Wave Retrievals From ScanSAR Images Under Tropical Cyclone Conditions

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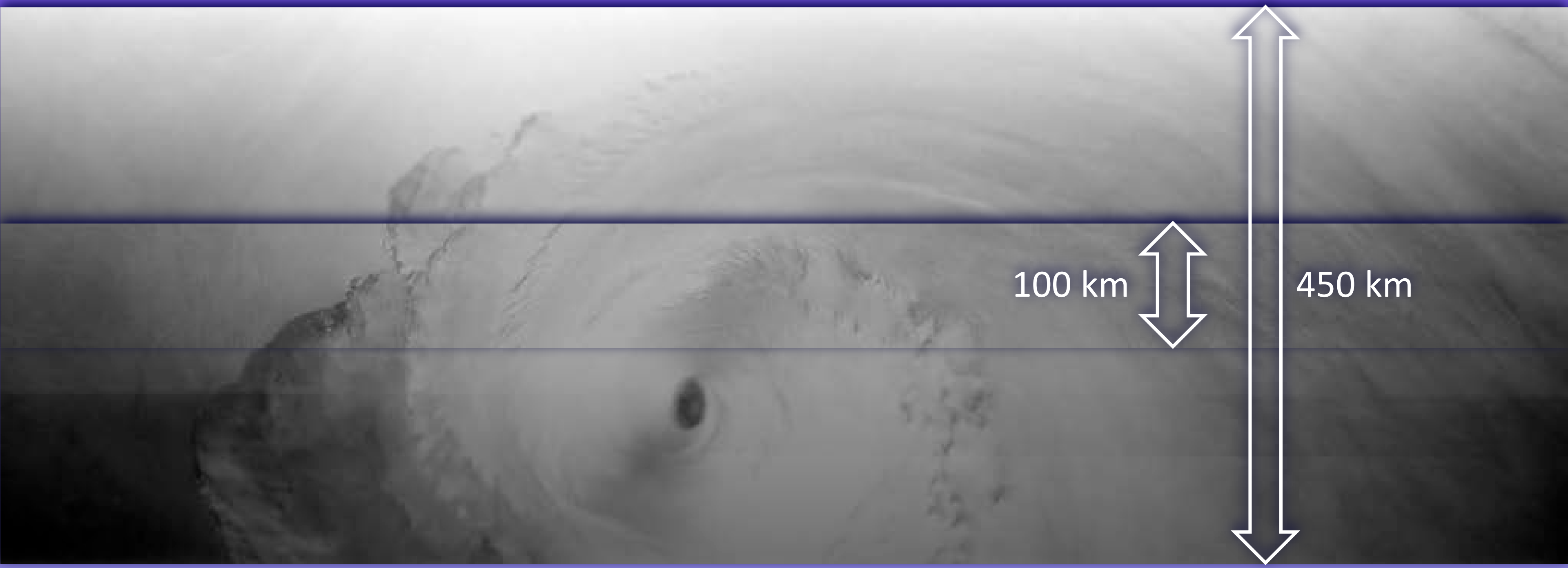
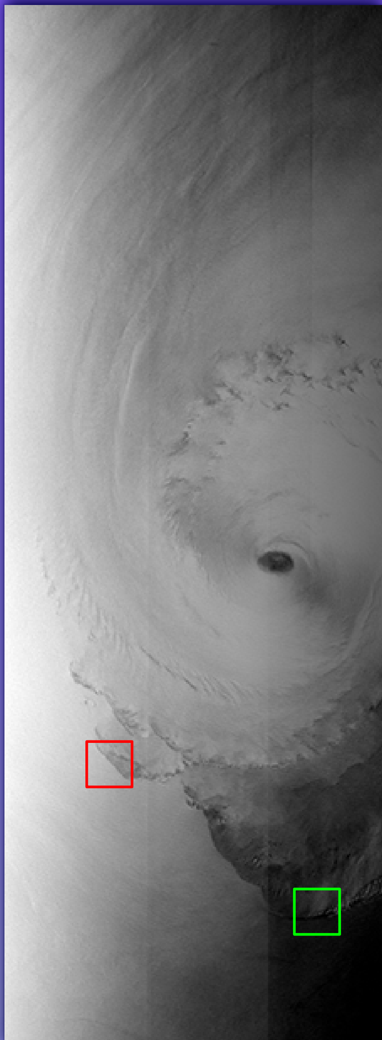
ScanSAR vs. Stripmap SAR

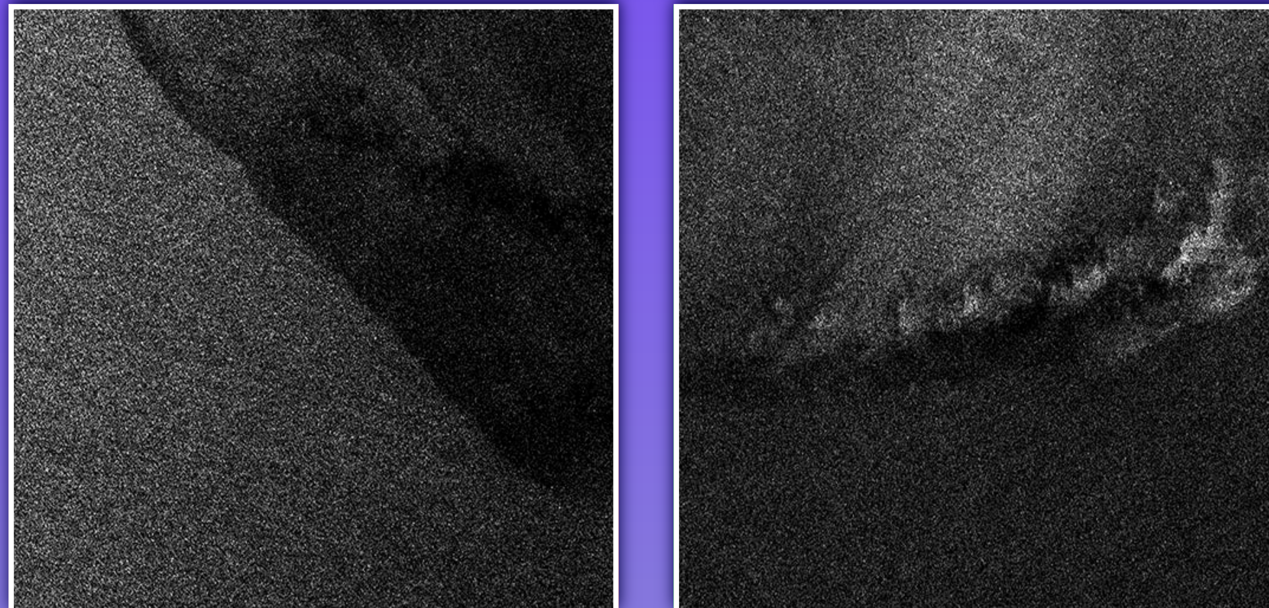


- Much better coverage, scanning over multiple adjacent sub-swaths
- Reduced spatial resolution (100 m vs. 25 m at C band)
- Sub-swath seams and scalloping cause additional problems

ScanSAR Imaging Artifact: Scalloping



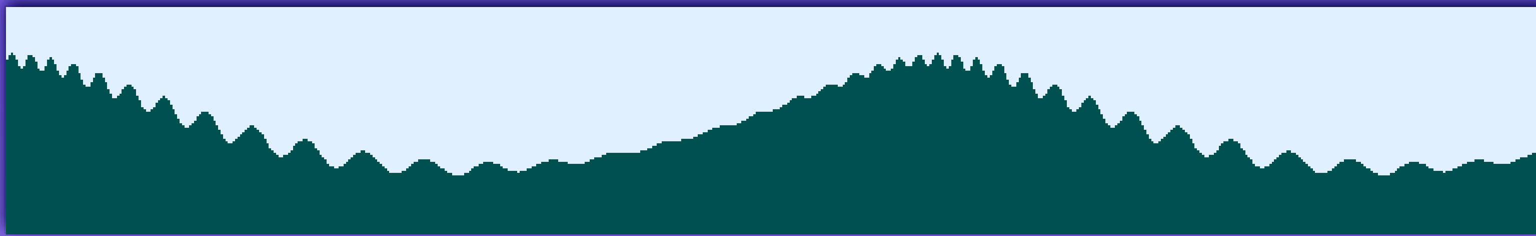
RADARSAT-1 ScanSAR image of hurricane Helene (2006), 450 km × 1240 km



Two subsections of 1024 × 1024 pixels = 51.2 km × 51.2 km

- Wave-like periodic intensity modulation artifact
- Found in many ScanSAR images of ocean scenes from various satellites and SAR processors
- Big problem for wave and wind retrievals
- Post-processing filter developed in ITOP

SAR Imaging of Ocean Waves



- Tilt modulation of scattering geometry
- Hydrodynamic modulation of small-scale roughness
- Nonlinear SAR imaging artifacts ("velocity bunching")
- Modulation strengths vary with wavelength and direction, as well as with wind vector, local incidence angle, etc.
- Imaging mechanism gets more complicated and nonlinear under storm conditions (large amplitudes, breaking, spray...)

MTF-Based Wave Retrieval Algorithm

SAR Image Intensity Array

↓

Fourier Transform

↓

Image Spectra

↓

Modulation Transfer Function

↓

Ocean Wave Spectra

↓

Analysis

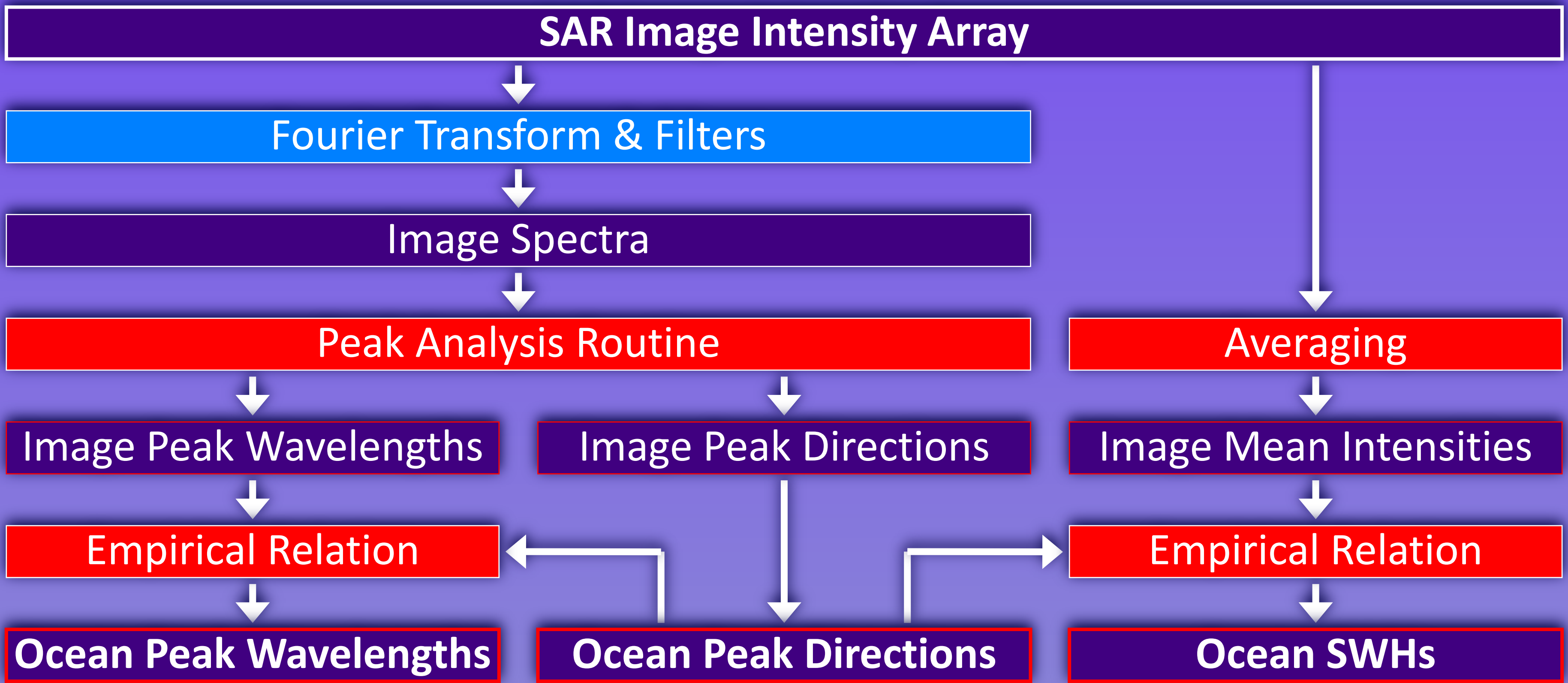
↓

Peak Wavelengths, Directions, SWHs

- Neglects nonlinearities of imaging mechanism
- Neglects wavelengths below spatial resolution
- Neglects specific high sea state effects
- Requires detectable wave signatures to work

- **Idea: Empirical algorithm could account for neglected effects, lead to improvements without complex theoretical modeling**
- **Wind algorithms have always used empirical models**

New Empirical Wave Retrieval Algorithm



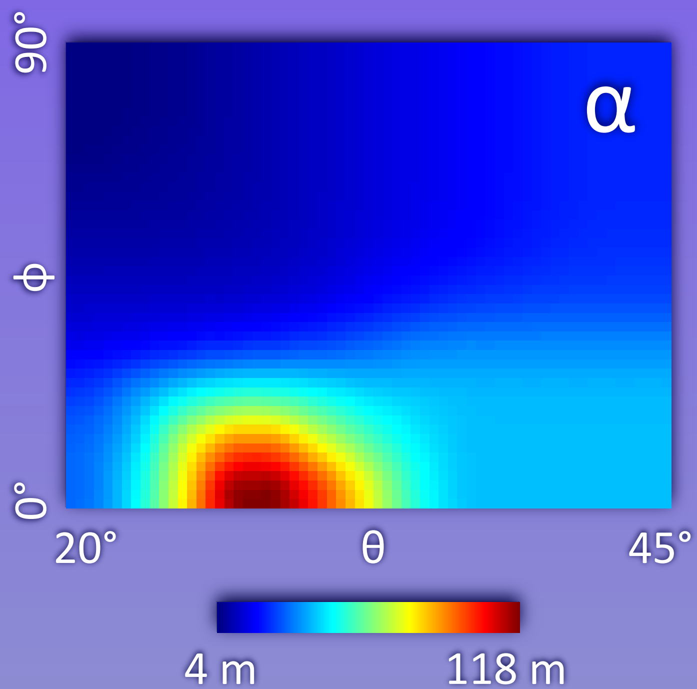
- Developed using RADARSAT-1 hurricane images and WAM spectra
- SWH depends most strongly on mean intensity & peak direction

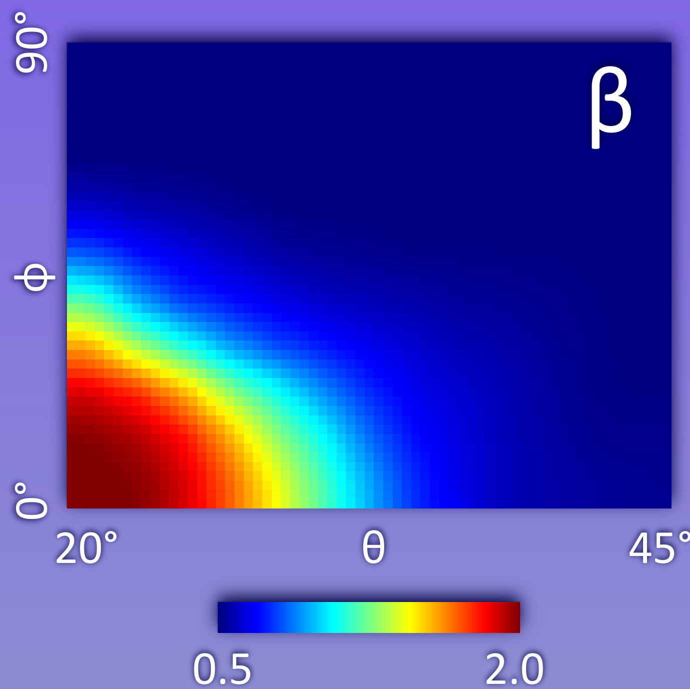
→ **Extrapolated peak directions permit SWH estimates everywhere; no wave signatures required!**

Empirical SWH Model Function

$$SWH = \alpha(\theta,\phi)\sigma_0^{\beta(\theta,\phi)}$$

- σ_0 = NRCS
- θ = incidence angle
- ϕ = relative peak direction





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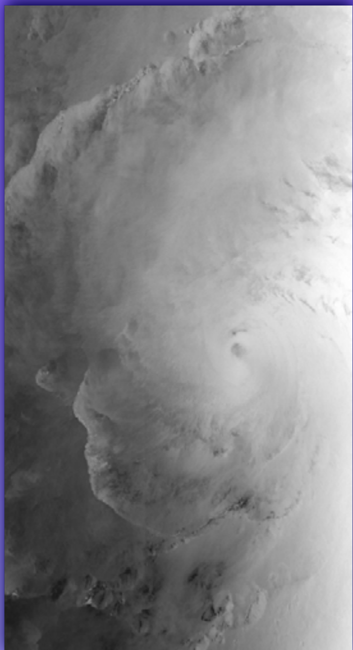
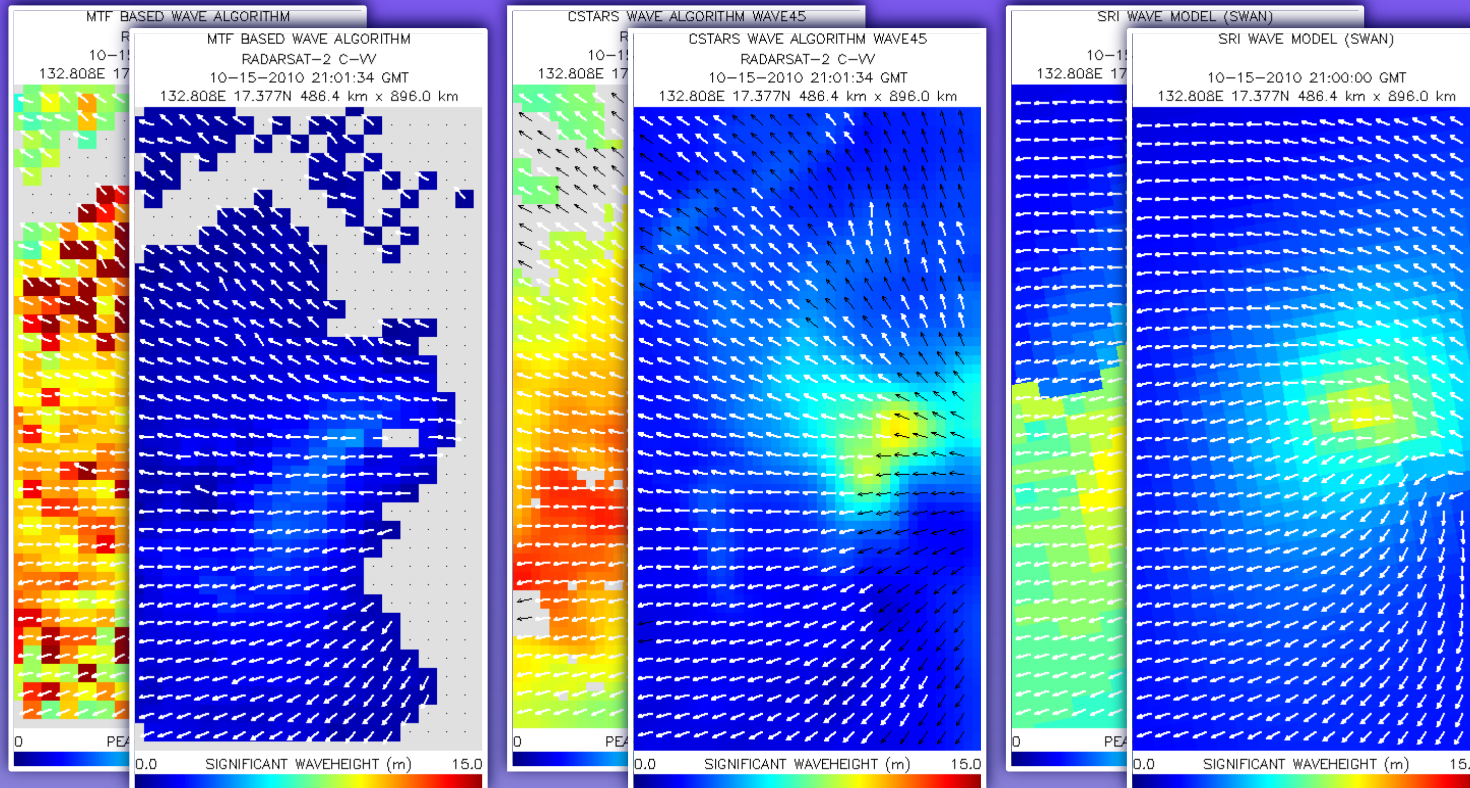
Example Result: Megi 2010-10-15 21:01 GMT



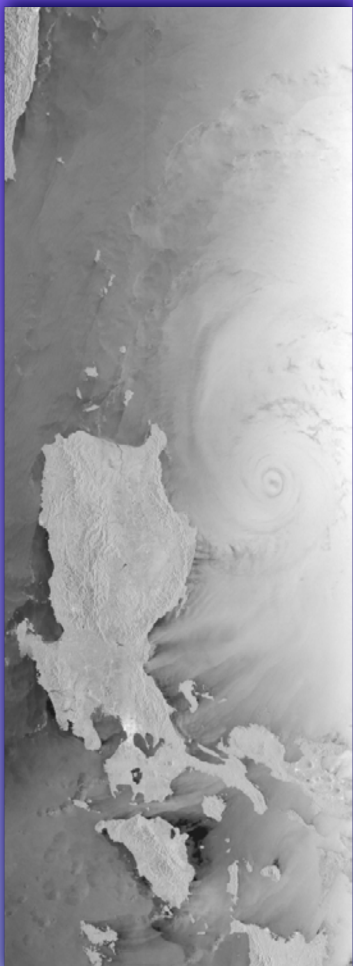
RADARSAT-2 Image



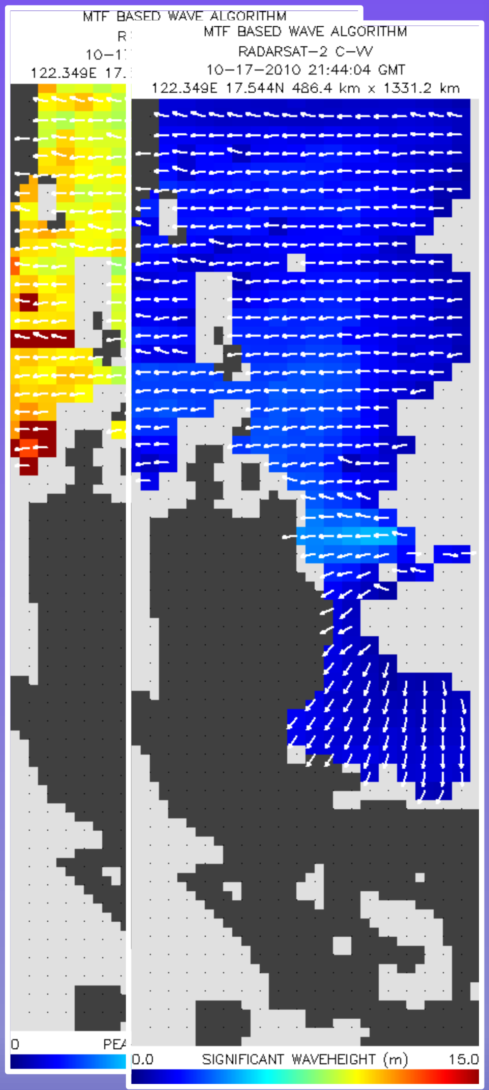
- Peak wavelength & direction: Similar results; differences partly due to different filtering & peak detection methods
- SWH: Better coverage with new method; large values around center of storm consistent with SWAN

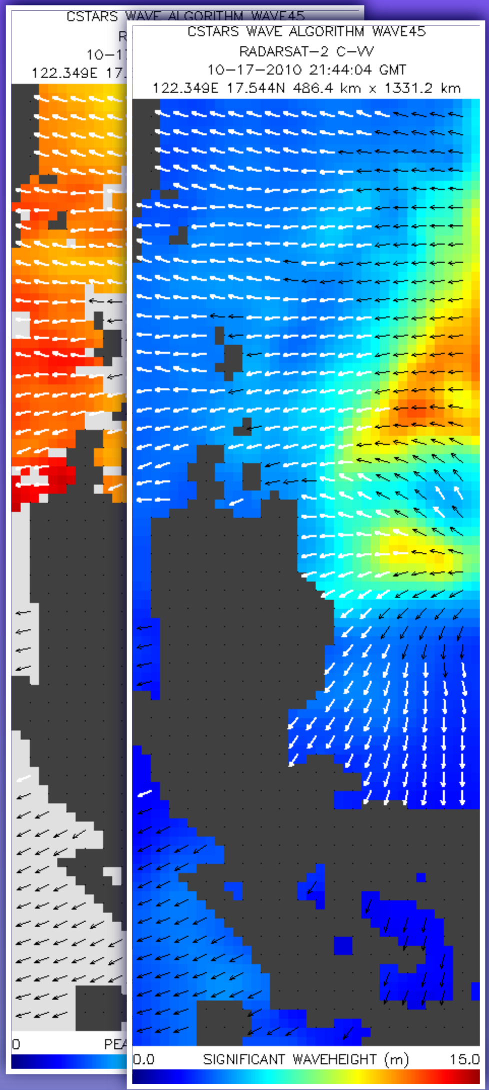
(SWAN model results provided by David Walker, SRI)

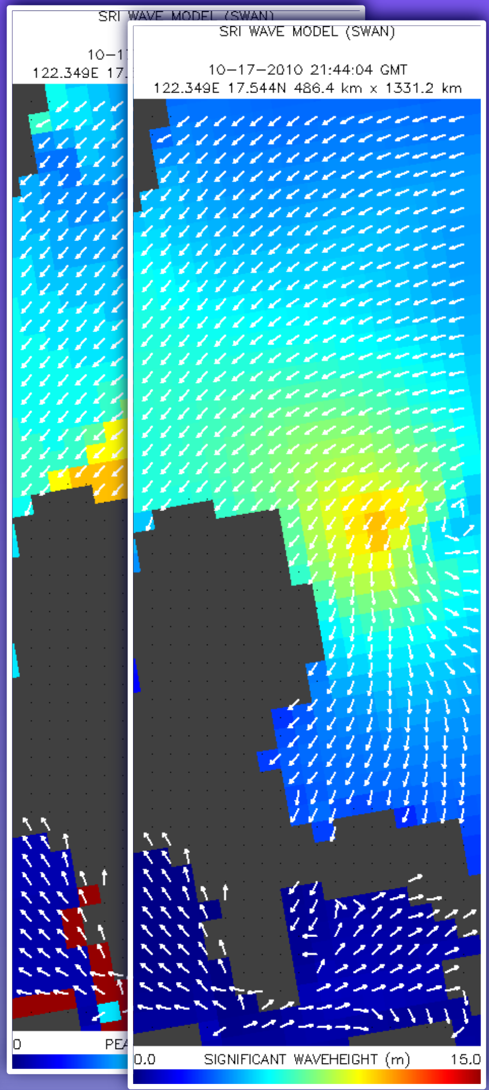
Example Result: Megi 2010-10-17 21:44 GMT



RADARSAT-2 Image







(SWAN model results provided by David Walker, SRI)

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DEPARTMENT OF THE NAVY ONR Science & Technology

Summary & Outlook

- New scalloping and beam seam filters enable routine use of ScanSAR imagery for wave and wind retrievals
- MTF-based wave retrieval neglects several effects, underestimates SWH without tuning, has limited coverage
- New empirical wave retrieval algorithm estimates wave parameters from properties of image and image spectrum
  - Similar to wind retrieval with empirical model function
  - Can account for effects of sub-resolution-scale waves and nonlinearities implicitly
  - **Can estimate SWH where no wave signatures exist**
- Upcoming: Detailed comparisons, further refinement, development of X band model function, combination of wave and wind algorithms

END OF PRESENTATION

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