USING THE VIIRS IMAGING BAND TO ENHANCE MONITORING OF COASTAL WATERS

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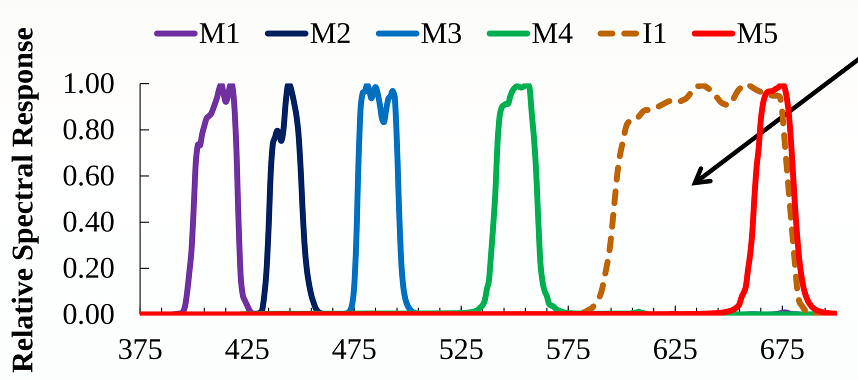
1. STUDY OBJECTIVES

The spatial dynamics of coastal and inland regions are highly variable and monitoring these waters with ocean color remote sensors requires increased spatial resolution capabilities. A **new approach** for spectral sharpening using VIIRS is developed by utilizing the spatial covariance of the spectral bands for sharpening the M bands (412, 443, 486, 551, 671 nm; 750-m resolution) with the I-1 band (645 nm; 375-m resolution). The spectral shape remains consistent by the use of wavelength-specific weight that is calculated according to I- and M-band variance at each pixel. We demonstrate that the increased spatial resolution improves the ability for VIIRS to characterize bio-optical properties in coastal waters and address the following questions:

- Is it possible to spatially enhance atmospherically-corrected radiance and derived bio-optical products using one or few wide spectral band(s), AND retaining accurate spectral information?
- Can *derived* high resolution products provide more accurate information and improve characterization of coastal waters?
- What ocean processes and features are we able to resolve by simply doubling the spatial resolution of a typical satellite mission?

2. METHODS

We attempt to spatially improve VIIRS ocean color products are by combining the 750-m M(λ) bands with the 375-m I1-band.



Challenge:
I1 band variability DOES NOT account for *dynamic variance* across the M(λ)-band spectrum based on differing absorption and scattering coefficients at each wavelength.

Solution: *Weight* the sharpening algorithm as a function of spatial covariance:

1) Determine wavelength specific spatial resolution ratio, R(λ), for every pixel in image. adjusted by ρ(λ):

$$R(\lambda) = \frac{[(I - I^{*})\rho(\lambda)] + I^{*}}{I^{*}}$$

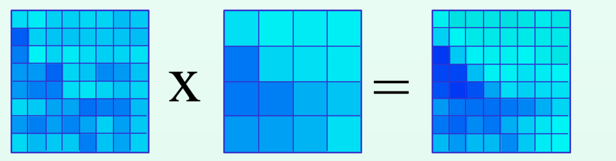
I = VIIRS I1-Band (375-m resolution)
I* = VIIRS I1-Band (750-m resolution)

2) ρ(λ), is computed from a moving 5 x 5 subarray surrounding each pixel in the image. It is a ratio of the M(λ) band coefficient variance in relation to the I1 band coefficient of variance:

$$\rho(\lambda) = \frac{[\sigma/\mu]_{M(\lambda)}}{[\sigma/\mu]_{I1}}$$

$[\sigma/\mu]_{M(\lambda)}$ = VIIRS M(λ) Band variance coefficient for 5x5 sub-array
$[\sigma/\mu]_{I1}$ = VIIRS I1 Band coefficient of variance for 5x5 sub-array

3) Apply the *dynamic* wavelength specific spatial ratio, R(λ), to each low-resolution M(λ)-band to create a sharpened nLw spectrum:

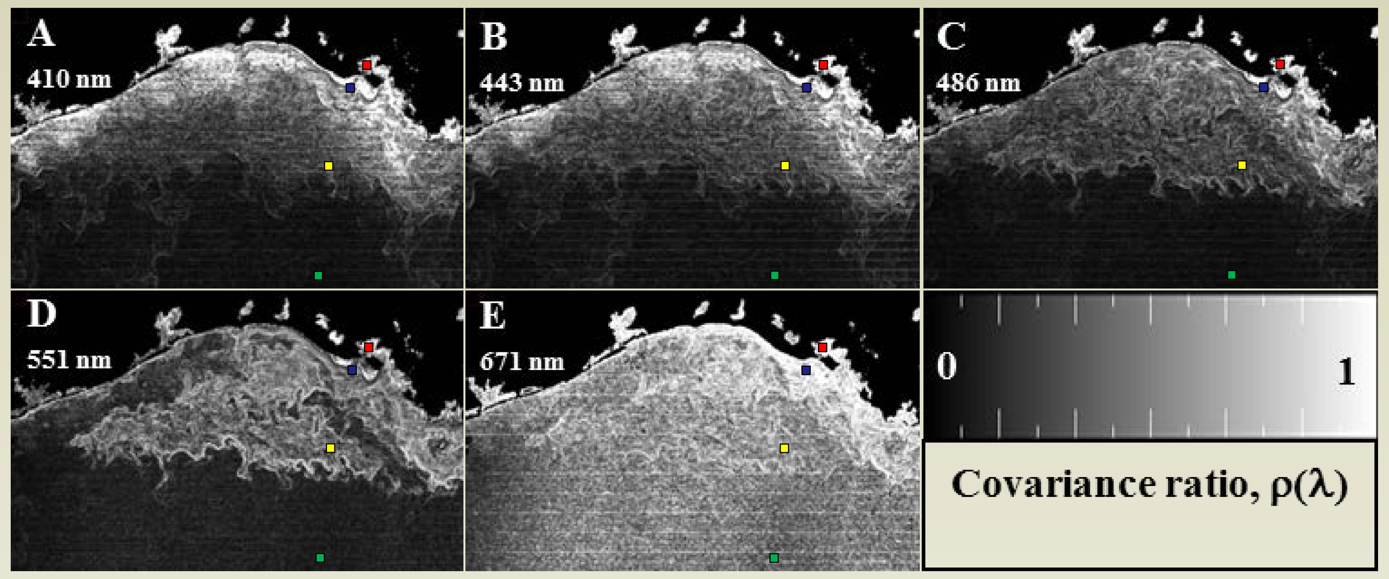


Ratio, R(λ)   M(λ)-band   Hires M(λ)-band

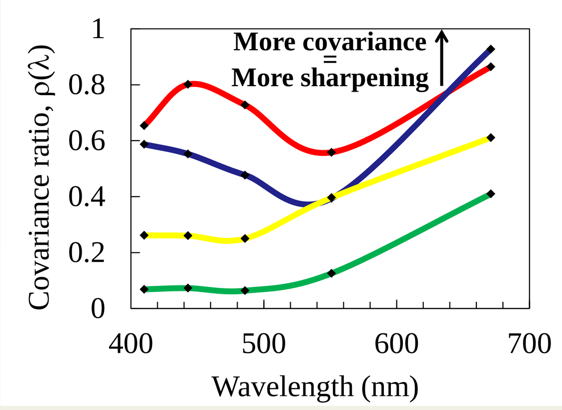
For more in depth information on methodology and results, see paper: *Enhanced satellite remote sensing of coastal waters using spatially improved bio-optical products from SNPP–VIIRS*, published in Remote Sensing of Environment (2015).

3. ANALYSIS OF COVARIANCE

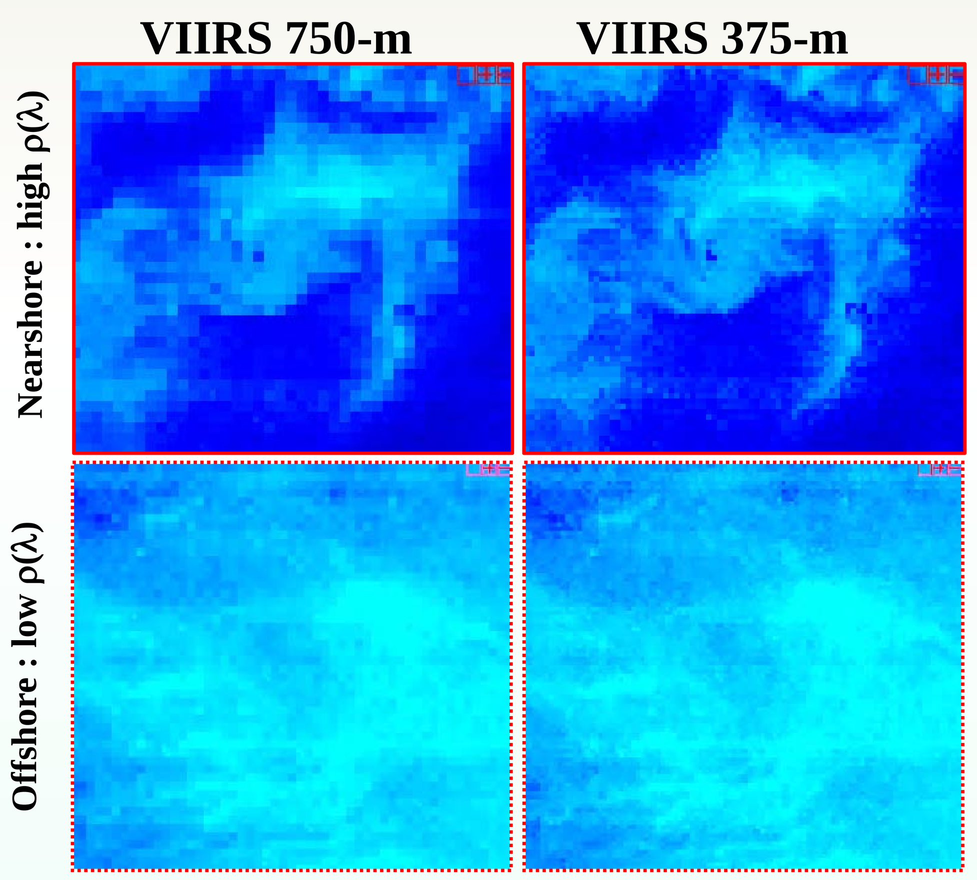
By comparing variance across the M(λ) spectrum with the variance of the high resolution I1 band, a "sharpening probability map" is created.



At pixels where ρ(λ) is closer to 1 (i.e. covariance of M and I-channel), M(λ) is sharpened according to I-band variance. Where divergence in variance occurs, the sharpening weight is adjusted in proportion to the difference in variance between the two bands.



4. SPATIAL ENHANCEMENT OF NLW(λ)



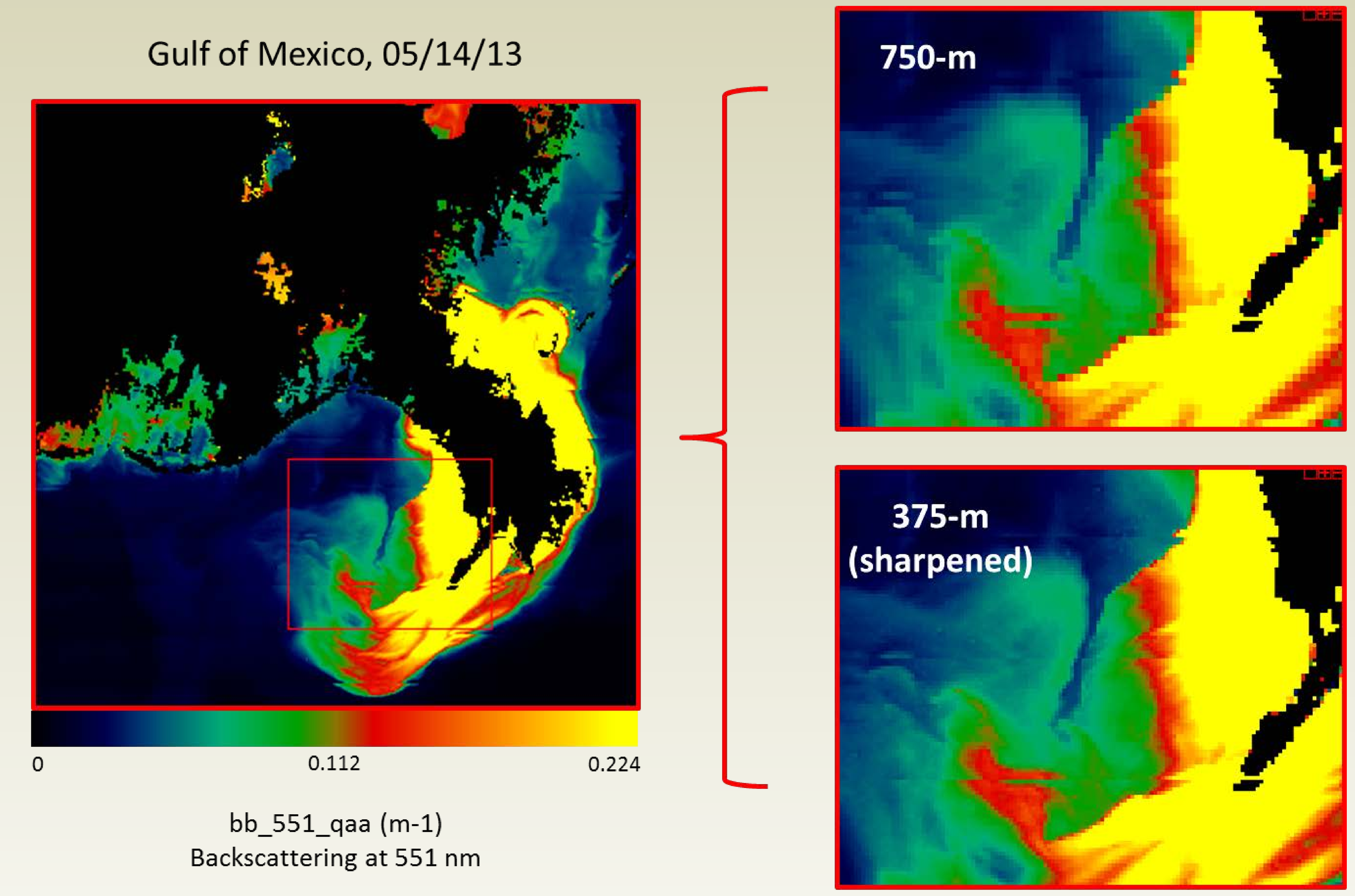
Selective sharpening
(LEFT) A comparison of VIIRS nLw_410 at standard 750-m resolution and 375-m resolution with ρ(λ) correction. A marked increase in detail in coastal gradients is shown in the 375-m resolution image. **NOTE:** the small ρ(λ) in offshore waters (lower panel) minimizes the effect of sharpening where there is less confidence to do so.

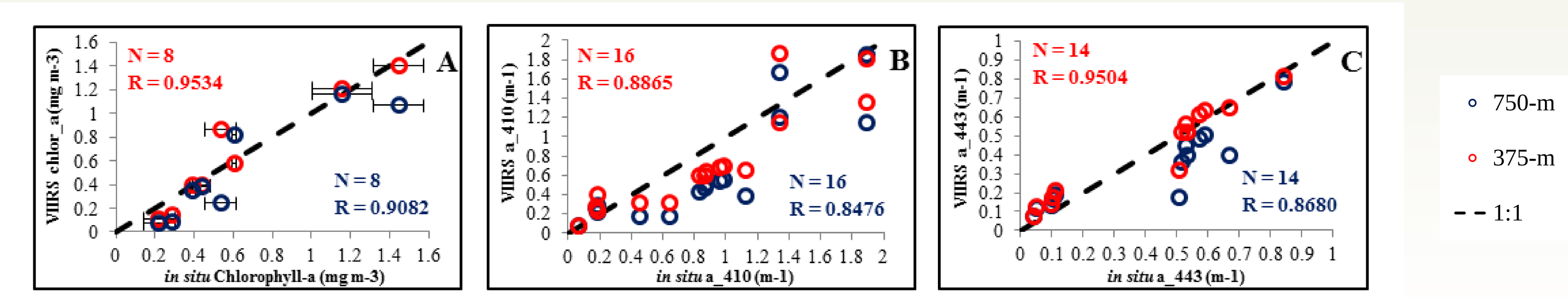
	VIIRS 375-m sharpened					VIIRS 750-m standard				
λ	410	443	486	551	671	410	443	486	551	671
Slope	1.019	0.947	0.981	1.065	1.115	1.019	0.933	0.994	1.058	1.201
y-int	0.024	0.037	-0.001	-0.064	0.031	0.027	0.047	0.012	-0.066	-0.007
R	0.664	0.891	0.949	0.972	0.971	0.621	0.868	0.931	0.958	0.961
RMSE	0.177	0.143	0.138	0.135	0.115	0.188	0.156	0.160	0.160	0.116
NMB (%)	8.09	0.93	-2.05	0.19	25.61	8.64	1.11	0.74	-0.67	17.86
N	44	44	42	40	42	44	44	42	40	42

(ABOVE) Scatter plot statistics comparing 44 *in situ* spectral reflectance measurements to VIIRS satellite data processed at two different resolutions, showing enhanced accuracy and precision at 375-m resolution compared to the native 750-m resolution of the sensor. Note that the correlation coefficients (R) are higher and RMSE lower for the VIIRS 375-m resolution dataset at ***every*** wavelength.

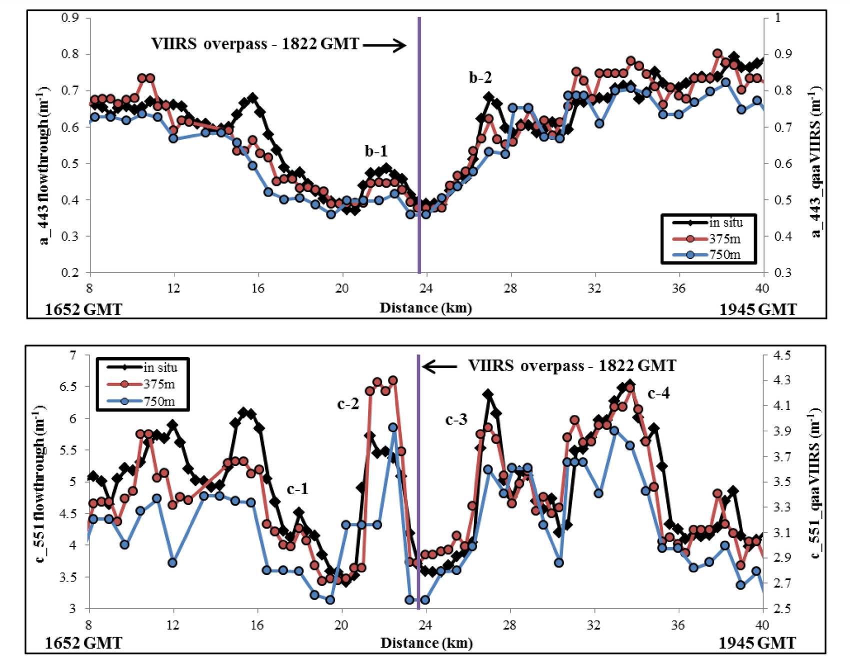
5. SPATIAL ENHANCEMENT OF OCEAN COLOR

The sharpened water leaving radiance (nLw) radiance spectrum is placed into l2gen software, and processed to produce bio-optical products at a higher spatial resolution.





(ABOVE) Scatter plot comparisons of *in situ* data to corresponding VIIRS data for several bio-optical products: (A) Chlorophyll-a, (B) total absorption at 410 nm, and (C) total absorption at 443 nm. The plots show higher correlation coefficients for VIIRS at 375-m resolution data (red) to *in situ* absorption, compared with VIIRS at 750-m resolution (blue).



(LEFT) An *in situ* flow through data set showing absorption (410 nm) and bean attenuation (551 nm), binned to 375-m (black line) and compared to satellite products at 375-m (red) and 750-m (blue). Results show an increased feature detection for VIIRS.

Semi-analytical algorithms that enable the exploitation of few spectral bands to enhance the ocean color spectrum may enable a cost-effective implementation procedure in order to improve future monitoring from space.

SUMMARY

1. **Enhanced spatial resolution for VIIRS ocean color (375-m) can be achieved by combining the I-bands with the M-bands.**
2. **Spatial covariance is used to spectrally weight band sharpening so that the spectral signature remains unbiased.**
3. **Results are confirmed in coastal waters and demonstrate new coastal applications and validation for the VIIRS sensor.**