Ocean Color and SST Progress and QA Assessments (MODIS)

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Overview

- Sensor characterization has examined several issues.
  - Detector-to-detector discrepancies within wavebands
  - Variations in the mirror response as a function of angle of incidence
  - Differences in characteristics between mirror sides
  - Problems associated with polarization and sun glint.
  - Initial SST and nLw error

Iterative steps in characterization/initialization:

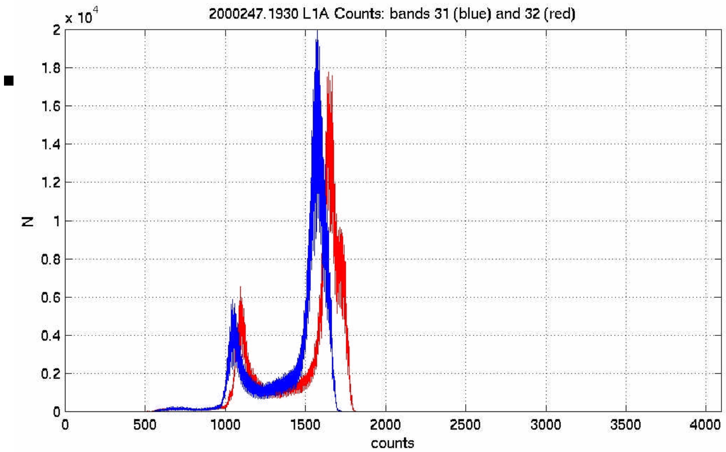
- **Remove Response versus scan angle (RVS).**
- **Remove Polarization effects.**
- **Adjust detector gains by evaluating Lt.**
- **Remove sun glint.**
- **Filter aerosol radiance (La) at 750nm & 865nm prior to epsilon calculations.**
- **Evaluate resulting satellite Lw fields propagated to the sea surface.**
- **Adjust Lt scaling factors based on inter-detector differences in satellite Lw. (Lw at detector x - Lw at reference detector 5).**
- **Repeat steps above until detector differences in Lw's within a given band approach zero (<0.0003)**
- **Adjust overall band gains and biases using matchup observations**

Digitizer noise - Full Range

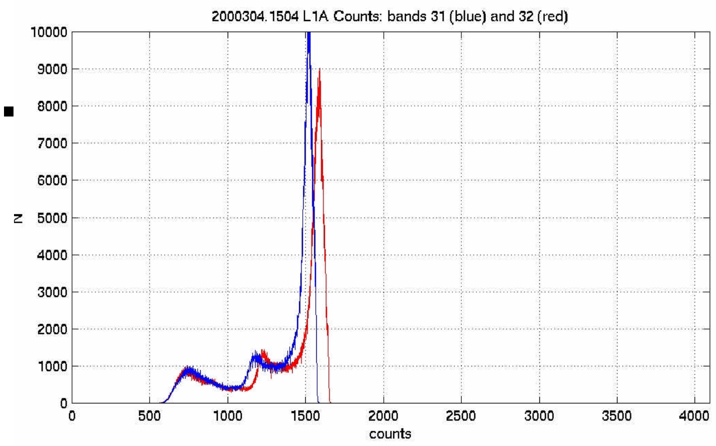
- Plots show effects of noise introduced during sensor A/D conversion.

Histogram of digitizer counts.
A. A side electronics
B. B side electronics

A.



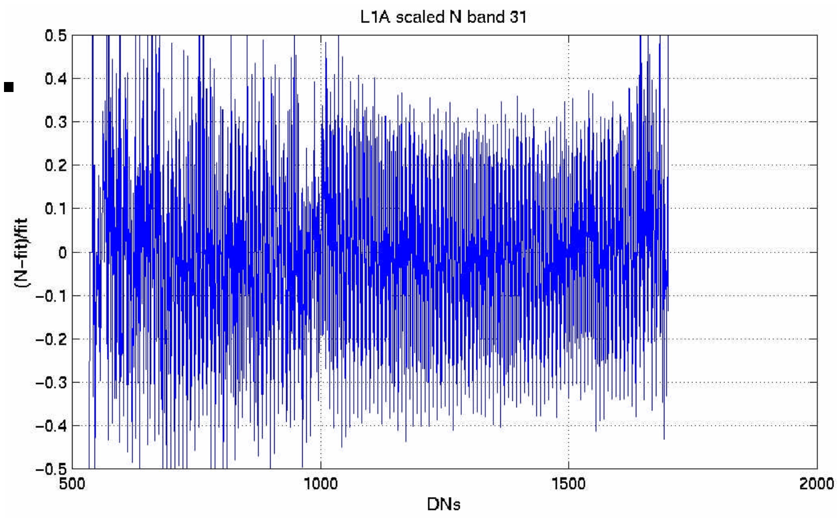
B.



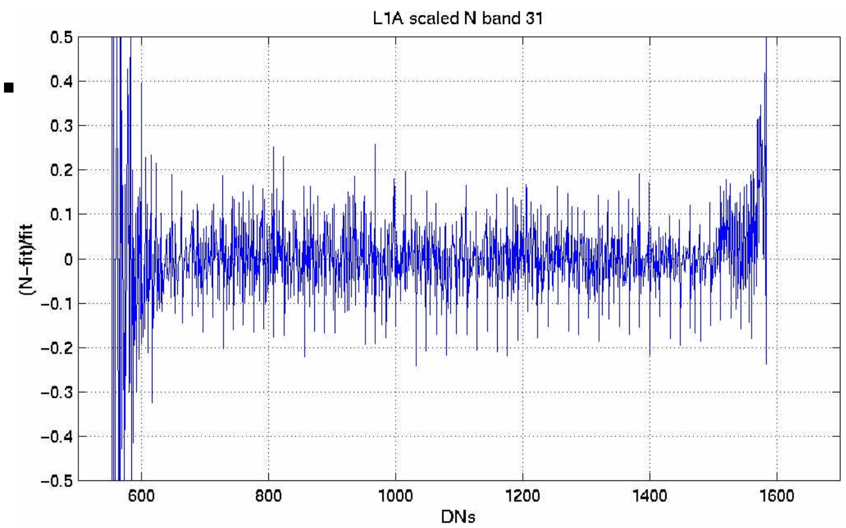
Digitizer noise - Expanded view of 500-2000

- **Over- and under-represented values are synchronous among wavebands at the $2^{n-1} \rightarrow 2^{n}$ transitions.**

A.



B.



Histogram of digitizer counts.

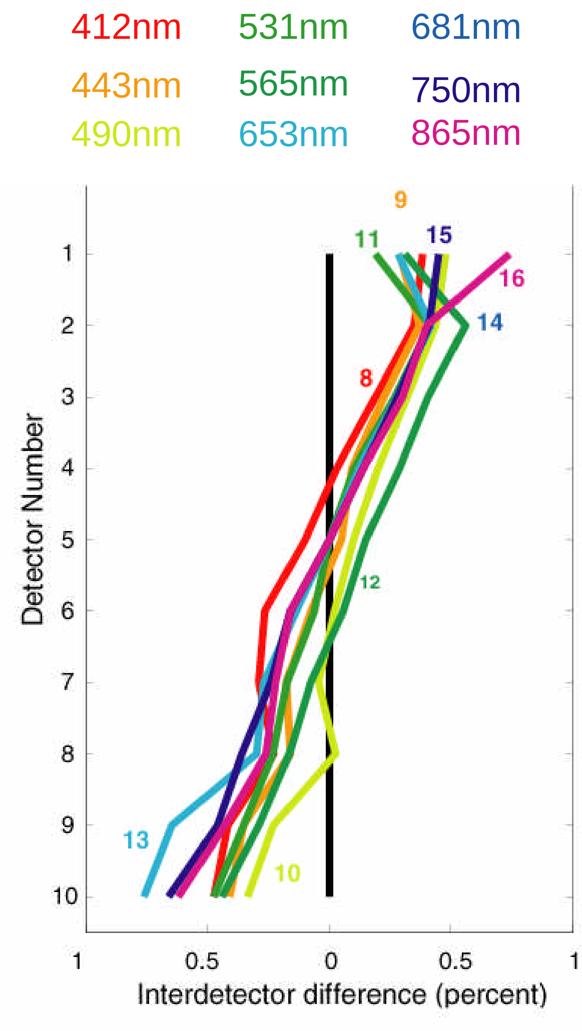
A. A side electronics

B. B side electronics

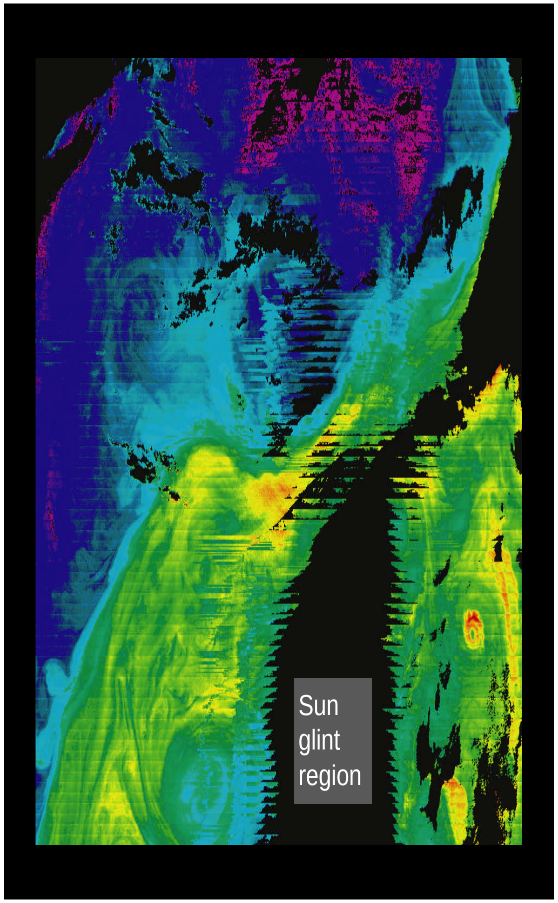
Order 50% noise reduction

Inter-Detector gain adjustments

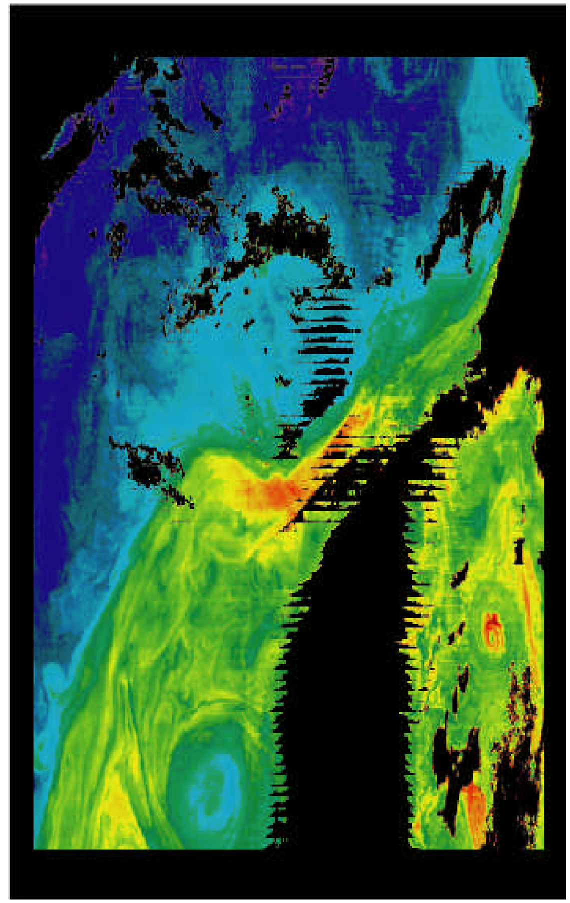
- Plot of the at-launch relative response of each of the 10 detectors.
- A general increasing linear response from detector 1 to detector 10 on the order of ~1% is present in all bands. The black line represents the inter-detector response after gains were adjusted by normalizing response to detector 5 and filtering La.



Stripe Corrections



- Early at-launch images demonstrated severe striping
- Sensor characterization and use of revised calibration tables produces a dramatically improved image
- Corrected images are remarkably full of detail, even in oligotrophic regions



Uncorrected
Level 2 1-km nLw_443 unmodified. East Coast U.S. May 8th, 2000

Corrected
Level 2 1-km nLw_443 East Coast United States

Spectral gain and bias

- **Setting of overall band gains:**
  - **Aerosol bands: Adjusted gain for band 15 (750nm) relative to band 16 (865nm) to produce "proper" aerosol model.**
  - **Visible bands (blue, green, red): Compared satellite and in situ observations from the MOCE-6 ship and Hawaii MOBY optical buoy observations. Adjusted satellite sensor gains to obtain Lw agreement.**
  - **Lw to La bands: Previous ocean color sensors only required relative calibration between the La and Lw bands. The MODIS Fluorescence Line Height (FLH) product requires an absolute calibration between band 14 (667nm) and band 15 (765nm).**
    - **We used the FLH and FLH baseline calculations in regions known to be without FLH (Hawaii) to verify that the relative band 15 and 16 gains adjustments produced equivalent fluorescence height and baseline retrievals (i.e. FLH - baseline = 0).**

Sun glint correction

Sun glint influences large portions of the image. Several approaches to correcting the glint problem were investigated.

a) We assumed sun glint was direct, i.e. no scattering component. Result: lower Lw's as increasing sun glint was removed.

b) Removed diffuse Rayleigh scattering component of the sun glint. Result: Lw retrievals showed a spectral behavior. Lw's were correct in the green region but under-corrected in the blue.

c) Included a diffuse aerosol component to the sun glint. Result: improved Lw retrievals in regions of sun glint contamination with reasonable spectral behavior.

Sun Glint Radiance equation

The glint radiance (Lg) is:

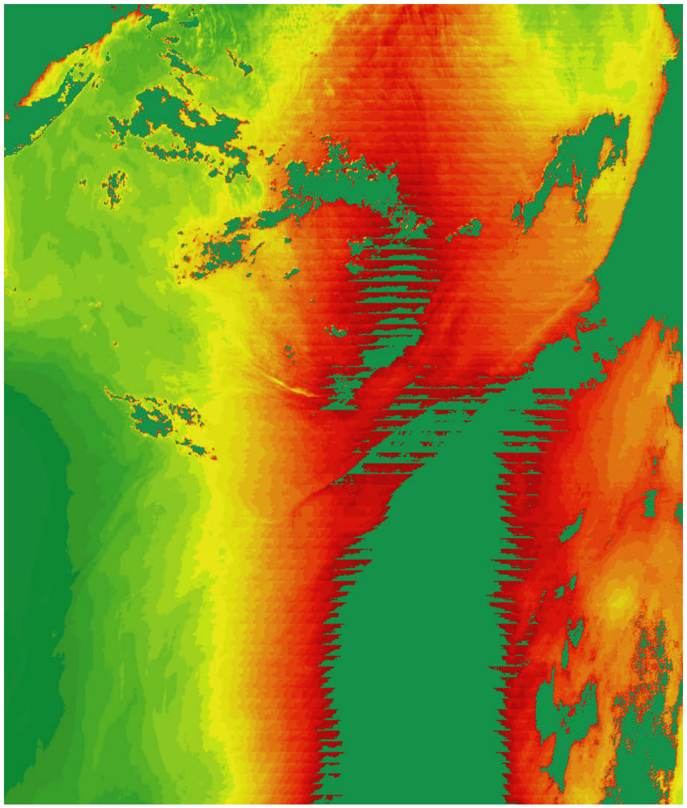
Lg = tg * Lt

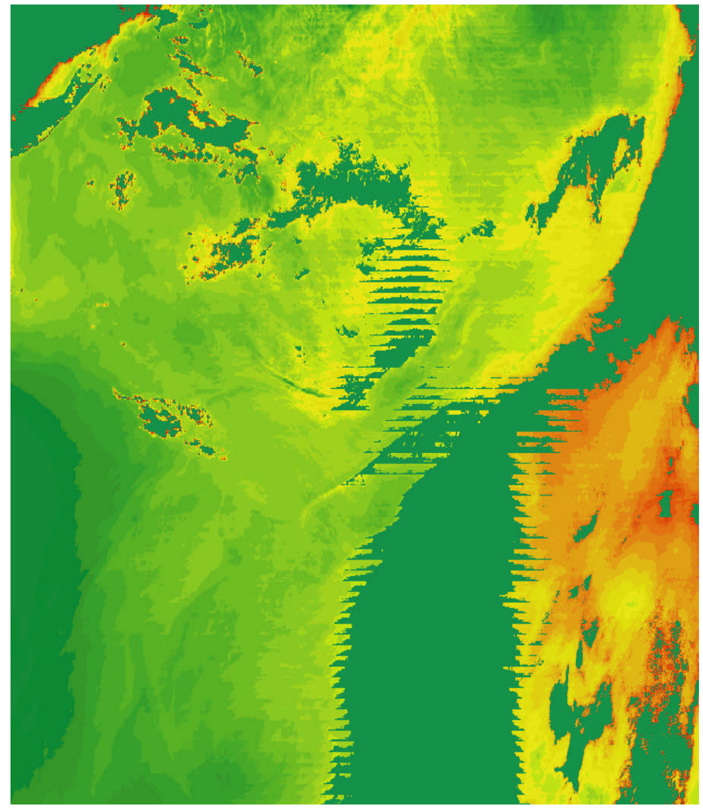
The sun glint reflectance is computed as:

tg = glintsc * zglint * zbst(l) * t_star(l)

- **Where:**
  - **glintsc = 1.65 (sun glitter coefficient scale factor)**
  - **zglint = sun glitter coefficient using Cox and Munk (1954a,b; 1956) , assumes isotropic wind.**
  - **zbst = two-way Rayleigh and Ozone diffuse transmittance; sun - ground - satellite.**
  - **t_star = one-way aerosol diffuse transmittance using chosen models; ground - satellite**

Glint Corrected La 865nm





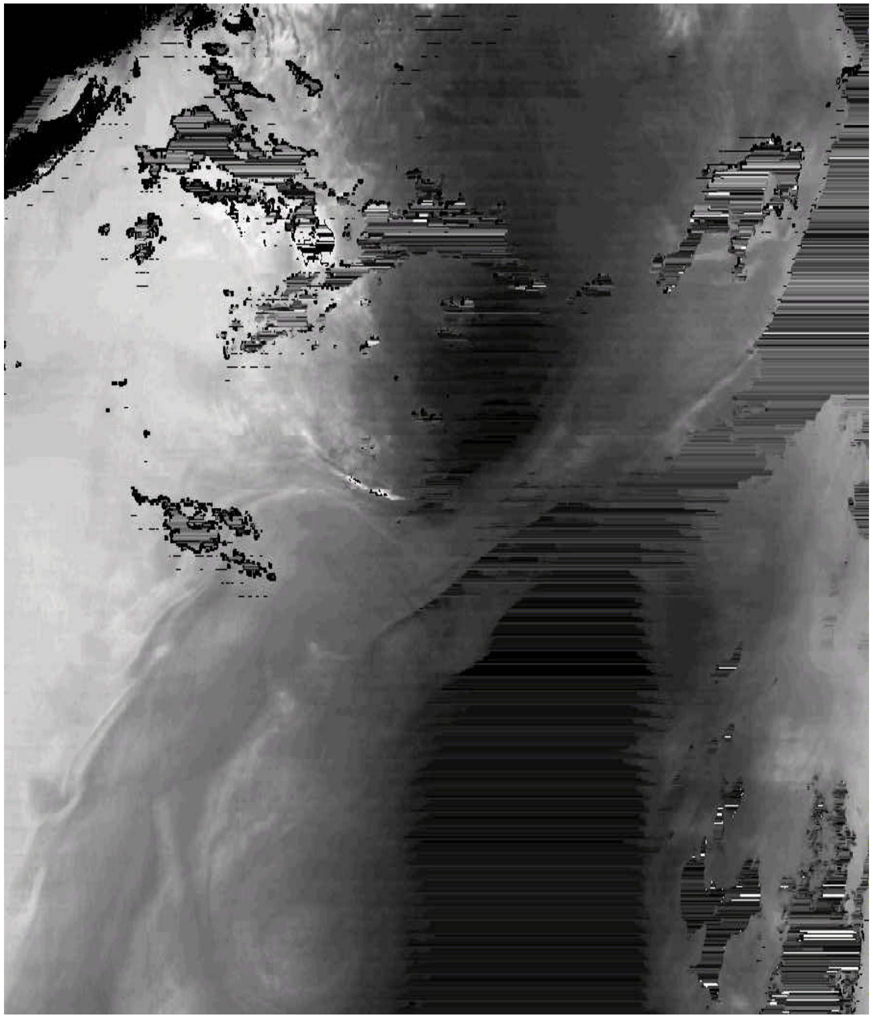
Uncorrected La 865nm
Yellow - red region glint contaminated
(Lg> 5*La).

Corrected La 865nm
Sun glint removed La865nm.

Epsilon 78

- **Epsilon 78 using filtered La 750nm and L_a 865nm in the calculation.**

  Gray scale: light -> dark decreasing values. Striped areas are clouds and glint.



- **Note the existence of Gulf steam and adjacent water features in L_a and epsilon fields.**

Polarization

The MODIS sensor has a rotating mirror such that the angle of incidence (AOI) changes dramatically from West to East across the scan line.

- Initial comparison of MODIS Lw's with Dennis Clark's Hawaii MOBY/MOCE optical buoy data indicated that the satellite Lw decreased with increasing AOI.
- The loss of the P component of the polarized light field begins to appear at nadir (AOI of ~30^o) and is most pronounced on the eastern side of the scan where the satellite zenith angle is high and the AOI approaches 65^o.
- We analyzed the instrument polarization tables and computed average polarization for each AOI by spectral band.

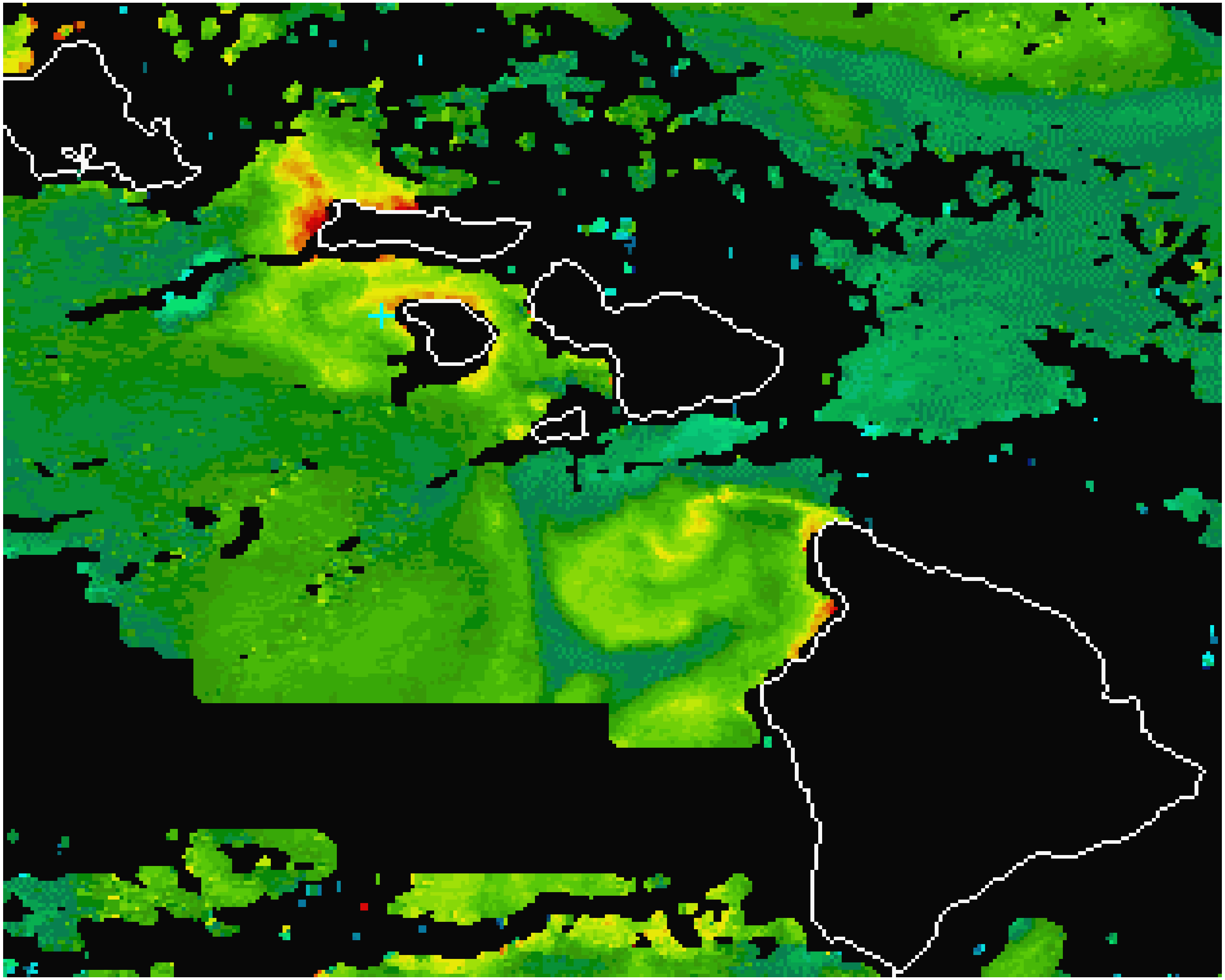
The result is a new table where the polarization factors are smoothed by AOI and fixed for all detectors across both mirror sides for each spectral band. The new tables produce stable retrievals across detectors adding radiance as a function of AOI.

Model selection

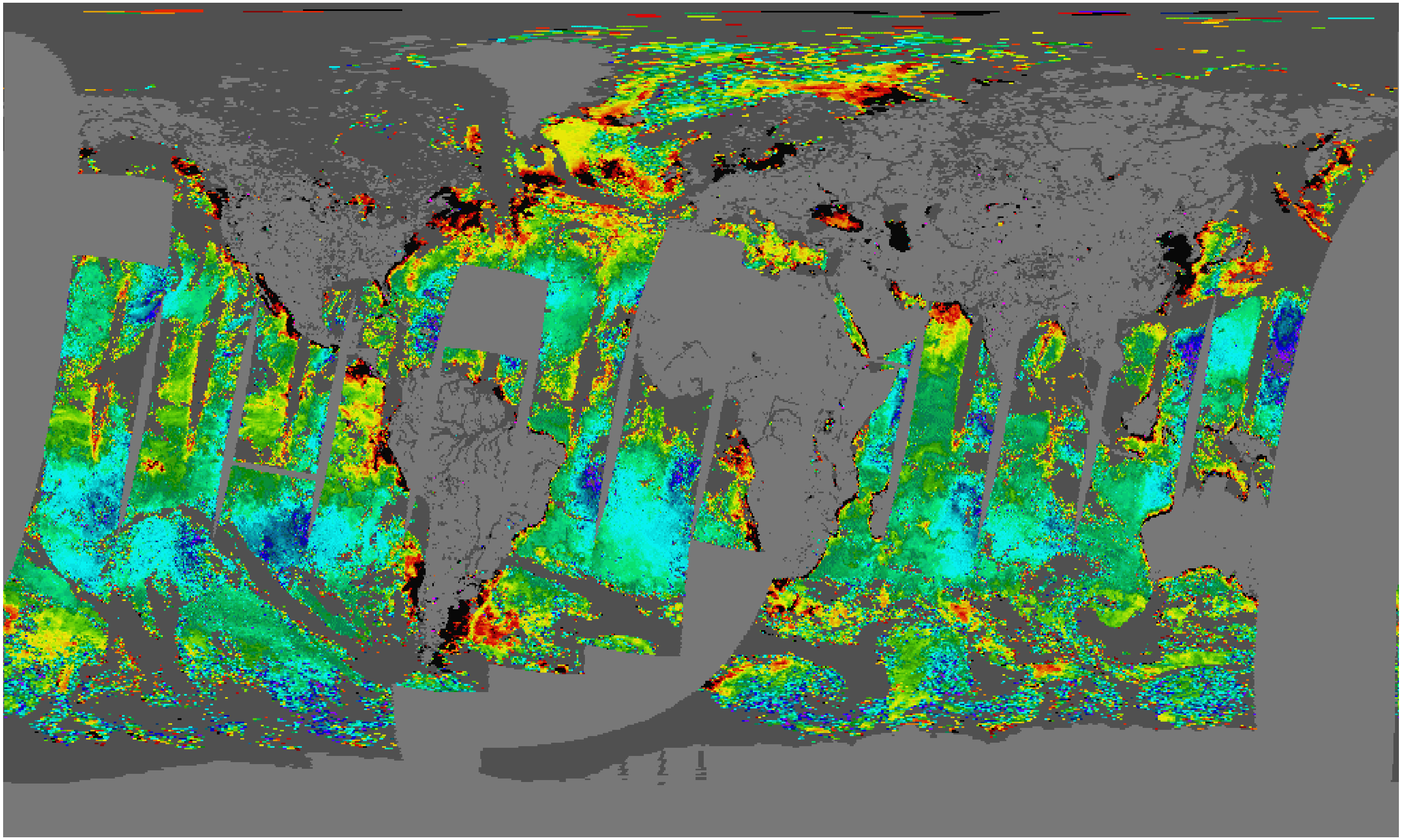
- L_a is a large fraction of the L_t in the Lw wavebands, as a consequence it is critical that the L_a fields and therefore the resulting epsilon and aerosol model selection be noise free. Any noise in the process will propagate bad L_a's into the L_w computation. ($L_w = L_t - L_a - L_g$)
  - We investigated several filtering techniques to produce uniform L_a750/L_a865 fields. The input to the epsilon calculation is the 750/865nm ratio. Filtering these wavebands results in a more uniform ratio across the scene and produced less noise in model selection.
    - 3x3 pixel average
    - Median filter
    - Median filter with nearest data neighbor averaging.

    The best approach to creating a nearly noise free ratio for the epsilon calculation was to average the median value and the two data value nearest neighbors in each of the L_a750 and L_a865 wavebands.

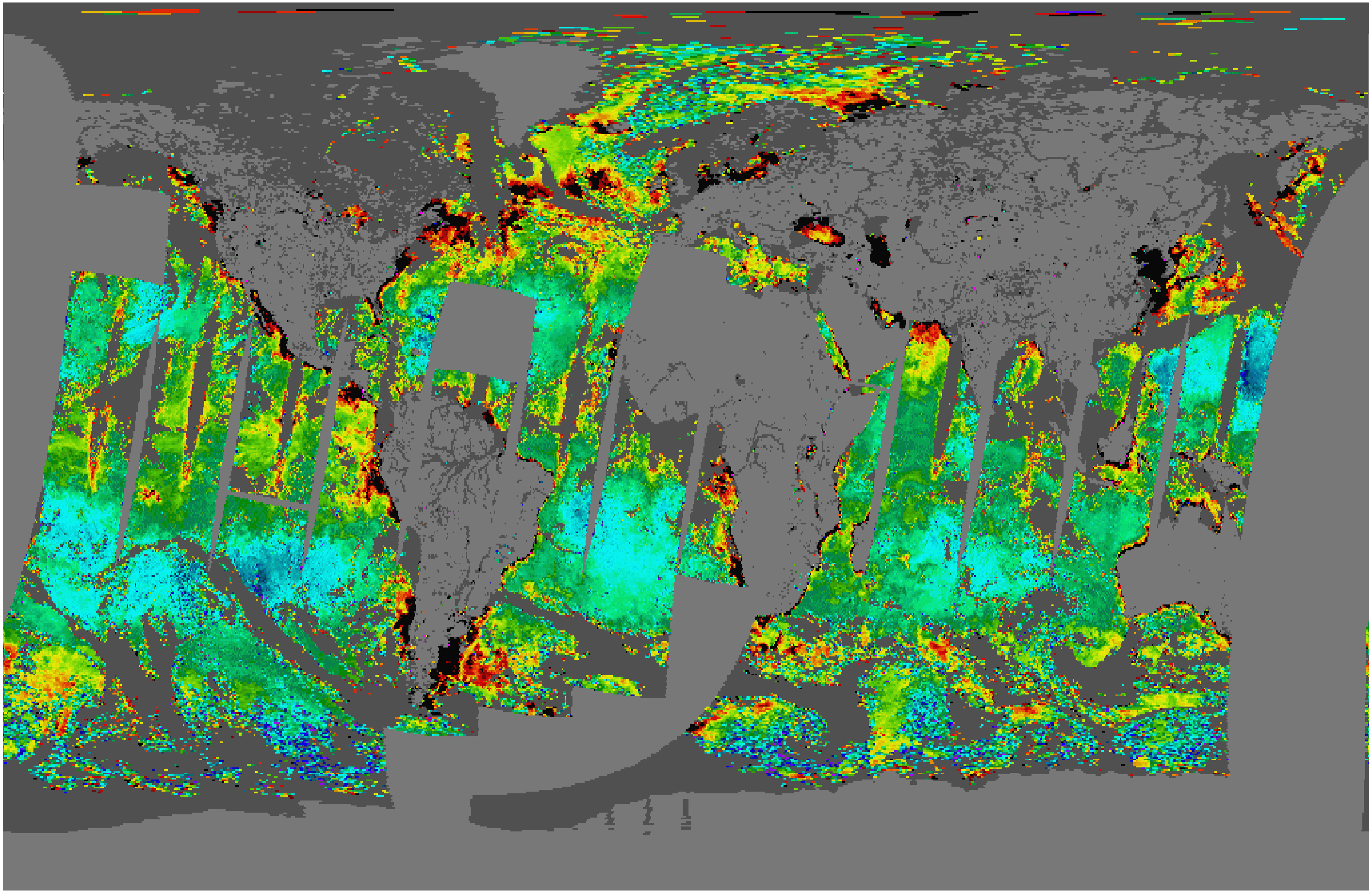
Chl - 4/11/00 MOCE6 Initialization



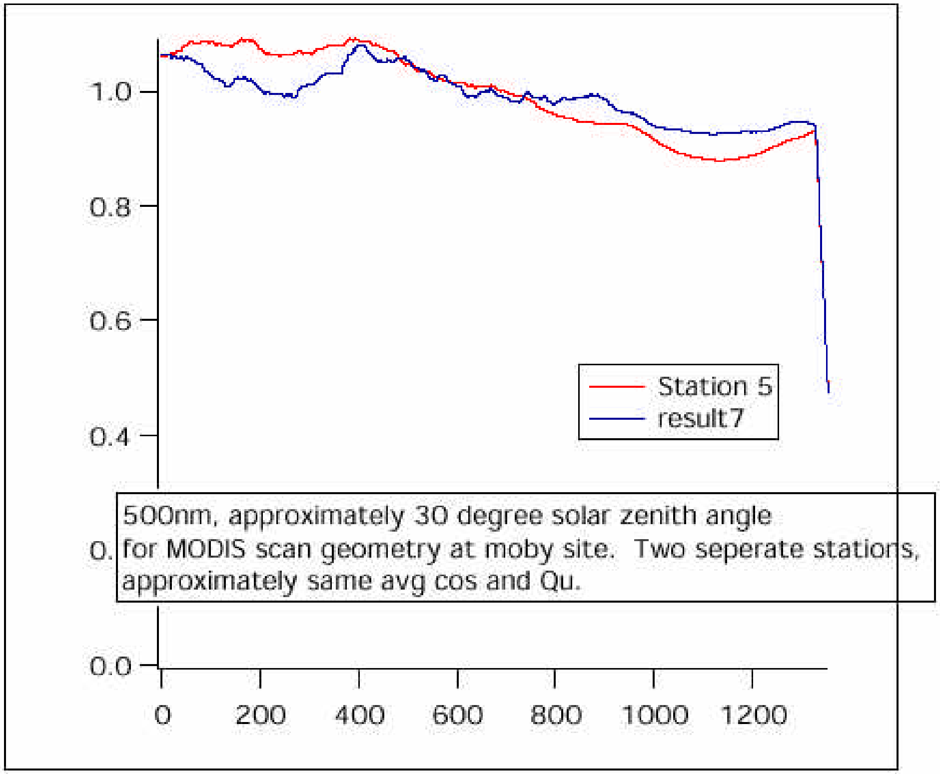
April 11,00 MODIS Chl, Old Pol Corr

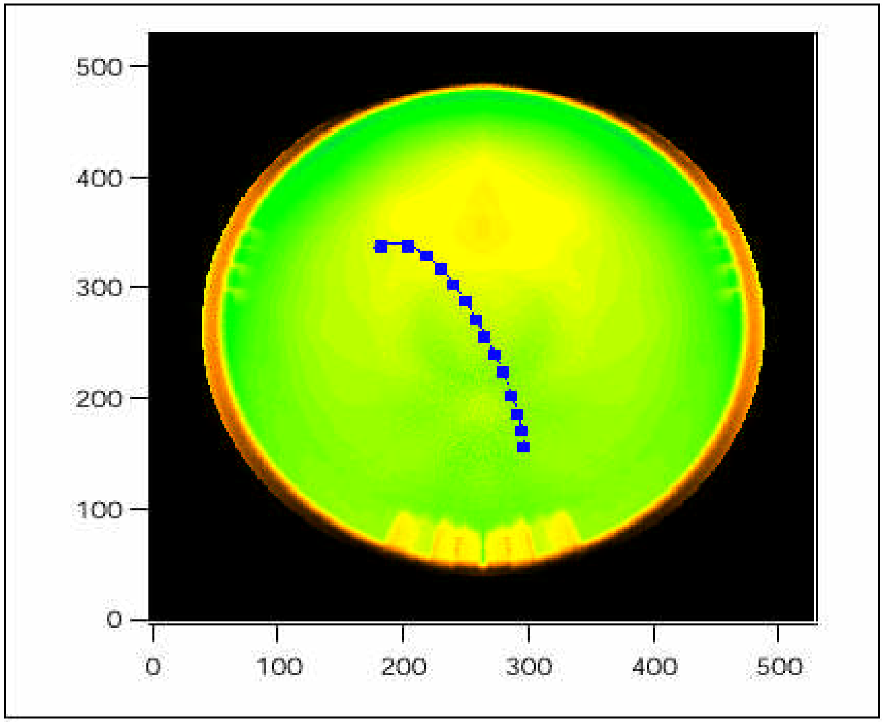


April 11,00 MODIS Chl, New Pol Corr

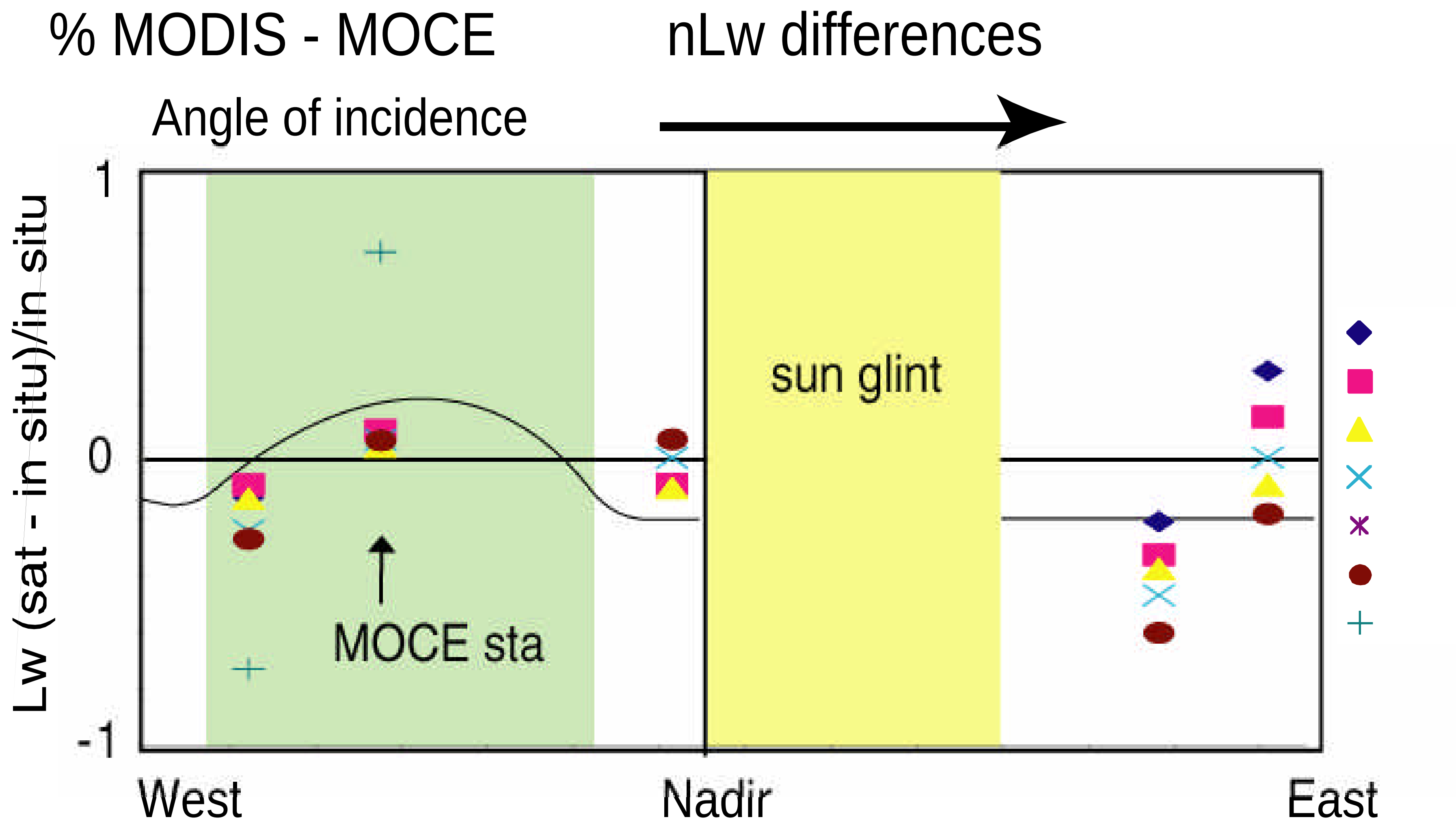


BRDF at MOBY 30º Solar Zenith Angle, 500mm



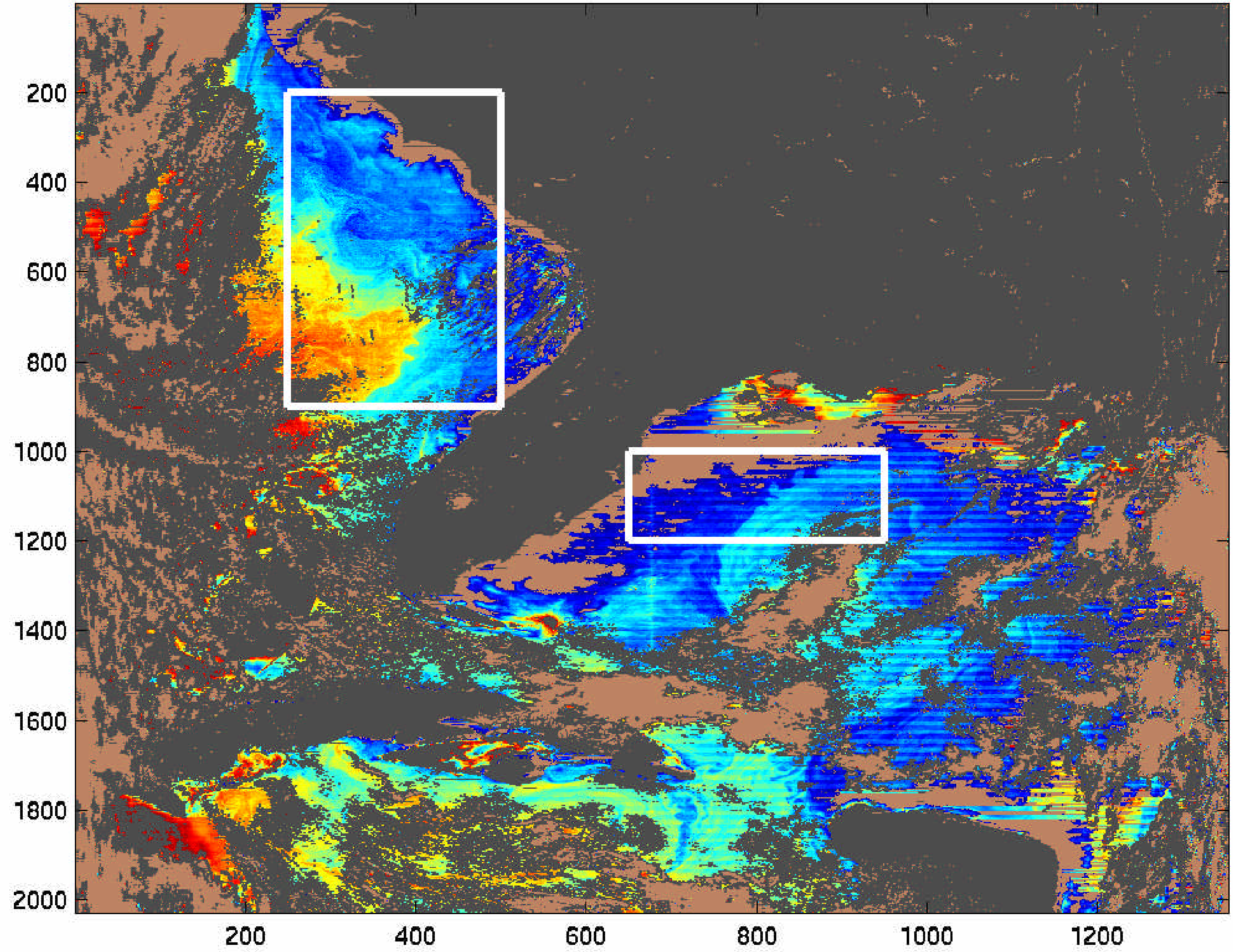


Comparisons to *in situ* data



Southeastern North America nLw 412nm

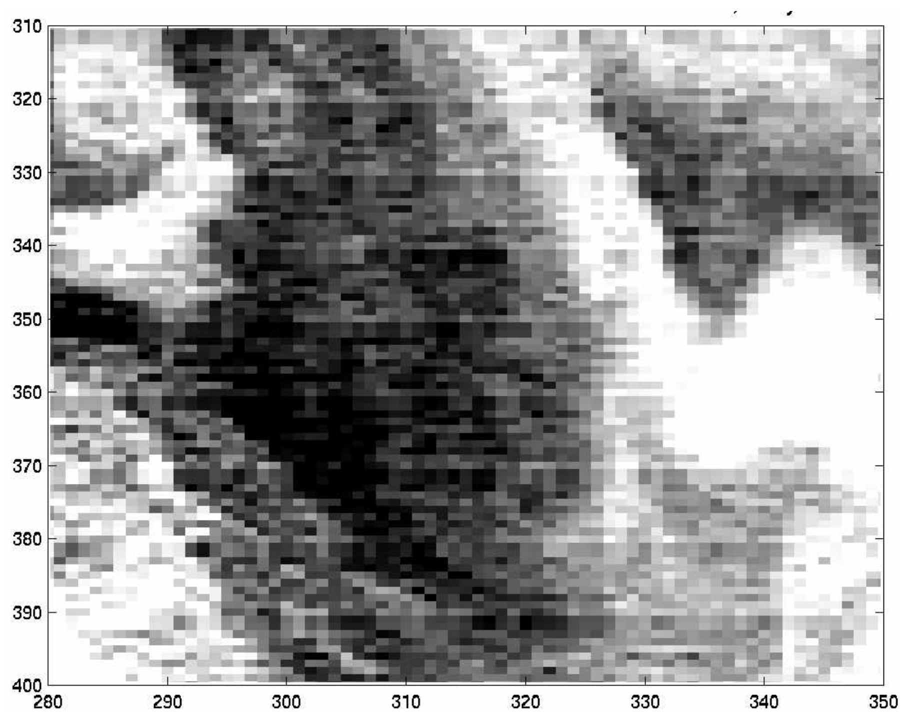
November 1, 2000



Northeastern Gulf of Mexico nLw 412 nm

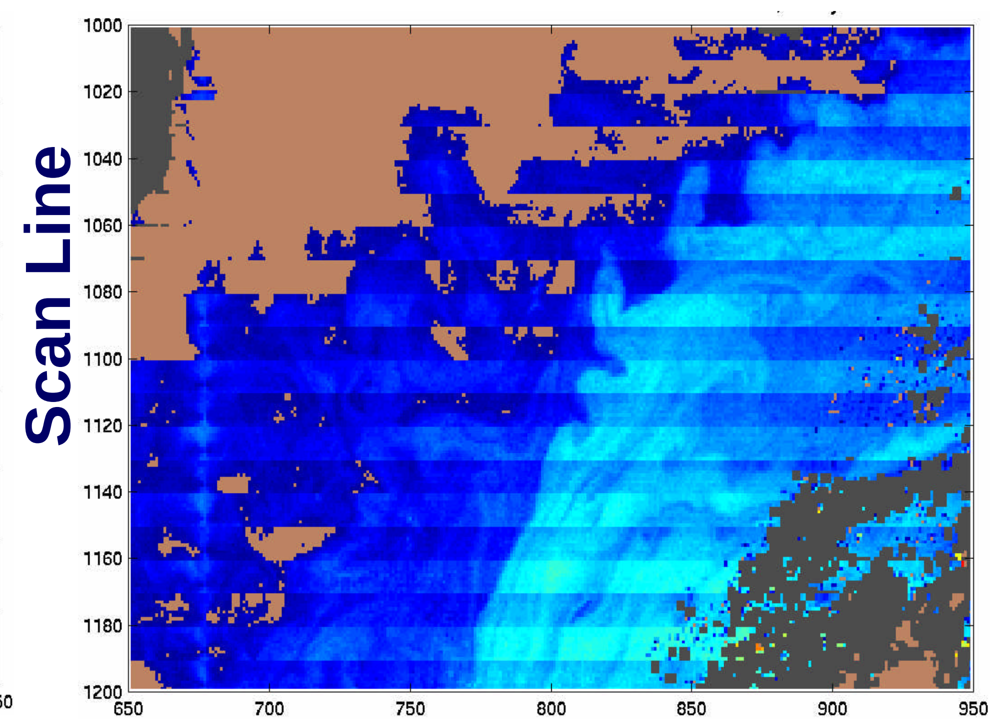
November 1, 2000

Detector Striping



Pixel Number

Mirror Side Banding



Pixel Number

MODIS Correction Schedule

last updated :11/22/00

MODIS Ocean Correction tables identified to date: 11 for IR, 4 for visible

(shaded areas represent a table change)

	day	E-side	Mirror state	LUT l1b	miami visible CT	Itwk/Vdet MWIR (ch 5-7,26,20-25)	miami IR CT
	59	A	A	2.4.3.1 (yrdoy 00059 - 00304)	1vct	Itwek/vdet=110/226	1sstct
	64					Itwek/vdet=110/224	2sstct
	65					Itwek/vdet=110/228	3sstct
	66					Itwek/vdet=110/226	1sstct
	77						
	78						
	83					Itwek/vdet=100/218	4sstct
	84					Itwek/vdet=110/226	1sstct
	171						
formatter	173					Itwek/vdet=79/190	5sstct
	174		B		2vct	Itwek/vdet=110/226	6sstct
Instrument reset	218						
	219		C		3vct		7sstct
	221					Itwek/vdet= 79/190	
	230						
	231						
	232					Itwek/vdet= 110/226	8sstct
	231						
	252					*Itwek/vdet= 79/100, 110/226	
	256					*Itwek/vdet= 79/100, 110/226	
	291					*Itwek/vdet= 79/100, 110/226	
	292					Itwek/vdet= 79/100	9sstct
	294					Itwek/vdet= 110/226	8sstct
	303						
	304	B	D	2.4.4	4vct	Itwek/vdet= 79/190	10sstct
	305					Itwek/vdet= 79/110	11sstct
			?				

*= testing for 2-3hr of day set QA for these few granules use single CT for period

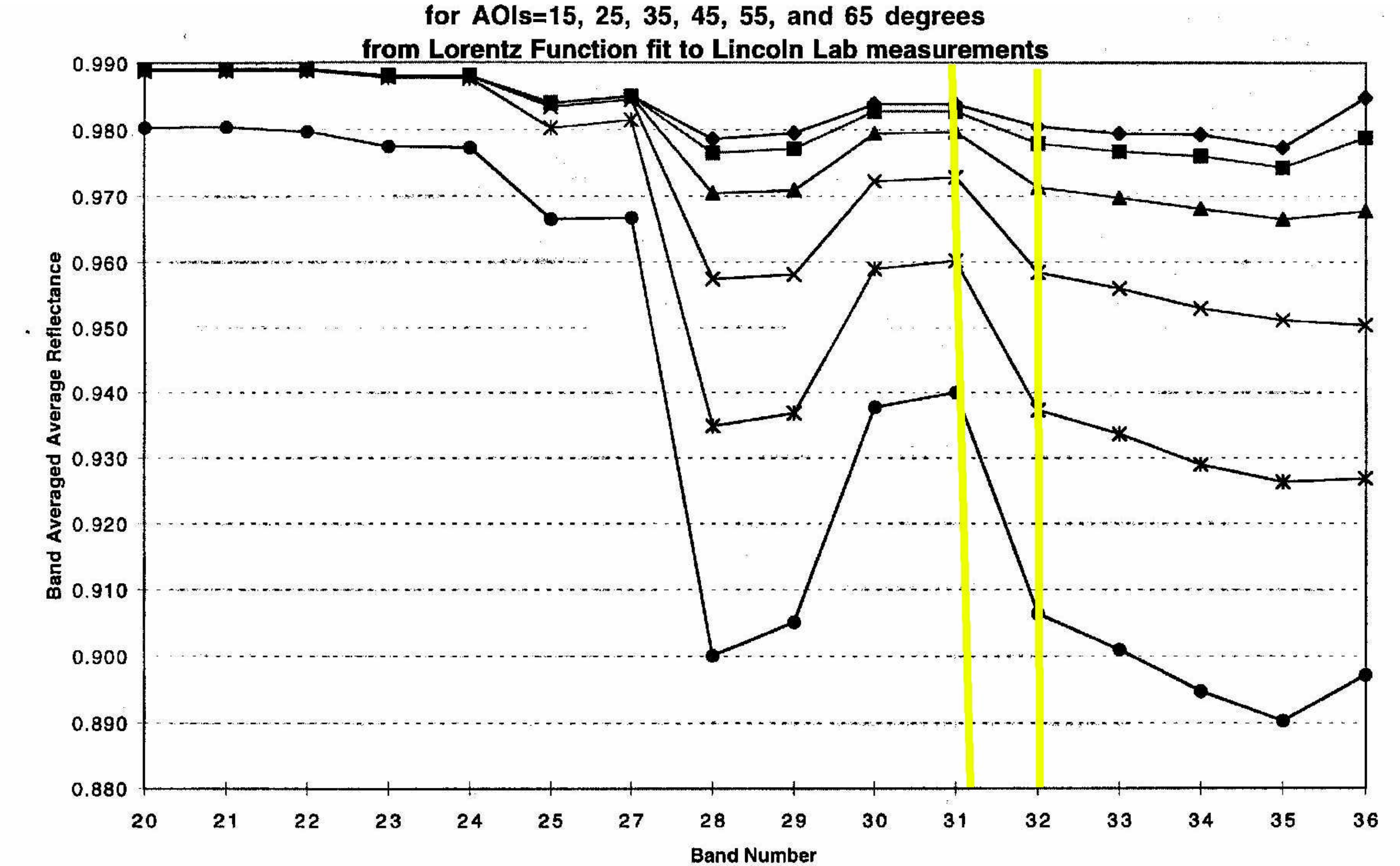
Visible Band Activities

- Time periods: In Situ:MOBY/MOCE
  - Initial “A-side” electronics April 11-16
  - After formatter reset (day 174) August 3-5 (~50%Lw)
  - “B-side” electronics (day 304) December 3-10
- Corrections required for each time period:
  - Detector-to-detector normalization within wavebands (~1% Lt)
  - Variations in the mirror response as a function of angle of incidence (differential RVS) (~1% Lt)
  - Differences in characteristics between mirror sides
  - Test correction for polarization and sun glint. (~30% Lw)
- Spectral ‘Calibration’
  - ***In situ*** (MOBY, MOCE)
  - Satellite (SeaWiFS-MODIS)
- Complete test of present polarization tables (4) to determine best correction

Visible Band Activities-2

- Satellite comparison, resolve mirror side difference between MODIS and SeaWiFS:
  - Produce nLw, chl fields separately for mirror sides 1 and 2
  - Match MODIS chl with SeaWiFS chl
  - Compute differential mirror side corrections (MODIS)
  - Compare with SeaWiFS chl to estimate residual RVS, polarization, … effects
- Repeat comparison to resolve MODIS-SeaWiFS satellite zenith angle behavior differences
- Examine time series of MODIS-MOBY observations to determine temporal stability of nLw retrieval errors.
- Noise in Space View, Test averaging
- Spectral ‘Calibration’, examine errors in nLw
  - ***In situ*** (MOCE,MOBY)
  - Satellite (SeaWiFS-MODIS, future ENVISAT-MERIS)
- BRDF corrections (TBD)

Scan Mirror Band Averaged Average Reflectance vs. Band Number



Mid and Long wave–SST Equations

Midwave Thermal-IR SST equation:

SST4 [C] = a + b * BT + c * dBT + d * dBT * (sec(theta) - 1)

BT20	dBT2320	const	b(BT)	c(dBT)	d(sec)
		2.21785	1.04977	0.453908 -0.622208	0.391 0.389

Longwave Thermal-IR SST equation:

SST = c1 + c2 * B31 + c3 * B3132 * refsst + c4 * secterm

Coefficients c1, c2, c3 and c4
are respectively 1.11071, 0.9586865, 0.1741229 and 1.876752
if B3132 <=0.7 and
are respectively 1.196099, 0.9888366, 0.1300626 and 1.627125
if B3132 > 0.7.

where B20 = Band 20 brightness temperature (Bt)
B2320 = Band 23 - Band 20 Bt difference
B31 = Band 31 Bt
B3132 = Band 31 - Band 32 Bt difference
refsst = Reynolds SST reference field
secterm = (sec(theta) -1) * B3132
(Band 22 has failed and noisy detectors)

MODIS-$_M$(Midwave), MODIS-$_T$ (Thermal) Pathfinder (Thermal) SST Comparisons

Warm Pixel Composite, Days Aug 30 – Sept. 6, 2000

MOD_T–PF (Night)

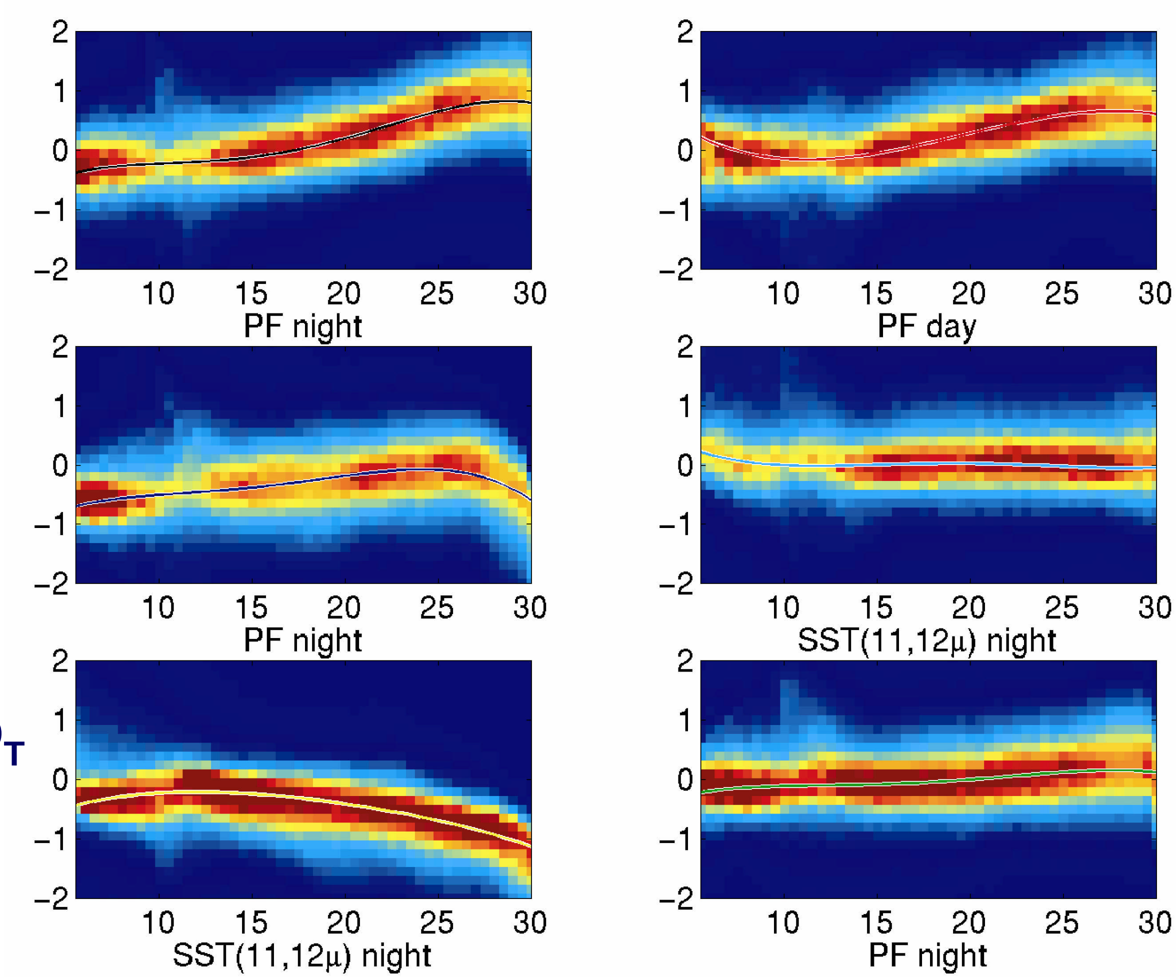
MOD_T-PF (Day)

MOD_M-PF (Night)

MOD_T (Day) – MOD_T-(Night)

MOD_M–MOD_T (Night)

PF (Day) – PF (Night)



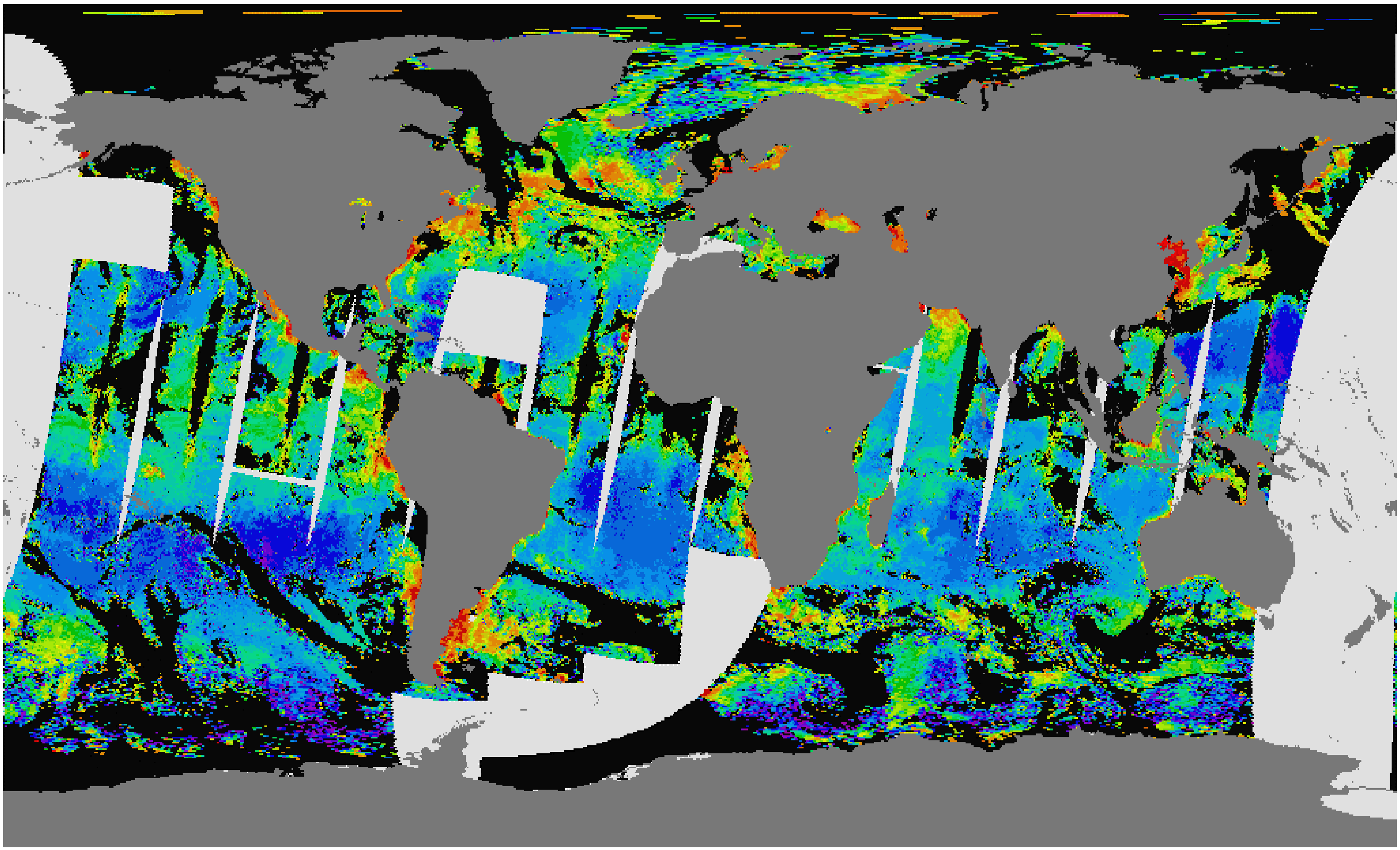
IR Band Activities

- Satellite comparison, resolve Longwave temp difference between MODIS and AVHRR: (order 1K) [absolute calibration of BT may be in error]
  - Produce brightness temp fields separately for mirror side 1 and 2
  - Match MODIS BT with AVHRR-Pathfinder SST
  - Compute retrieval equation coefficients MODIS-Pathfinder
  - Compare with RT derived coefficients
- Repeat comparison for Midwave to resolve MODIS-Pathfinder satellite zenith angle behavior differences (order 2K)
- Examine time series of MODIS-MAERI observations to determine temporal stability of SST retrieval errors. (unknown)
  - MAERI (Explorer) time series

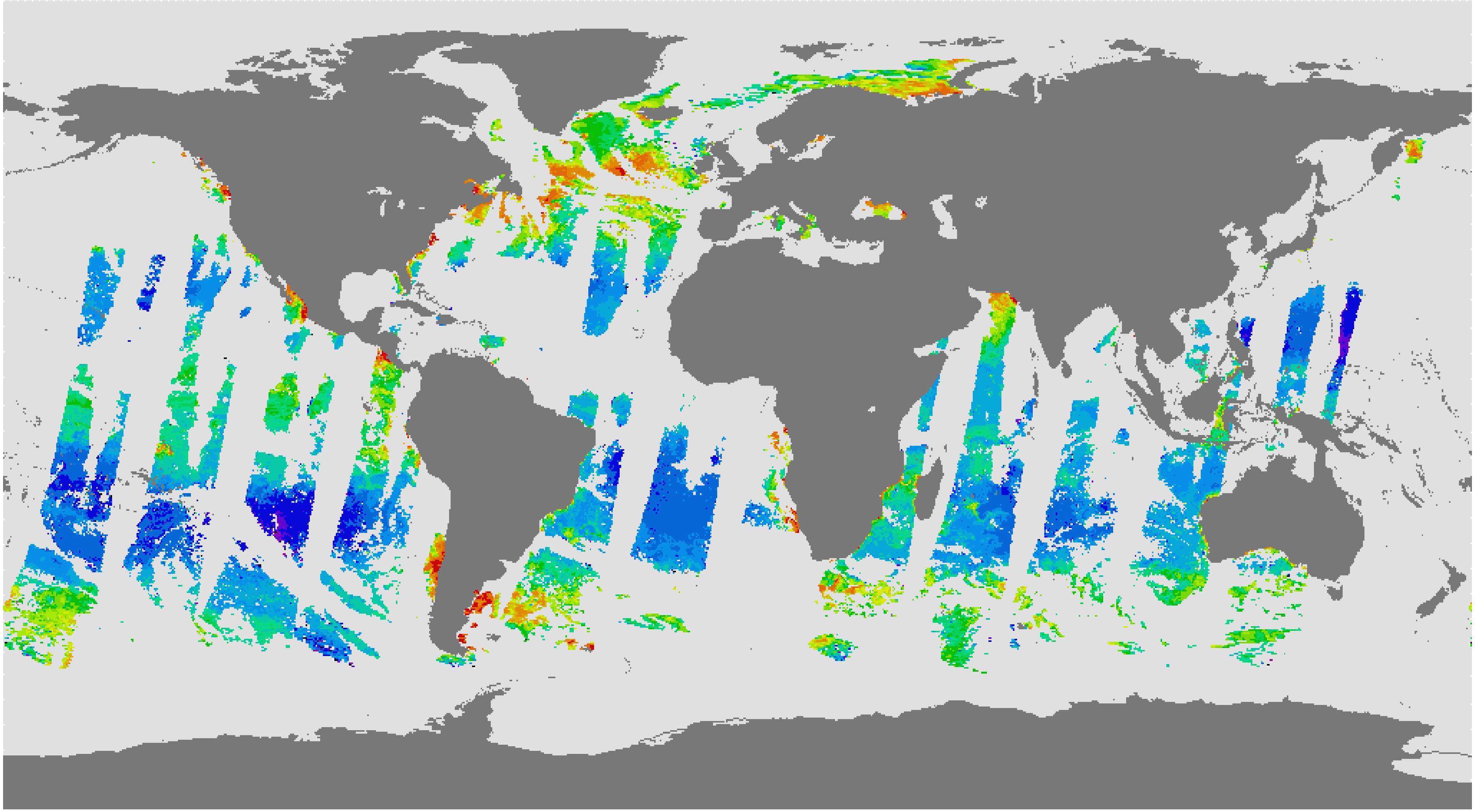
IR Band Activities -2

- Satellite comparison, resolve Longwave temp difference between MODIS and AVHRR:
  - Produce brightness temp fields separately for mirror side 1 and 2
  - Match MODIS Bt with AVHRR-Pathfinder SST
  - Compute retrieval equation coefficients MODIS-Pathfinder
  - Compare with RT derived coefficients
- Repeat comparison for Midwave to resolve MODIS-Pathfinder satellite zenith angle behavior differences
- Examine time series of MODIS-MAERI observations to determine temporal stability of SST retrieval errors.
- Noise in Space View, Black Body -> Counts to Radiance -- Need to test averaging

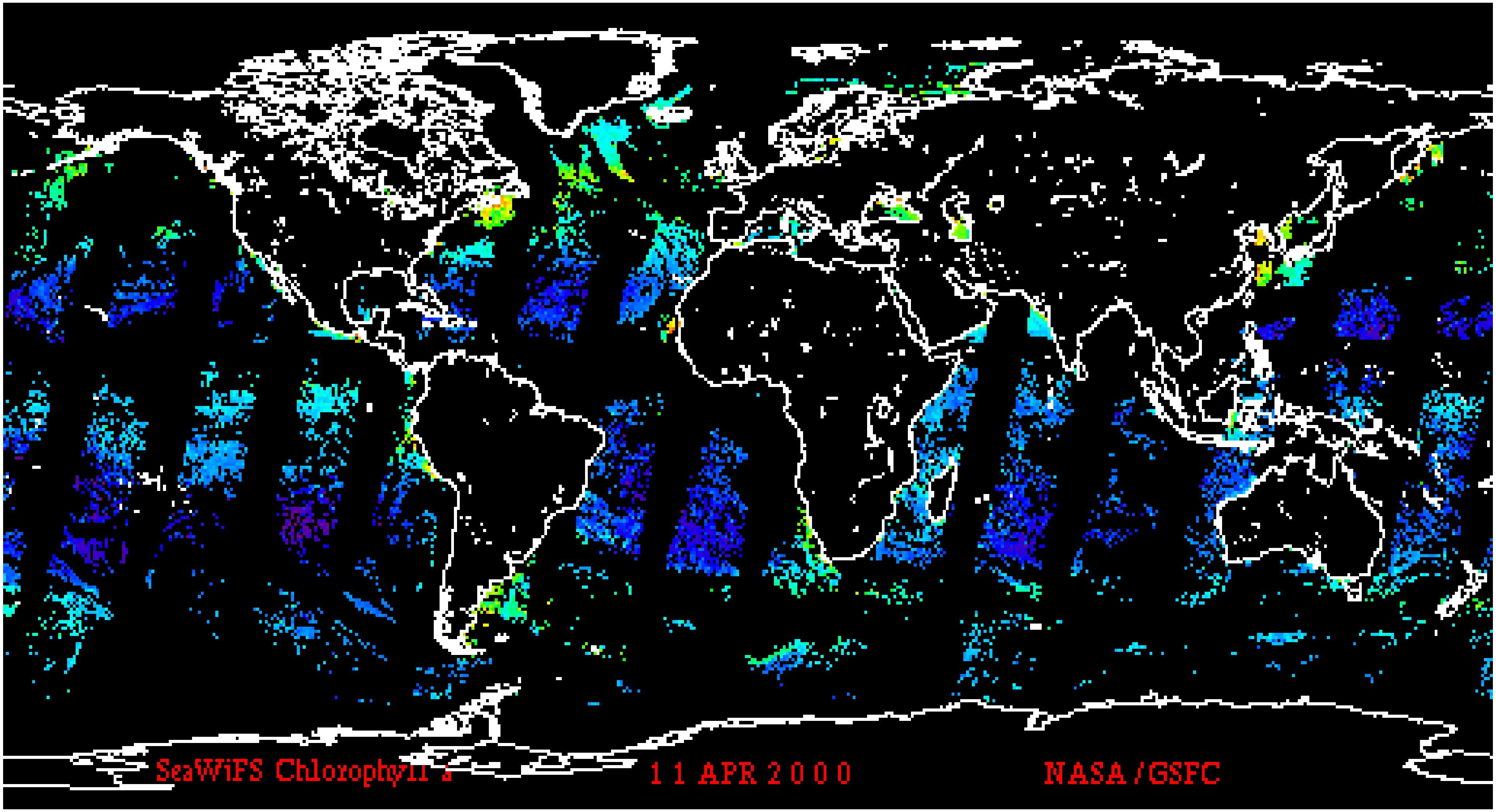
Modis Chl-Clark, 4/11/00, All pixels



Modis Chl-Clark, 4/11/00, Best pixels

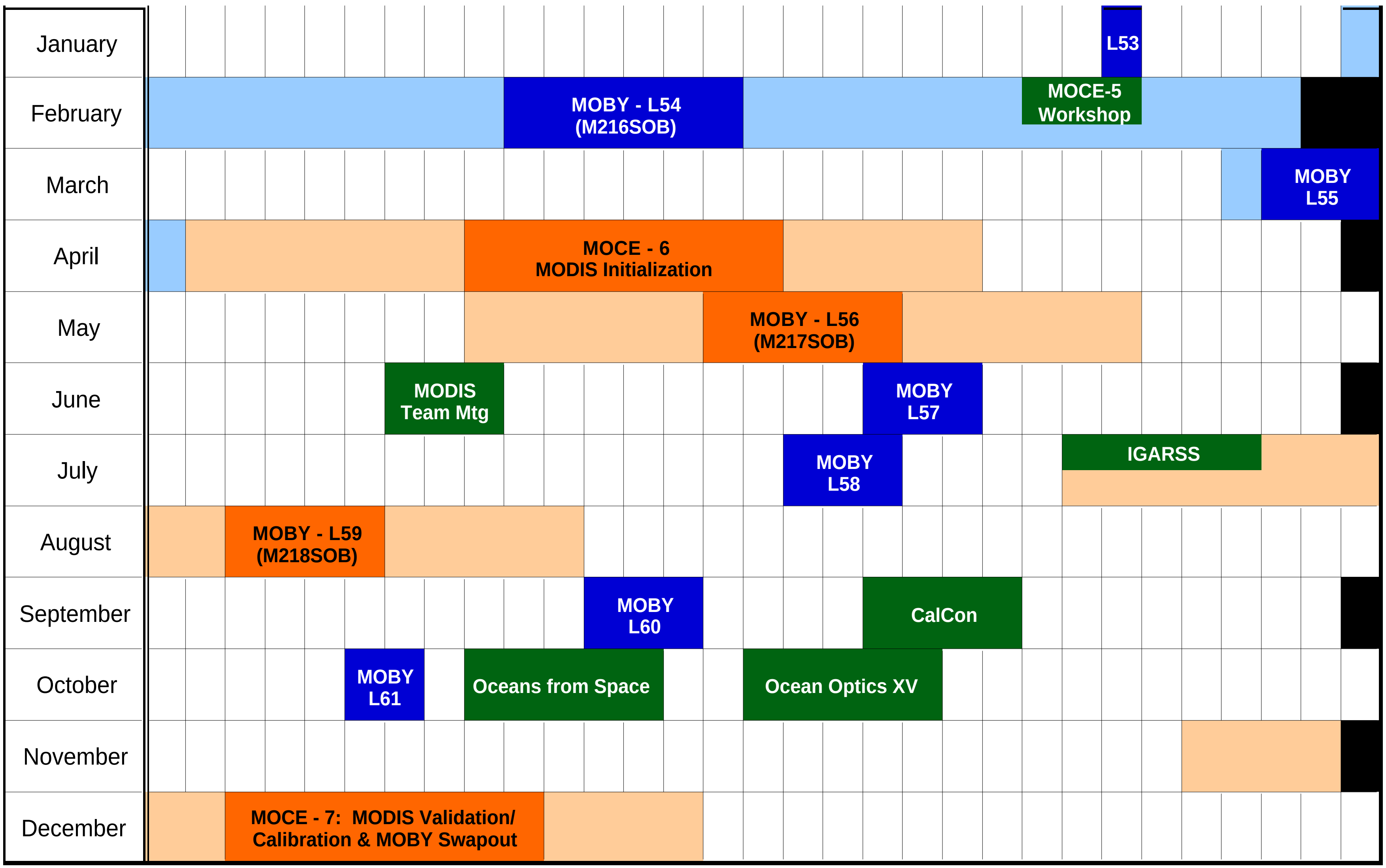


SeaWiFS Chl, 4/11/00, Best pixels



Month	YR	Cruise	ap,ad	chl	HPLC	ag	rrs	Drop	Ed	Flo Pak	Location	Ship
2	98	TB	X	X		X	X				Tampa Bay	Subchaser
4	98	TB	X	X		X	X				Tampa Bay	Gilbert
4	98	TOTO 1	X	X		X	X				TOTO/WFS	Bellows
5	98	CoBOP	X	X		X	X				Bahamas/WSF	Suncoaster
6	98	EcoHAB	X	X		X	X				EcoHAB hourglass	Suncoaster
10	98	TB98	X	X		X	X				West Fla. Shelf	Edward Link
10	98	TB98	X	X		X	X	X			Tampa Bay	Subchaser
11	98	TB	X	X		X	X				Tampa Bay	Subchaser
3	99	EcoHAB	X	X	X	X	X				EcoHAB hourglass	Suncoaster
4	99	TOTO 2	X	X		X	X				TOTO/WFS	Bellows
5	99	CoBOP	X	X		X	X			X	Bahamas/WSF	Suncoaster
7	99	EcoHAB	X	X	X	X	X				EcoHAB hourglass	Suncoaster
9	99	EcoHAB	X	X		X	X				EcoHAB hourglass	Suncoaster
11	99	EcoHAB	X	X	X	X	X	X	X		EcoHAB hourglass	Suncoaster
1	00	EcoHAB	X	X		X	X				EcoHAB hourglass	Suncoaster
3	00	EcoHAB	X	X	X	X	X	X	X		EcoHAB hourglass	Suncoaster
3	00	EcoHAB	X	X		X	X				EcoHAB hourglass	Bellows
4	00	TOTO 3	X	X		X	X	X	X	X	TOTO/WFS	Bellows
5-6	00	CoBOP	X	X		X	X			X	Bahamas/WSF	Suncoaster
5-6	00	CoBOP					X				Bahamas/WSF	Subchaser
7	00	FSLE3	X	X		X	X	X	X		West Fla. Shelf	Pelican
7	00	FSLE3					X				West Fla. Shelf	Bellows
7	00	FSLE3	X	X		X	X				Tampa Bay	Subchaser
8	00	EcoHAB	X	X	X	X	X			X	EcoHAB hourglass	Suncoaster
9	00	EcoHAB	X	X		X	X			X	EcoHAB hourglass	Suncoaster
10	00	EcoHAB	X	X	X	X	X			X	EcoHAB hourglass	Suncoaster
11	00	FSLE4	X	X		X	X	X	X		Sarasota offshore	Pelican
11	00	FSLE4					X				Sarasota offshore	Bellows
11	00	FSLE4					X			X	Sarasota offshore	Subchaser
11	00	EcoHAB	X	X	X	X	X			X	EcoHAB hourglass	Suncoaster

MOBY/MOCE SCHEDULE - 2000



Modis Oceans QA and product improvement Activities

Activity Name	***Start Date***	***Finish Date***	***FEB***					***MARCH***				***APRIL***					***May***				***JUNE***			
			1	***8***	***15***	***22***	***28***	***3***	***11***	***18***	***25***	***1***	***8***	***15***	***22***	***29***	***6***	***13***	***20***	***27***	***3***	***10***	***17***	***24***
Quantify quality status and error budget of MODAPS products by Science Team members																								
A-side existing Beta products (#A1)	-	2/28/01																						
Beta Quality status summary report due (A-side)		3/1/01																						
B-side beta testing (#B1)	2/28/01	3/11/01																						
A-side beta testing april, (#A2)	3/11/01	3/18/01																						
B-side provisional testing (#B1)	4/15/01	5/1/01																						
Provisional Quality status summary report due																								
B-side Science testing #B2	6/1/01	-																						
B-side Science final #B2	8/1/01	9/1/01																						
A-side provisional (#A2) reprocess	TBD	TBD																						
Calibration activties performed at Miami																								
B-side preliminary #B1 (december MOCE cal/valcruise)		2/28/01																						
A-side revisited april #A2	2/22/01	3/11/01																						
B-side continuing #B2… (next cal/val MOCE cruise scheduled early march)	4/1/01	-																						
Aside other #A3-?	TBD	TBD																						
Review error budgets and integrate suggested algorithm changes at Miami SCF																								
provisional code integration B-side	3/11/01	4/15/01																						
science code integration #1	6/1/01	7/1/01																						
Miami production of test productsfor evaluation by Science team																								
b-side #B1 test data	2/28/01	3/3/01																						
A-side #A2 test data	3/3/01	3/11/01																						
B-side provisional products with #B1	4/8/01	4/22/01																						
ongoing science test/evaluation	5/6/01	-																						
A-side re-calibarted test data other	TBD	TBD																						
Miami deliveries improved code to MODAPS																								
beta update cal LUT swapping		2/29/200																						
Provisional code		4/29/01																						
scientific code		9/1/01																						
Integration and testing of new code deliveries or Ocean LUT's at MODAPS																								
beta update cal LUT swapping	2/29/200	3/30/01																						
provisional code	5/1/01	6/1/01																						
scientific code	9/1/01	10/1/01																						
new versions in operations																								
beta code update LUT swapping	4/8/01	5/31/01																						
provisional code	6/1/01	11/30/01																						
scientific code	12/1/01																							

Outstanding issues

- **Examine behavior of Data Quality Flags as product error becomes better understood**
- **Extend MOBY, MOCE, MAERI - MODIS comparisons to better quality errors in retrieved radiance**
- **Continue to test time dependent correction tables against MODIS-*in situ* time series, update tables as required**
- **Future algorithm improvements (*e.g.* BRDF, atmospheric correction…) likely will require reexamination of (spectral) sensor correction tables.**
- **Test methods to determine correction coefficients, QA, … across instrument events as preparation for Aqua**
- **Absolute Calibration of spectral radiances**
- **Develop correction model for time dependence of (mirror side, RVS, detector) corrections**
- **Averaging of Space View, Black Body to reduce noise, Detector-detector, mirror side corrections not stable granule to granule**