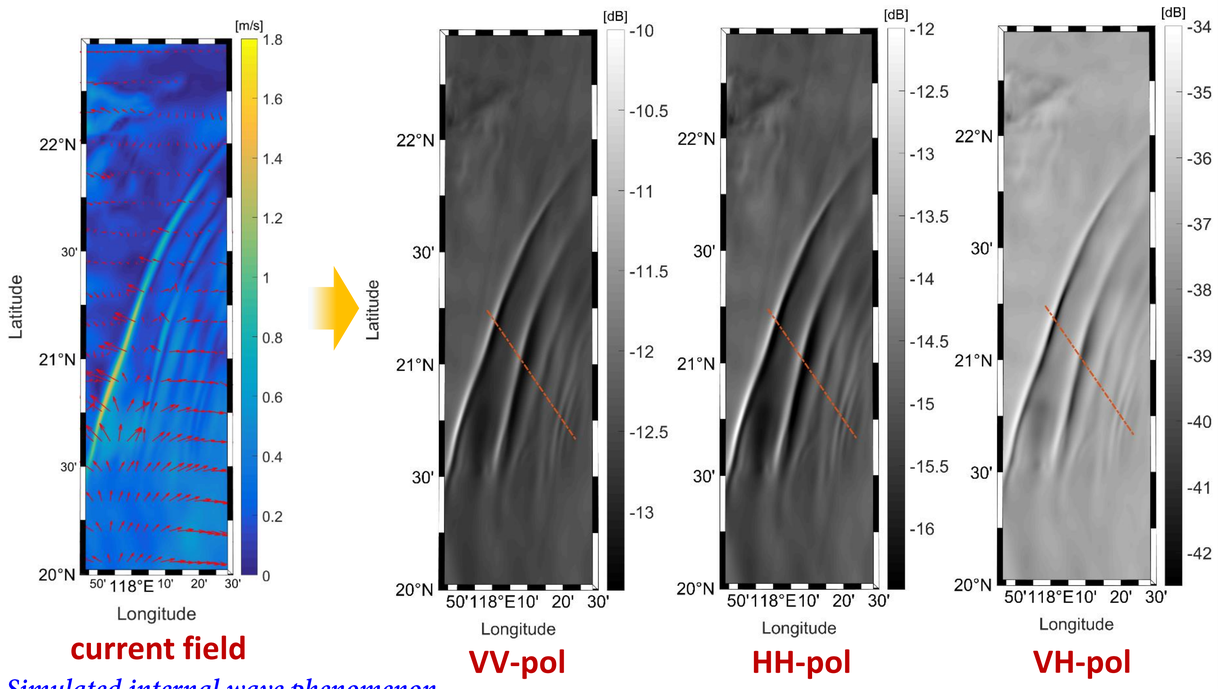
- Current modulation: $m_\kappa^{ij}\hat{u}_{i,j} \approx m_\kappa \nabla\cdot\mathbf{u}$ Divergence of current field
- Wind modulation: mainly related to friction wind speed
- Modulation by wave breaking effect to short waves and parasitic capillary wave

B. Fully-polarized radar imaging model (RIM)

$$\sigma^0_{RIM} = \left[\sigma^0_{KA-GO}+\sigma^0_{Bragg}\right](1-q)+\sigma^0_{wb}\cdot q$$

σ^0_{KA-GO}: specular component; σ^0_{Bragg}: Bragg scattering component; q: wave breaking fraction; σ^0_{wb}: Wave breaking contribution

C. Simulation Results

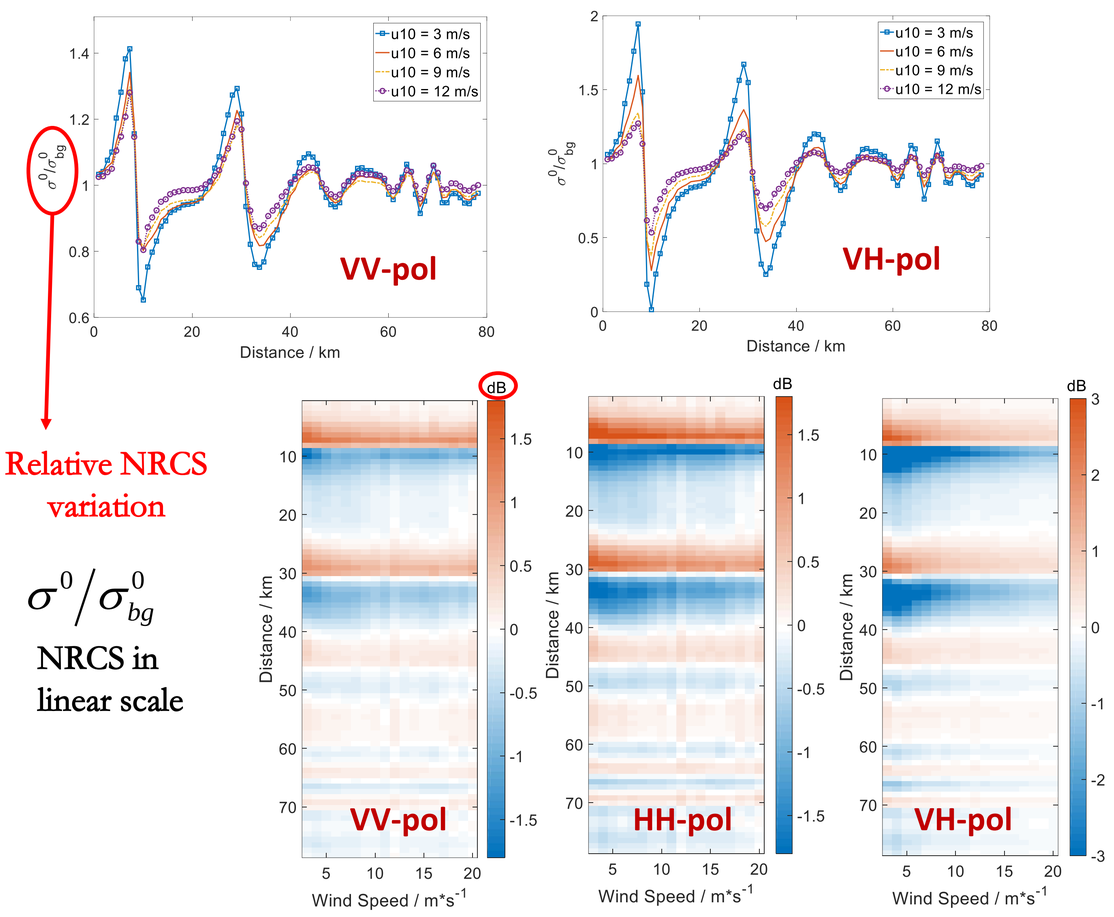


Simulated internal wave phenomenon in South China Sea generated by the MITgcm numerical mode

NRCS images simulated by RIM model using the current field

3. Results and Discussions

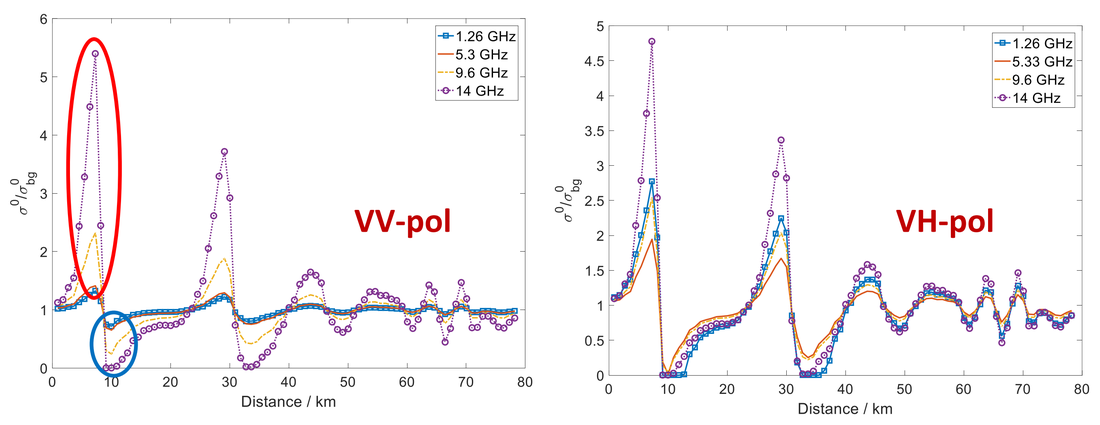
Current modulation at various wind speeds



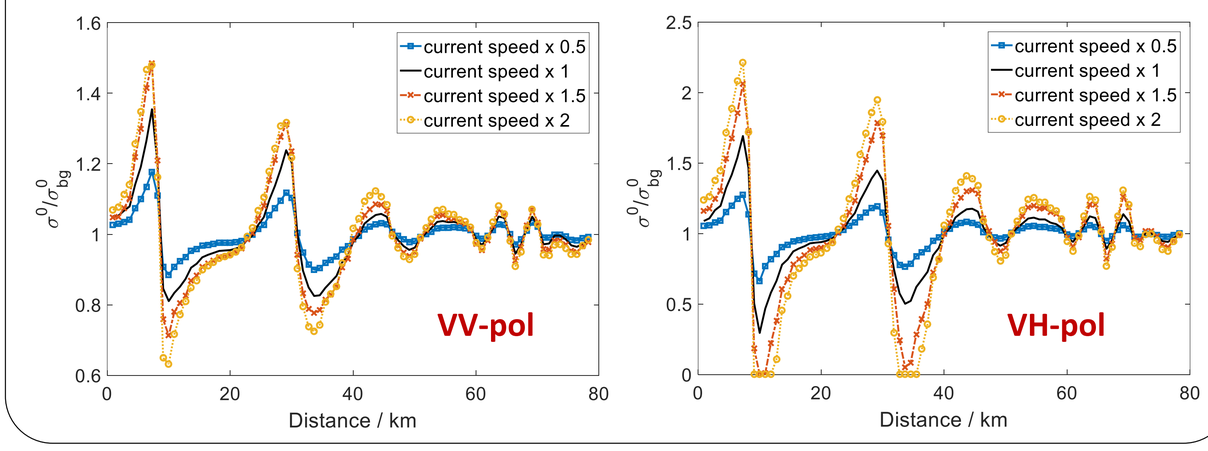
Relative NRCS variation

σ^0/σ^0_{bg} NRCS in linear scale

Current modulation at various frequencies



Current modulation at various current velocities



4. Conclusion

- We numerically investigate the polarimetric SAR imaging responses to two-dimensional ocean surfaces with currents using the radar imaging model (RIM).
- Current modulation effect on ocean scattering decreases with the wind speed increasing, particularly for strong current modulation.
- At low wind speeds, the current effects on ocean scattering is larger at higher frequency for co-polarizations.
- Ocean scattering is more sensitive to converging currents comparing to the diverging currents..