DESTRIPING ALGORITHM FOR IMPROVED SATELLITE-DERIVED OCEAN COLOR PRODUCT IMAGERY

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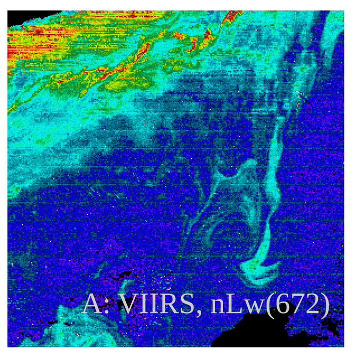
INTRODUCTION

Types and sources of striping

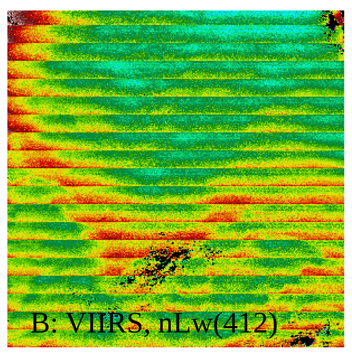
A. Minor differences in detector calibration and sensitivity

- Small amplitude
- No direct relation with detector number
- Affects all bands
- [M. Bouali, A. Ignatov, *J. Atm. & Oc. Tech.* **31**, 150]



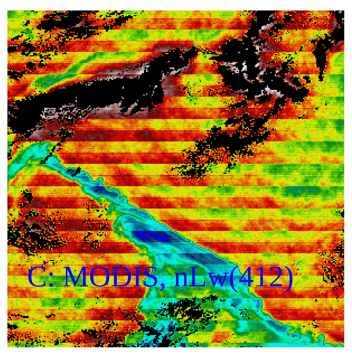
B. Differences among detector azimuthal and zenith angles

- Linear dependence on detector
- Very strong near glint areas
- Affects reflective bands
- [Q. Liu *et al*, *J. Atm. & Oc. Tech.* **30**, 2478]



C. Differences in sensor mirror side (MODIS)

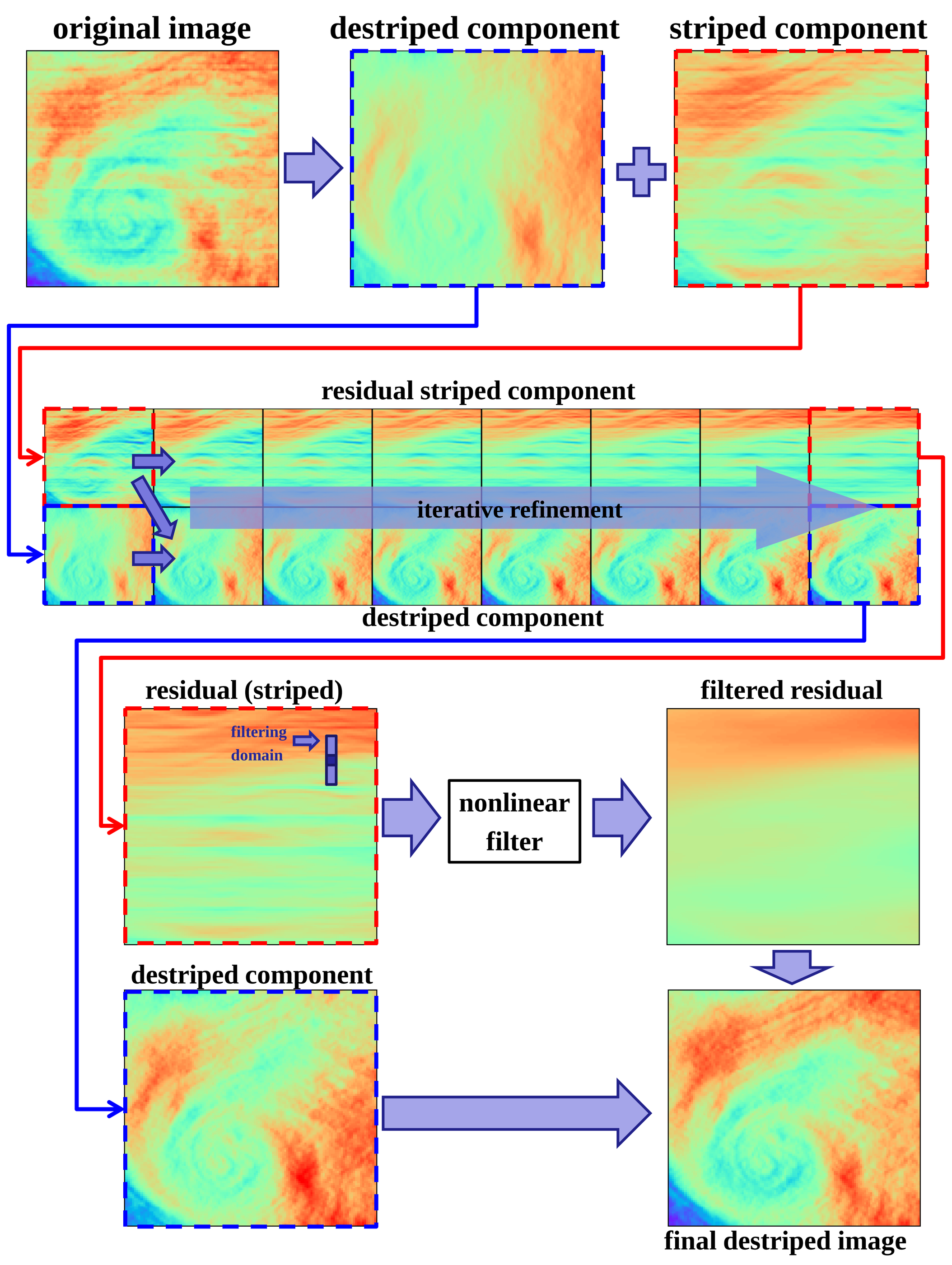
- Alternating values for even – odd scans
- Nearly same offset for all pixels within one scan
- Most pronounced in MODIS blue bands
- [X. Geng *et al*, Proc. SPIE 8153, Earth Observing Systems XVI 2011]



DESTRIPING ALGORITHM

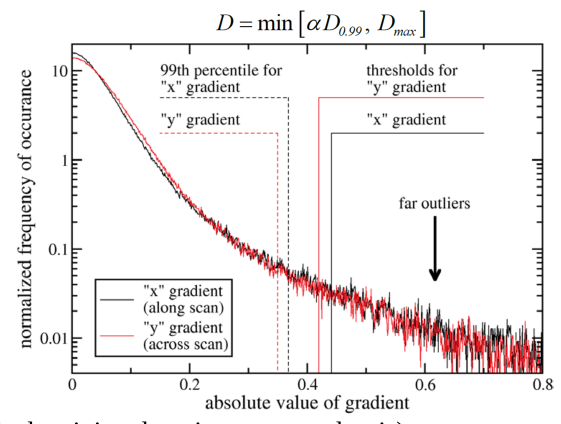
Mikelsons et al. (2014) destriping algorithm [Opt. Express, **22**, 28058-28070, (2014)] for Ocean Color products is based on *Bouali & Ignatov* method for SST [*J. Atmos. Oceanic Technol.*, **31**, 150-163 (2014)].

1. Start with striped image, calculate gradients
2. Discard "y" gradients in striped, but otherwise smooth regions
3. Poisson reconstruction (with DCT using FFT) yields approximate destriped image
4. Split the original image into destriped and striped components



Adaptive adjustment of parameters
A: defining destriping domain

1. Exclude land, ice, clouds, and high glint pixels
2. Collect statistics of nL_w gradient magnitudes of remaining pixels
3. Adaptively obtain optimal gradient threshold based on statistics
4. Define destriping domain via binary matrix *M:*



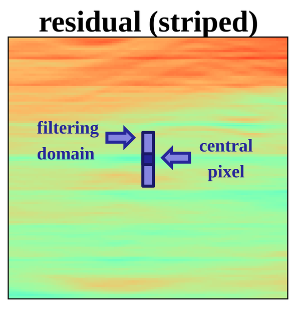
(pixels outside destriping domain - preserved as is)

$$M(x,y)=\begin{cases}1, & \left|f(x+1,y)-f(x,y)\right|>D_x \cup \left|f(x,y+1)-f(x,y)\right|>D_y \cup (x,y)\in(\text{land, ice, clouds})\\ 0, & \text{otherwise}\end{cases}$$

(pixels within destriping domain - subject to destriping)

B: nonlinear filter parameters

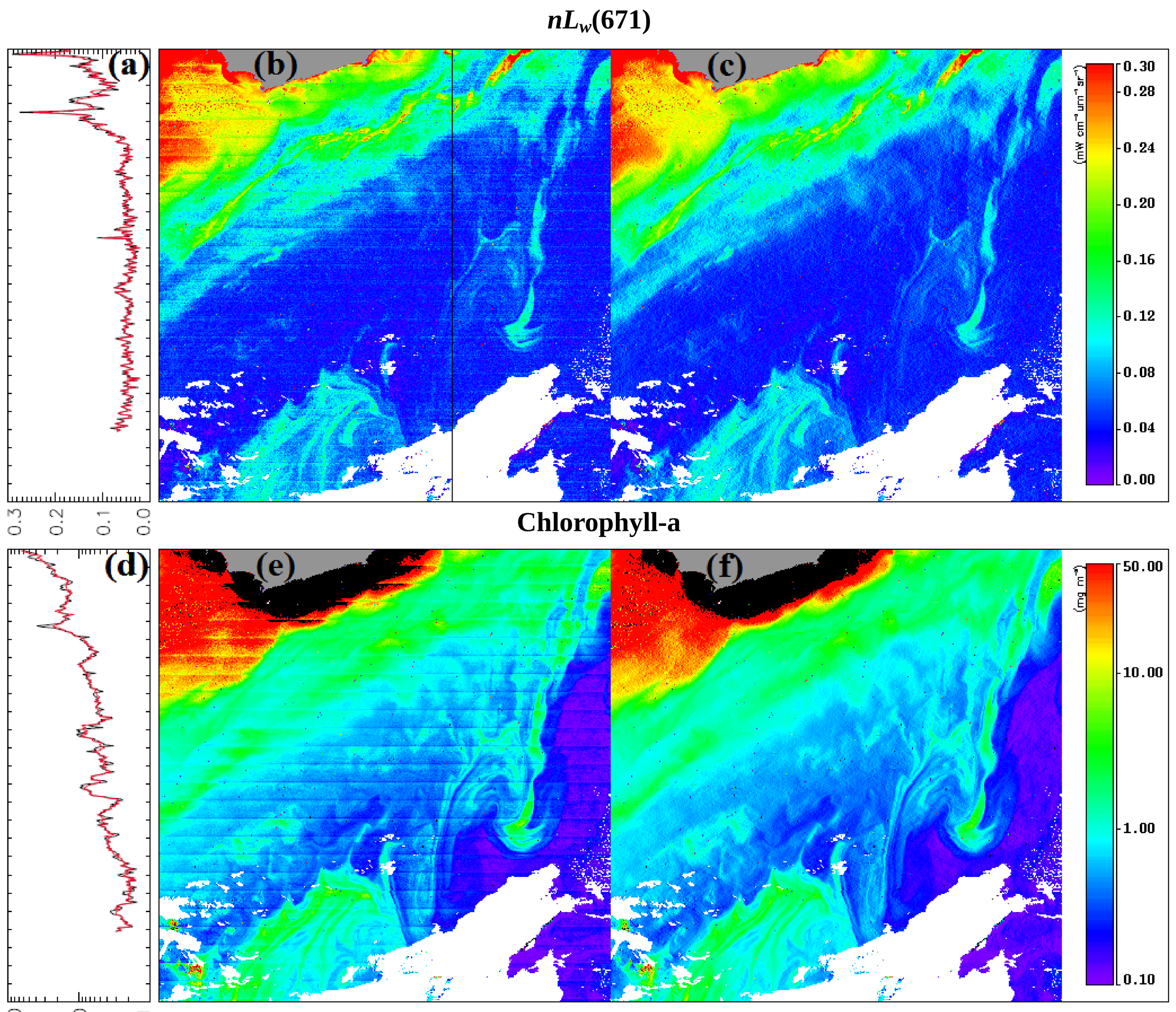
1. Nonlinear filter domain is one pixel wide and one scan high
2. For MODIS bands with mirror striping effect filtering domain height is two scans
3. For all central pixels in the destriping domain, collect statistics of residual variations within the filtering domains
4. Obtain optimal nonlinear filter parameter $[\sigma]$ based on collected statistics



$$\underbrace{p(x,y)}_{\text{filtered residual}}=\sum_{z=y-H/2}^{z=y+H/2}\underbrace{r(x,z)}_{\text{residual}}\exp\left\{-\frac{\left[r(x,y)-r(x,z)\right]^2}{2\sigma^2}\right\}\Bigg/\underbrace{\sum_{z=y-H/2}^{z=y+H/2}\exp\left\{-\frac{\left[r(x,y)-r(x,z)\right]^2}{2\sigma^2}\right\}}_{\text{normalization}}$$

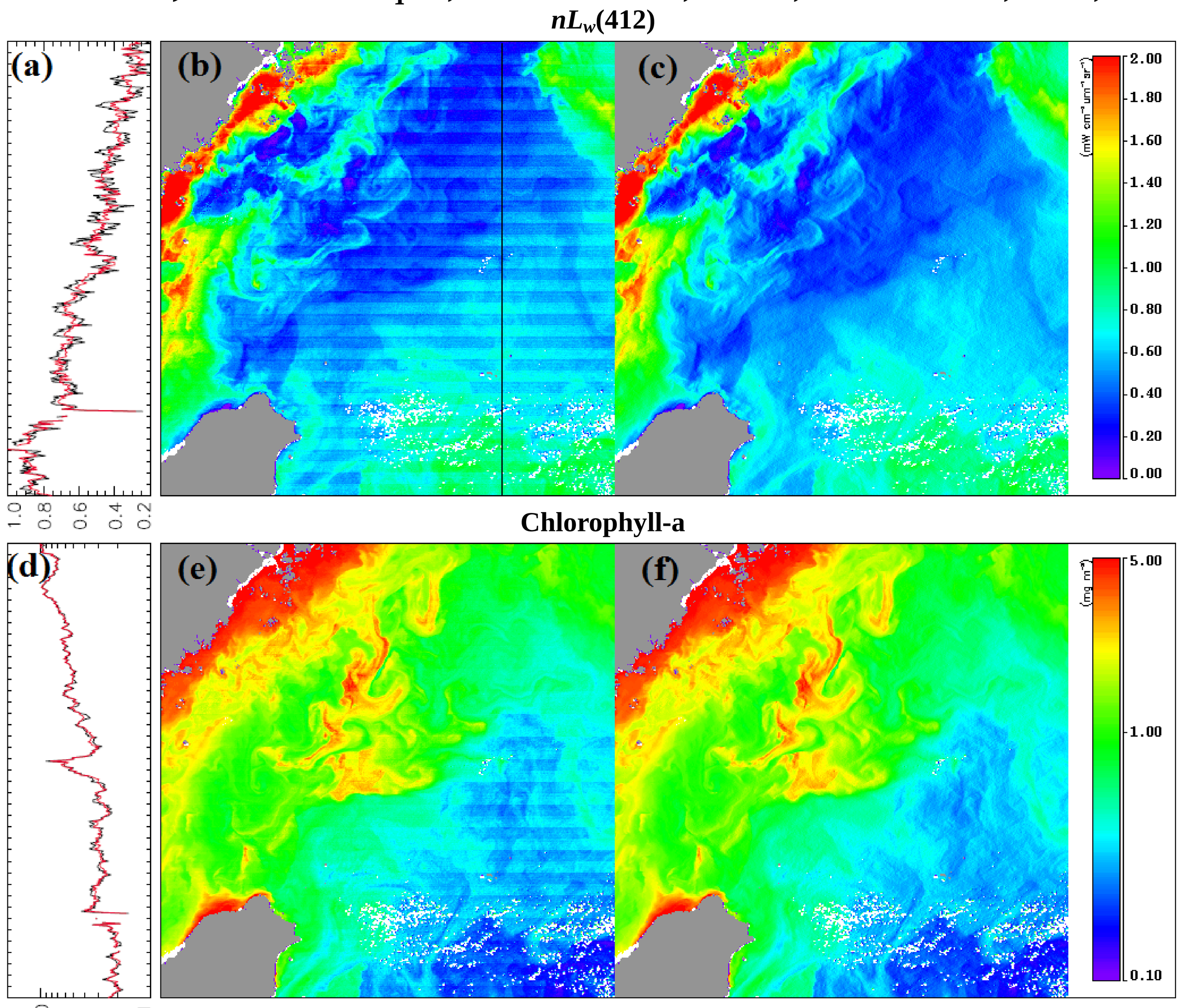
RESULTS

La Plata River, SNPP-VIIRS, July 16, 2013, 17:38UTC, 36S, 55W



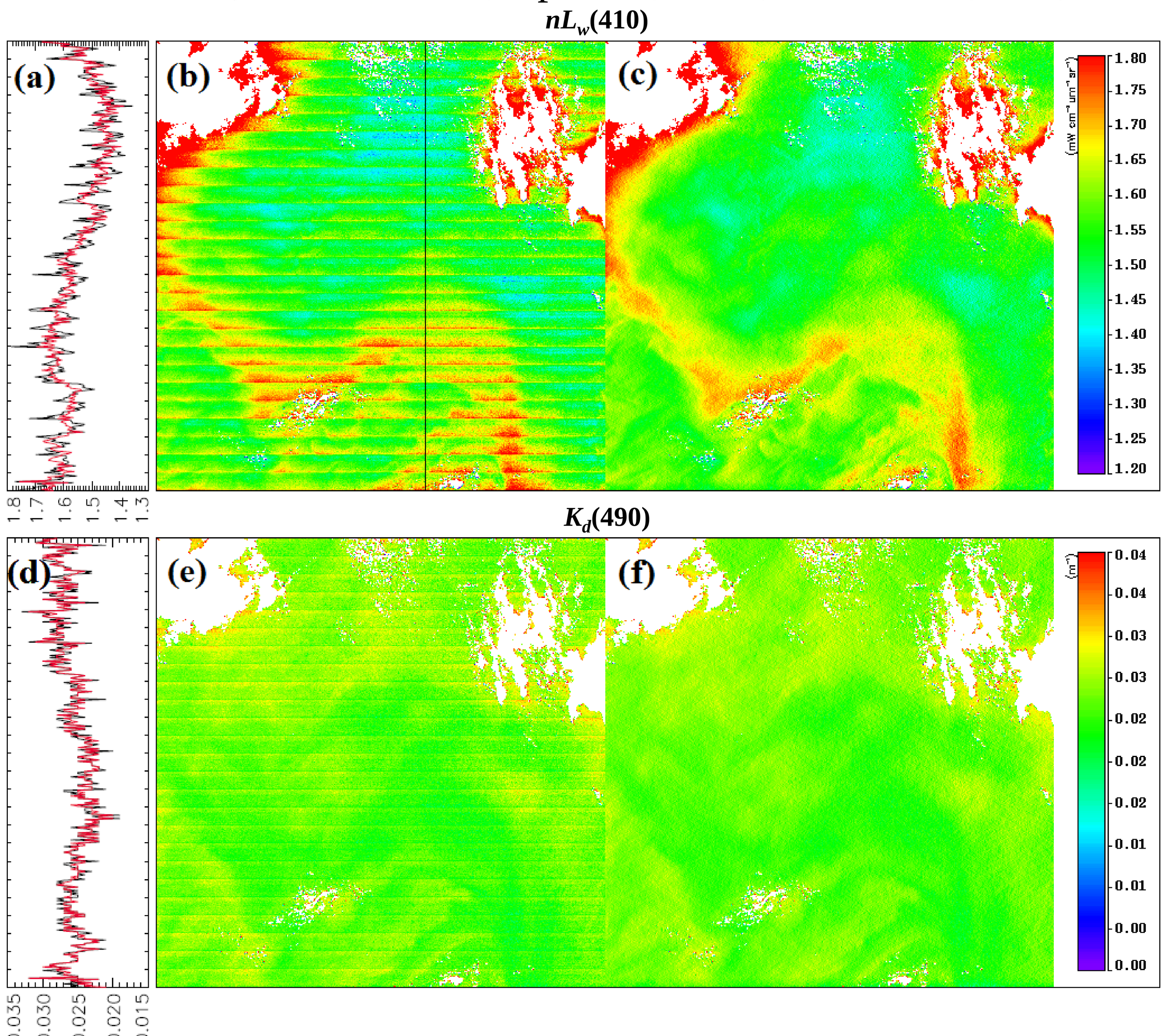
1. VIIRS 671 nm band shows striping due to differences among detectors
2. Striping pattern repeating with a period of one scan = 16 lines
3. Destriped data retain genuine image features while removing striping artifacts
4. Striping propagates from original nL_w to *Chl-a* , but destriped nL_w yield improved *Chl-a* imagery free of striping artifacts

East China, MODIS-Aqua, December 3, 2013, 05:05UTC, 26S, 123W



1. MODIS-Aqua 412nm band has strong striping due to sensor mirror side differences
2. Such striping can still be removed, but nonlinear filter size needs to be doubled
3. Striping propagates from nL_w to *Chl-a*, but destriped nL_w yield improved *Chl-a* imagery

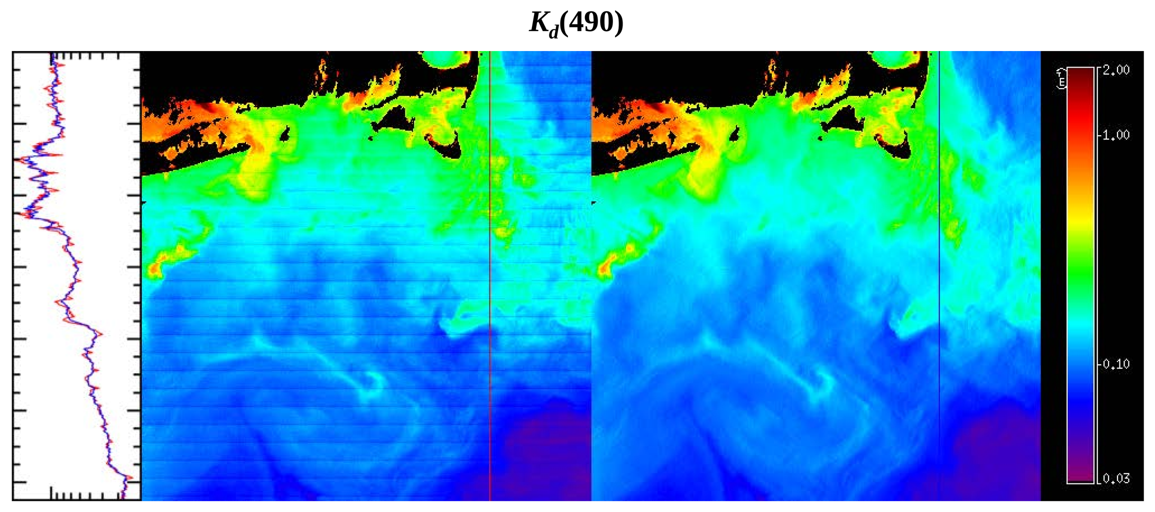
South Pacific, SNPP-VIIRS, April 19, 2014, 21:20UTC, 13S, 114W



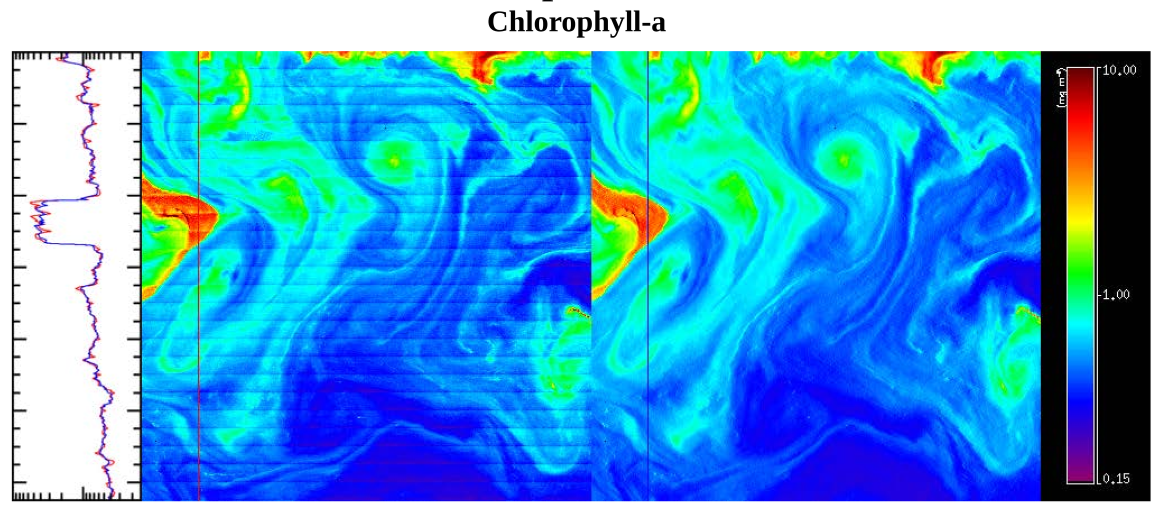
1. VIIRS 410 nm band shows striping due to changes of retrieval geometry within one scan
2. Striping "saw-tooth" like pattern repeating with a period of one scan = 16 lines
3. Destriped data retain genuine image features while removing striping artifacts
4. Areas around sparse clouds may not get completely destriped
5. Striping propagates from original nL_w to K_d(490), but destriped nL_w improves K_d(490) imagery

RESULTS (cont.)

US East, SNPP-VIIRS, June 4, 2013, 17:47UTC, 41N, 70W

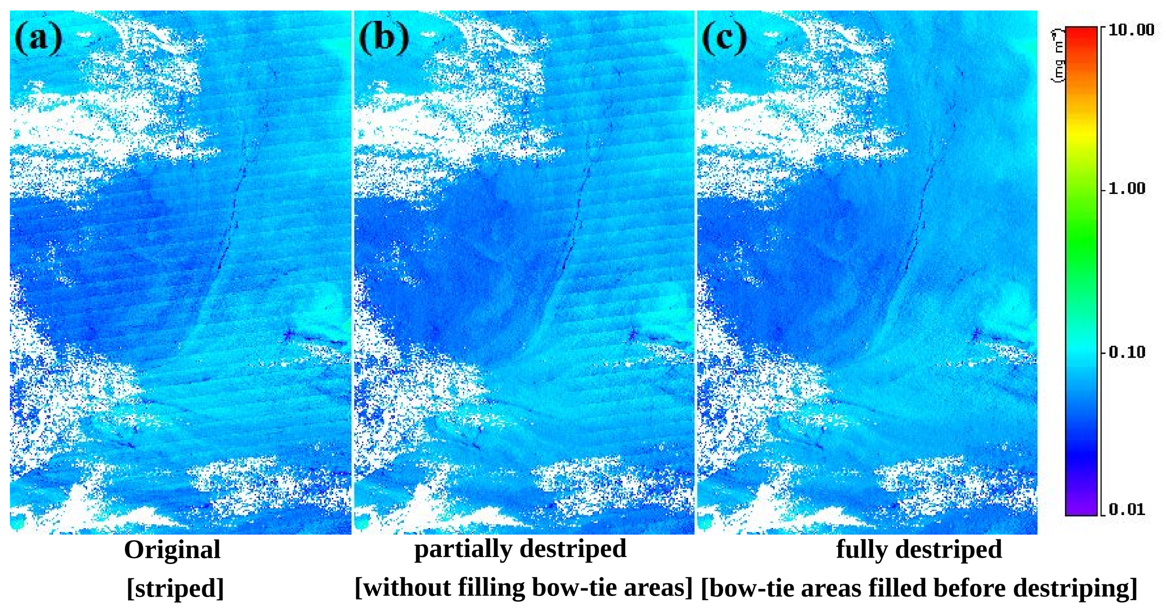


Arabian Sea, SNPP-VIIRS, April 10, 2014, 9:10UTC, 24N, 64E



VIIRS bow-tie areas

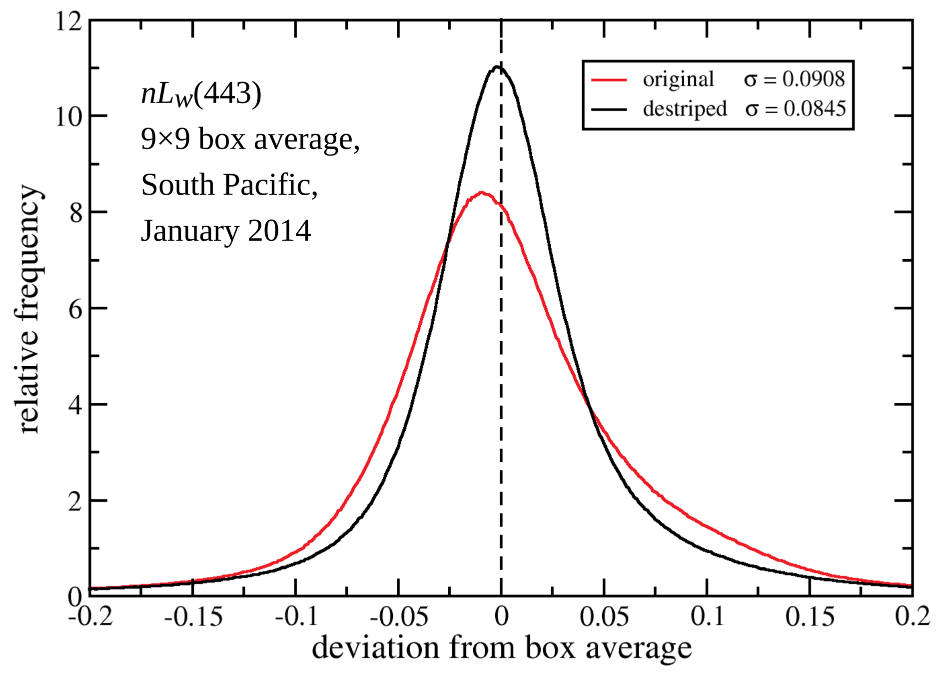
Mapped Chlorophyll-a, May 23, 2014, 19:12UTC, 26N, 84W



Original [striped] partially destriped [without filling bow-tie areas] fully destriped [bow-tie areas filled before destriping]

1. Quality of destriping in mapped images can be improved by filling VIIRS bow-tie areas with interpolated values before destriping processing
2. Similar idea used to avoid discontinuities between adjacent granules

DESTRIPING STATISTICS



1. Before destriping: distribution skewed due to striping artifacts
2. After destriping: distribution less skewed; smaller standard deviation indicate removal of striping artifacts
3. Mean is zero both before and after destriping

CONCLUSIONS

1. Destriping algorithm by Bouali & Ignatov (2014) is very versatile and works very well for larger amplitude striping artifacts in reflective bands.
2. Destriping for Ocean Color should be done on nL_w, not the TOA radiances [Mikelsons et al. (2014)].
3. Adaptive adjustment of parameters is essential.
4. Chlorophyll-a, K_d(490) and other nL_w-derived products should be obtained from destriped nL_w spectra.
5. Striping may not be completely removed in small clear sky areas separated by sparse clouds.
6. Filling VIIRS bow-tie areas improves destriping data quality.
7. As expected, destriping improves data statistics.

References:

K. Mikelsons, M. Wang, L. Jiang, and M. Bouali, Opt. Express, 22, 28058-28070 (2014).

M. Bouali and A. Ignatov, J. Atmos. Oceanic Technol., 31, 150–163 (2014).