# Ocean color atmospheric correction for operational remote sensing of Chesapeake Bay

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Acknowledgements:

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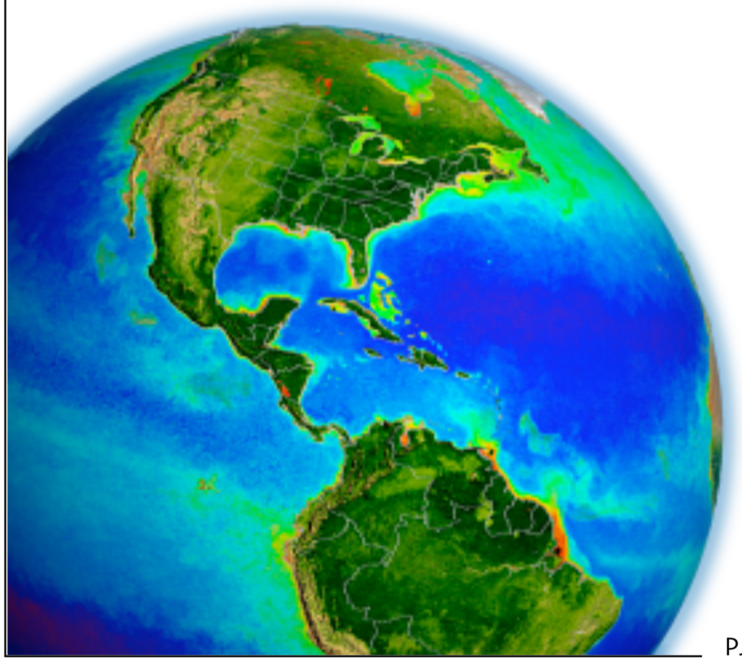


# challenges for remote sensing of estuaries

temporal & spatial variability

- satellite sensor resolution
- satellite repeat frequency
- validity of ancillary data (SST, wind)
- resolution requirements & binning options

straylight contamination (adjacency effects)

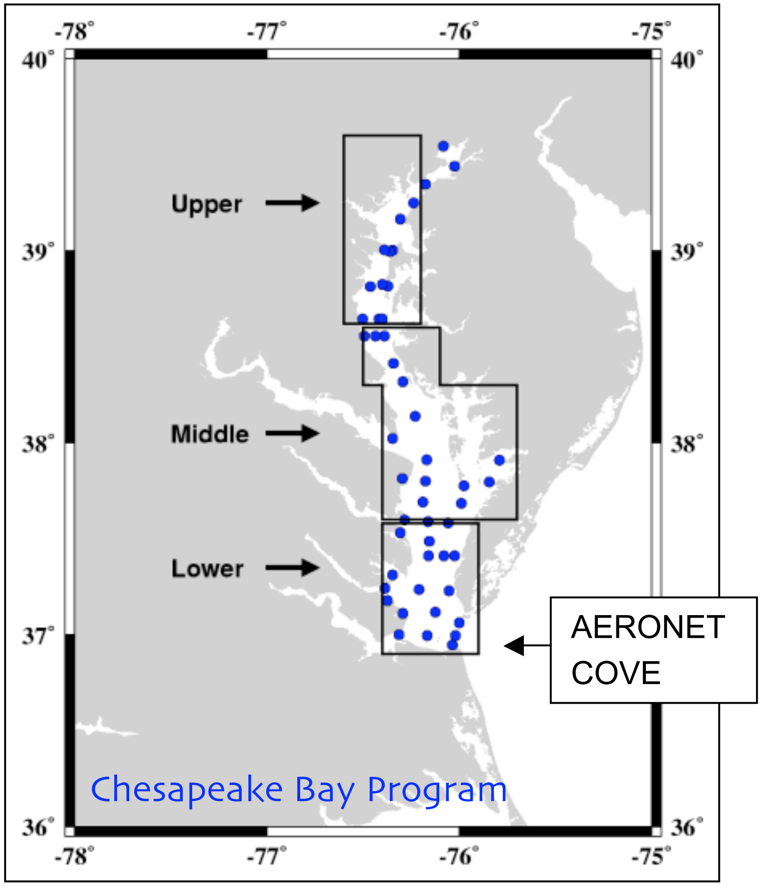
non-maritime aerosols (dust, pollution)

- region-specific models required?
- absorbing aerosols

suspended sediments & CDOM

- complicates estimation of $R_{rs}$(NIR)
- complicates BRDF (f/Q) corrections
- saturation of observed radiances

anthropogenic emissions ($NO_2$ absorption)



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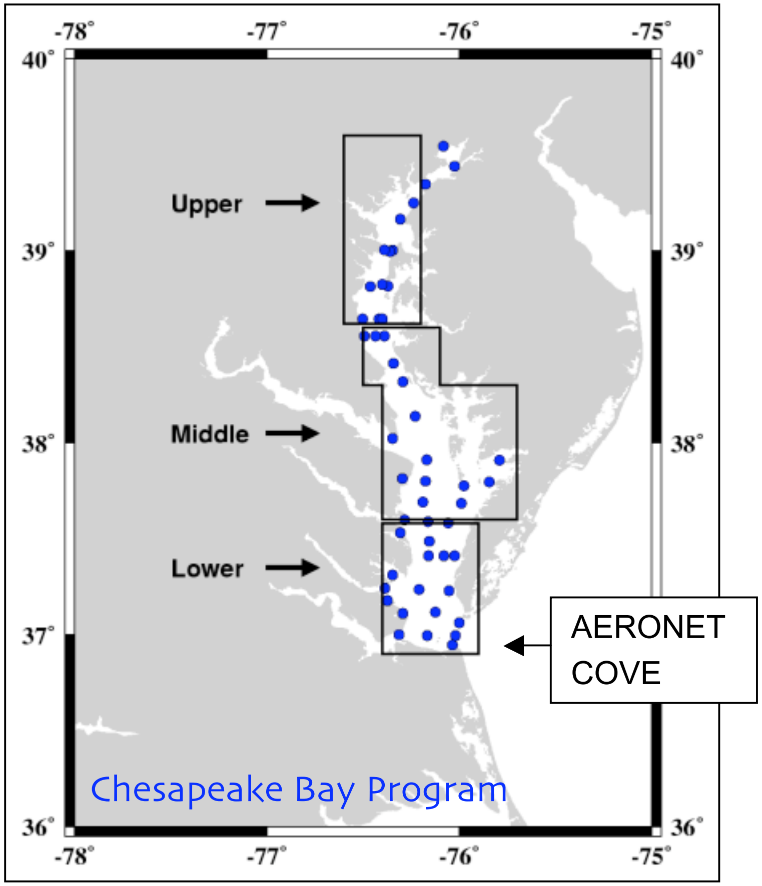

# the experiment

collaboration with NOAA, EPA Chesapeake Bay Program, University of Maryland, & colleagues since 2006 Chesapeake Bay Remote Sensing Symposium

NOAA CoastWatch East Coast Node using results for operational processing

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run multiple long-term time-series of MODIS-Aqua

- Lower Chesapeake Bay, June 2002 - December 2008
- processing configuration follows Reprocessing 2010
- QC metrics:  exclude cloudy days & high sensor zenith angles
- final analyses use ~ 13 days per month

- generate frequency distributions and monthly time-series
- use in situ measurements as reference

consider potential for application in an operational environment

# atmospheric correction & the "black pixel" assumption

| $\rho_t(\lambda)$ | = | $\rho_w(\lambda)$ | + | $\rho_g(\lambda)$ | + | $\rho_f(\lambda)$ | + | $\rho_r(\lambda)$ | + | $\rho_a(\lambda)$ |
|---|---|---|---|---|---|---|---|---|---|---|
| TOA | | water | | glint | | foam | | air | | aerosols |

need $\rho_a(\lambda)$ to get $\rho_w(\lambda)$ and vice-versa

# atmospheric correction & the "black pixel" assumption

$$\rho_t(\lambda) = \rho_w(\lambda) + \rho_g(\lambda) + \rho_f(\lambda) + \rho_r(\lambda) + \rho_a(\lambda)$$

| TOA | water | glint | foam | air | aerosols |
|---|---|---|---|---|---|

need $\rho_a(\lambda)$ to get $\rho_w(\lambda)$ and vice-versa

the "black pixel" assumption (pre-2000):

$$\rho_a(NIR) = \rho_t(NIR) - \rho_g(NIR) - \rho_f(NIR) - \rho_r(NIR) - \cancelto{0}{\rho_w(NIR)}$$

# atmospheric correction & the "black pixel" assumption

$$\rho_t(\lambda) = \rho_w(\lambda) + \rho_g(\lambda) + \rho_f(\lambda) + \rho_r(\lambda) + \rho_a(\lambda)$$

TOA water glint foam air aerosols

need $\rho_a(\lambda)$ to get $\rho_w(\lambda)$ and vice-v

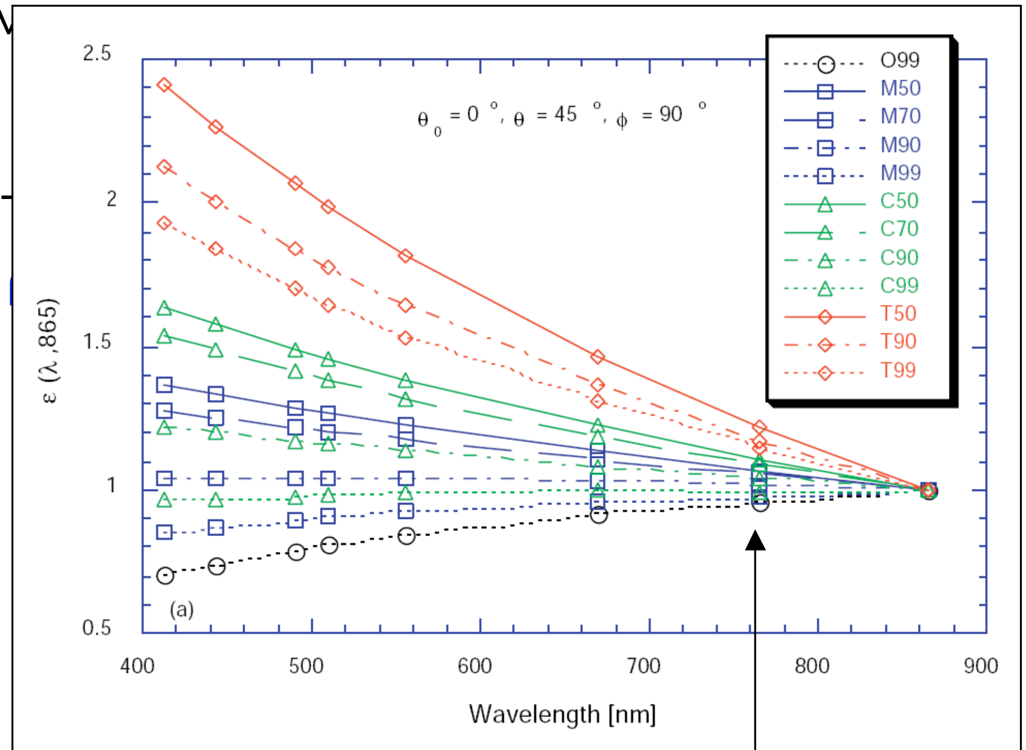
the "black pixel" assumption (pre-

$\rho_a(NIR) = \rho_t(NIR) - \rho_g(NIR) -$

calculate aerosol ratios, $\varepsilon$ :

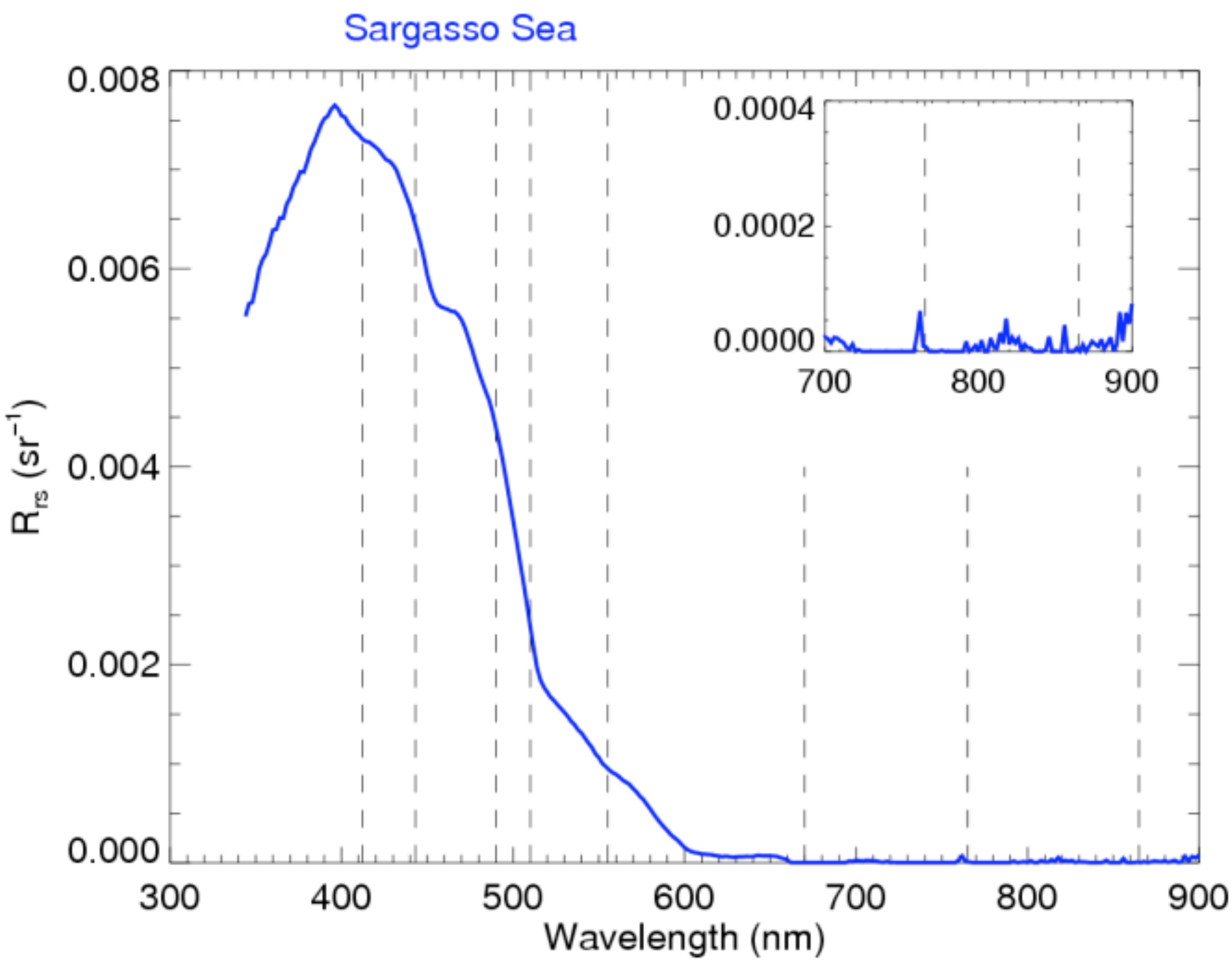
$$\varepsilon(748,869) \approx \frac{\rho_a(748)}{\rho_a(869)}$$

$$\varepsilon(\lambda,869) \approx \frac{\rho_a(\lambda)}{\rho_a(869)}$$




$\varepsilon(748,869)$

## are Rrs(NIR) really black?



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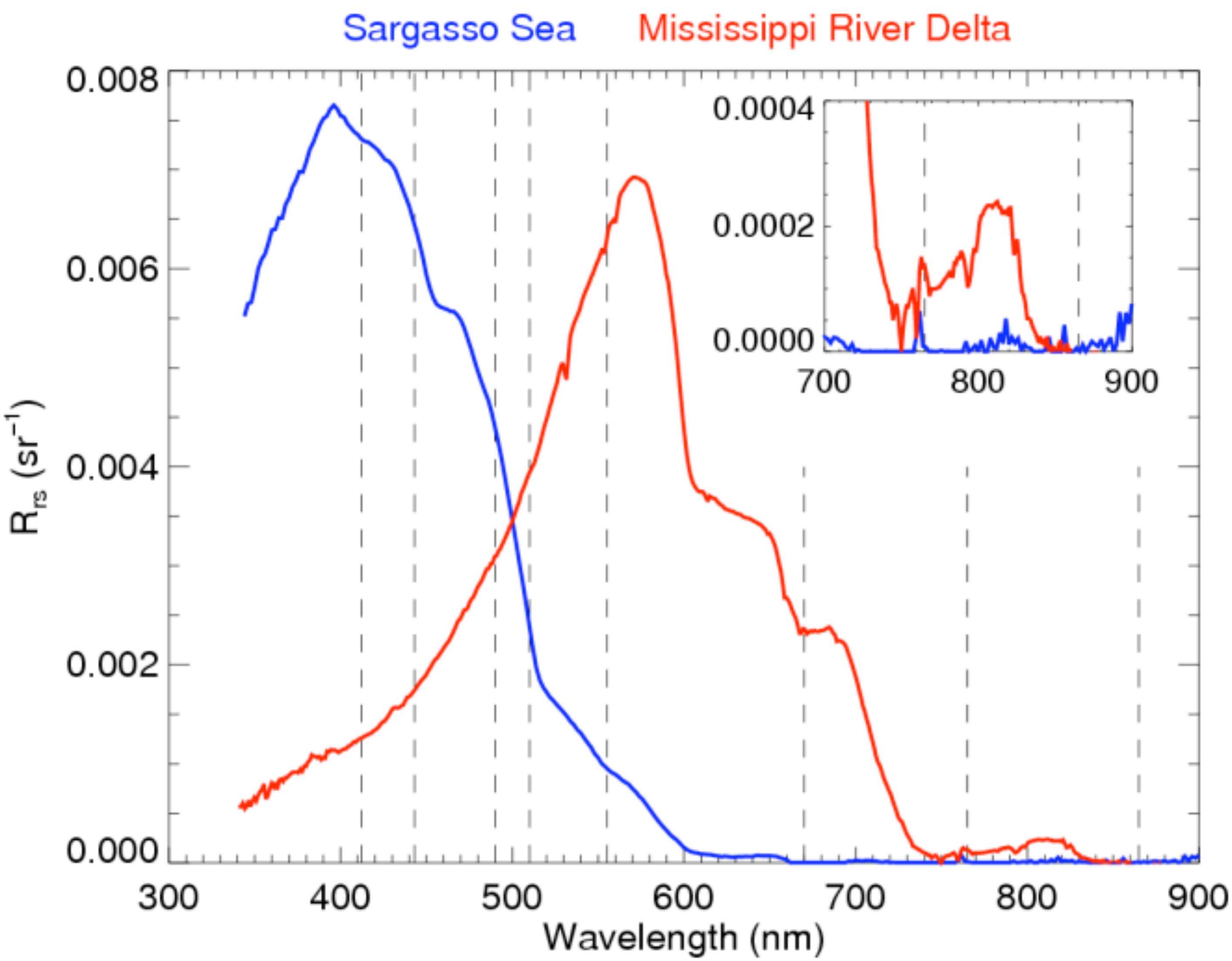
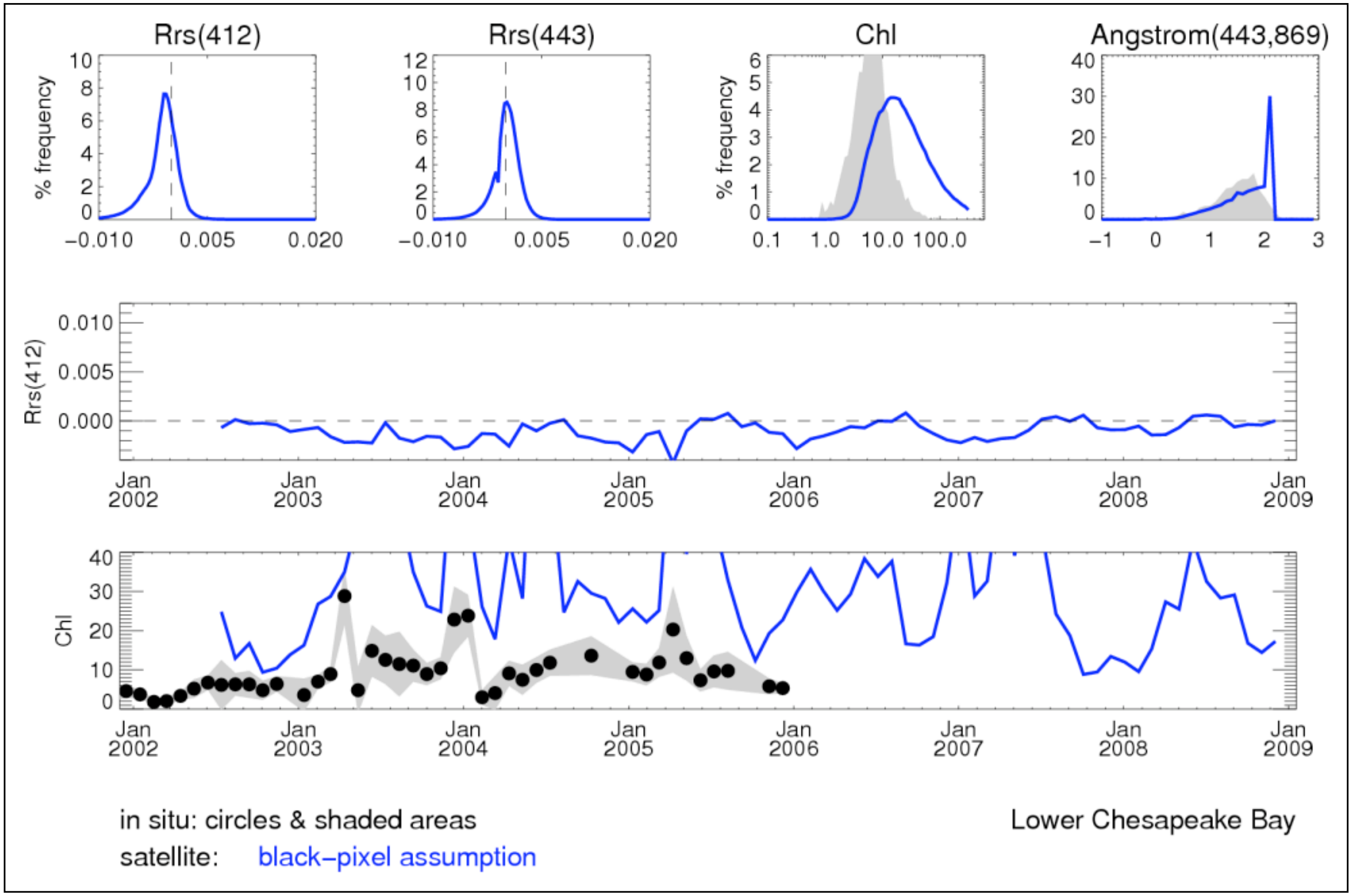


# what happens when we don't account for $R_{rs}(NIR) > 0$?




use the "black pixel" assumption (e.g., SeaWiFS 1997-2000)

# what to do when Rrs(NIR) > 0?

many approaches exist, here are a few examples:

assign aerosols (ε) and/or water contributions (Rrs(NIR))

e.g., Hu et al. 2000, Ruddick et al. 2000

use shortwave infrared bands

e.g., Wang & Shi 2007

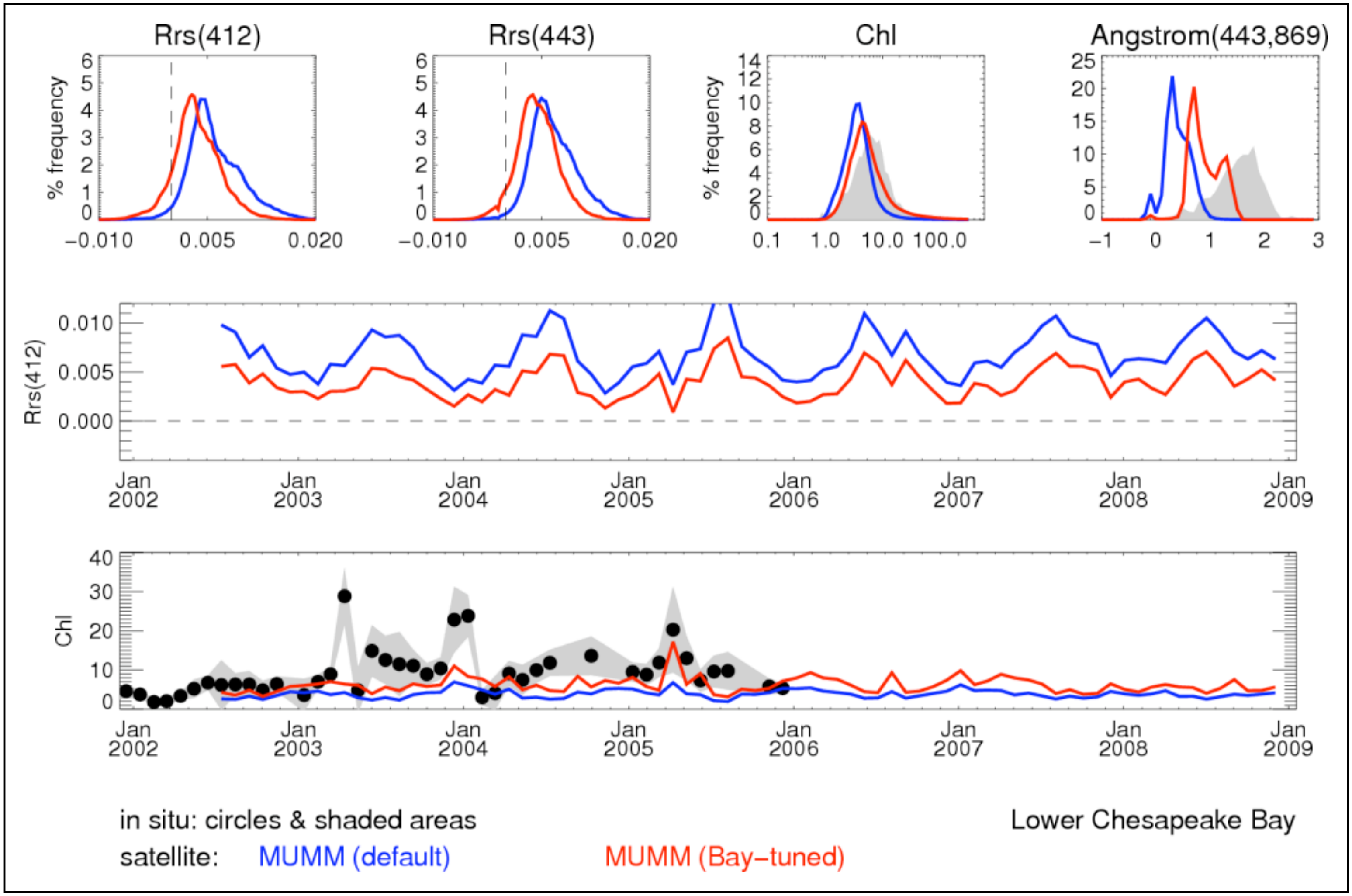
correct/model the non-negligible $R_{rs}$(NIR)

| | |
|---|---|
| Siegel et al. 2000 | used in SeaWiFS Reprocessing 3 (2000) |
| Stumpf et al. 2003 | used in SeaWiFS Reprocessing 4 (2002) |
| Lavender et al. 2005 | MERIS |
| Bailey et al. 2010 | used in SeaWiFS Reprocessing 6 (2009) |

use a coupled ocean-atmosphere optimization

e.g., Chomko & Gordon 2001, Stamnes et al. 2003, Kuchinke et al. 2009

# fixed aerosol & water contributions (MUMM)




assign ε & $\rho_w$(NIR) (via fixed values, a climatology, nearby pixels)

# advantages & disadvantages

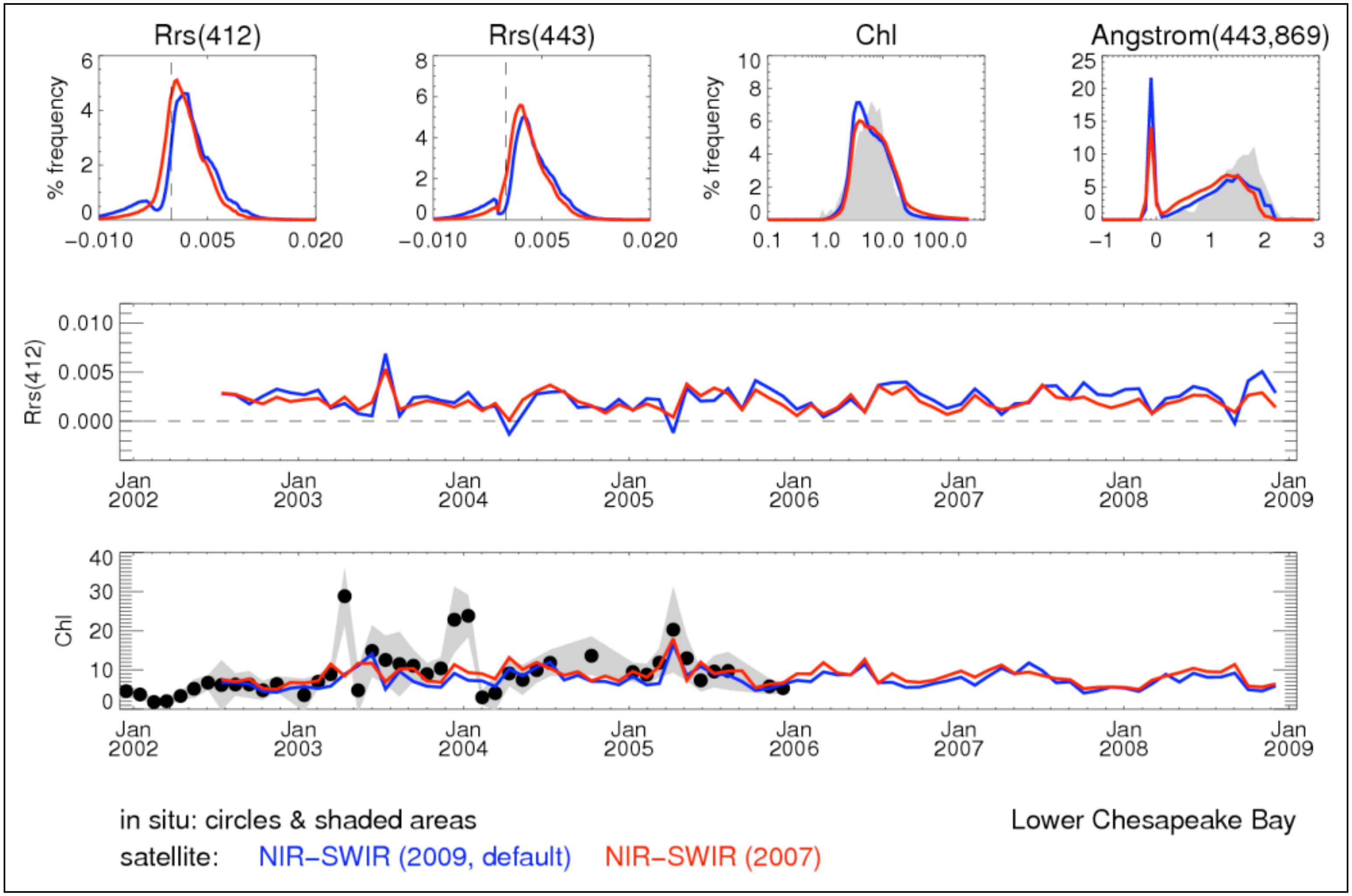
## advantages:

accurate configuration leads to accurate aerosol & $R_{rs}$(NIR) retrievals
several configuration options: fixed values, climatologies, nearby pixels
method available for all past, present, & future ocean color satellites

## disadvantages:

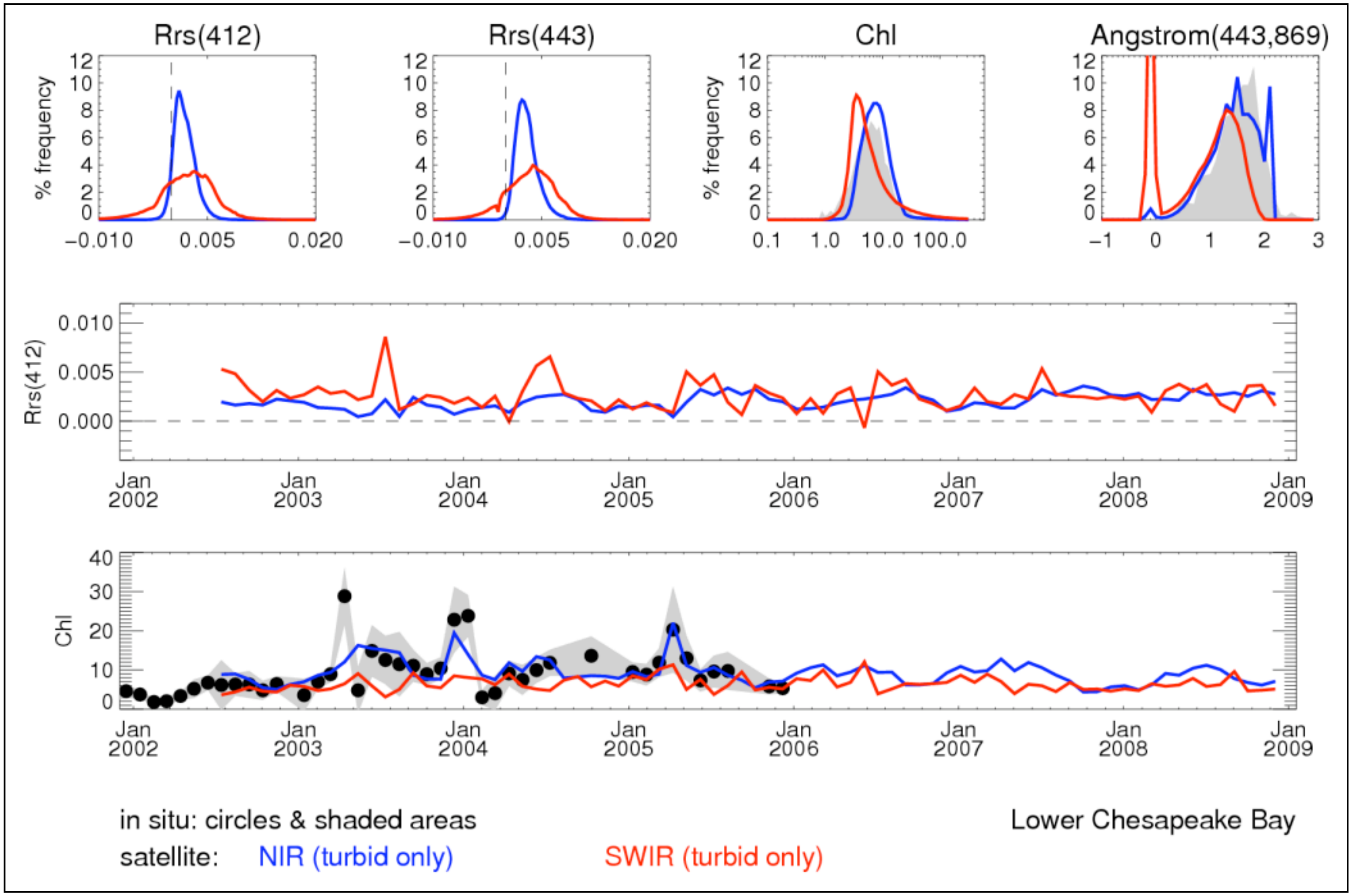
no configuration is valid at all times for all water masses
requires local knowledge of changing aerosol & water properties
implementation can be complicated for operational processing

# use of NIR + SWIR bands




use SWIR bands in "turbid" water, otherwise use NIR bands

# use of SWIR bands only




compare NIR & SWIR retrievals when considering only "turbid pixels"

# advantages & disadvantages

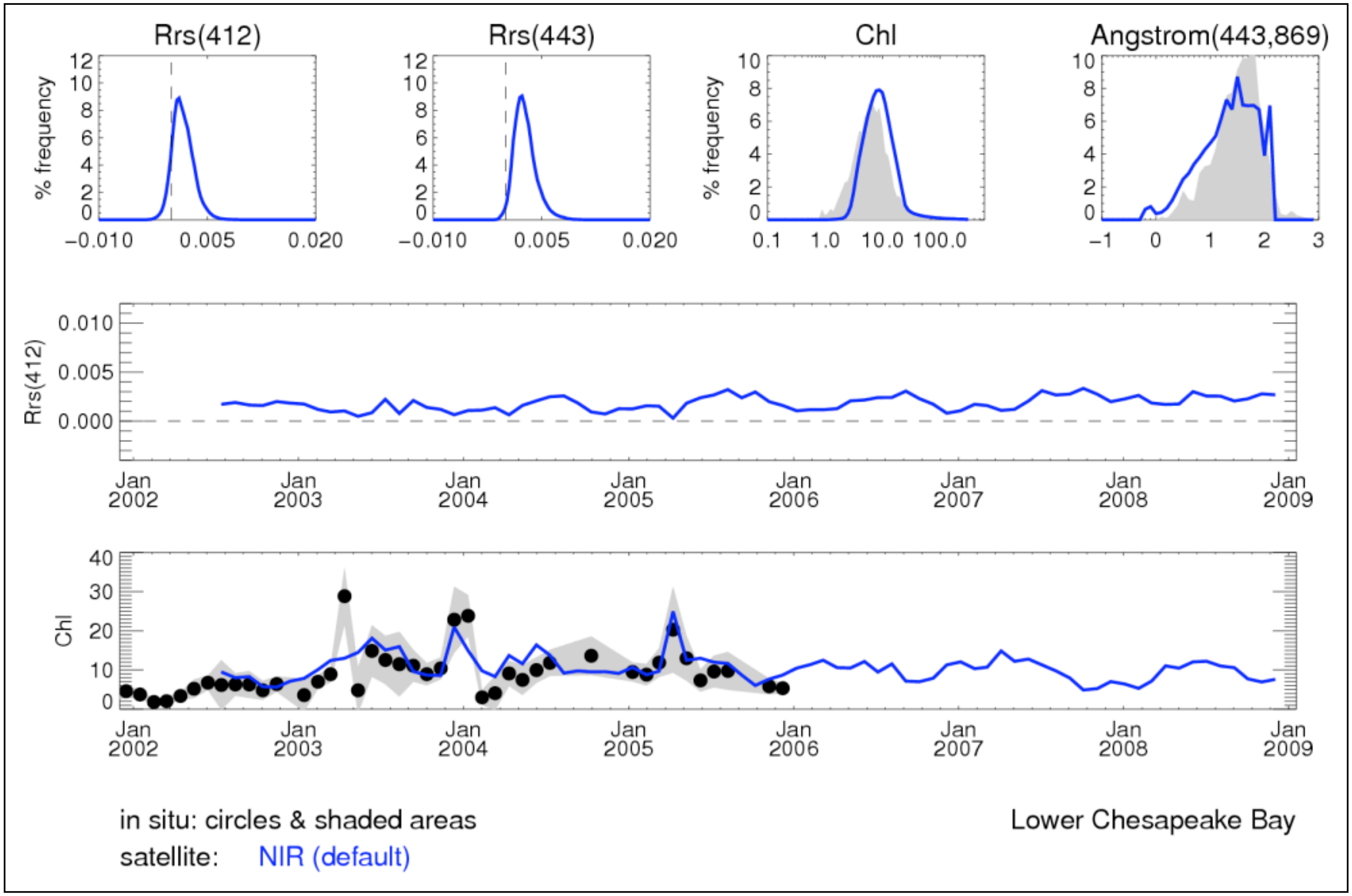
## advantages:

"black pixel" assumption largely satisfied in SWIR region of spectrum
straightforward implementation for operational processing

## disadvantages:

only available for instruments with SWIR bands
SWIR bands on MODIS have inadequate signal-to-noise (SNR) ratios
difficult to vicariously calibrate the SWIR bands on MODIS
must define conditions for switching from NIR to SWIR

# correction of non-negligible $R_{rs}$(NIR)




estimate $R_{rs}$(NIR) using a bio-optical model

operational SeaWiFS & MODIS processing ~ 2000-present

## advantages & disadvantages

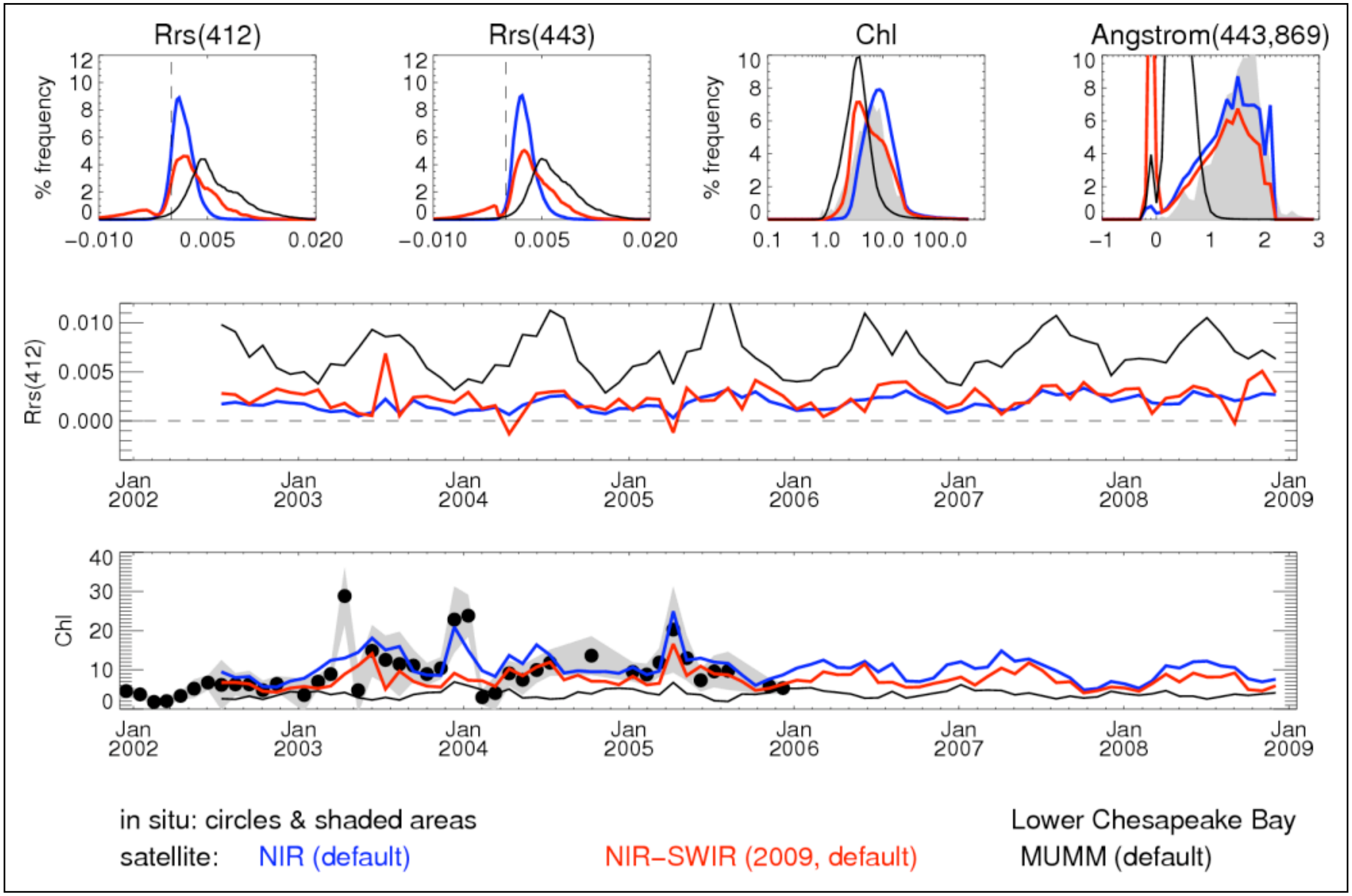
advantages:

method available for all past, present, & future ocean color missions
straightforward implementation for operational processing

disadvantages:

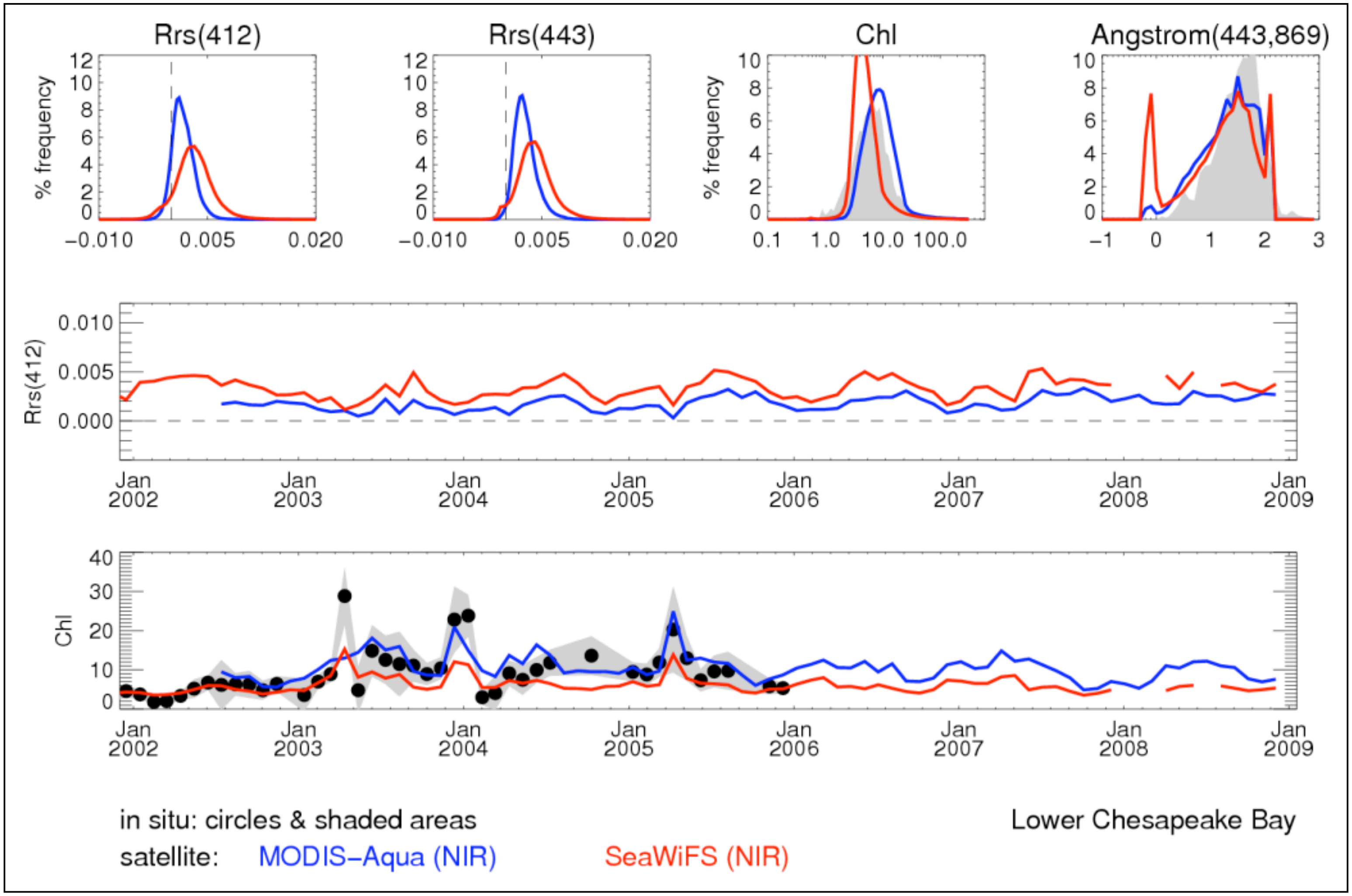
bio-optical model not valid at all times for all water masses

# summary of the three approaches



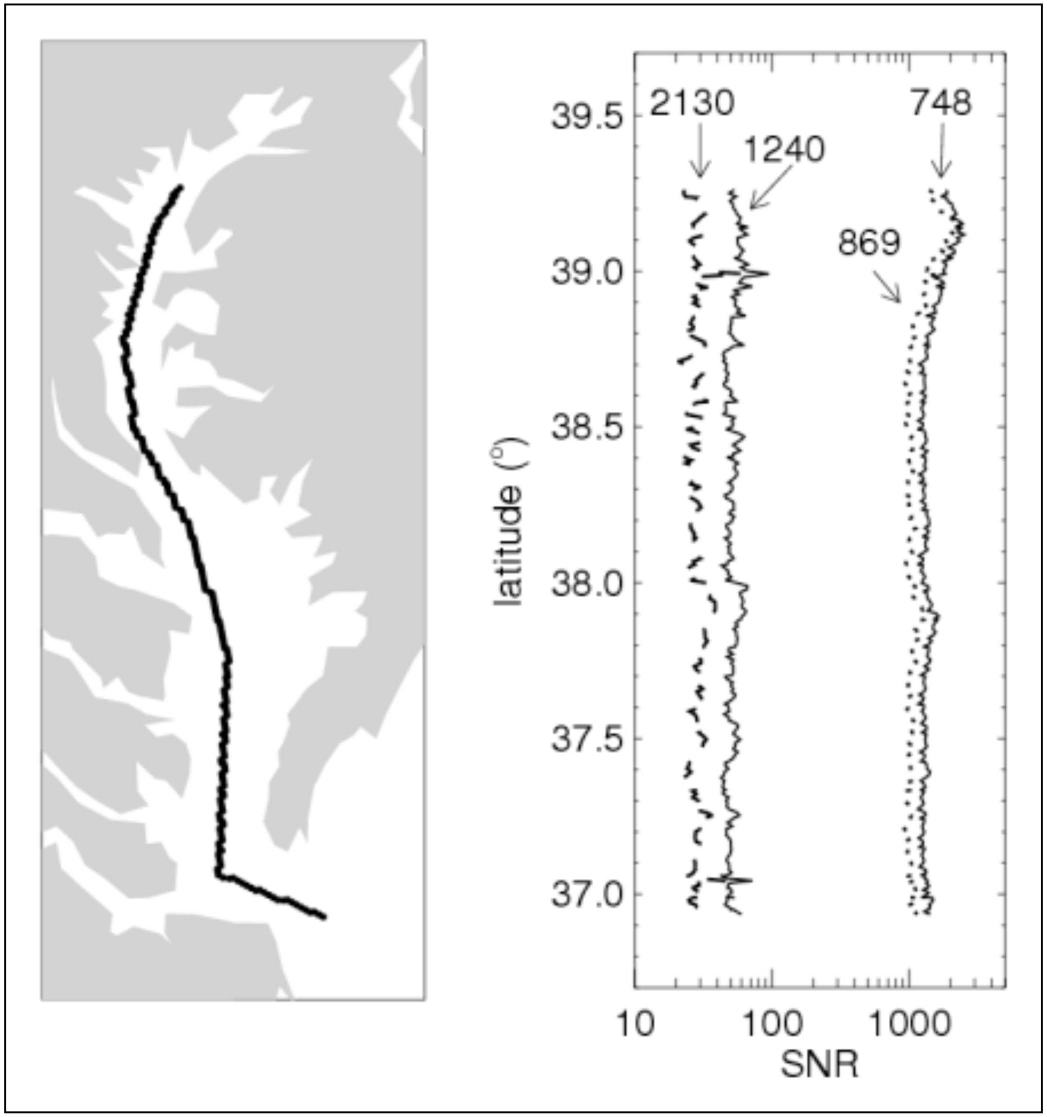

defaults as implemented in SeaDAS

# MODIS-Aqua vs. SeaWiFS

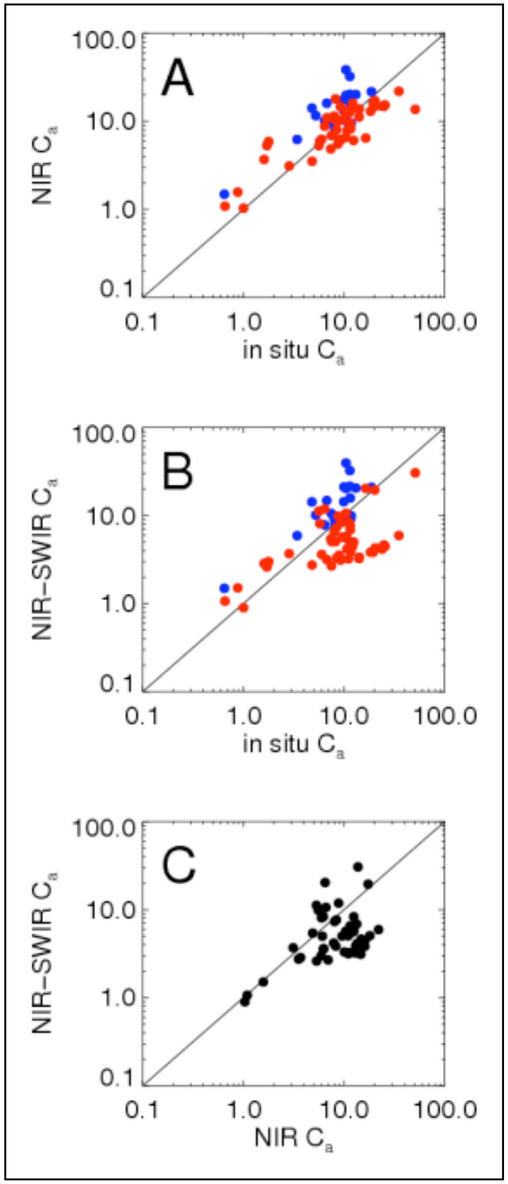



default processing ~ OC3 for MODIS-Aqua & OC4 for SeaWiFS

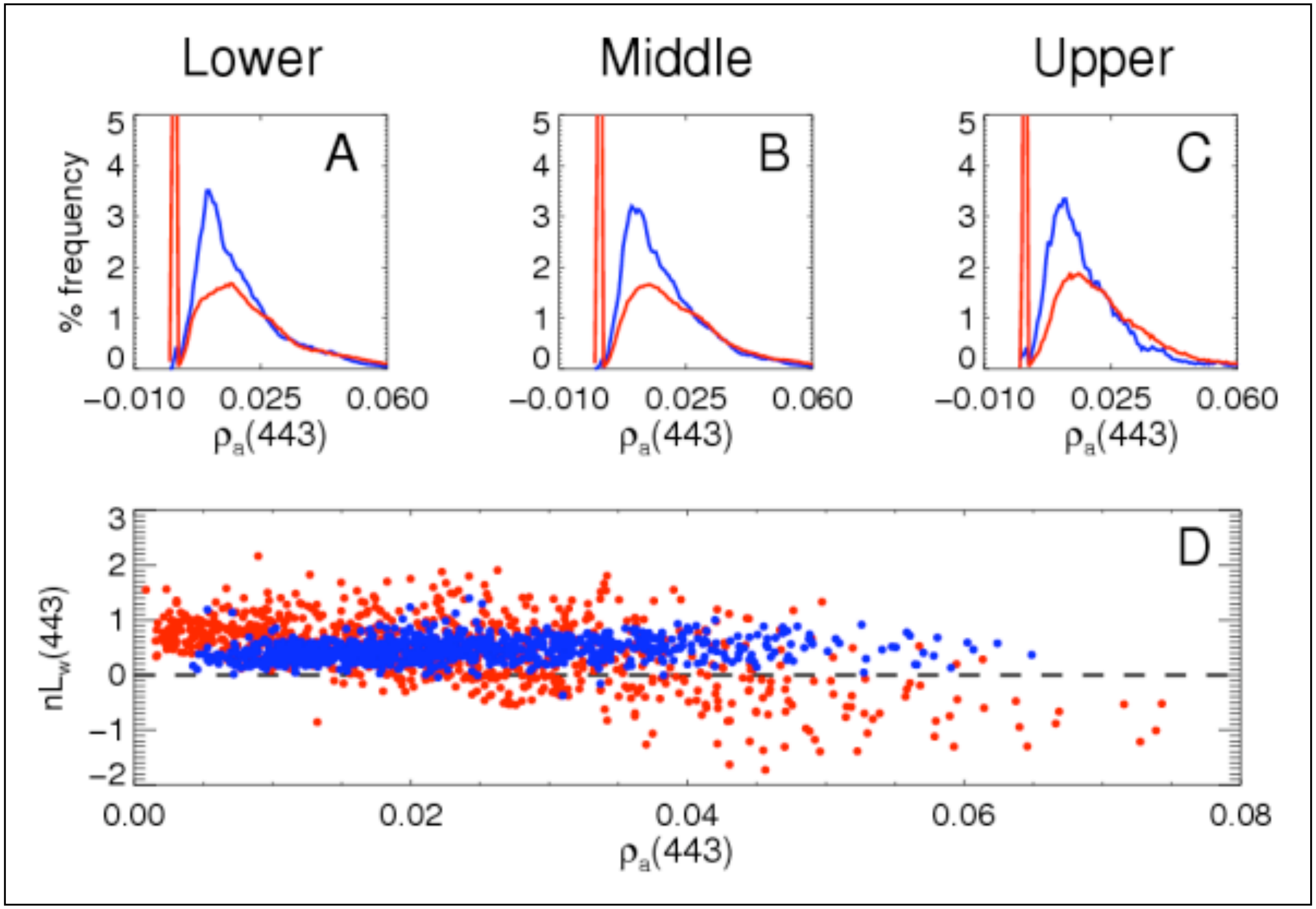
# SNR transect for MODIS-Aqua NIR & SWIR bands



# MODIS-Aqua Level-2 Chl "match-ups" for NIR & SWIR processing



# MODIS-Aqua $\rho_a(443)$



# distribution of the turbidity index using in NIR-SWIR switching