Miami Update:
VIIRS Sea-Surface Temperatures:
pathways for improvements

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NOAA JPSS annual VIIRS SST Science Team Meeting
11 August 2016 Greenbelt, MD

Focus of studies

- VIIRS Continuity with heritage sensors
- Improving and evaluating algorithm performance at higher viewing angles
    - Response versus scan angle corrections
- Sensor validation
    - Analysis of global fields and matchups with in situ data from NOAA IQUAM.
- Improving Cloud screening algorithms
    - machine learning ensemble algorithms
- Impact of Sampling Bias in gridded Level 3 products

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Algorithm Continuity

- Coefficients tuned to atmospheric conditions
  - AVHRR Pathfinder wet/dry atmospheres monthly
  - C6 MODIS/VIIRS – latitude and month of year

- Extend retrievals towards edge of VIIRS & MODIS swaths

$$\mathrm{SST}_{sat} = a_0 + a_1 T_{11} + a_2 (T_{11} - T_{12})\, T_{sfc} + a_3(\sec(\theta)-1)(T_{11\mu m} - T_{12\mu m}) + a_4(\mathrm{mirror.side}) + a_5(\theta) + a_6(\theta^2)$$

- Cloud/anomalous atmosphere detection

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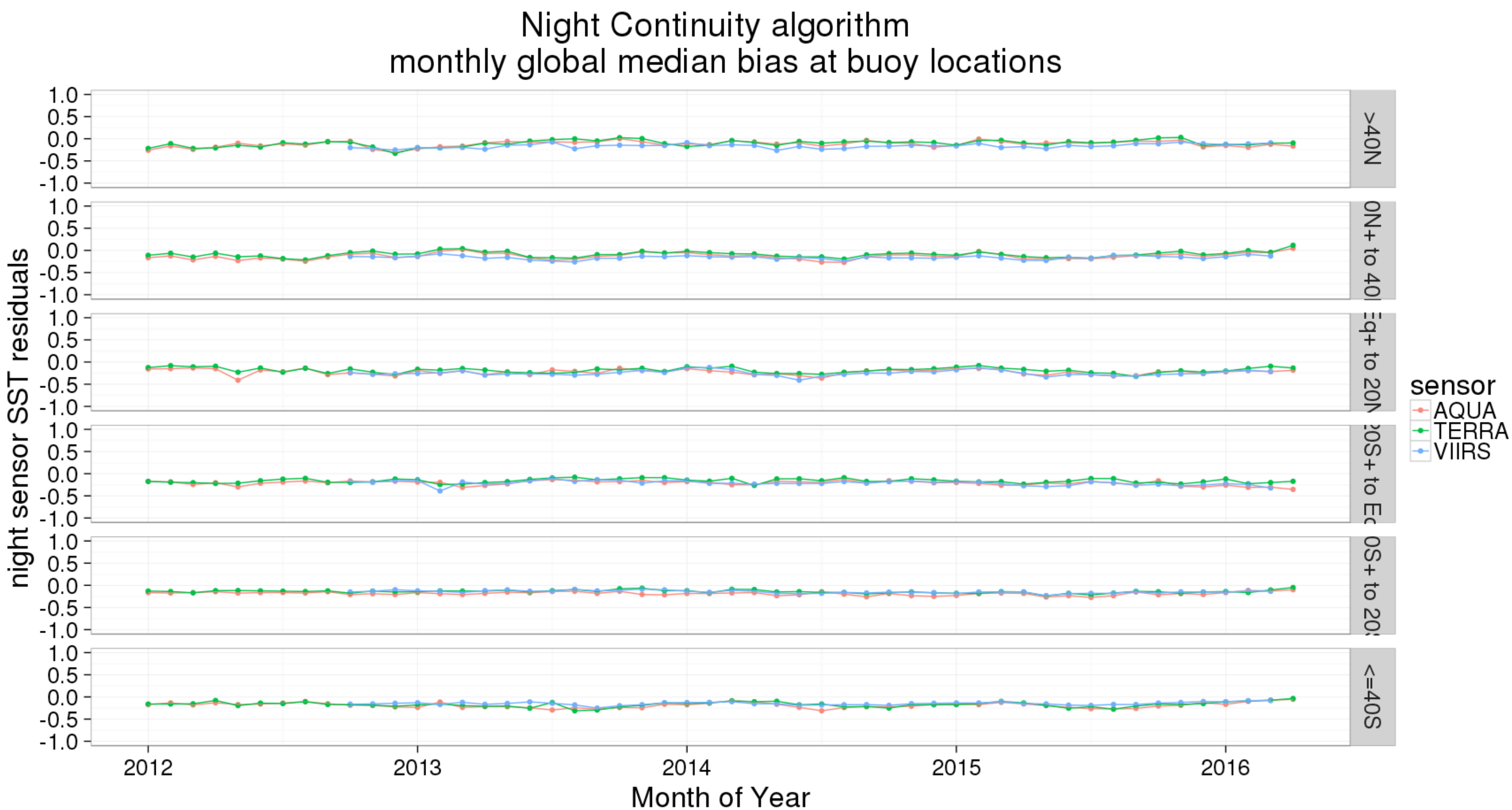
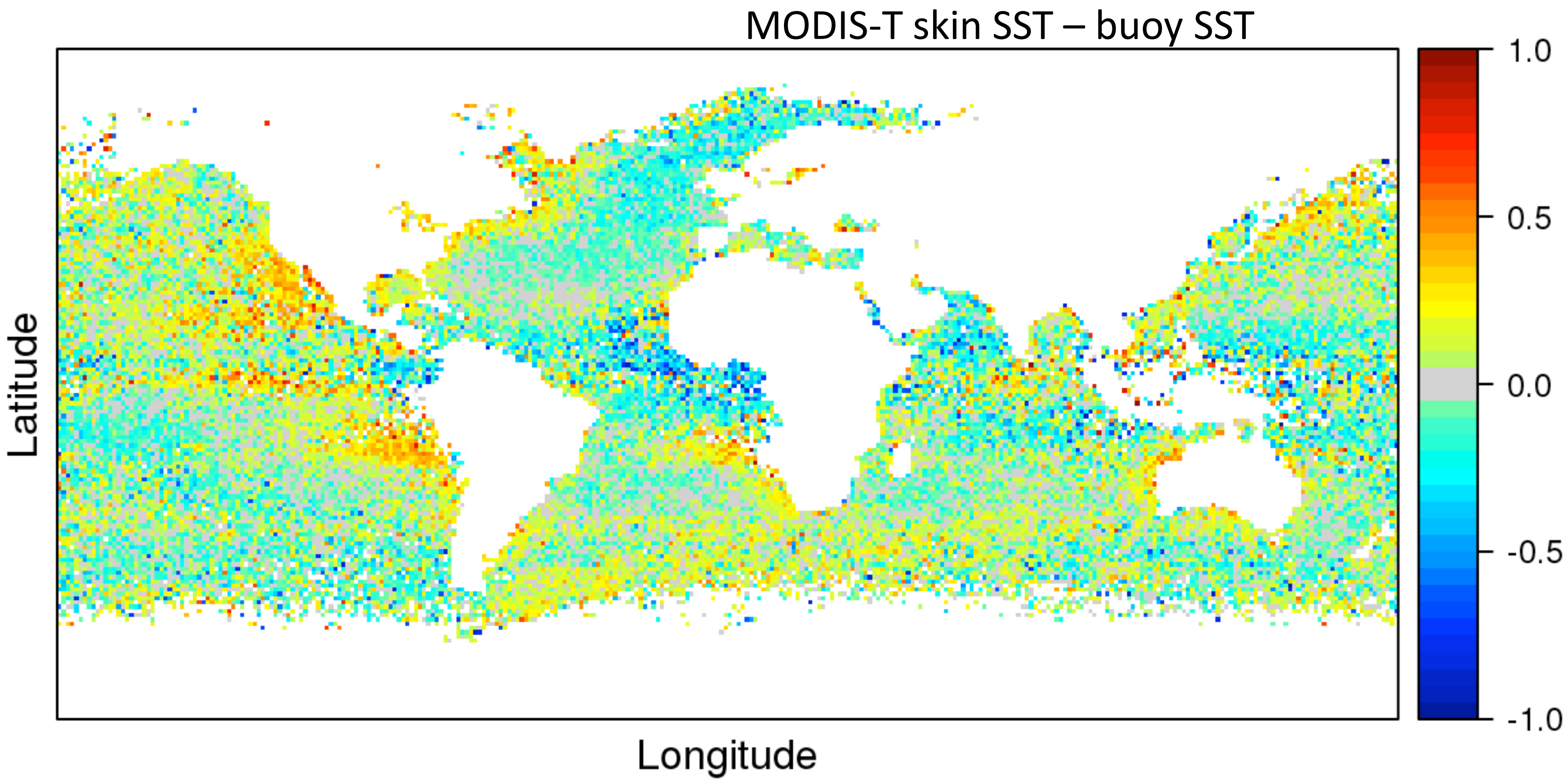
VIIRS residuals consistent with MODIS A&T



Regional versus global accuracy
1km matchups +- 30 minutes of over pass

MODIS TERRA mean 16 year average 1 degree resolution



1 degree resolution grid

Cloud mask

- IR algorithms are only accurate in cloud free and atmospherically "clean" pixels

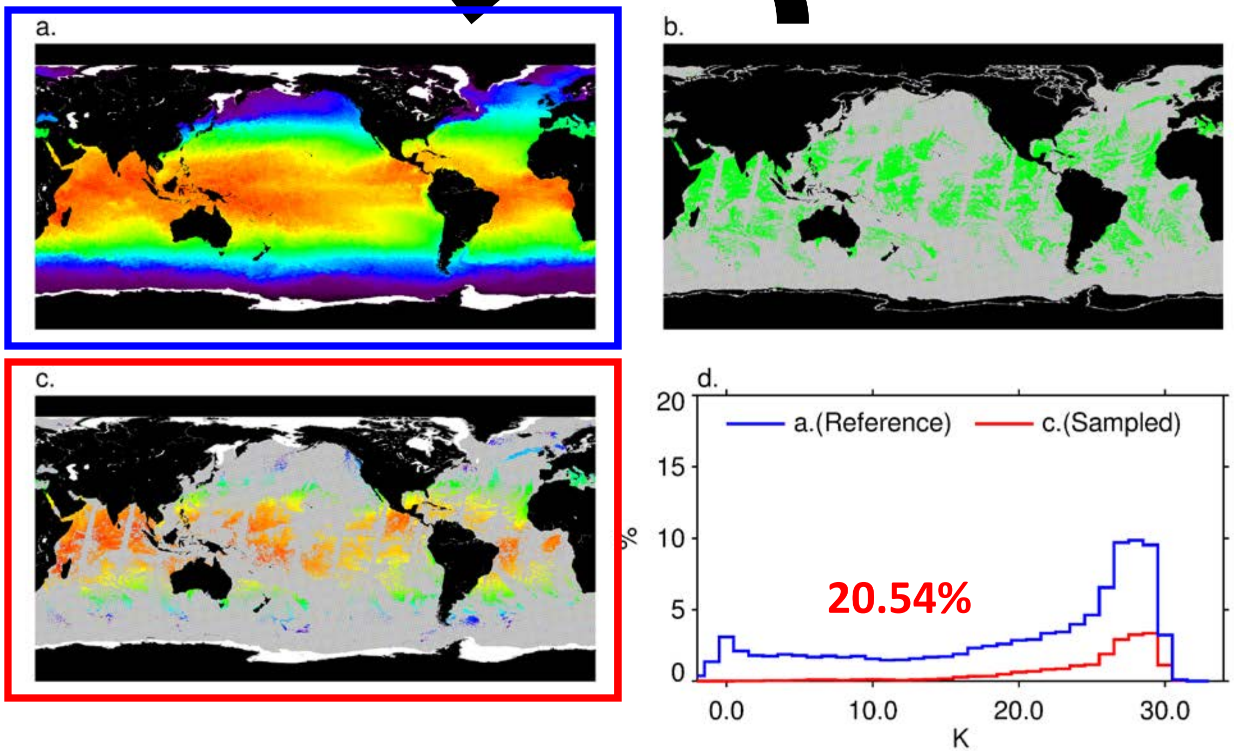
- Decision Tree misclassification errors.
  - Sensitivity versus specificity
  - Good classified as bad and bad classified as good.

- Persistent clouds and differences in ability to detect clouds between day and night can impact sampling/binning of higher level products.
  - Differences in gap free fraction

- Ensemble classification using boosting and alternating decision trees (ADTree) methods reduce both the gap fraction and misclassification errors.

L3 Method used to evaluate sampling bias and cloud mask

MUR



MODIS 4km-daily L3 Cloud mask

D: SST mask

N: SST4 mask

MUR Sampled by MODIS

1 day… 4km map

Base resolution

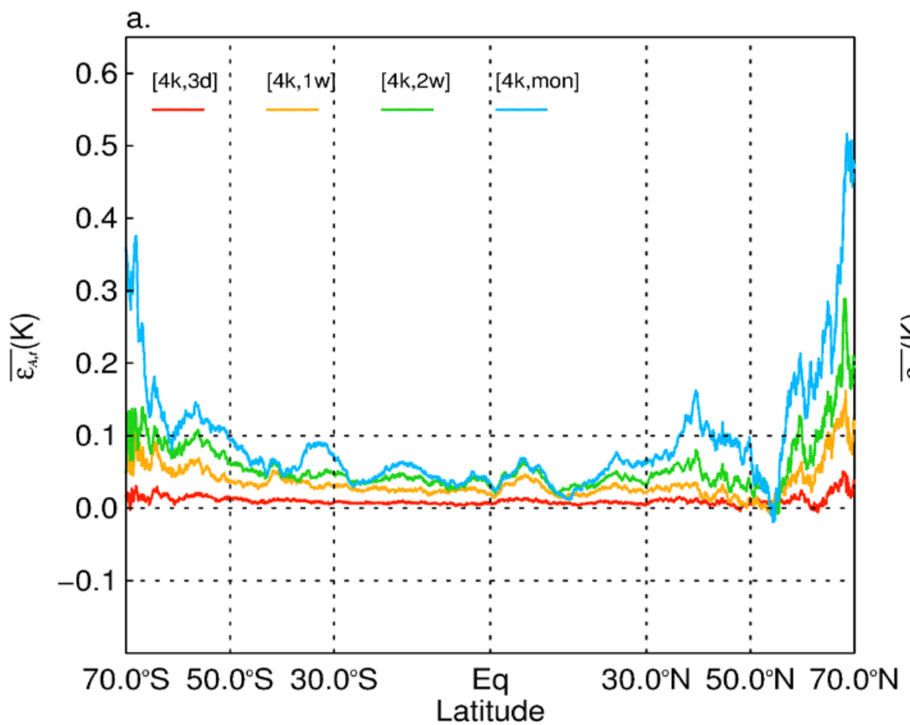
Averaging

Temporal: 3d,1w,2w,mon

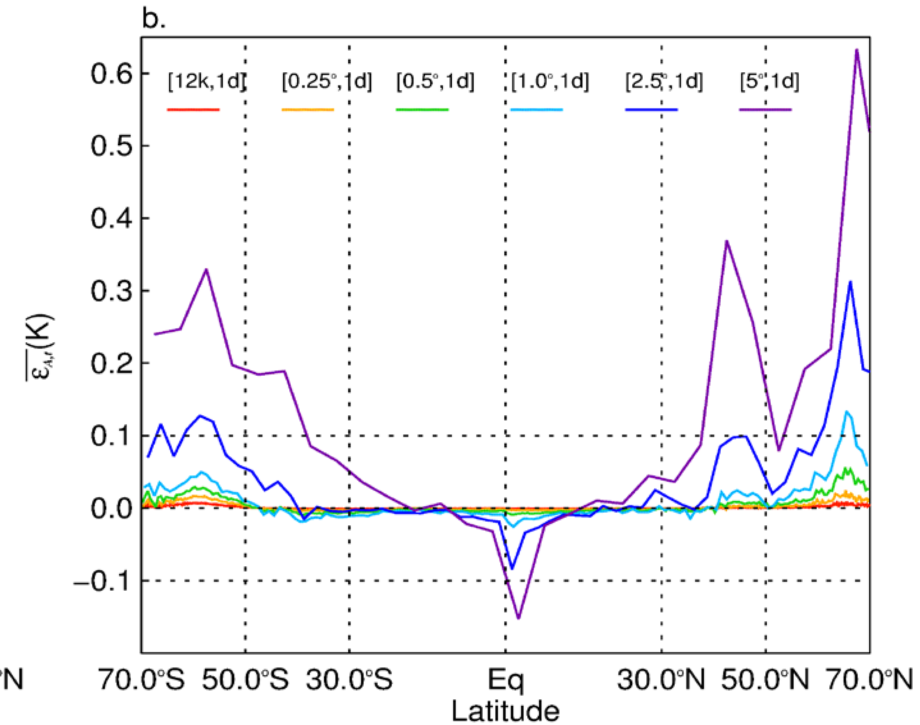
Spatial: 12k, 0.25°,0.5°,1°,2.5°,5°

MODIS SST Zonal Mean
Sampling error

Temporal



Spatial



Mean of the 4 months data

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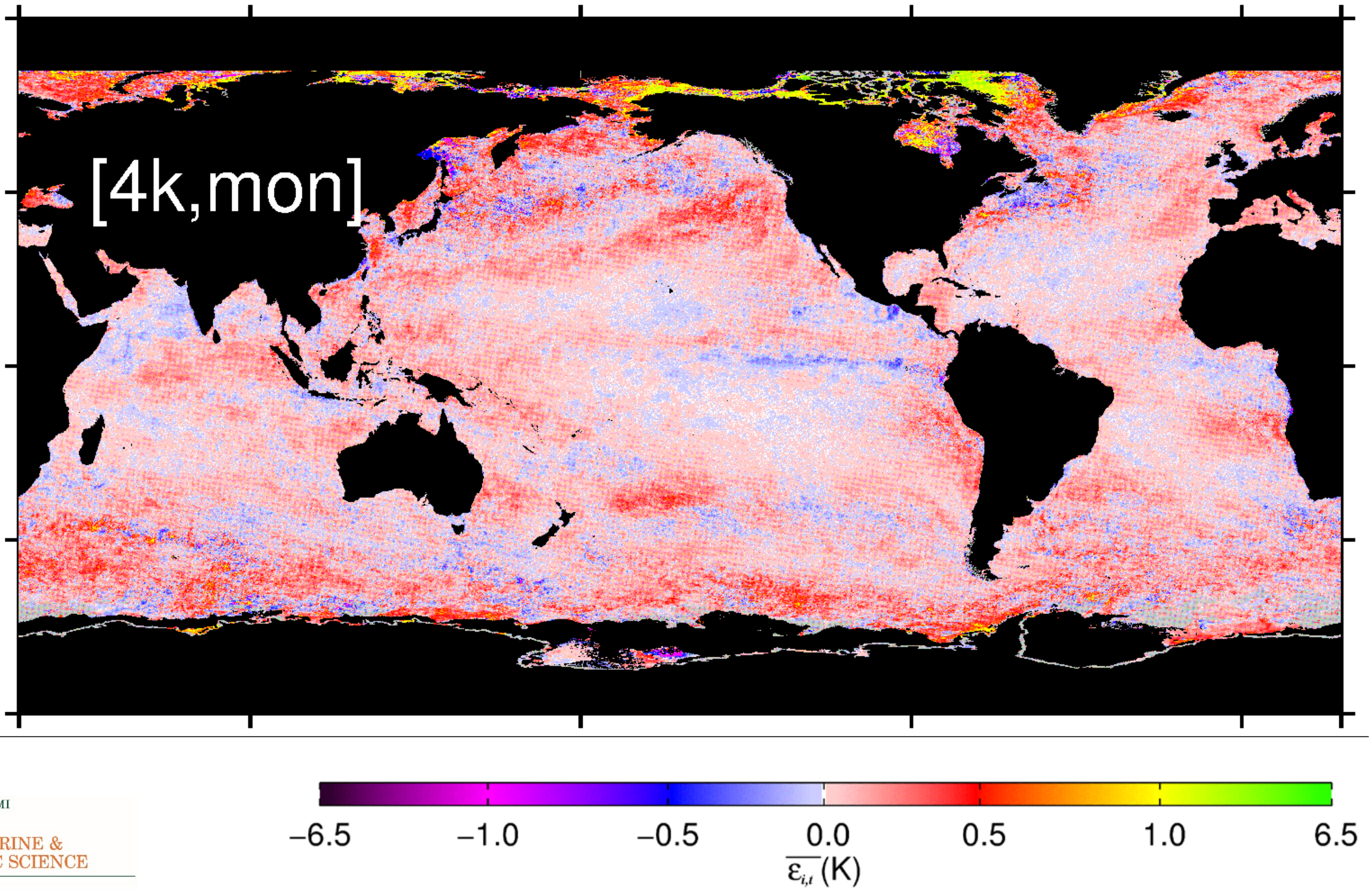
Temporal averaging MODIS SST Difference from MUR

Mean of the 4 months data

a.



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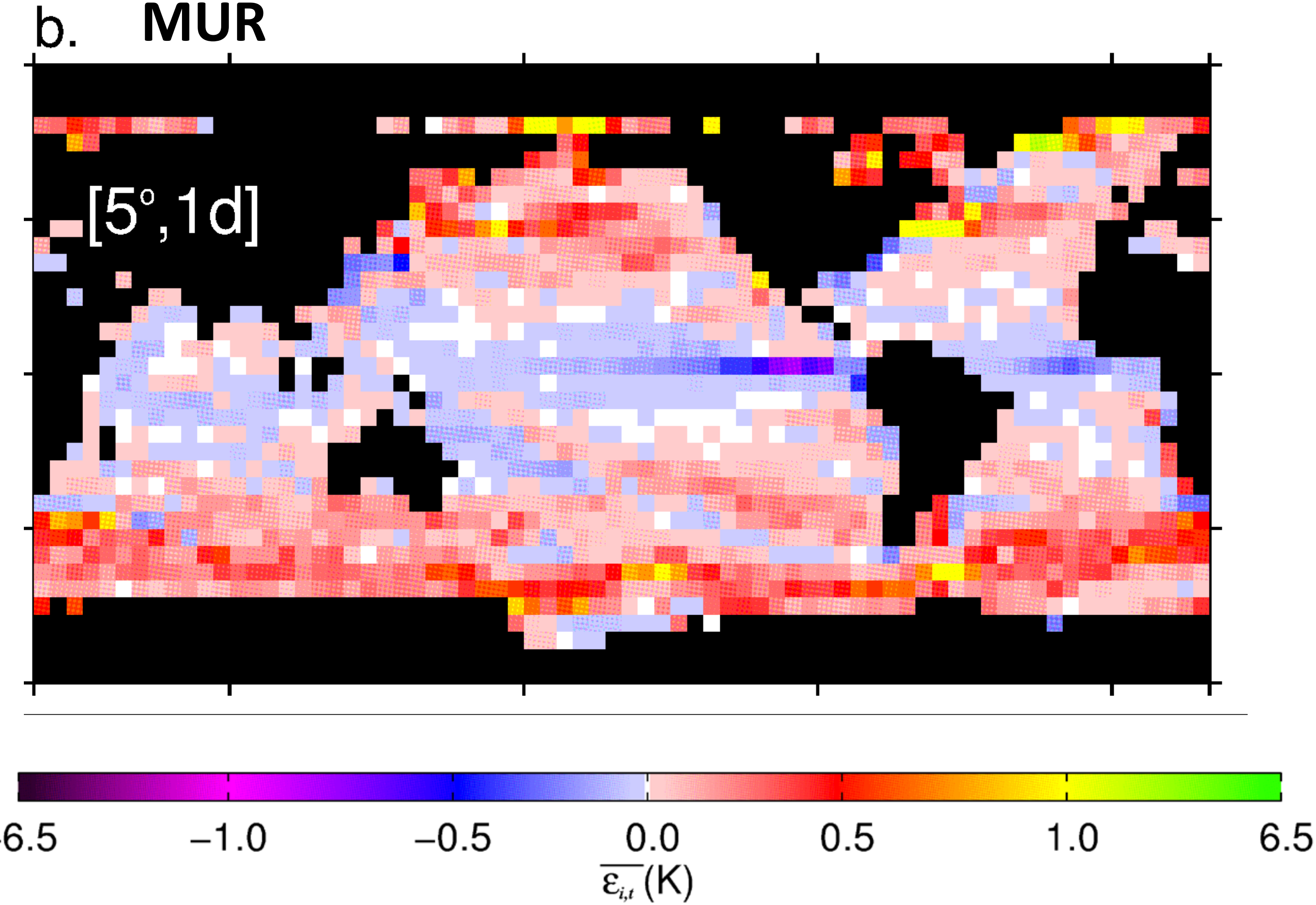
Spatial averaging Difference from MUR

Mean of the 4 months data



Improved cloud classification for VIIRS reduces sampling bias compared to products from heritage sensors

Alternating Decision Trees * are an ensemble collection both weak and strong classifiers with each binary decision nodes ending with a prediction node containing vote. Each vote is scaled to the predictive power of the test.

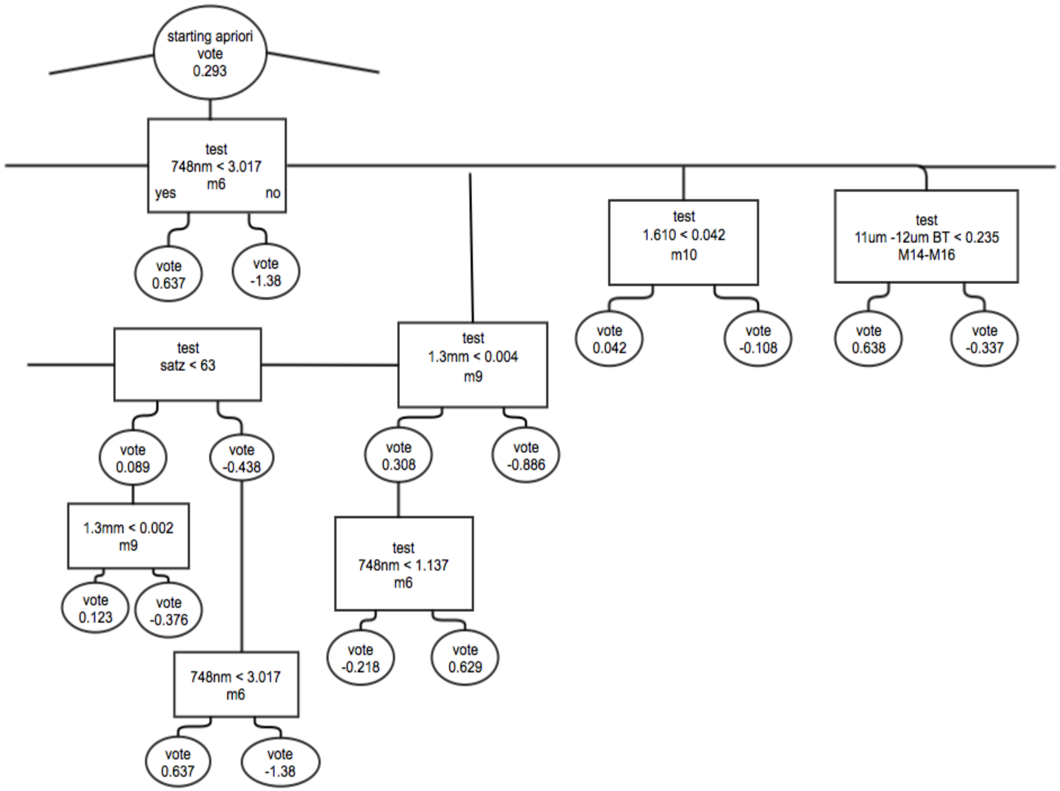
The combined vote from a collection of weak prediction nodes when voting together as a block can modify or over ride the vote of a single strong prediction node.

Combined with boosting algorithms a very accurate ensemble classification model can be developed.

* Freund and Mason 1999, Pfahringer et. al . 2001)

Branch of SST ADTree cloud classifier

(crowd sourcing classification with the help of experts)



Classification is based on sum of community vote across all tree stumps and branches.

A positive sum is classified as good/clear and a negative is bad/cloud. The absolute magnitude of the sum provides an estimate of the confidence in the classification.

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Classifier Ensemble Vote

An ensemble of 4 Alternating Decision Trees classifiers were trained to classify VIIRS SST retrievals as either clear or cloudy, using 10 fold-cross validation and boosting. The training sets consisted of a subset of randomly selected records in the VIIRS buoy Matchup Database (MUDB).

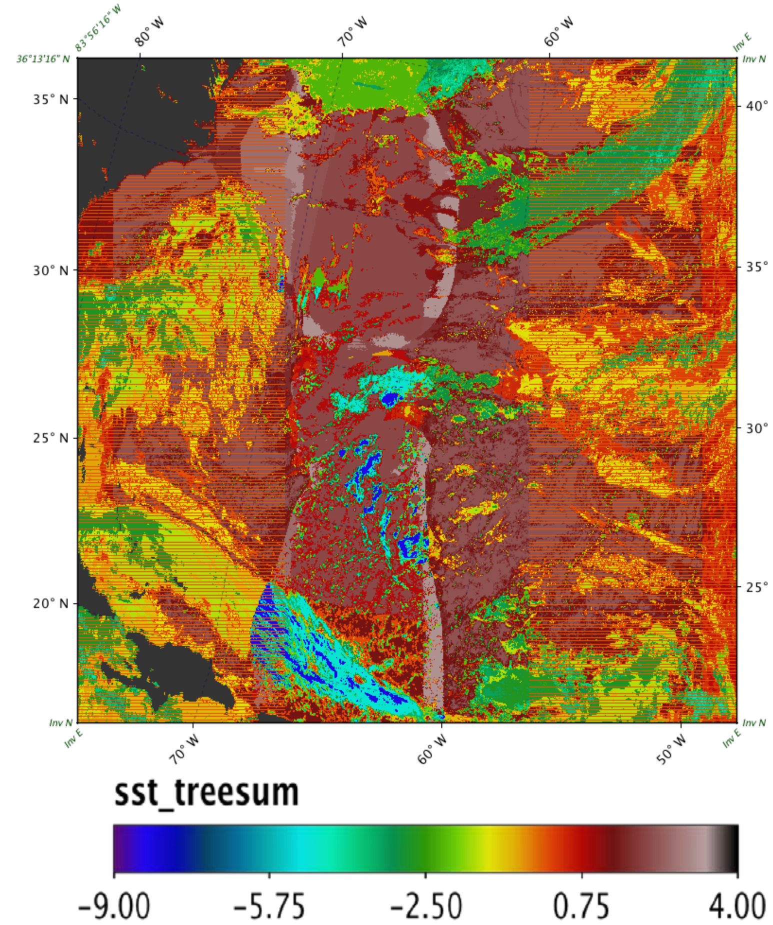
Classification model cases:

- ❖Night
- ❖Day non glint coeff < 0.005
- ❖Day moderate glint coeff 0.005 - 0.01
- ❖Day high glint coef > 0.01

~ 30-40 nodes/leaves for each model

classification model validation data set:

Correctly Classified	29732	91.0015 %
Incorrectly Classified	2940	8.9985 %



+ confidently clear
- Confidently cloudy

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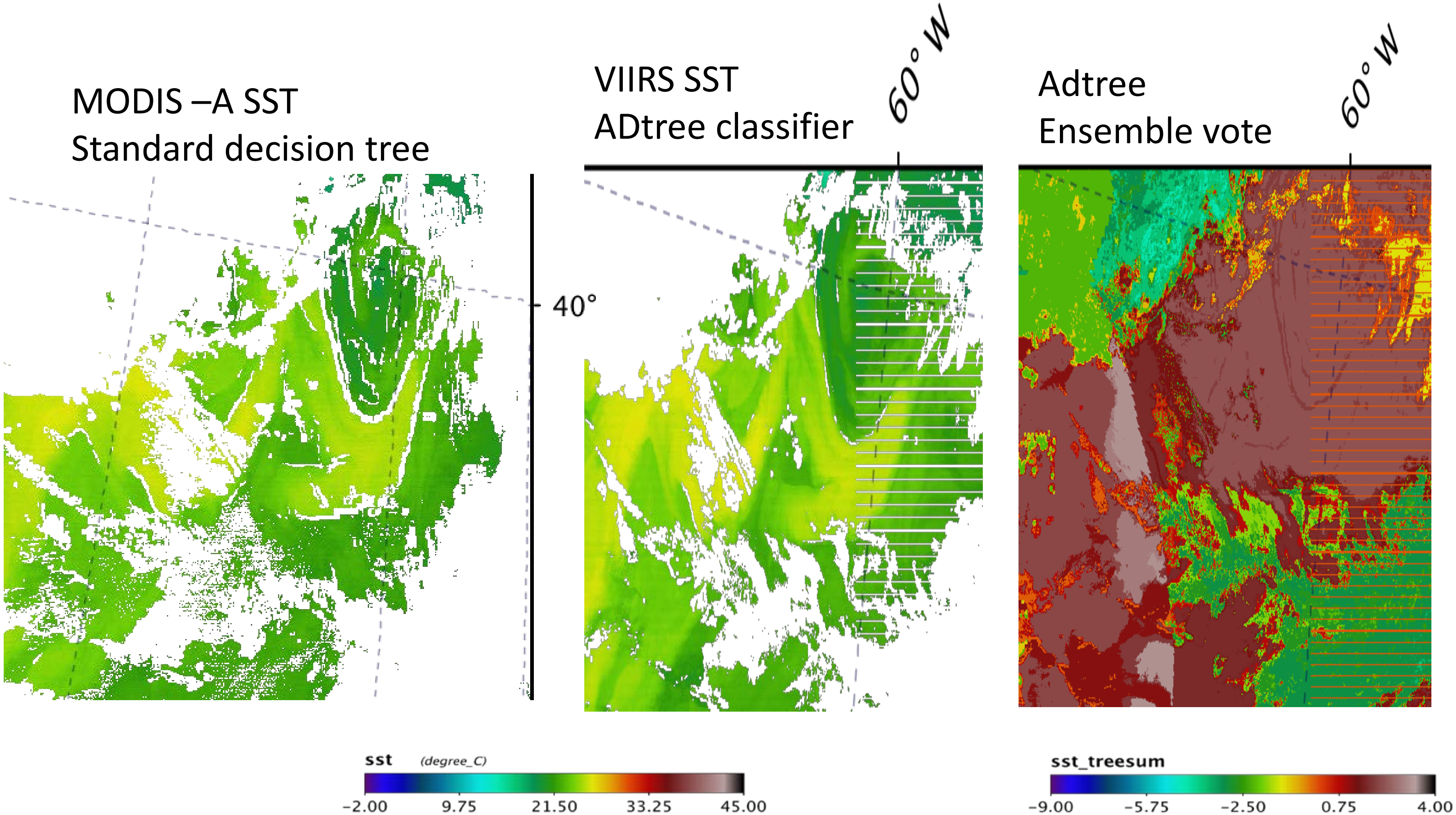
Ensemble of ADTree classifier improves retention of good quality pixels at frontal boundaries



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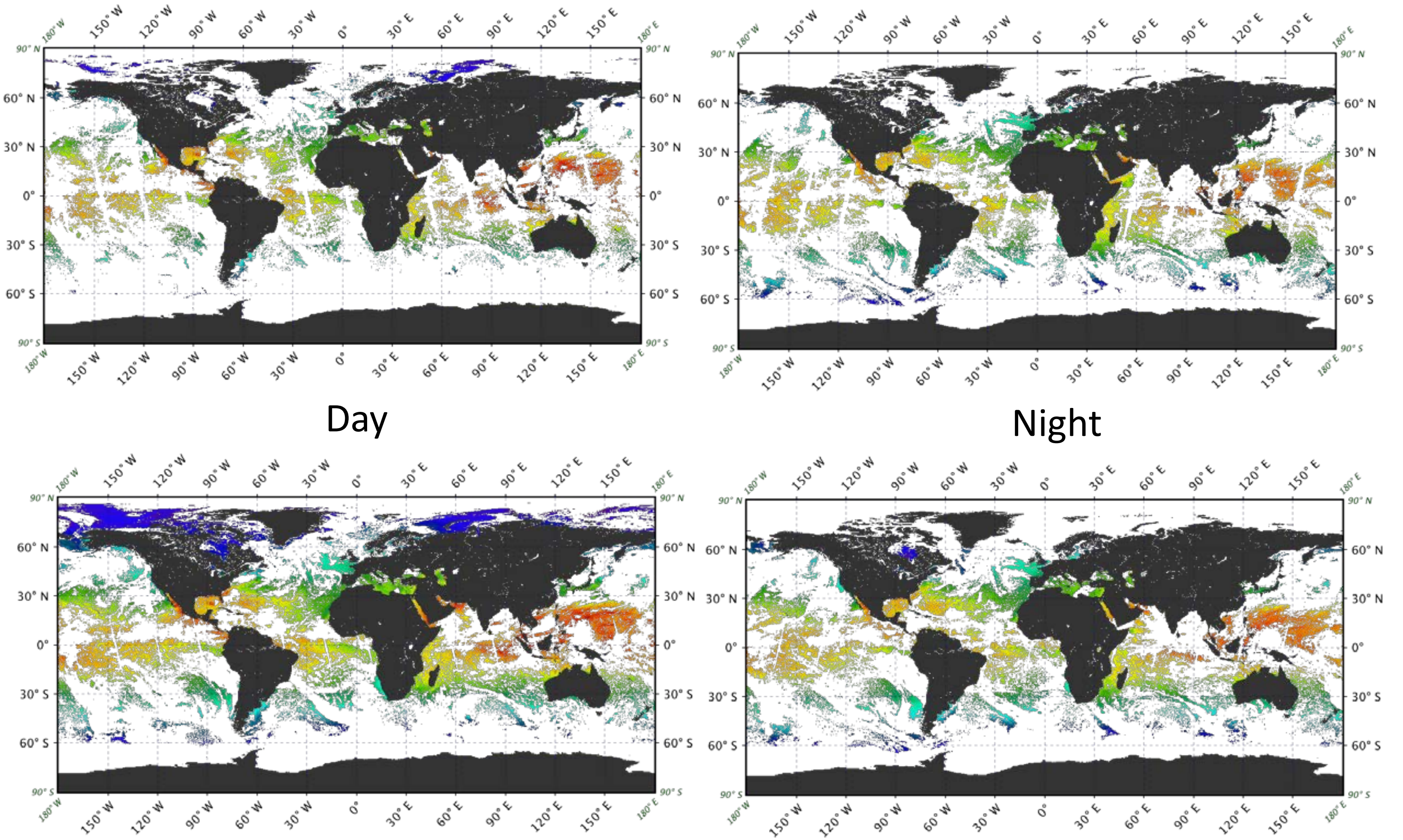
June 19 2014 L2 over Gulf Stream

Ensemble ADTree classifier Increases number of valid retrievals

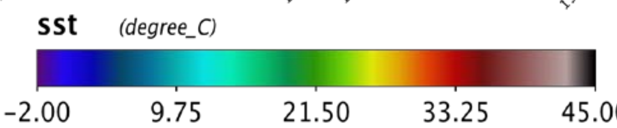
MODIS-A

VIIRS



Day

Night



June 19 2014

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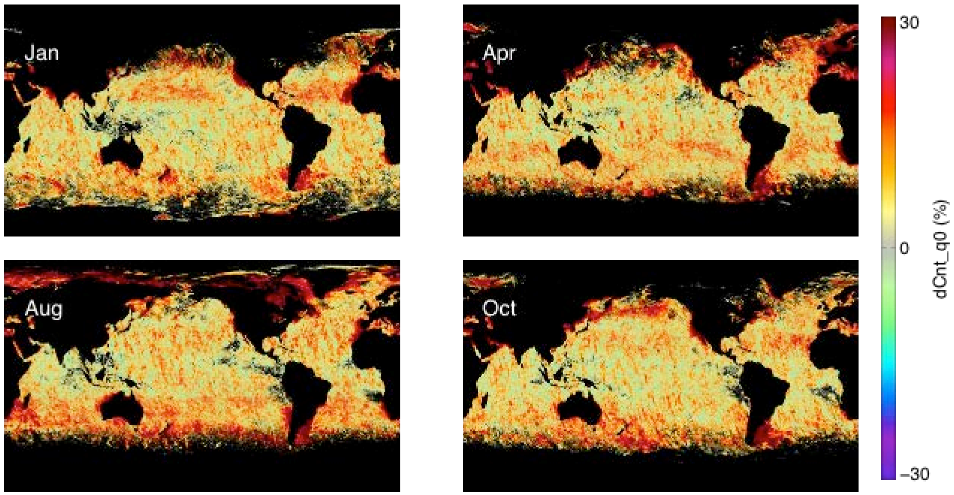
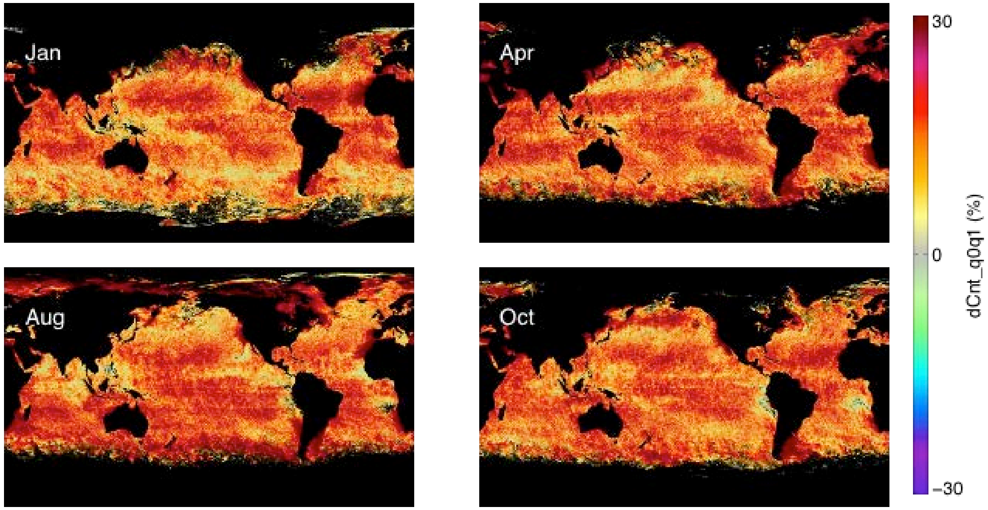
Difference in Miami cloud free fraction
Best quality VIIRS – MODIS-A 2014

V6 V_SST – A_SST : Cnt_q0 (%)(q0)



Scan angles < 55

Full swath



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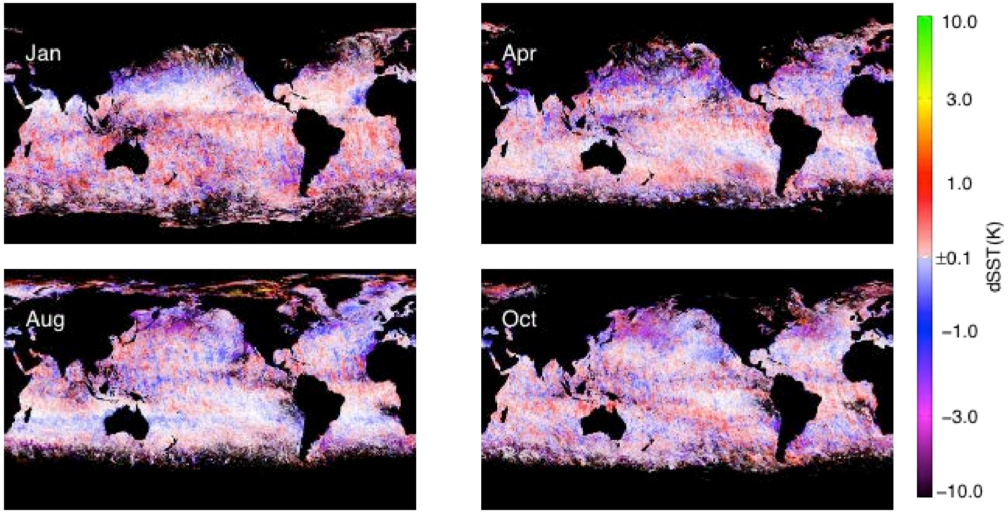
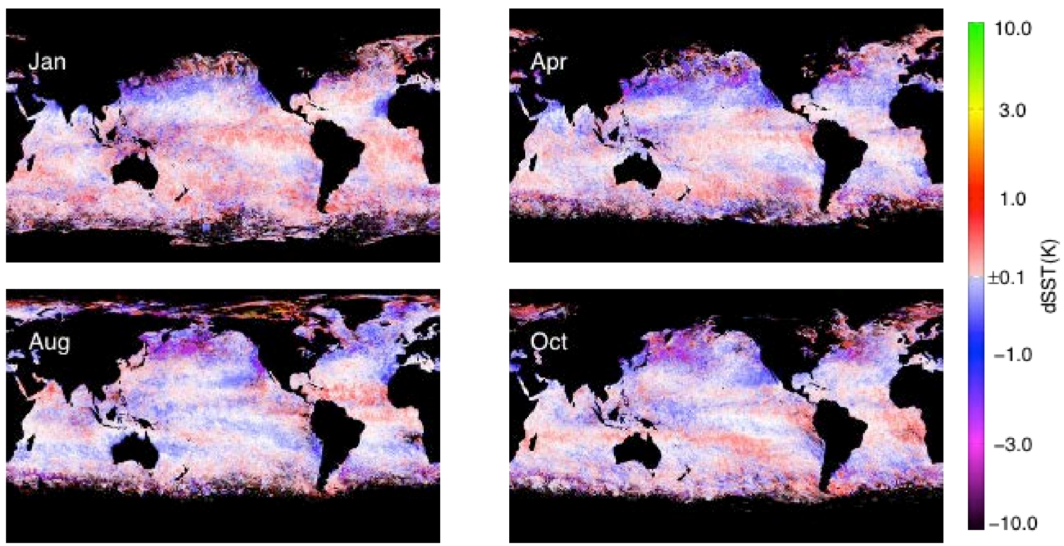
Monthly 4km SST difference VIIRS ADtree cloud mask-MODIS-A

Scan angle < 55 degrees quality 0



VIIRS L3 is often cooler than MODIS-A in regions where MODIS A showed a warm sampling bias relative to MUR and the converse warmer for persistently cloudy regions



Full swath quality 0 and 1

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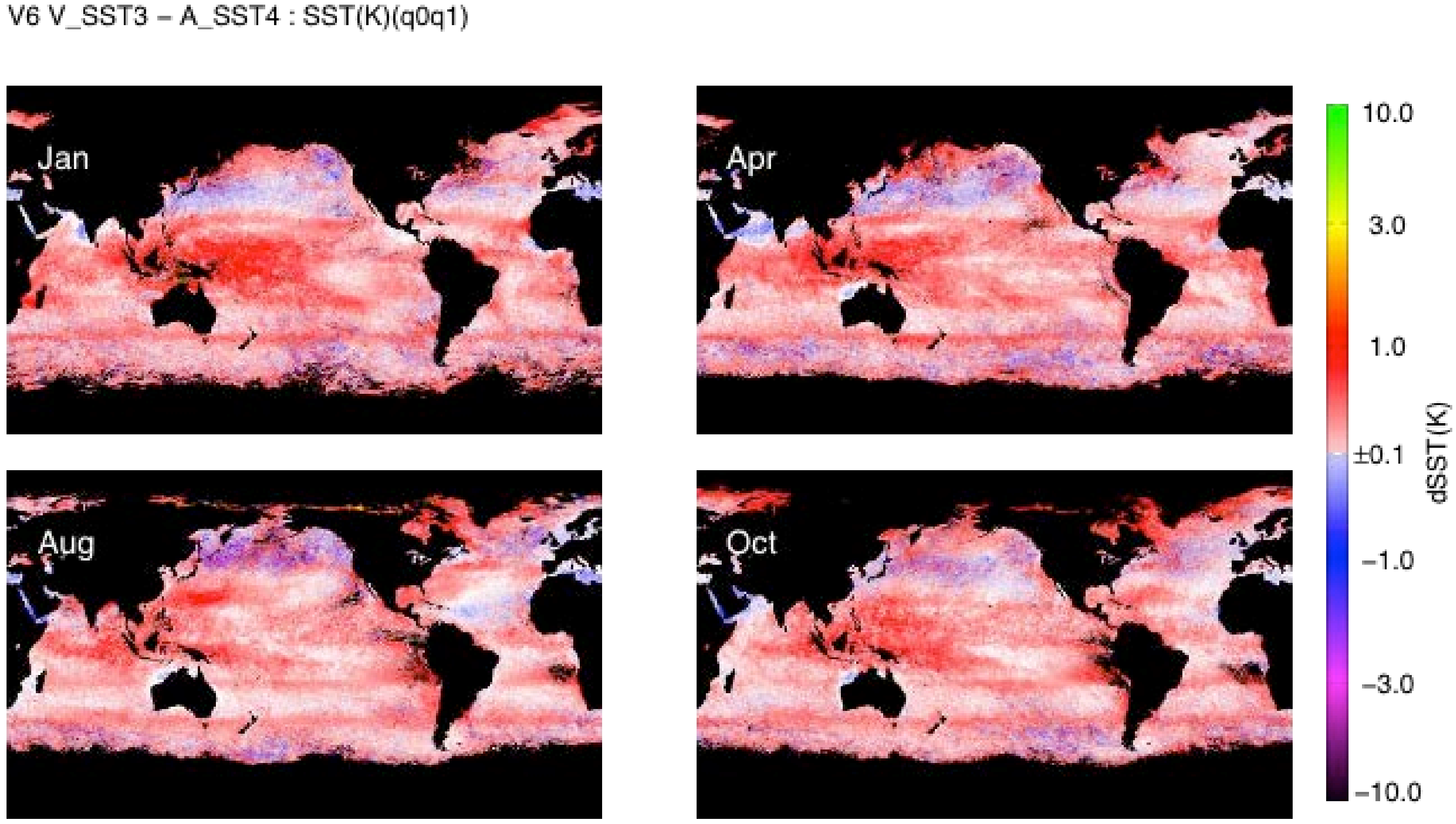
Full swath comparisons VIIRS 3band-MODISA 4um



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Summary

✓Continued excellent agreement at 1km between VIIRS LWIR SST and both MODIS sensors using an NLSST continuity algorithm

✓VIIRS Cloud identification using an ensemble of Alternating Decision Trees reduces misclassification in frontal zones and cloud edges

✓Increased number of valid retrievals at 1 km better captures SST geophysical variability reducing L3 sampling bias in IR SST products

✓Together MODIS, VIIRS and NOAA PFSST produce 36 years of consistently processed SST

Buoy SST accuracy characterization

Is the accuracy and stability of buoy SST measurements good enough for Satellite SST CDR validation?

- Study calibration drift and accuracy over a 1 to 2 year deployment in Bear cut

- 1-2 years of monthly comparison to thermometers calibrated against the RSMAS black body

- 12 moored buoys - 3 each of 4 designs
    - 3 designs SIO
    - 1 design NOAA/AOML

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Thank you.

VIIRS Alternating decision tree Model for day non glint:

Instance where the Glint coef < 0.005
Decision node:vote += confidence good clear -= confidence bad cloud
Final sum votes all TRUE nodes <0 flag as cloud
Tree size (total number of nodes): 46

: 0
| (1) rho 1610 < 0.16: 0.805
| | (2) rho 748 < 0.062: 0.393
| | | (3)rho 1380 < 0.004: 0.287
| | | | (9)BT deficit 11um < 0.002: -0.681
| | | | (9)BT deficit 11um >= 0.002: 0.026
| | | | | (13)rho 748 < 0.039: 0.364
| | | | | (13)rho 748 >= 0.039: -0.21
| | | (3)rho 1380 >= 0.004: -1.244
| | (2)rho 748 >= 0.062: -0.572
| | | (5)min rho 610 5x5 box < 0.032: 0.455
| | | (5)min rho 610 5x5 box>= 0.032: -0.395
| | (4)sensor zenith angle < 64.994: 0.216
| | | (8)rho 1380 < 0.007: 0.065
| | | (8)rho 1380 >= 0.007: -1.077
| | (4)sensor zenith angle >= 64.994: -0.708

| (1)rho 1610 >= 0.16: -1.755
| | (6)rho 1610 < 0.266: 0.642
| | (6)rho 1610 >= 0.266: -0.19
| | | (14)max-min rho 678 5x5 box < 0.103: 0.425
| | | (14) max -min rho 678 5x5 box >= 0.103: -0.195
| | (10)11um-12um BT < 0.235: -0.189
| | (10) 11um-12um BT >= 0.235: 0.411
| | (15)water vapor NCEP Kg/m2 < 2.946: 0.038
| | (15) water vapor NCEP Kg/m2 >= 2.946: -1.137
| (7)max -min 11um BT 5x5 box < 0.762: 0.156
| (7) max -min 11um BT 5x5 box >= 0.762: -0.188
| (11) water vapor NCEP Kg/m2 < 1.315: 0.327
| (11) water vapor NCEP Kg/m2 >= 1.315: -0.054
| | (12)sst < 278.171 K°: -0.679
| | (12)sst >= 278.171 K°: 0.05

rho= visible band reflectance BT= brightness temperature K

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