MODIS and VIIRS SST continuity algorithms

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Outline

- CDR Continuity Algorithm and atmospheric correction equations MODIS/ VIIRS
- MODIS AQUA and TERRA C5 and recent C6 reprocessing 2015
- VIIRS relationship to the 30 years of heritage IR measurements
- CDR multi sensor time series of accuracy and uncertainty
- Matchup data bases
- VIIRS scan angle correction
- Quality and cloud flagging machine learning

C(onsistent) Data Record -> Climate Data Record

- Long-term, multi-mission time series, such as AVHRR Pathfinder and MODIS Terra and Aqua. Broad swath imagers (not ATSR)
- Focus on achieving consistent error and uncertainty characteristics over time and space
- Reference temperatures – drifting buoys
- C(limate) Data Record requires SI traceability

Consistent with heritage sensors

- The algorithm for MODIS and Pathfinder AVHRR – is the Non-Linear SST (NLSST; Walton et al., 1998) as modified for the Pathfinder CDR (Kilpatrick et. al. 2001, Kilpatrick et. al. 2015 in press):

$$SST_{skin} = a_0 + a_1 T_{11} + a_2 (T_{11} - T_{12}) T_{sfc} + a_3 (T_{11} - T_{12})(\sec(\theta) - 1)$$
$$+ a_4 (mirror) + a_5 (\theta) + a_6 \ (\theta^2)$$

MODIS and VIIRS coefficients are derived for each latitude band and month of year. (note: PF AVHRR a4-6 are set to zero, for VIIRS a4 is zero)

T_{sfc} is in units of Celsius (scaling factor temperature deficit)

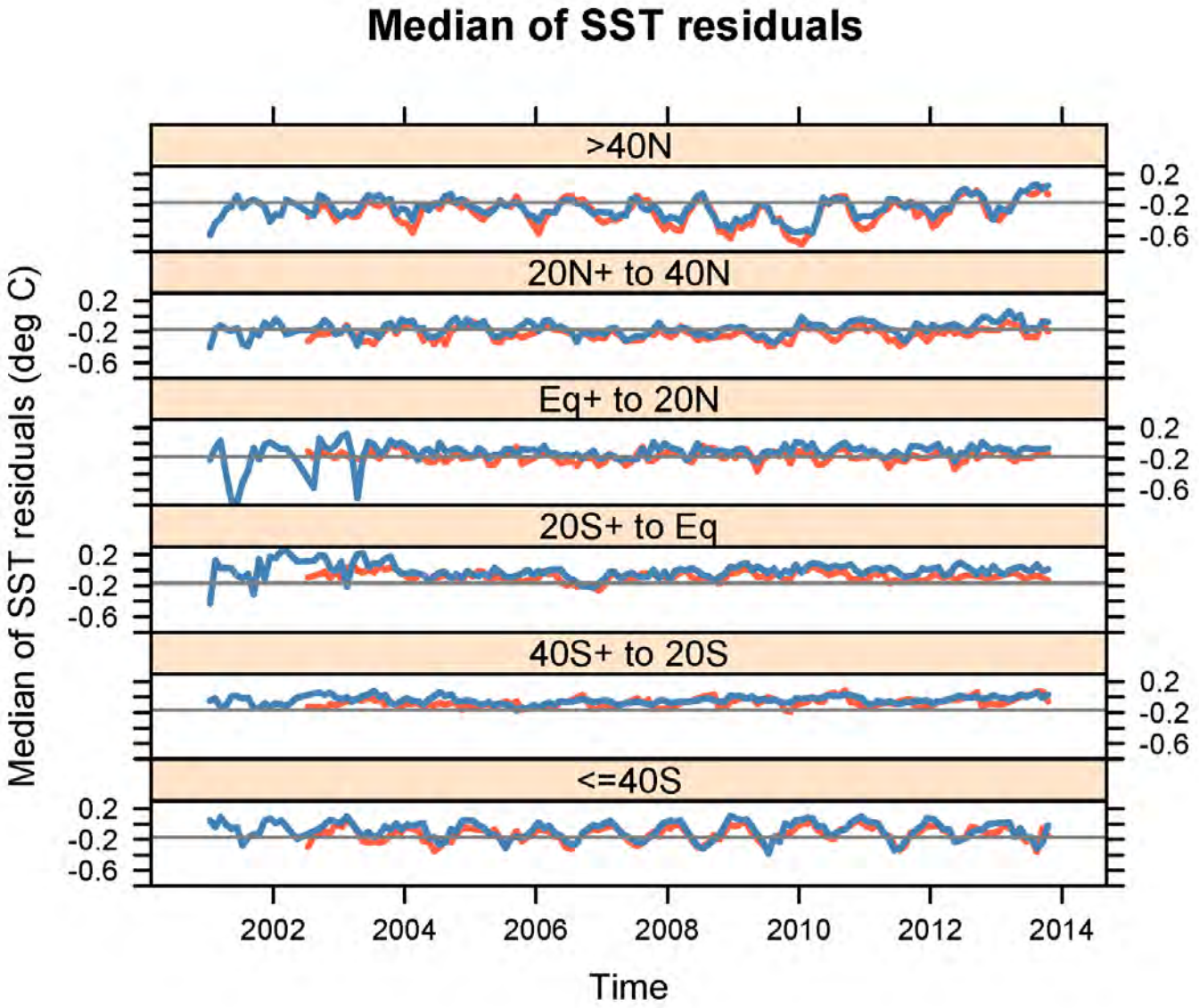
Regional and latitude bias C5

High latitude seasonal signal of ~ 0.2K

AVHRR and MODIS and VIIRS show this type of pattern with heritage algorithm

MODIS V5
Blue- Terra
Red- AQUA

High latitude is where we are see climate change first but where we have problems in the retrievals.



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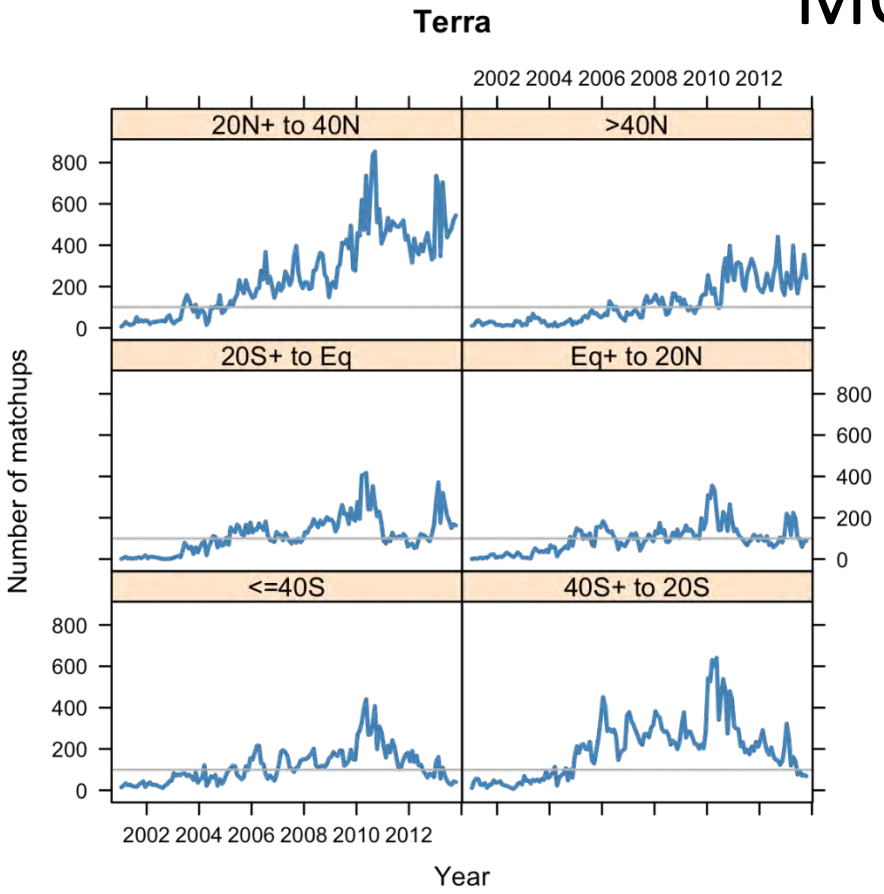
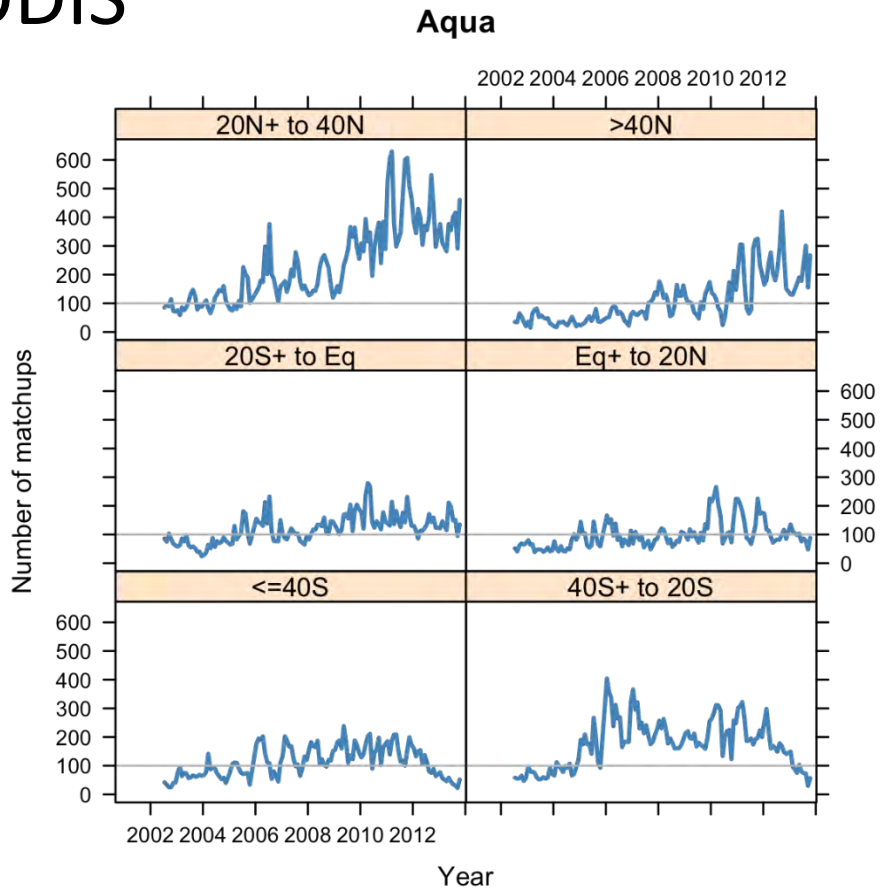
C5 versus C6 MODIS SST

- C5 used global coefficients for two water vapor regimes and ad hoc corrections for mirror side
- C6 stability of level 1b calibration and growing buoy network allowed for coefficients to be estimated within latitude bands for a month of year
- Revised hypercube of uncertainty estimates for GHRSST L2p files

Geographical distribution of ql=0 matchups MODIS





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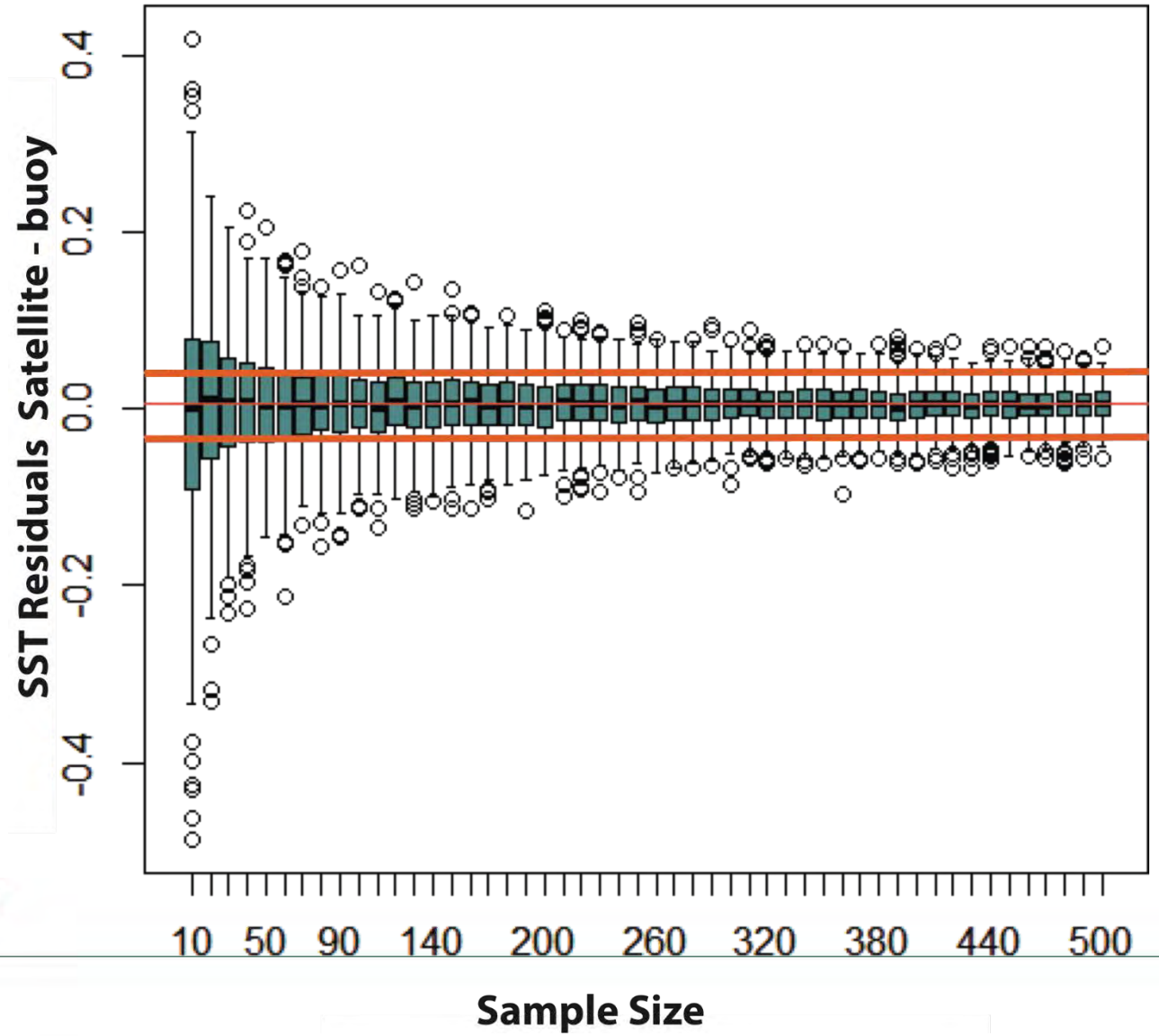
Number of matchups needed for statistical stability



Matchup databases

- VIIRS MDB 1,513,222 records

DriftingBuoy	MooredBuoy	radiometer	Ship
1074357	348477	soon	90,388

- AQUA 5,999,905 records

DriftingBuoy	MooredBuoy	radiometer	Ship
5248210	593073	14910	143712

TERRA 6,253,425 records

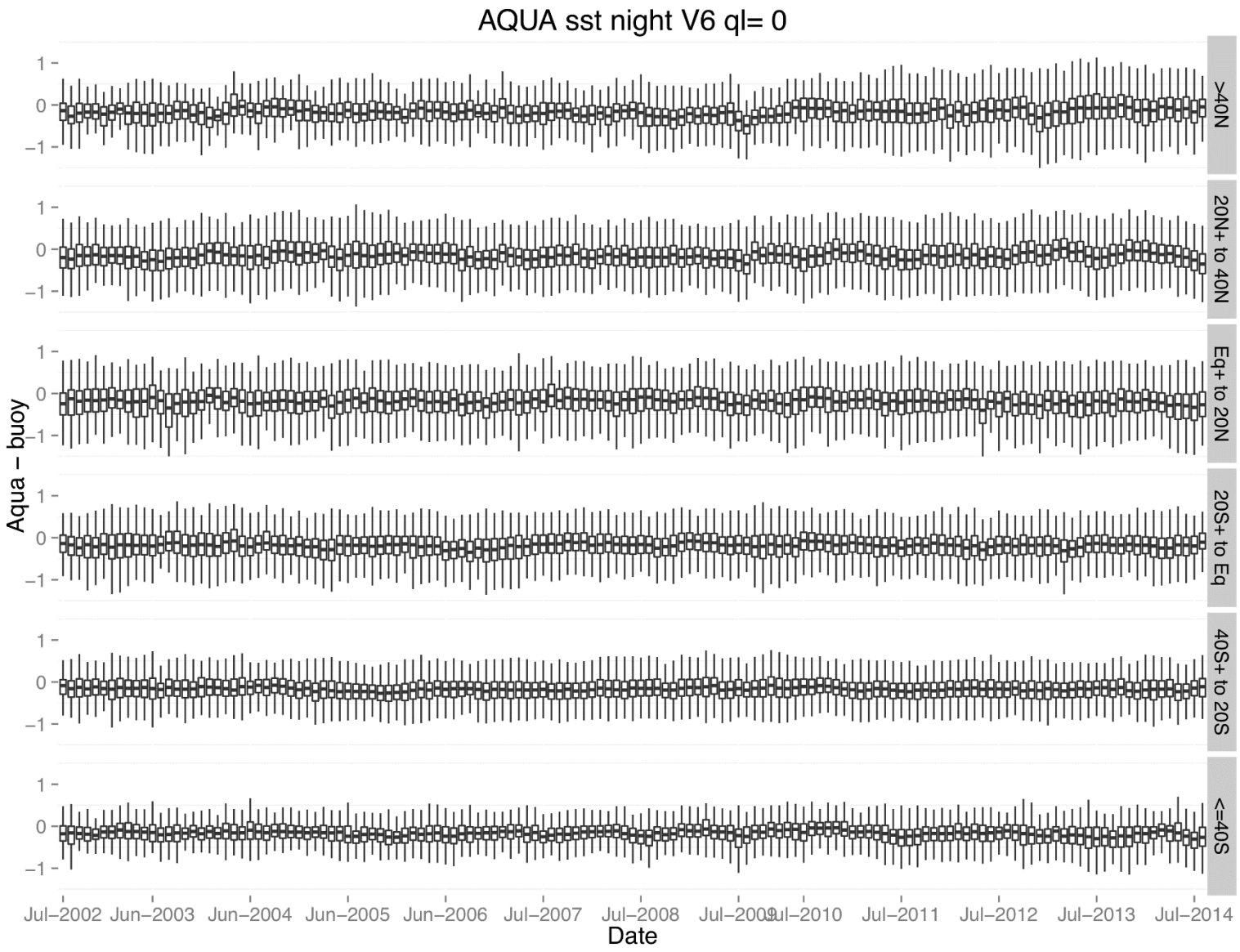
DriftingBuoy	MooredBuoy	radiometer	Ship
5618462	468781	18381	147801

The SI traceable skin SST measurements for VIIRS validation

- Newly developed second-generation Marine-Atmospheric Emitted Radiance Interferometers (M-AERI) have recently been deployed for VIIRS SST validation.

- R/V Knorr Woods hole to Cape Town
- NOAA ship Ronald H. Brown – 2 Atlantic cruises
- Cruise ships Celebrity Equinox and Allure of the Sea

MODIS AQUA V6 SST 2015 reprocessing



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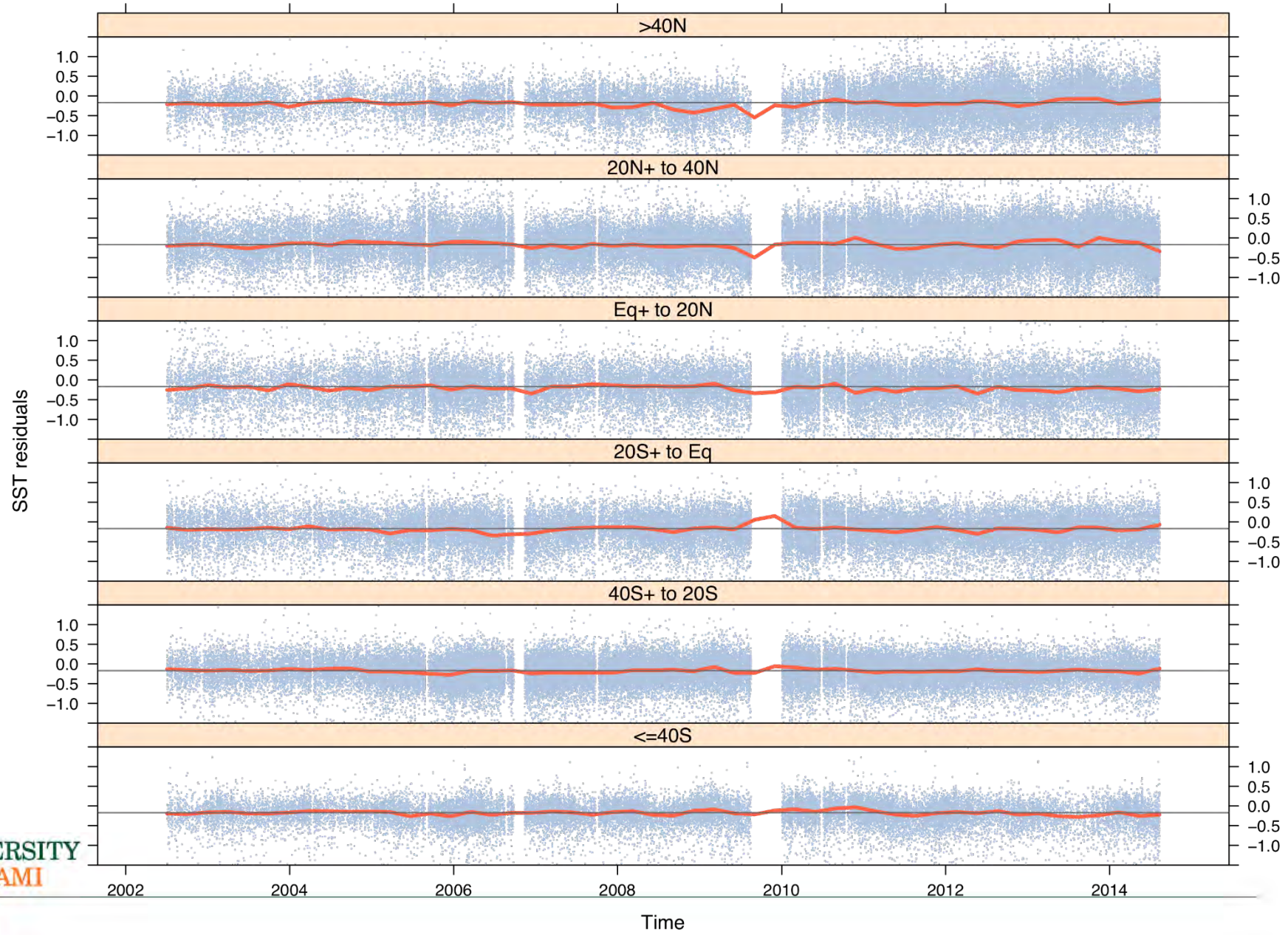
AQUA night SST C6 2015 reprocessing



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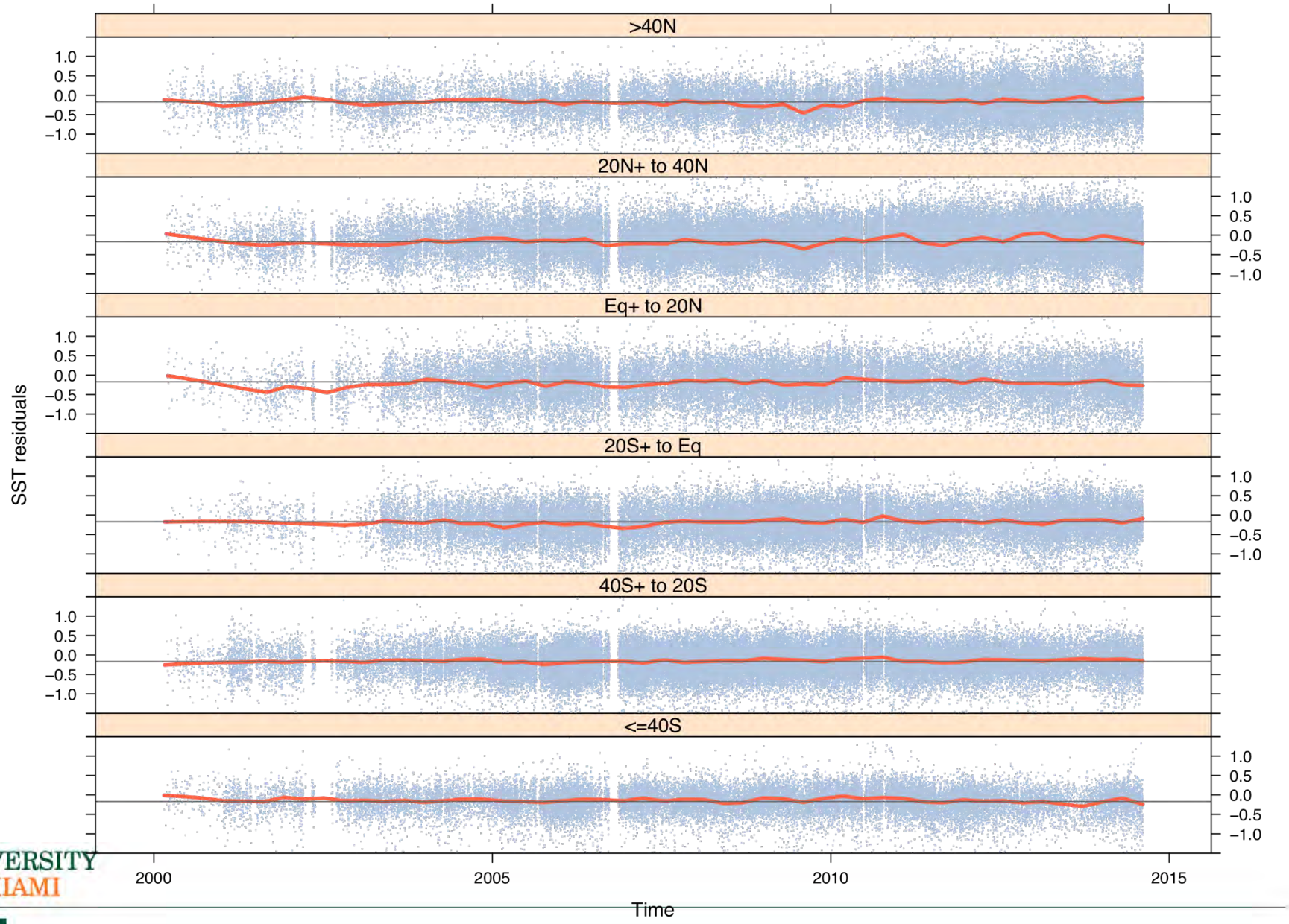
Night SST TERRA 2015 Reprocessing



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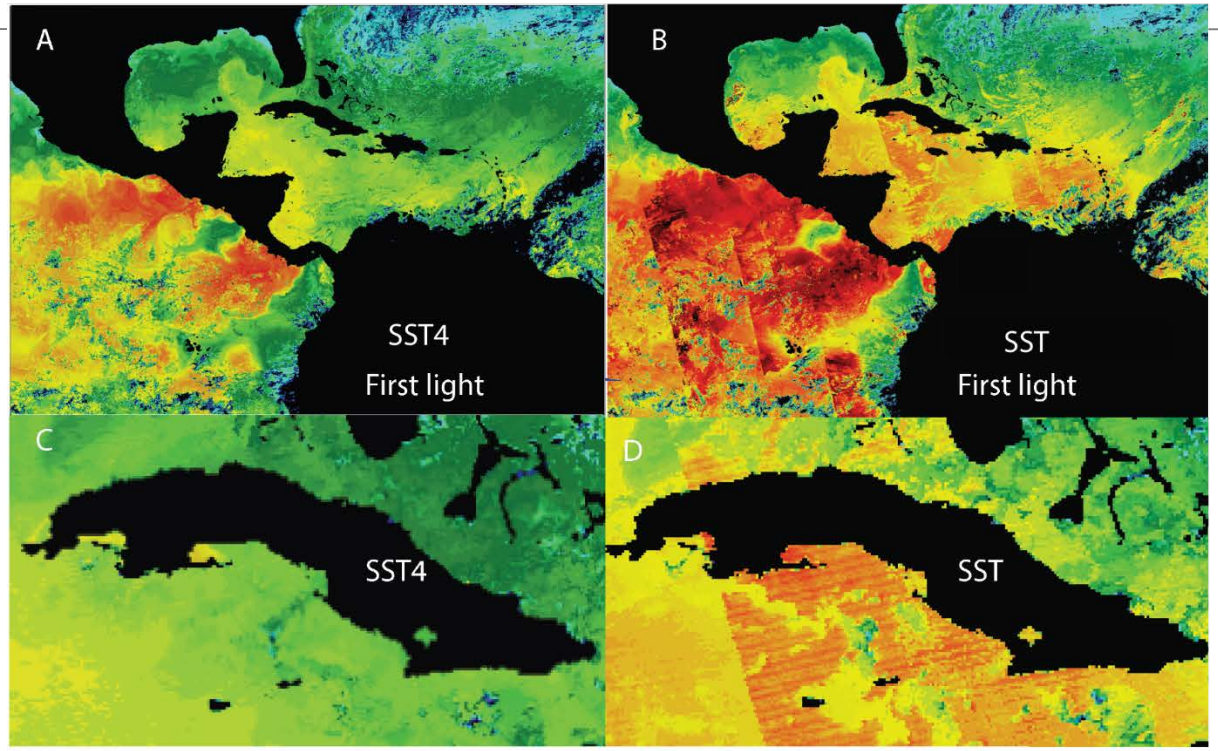

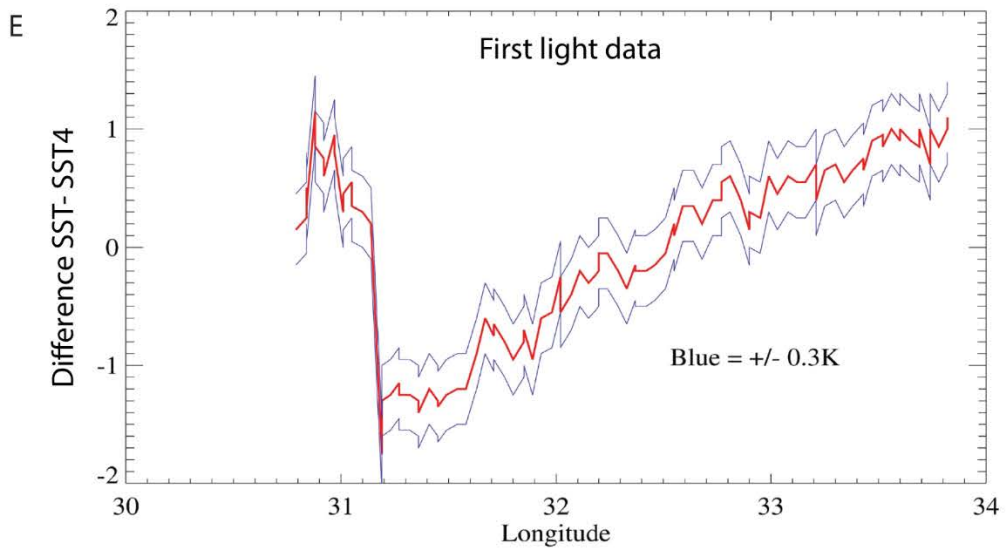

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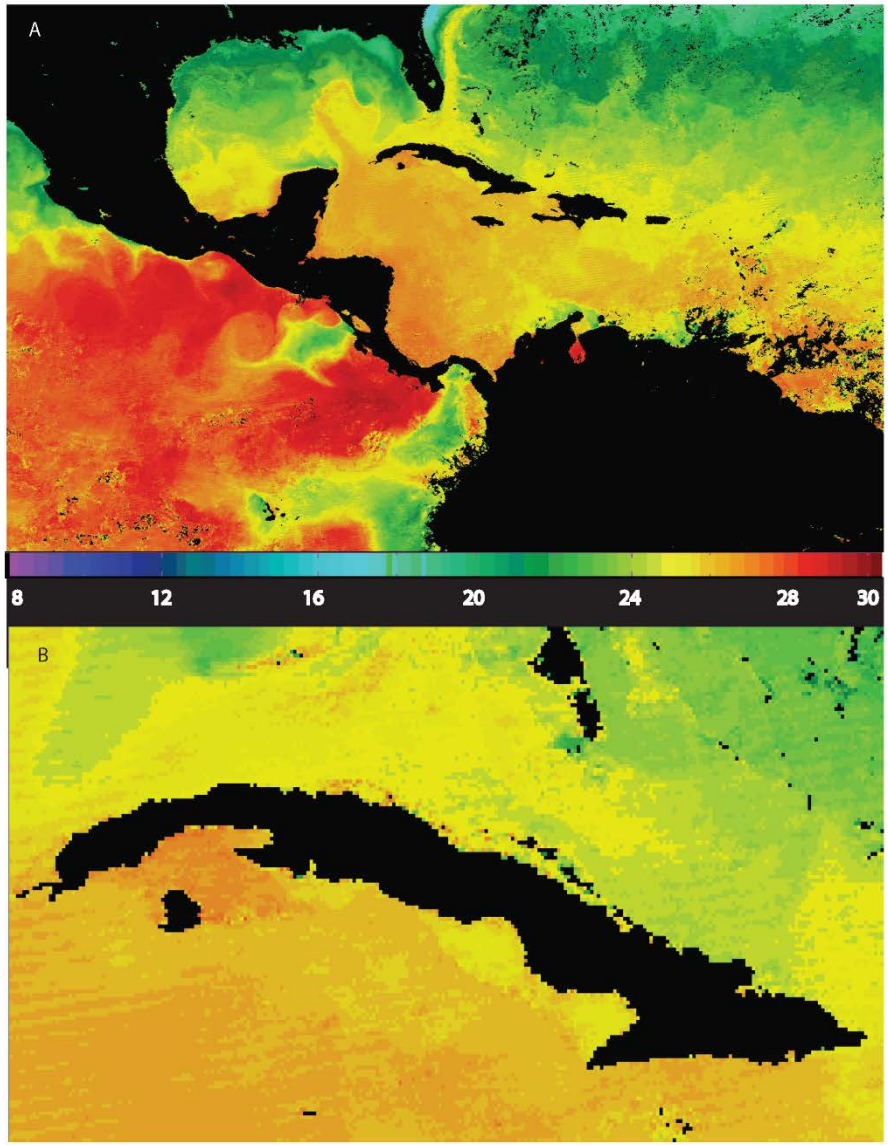

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Collection 5 LWIR SST Temperature °C

Current limitations

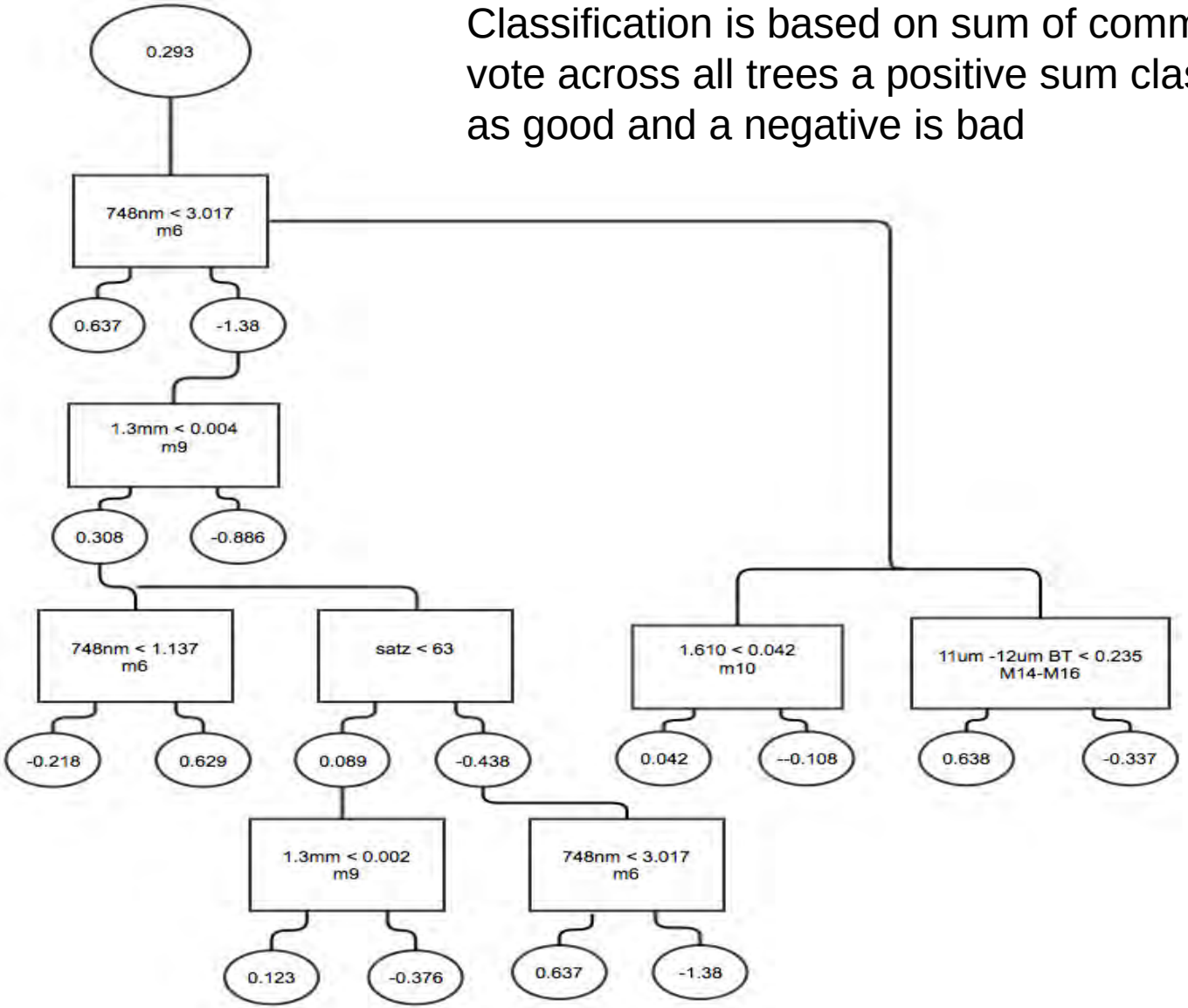
- Satellite zenith angle
- Regional versus global uncertainty
- Cloud and dust masking

Quality

- Cloud/quality masks and machine learning/ensemble classification methods
  - Difference in ability to detect clouds between day and night impacts sampling/binning of higher level products
- Data quality levels and uncertainty estimates
  - Different uncertainty requirements depending on the application – my “so-so” may not be the same as your “so so”

Alternating decision Tree example night

Classification is based on sum of community vote across all trees a positive sum classified as good and a negative is bad



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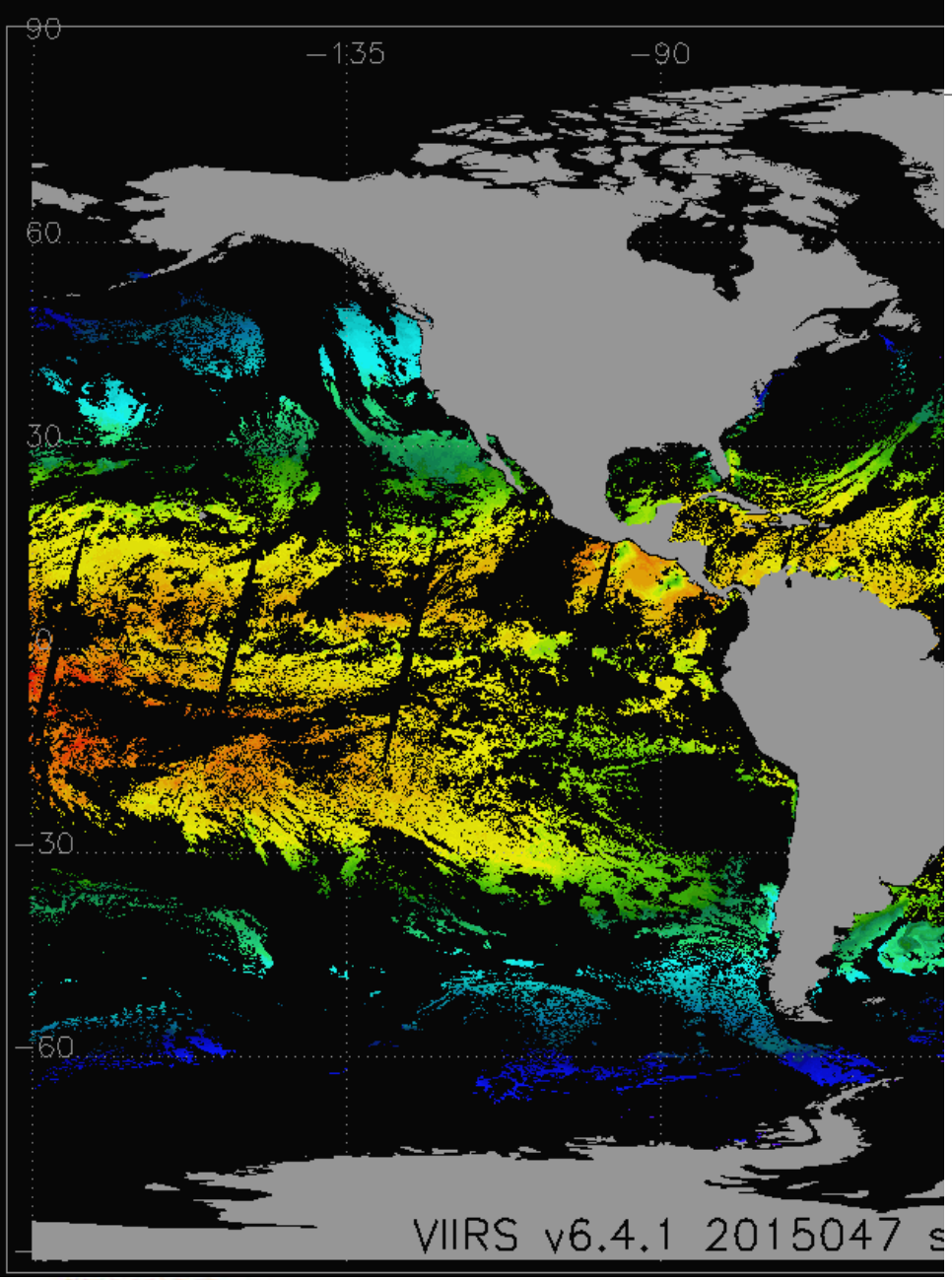
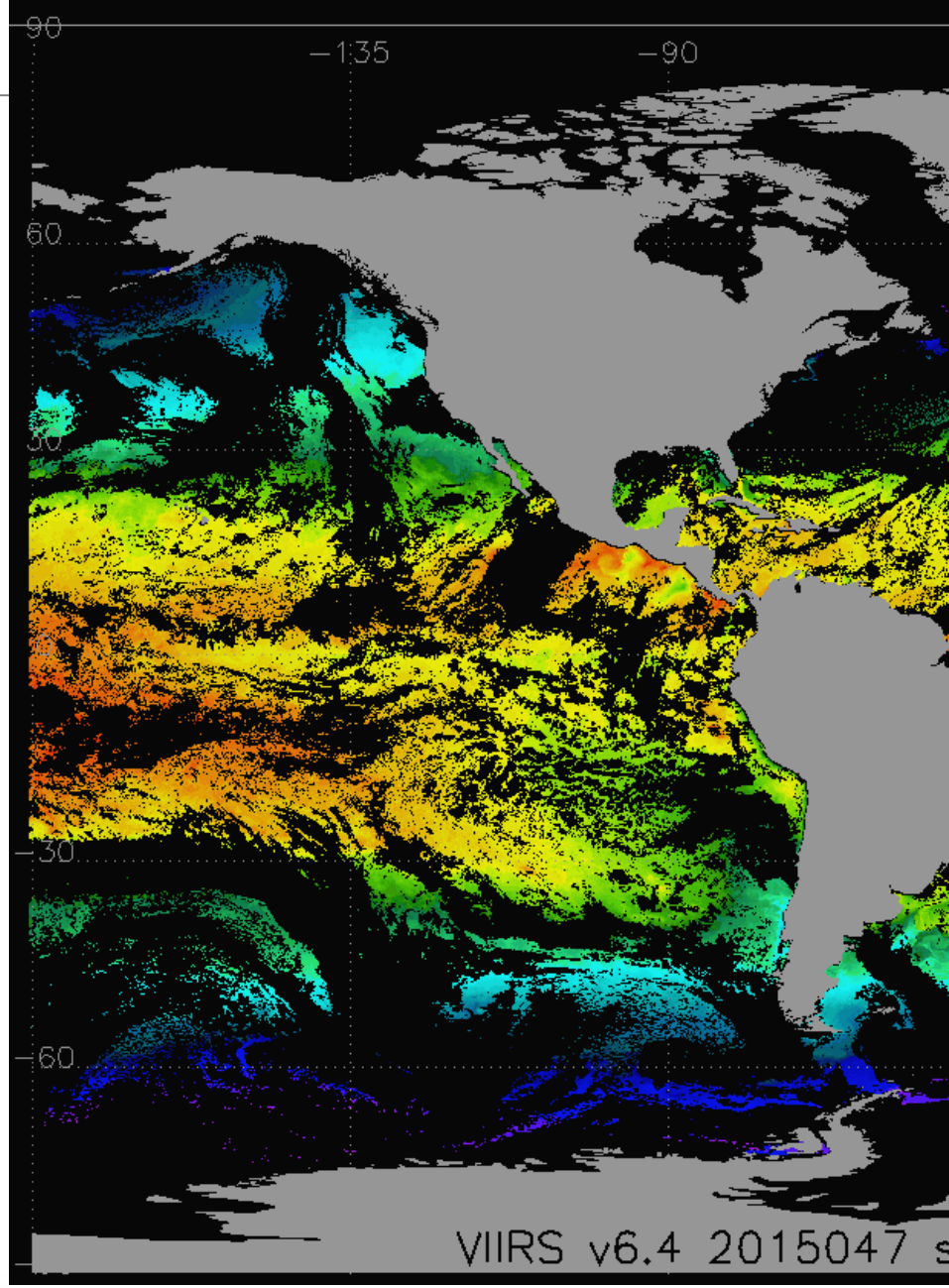
```
# > day.no.glint.adt v6.4
# Alternating decision tree:
#
#    : 0.293
# |  (1)m6 < 3.017: 0.637
# |  (1)m6 >= 3.017: -1.38
# |  |  (5)dm15m16 < 0.235: -0.337
# |  |  (5)dm15m16 >= 0.235: 0.638
# |  |  (10)m10 < 0.042: 0.464
# |  |  (10)m10 >= 0.042: -0.108
# |  (2)m9 < 0.004: 0.308
# |  |  (4)m6 < 1.137: 0.626
# |  |  (4)m6 >= 1.137: -0.218
# |  |  (6)satz < 63.123: 0.089
# |  |  |  (9)m9 < 0.002: 0.123
# |  |  |  (9)m9 >= 0.002: -0.376
# |  |  (6)satz >= 63.123: -0.438
# |  |  (7)dm15m16 < 1.133: -0.198
# |  |  (7)dm15m16 >= 1.133: 0.323
# |  (2)m9 >= 0.004: -0.886
# |  |  (8)m9 < 0.007: 0.36
# |  |  (8)m9 >= 0.007: -0.303
# |  (3)sst2b < 270.087: -4.085
# |  (3)sst2b >= 270.087: 0.06
# Legend: -ve = Bad, +ve = Good
# Tree size (total number of nodes): 31
# Leaves (number of predictor nodes): 21
```

Correctly Classified Instances 126547 90.0408 %
Incorrectly Classified Instances 13997 9.9592 %

Confusion matrix (A= bad, B= good)

	A	B
A	61566	13908
B	7412	128120





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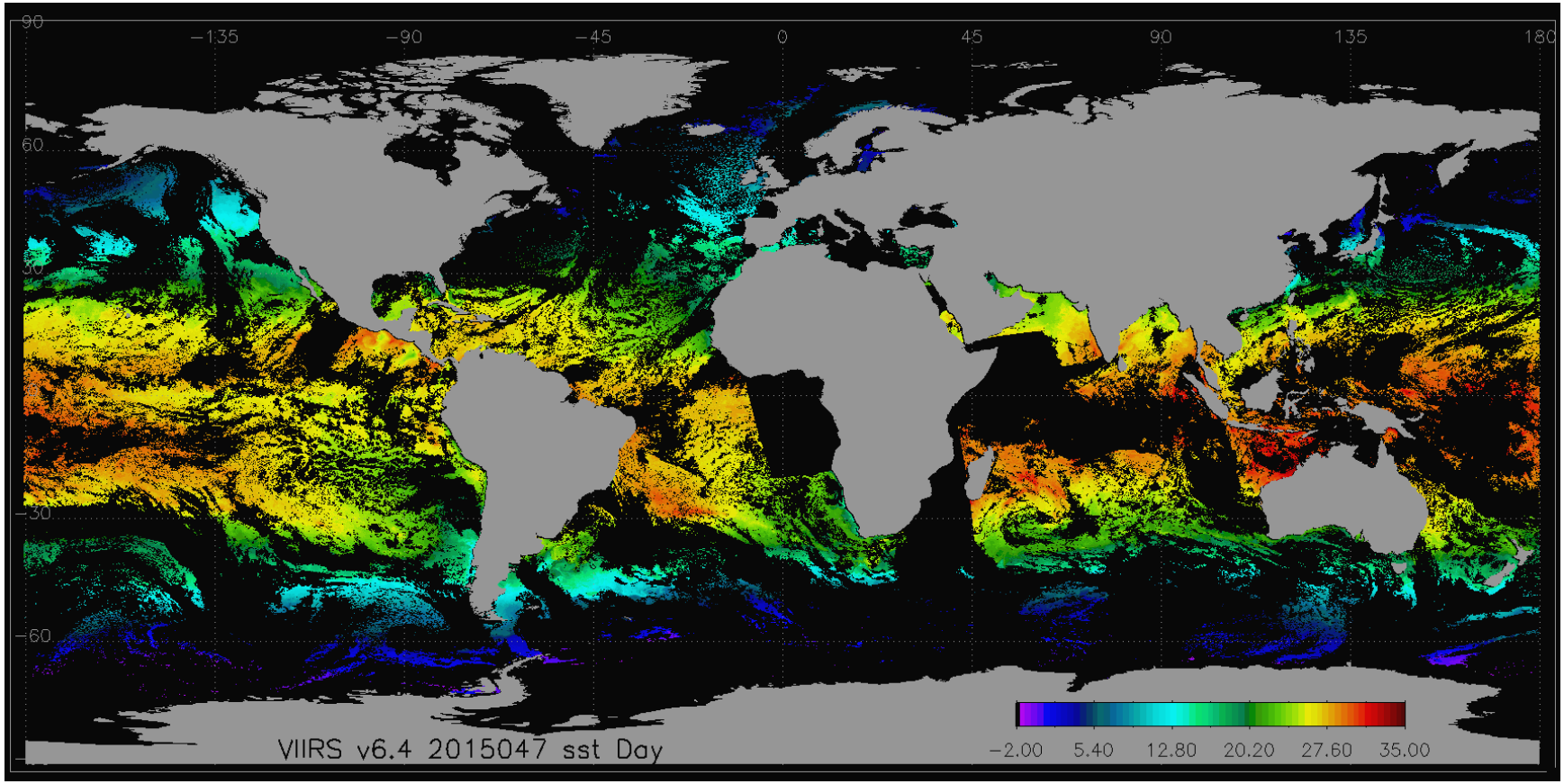
night

day

VIIRS Global 4km map day time SST Feb 16 2015



V6.4 no additional scan angle correction terms

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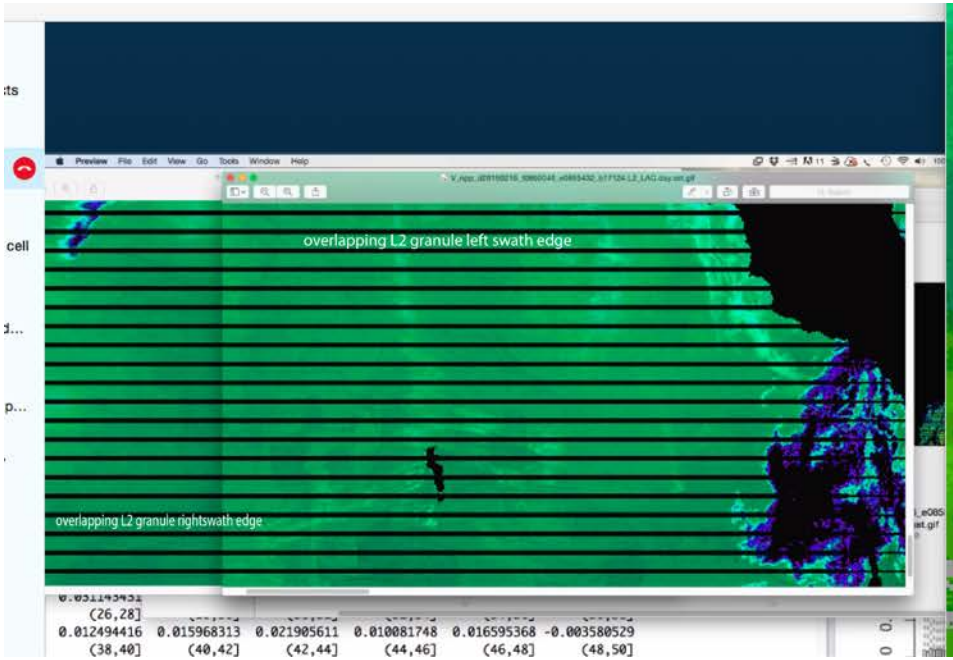
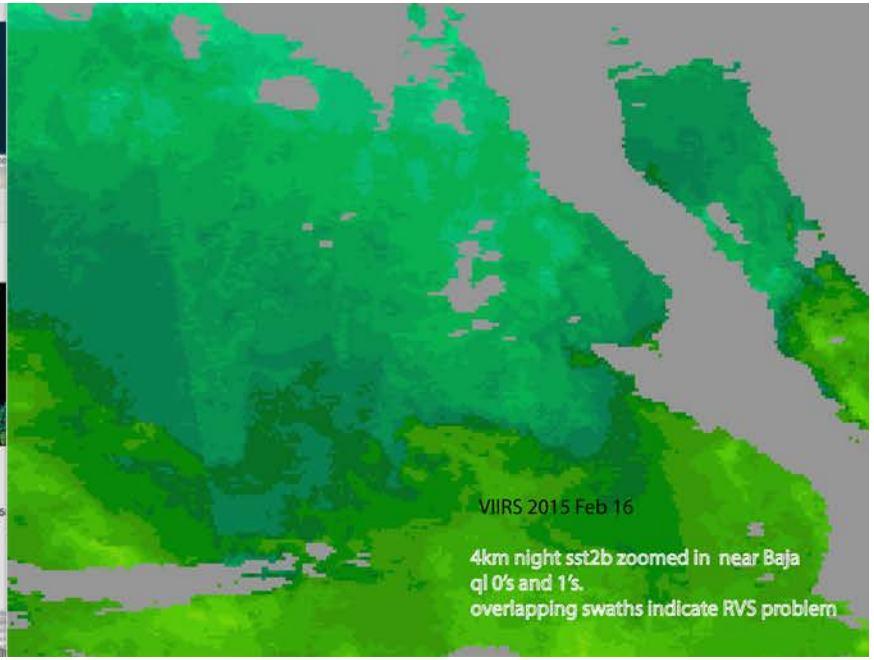
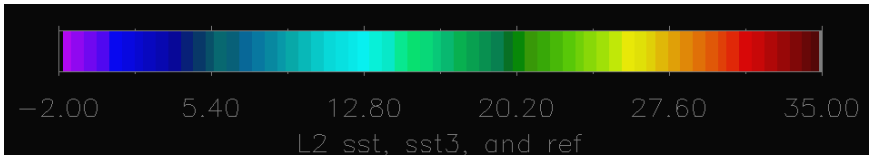
VIIRS Overlapping swaths night

L2's 1km from adjacent swaths

Enlarged 4km res region off of Baja







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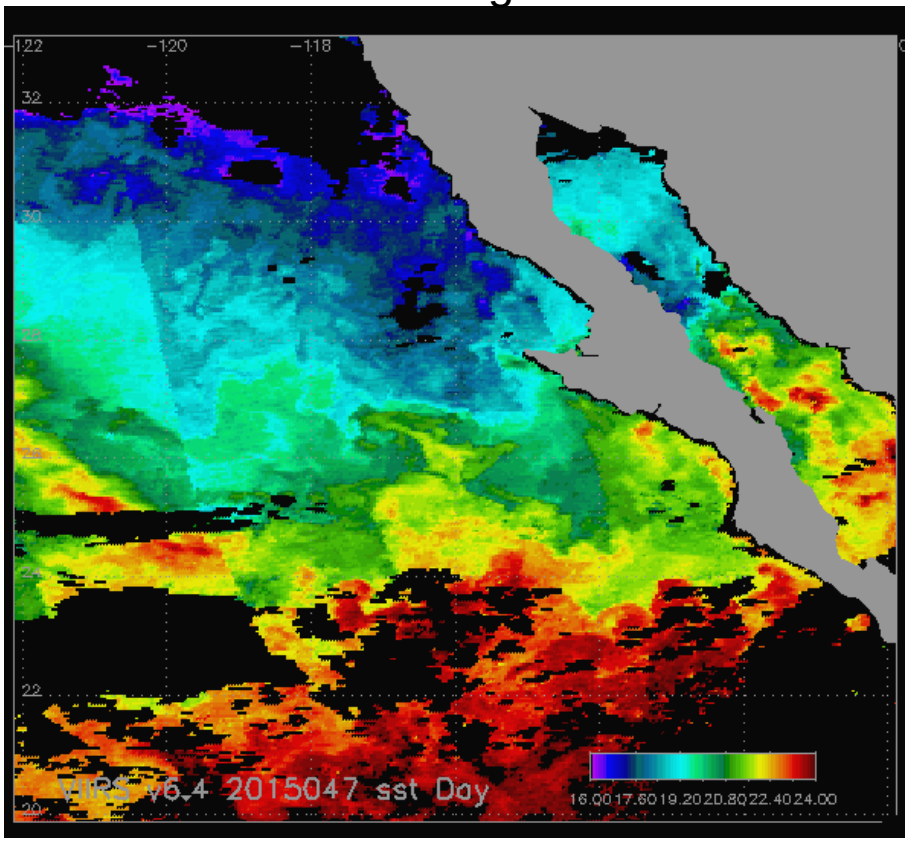
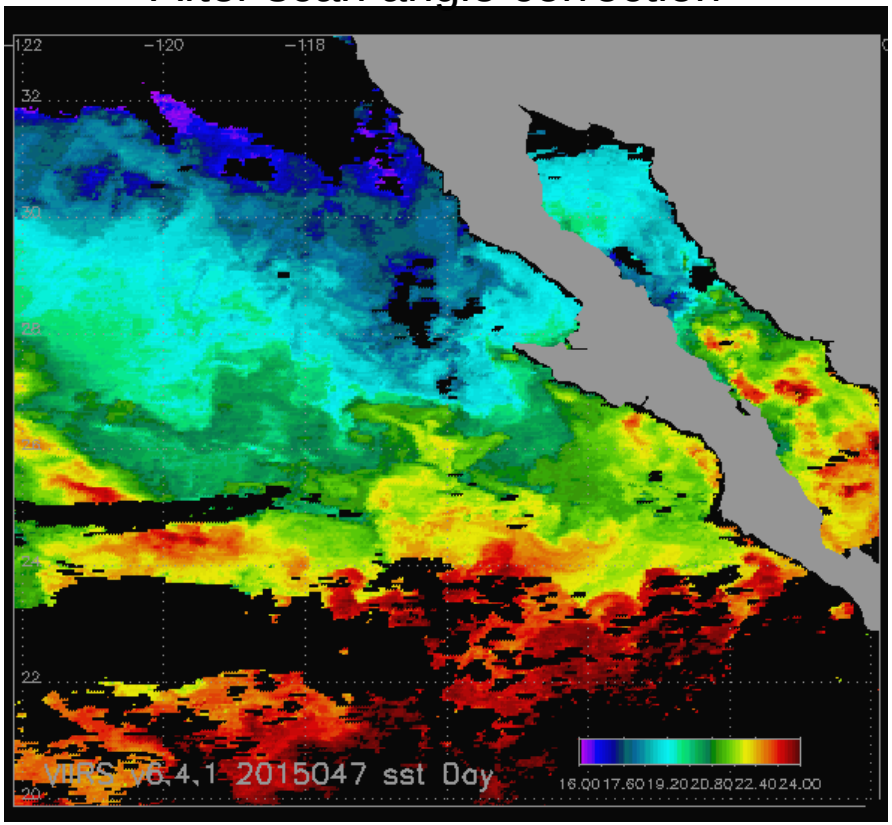
VIIRS Day time SST Feb 16 2015

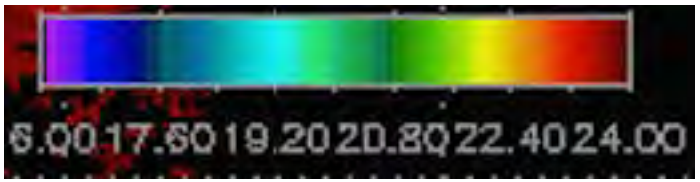
4km map image

Before scan angle correction



After scan angle correction





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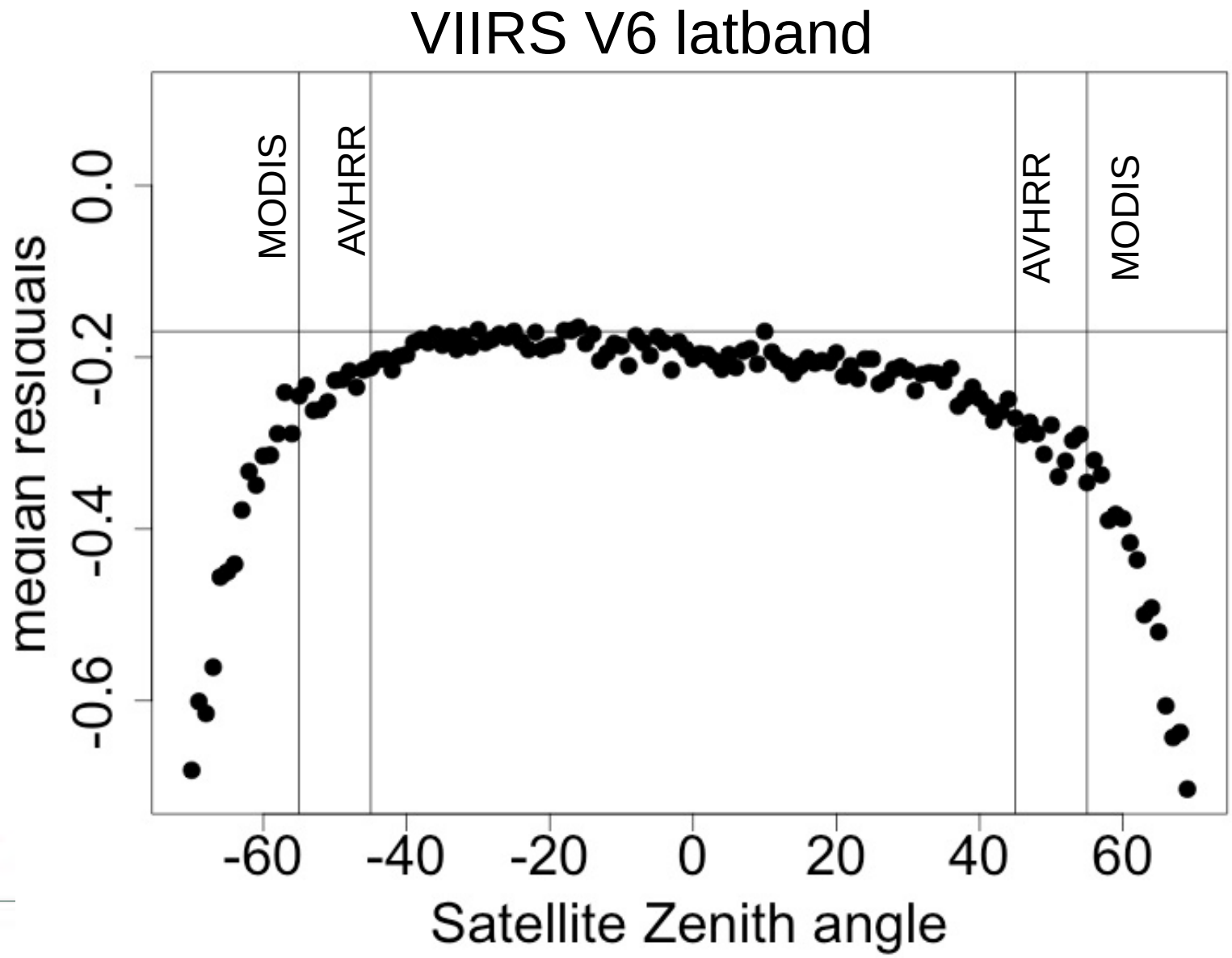
Satellite Zenith angle



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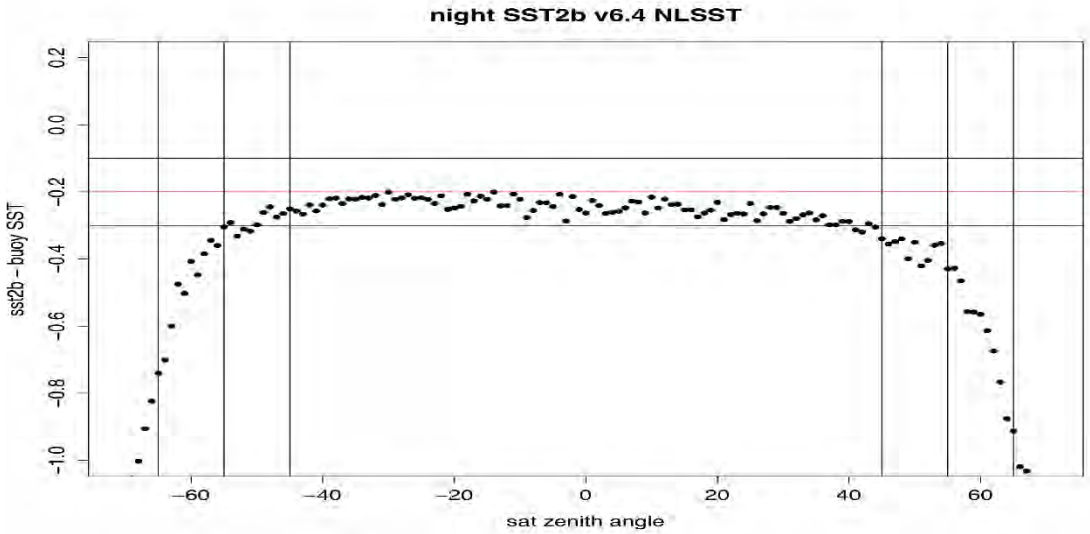

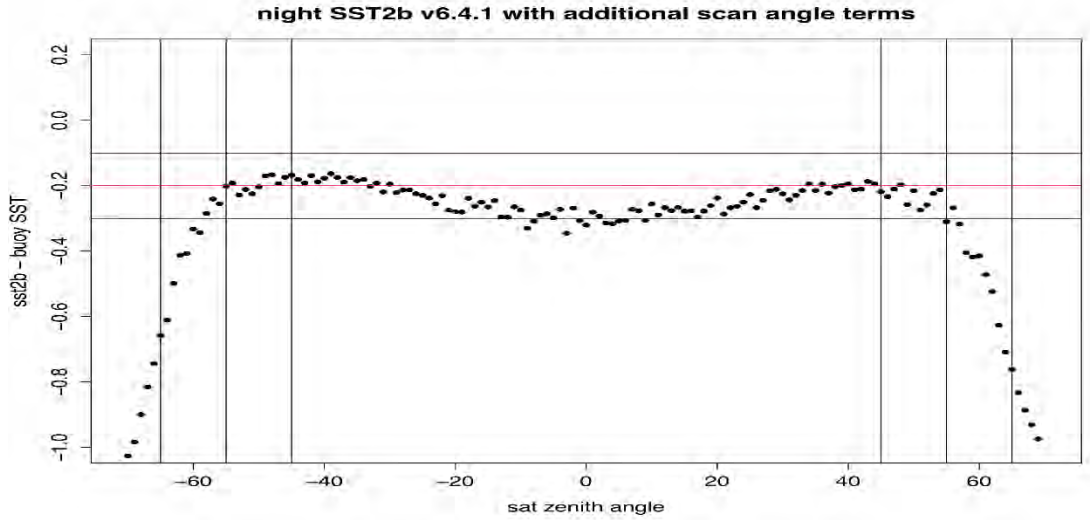

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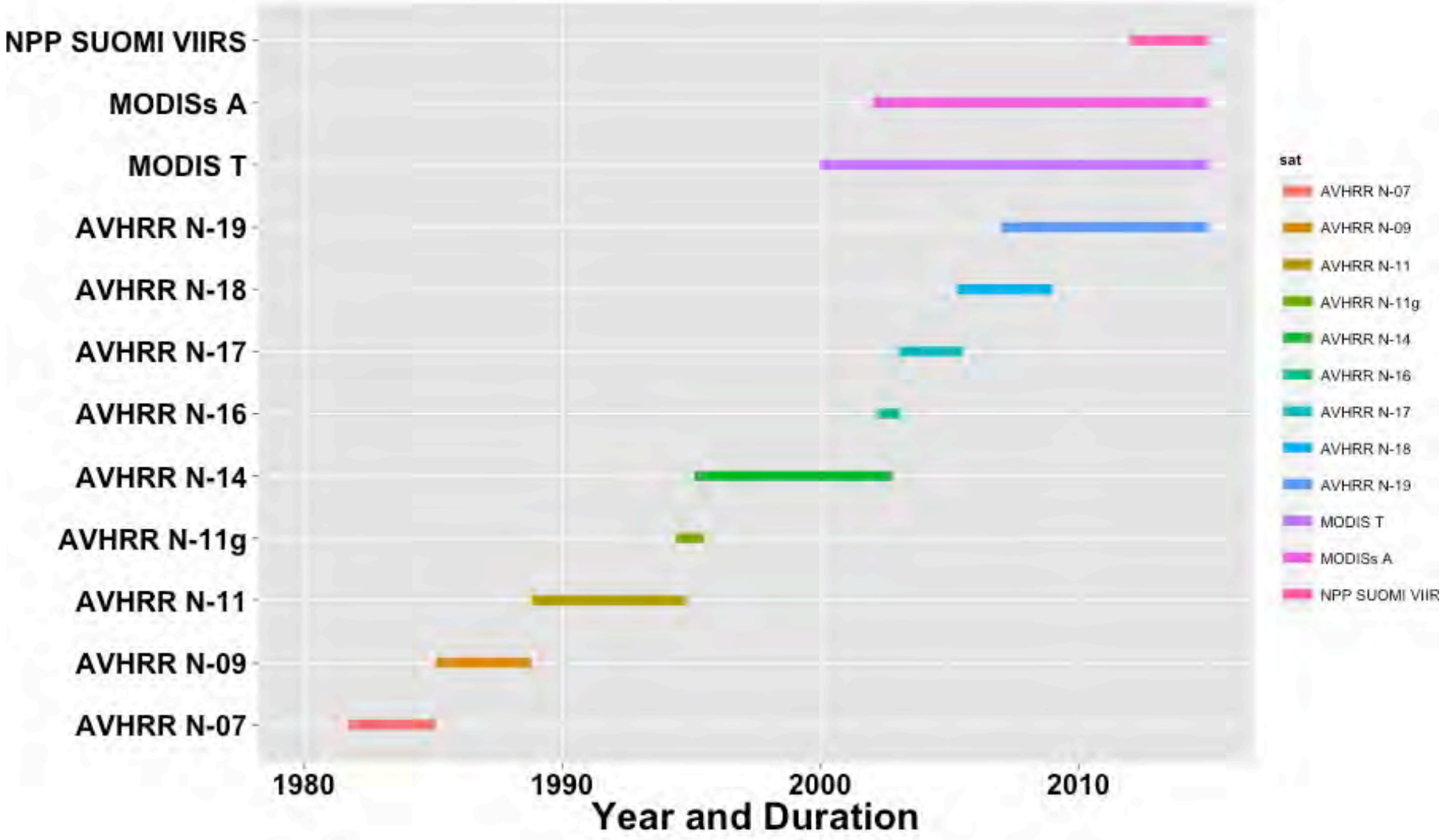
NOAA and NASA IR broad swath sensors in CDR 1980-current



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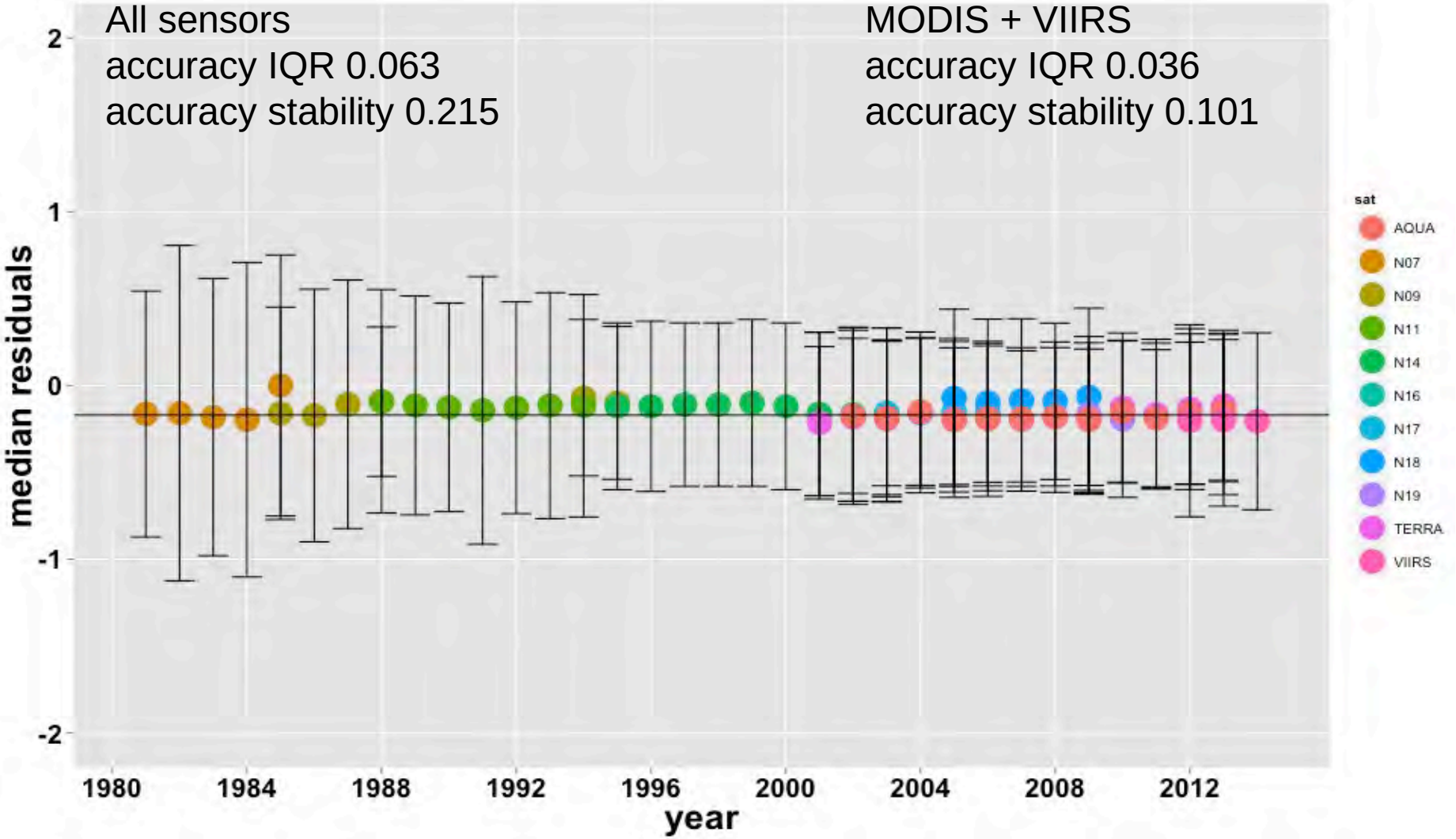
Afternoon Equatorial crossing times 0130-0230 except N17

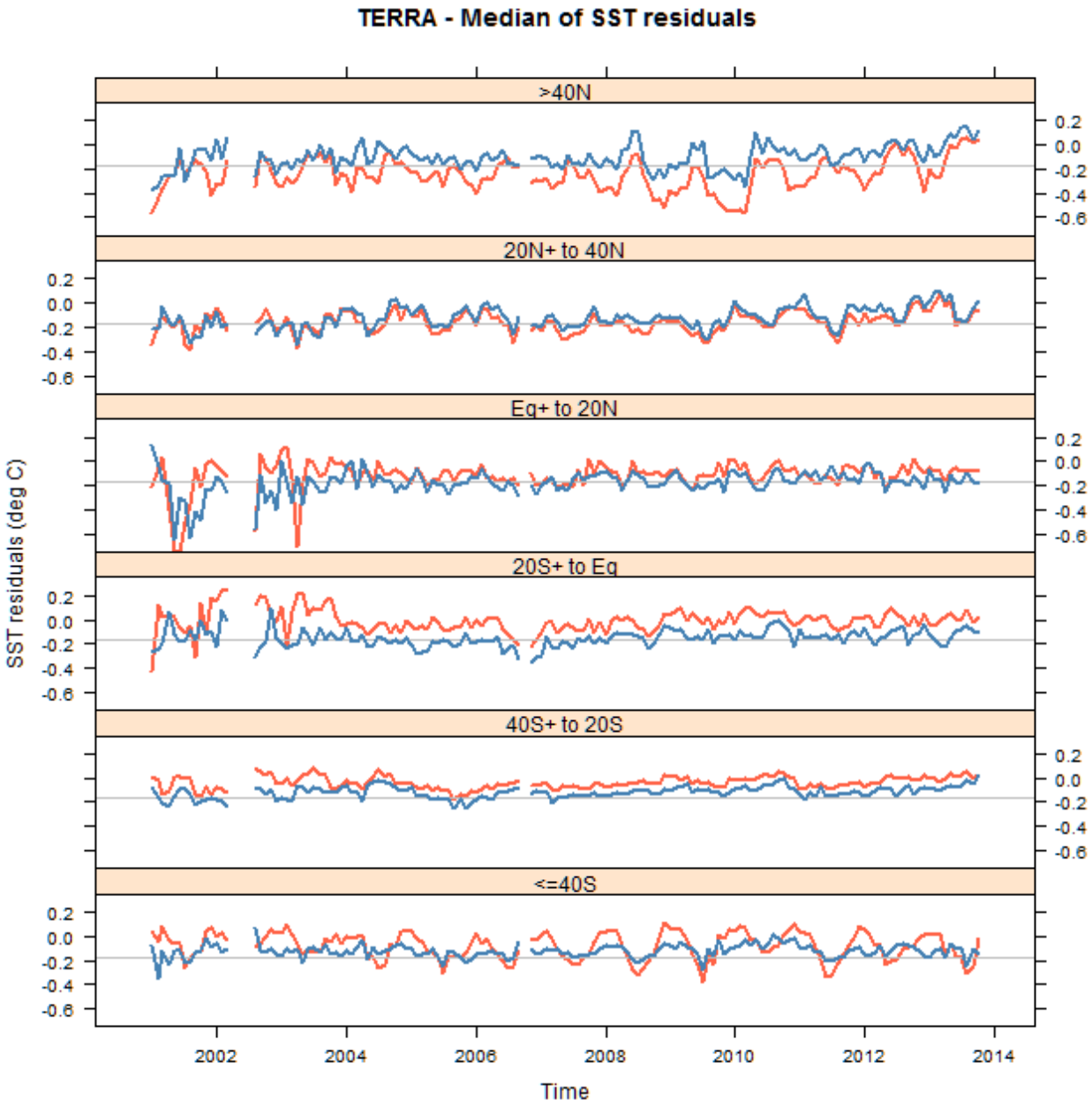
Consistent Record

Bias and Standard deviation all sensors 1980-2014 from buoys



Latitude band coefficients

Red- V5 Blue- V6 latband



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Summary

- Global accuracy is 0.1 relative to buoys, 0.05 to skin
- Global year to year stability over 30 years of 0.2 (0.1 since 2000)
- SI traceability and new MAERI MK-3 are deployed in under sampled problem atmospheres
- Accuracy at higher viewing angles work in progress (alternative algorithms)
- Accuracy limitations particularly at high latitudes
- Reprocesses SST CDR VIIRS data available NASA OBPG SIP available Spring/Summer