Overcoming Dimensionality Barriers in Satellite Data to Elucidate SPECTRAL-SPATIAL-TEMPORAL Trends in the Ocean

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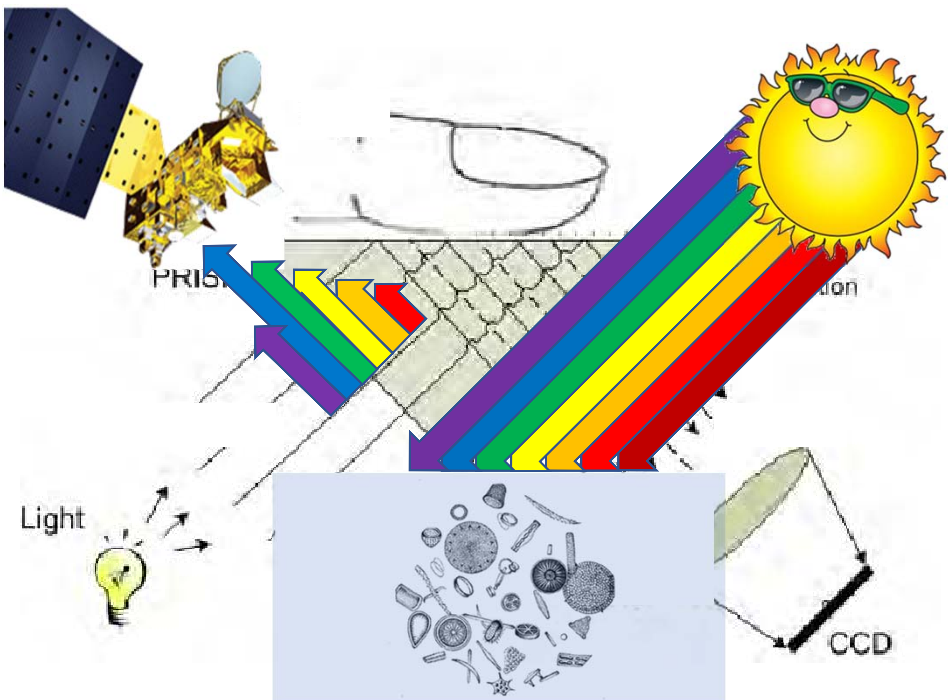
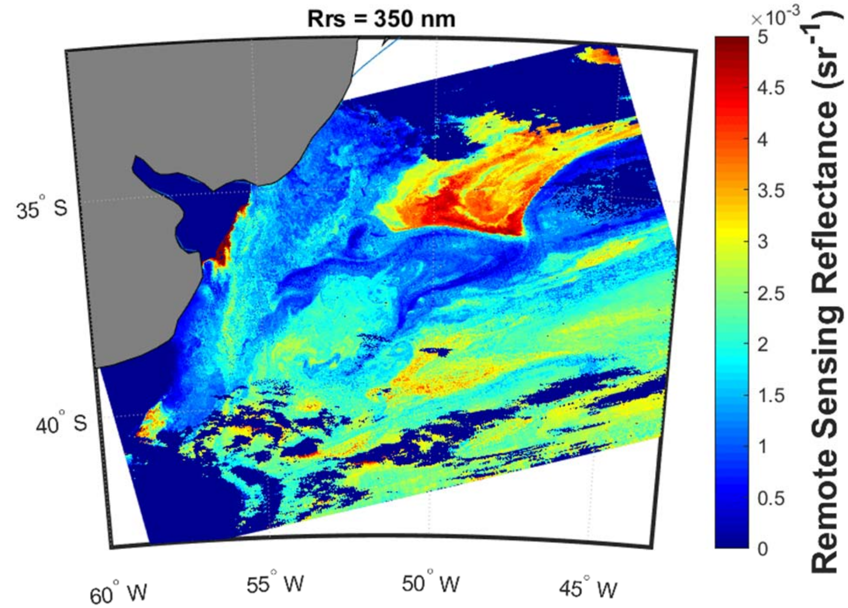
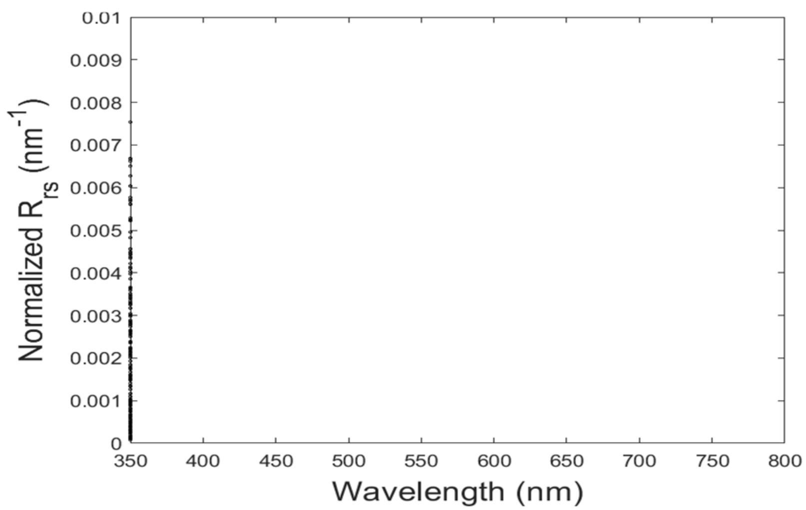
Optical “Fingerprints”



How can quantify and analyze the differences between multiple layers of spectral information within the context of a two-dimensional image?

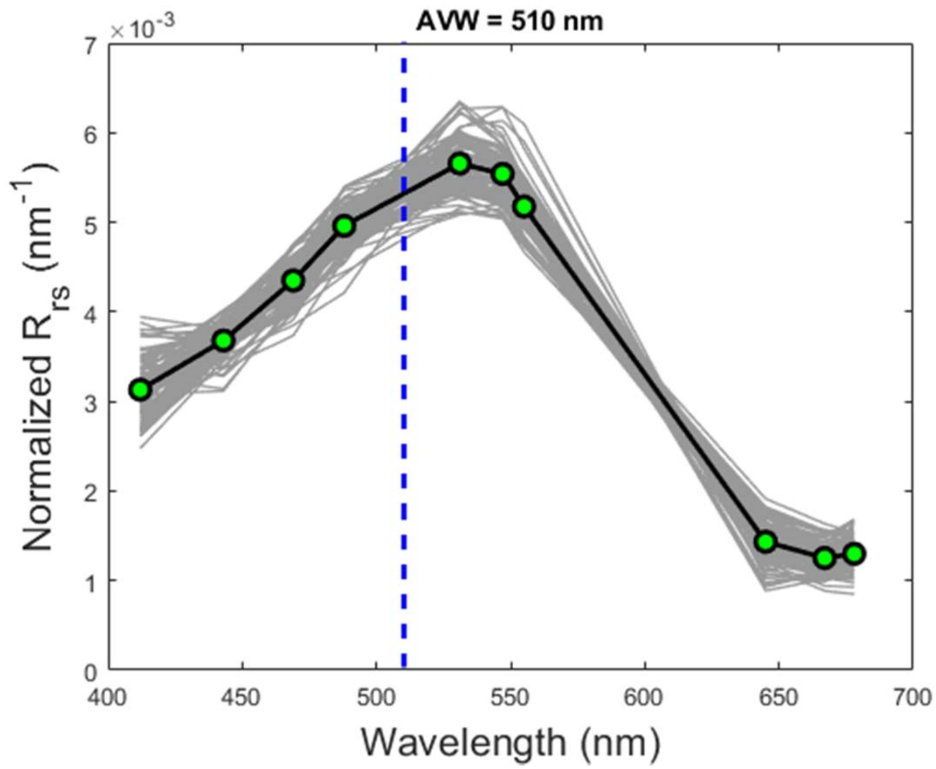




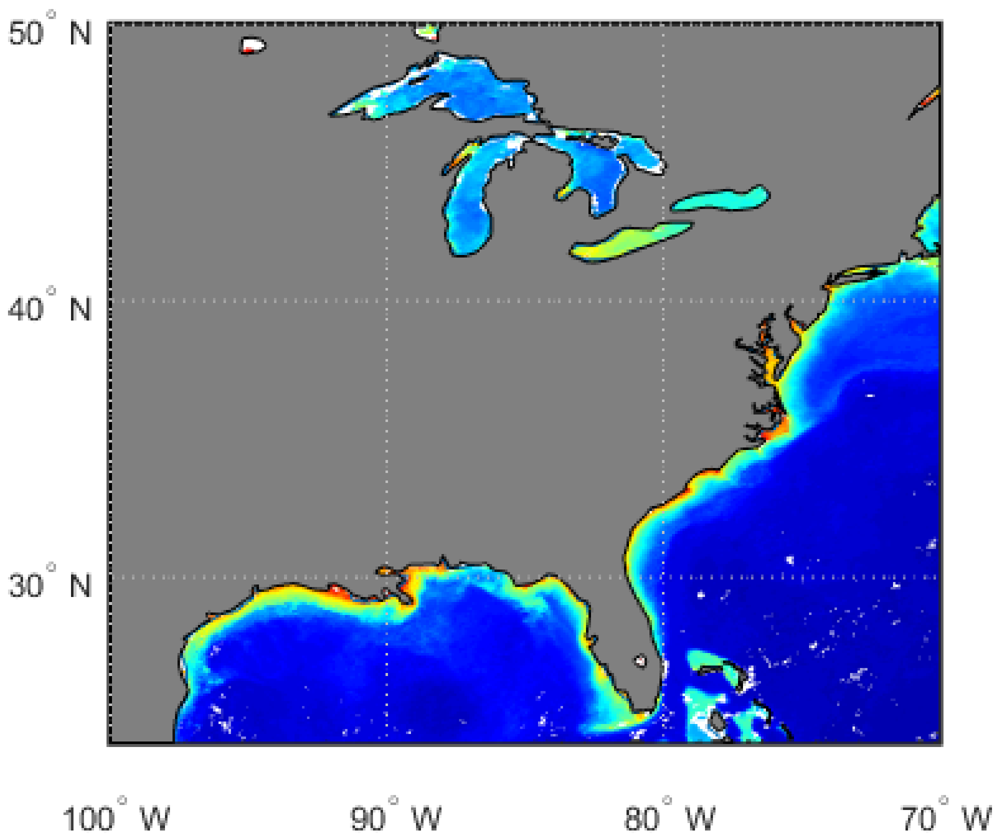
Apparent Visible Wavelength

$$AVW = \frac{\sum_{i=\lambda_1}^{\lambda_n} R_{RS}(\lambda_i)}{\sum_{i=\lambda_1}^{\lambda_n} \frac{R_{RS}(\lambda_i)}{\lambda_i}} = \left(\frac{\sum_{i=\lambda_1}^{\lambda_n} \lambda_i^{-1} R_{RS}(\lambda_i)}{\sum_{i=\lambda_1}^{\lambda_n} R_{RS}(\lambda_i)} \right)^{-1}$$

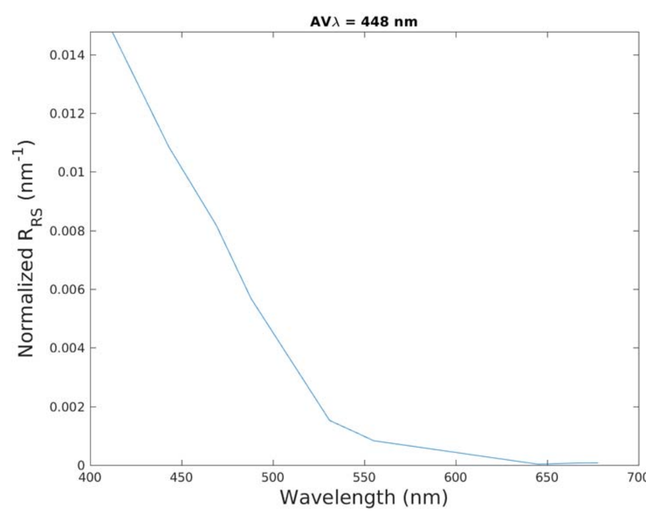
The weighted harmonic mean of the R_{RS} wavelengths, outputs an ***Apparent Visible Wavelength, AVW*** *(in units of nm). The derivation of the AVW is simply a first-order measure of the dominant color of the water, as determined by the weight that each measured channel contributes to the reflectance in the visible range of the spectrum.*

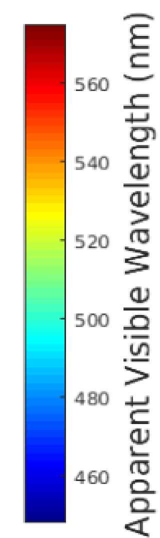


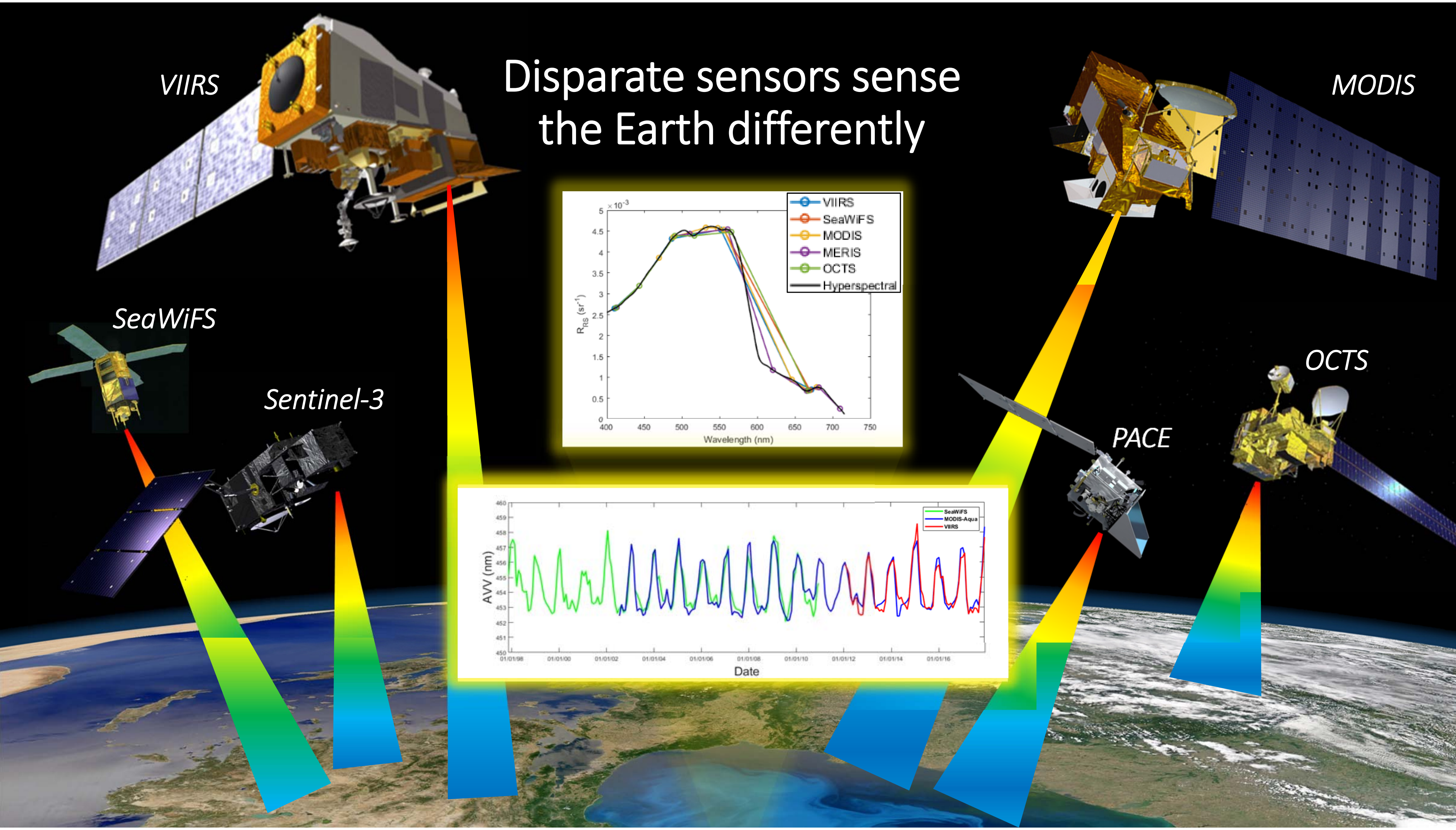
Apparent Visible Wavelength



Every color on the map represents a different spectral shape. Constraining multiple layers (wavelengths) of multi-spectral $R_{rs}(\lambda)$ into one dimension is a simple and robust way for users to visualize and quantify trends in spectral $R_{rs}(\lambda)$ in terms of its apparent dominant color, which, inherently relates to a specific spectral shape and a unique combination of absorption and scattering properties.

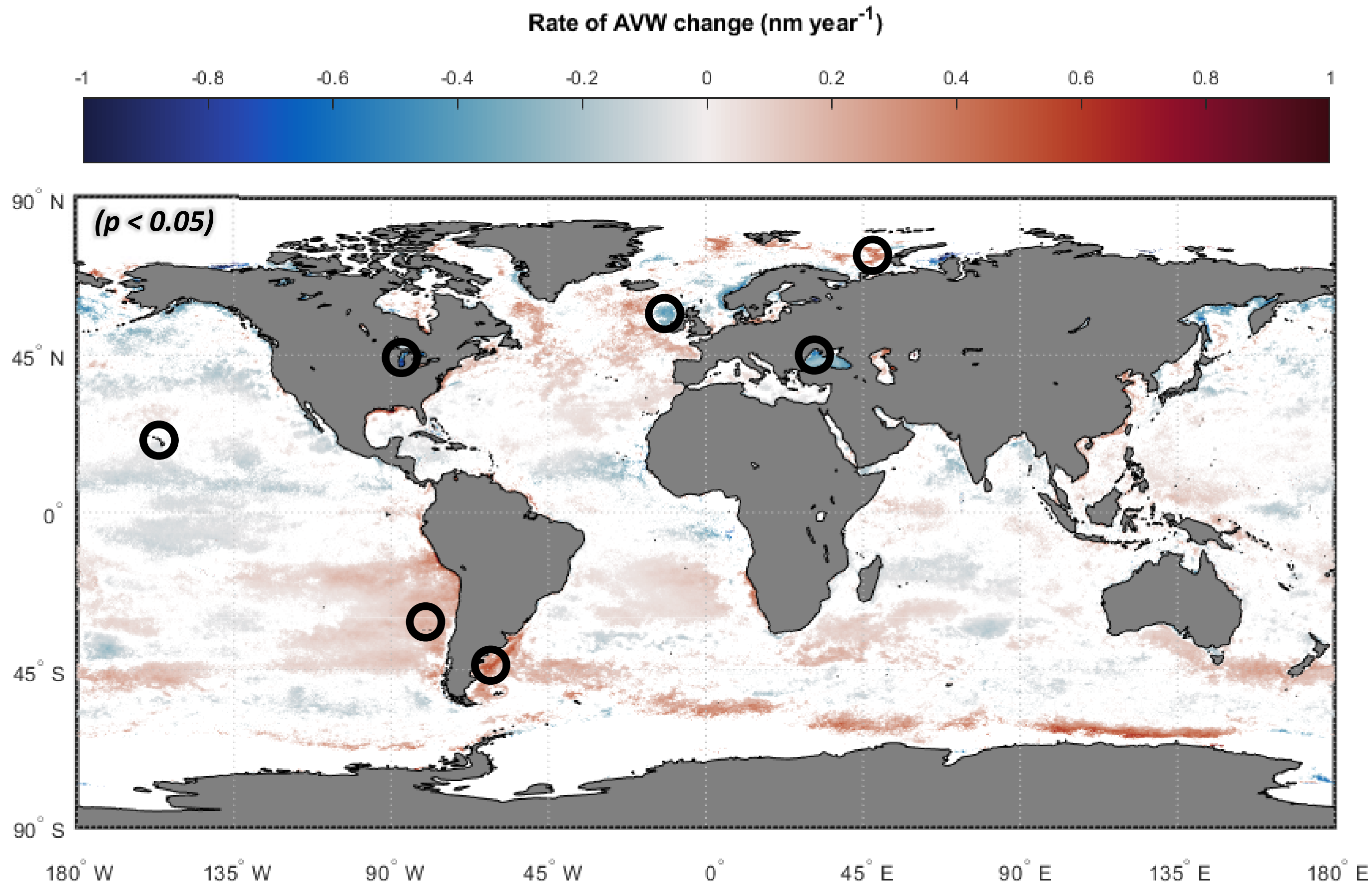


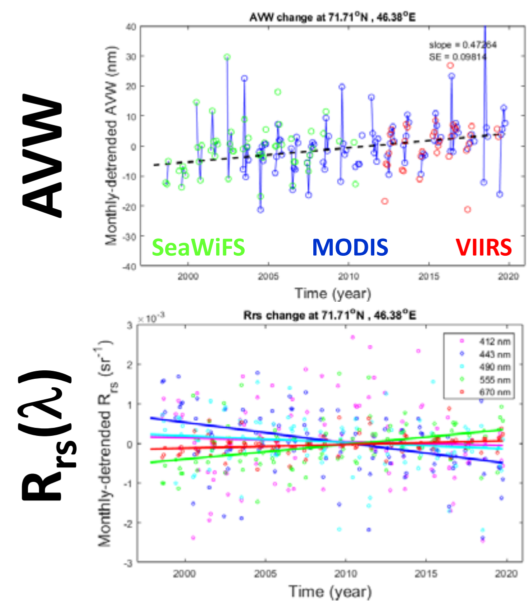




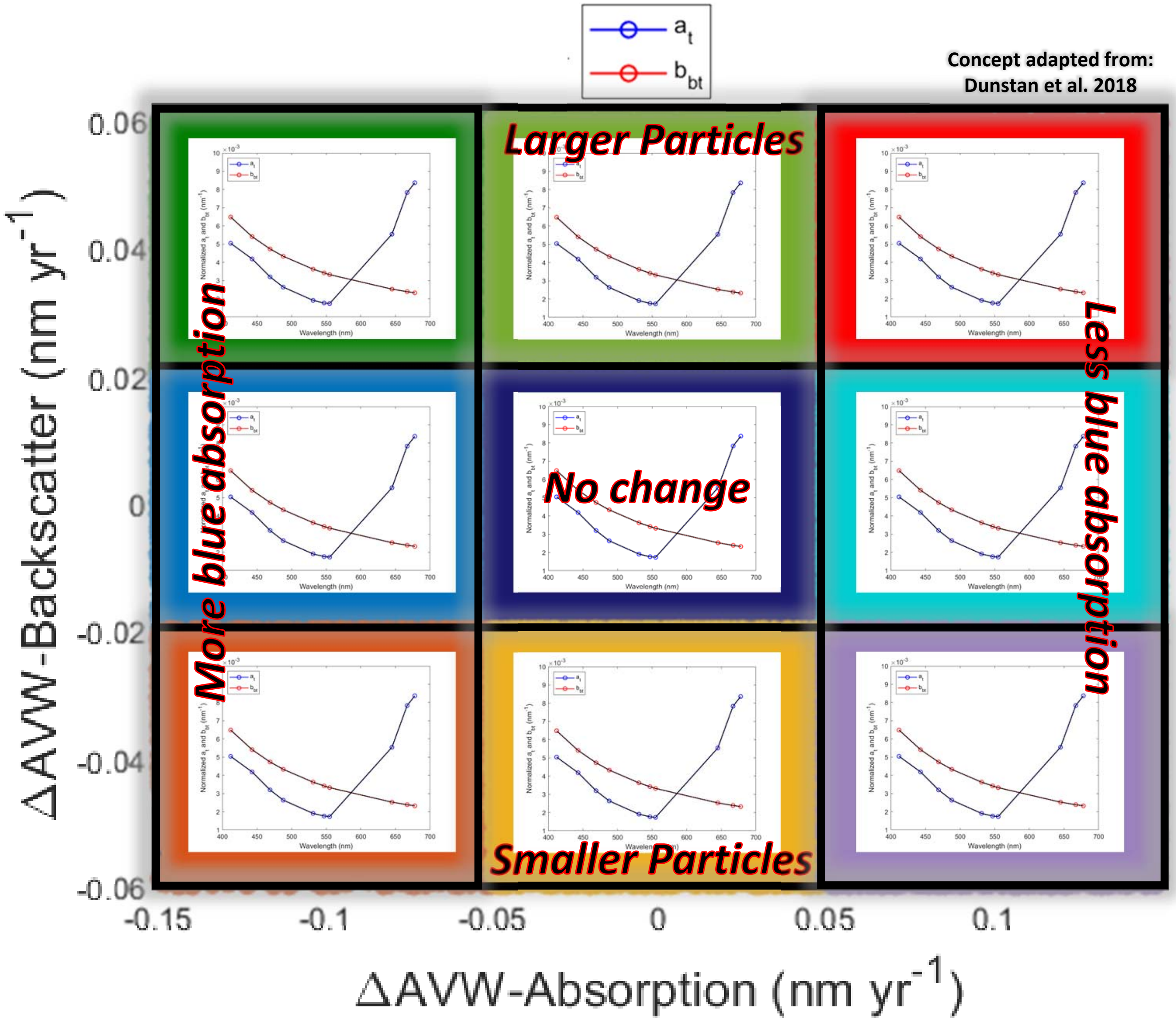
Disparate sensors sense the Earth differently
VIIRS
MODIS
SeaWiFS
Sentinel-3
OCTS
PACE
VIIRS
SeaWiFS
MODIS
MERIS
OCTS
Hyperspectral
×10^-3
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
R_RS (sr^-1)
400
450
500
550
600
650
700
750
Wavelength (nm)
SeaWiFS
MODIS-Aqua
VIIRS
AVV (nm)
Date

Elucidating spectral shifts over time (SeaWiFS → MODIS/VIIRS → PACE)



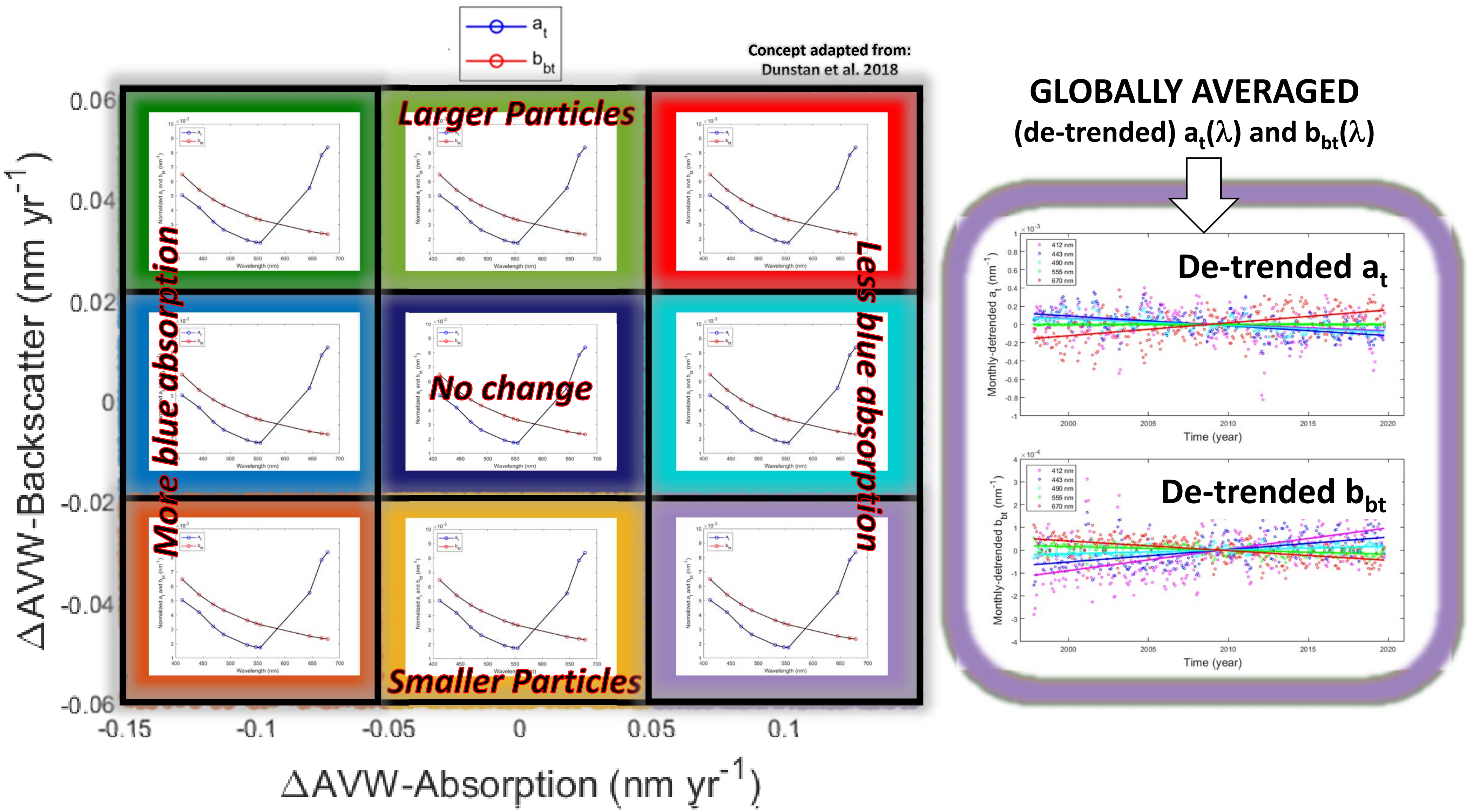


Robust Linear regression/time of AVW enables the examination of spectral shift in $R_{rs}(\lambda)$ over time



Apparent Visible Wavelength *into the IOP-verse*

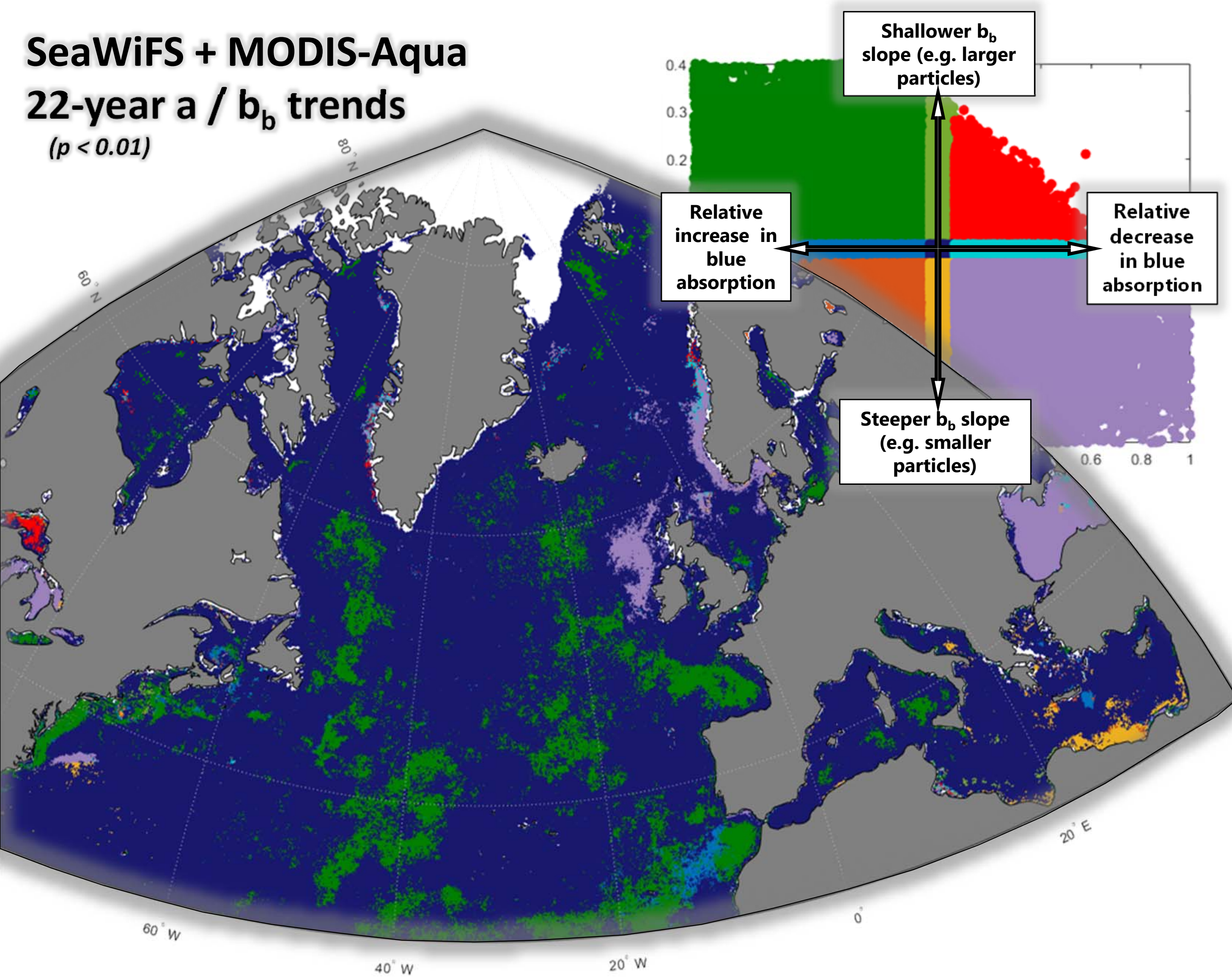
- AVW concept can be seamlessly applied to IOPs (total absorption and backscatter, GIOP).
- If we compare the rate of change in spectral shape of a_T relative to that of b_{bT}, we find that the two are no always directly correlated or proportional.
- Subtle changes in the relative directionality of spectral trends may help elucidate bio-optical (or other) shifts within the satellite data record.



Concept adapted from:
Dunstan et al. 2018
GLOBALLY AVERAGED
(de-trended) $a_t(\lambda)$ and $b_{bt}(\lambda)$
Larger Particles
No change
Smaller Particles
More blue absorption
Less blue absorption
ΔAVW-Backscatter (nm yr^{-1})
ΔAVW-Absorption (nm yr^{-1})
De-trended a_t
De-trended b_{bt}
Time (year)

SeaWiFS + MODIS-Aqua 22-year a / b_b trends

($p < 0.01$)



What this does show:

- Relative *magnitude* and *directionality* of spectral shifts in GIOP products.

What this does NOT show:

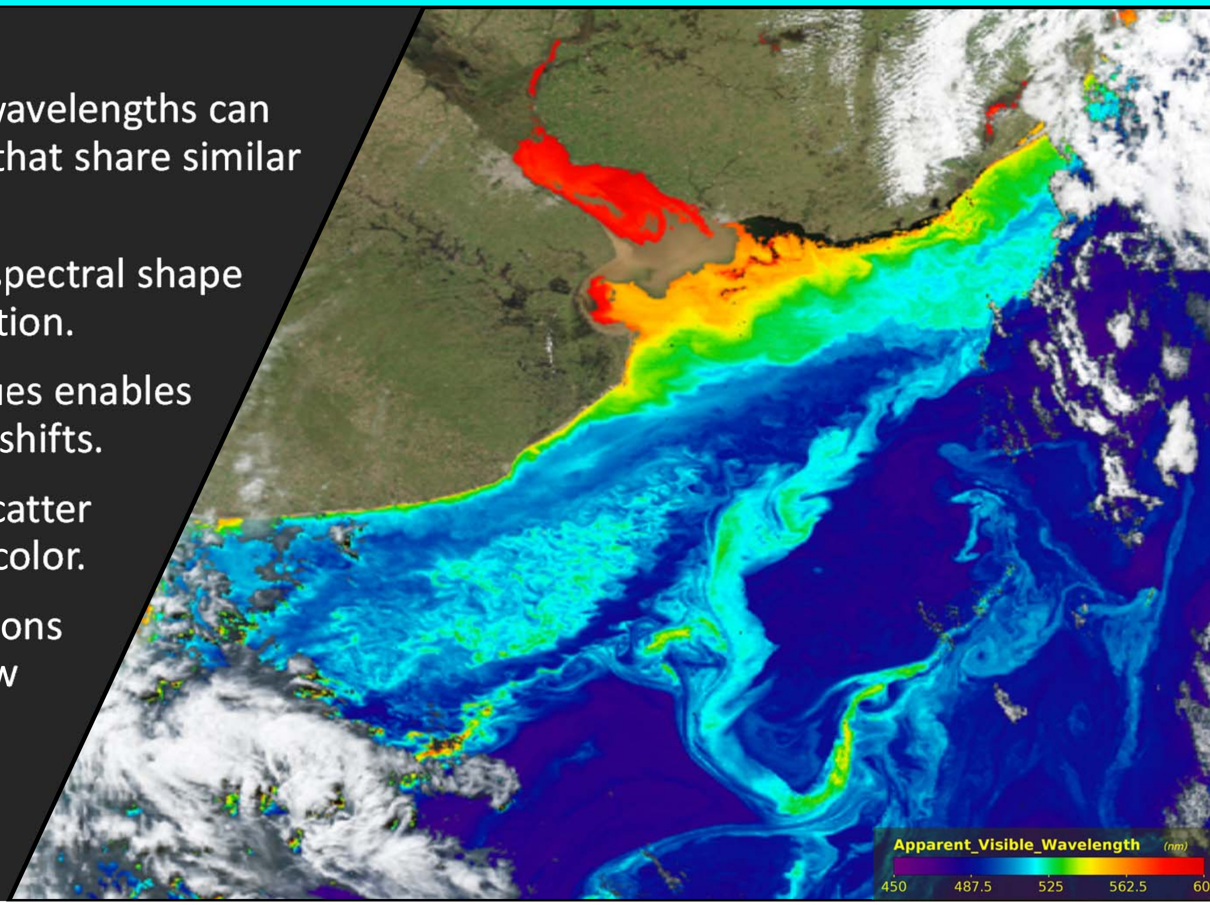
- Where these measurements have been adversely impacted by atm-correction.
- A truly independent assessment of IOP behavior ($S = 0.018$, $\eta \sim r_{rs}443/r_{rs}55x$, $a_{ph} \sim$ chl-a $\sim r_{rs}443/r_{rs}55x$).

So why do we care?

- The simultaneous conceptualization of multiple data dimensions maximizes the full capacity of a given sensor. Can we link bio-optical behavior over time with shifts in community composition?

Summary

1) The weighted harmonic mean of spectral wavelengths can be used as an index of optical water types that share similar spectral signatures.
2) This technique can be translated to relate spectral shape between sensors of varying spectral resolution.
3) The output along a continuum of color values enables spatio-temporal analysis of subtle spectral shifts.
4) Directional trends in absorption and backscatter lend a hidden context to changes in water color.
5) Conceptualization of multiple data dimensions is imperative as passive/active sensors grow increasingly sophisticated in nature.



Posters addressing spectral-spatial trends:

- **ME24C-0118** - *Sensor Fusion in the Chromatic Domain: Expanding the spatiotemporal reach of the operational ocean color constellation* (Jolliff et al.) - Tuesday
- **OB24C-0472** - *Global trends of transparency and color based on merged multi-sensor satellite data* (Pitarch et al.) - Tuesday
- **CP14D-1090** - *Water Clarity in Large Lakes and Reservoirs across China between 2000 and 2017 Observed from MODIS* (Li and Wang) – Monday
- **ME24C-0117** - *Retrieval of Water Quality Parameters from NOAA Hyperspectral Data Using Neural Networks - Western Lake Erie* (Zolfaghari et al.) – Tuesday