

**Ongoing calibration and extension of SST 4
and 11 μm waveband algorithms for AQUA
and TERRA MODIS using the in situ buoy,
radiometer matchup database**

**Robert Evans
Guillermo Podesta'
RSMAS**

May 17-20, 2011

**with special thanks to R. Reynolds for
the provision of AVHRR OI reference fields
and**

**Chelle Gentemann
for provision of AMSR fields**

Proposal Activities - Maintenance Component

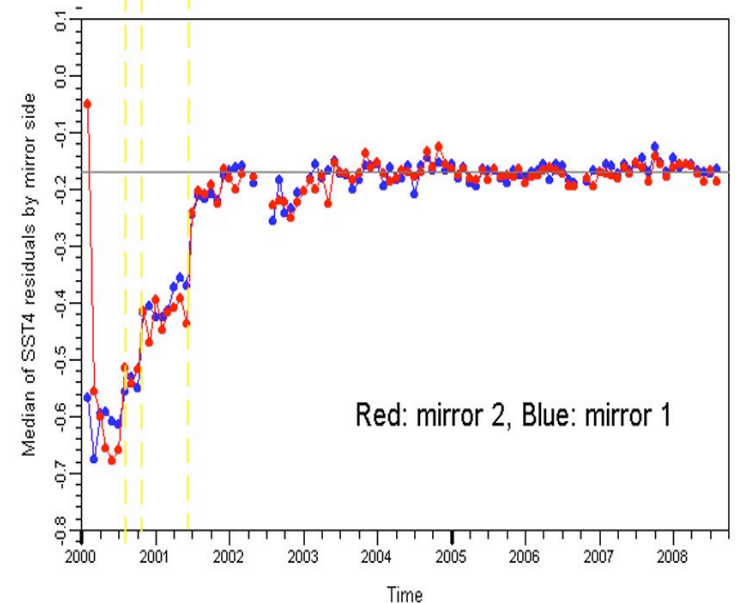
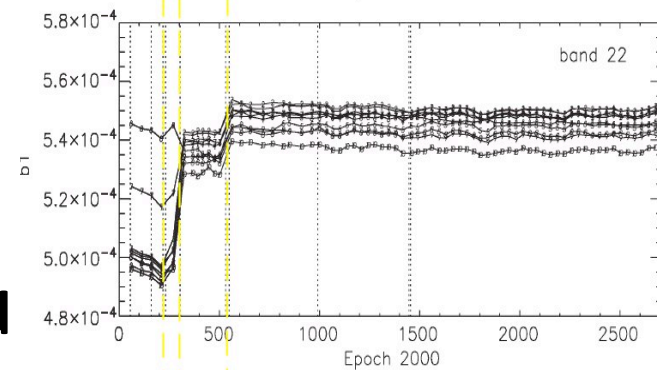
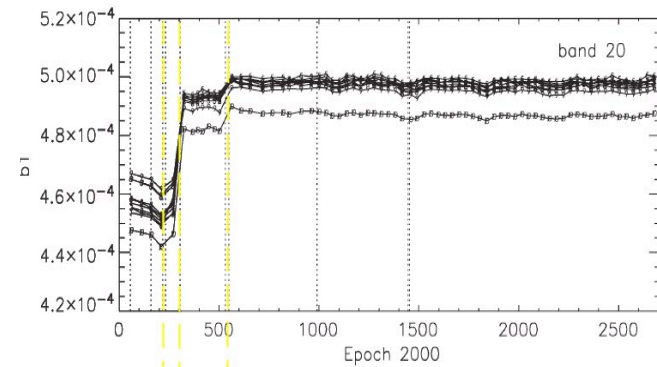
- Update MODIS SST algorithm coefficients and uncertainty estimates (Hypercube) based on new MCST calibration “collection 6.”**
- Monitor and validate SST retrievals for MODIS AQUA and TERRA with respect to in situ observations to enable calculation of a seamless climate-quality data record.**
- Maintain and update the MODIS SST Matchup Database.**
- New Hypercube and algorithm coefficient tables based on the MCST Collection 6 MODIS calibration have been computed and are being tested. Delivery to OBPG will follow.**

Development of Version 6, Collection 6 SST algorithm

Correction to SST4 bias resulting from TERRA configuration changes

Upper and middle panels: MODIS-Terra
calibration changes for channels 20 and
22.

Lower panel: Median of SST4 residuals
estimated using 4μ channels. In all
panels the x-axis indicates time. It is
clear that calibration issues during 2000
and 2001 had considerable impact on
SST retrievals based on $4\mu\text{m}$ bands.



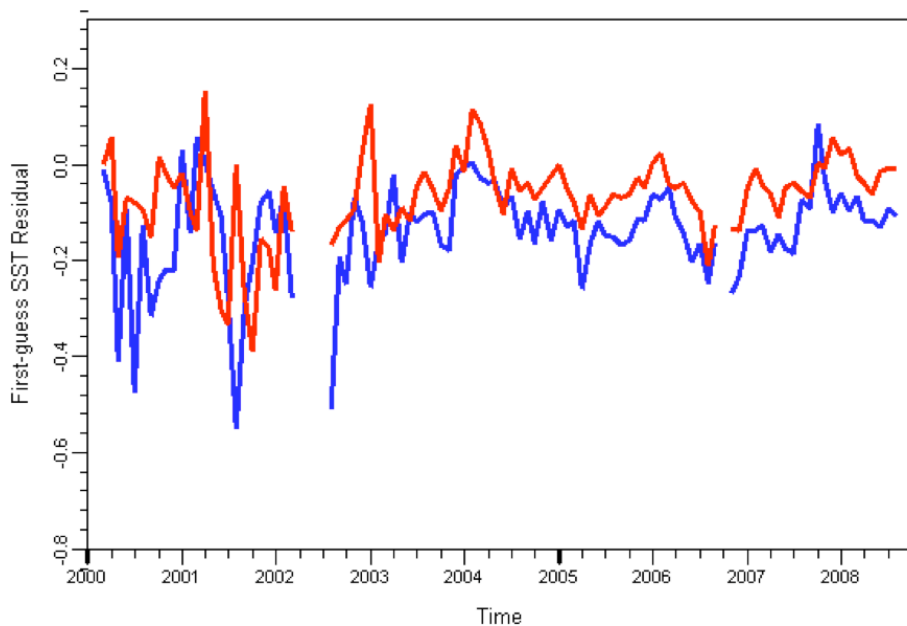
MODIS TERRA Mirror side and Scan Angle corrections to SST

(analogous corrections computed for AQUA)

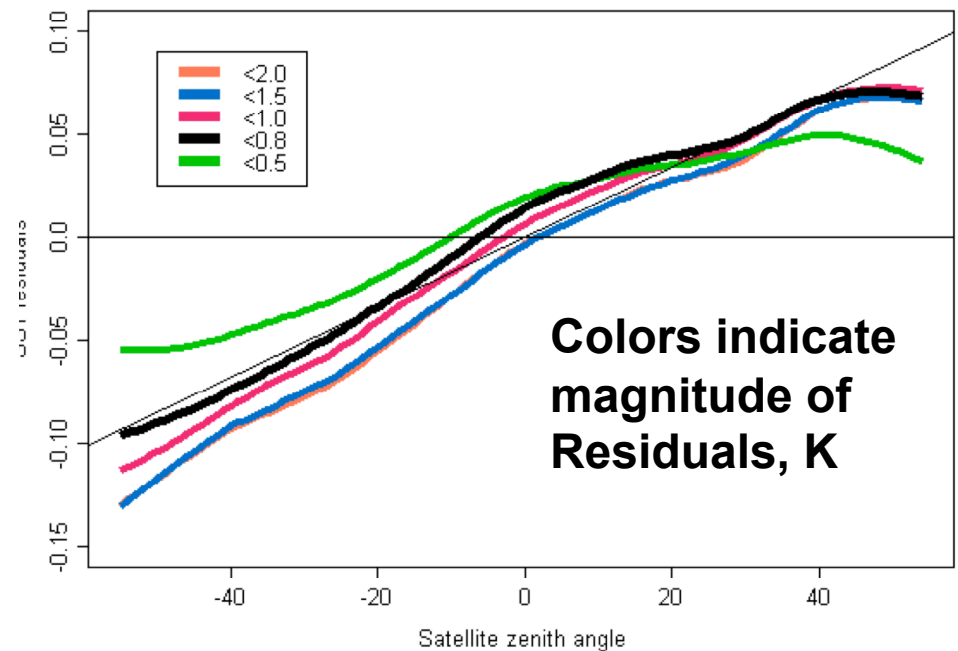
Terra mirror side
offset order 0.1K

Terra cross-scan
correction order
0.15K

TERRA - Residuals by mirror (blue:1; red:2)



MODIS AQUA Coll 6 - Effects of SZA



Description of LATBAND formulation and Matchup criteria

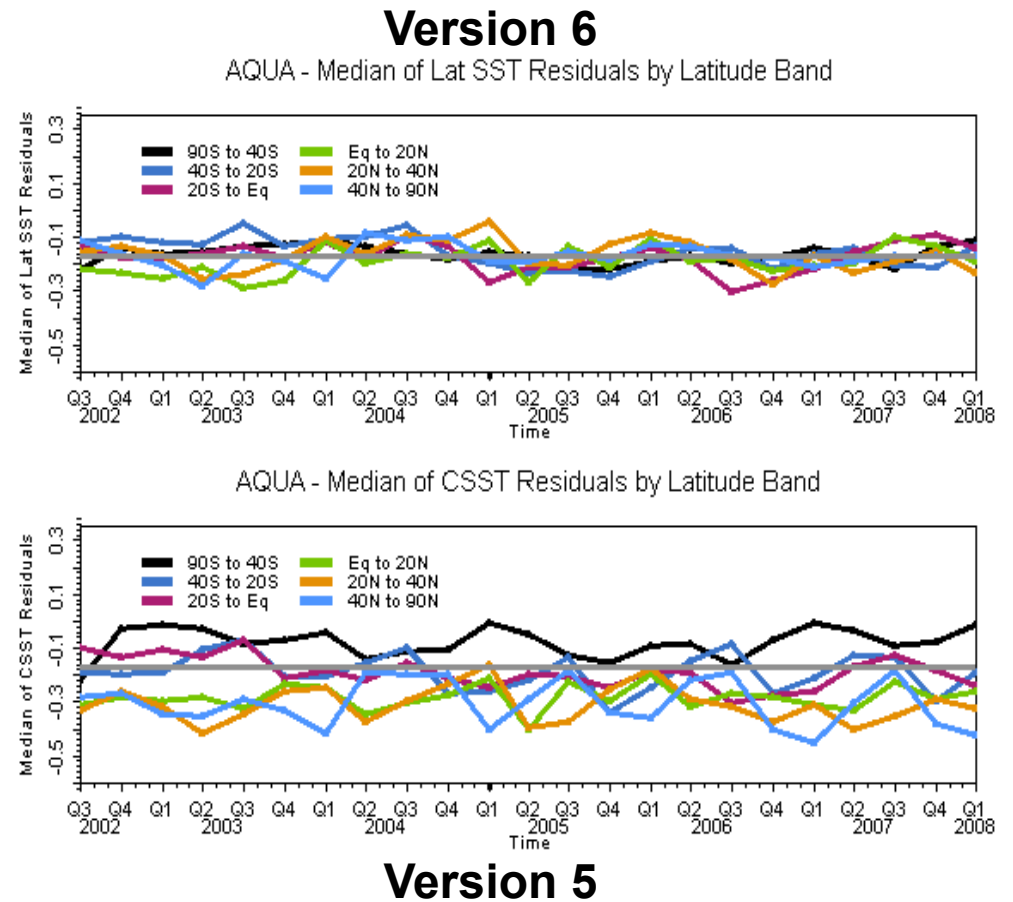
- MODIS Version 6 (+Collection 6 calibration) based on LATBAND formulation – 6 zonal bands 20 degrees wide centered on the Equator
- 2.5 degree wide transition band, linearly interpolated
- Coefficients estimated monthly, *e.g.* all January *sat-in situ* observations grouped, for each month of all years for a given sensor
- Matchup criteria – within 2km and ± 30 minutes for buoy-satellite observation
- Skin temperature product
- SST retrievals validated against radiometer matchups (M-AERI)

LATBAND Layout	
40-90°N	LATBAND Latitude increments
20-40°N	
0-20°N	
20-0°S	
40-20°S	
90-40°S	

Comparison of Version 5 & 6, AQUA (after correction for mirror side, scan angle)

Time series of mean SST residuals for MODIS-Aqua. SSTs were calculated using algorithm coefficients estimated separately for six fixed latitudinal bands and for each month of the year. This approach is referred to as the “LATBAND” approach.

Lower panel: mean SST residuals for MODIS-Aqua calculated using the current (Version 5) formulation of the MODIS SST algorithm. It is clear that the latitude-specific coefficients contribute to lower and more stable values of retrieval bias.



MODIS Pixel Level Error Characterization

Definition of Hypercube Bins

Variable	Intervals	Number of Levels
Day or night	2	(1) Daytime; (2) Nighttime (solar zenith angle > 90 degrees)
Quarter	4	(1) Jan-Mar; (2) Apr-Jun; (3) Jul-Sep; (4) Oct-Dec
Latitude Band	6	(1) 90S to 40S; (2) 40S to 20S; (3) 20S to Eq; (4) Eq to 20N; (5) 20N to 40N; (6) 40N to 90N
In Situ SST	7	(1) -2 to 3C; (2) 3 to 8C; (3) 8 to 13C; (4) 13 to 18C; (5) 18 to 23C; (6) 23 to 28C; (7) >28C
Satellite zenith angle	4	(1) 0 to 30 deg; (2) 30 to 40 deg; (3) 40 to 50 deg; (4) 50+ deg
For SST:		
BT31-BT32	4	(1) 0<C; (2) 0.0 to 0.7C; (3) 0.7 to 2.0C; (4) >2C
For SST4:		
BT22-BT21	4	(1) 0.0 to 2.0C; (2) 2.0 to 3.0C; (3) 3.0 to 4.0C; (4) >4.0C

Proposal Activities -Research Component

- **Correct regional SST biases through dynamic selection of algorithm coefficients based on atmospheric regime (e.g., low, medium or high water vapor concentration).**
- **Enhancement of SST retrievals by improving detection of high-quality SST retrievals.**
- **Enhancement of SST retrievals through appropriate use of augmented (3-band) algorithms.**
- **Enhance uncertainty characterization of SST retrievals through development of continuous surfaces for Single Sensor Error Statistics (Hypercube).**
- **Provide smooth transition of science findings into OBPG processing.**

SST Reference File – Selection

Difference field for computation of global anomalies

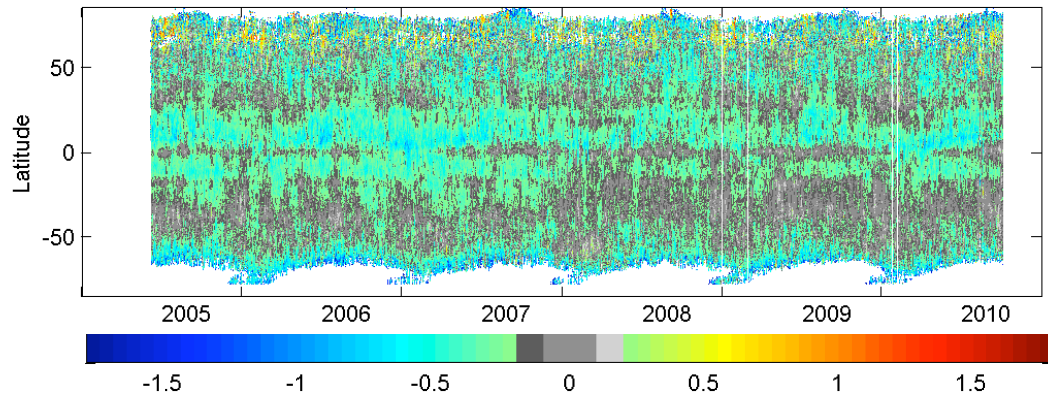
- Richard Reynolds provided 3 versions of the $\frac{1}{4}$ degree, daily V2 OI
 - OI + AVHRR (from NAVO, day + night satellite data)
 - OI + AVHRR + AMSR (day + night satellite data)
 - OI + AVHRR + AMSR (night only satellite data, minimize possible impact of residual diurnal warming)
- 3 Day AMSR composite (day + night), daily, $\frac{1}{4}$ degree field (Chelle Gentemann, RSS)
- **3 Day AMSR composite (separate day and night fields)**
- AATSR (night only), based on 0.1 degree night only, 3 channel, dual view product (processing version: May, 2010)
 - R . Reynolds processed AATSR daily fields into monthly, $\frac{1}{4}$ degree maps to fill gaps due to combination of narrow swath and cloudy observing conditions

6 Year Night Pathfinder V6-Reference Comparisons

3day AMSR (day+night)

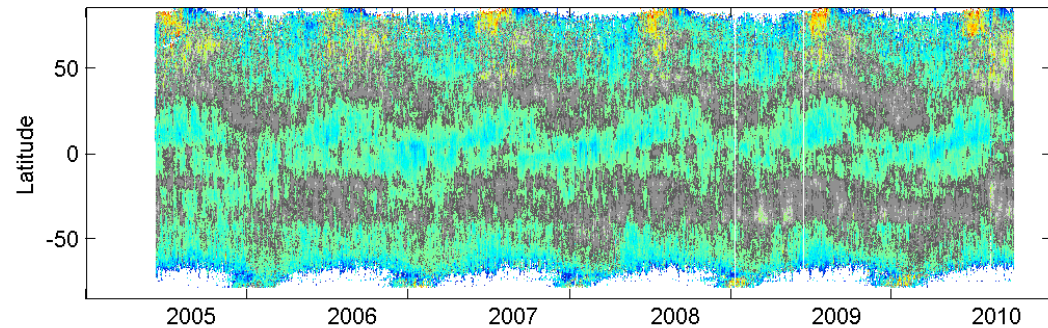
Little difference at high lat,
minimal zonal and temporal
oscillation

Middle grey band $\pm 0.1K$



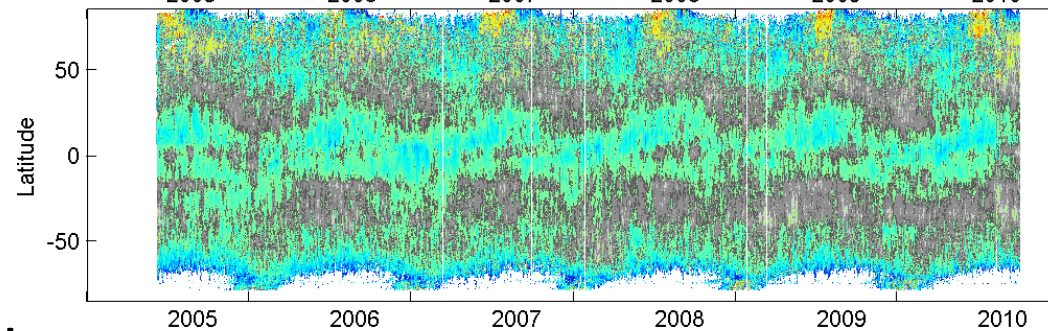
OISST: NAVO AVHRR

High north lat summer,
mid lat zonal oscillation (N)



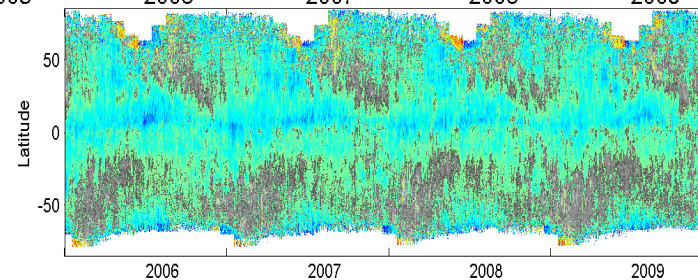
OISST: NAVO AVHRR+ AMSR

Similar comparison for all
OI versions



AATSR : Monthly Average

Night – Dual view, 3 channel
High lat not available in summer
Pronounced seasonal zonal oscillation (N+S)
N equatorial aerosol more pronounced

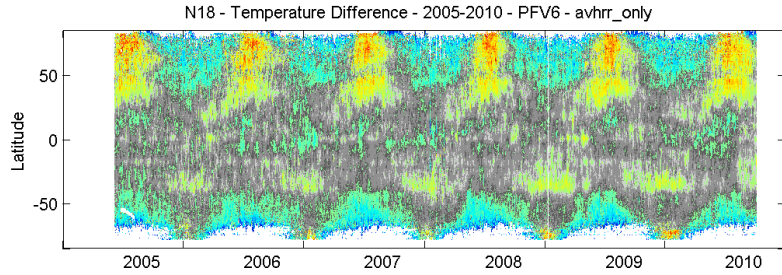


Day

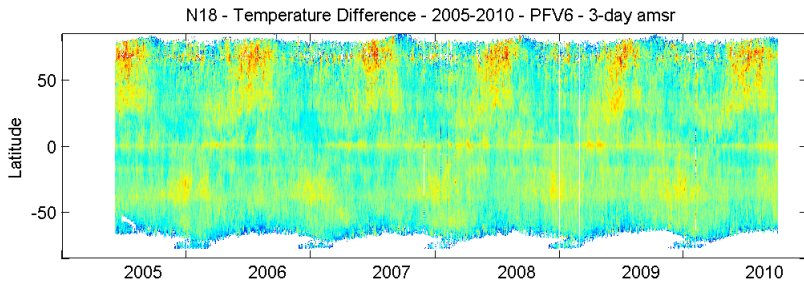
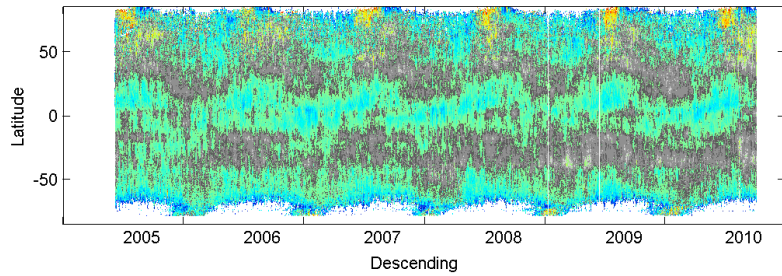
Impact of diurnal warming on comparison to reference fields

Anomaly fields show significant difference when a single reference field is used for both day and night satellite fields

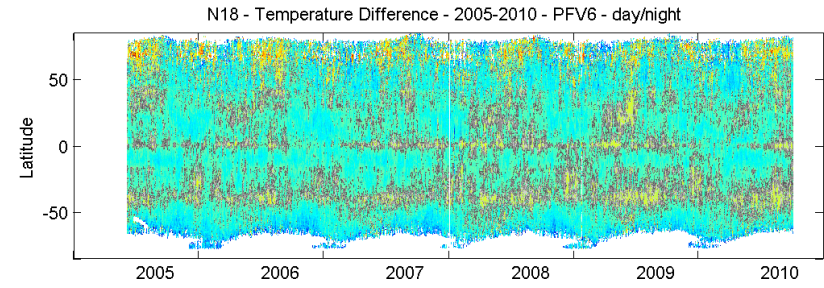
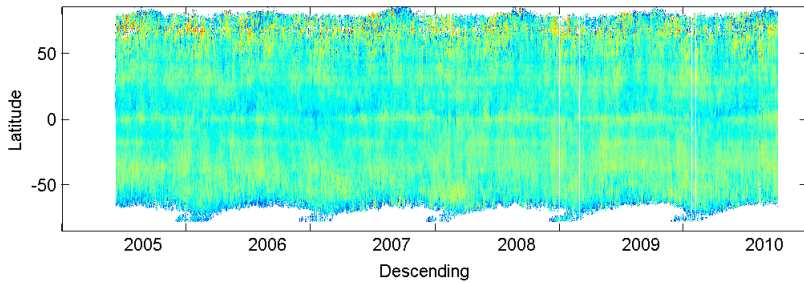
Anomaly fields are very similar when reference field is temporally matched to satellite observation time



Path V6- Reynolds OI (single field for 24 hours)



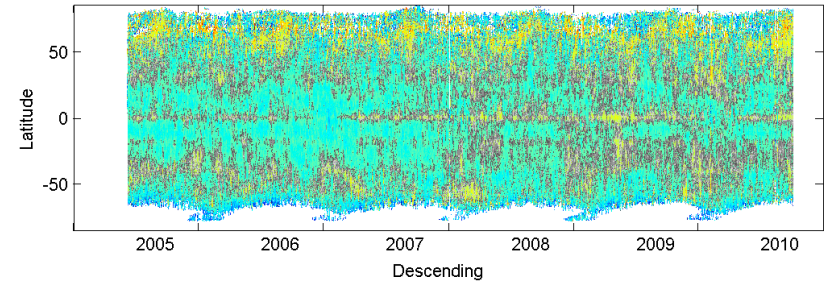
Path V6 - 3day AMSR Ascending (single field for 24 hours)



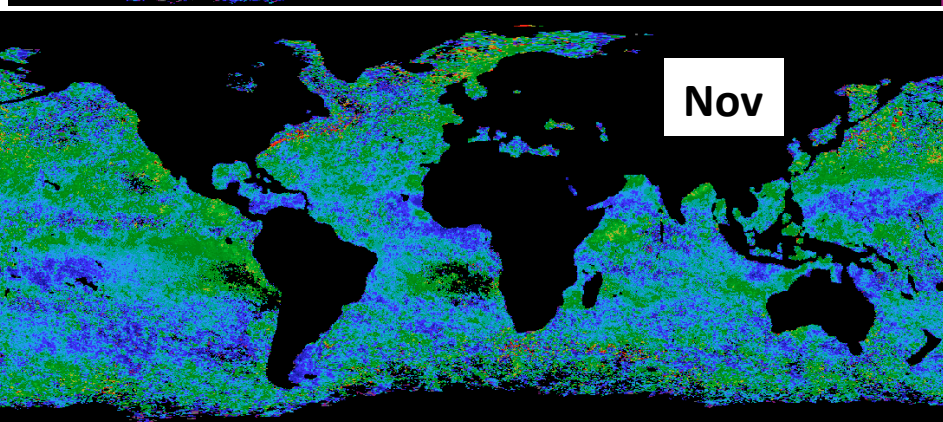
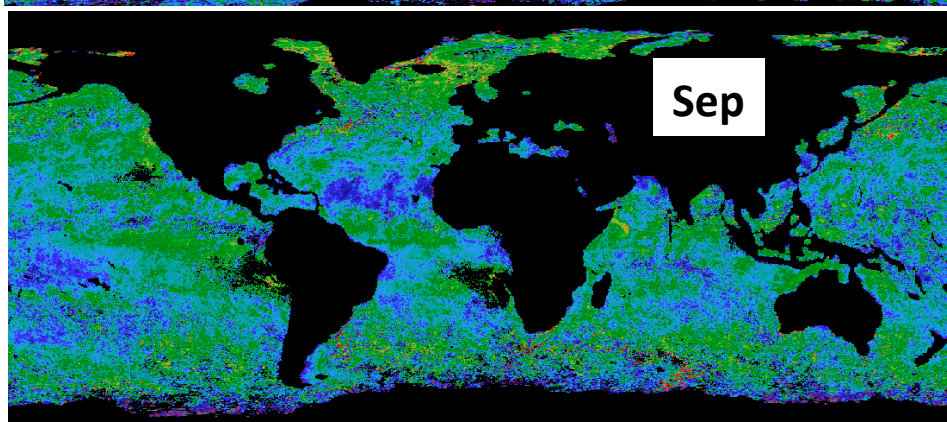
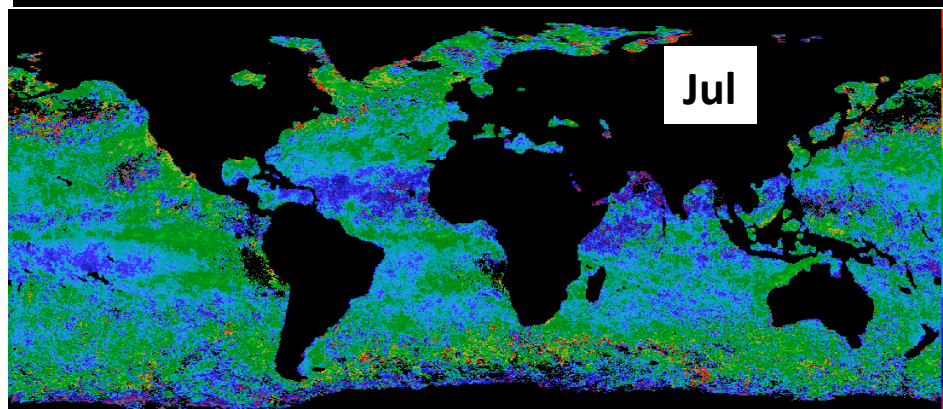
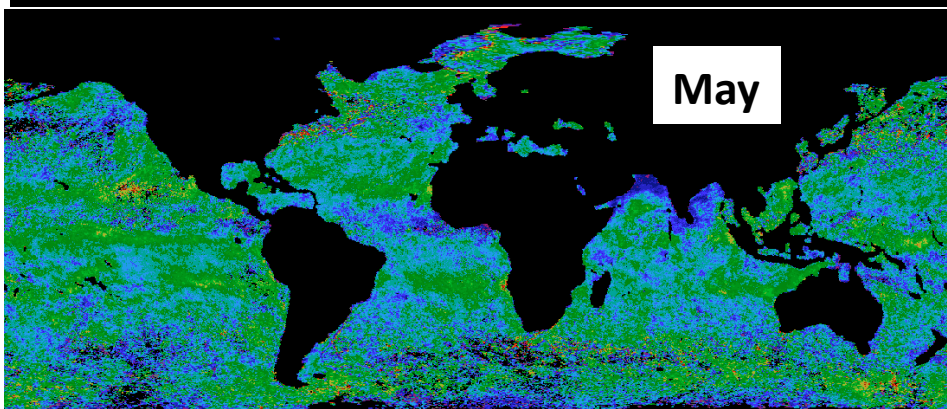
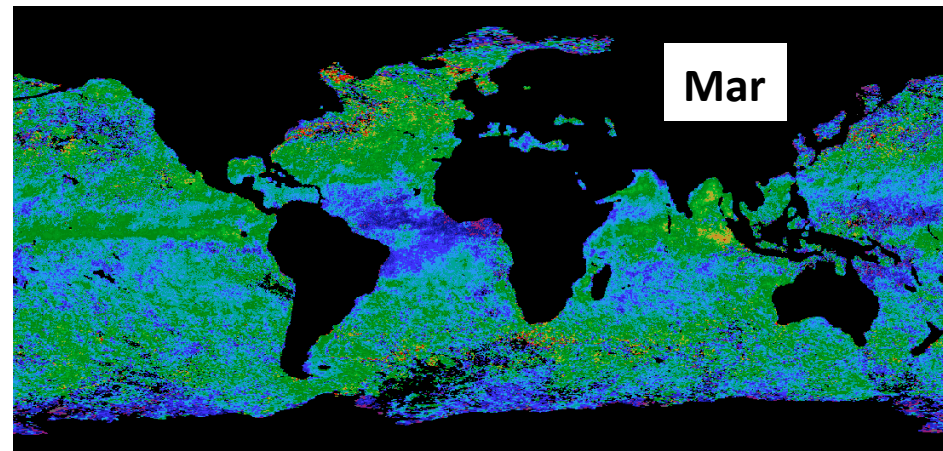
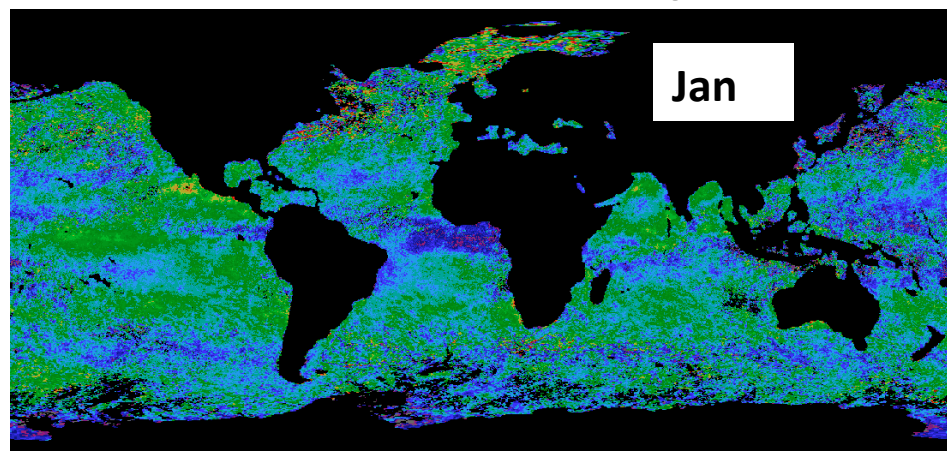
Path V6 - AMSR 3 day composite, separate day and night

Day

Night



N18 PF6-AMSR (night only) monthly, best quality, 2006
Residual patterns evolve month to month



Version 7 SST algorithm

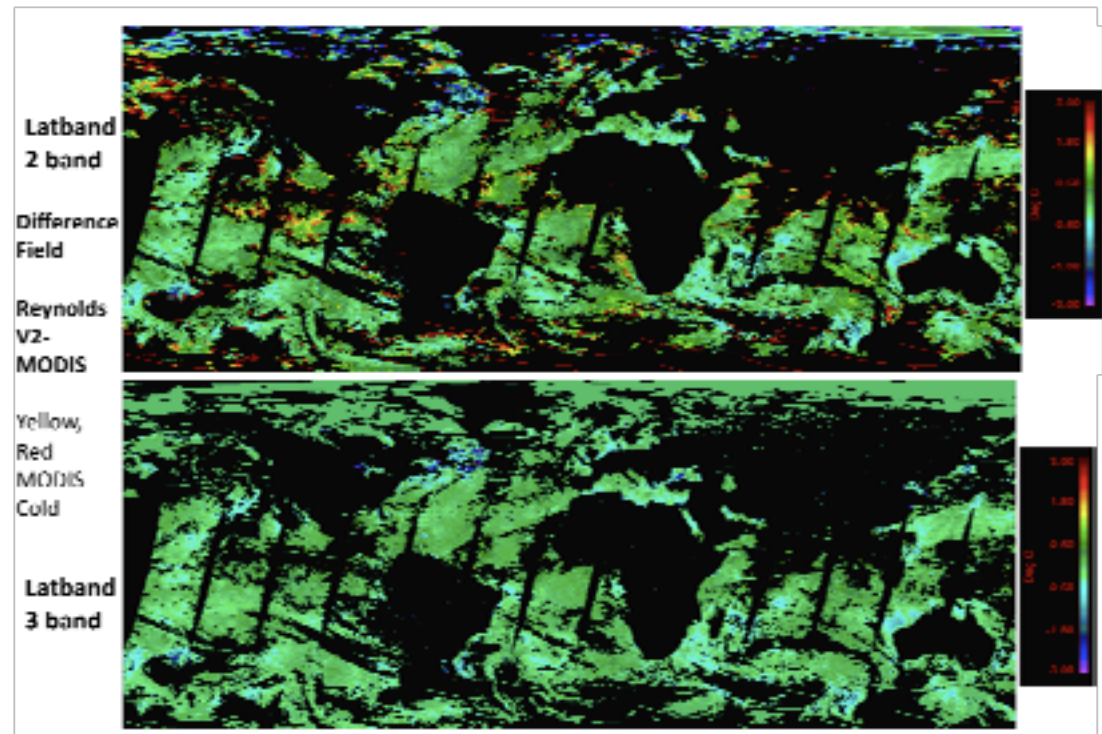
- **Version 7 will retain the 6 regions use by the Version 6 LATBAND algorithm but will use the 11-12 μ m brightness temperature difference (water vapor proxy) to select region boundaries, 3 each in the northern and southern hemispheres to minimize seasonal, regional anomalies.**
- **Hypercube implementation for Version 6 uses discrete intervals for the selection variables. Version 7 will use smoothly varying parameterization for scan angle, brightness temperature difference and temperature**

Comparison of 3 band vs 2 band SST4

Difference fields between MODIS Aqua SST4 (2 July 2006) and corresponding Reynolds V2 SST analysis.

The upper panel is based on a two-band (3.95 and 4.05 μm bands) LATBAND SST4 algorithm.

The lower panel is based on a three-band SST4 algorithm incorporating data from the 3.75 μm band. The color scale at right goes from -3 to +3 K.



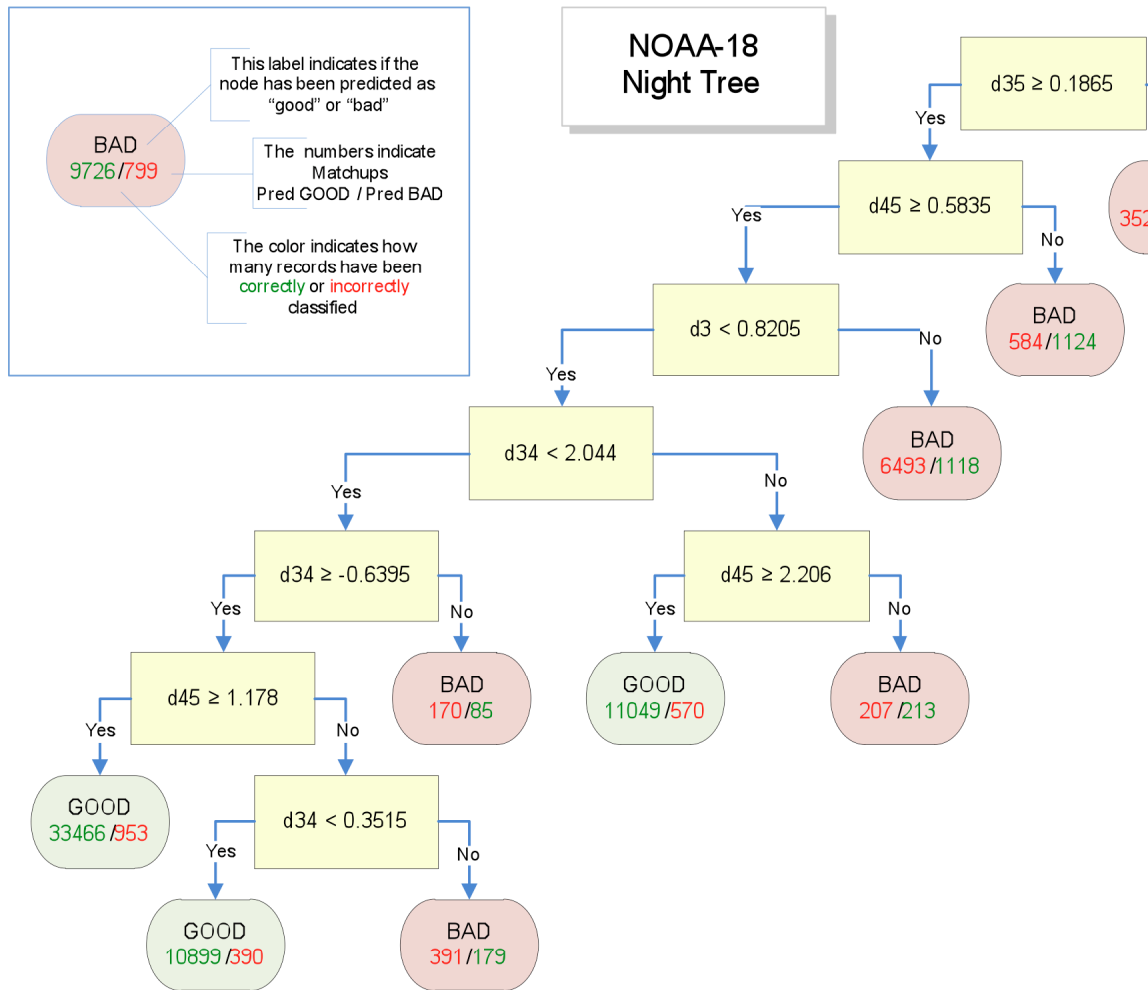
Conclusions

- Collection 6 based Version 6 SST LATBAND algorithm coefficients and uncertainty Hypercube being validated for AQUA and TERRA. Delivery to OBPG will follow.
- Use of reference fields temporally matched to the satellites minimizes the magnitude of residual patterns, AMSR 3 day composite day and night fields are the preferred reference SST field.
- A Version 7 SST algorithm will be investigated to determine if the residual seasonal, regional anomalies are minimized.
- Implementation of a smoothed field Hypercube will be investigated to remove field discontinuities present in the current discrete implementation
- The 3 band SST4 algorithm will be tested to validate its ability to more completely address identification and correction of dust aerosol influence.
- SeaDAS now has LATBAND support for MODIS, VIIRS and AVHRR.

END

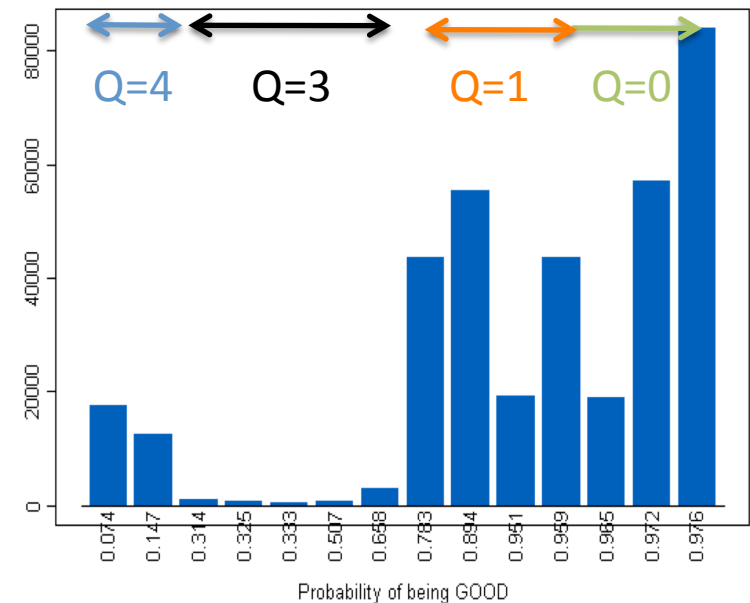
Use of homogeneity and channel difference to develop a probability tree to assign quality level –

PF6



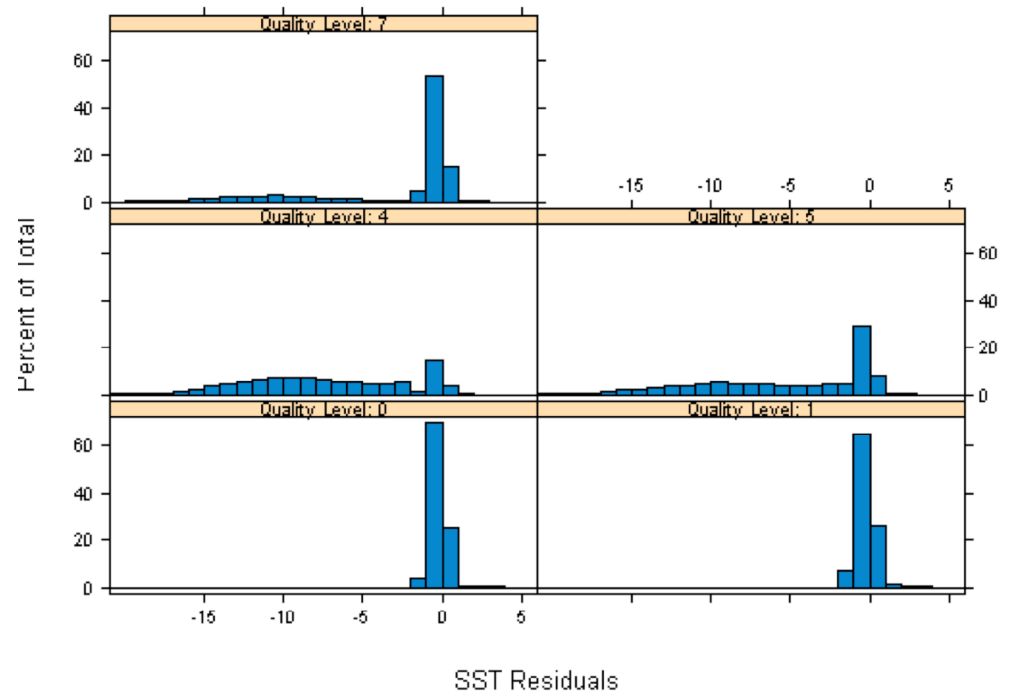
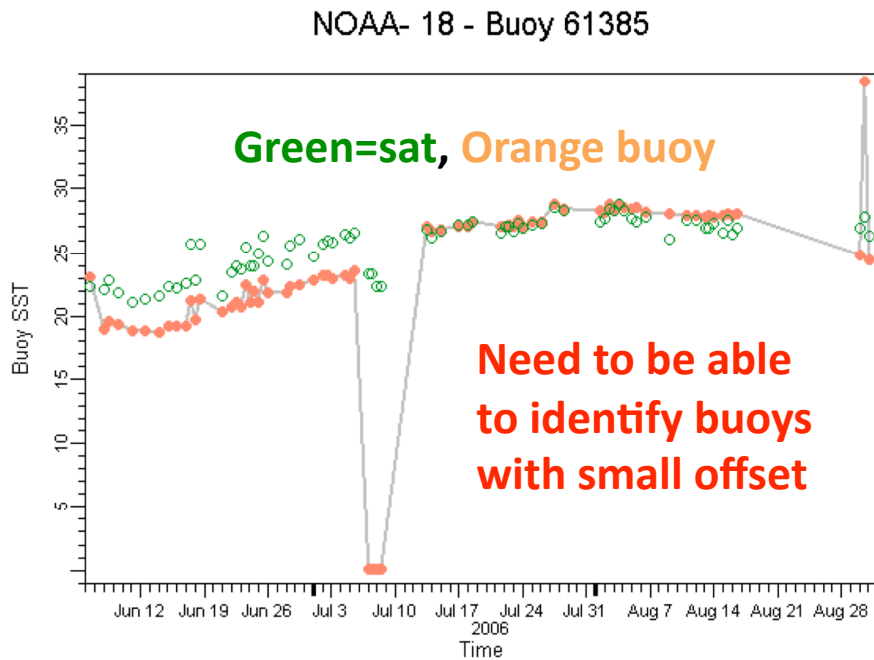
Example of using a probability distribution approach to assign quality. Implementation of this approach will require exploration of multiple categories, e.g. small; large residuals

NO18 All matchups - Day and night trees

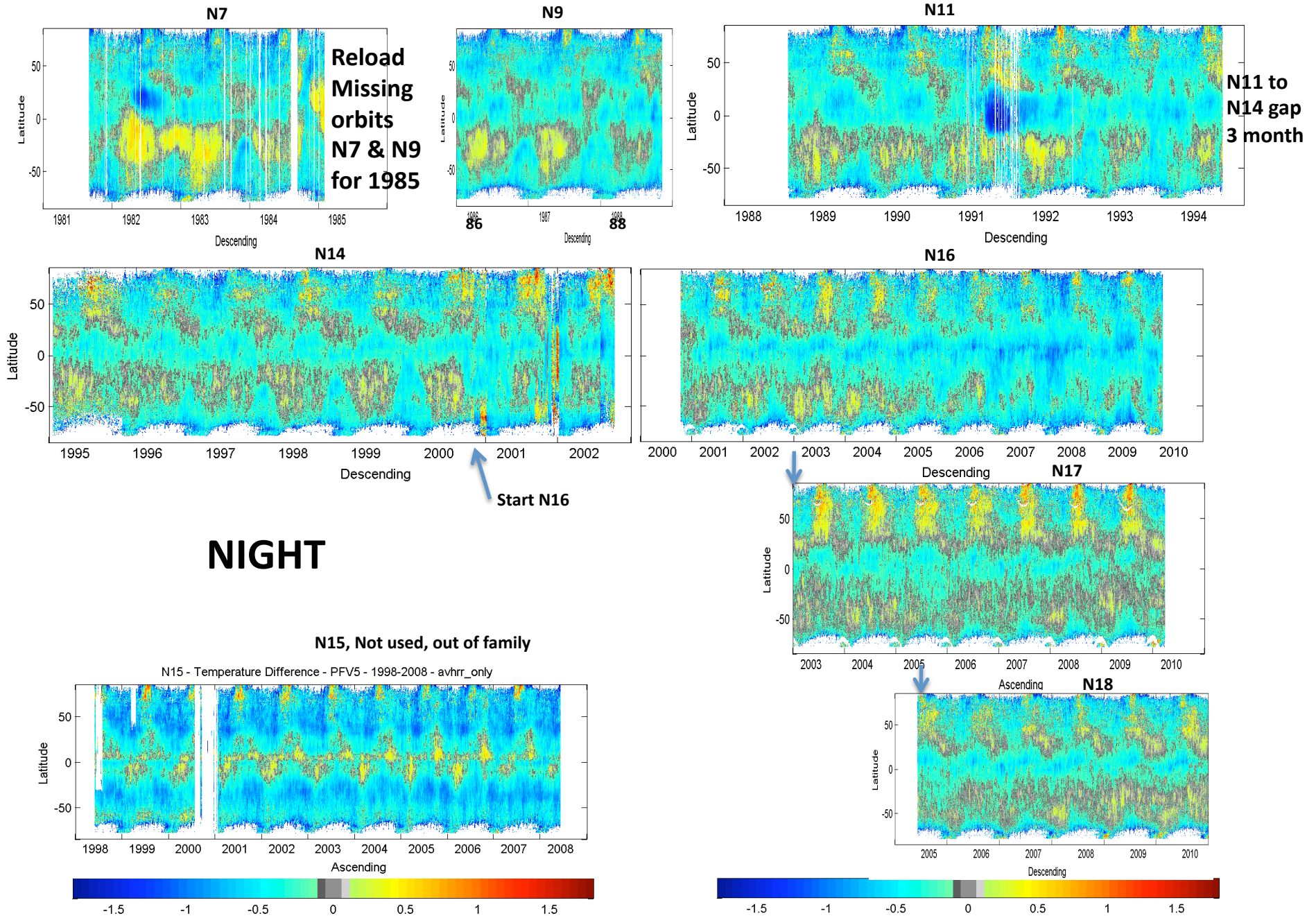


Rejection of cold retrievals by quality level

NOAA-18 - Residual Statistics for each quality level									
Quality	Min	Q1	Median	Mean	Q3	Max	RMS	SD	MAD
0	-2.000	-0.426	-0.202	-0.185	0.015	23.267	0.655	0.629	0.327
1	-2.000	-0.513	-0.229	-0.213	0.040	22.304	0.743	0.712	0.410
2									
3									
4	-42.076	11.105	-7.478	-7.262	-2.731	18.694	8.903	5.151	6.111
5	-30.771	-9.646	-3.961	-5.394	-0.494	20.052	7.622	5.385	5.545
6									
7	-28.391	-2.379	-0.462	-2.876	-0.134	3.952	5.649	4.862	0.635
8									



Pathfinder Version 5.2 progress, N7-> N18



Comparison of 1 day Pathfinder vs ref fields

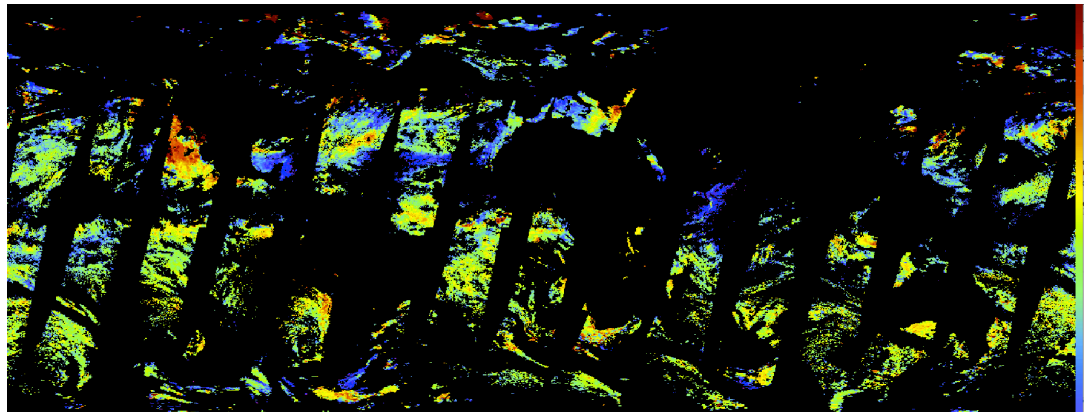
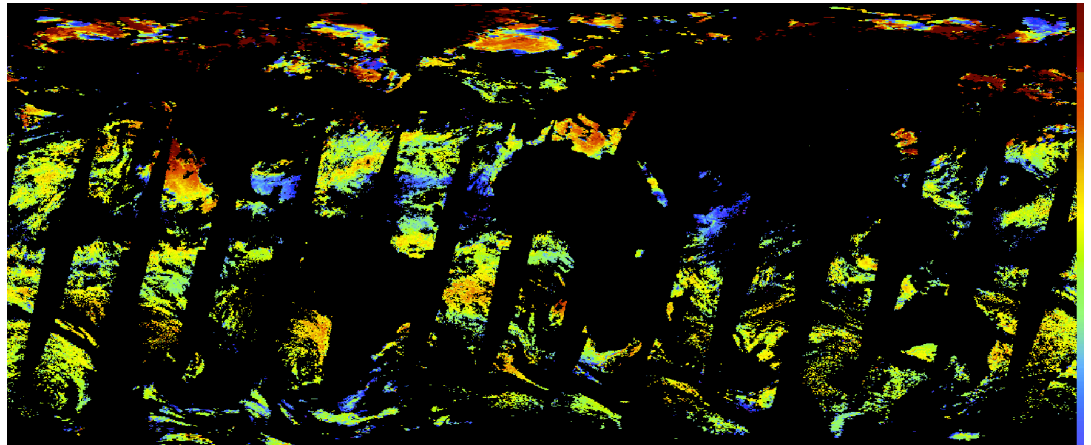
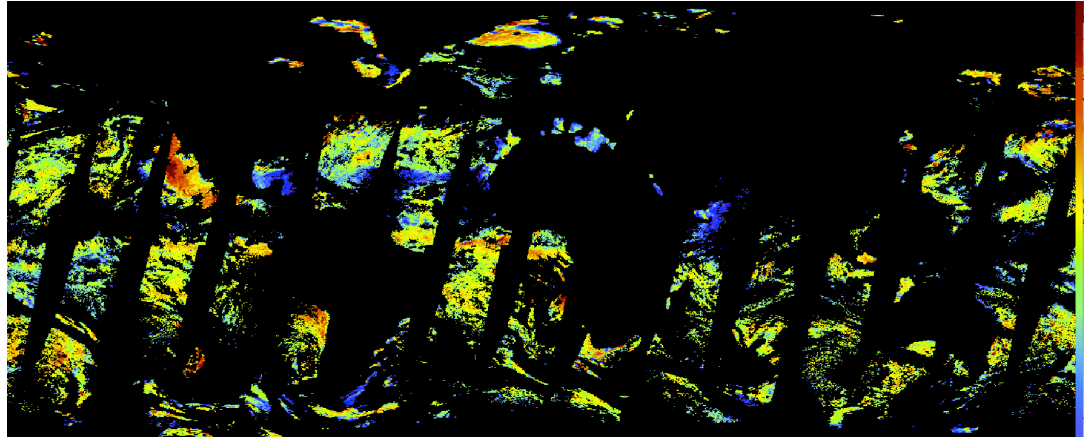
3day AMSR reference

July 19, 2009 N18 night

OISST (NAVO AVHRR) reference

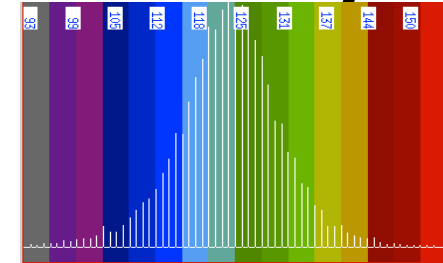
Note differences, Med, high lat

Monthly AATSR reference
Night, Dual view, 3 channel

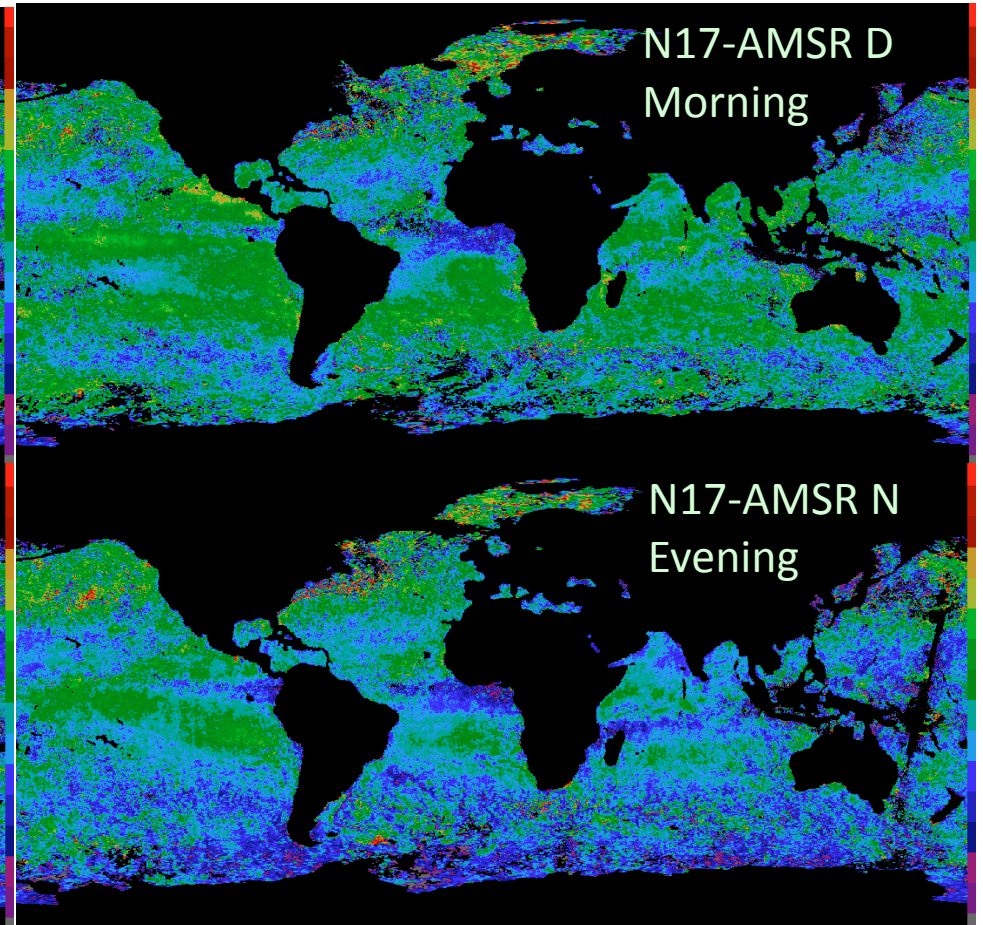
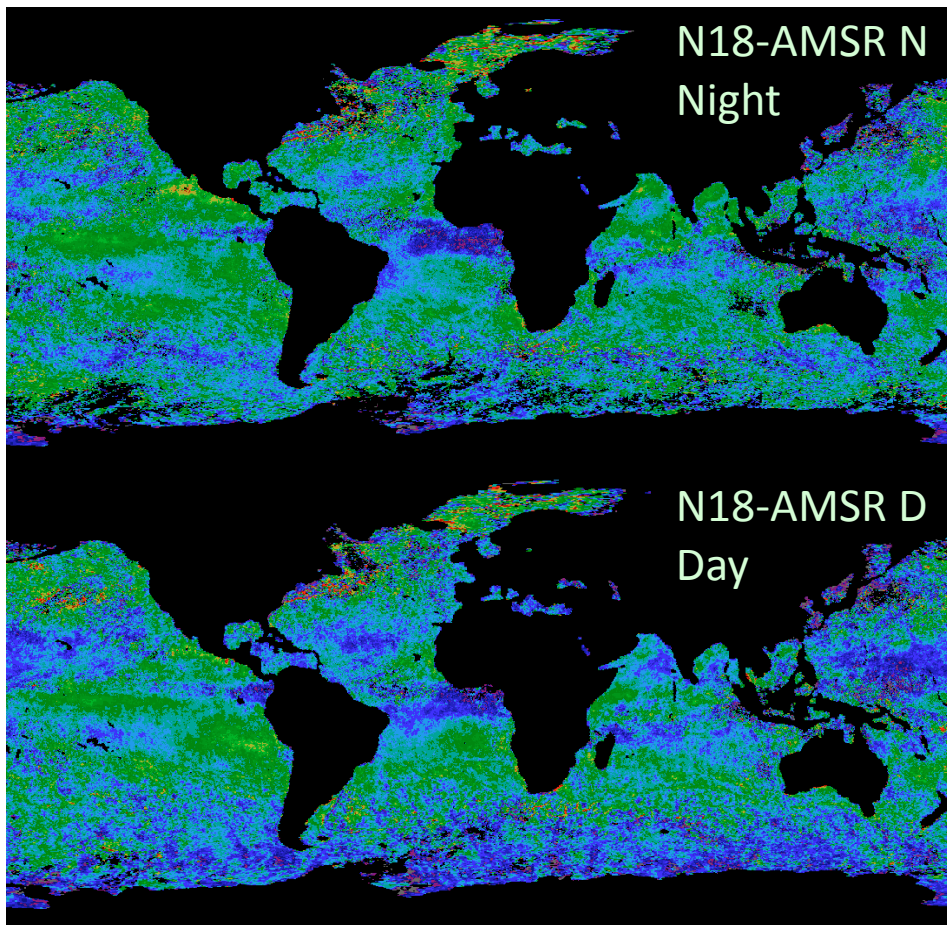


Monthly DT field, Pathfinder V6 – 3 day AMSR (separate Day and Night reference) for January 2006

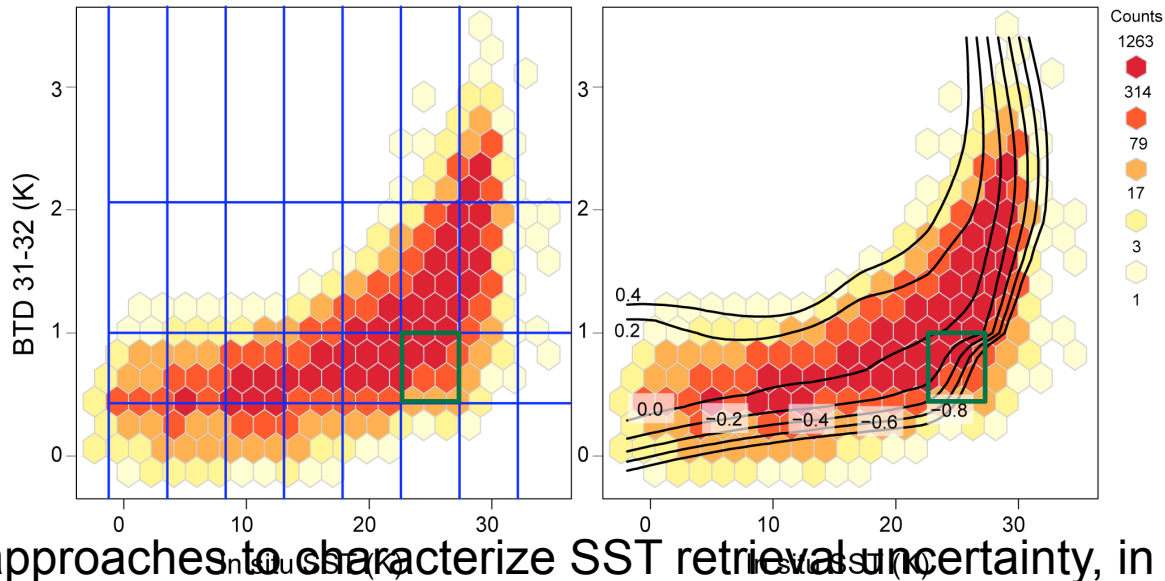
Anomalies reasonably consistent
across satellites although diurnal
variability is present



Color step = 0.2K -2.0 .2

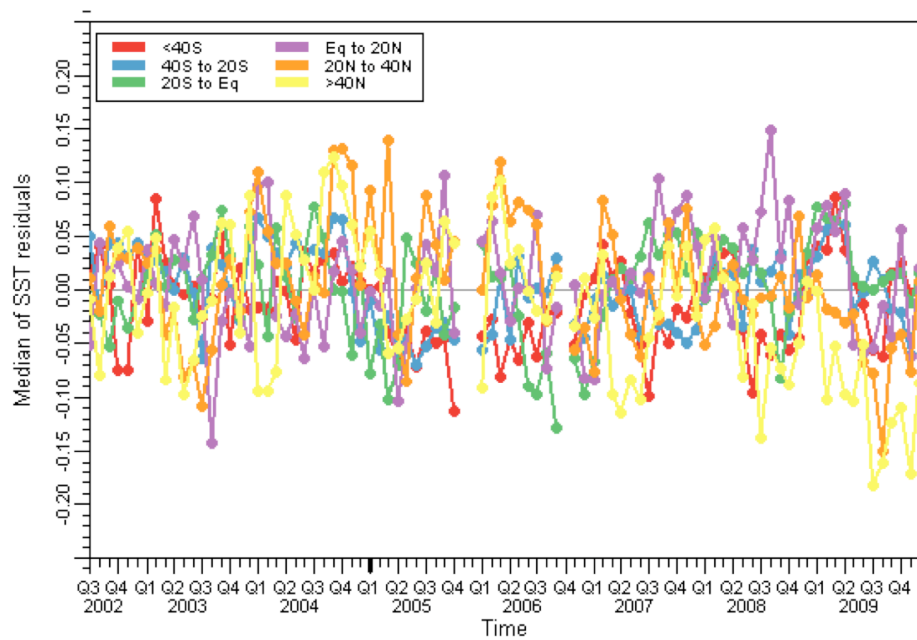


Aqua Hypercube - Median SST residuals

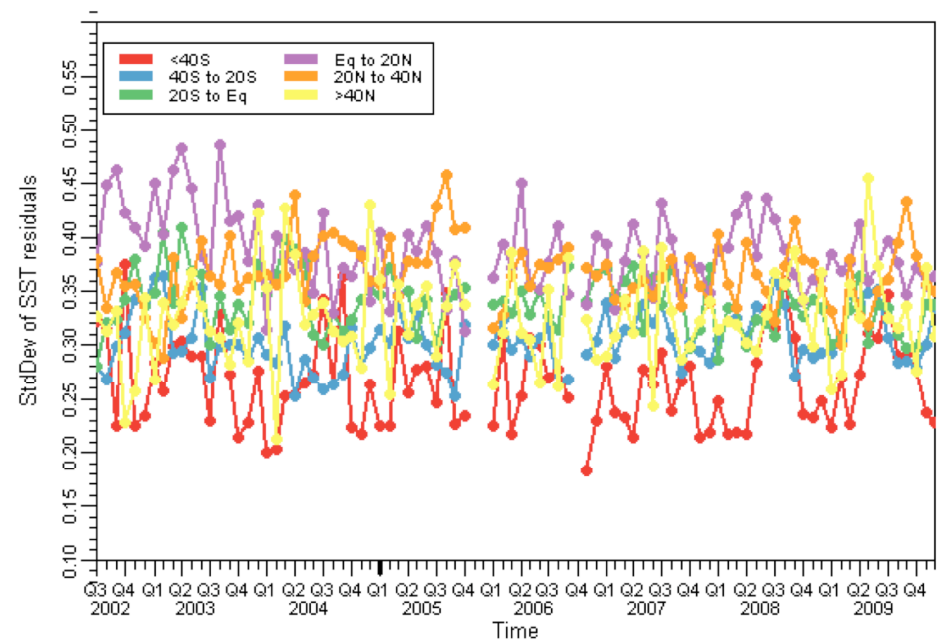


Two alternative approaches to characterize SST retrieval uncertainty, in this case the bias of SST estimates (calculated as the median of SST residuals). The colored hexagons represent the abundance of matchups in a two-dimensional space defined by buoy SST (in the x-axis) and the brightness temperature difference between MODIS channels 31 and 32 (on the y-axis). The five colors in the hexagons encode counts per cell (see scale to the right of the plot). Left panel: this panel represents the current approach to characterize uncertainty. A bias value is computed by each bin (blue rectangles) defined by partitions of the two-dimensional space. This single statistic represents the entire bin, even though it is clear from the figure that (a) some bins are not uniformly occupied, (b) some bins have very low counts, and (c) the mean values can change substantially between adjacent bins, leading to discontinuities in the retrieved uncertainty field. Right panel: In the proposed approach, a surface is fit to the median of residuals as a function of the two dimensions selected. Contour lines describe SST residual bias (values shown for 0.4K to -0.8K, every 0.2K). A rectangle overlaid on the contours (corresponding to one of the bins in the left panel) shows that the same bin may have a very broad range of bias values, and a single value fails to

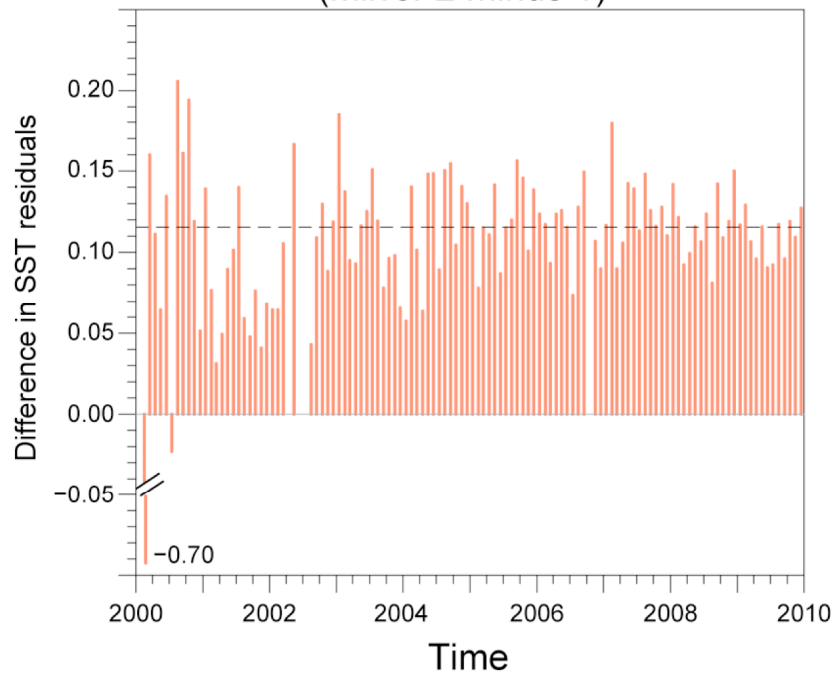
Median of SST residuals - AQUA



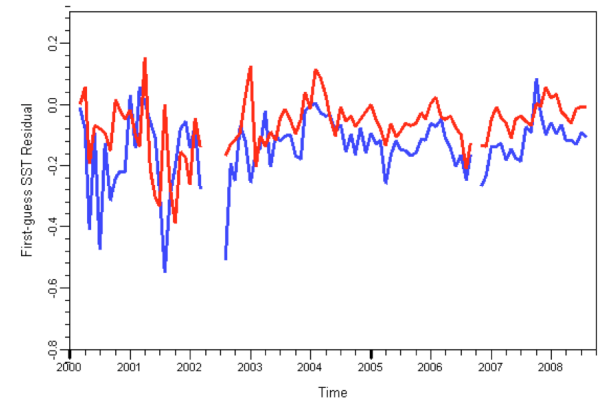
StdDev of SST residuals - AQUA



MODIS TERRA Coll 6 – SST residuals difference
(mirror 2 minus 1)



TERRA - Residuals by mirror (blue:1; red:2)



TERRA - Difference in Median Resids btw mirror sides
(mirror 2 minus mirror 1)

