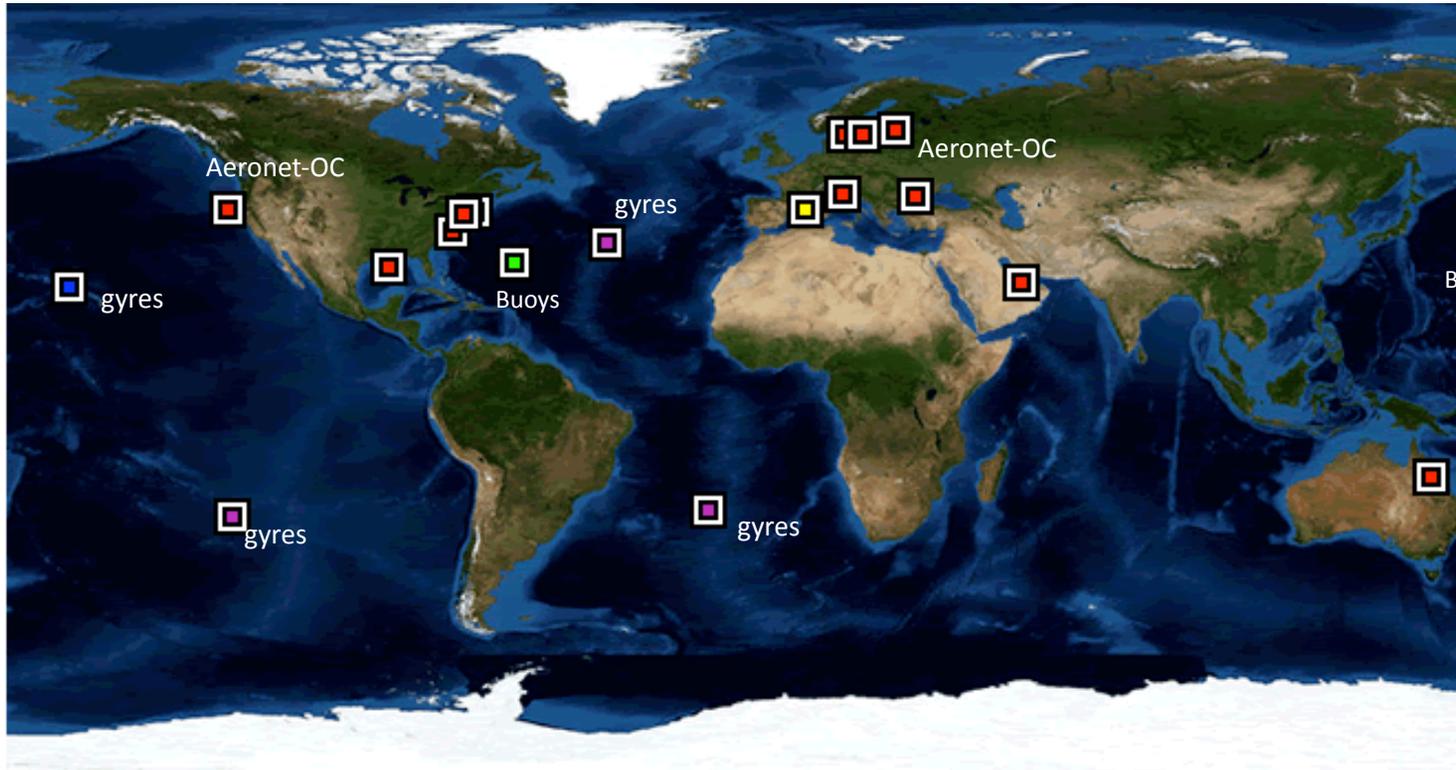


**Spatial and Temporal Uncertainty
of satellite ocean color :
Real time Satellite and Aeronet_OC Matchup**

R. Arnone , G. Fargion, Z. Lee
P. Martinolich, A. Weidemann, A. Lawson, R. Vaughn, D. Lewis
Aeronet – site Stakeholders

Global Network Monitoring Satellite products

“Real time monitoring capability”



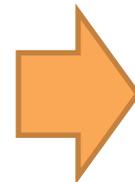
Golden regions		
	Areas	Data
1	Long Island	Aeronet
2	Venice	Aeronet
3	MVCO	Aeronet
4	WaveCIS (Gulf)	Aeronet
5	Lucinda	Aeronet
6	COVE (Chesapeake)	Aeronet
7	Gustav Dalen	Aeronet
8	Helsinki	Aeronet
9	Gloria	Aeronet
10	MOBY - Buoy	cal val Mooring
11	Boussole Buoy france	cal val Mooring
12	South pacific	Gyre
13	North Pacific	Gyre
14	North Atlantic	Gyre
15	South Atlantic G	Gyre
16	West Coast US - Aeronet	Aeronet
17	Abu Al Bukhoosh	Aeronet
18	Palgrunden	Aeronet
19	HOTS	Time Series
20	BATS	Rime Series
21	CalCOFI	Time Series

Real time Observations
Real time Satellite products

MODIS, MERIS, Proxy NPP



Product evaluation
Tracking Algorithm
Stability & Satellite
calibration



Product
Uncertainty



Data access underway

Status

(Feb 17, 2011)

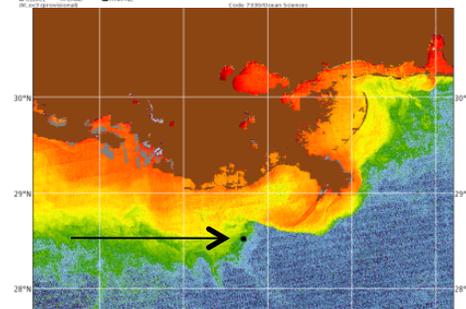
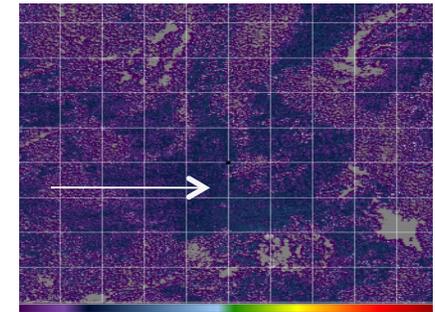
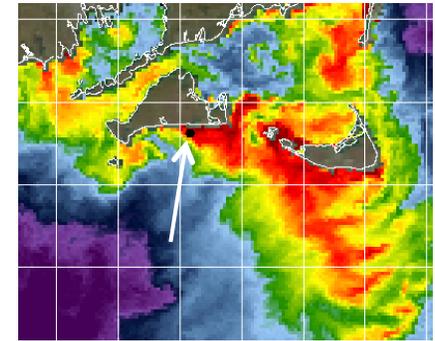
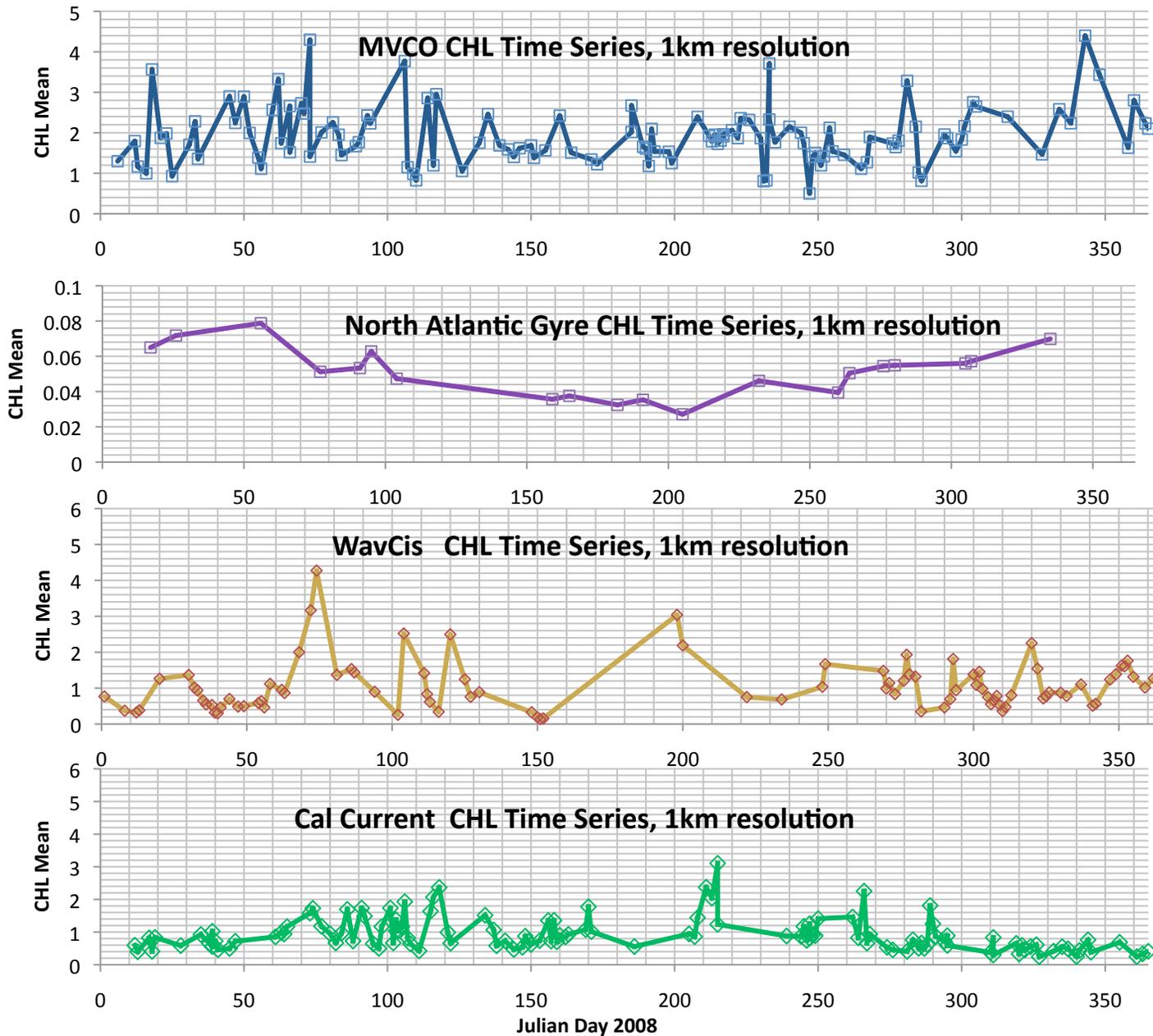
Back to Jan 2010

Golden Regions

	Areas	Data	Map	Lat/Lon (Rounded)	Date Online	SeaWiFS 1Km	MODIS 1km	MODIS 250m	MERIS 1km	MERIS 300m	NPP Proxy
1	Long Island Sound	AERONET OC	MVCOX (MVX)	N/S 40; E/W -73	Jan 2010	X	x	X	X	X	X
2	Venice	AERONET OC	AAOT (AOT)	N/S 45; E/W 12	Jan 2010	X	x	X	X	X	X
3	MVCO	AERONET OC	MVCOX (MVX)	N/S 41; E/W -70	Jan 2010	X	x	X	X	X	X
4	Wave CIS (Gulf)	AERONET OC	WaveCIS (WCS)	N/S 29; E/W -90.5	Jan 2010	X	x	X	X	X	X
5	Lucinda	AERONET OC	LucindaJetty (LJY)	N/S -18; E/W 146.4	Jan 2010	X	x	X	X	X	X
6	COVE (Chesapeake)	AERONET OC	COVE (COV)	N/S 36.9; E/W -75.7	Jan 2010	X	x	X	X	X	X
7	Gustav Dalen	AERONET OC	GDAT (GDT)	N/S 58.6; E/W 17.5	Jan 2011	Na	x	X	X	X	X
8	Helsinki	AERONET OC	Helsinki (HLH)	N/S 59.9; E/W 24.9	Jan 2011	Na	x	X	X	X	X
18	Gloria	AERONET OC	Gloria (GAS)	N/S 29.36; E/W 44.6	Jan 2011	Na	x	X	X	X	X
9	MOBY - Buoy	Cal/Val Mooring	MOBY (M [★])	N/S 20.5; E/W -157.19	Jan 2011	Na	x	X	X	X	X
17	Boussole Buoy	Cal/Val Mooring	Boussole Buoy (BOB [★])	N/S 42.37; E/W 7.9	Jan 2011	Na	x	X	X	X	X
10	South Pacific	Gyre	SouthPacific Gyre (SPG)	N/S -26.5; E/W -135.5	Jan 2011	Na	x	X	X	X	X
11	North Pacific	Gyre	NorthPacific Gyre (NPG)	N/S 32.1; E/W 178.1	Jan 2011	Na	x	X	X	X	X
12	North Atlantic	Gyre	NorthAtlantic Gyre (NAG)	N/S 25; E/W -42	Jan 2011	Na	x	X	X	X	X
13	South Atlantic	Gyre	SouthAtlantic Gyre (SAG)	N/S -36.5; E/W -20.1	Jan 2011	Na	x	X	X	N/A	X
14	West Coast US – Eureka (spring 2011)	AERONET OC	Eureka	N/S 33; E/W 118	Feb 2011	Na	x	X	X	X	X
15	Abu Al Bukhoosh	AERONET OC	AbuAlBukhoosh (AAB)	N/S 25.5; E/W 53.1	Jan 2011	Na	x	X	X	N/A	X
16	Palgrunden	AERONET OC	Palgrunden (PAL)	N/S 58.75; E/W 13.15	Jan 2011	Na	x	X	X	N/A	X
19	HOTS	Time Series	HOTS [★]	N 23.75; S 23.5; W -158.75 ; E -157.5	Jan 2011	Na	X	X	X	N/A	X
20	BATS	Time Series	BATS (B [★])	N 34; S 30; W -66; E -62	Jan 2011	Na	X	X	X	X	X
21	CalCOFI	Time Series	CalCOFI (C [★])	N 34; S 29; W -124.5; E -118.5	Jan 2011	Na	X	X	X	X	X

Examples MODIS – Chlorophyll 1 km Time series (5x5 box mean)

All Golden Regions satellite products running Now - Feb 2011



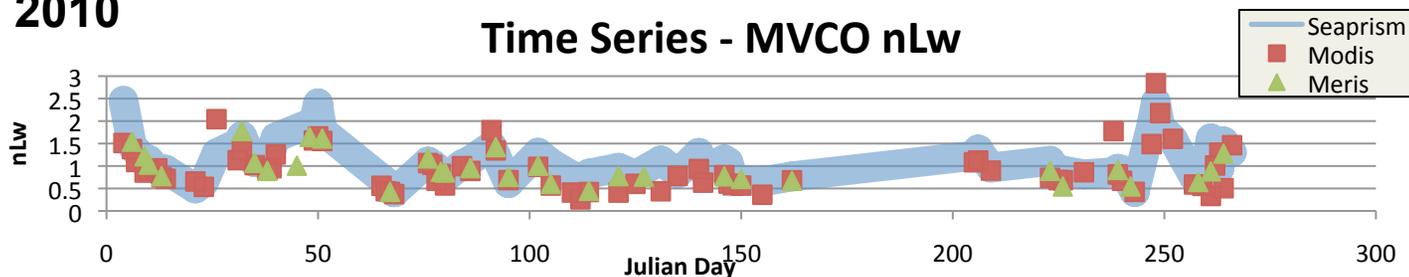
**Additional, satellite
Bio-optical Products,
Aerosol Properties**

All satellites .

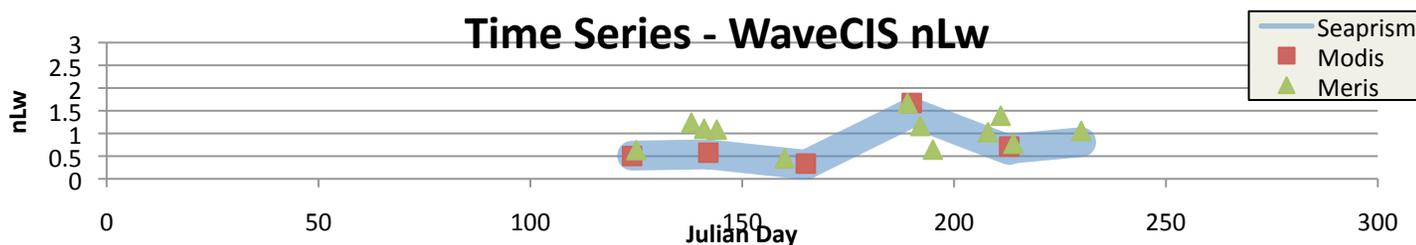
Daily updates from Aeronet –OC and Satellite - Running Now – Feb 2011!

2010

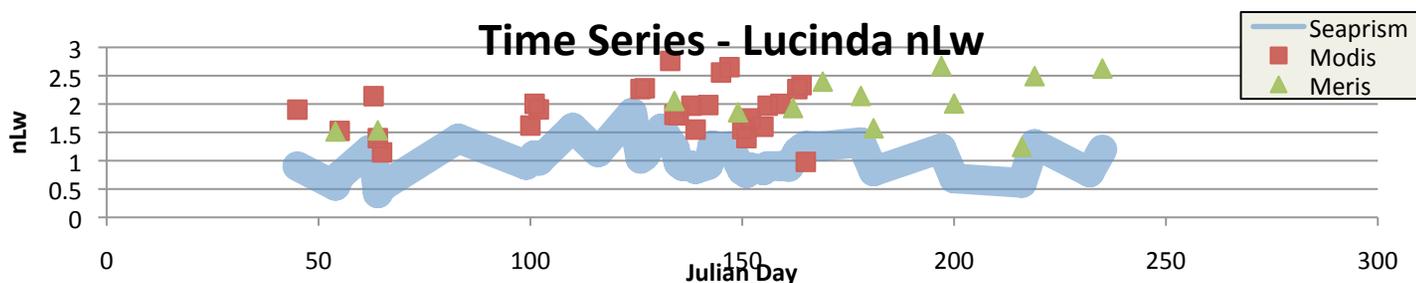
Time Series - MVCO nLw



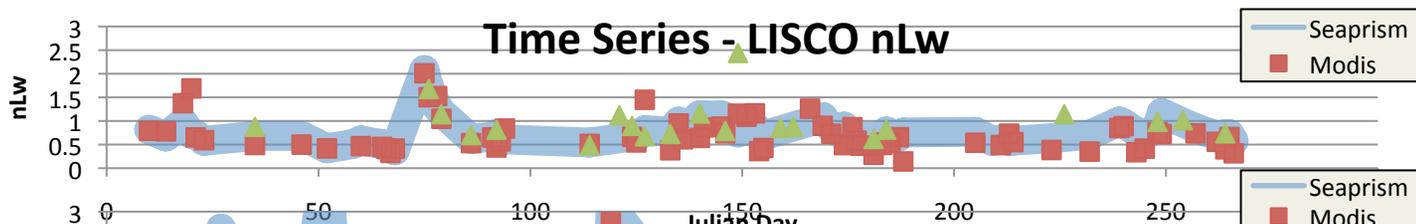
Time Series - WaveCIS nLw



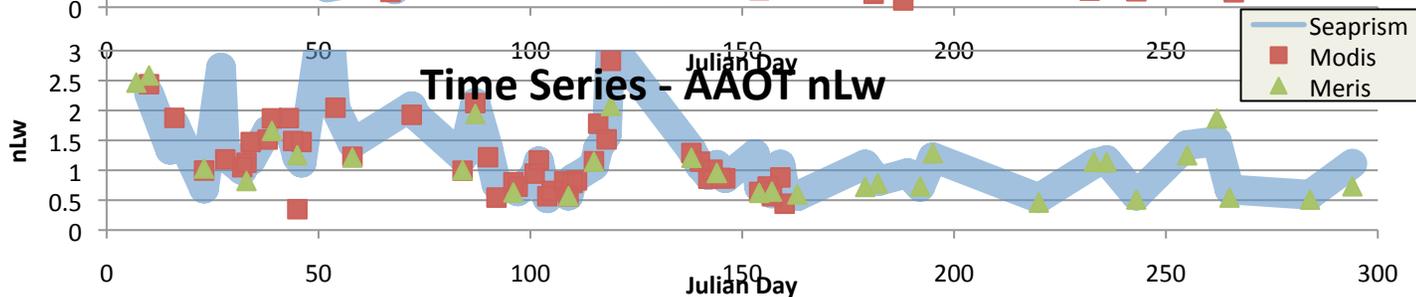
Time Series - Lucinda nLw



Time Series - LISCO nLw



Time Series - AAOT nLw



Aeronet –OC
MODIS 1 km
MERIS 1 km

Matchup
 Constraints

- + 1 hour
- 5x5 box (25 km)
- Mean nLw
- Std- 0.02
- 50% valid
- SAngle – 30°
- SpAngle - <30°
- LV1.5
- Start 1/1/2010
- End 1/10/2010
- Wind – NA

- No spectral shift

Matchup Tool for Golden Regions



NRL Cal/Val Matchup Tool

Naval Research Laboratory Code 7331
 Bio-Optical Physical Processes and Remote Sensing, Bldg 1009
 Stennis Space Center, MS 39529



Compare Satellite and In Situ Products

Validate a Product

This section compares a satellite sensor to the SeaPRISM of certain locations. Simply choose the details of your timeframe and what you want to compare, and a new window/tab will appear with all of the comparisons within the selected timeframe. The data is output into a comma delimited format with the details listed [below](#). The Time Difference criteria is + or - from the time of the satellite pass.

Due to the nature of subsampling a box for the database there is a delay when getting any subsample of the higher resolution 25km² box. Also, at the higher resolution there is a slight offset due to spatial geometry and the station won't be exactly at the far corner pixel. The Corner referred to is which corner to place the in situ sensor in the box.

Choose the satellite information

The 'H' indicates High Resolution.

VIIRS 547 Normalized Water Leaving Radiance
 MODIS 547 Normalized Water Leaving Radiance
 MERIS 555 Normalized Water Leaving Radiance
 HMODIS 555 Normalized Water Leaving Radiance
 HMERIS 555 Normalized Water Leaving Radiance

* Does not have a wavelength; choose "0"
 ** Has an algorithm; change from null.
 See table below for algorithm-wavelength-product combinations.

Minimum Satellite Zenith Angle: -180
 Maximum Satellite Zenith Angle: 180

APS Processing Version: v4.0
 Max Satellite Coefficient of Variance: 1
 Satellite Standard Deviation: 0.0
 *The default of 0.0 will show all the values and not exclude anything.
 Minimum Percent Valid Satellite Pixels: 50.0
 Box Size*: 25km
 Time Difference: +/- 6 hr
 Minimum Solar Zenith Angle: -180
 Maximum Solar Zenith Angle: 180

Choose the meta information:

Select What to Display:

In situ Only
 Satellite Only
 Both (Matchups only)

Choose a Location: WaveCIS Site 6
 * Indicates a satellite only area.

Year: 2011
 Start Time: Jan 1
 End Time: Feb 15

Choose the in situ information

Choose a Seaprism Product:

Aerosol Optical Thickness
 Chlorophyll-a *
 Water Leaving Radiance
 Normalized Water Leaving Radiance
 Normalized Water Leaving Radiance (fQ)
 Water Leaving Radiance (Q)
 Ozone Optical Thickness
 Sea_Surface_Reflectance *

SeaPRISM Level:
 1.0
 1.5
 2.0

SeaPRISM Wavelength: 442
 * Select wavelength 0 for products marked by an asterisk (*) as they have no given wavelength.

Matchup Tool for Golden Regions

Ocean Cal Val – Data base Query

This section compares a satellite sensor to the SeaPrism or certain locations. Simply choose the details of your timeframe and what you want to compare, and a new window/tab will appear with all of the comparisons within the selected timeframe. The data is output into a comma delimited format with the details listed [below](#). The Time Difference criteria is + or - from the time of the satellite pass.

Due to the nature of subsampling a box for the database there is a delay when getting any subsample of the higher resolution 25km² box. Also, at the higher resolution there is a slight offset due to spatial geometry and the station won't be exactly at the far corner pixel. The Corner referred to is which corner to place the in situ sensor in the box.

#1 Select One Golden Regions

In situ Only (i.e Aeronet)
 Satellite Only
 Both (Matchups only)

Choose a Location: WaveCIS Site 6
** Indicates a satellite*

Start Time: Jan 2011
 End Time: Feb 15

Select In situ data
SeaPrism Product

- Aerosol Optical Thickness
- Chlorophyll-a *
- Water Leaving Radiance
- Normalized Water Leaving Radiance
- Normalized Water Leaving Radiance (f/Q)
- Water Leaving Radiance (Q)
- Ozone Optical Thickness
- Sea_Surface_Reflectance *
- Wind speed

Level: Long Island Sound
Helsinki
Gloria
Gustav Dalen Tower
Chesapeake Bay
Venice
Abu Al Bukhoosh
MOBY*
North Pacific Gyre*
South Pacific Gyre*
South Atlantic Gyre*
North Atlantic Gyre*
Boussole Buoy*
BATS*

Wavelength: 442
wavelength 0 for products marked by an asterisk () as they have no given wavelength.*

Select Satellite data

The 'H' indicates High Resolution.

VIIRS 547 Normalized Water Leaving Radiance null
 MODIS 443 Normalized Water Leaving Radiance null
 MERIS 555 Normalized Water Leaving Radiance null
 HMODIS 555 Normalized Water Leaving Radiance null
 HMERIS 555 Normalized Water Leaving Radiance null

** Does not have a wavelength; choose "0"*
*** Has an algorithm; change from null.*
See table below for algorithm-wavelength-product combinations.

Minimum Satellite Zenith Angle: -180
 Maximum Satellite Zenith Angle: 180
 Min Satellite Azimuth Angle: -180
 Max Satellite Azimuth Angle: 180

APS Processing Version: v4.0
 Max Satellite Coefficient of Variance: 1
 Satellite Standard Deviation: 0.0
**The default of 0.0 will show all the values and not exclude anything.*
 Minimum Percent Valid Satellite Pixels: 50.0
 Box Size*: 25km
 Time Difference: +/- 6 hr
 Minimum Solar Zenith Angle: -180
 Maximum Solar Zenith Angle: 180
 Minimum Solar Azimuth Angle: -180
 Maximum Solar Azimuth Angle: 180

Reset Get Data File

*Due to the number of look up options, this may take a couple of minutes. Please be patient.

Spatial Uncertainty

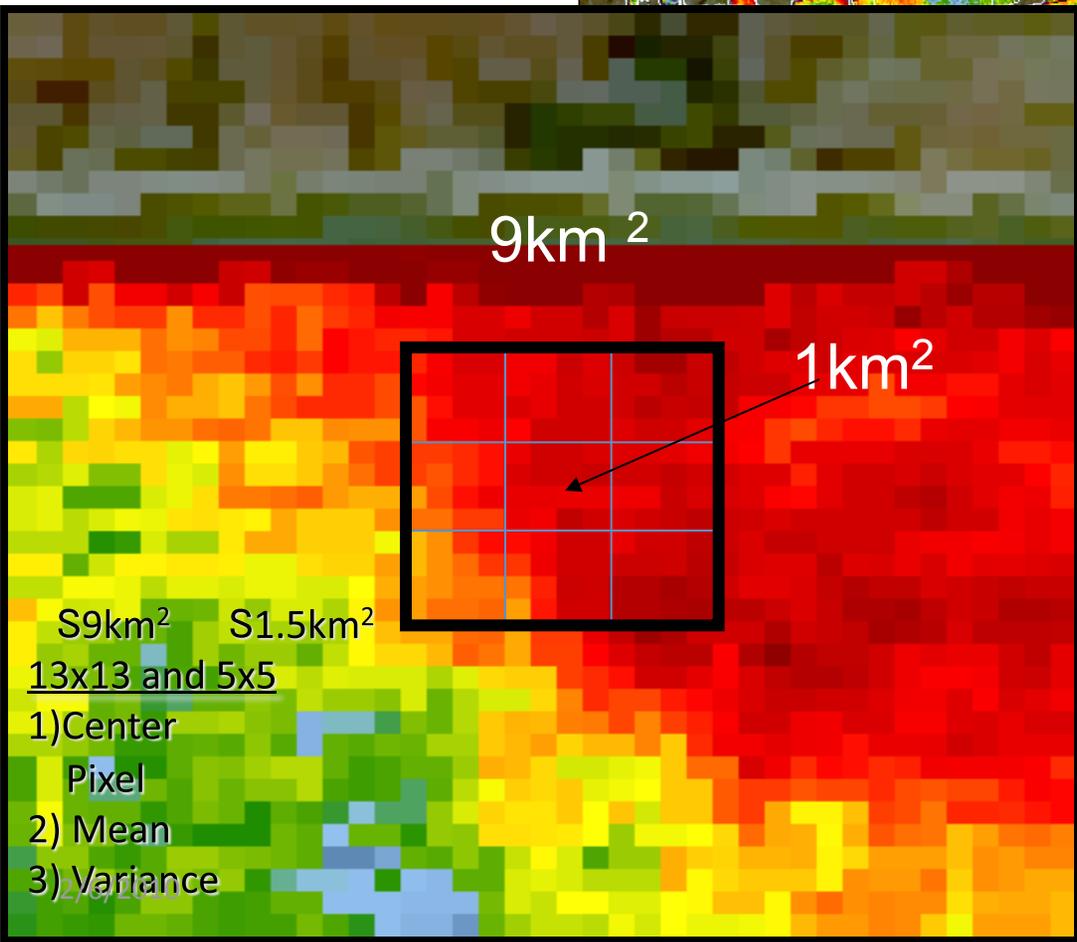
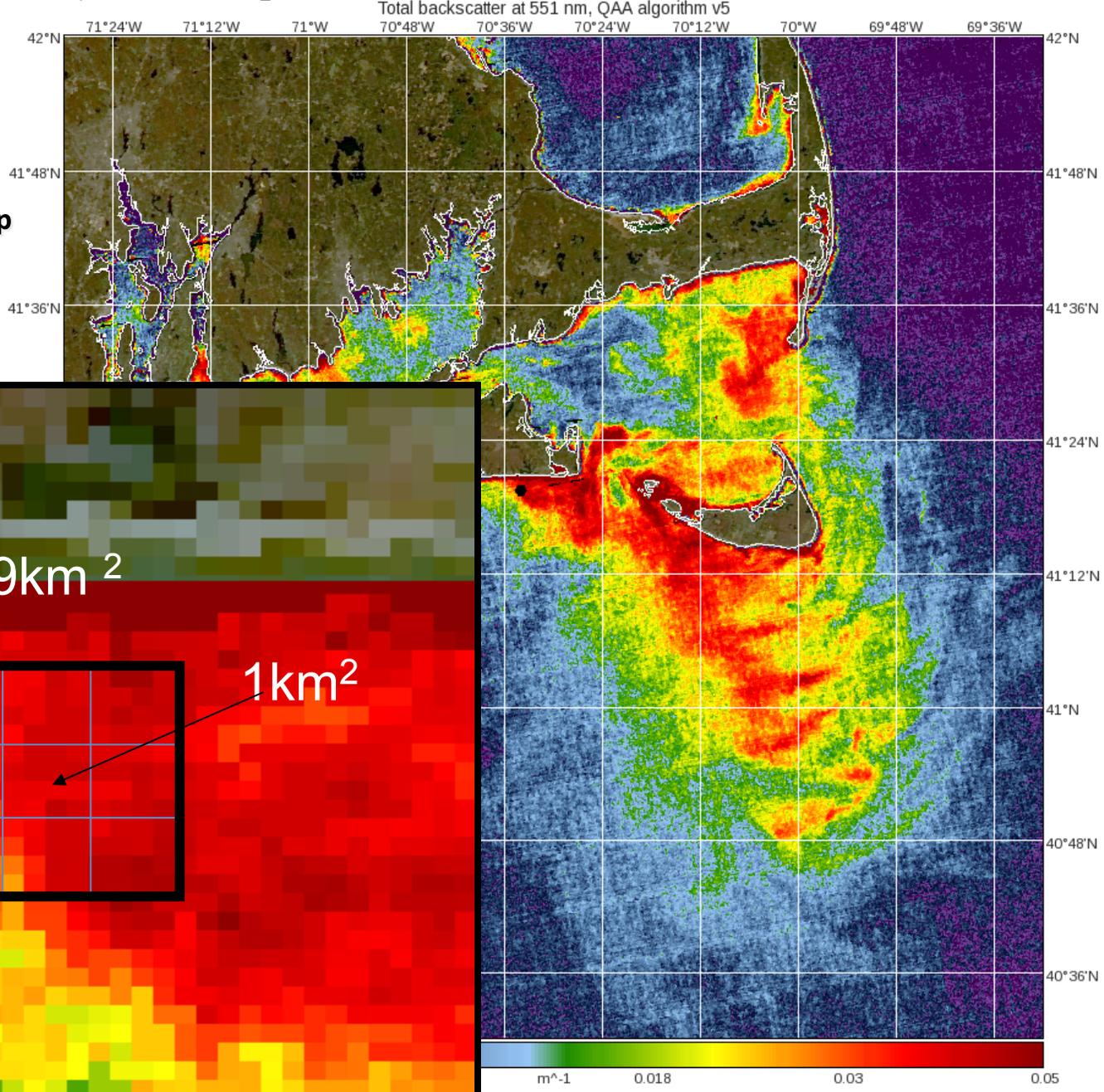
Martha's Vineyard

October 31, 2008

Automated – real time Match-up

- 1- aerosol optical depth
2. Remote sensing reflectance
3. In- water optics

aqua.2008305.1031.D.L3_Mosaic.hmodis.MVO.v08.250m.hdf Fri Oct 31 2008 Mosaic

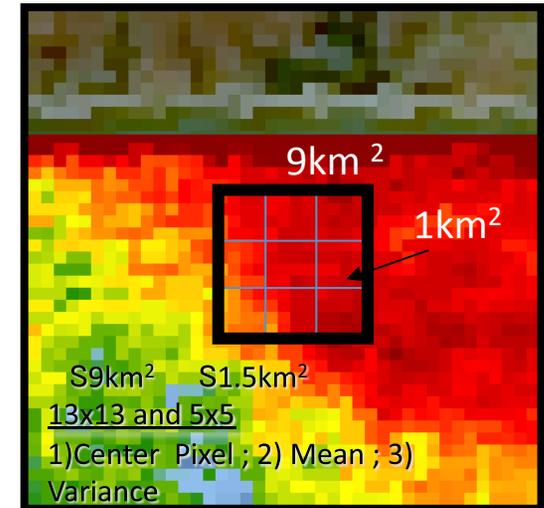


Code 7330/Ocean Sciences
 Naval Research Laboratory
 Stennis Space Center, MS

Satellite Product - Spatial Uncertainty

Spatial analyses in data base

Information Given	Details/Definition
Year	The year of the comparison.
Wavelength	The wavelength of the SeaPRISM in nanometers.
Julian Day	The day of the SeaPRISM observation.
Observation Time	The time the SeaPRISM observation was taken, given in hours:minutes format.
Value	The value from the SeaPRISM observation.
Number of Observations in a Day	The total number of valid observations the SeaPRISM took for the given julian day.
Daily Mean	The mean of the SeaPRISM's valid observations for the specified julian day.
Daily Standard Deviation	The standard deviation of the SeaPRISM's valid observations for the specified julian day.
Satellite Wavelength	The wavelength of the specified satellite in nanometers.
Satellite Julian Day	The julian day of the satellite.
Observation Time	The time of the satellite observation, given in hours: minutes format.
Number of Valid Pixels	From a 5x5 box with the center pixel being the location of the SeaPRISM, the number of good, unflagged pixels from the satellite data.
Center Pixel Value	The center pixel from the 5x5 box. It is the satellite's value at the specified SeaPRISM location.
5x5 Box Mean	The average of all the valid, unflagged pixels from the 5x5 box of the satellite pass.
Standard Deviation	The standard deviation of all the valid, unflagged pixels from the 5x5 box of the satellite pass.



Matchup Tool for Golden Regions

Reports back ASCII file of the matchup



Excel and plot generation

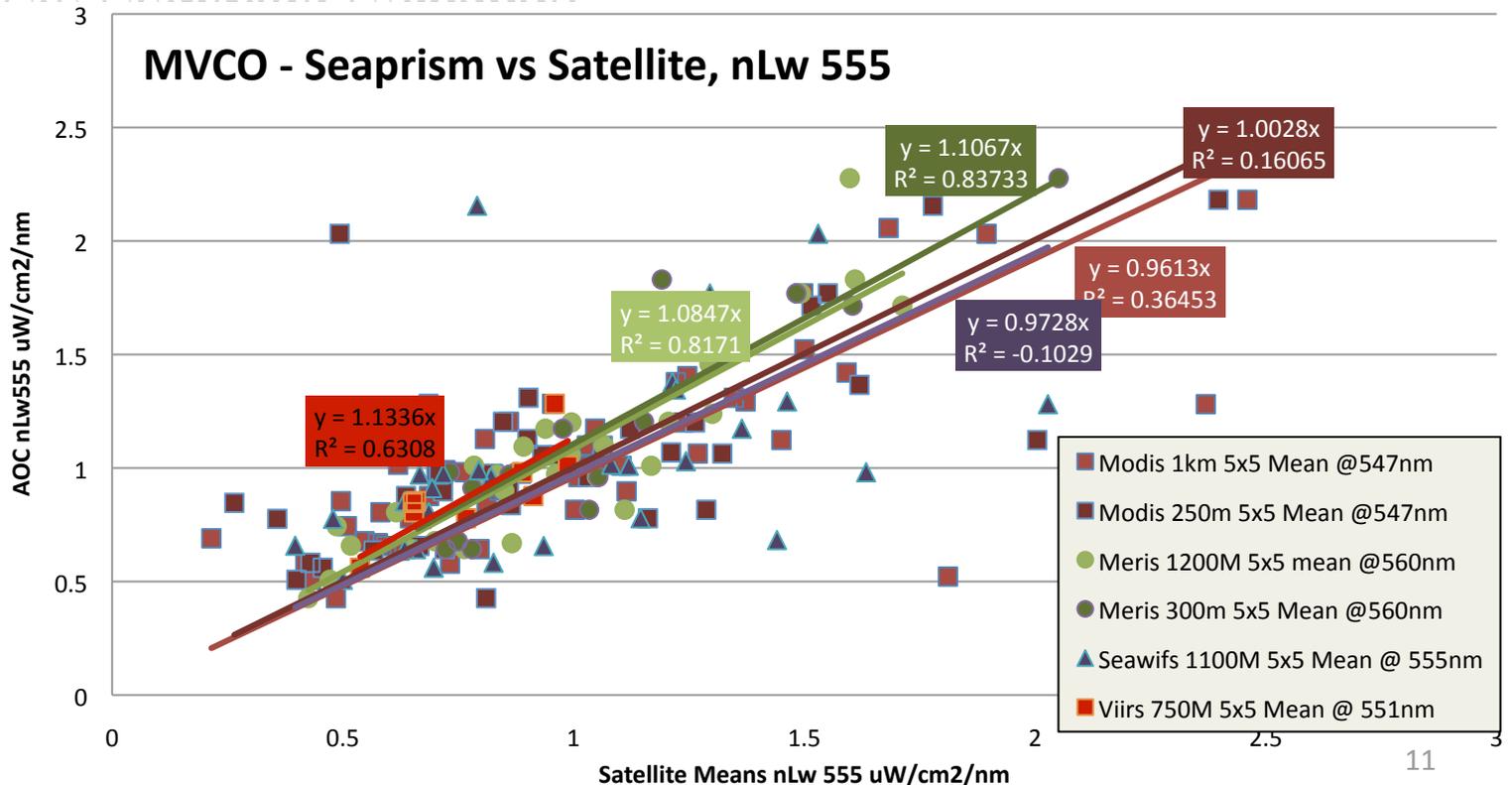
Lwn_fQ Data for Martha's Vineyard at Wavelength 412 (nm)

Julian Day, # Valid Observations, Daily Mean, Daily Standard Deviation, MODIS Julian Day, # Valid Pixels, Center Pixel Value, 5x5 Mean, Standard Deviation

```
4, 2, 0.578622, 0.003854, 4, 26, 0.3437, 0.40483076923077, 0.15546920488842
6, 2, 0.491799, 0.000222, 6, 26, 0.7656, 0.75851538461538, 0.17793221201066
7, 5, 0.5070244, 0.021958018695684, 7, 26, 0.6048, 0.68447307692308, 0.18241960622884
9, 2, 0.398855, 0.076868, 9, 26, 0.2927, 0.33406153846154, 0.064745335899276
10, 8, 0.333815, 0.08307959790466, 10, 26, 0.5162, 0.6037, 0.20081583985946
11, 11, 0.27754890909091, 0.057774160878143, 11, 5, 0.5162, 1.75342, 0.31868344418874
12, 4, 0.29243025, 0.033045384574665, 12, 26, 1.0465, 1.2163346153846, 0.39995732747604
32, 2, 0.203186, 0.051745, 32, 30, 1.5637, 0.56688333333333, 0.40575648286736
```

Matchup Constraints

- + 1 hour
- 5x5 box mean
- Std- 0.02
- 50% valid
- SAngle - 30°
- SpAngle - <30°
- LV1.5
- Start 1/1/2010
- End 1/10/2010
- Wind - NA

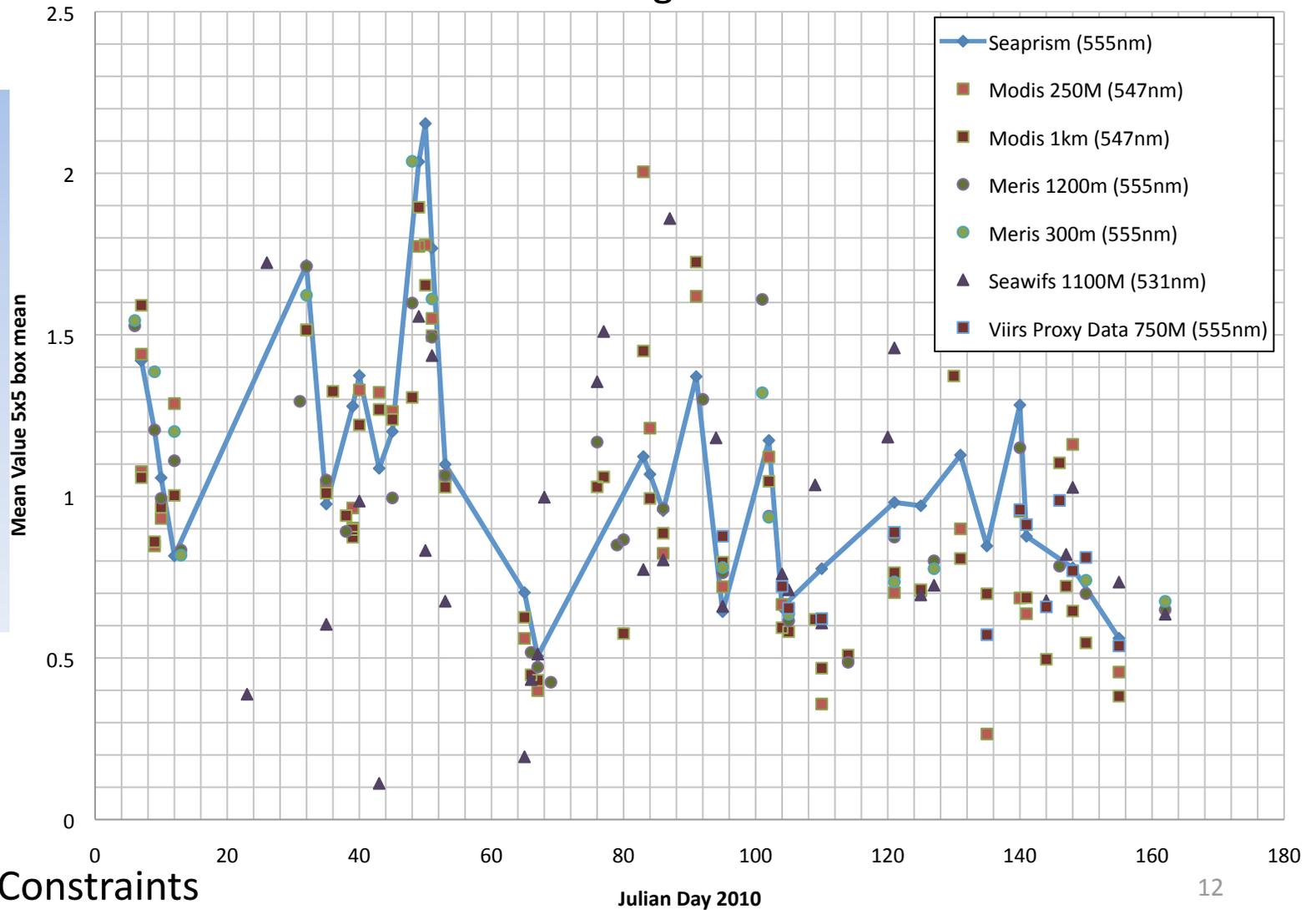


Spatial uncertainty from different satellites

25 km Box surrounding MVCO Aeronet

Matchup Constraints

- + 1 hour
- 5x5 box (25 km)
- Mean nLw
- Std- 0.02
- 50% valid
- SAngle - 30°
- SpAngle - $<30^\circ$
- LV1.5
- Start 1/1/2010
- End 1/10/2010
- Wind - NA
- No spectral shift

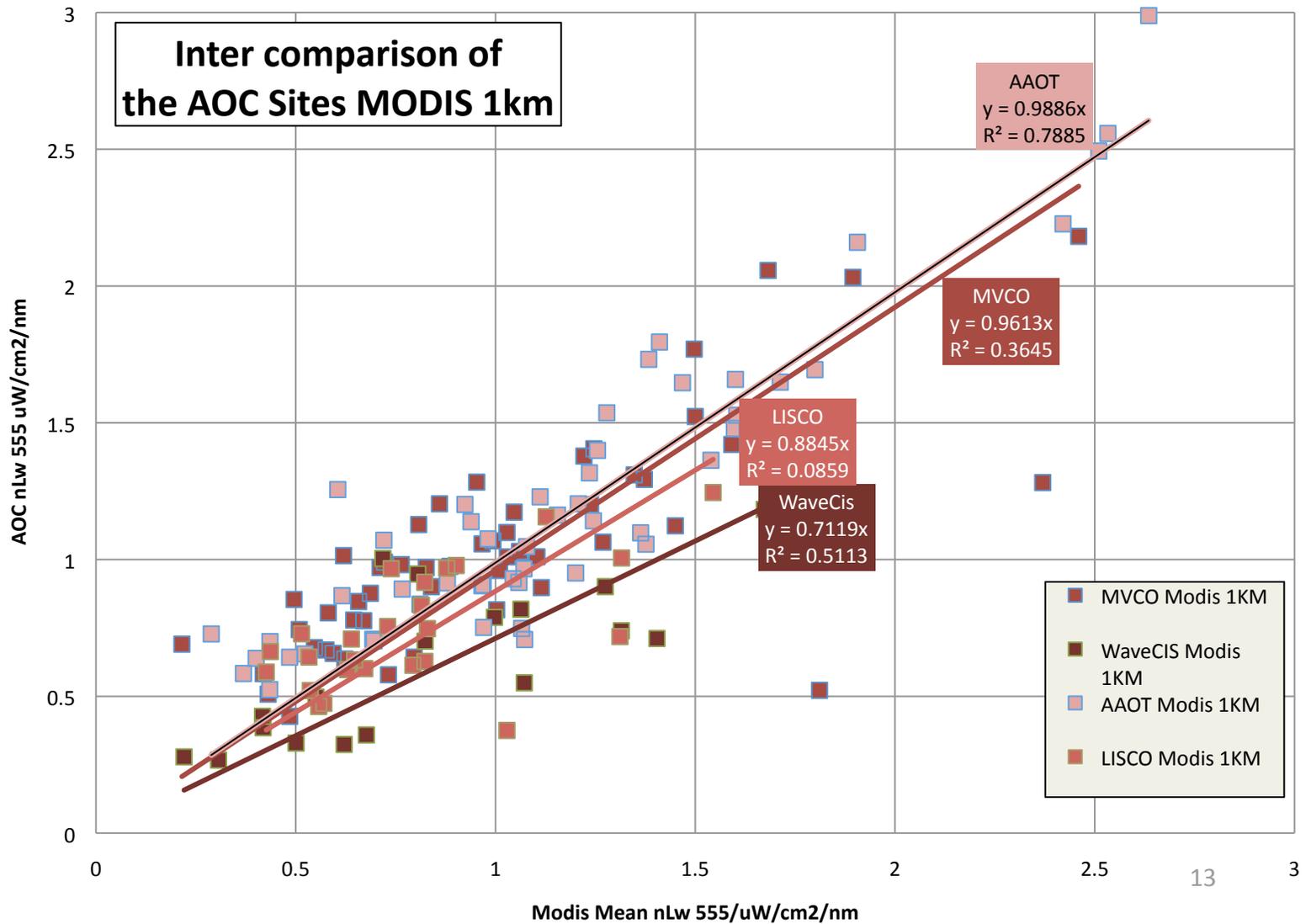


Tighten the Constraints

Comparison of different sites for MODIS nLw 550

Matchup Constraints

- + 1 hour
- 5x5 box (25 km)
- Mean nLw
- Std- 0.02
- 50% valid
- SAngle - 30°
- SpAngle - <30°
- LV1.5
- Start 1/1/2010
- End 1/10/2010
- Wind - NA
- No spectral shift



Matchup requires the Spectral Shift

Adjust the SeaPrism channels to the Satellite Channels

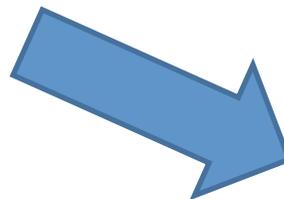
Similar problem with the VIIRS proxy data

took MODIS TOA

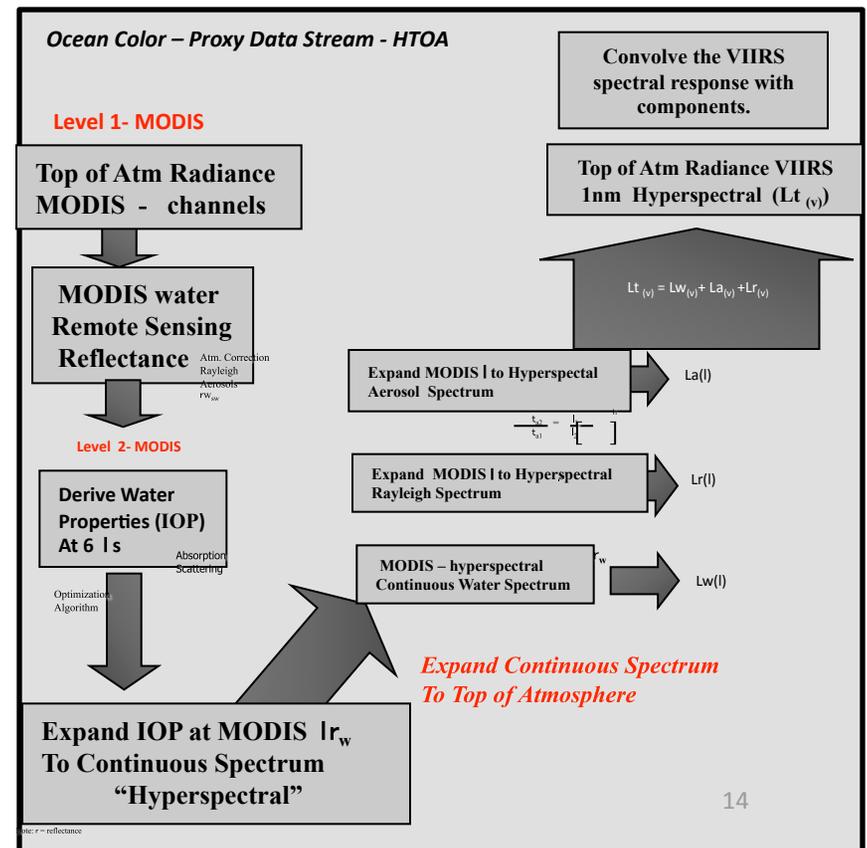


NPP data

Use this for the Spectral shift



Lee et al, 2011



Hyperspectral Rrs (Lw)

Step 1: From Aeronet Rrs, calculate parameter _ equivalent Chlorophyll Conc "Z":

$$x = \log\left(\frac{Rrs(443) + Rrs(488)}{Rrs(557) + Rrs(667)}\right)$$

$$y = 10^{-0.407 - 1.574x + 0.531x^2}; \quad \leftarrow \text{total absorption at 443 nm - at}$$

$$z = \left(\frac{y - 0.00635}{0.110}\right)^{\frac{1}{0.672}}. \quad \leftarrow \text{equivalent chlorophyll conc.}$$

Step2: Total Absorption coefficient: Using "z", generate (hyperspectral and MODIS bands)

$$a(H) = a_w(H) + K(H)z^{e(H)}$$

Values of K and e are based on Morel et al (2001)
H = Hyperspectral B= Band

Step 3: Backscattering - Using a(B) and Aeronet Rrs at each band, Rrs(B), calculate $b_{bp}(B)$

$$b_{bp}(B) = R_{rs}(B)a(B)/0.05 - b_{bw}(B)$$

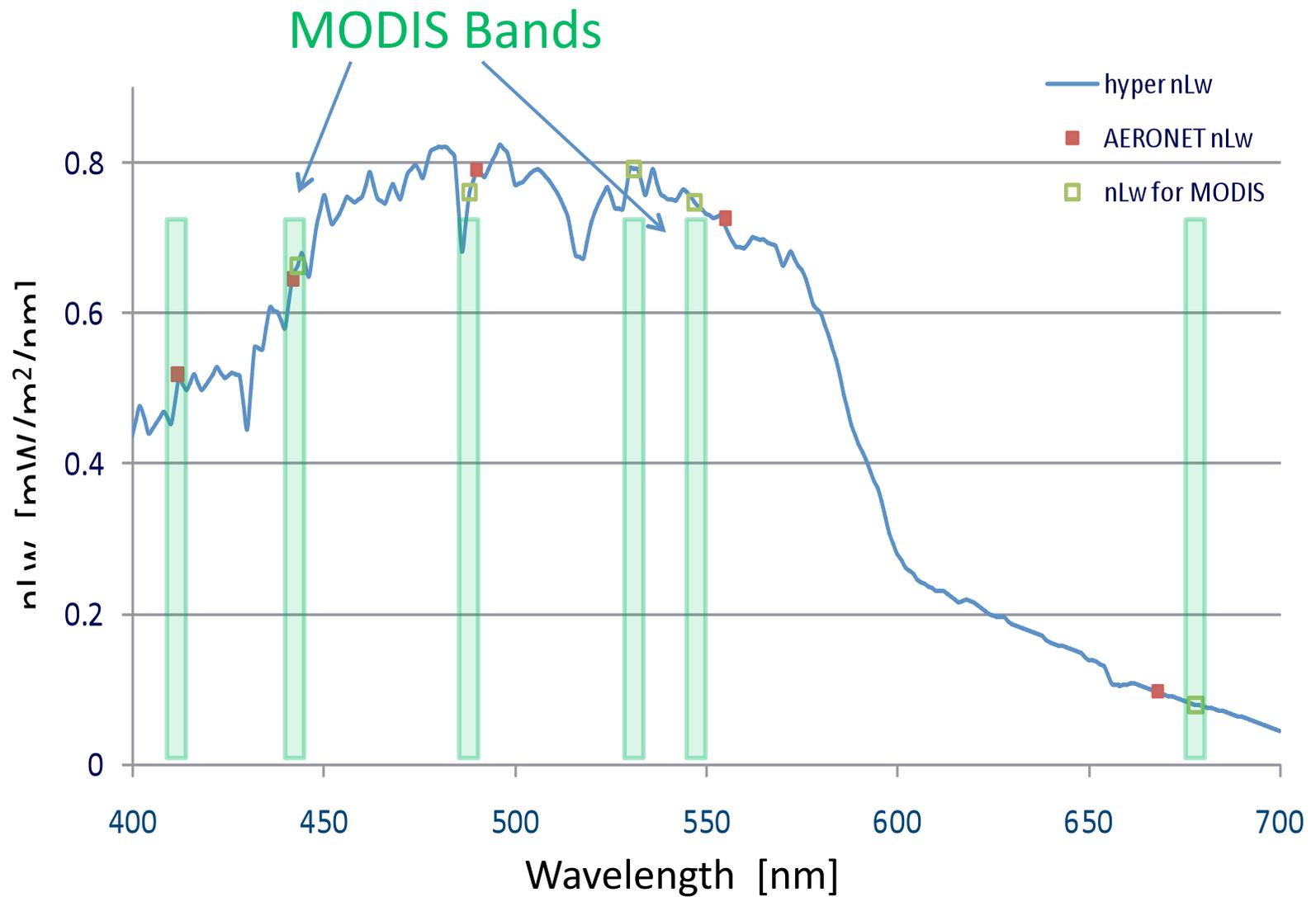
Hyperspectral backscattering $b_{bp}(H)$
Interpolate the above (every 1 nm)

Step 4: From the above a(H) and $b_{bp}(H)$, calculate hyperspectral Rrs(H):

$$R_{rs}(H) = 0.05 \frac{b_{bw}(H) + b_{bp}(H)}{a(H)}$$

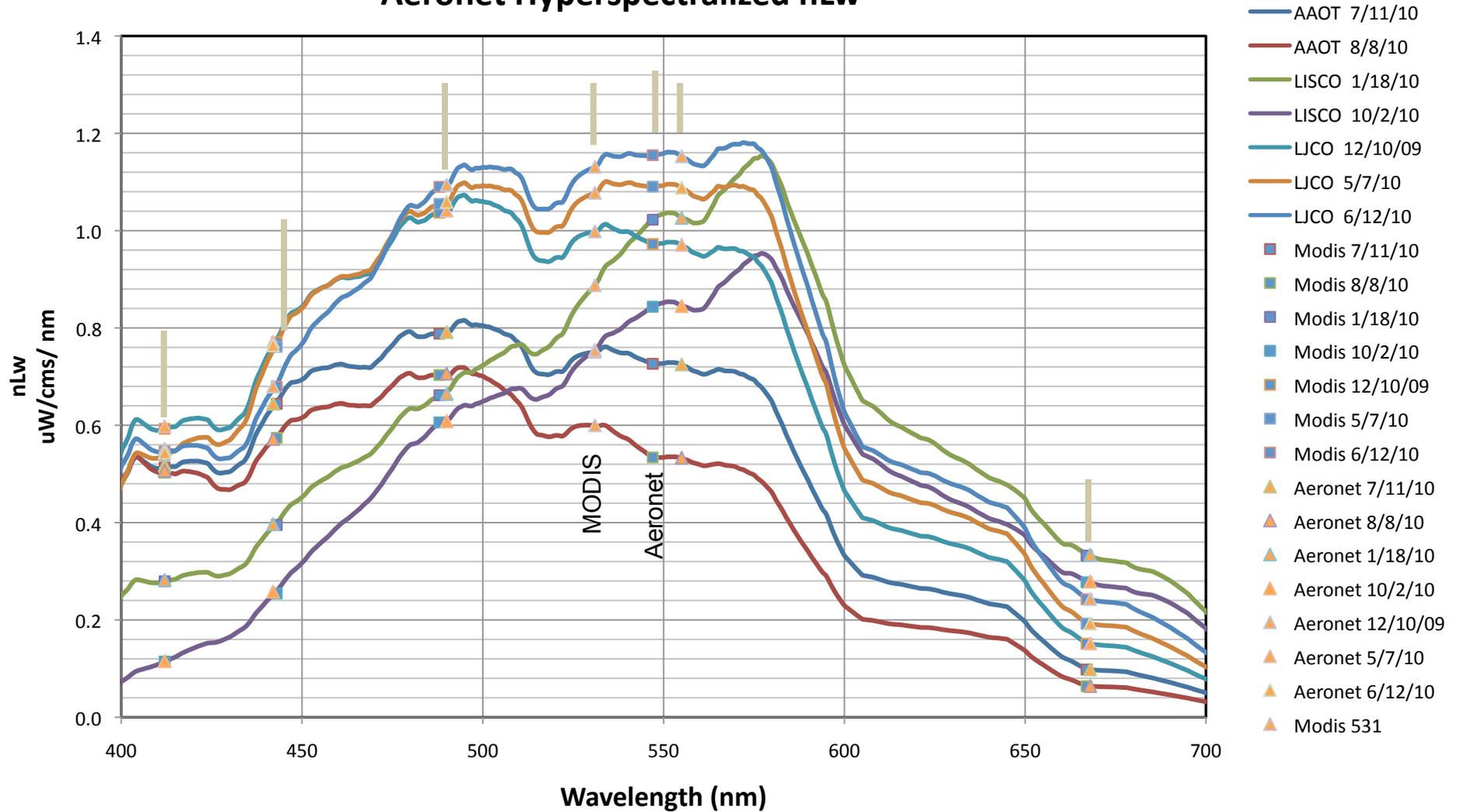
Hyperspectral Rrs !!!

Example of band shift of Aeronet nLw

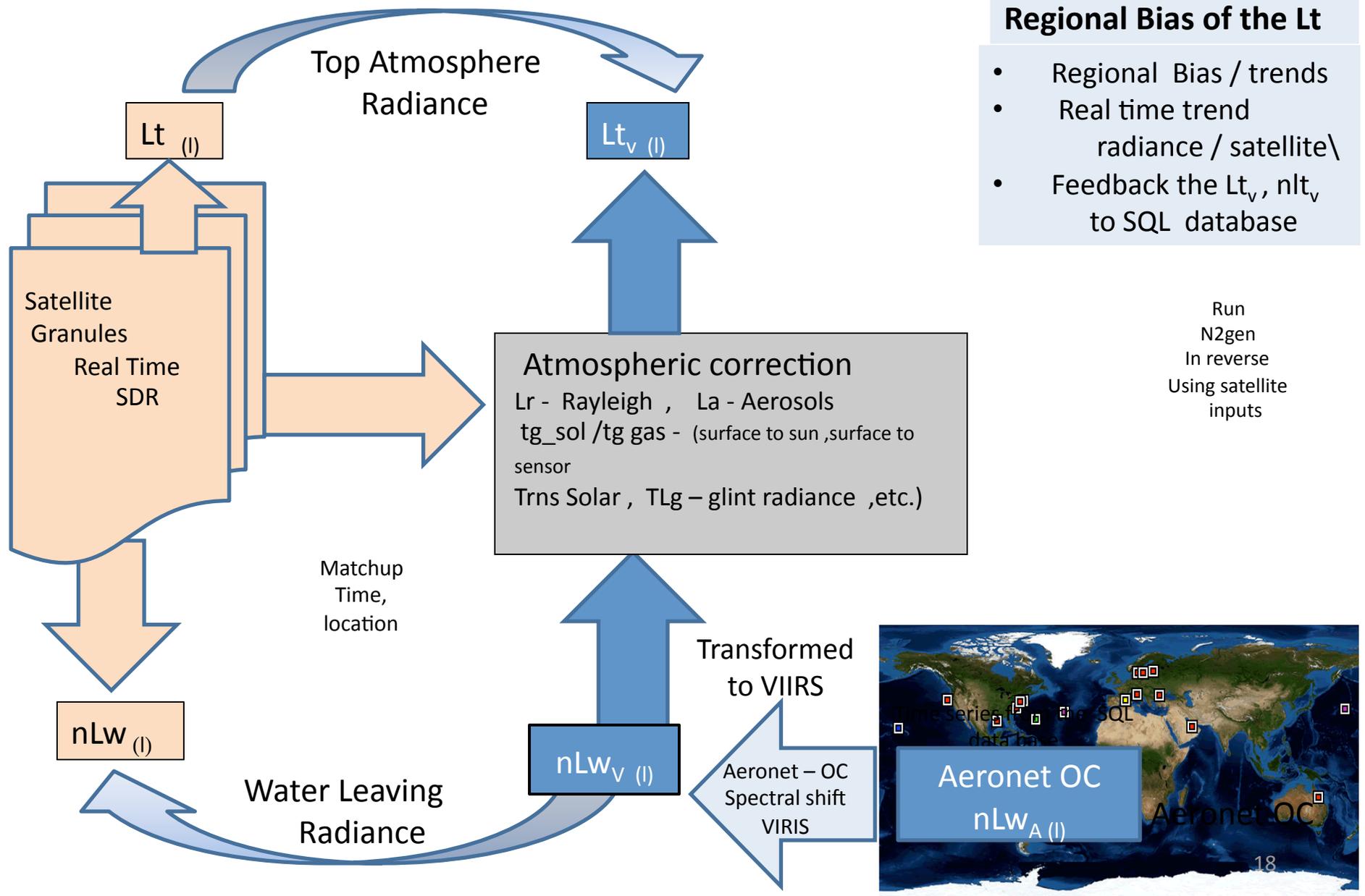


Spectral Shift of water leaving radiance

Aeronet Hyperspectralized nLw



Monitoring a Vicarious Regional matchup Lt and nLw



Vicarious Matchup → Lt

$$\mathbf{vLt} = [(\mathbf{TL}_g + \mathbf{L}_a)\mathbf{t}_{o2} + \mathbf{tL}_f + \mathbf{L}_r]\mathbf{polcor} \mathbf{tg}_{sol} \mathbf{tg}_{sen} \\ + \mathbf{vnL}_w / \mathbf{brdf}_{sensor} \mathbf{polcor} \mathbf{t}_{sen} \mathbf{t}_{sol} \mathbf{tg}_{sol} \mathbf{tg}_{sen} \cos(\theta)\mathbf{f}_{sol}$$

- \mathbf{TL}_g - TOA Glint Radiance
- \mathbf{L}_a - Aerosol Radiance
- \mathbf{tL}_f - White-cap Radiance
- \mathbf{L}_r - Rayleigh Radiance
- \mathbf{t}_{o2} - Total Oxygen Transmittance
- \mathbf{t}_{sol} - Rayleigh-Aerosol Diff. Trans., Sun to Surface
- \mathbf{t}_{sen} - Rayleigh-Aerosol Diff. Trans., Surface to Sensor
- \mathbf{tg}_{sol} - Gaseous Transmittance, Sun to Surface
- \mathbf{tg}_{sen} - Gaseous Transmittance, Surface to Sensor
- \mathbf{brdf} - Bi-directional
- θ - Solar Zenith Angle
- \mathbf{f}_{sol} - Earth-Sun distance correction
- \mathbf{polcor} - polarization correction

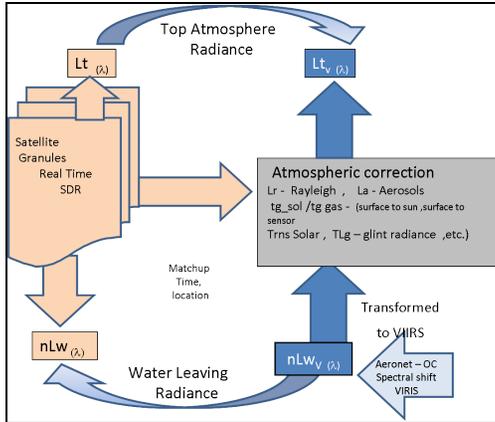
Parameters integrated into the SQL data base
Plus: file, date, Level-2 flags, aeronet instrument, data level

Automated Regional Vicarious Matchup at “vLt”

Script to produce vicarious matchups.

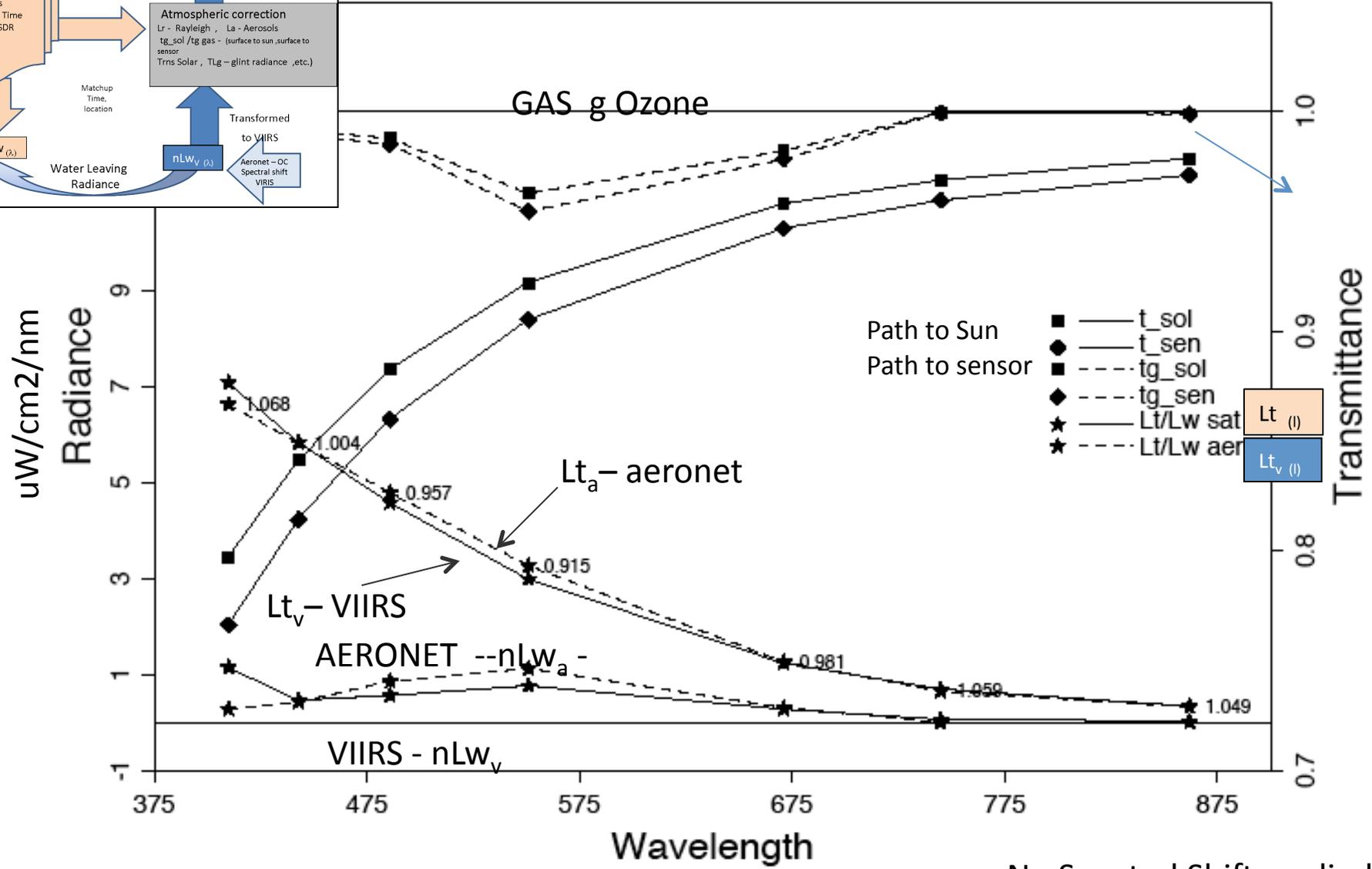
1. Input is configuration file and list of satellite file(s).
2. Time, wavelengths are extracted from satellite.
3. Aeronet database queried for all matching locations and time.
4. For each aeronet–site and satellite match:
 - a. Find closest aeronet record and satellite based on time.
 - b. Get nLw from aeronet record
 - c. Create vicarious matchup parameter file (Lt, vLt, La, Lr, etc.)
 - d. Run vicarious mode to get vLt (see next slide)
 - e. Pull results from file
 - f. Push results back to database (Lt, vLt, La, Lr, solzen, etc.)
5. Generate Plots of gain ratios (Lt/vLt)
6. Perform regression to obtain vicarious gains/offsets (use quality checks)

Example from LISCO Aeronet using VIIRS Proxy Scene.



Vicarious Matchup

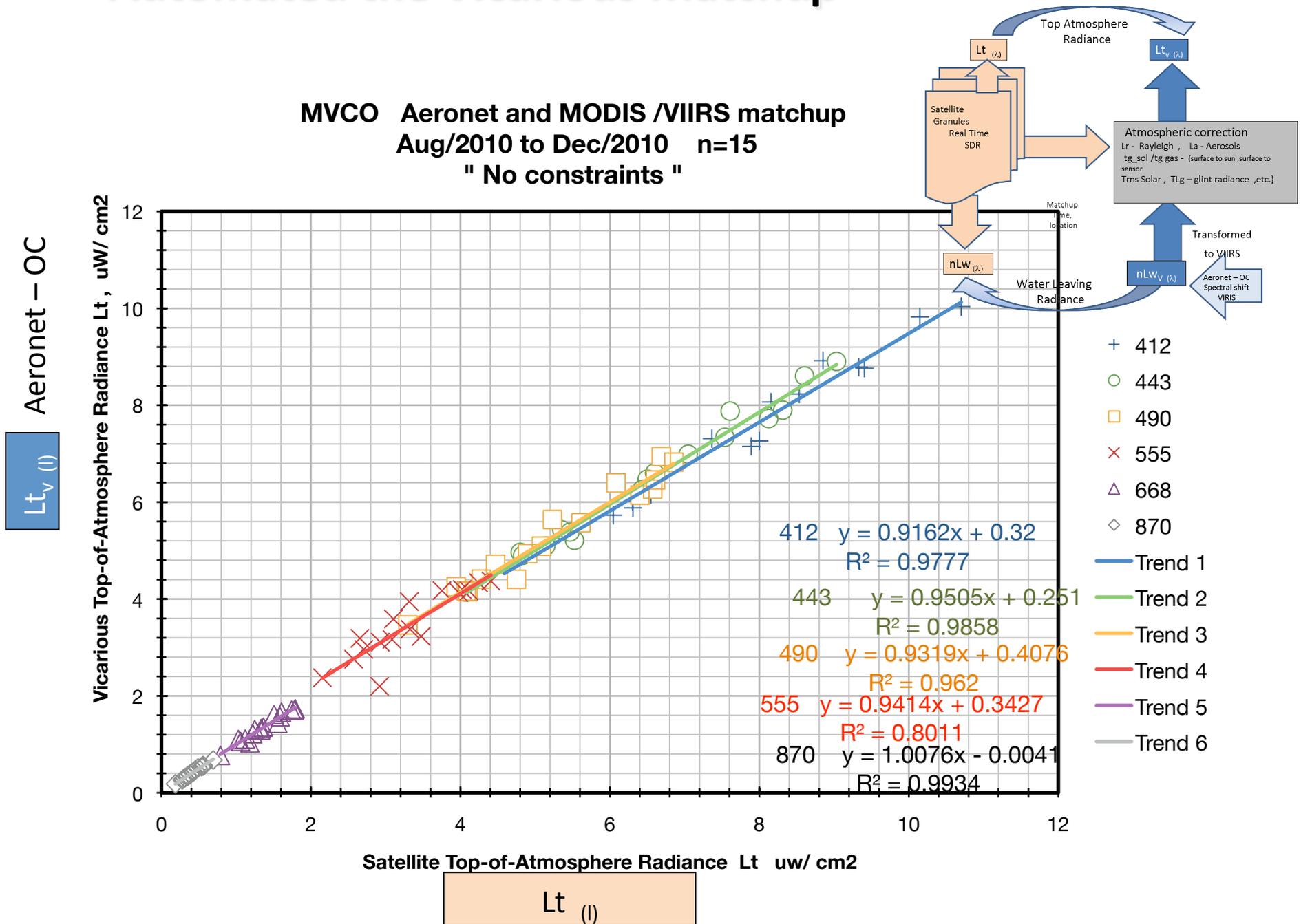
npp.2010275.1002.172010.D.L2.viirs.LISCO.v01.750m.hdf



No Spectral Shift applied !

Automated the Vicarious Matchup --

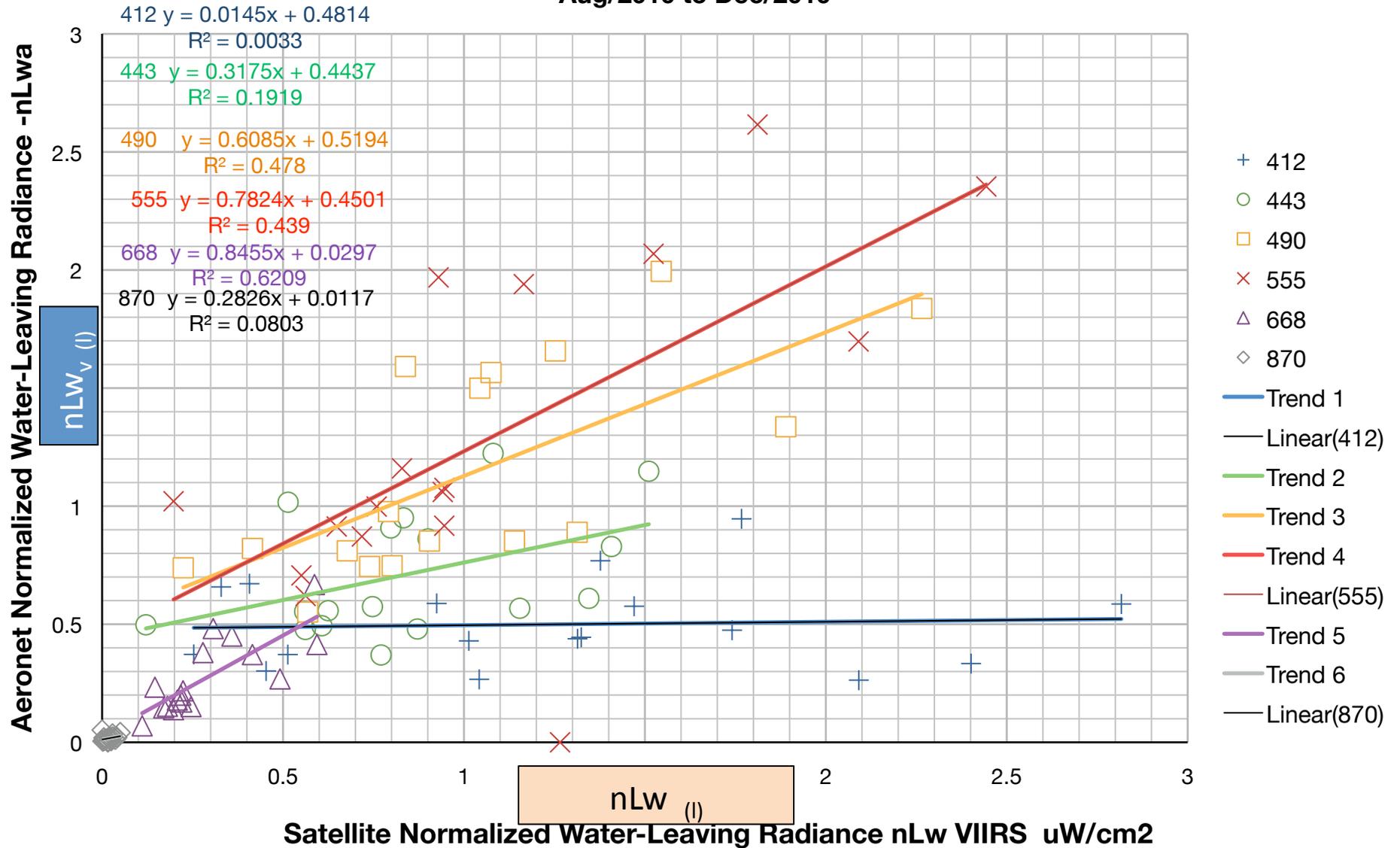
MVCO Aeronet and MODIS /VIIRS matchup
 Aug/2010 to Dec/2010 n=15
 " No constraints "



Automated the Vicarious Matchup --

MVCO Aeronet and MODIS VIIRS match "No Constraints"

Aug/2010 to Dec/2010



Applications for monitoring the “Golden Regions”

- **Determine satellite product trending both seasonally and in different coastal and open ocean regions**
- **Examine in real time (2 weeks) vicarious matchups - track regional validation**
 - **Assess the regional Bias at different sites (globally)**
 - **Determine the impact of new LUT using the matchup**
 - **Maintain “golden site” reprocessing .**
 - **Demonstration in Summer.**

**Spatial and Temporal Uncertainty
of satellite ocean color :
Real time Satellite and Aeronet_OC Matchup**

Summary

- Aeronet – OC and observation data streams being assembled with satellite data streams
- Developing real time Match –up
 - Satellite products validation
 - Inter- satellite comparison and product consistency
 - Spatial and temporal uncertainty in coastal areas being addressed, using “constraints”
- Coordinate with national and international collaborators

Questions ?

- Golden Regions Satellite Processing -

NPP – VIIRS proxy data processing

	Parent Directory	
1-	AAOT/	11-Feb-2011 15:01
2-	AbuAlBukhoosh/	22-Jan-2011 06:49
3-	BATS/	21-Jan-2011 14:07
4-	BoussoleBuoy/	22-Jan-2011 09:46
5-	CalCOFI/	21-Jan-2011 19:21
6-	ChesapeakeBay/	14-Feb-2011 11:35
7-	Cove/	14-Feb-2011 11:22
8-	GDAT/	22-Jan-2011 10:57
9-	Gloria/	22-Jan-2011 08:12
10-	Gomex/	14-Feb-2011 11:26
11-	GreatLakes1km/	14-Feb-2011 12:40
12-	GulfOfMaine/	11-Feb-2011 15:04
13-	Helsinki/	22-Jan-2011 10:57
14-	HelsinkiLH/	11-Feb-2011 15:04
15-	LigurianSea/	11-Feb-2011 15:04
16-	LucindaJetty/	22-Jan-2011 02:49
17-	MOBY/	21-Jan-2011 21:23
18-	MVCO/	14-Feb-2011 11:23
19-	MVCOX/	14-Feb-2011 11:21
20-	MissBight/	14-Feb-2011 11:24
21-	NYBight/	14-Feb-2011 11:24
22-	NorthAtlanticGyre/	21-Jan-2011 14:31
23-	NorthEastAustralia/	11-Feb-2011 15:08
24-	NorthEastAustralia/	11-Feb-2011 15:08
25-	NorthPacificGyre/	23-Jan-2011 00:42
26-	Palgrunden/	22-Jan-2011 10:57
27-	PersianGulf/	11-Feb-2011 15:08
28-	SouthAtlanticGyre/	21-Jan-2011 12:30
29-	SouthPacificGyre/	21-Jan-2011 20:58
30-	WaveCIS/	14-Feb-2011 11:22

Reprocessing

- Level 0 –
- Level 1b –
-
- Level 3 - daily imagery
-And mosaics
- Level 4 – composites daily,
Weekly , months
7 day latest pixel