Session 7

2016 STAR JPSS Annual Science Team Meeting,
College Park, Maryland
August 8-12, 2016

Evaluation of VIIRS Ocean Color products and development of enhanced ocean products and applications

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4. SSAI/NASA.GSFC

Stennis - Cal val Team
Annual Summary

Cal Val Highlights of the Past year 2015 – 2016

Outline

A. Foster Cruise – Dec 2015 - Tongue of Ocean / Gulf Stream Cruise
   1. Cruise track - Optical Shallow - Gulf Stream Crossing and Shingles
   2. Protocols Floating HyperPro ,ASD, IOP Flow–

B. VIIRS Validation in Gulf of Mexico

C. Diurnal changes in ocean color - VIIRS validation

   WavCis changes in Color

   VIIRS orbital overlaps and Matchups

   Processes shown in Diurnal changes

D. WavCis -- status

Stennis - Cal val Team

Dec 2015 – Cal Val Cruise - Nancy Foster

Gulf Stream and Tongue of Ocean

Stennis Cal Val team

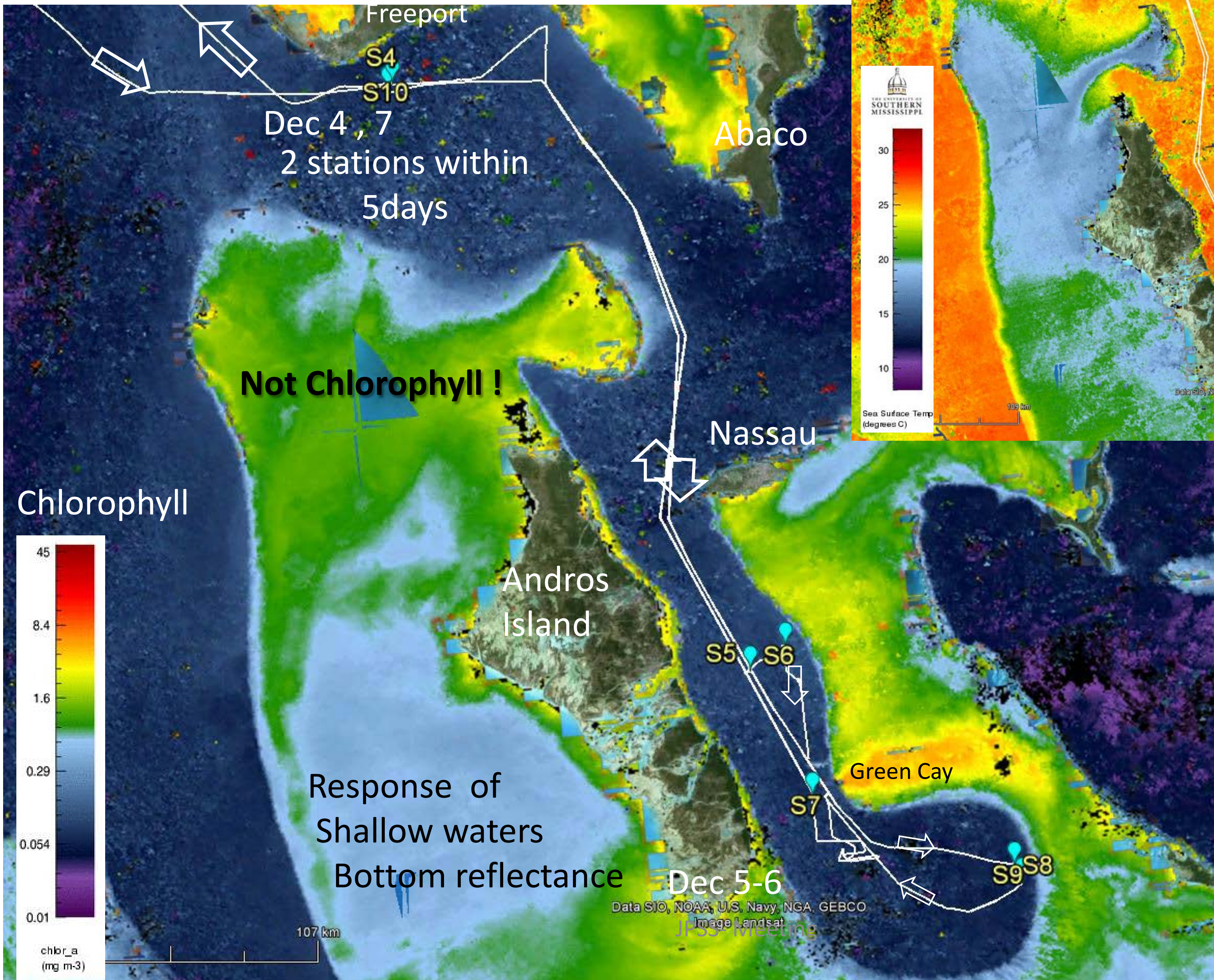
GOALS:

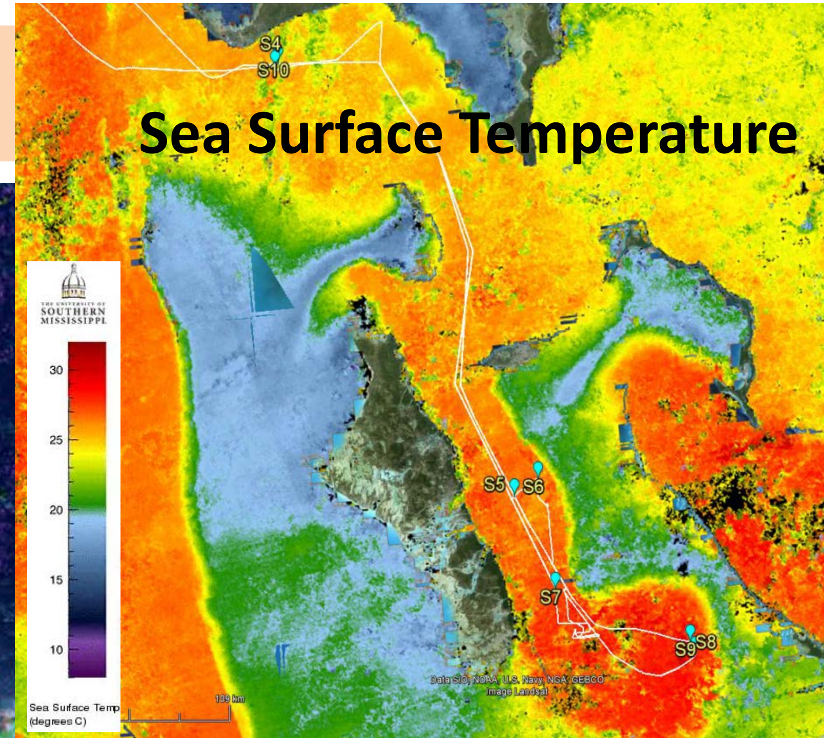
1. **Tongue of Ocean - Optically Shallow waters-**
   Examine the changes in nLw in optically shallow waters in Tongue of Ocean
2. **Compare optical measurements for nLw for VIIRS validation ASD/ Hyperpro**
3. **Protocols for insitu data collection**
4. **Validate VIIRS products to define Gulf Stream processes waters**
   (Eddies, Shingles, Fronts)

Dec 2015 Cruise

Tongue of the Ocean → 7 Stations

Water – Stable, Consistency,





Response
Of SST over
shallow Waters
- Cooler of
Shallow waters

Tongue waters
- Stable
- Low Winds
- Optically Clear

Dec 2015 Cruise

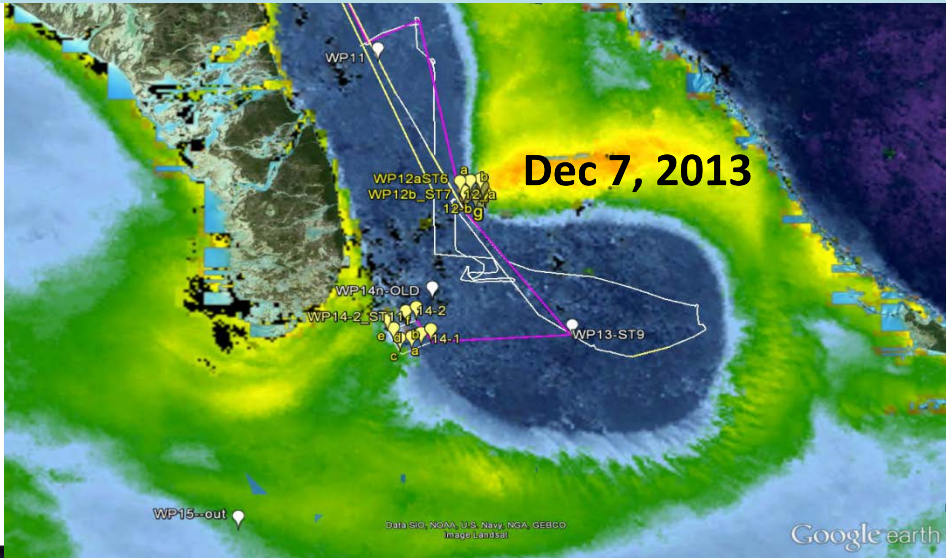
Similar VIIRS Products in Optically Shallow waters !

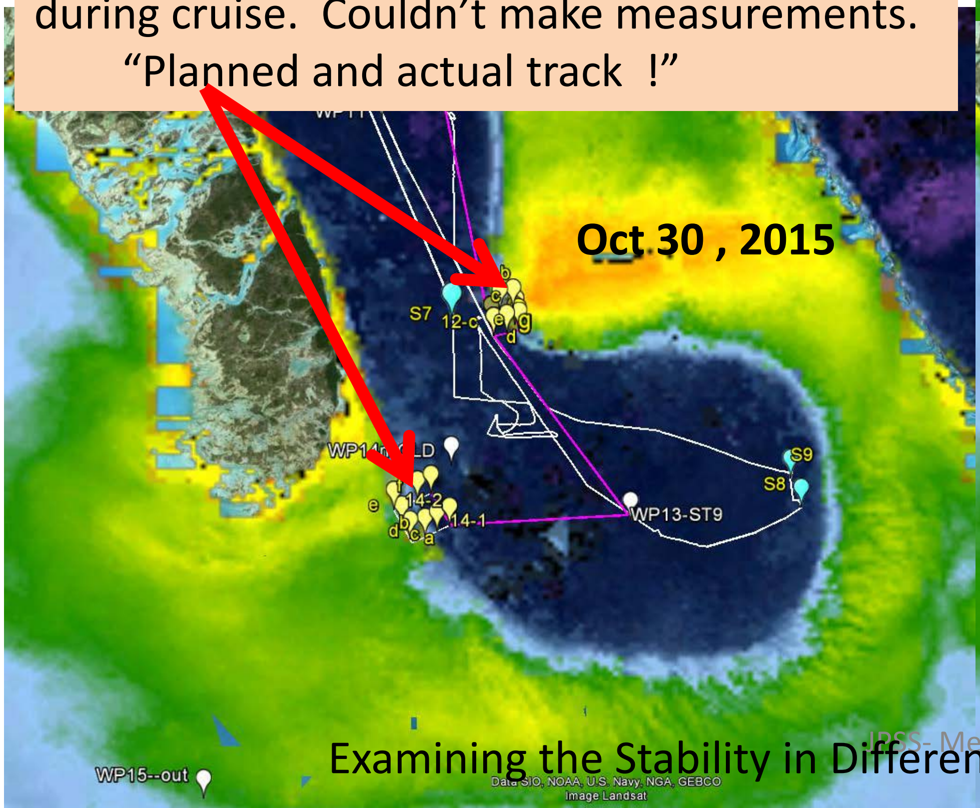
Tongue of Ocean

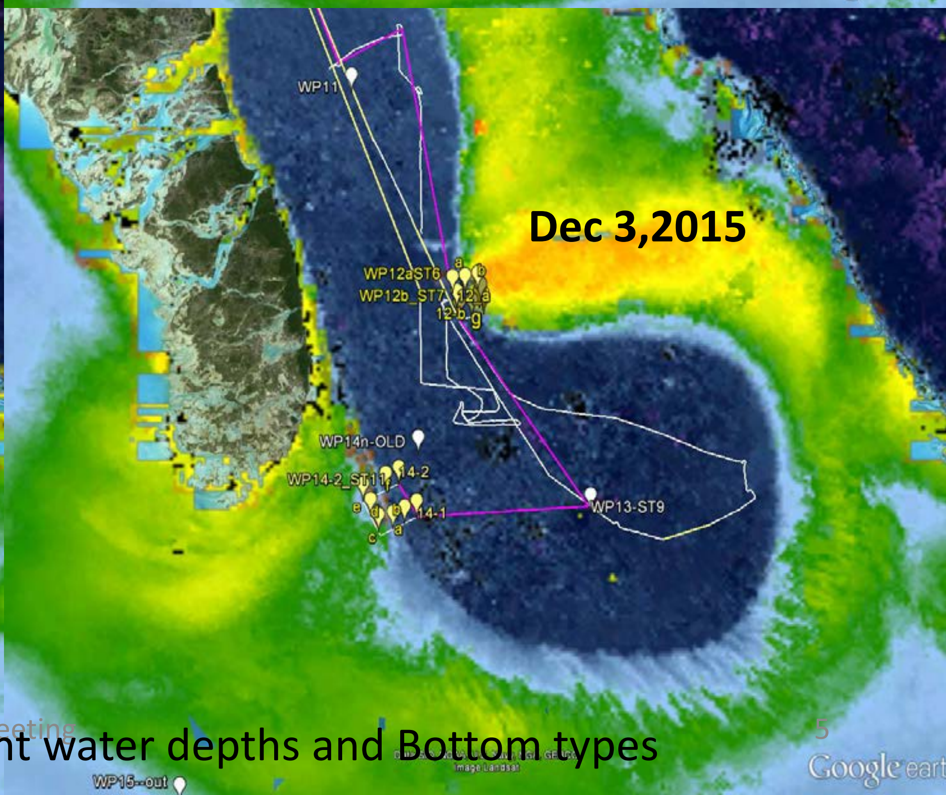
1- Optically Shallow waters Show similar
nLw and Chl through the year. !
How stable are this RRS?
Stability in water depth and bottom reflectance

2- Can Stable Optically Shallow regions be used
for VIIRS nLw validation?

Unfortunately
Had Bad weather conditions in Tongue during cruise. Couldn't make measurements.
"Planned and actual track !"







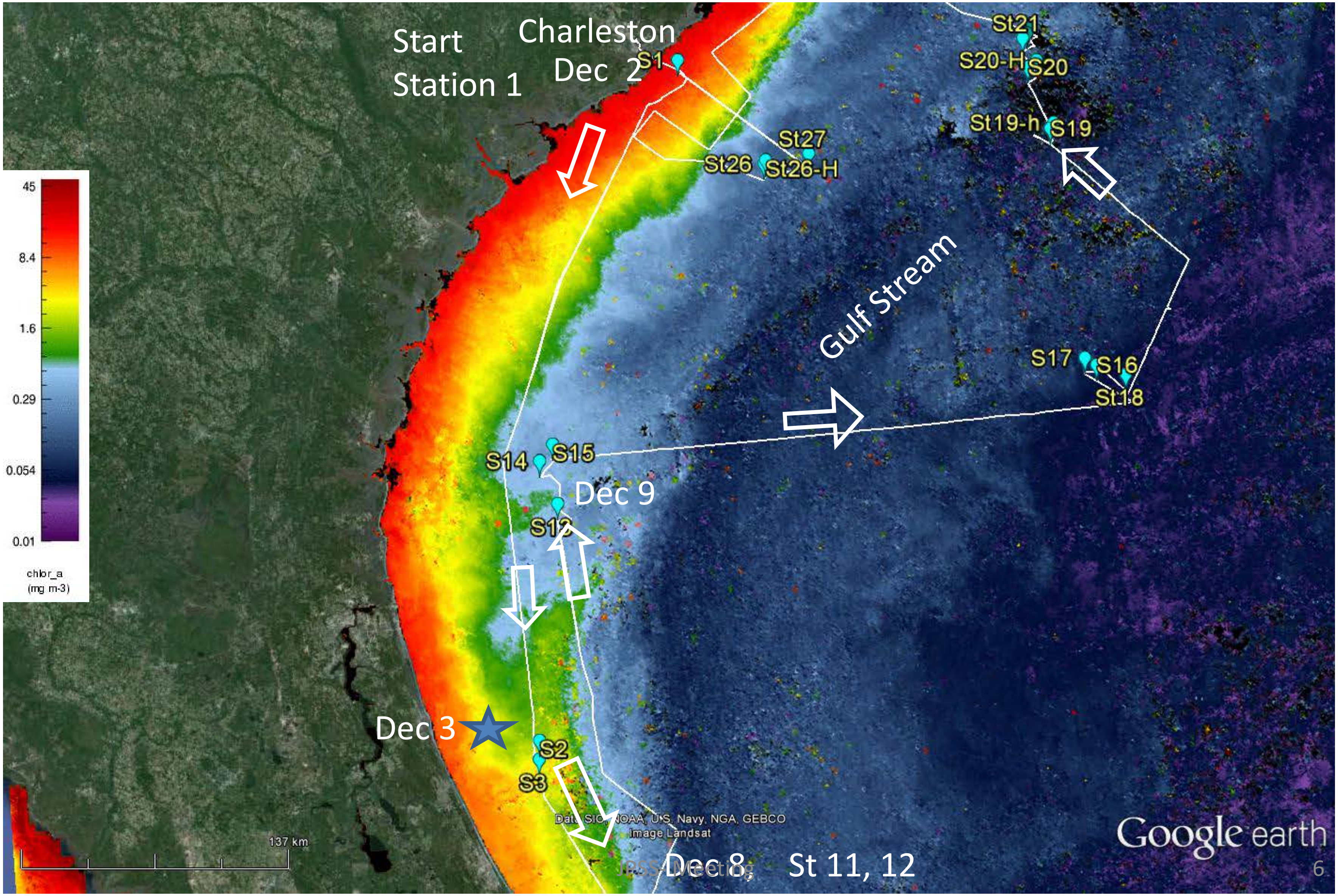
Examining the Stability in Different water depths and Bottom types

Dec 2015 Cruise

Foster 2015 Cruise Track and Stations Selection

Conditions improved Dec 8

Crossed Gulf Stream twice



Dec 2015 Cruise

Cruise Data Collected

UTC is +0500 local

Station Specs

- Date - 2015
- start time (UTC)
- Julian -Day
- Start time (GMT)
- Julian date+time
- Lat (degrees decimal min)
- Lon (degrees decimal min)
- Flowthrough hour Scan count(ship)
- Sky cover (% clouds)
- wind direction
- wind speed (kt)
- sea state (feet)
- Water Depth
- Secchi depth (Time same as Floaters)

Optical Profilers 3

- Ship Rossett - profiler- CTD, Chl-Fluorometer, O2
- NASA -IOP Package , acs,ac9,bb9,vsf,SBE (Comments)
- UMB - opticsPackage CTD, ACS,
- GOOD VIIRS_MATCHUP - Mike

Hyperpro Profilers 4

- HyperPro - MIKE
- C-Ops NASA (ELMO) 3(radiometers)
- Hyperpro - USF
- Hyperpro- OSU

Floats 3

- Hyperpro- Float (PUFF) USM
- Hyperpro- Float (NRL)
- Hyperpro SBA- (BIG BIRD)
- NURADS
- Fiber - CUNY

ABOVE WATER Radiometry 9

- ASD - NOAA 1847
- ASD - USM 1338
- ASD - NRL 1707
- ASD -USF 1007
- ASD - CUNY 1075
- ASD - Fiber CUNY
- ASD Blue Card comparison
- Specreal Evolution - OSU
- Spectral Evolution - UMB
- GER -CUNY
- GER Fiber - CUNY
- Cuny polarizatom Camera
- Microtops - NOAA
- Microtops - NRL
- Microtops - USF
- Microtops - CUNY
- Microtops - umb

Bow mounts

- HYPERsas - Bow CUNY
- Hypersas - Bow Scott

Water Samples 9

- CHl_filted =Mike
- Chlorophyll Filtered - NASA
- HPLC Pigment
- Nutrients
- Particulate Org Carbon
- CDOM
- Dissolved Org Carbon
- Pad absorption - USF
- TSS- Stengel *

Ship Flow 9

- Flowcam ifcb
- Samples - LUGOL'S
- FLOWTHROUGH Data entire cruise
- Ship Temperature
- Ship Salinity
- Ship Fluorescence volts chl and UV
- IOP- Flowthrough acs- Filtered and Unfiltered
- Flowthrough Backscattering (470,532,670 Nm)
- PAR- 2

Station Specs

- VIIRS Overpass Time (UTC)
- Time off station
- LATITUDE
- LONGITUDE
- Station Notes - drift

S- Meeting

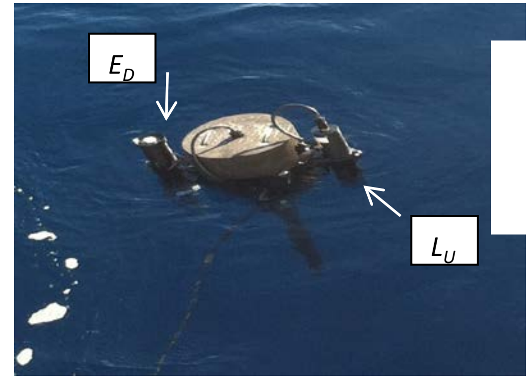
Dec 2015 Cruise

Objective 2: Compare Variability in Insitu Data Radiometry for Cal Val of VIIRS

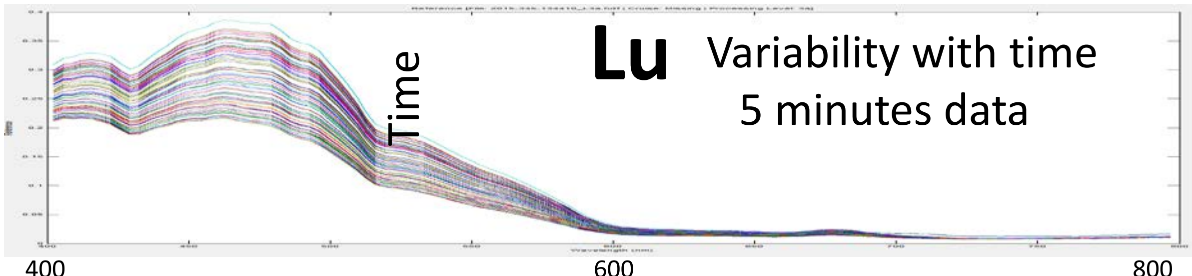
Establish protocols

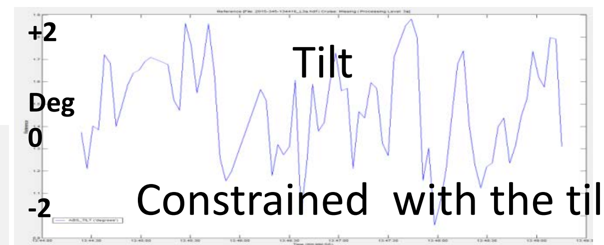
" Floating Hyperpros" - Prosoft 8.1.4

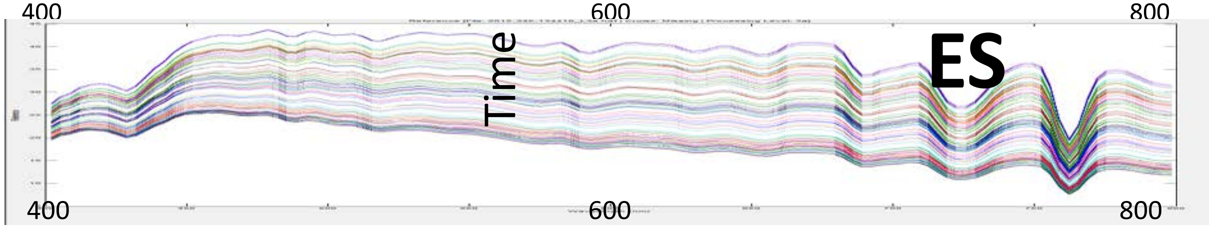
Time changes of the Radiances - Constrained the tilt

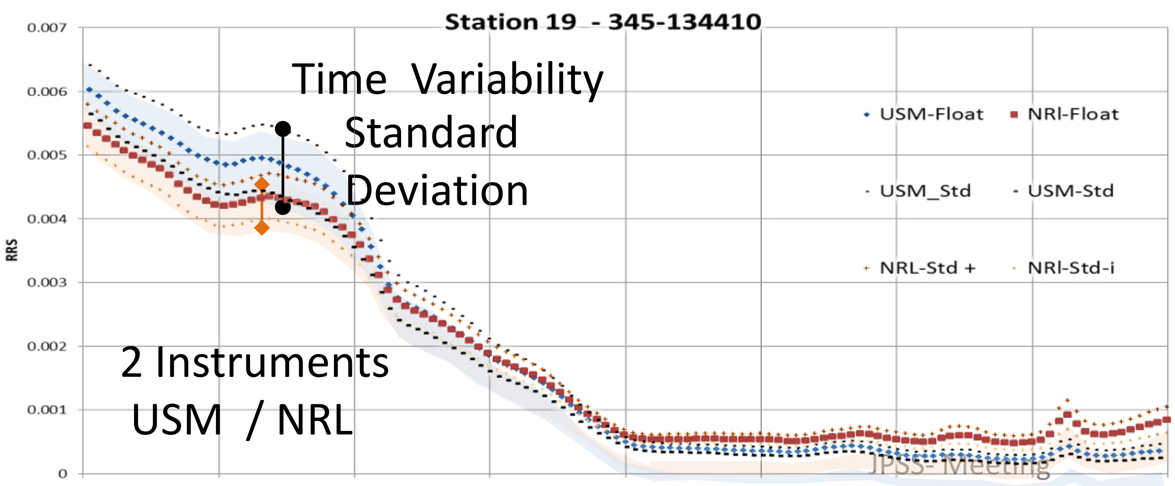


ES on Ship



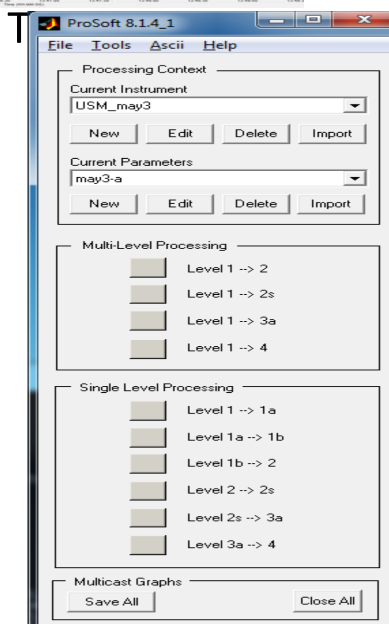






Prosoft Processing Details

Similar results For 2 Float Hyperpros



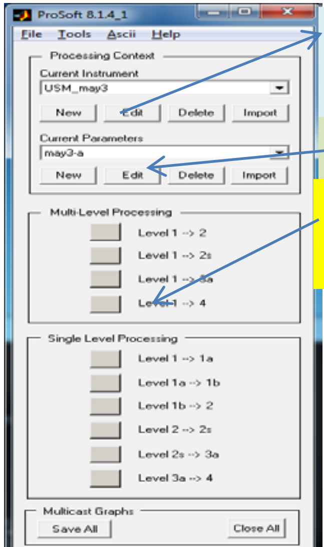
Floating “Hyperpros” Protocols
Prosoft 8.1.4.

From: Bob Arnone

Floating Hyperpro Protocols For RRS

Protocols used - for Post Processing

Steps



#1 Edit and load the cal
-

#2 - Edit to set up parameters

#3 Ready to process.
level 1→ Level 4

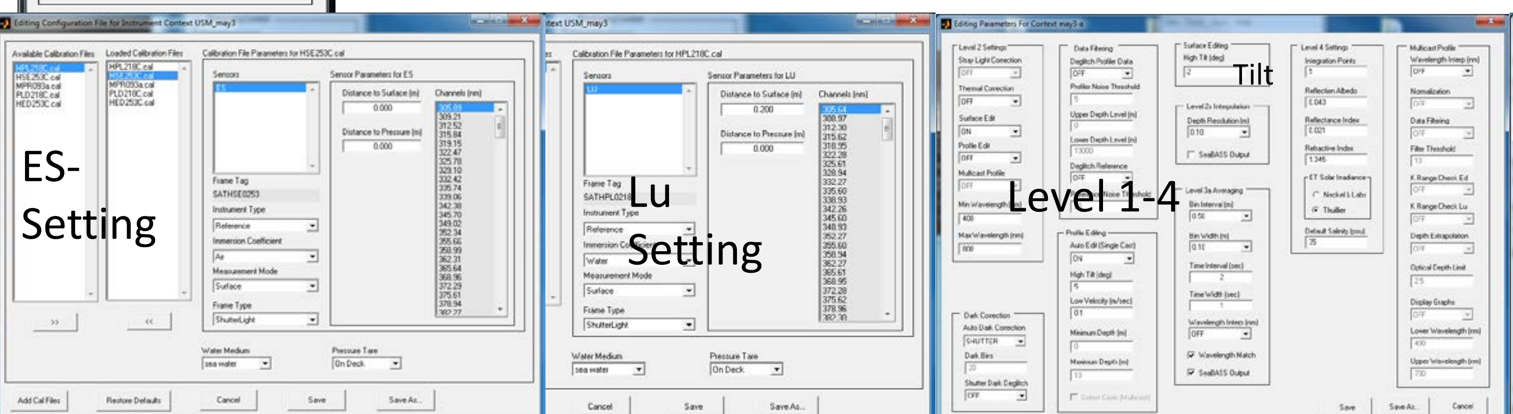
PROFILER : WET
REFERENCE : OFF
PRO-DARK : OFF
REF-DARK : OFF
PRO-ID : MPR0093
PROCESSING_LEVEL : 4
FILE_CREATION_TIME : 11-Mar-2016 17:27:47
DEGLITCH_PRODAT : OFF
DEGLITCH_REFDAT : OFF
STRAY_LIGHT_CORRECT : OFF
THERMAL_RESPONSIVITY_CORRECT : OFF
DEPTH_RESOLUTION : 0.01 m
BIN_INTERVAL : 0.05 m
BIN_WIDTH : 0.1 m
TIME_INTERVAL : 2 sec
TIME_WIDTH : 1 sec
WAVEL_INTERP : 0 nm
INTEGRATION_POINTS : 5
REFLECTION_ALBEDO : 0.043
REFLECTANCE_INDEX : 0.021
REFRACTIVE_INDEX : 1.345
ET_SOLAR_SPECTRUM : Thuillier
WATER_MEDIUM : sea water
LS_DISTANCE_SURF : 0.2

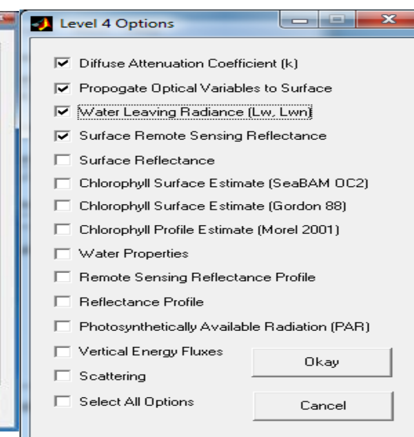
$$L_W(\lambda) = \frac{1-\rho}{n^2} L_u(0^-,\lambda)$$

ρ = 0.025 is the Fresnel reflectance of the air sea interface,
n = 1.34 is the refractive index of seawater.

Remote sensing reflectance

$$R_{RS}(\lambda) = \frac{L_W(\lambda)}{E_S(\lambda)}$$





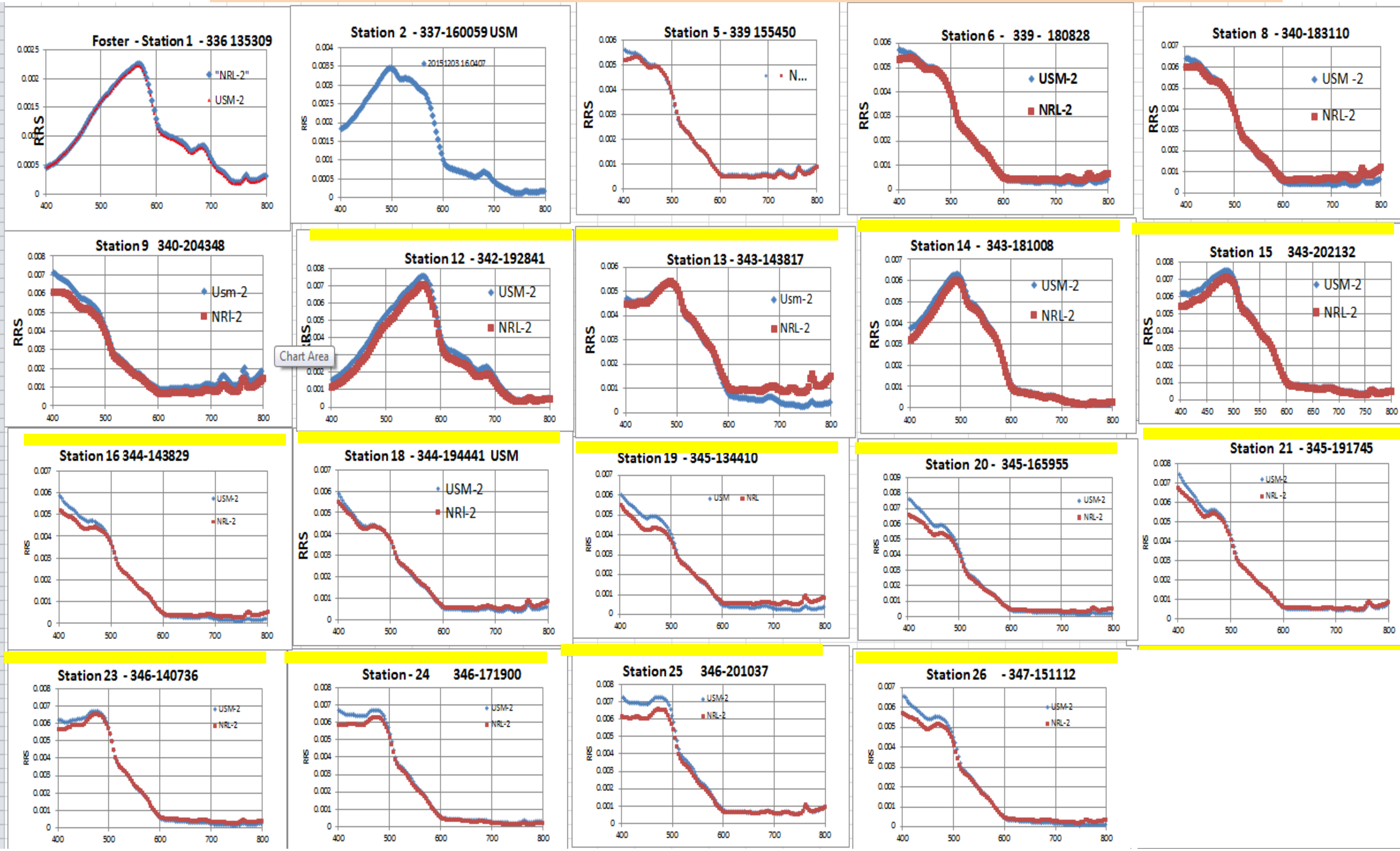
Have details for Hyperpro Processing
For anyone interested ?

Dec 2015 Cruise

Agreement of 2 Floating Hyperpro USM and NRL

Averaged Lu and Es Sensor filtered the 2deg Tilt

Compared with the Above water ASD 14 Station Matchups



Dec 2015 Cruise

Above water measurements of Rrs from ASD
How does the distance above water affect the RRS ?

ASD Protocols For RRS

Which deck on Foster should be used to collect ASD ?

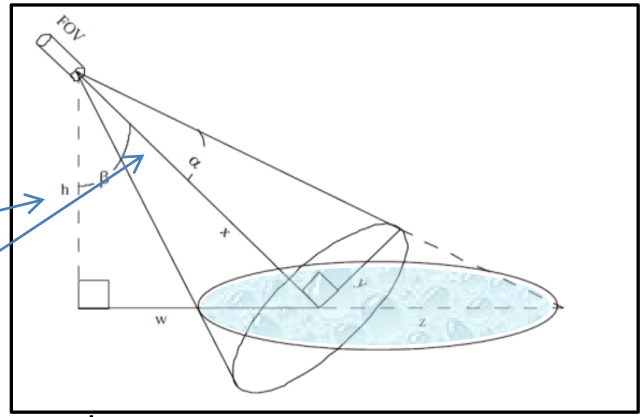
ASD collected data

Distance above water

Bow = 2m

01 deck = 5m

02 deck = 8m

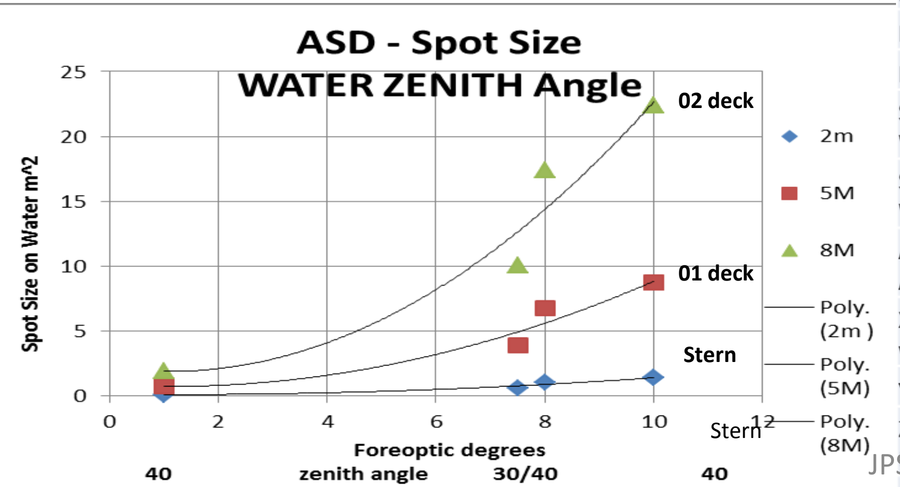


Comparison of Spot Size

Fore optics 10 and 1 and Viewing angle

Top deck and large fore optics has largest Spot size

5 Above Water instruments have Differences



Institution	USM	NRL	NOAA	USF	CUNY
Foreoptic (degrees)	1	10	10	7.5	8
Foreoptic (radians)	0.01745329	0.17453293	0.17453293	0.13089969	0.13962634
Sampling Zentih Angle - Water target (degrees)	40	40	40	30	40
Sampling Zentih Angle - Water target (radians)	0.6981317	0.6981317	0.6981317	0.52359878	0.6981317
Average Sampling Height Above Water (meters)	2	2	2	2	2
X, where x = SQRT(h^2 + w^2), and w = h tan b	2.61081458	2.61081458	2.61081458	2.30940108	2.61081458
Y, where y = x tan a	0.02278423	0.22841668	0.22841668	0.15136614	0.18256594
Z, where z=h [tan(b) + tan(b + a)]	3.38636063	3.67819926	3.67819926	2.49105781	3.60957681
AREA (m^2)	0.12201122	1.40167848	1.40167848	0.62827694	1.0874876

Dec 2015 Cruise

ASD protocol -

Results - ASD Requires Spot Size from 2- 10 Meters!
For the Foster – collect ASD on 01 deck !

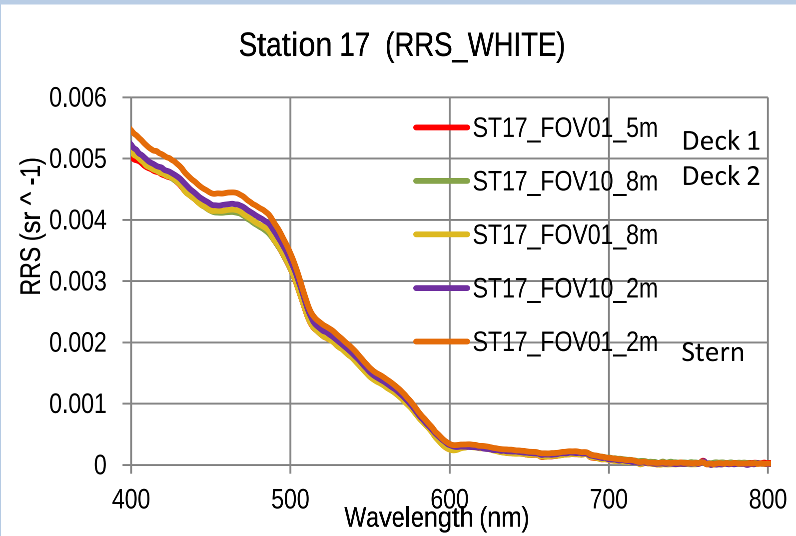
ASD Protocols For RRS

Shooting ASD from which deck ?

2 m - stern
5m - O1 deck
8m - 02 Deck

Blue Water Matchups

R_{RS} – Uncertainty in above-water spot size

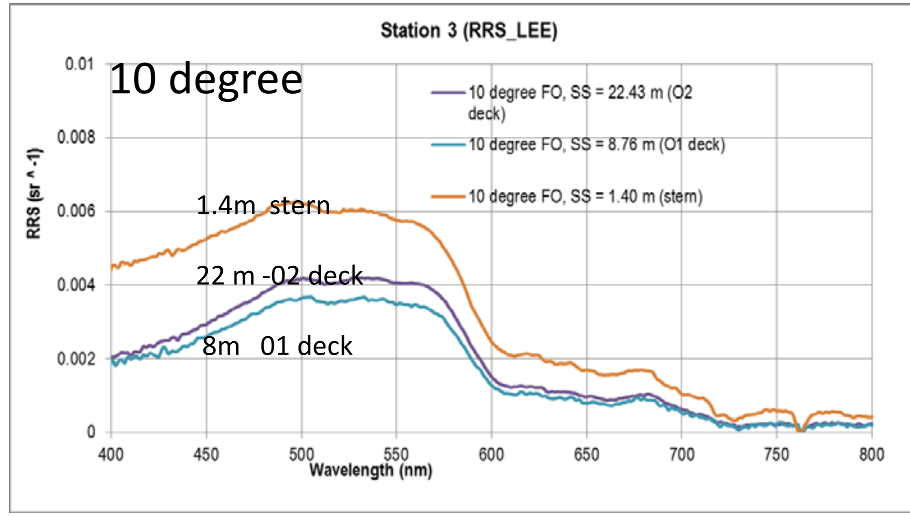


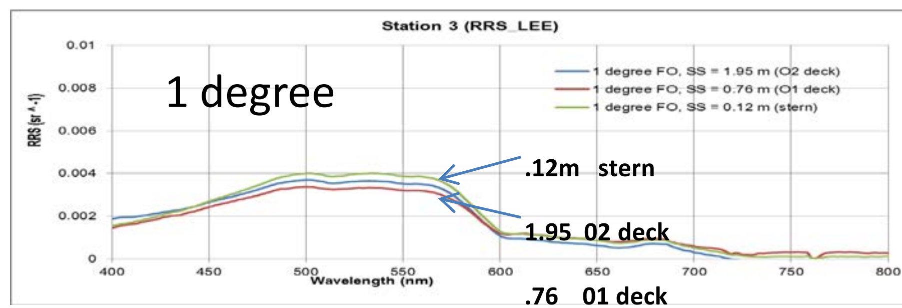
No apparent trend in sampling height FOV and quality of returns

Very good agreement in blue waters for all stations!

Coastal Matchups

R_{RS} – Uncertainty in above-water





Stern – highest uncertainty 10 deg FOV - higher

O1 Deck is most consistent for 1 and 10 degree FOV 1.95 and 8m spot size Selected as the Protocol

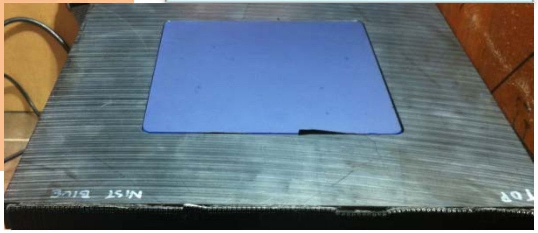
Dec 2015 Cruise

Radiometer – NIST blue tile

Instruments =*5 ASD* *1 SpecEvol* *1 GER*

ShowS good agreement among different systems

ASD
Protocols For RRS



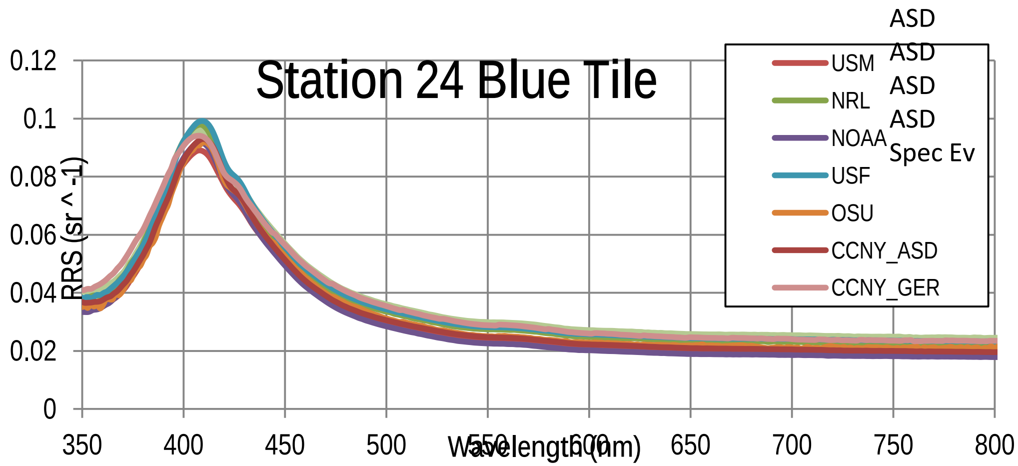
Similar Protocols

files collected.
dark Targets
Angles,
NRL Grey card
NRL processing

Different % Clouds

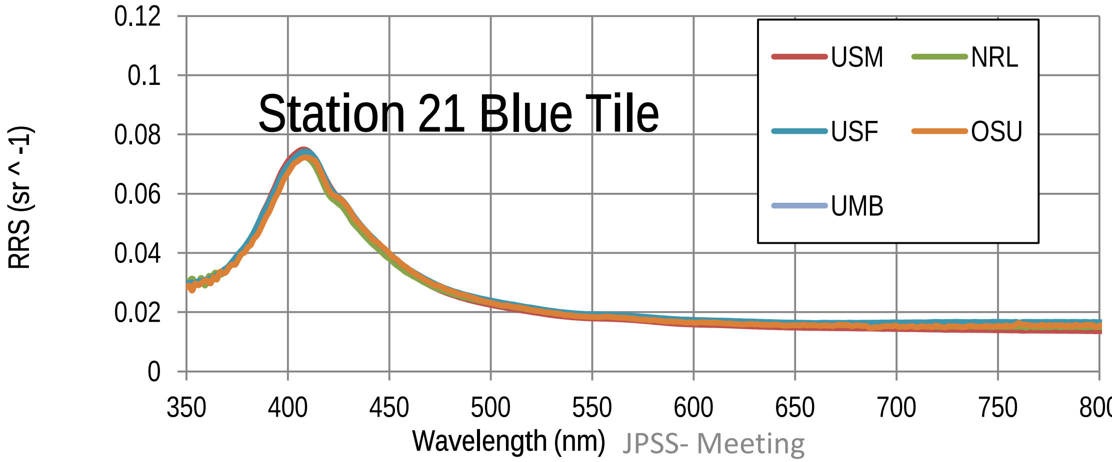
Similar Processing on all Systems

Several Blue tile Stations Collected
These are best days!



135 degree azimuth T1430 GMT

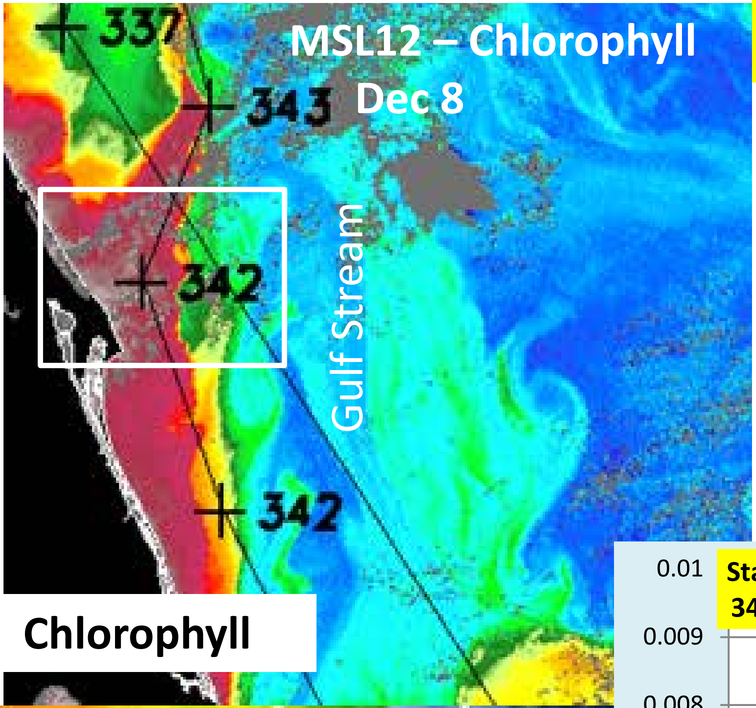
$$R_{tile}(\lambda) = R_g(\lambda)\frac{S_{tile}(\lambda)}{S_{ref}(\lambda)}$$

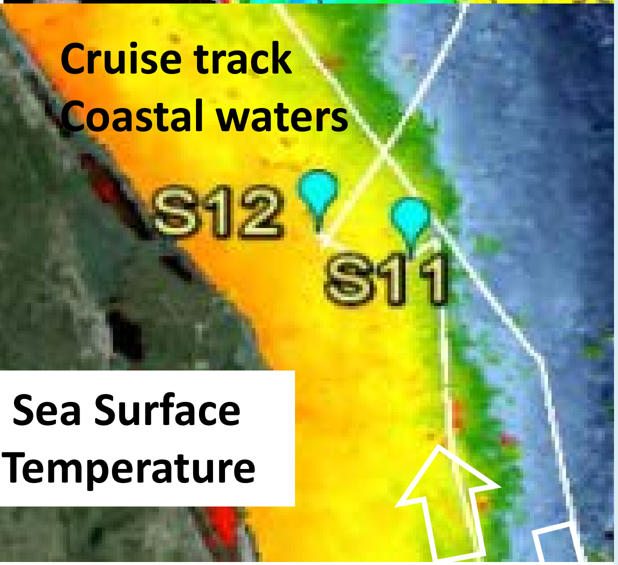


90 degree azimuth T1910 GMT

3 ASD
2 SpecEvol

Dec 2015 Cruise VIIRS and Insitu Matchup - Floating Hyperpro -and ASD





Station 12 – Dec 8, 2016 Coastal waters

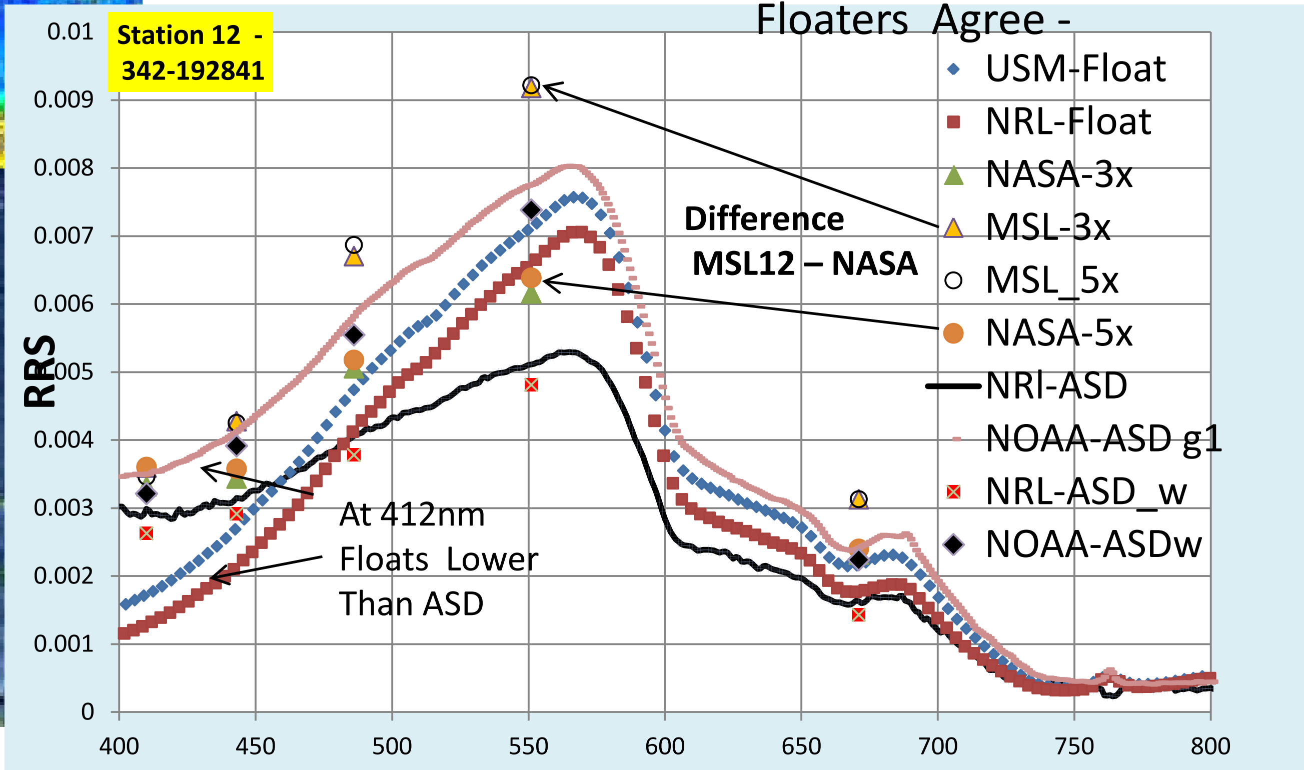
Uncertainty with VIIRS data

Scattered Clouds VIIRS Satellite Matchup

No center pixel, only 3x3 , 5x5 mean

Require Protocol for VIIRS data – matchups

ASD better agreement with VIIRS At 400 nm



Dec 2015 Cruise

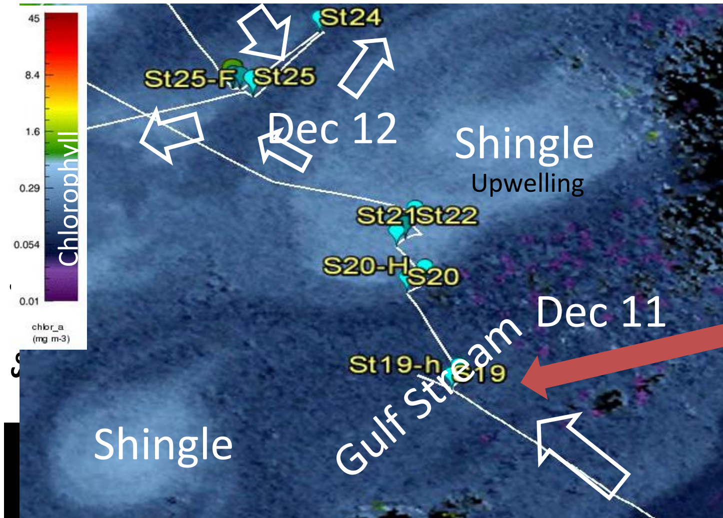
VIIRS and Insitu Matchup - Floating Hyperpro -and ASD

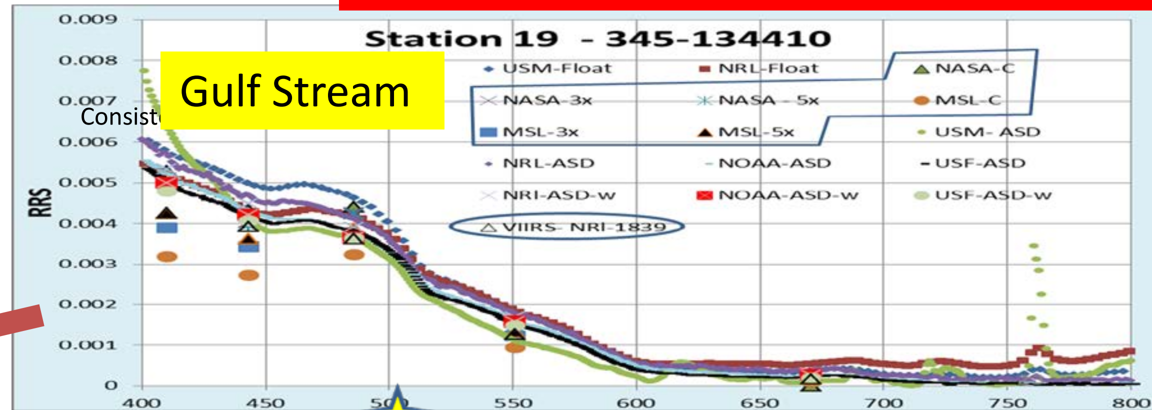
Day 345 Dec 11, Station 19, 20, 21

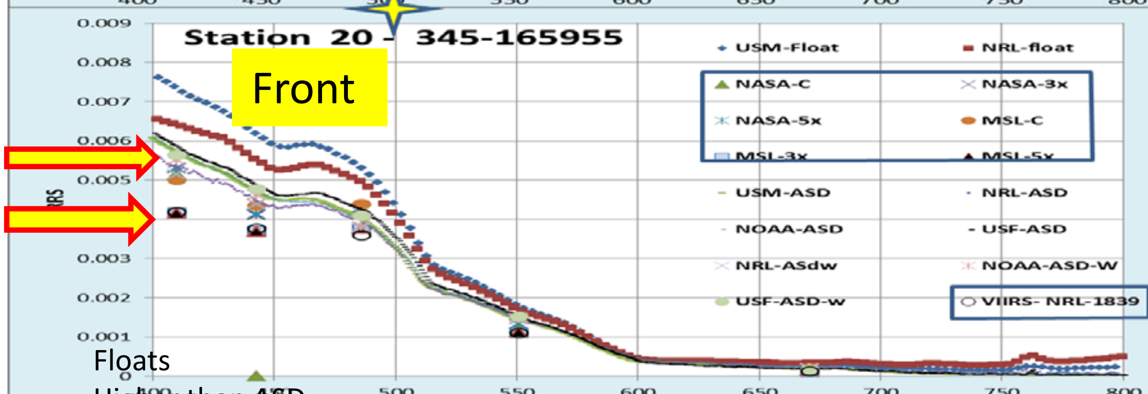
Clear Skies

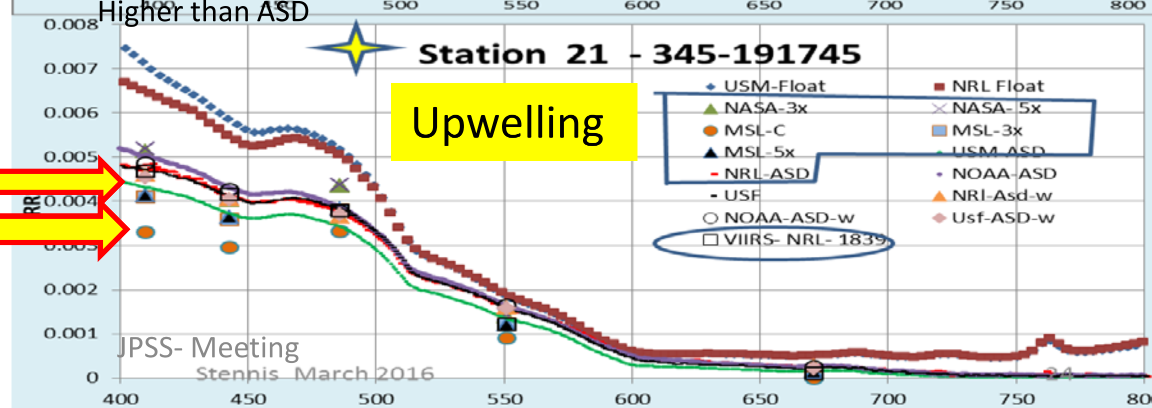
Gulf Stream St 19 Shingle St 20 – 21

RRS from Floaters and ASD Consistent.









Suggests Protocols

VIIRS Matchup

Note Differences ~ 13% in

Center Pixel,

3x3

5x5

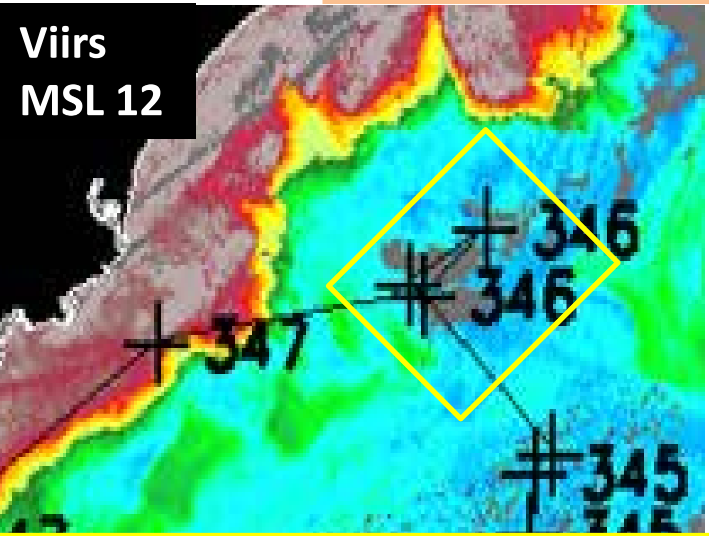
Remove Cloud Shadows .

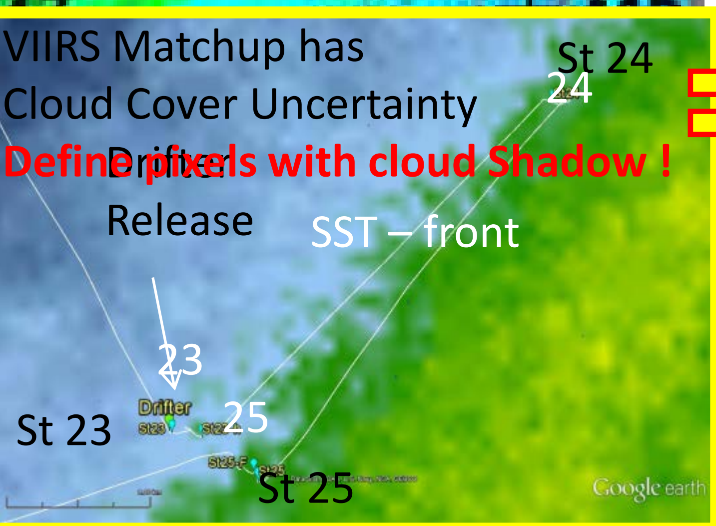
VIIRS MSL – and NASA = Low

VIIRS overpass at 1838 = St 21

Dec 2015 Cruise — VIIRS and Insitu Matchup - Floating Hyperpro -and ASD

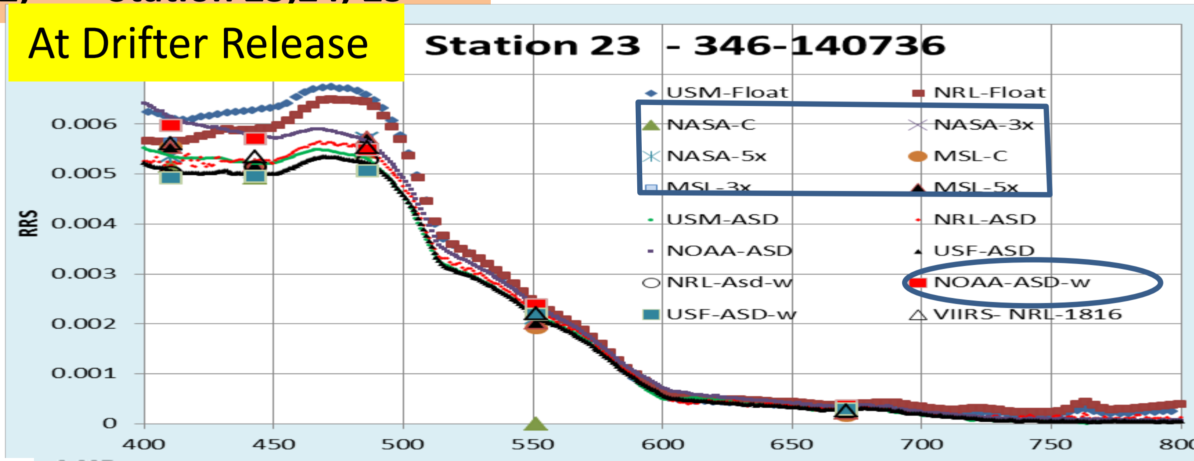
Day 346 Dec 12, Station 23,24, 25

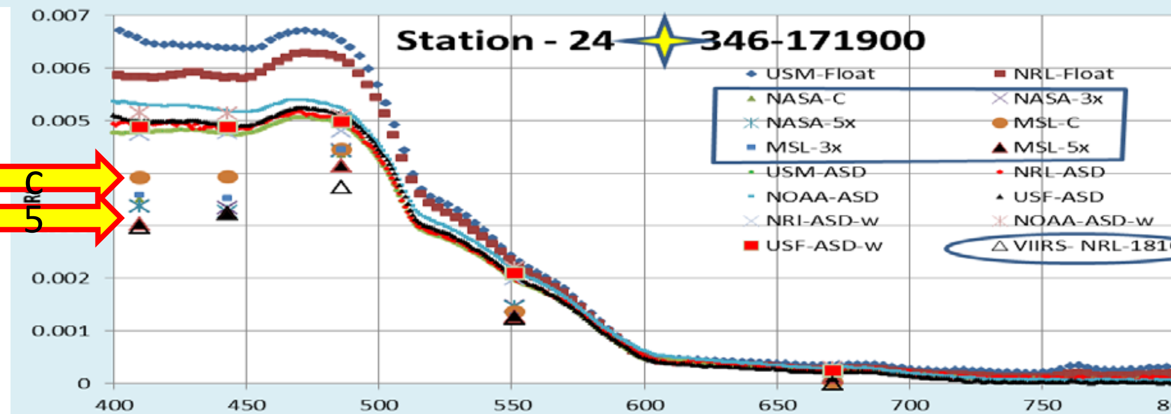


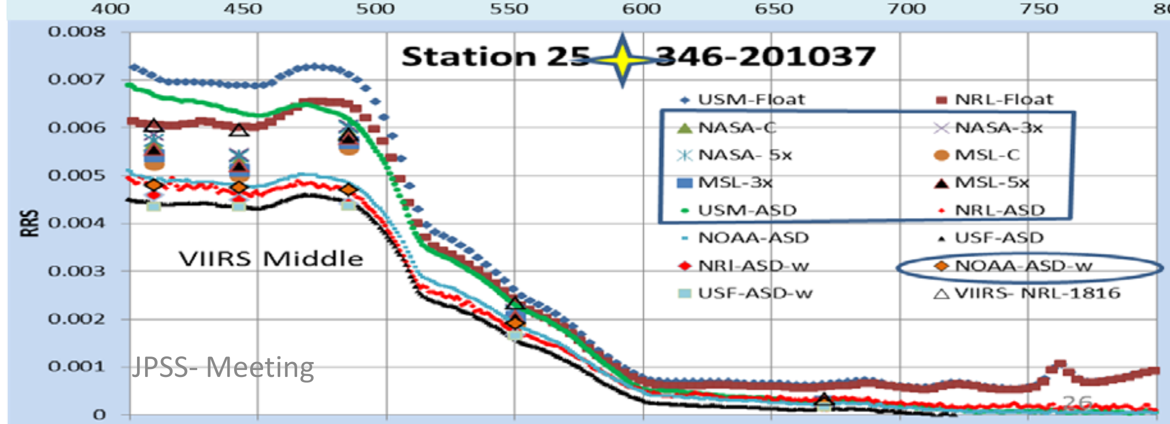


VIIRS Scattered Clouds
Has VIIRS Center Pixel
Along SST frontal boundary

At Drifter Release



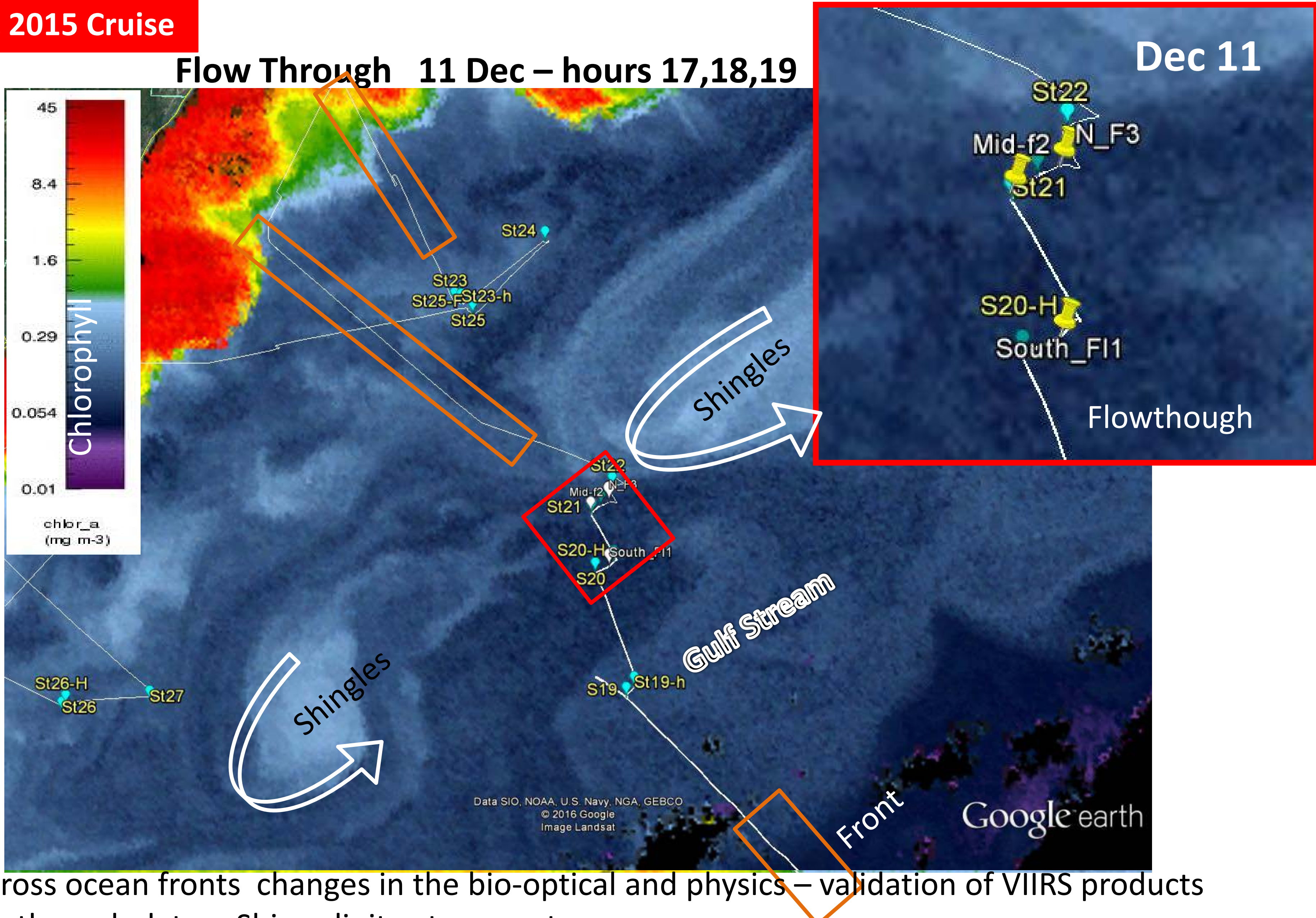




JPSS- Meeting

Dec 2015 Cruise

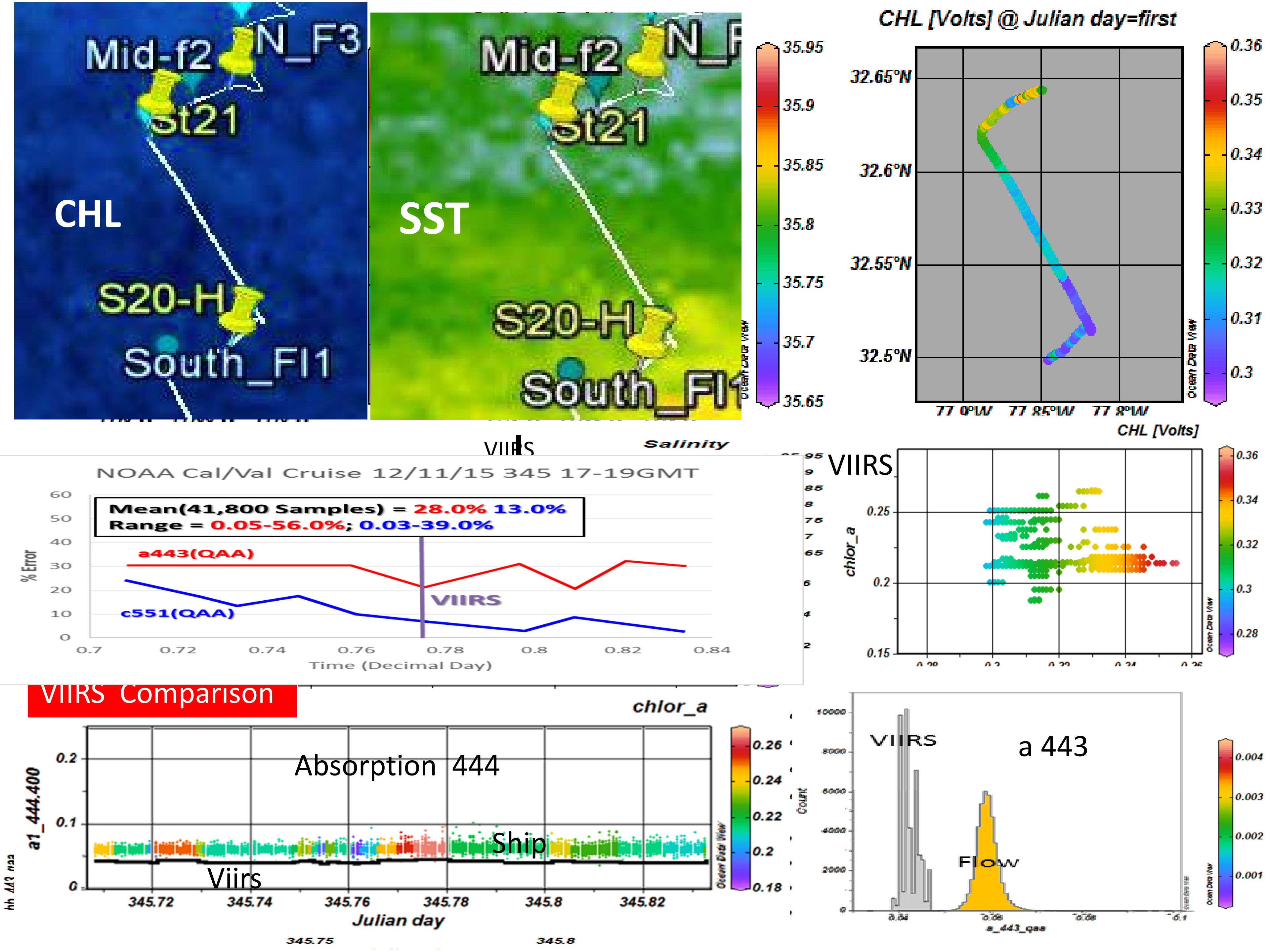
Flow Through   11 Dec – hours 17,18,19



Cross ocean fronts changes in the bio-optical and physics – validation of VIIRS products

Flowthrough data -- Ship salinity , temperature

IOP- total and filtered absorption (λ) , scattering (λ), CDOM, spectral slope → particle size, bb - backscattering


CHL
Mid-f2
N_F3
St21
S20-H
South_FI1
SST
35.95
35.9
35.85
35.8
35.75
35.7
35.65
CHL [Volts] @ Julian day=first
32.65°N
32.6°N
32.55°N
32.5°N
0.36
0.35
0.34
0.33
0.32
0.31
0.3
CHL [Volts]
Salinity
VIIRS
NOAA Cal/Val Cruise 12/11/15 345 17-19GMT
Mean(41,800 Samples) = 28.0% 13.0%
Range = 0.05-56.0%; 0.03-39.0%
a443(QAA)
c551(QAA)
VIIRS
% Error
Time (Decimal Day)
0.7
0.72
0.74
0.76
0.78
0.8
0.82
0.84
VIIRS
chlor_a
0.25
0.2
0.15
VIIRS Comparison
chlor_a
Absorption 444
Ship
Viirs
a1_444.400
Julian day
345.72
345.74
345.76
345.78
345.8
345.82
0.26
0.24
0.22
0.2
0.18
VIIRS
a 443
Flow
Count
a_443_qaa
0.004
0.003
0.002
0.001

Diurnal changes in ocean color in coastal waters

How does Diurnal Changes in ocean color affect Cal – Val of VIIRS?

1. **How rapidly does ocean color change in the coastal ocean ?**
   What is the spectral uncertainty of these changes?
2. **Diurnal changes in ocean color can occur from:**
   - **a. Advection of water masses.**
   - **b. Upwelling, downwelling of subsurface optical layers.**
   - **c. Biological activity → Phytoplankton blooms and decay**

4. **Can VIIRS 100 minute "orbital overlaps" detect diurnal changes?**
   - **a. Validate diurnal Ocean color signatures and define the temporal certainty.**
   - **b. Diurnal ocean color can characterize coastal physical and bio-optical processes.**
   - **c. New products can be developed from diurnal ocean color to define coastal processes**
5. **Many examples from Aeronet showing the ocean color changes every 20 minutes .**

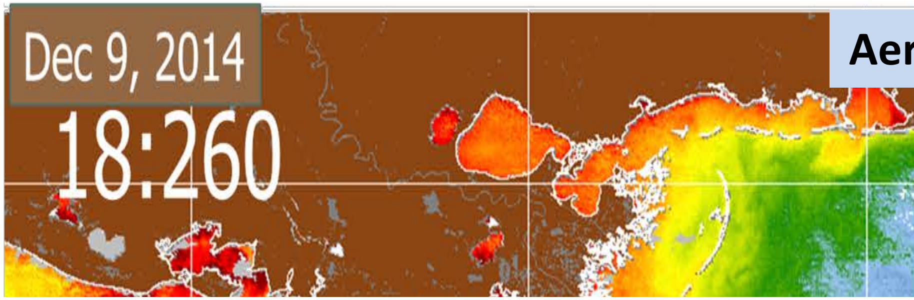
Citation: Robert Arnone ; Ryan Vandermeulen ; Sherwin Ladner ; Michael Ondrusek ; Charles Kovach, H. Yang, J.Salsbury: " Diurnal changes in ocean color in coastal waters ", *Proc. SPIE* 9827, Ocean Sensing and Monitoring VIII, 982711 (May 17, 2016); doi:10.1117/12.2241018; http://dx.doi.org/10.1117/12.2241018

http://proceedings.spiedigitallibrary.org/proceeding.aspx?articleid=2524464

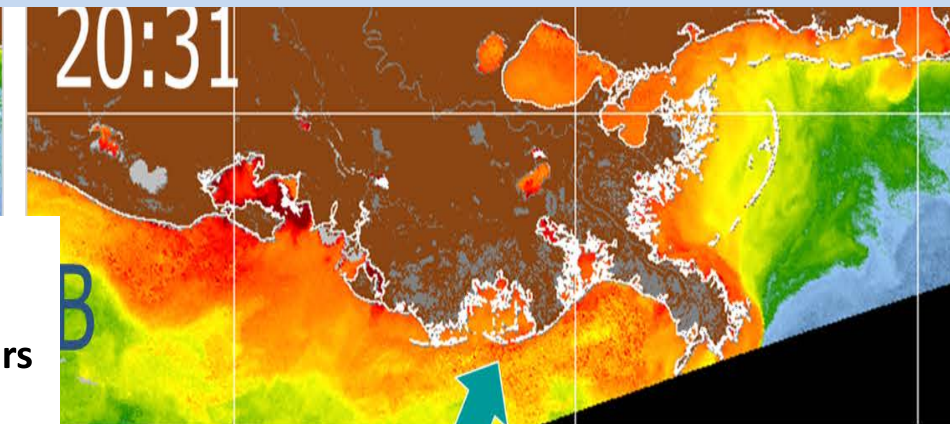
VIIRS Orbital overlap showing Diurnal Chlorophyll changes ~ 100 minutes.

At ~30 Latitude - overlap Sensor angles ranges from 56 t0 70 degrees

VIIRS shows it can validate track rapid Diurnal changes at Aeronet



Aeronet Shows the Diurnal changes in ocean color .

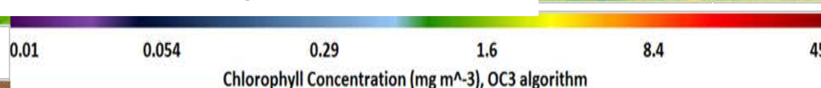


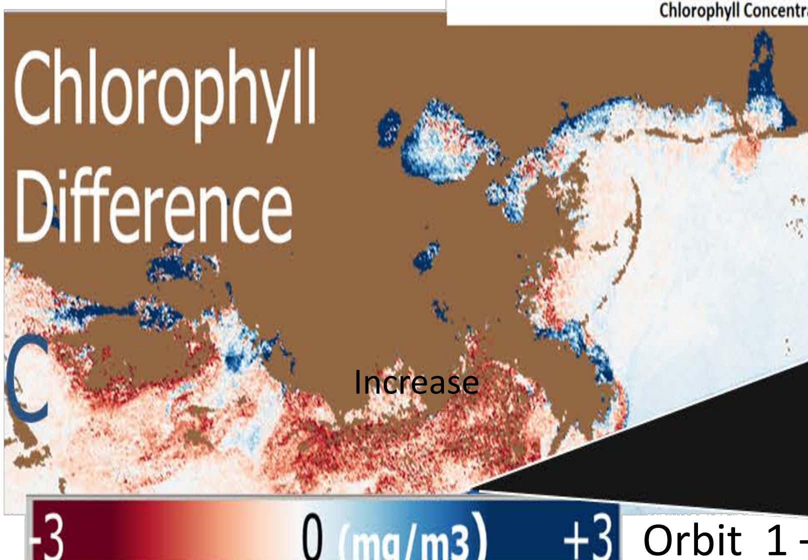
Diurnal Changes occur

1.Advection of Water Masses

2.Upwelling, downwelling of Subsurface optical layers

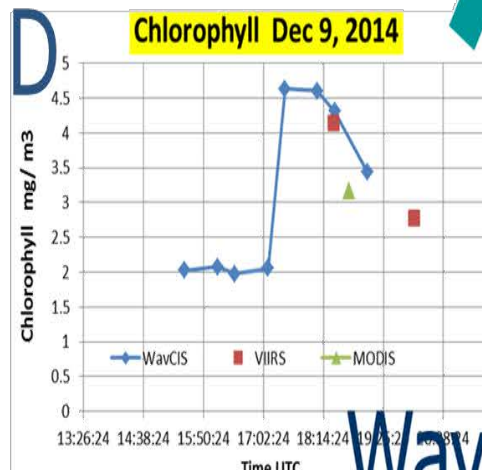
3. Biological Activity- Blooms and decay

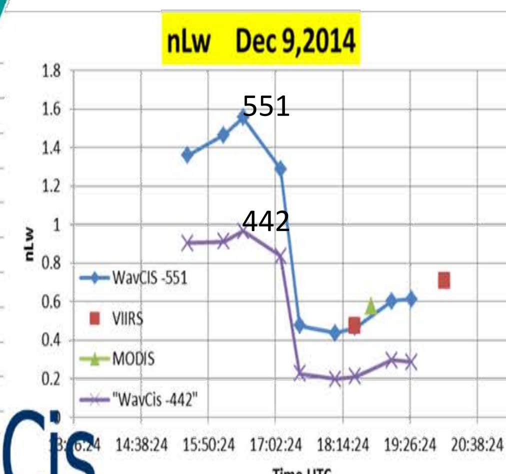




Orbit 1 – Orbit 2

Bloom Mg/m3 Decay First Greater





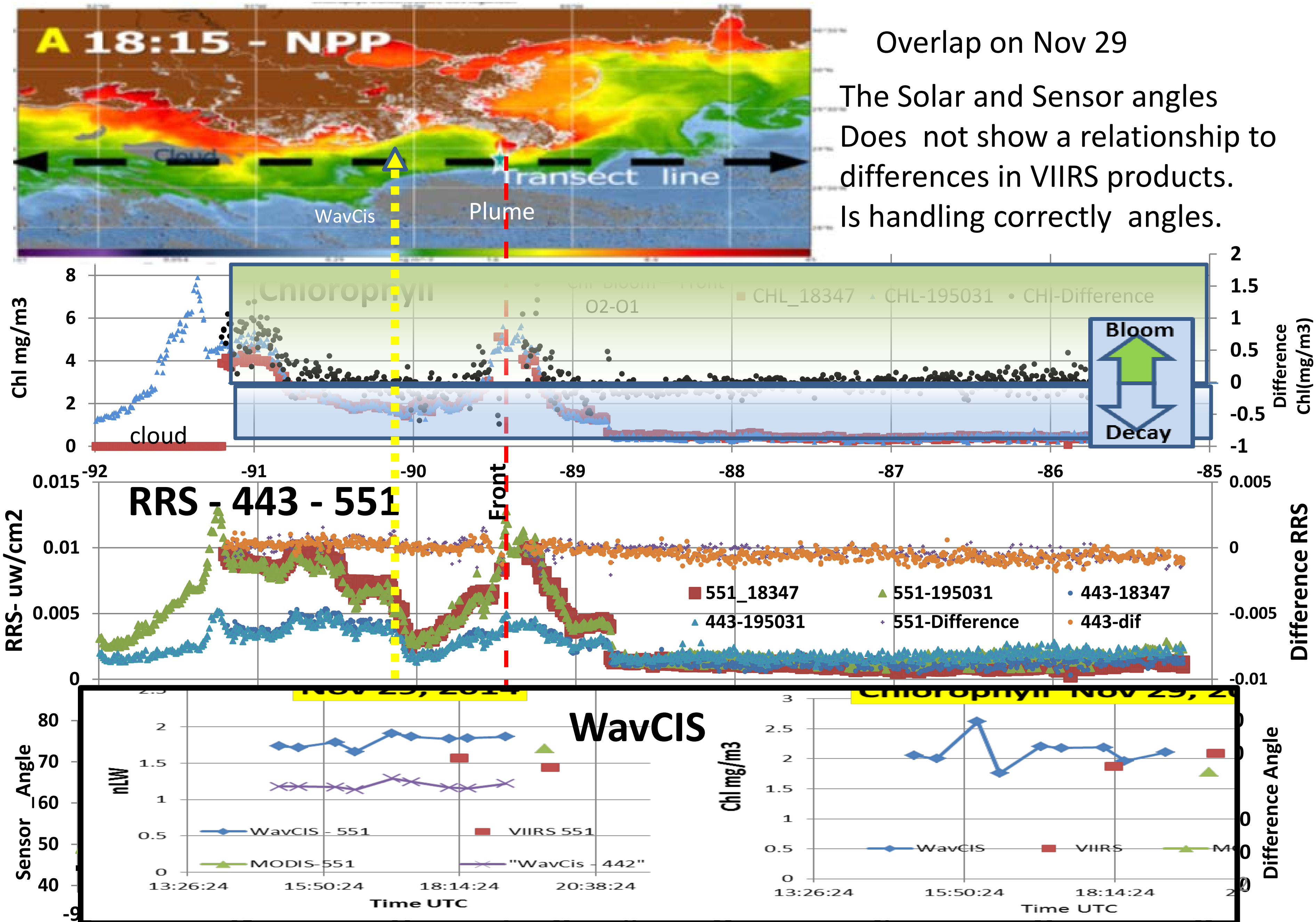
WavCis

VIIRS Following Trend

Does VIIRS orbital overlap correctly handle the large sensor angles ?

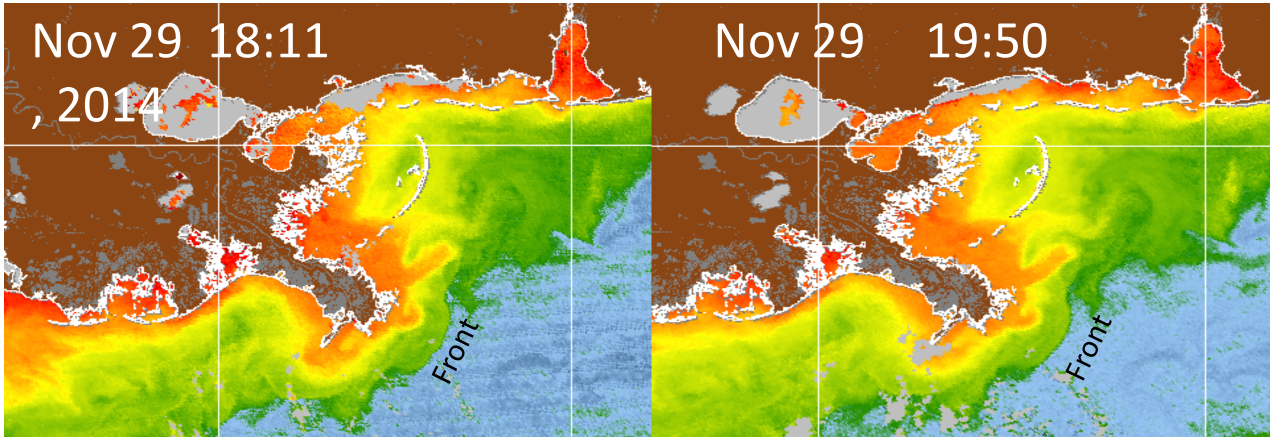
Overlap on Nov 29

The Solar and Sensor angles
Does not show a relationship to
differences in VIIRS products.
Is handling correctly angles.



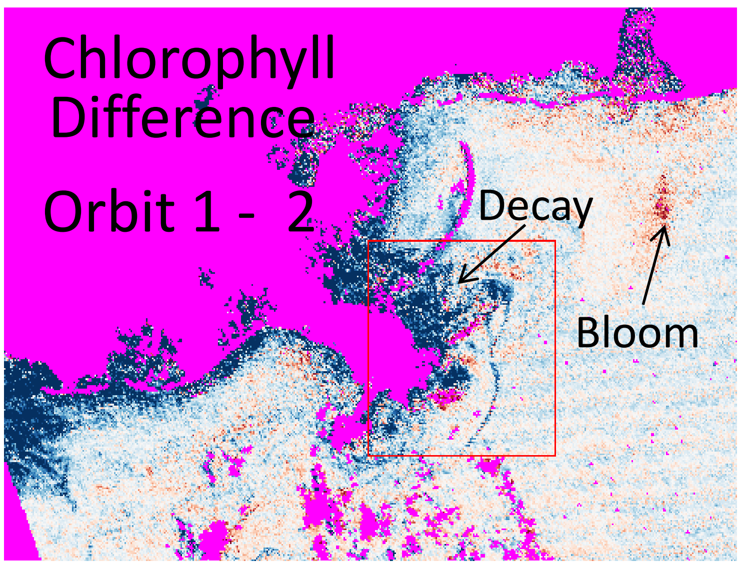
VIIRS Diurnal Changes can identifies Surface Processes in the Ecosystem

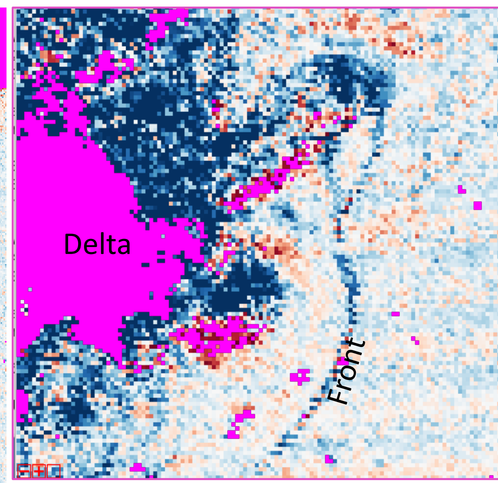
First orbit　　　　　　　　Second orbit



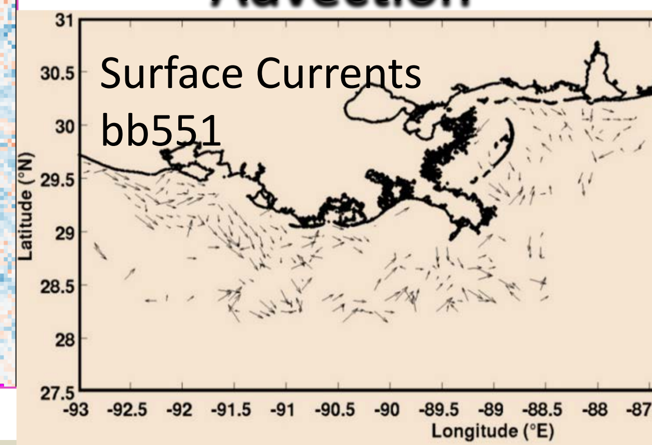
Products

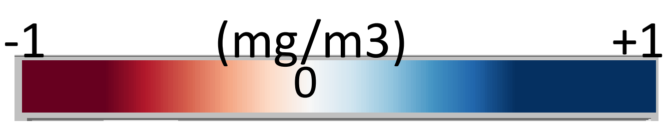
1) Phytoplankton Blooms and Decay
2) Water Mass Advection surface Currents





Frontal Movement Advection



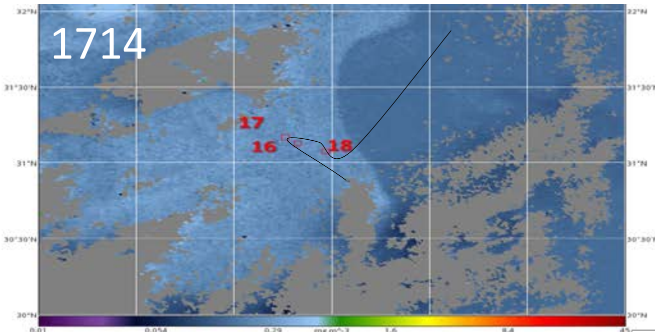


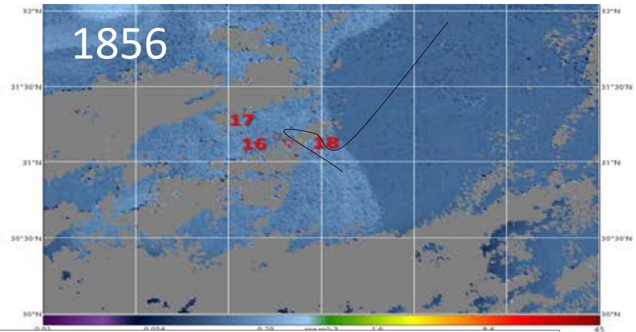
Bloom　Second Pass Greater　Decay

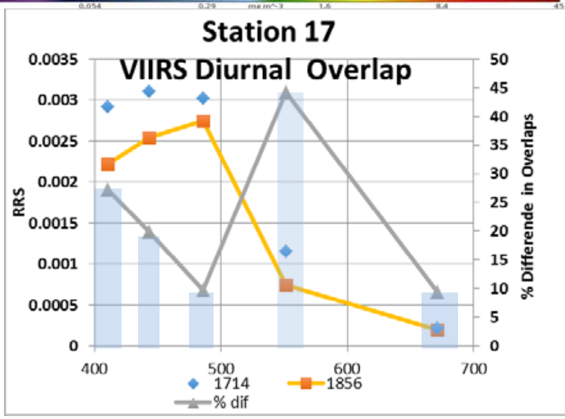
- Maximum Cross Correlation used to estimate surface currents .
- Different Color Products used for surface advection vs Biology

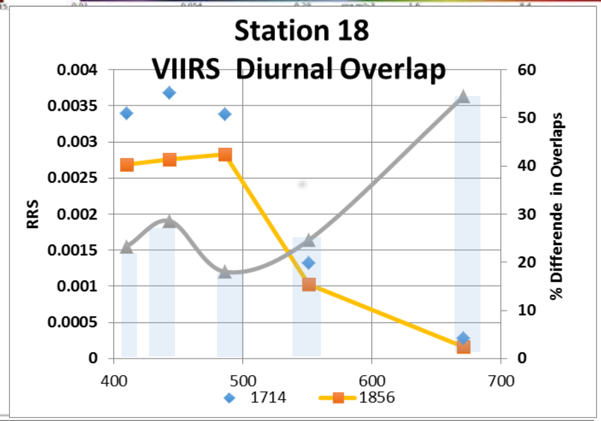
How Rapidly did VIIRS Ocean Color Change for Dec Foster cruise?

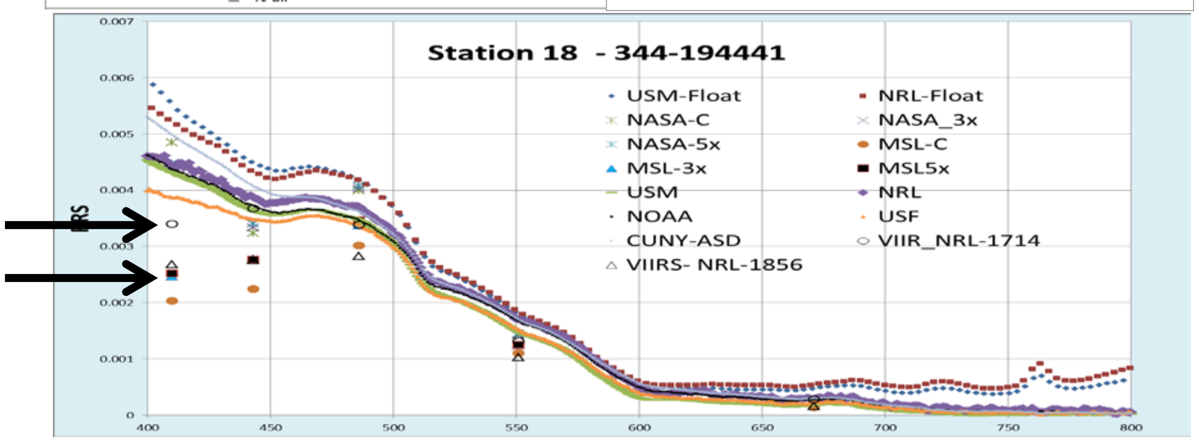
Foster Dec 10, 2015
VIIRS – Diurnal Overlaps











Diurnal variability within 100 minutes at these Station locations.

- **First Orbit is larger.**
  % change in RRS

% Change

410 – 25%
443 – 24%
486 – 14%
551 – 34%
671 – 32%

Spectrally different changes major 551 and 671

These spectral changes support the Variability in VIIRS matchup for these waters ?

Diurnal Changes in ocean color

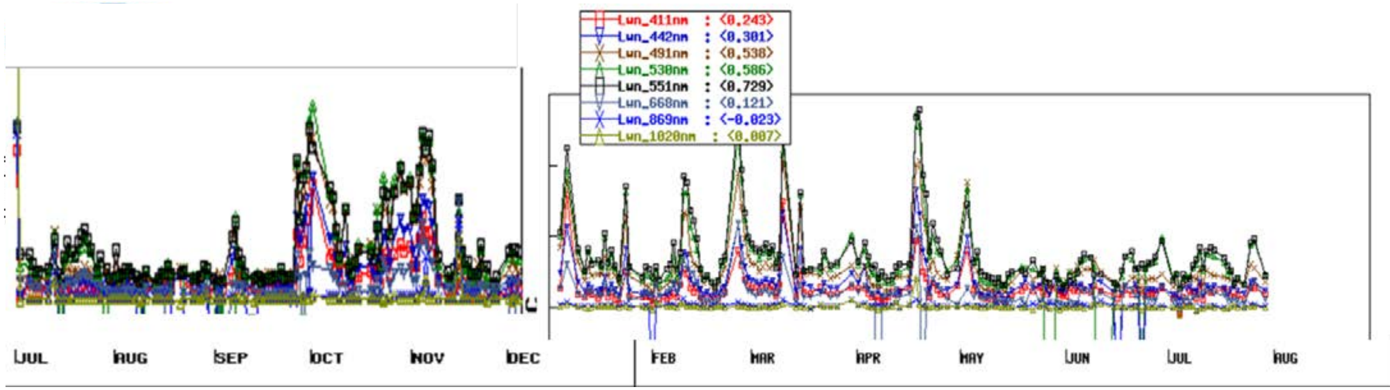
- ***Diurnal processes (hours) occur in coastal regions which impact the ocean color signatures.***
  - ***WavCis SeaPrism shows hourly color response in the nLw***
- ***VIIRS overlaps detected the diurnal hourly ocean color within 100 Minutes !!!***
- ***Rapid ocean color changes "must " be accounted for in coastal satellite calibration/validation.***
- ***New VIIRS ocean color Products – from Diurnal changes.***
  - ***Water mass Advection →***
    VIIRS OVERLAP ocean color can be used to derive surface currents!!!
  - ***Bio-optical changes***
    VIIRS Chlorophyll DIFFERENCES identify BLOOM and DECAY regions !

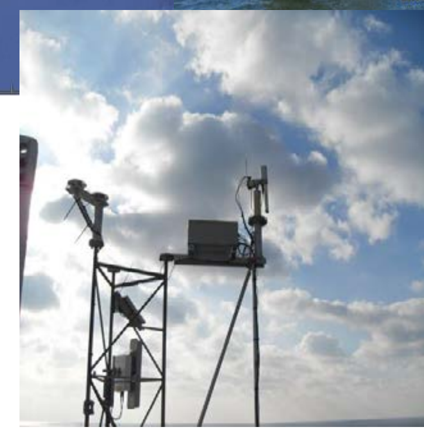
Future VIIRS Cal Val Cruises

1. Diurnal Changes in Color - 6 hours per day -Overlaps
2. Optically Shallow waters – depth , bottom reflectance's
   - Stability of a ocean site
3. VIIRS Data matchup Protocols

WavCIS SeaPrism Status
SN 610

1) WavCis SeaPrism has been operating successfully throughout the year and reporting to AERONET.





2) SeaPrism Calibration.

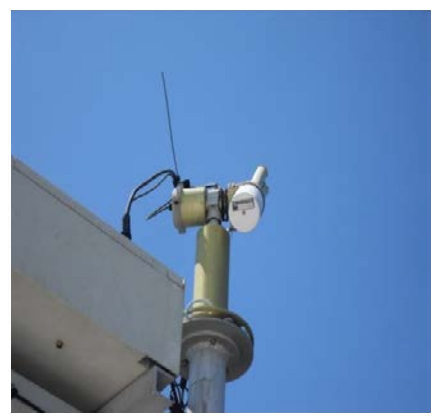
On 7/28/2015, SN 610 re-installed and put back into operation.

Aug 2016, Next Scheduled Calibration, to include Robotic Arm.

Have Loaner & Robotic arm, waiting good weather & mostly sunny day.

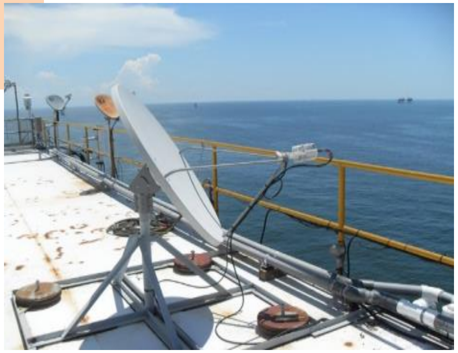
3) Maintenance Summary

- Robotic Arm is scheduled to be replaced as it has been in operation since 2010. Because the optical cable being rapped around the elevation shaft last year, Goddard and Giuseppe are recommending we replace the Robotic Arm on the next calibration run.



Likely cause was heavy winds from thunderstorms, reported 50 to 100 mph winds

WavCIS SeaPrism Status
SN 610



Maintenance past year

- **Aeronet was Down Oct 19th - Nov 6th of 2015 satellite Communications but no loss of data**
  - Power cycled on Nov 6th by Chevron Personnel resulting in the Satellite link being restored. Although no data was being transferred during that time period, it was being saved on the computer resulting in ***no loss of data.*** Once the Satellite link was back up, all data was then transferred and caught back up by the afternoon of Nov 6th. The cause of the outage was the repainting of the roof. Workers covered up the Satellite Dish, causing the link to shut down.
  - **The Dish was re-aligned in December 2015 to achieve optimal performance.**

- **Three inspection trips were made between December 2015 and June 2016 to the Sea Prism site**.
  - Clean the rain sensor as salt crystals do form on it and cause false rain errors,
  - Inspect the interior of box for water
  - Replace the desiccant that keeps the interior of the box dry and electrical connections corrosion free and to grease the gasket on the door to insure proper water tight seal.
  - Check computer for proper operation, Sea Prism data is backed up to an external hard drive, that data is then removed and disk maintenance is performed to insure reliability of the computer.

Summary

1. Dec Foster cruise   and Gulf of Mexico
   Tongue can address   - Optically Shallow areas for Cal Val
   Developing protocols for Floating Hyperpro ,   ASD - Deck 02
   Protocols   for VIIRS satellite - cloud cover etc - Center Pixel.

2. Diurnal ocean color using VIIRS Orbital Overlaps - New products
   Ocean Color Changes in coastal areas with time
   - Aeronet use for diurnal color changes can be significant
   - VIIRS Overlap shows the changes within 100 minutes.
   - Diurnal processes identified by Overlap   Blooms and Decay
   VIIRS overlaps provide support for a Geostationary Sensor

3. WavCis – Aeronet Operational and Calibrated at NASA

Stennis - Cal val Team
Annual Summary

Thank You