Comparison of VIIRS SST fields obtained from differing SST equations applied to a region covering the Northern Gulf of Mexico and Western North Atlantic.

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ABSTRACT

The Several groups produce Sea Surface Temperature (SST) retrievals derived from data acquired by the Visible Infrared Imaging Radiometer Suite (VIIRS) sensor on-board the S-NPP satellite. Because of varying requirements or history, the groups often use differing SST equations to make their SST retrievals. Here we compare and discuss the equations through an examination of the SST fields. In most cases, the fields are created using the same program but differing equations, while in other cases, such as for the Interface Data Processing Segment (IDPS) Environmental Data Records (EDR), the SST fields are directly produced by other groups. Also discussed is the effect of the equation coefficients because independent groups may use the same equation but with different coefficients The focus of this study is on a region covering the Northern Gulf of Mexico and part of the Western North Atlantic. The comparison to buoys tries to minimize the effect of data contamination such as clouds on the results by matching the best satellite derived SST value in a neighborhood to the value from drifting or moored buoys. Finally we look at the overlap between consecutive passes to evaluate how the various equations perform at higher satellite zenith angles.

keywords: SST, VIIRS, NAVOCEANO, cloud mask, NCM, VCM

1. INTRODUCTION

Sea Surface Temperature (SST) retrievals derived from data acquired by the Visible Infrared Imaging Radiometer Suite (VIIRS) sensor on-board the S-NPP satellite are produced using a number of SST equations. This study examines the effect on the produced SST fields of daytime SST equations that are or were used by the Naval Oceanographic Office (NAVOCEANO), NOAA/STAR, Météo France, the Integrated Data Processing Segment (IDPS) and the University of Miami. For the Météo France equation, coefficient values from NAVOCEANO, NOAA and Météo France are tested. To match a scene provided by the University of Miami, the region in this study covers the Northern Gulf of Mexico and part of the Western North Atlantic for a daytime scene which was captured on May 14, 2013. We attempt to validate the SST fields by comparing the satellite derived values with those of drifting or moored buoys. We also examine the end of scan region as it is the area where results of the SST equations differ most. Analyzing the difference in temperature at the overlap between swaths provides insight on how well the various equations and coefficients combinations perform at higher satellite zenith angles.

2. SST EQUATIONS

All the SST equations that are examined here are Non Linear (NL) SST equations that are applicable to the production of daytime SST retrievals. Usage status and coefficient values were those in effect as of November 2013. For all equations, the a_n parameters are coefficients which are usually derived by regression to buoy temperature data, θ is the satellite zenith angle, T_f is the first guess, or previous day SST field, and, T_{11} and T_{12} are the brightness temperatures at the 10.8μm and 12μm wavelengths.

The first equation, eq. (1), was designed to perform at a satellite zenith angle of less than 53°. Performance degrades rapidly of at higher satellite zenith angles. A particularity of eq. (1) is that to maximize the accuracy of the equation, T_f has to be expressed in degrees Celsius when deriving its coefficients. This equation is used for the IDPS EDR SST and University of Miami “Lat Band” algorithm.

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(1)

The second equation, eq. (2) addresses the issue of the dependence of eq. (1) on the unit on which T_f is expressed . In effect, eq. (1) relied on an implicit 273°K offset to T_f. Introducing the a_3 parameter makes the offset explicit and allow for optimization. This equation, NL53deg is the current operational equation at NAVOCEANO. Of note is the fact that the coefficients of eq. (2) are derived on domain limited to a satellite zenith angle of less than 53°.

(2)

The next two equations add satellite zenith angle terms to eq. (2).Both equations are similar and differ by only one term: Eq (3) which was developed at NAVOCEANO adds the a_6 and a_7 terms to eq. (2) while eq. (4), which was developed by Météo France for EUMETSAT Ocean & Sea Ice Satellite Application Facility (OSI SAF) SST, adds the a_6 and a_1 terms. Eq.(3), “NL+2”, is currently being tested at NAVOCEANO.

(3)

Eq. (4), NLC (“NL Complete” as opposed to truncated forms of the NL equation), is currently used by Météo France and by the Advanced Clear Sky Processors for Oceans (ASCPO) at the National Oceanic and Atmospheric Administration (NOAA) Center for Satellite Applications and Research (STAR). It is also being tested at NAVOCEANO.

(4)

3. SST FIELDS

The region under consideration covers an area from 96W to 71W and 20N to 33N which includes most of the Northern Gulf of Mexico and part of the Western North Atlantic. The daytime SST fields include data from two successive Suomi NPP orbits that were acquired on May 14, 2013 between 17:31 UT and 17:42 UT, and, between 19:13 UT and 19:25 UT. To create the fields, the full swath SST data are regridded into an equirectangular projection at a resolution of approximately of 1.5 km. Multiple SST retrievals that fall in a single grid cell are simply averaged together to obtain the SST value at the grid cell. This last point is particularly important for the region, around Florida, where the satellite swaths for the successive orbits overlap.

SST fields created with the NL53deg, NL+2, and NLC SST equations were all produced at NAVOCEANO with same minimal cloud detection. Coefficients derived at NAVOCEANO, and, provided by NOAA/STAR and Météo France were tested with the NLC equation. Only SST values between 15°C and 35°C are taken into account for the creation of all the following SST fields. For brevity, we only show the SST fields created with the NL53deg equation (Figure 1.A) and those created with the NL+2 equation (Figure 1.B) as those show the most visible differences of all the SST fields created here.

IDPS EDR SST data were retrieved from the Comprehensive Large Array-data Stewardship System. For that data set, only high quality SST were retained: Except for the satellite zenith angle and the sun glint flags which were ignored, all other flags had to be clear. Figure 3 shows SST field after regridding of the IDPS EDRSST data. The Miami SST field was provided by the University of Miami/Rosenstiel School of Marine and Atmospheric Science, in that case only the data in the best two quality levels were kept. Figure 4 shows the resulting SST field.

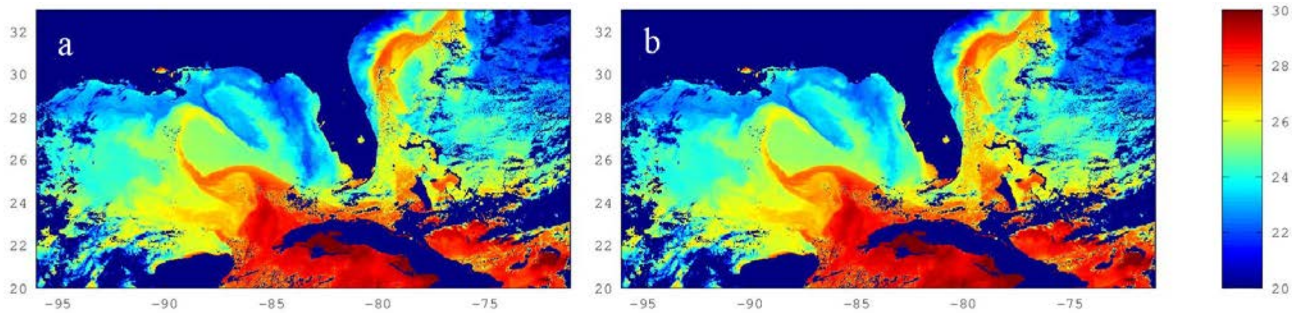

Figure 1: May 14, 2013 composite SST fields created with NAVOCEANO processing and minimal cloud detection. a) NL53deg SST b) NL+2 SST

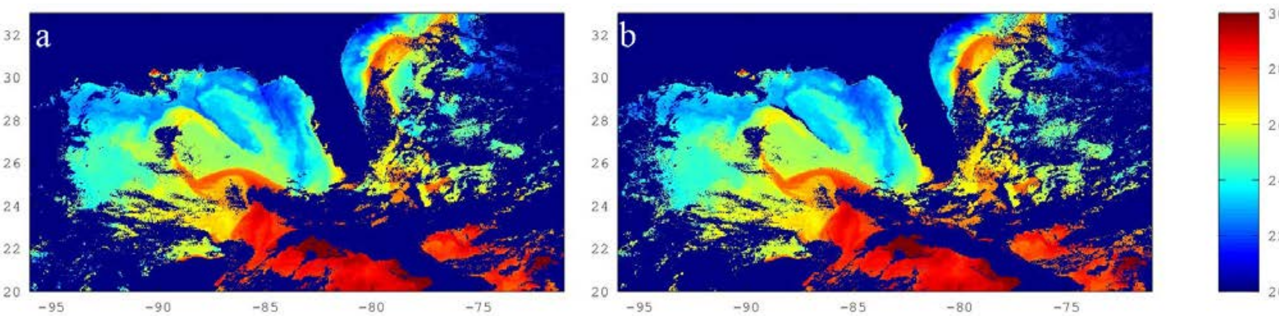

Figure 2: May 14, 2013 composite SST fields a) from best quality IDPS EDR SST data. b) from Miami/RSMAS Lat-Band algorithm, best 2 quality levels.

4. COMPARISON BETWEEN SST FIELDS

4.1 Difference fields

In this section we compare all the SST fields against the SST field created with the NLC equation and Météo France coefficients.

Both the IDPS and the NL53deg equations aredesigned to make SST retrievals at a maximum satellite zenith angle of 53 degrees, with IDPS flagging all data over 40 degrees as lower quality. Over that limit, their performance degrade rapidly. This is seen in the next two pictures of SST difference fields “IDPS minus NLC” and “NL53deg minus NLC” where we observe a cold bias in the swath overlap region (Figure 3).

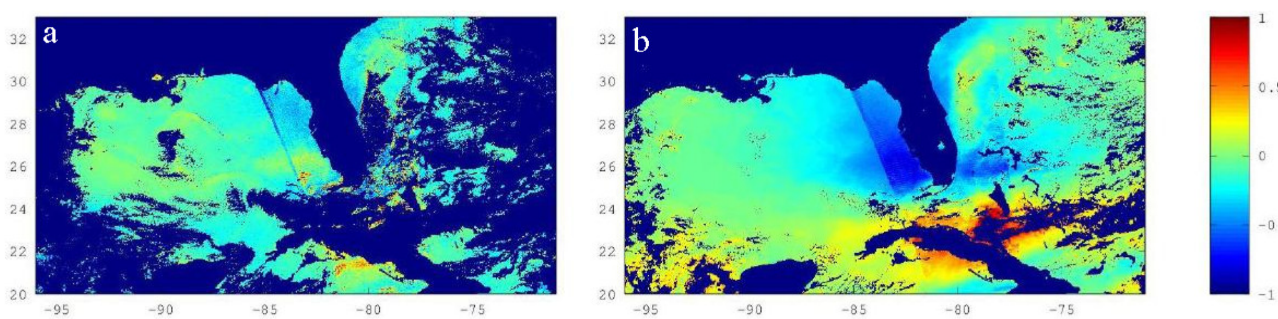

Figure 3:Difference between NLC/Météo France and a) IDPS EDR SST field, b) NL53deg SST field. With its coefficients evaluated for a satellite zenith angle < 53°, NL53deg shows a colder bias in the swath overlap region around Florida.

Between SST fields that are created with the NLC equation differences appear depending on which set of coefficients is used. There are relatively minor differences between fields with the Météo France and NOAA sets of coefficients. More significant differences are observed with the NAVOCEANO coefficients. In particular at high satellite zenith angle where the limb effect correction is more accentuated with the NAVOCEANO coefficients than with either the Météo France or NOAA coefficients.

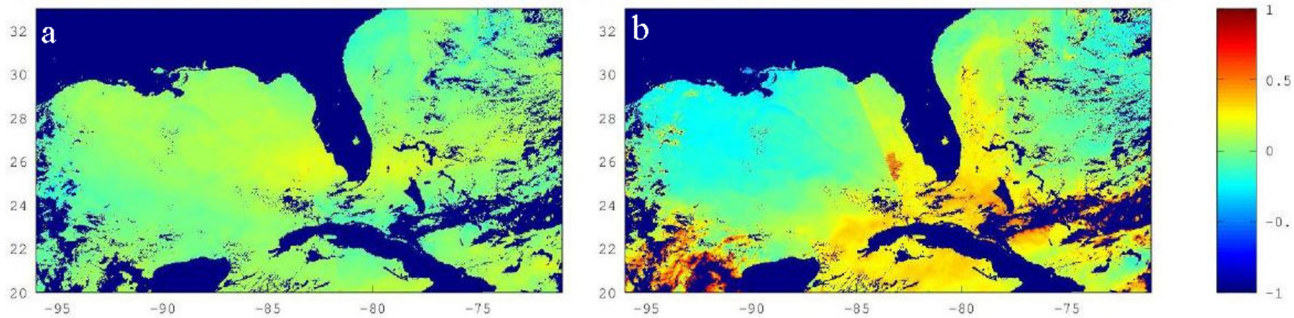

Figure 4: Difference between NLC/Météo France and a) NLC/NOAA, b) NLC/NAVO. NLC/NOAA show good agreement with NLC/Météo France, while NLC/NAVO shows a stronger correction of the limb darkening effect.

The Miami latitude bands algorithm produces fields which are close to those obtained the NLC equations and Météo France coefficients. This is surprising because the Miami algorithm relies on a standard NLSST equation like IDPS (Figure 5.a). Comparison between the SST fields derived from the NLC and NL+2 equations, both with NAVOCEANO determined coefficients, show little differences, smaller than those observed with NLC with NOAA or Météo France coefficients (Figure 5.b).

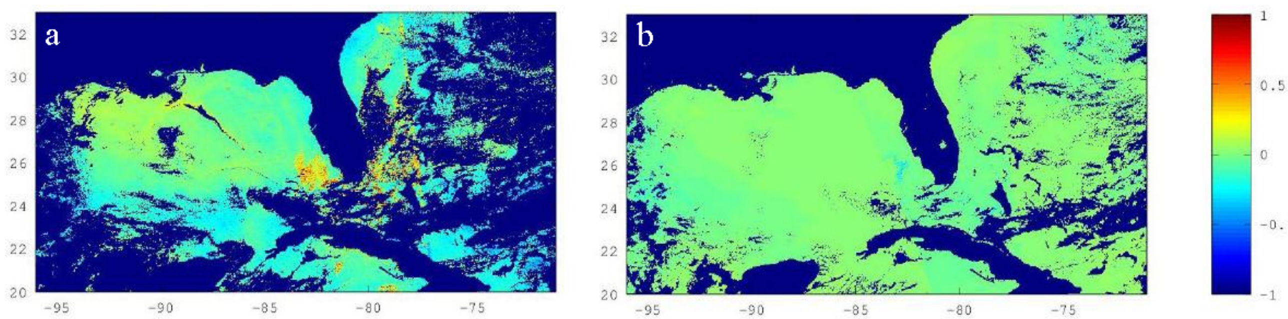

Figure 5: The difference field between a) NLC/Météo France and Miami Lat-Band algorithm show much less difference than expected. b) NLC/NAVO and NL+2 shows little difference, indicating in that case the choice of coefficients has more effect than the form of the equation.

4.2 Transect line

SST profiles along a transect line help better illustrate the behavior of the various SST equations on this particular scene (figure 6). Using the NLC equation with Météo France coefficients as the reference (figure 6.c), a look at Miami, NL53deg, IDPS and NLC with NAVOCEANO coefficients confirms the previous observations, namely:

1. The Miami algorithm corrects the limb darkening effect almost as well as NLC with Météo France coefficients.
2. The IDPS equation does not correct as much as NLC with Météo France coefficients..
3. The NL53deg does not perform well at high satellite zenith angle, because of the equation, but also because its coefficients are derived from data within the 53 degree satellite zenith angle domain.
4. The correction of the limb darkening effect is stronger for NLC with NAVOCEANO coefficients than for NLC with Météo France coefficients.

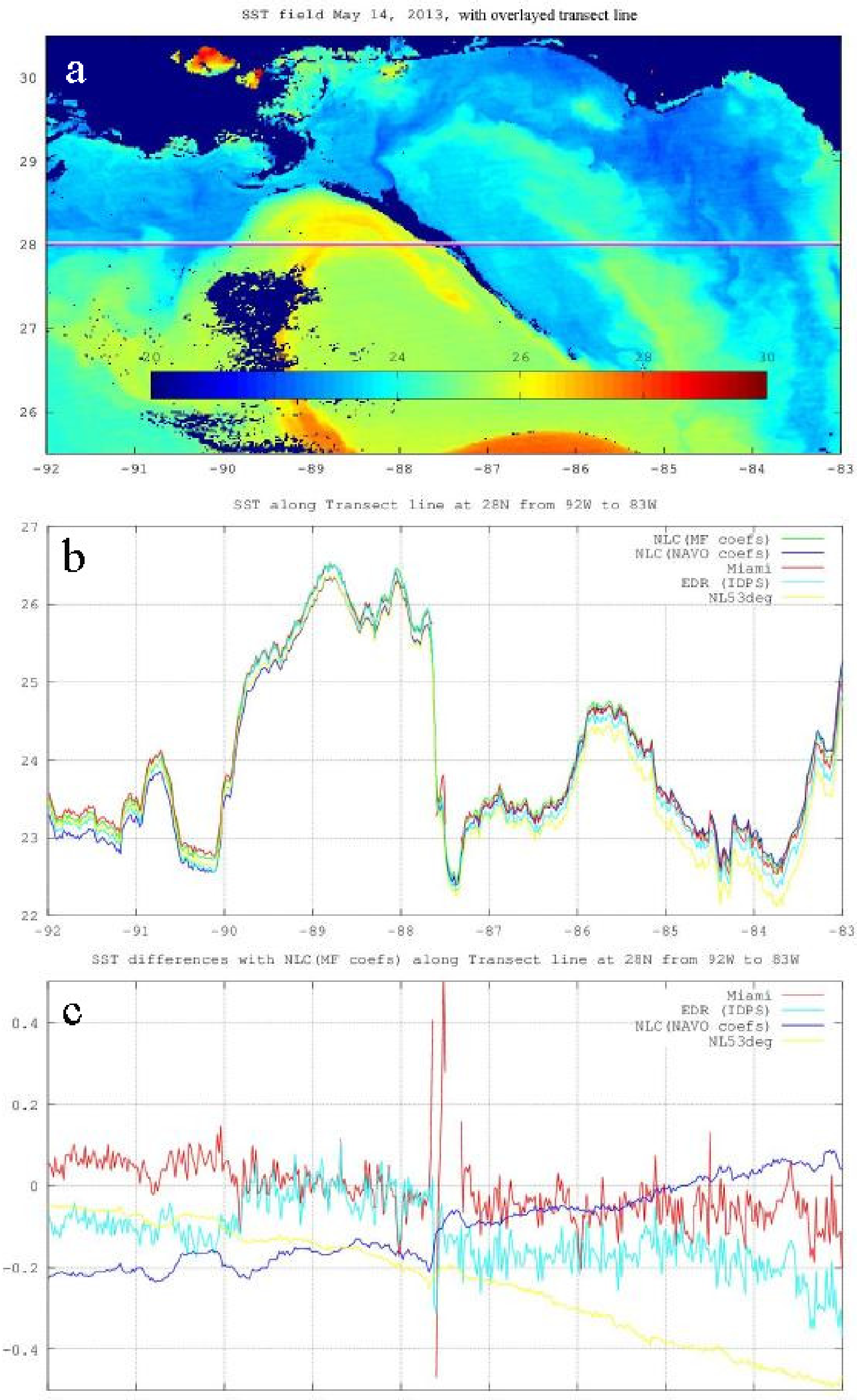
SST field May 14, 2013, with overlayed transect line
a
SST along Transect line at 28N from 92W to 83W
b
NLC(MF coefs)
NLC(NAVO coefs)
Miami
EDR (IDPS)
NL53deg
SST differences with NLC(MF coefs) along Transect line at 28N from 92W to 83W
c
Miami
EDR (IDPS)
NLC(NAVO coefs)
NL53deg

Figure 6: a)

Transect line overlaid on to of Miami SST Fields. b) SST profiles for various equations along the transect line.c) SST difference between NLC/Météo France and other equations along the transect line.

5. VALIDATION BY COMPARISON TO BUOYS

In this Section we match the SST derived with the various equations to the SST measured by buoys. The location of the buoys is shown in Figure 7.

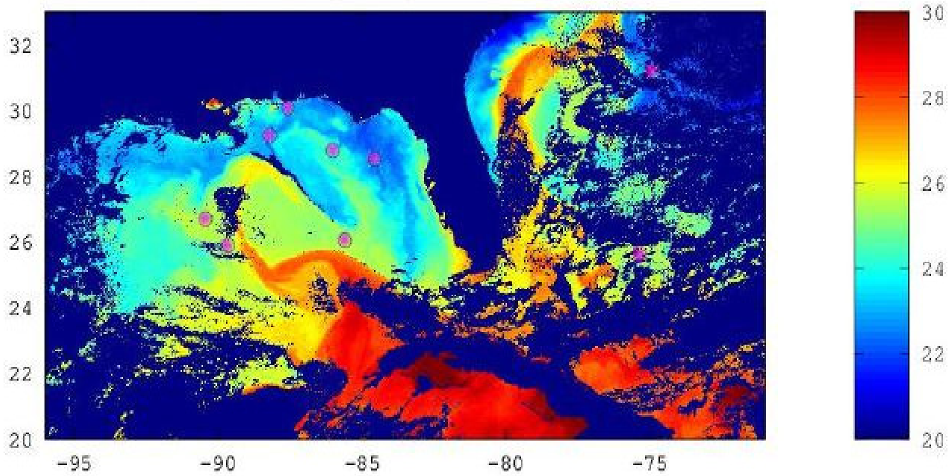

Figure 7: The location of buoys is overlaid as magenta dots on the Miami SST field.

Because of the low number of buoys, results are not statistically significant (Results in Table 1). However they do offer a sanity check on all the SST fields. Of note, to better evaluate the SST equations and not the cloud detection, the closest SST retrieval to the buoy temperature, within the immediate neighborhood of the buoy, is selected as the match-up.

Table 1: Results of of the comparison of satellite derived SST to buoy measured SST

	Bias °C	Std Deviation °C
NL53deg (NAVO)	0.08	0.26
IDPS	0.04	0.31
Miami	0.04	0.29
NLC (NOAA)	0.11	0.26
NLC (MeteoFrance)	0.05	0.26
NLC (NAVO)	0.00	0.32
NL+2	0.01	0.3

6. VALIDATION BY ANALYSIS OF OVERLAP BETWEEN SWATHS

The overlap between two successive satellite swaths allows the view of a scene at an interval of about 1 hour and 36 minutes. Here, the SST field of the later orbit is subtracted from that of the earlier orbit, and as such, a small cold bias can be expected because of daytime warming. The uncorrected limb darkening effect appears as a cold bias on west side of the overlap region and a warmer bias on the east side. As expected the NL53deg and IDPS equations perform poorly in the swath overlap region as they were not designed to work at a high satellite zenith angle. Figure 8 shows the difference fields in the overlap region for 6 of the equations.

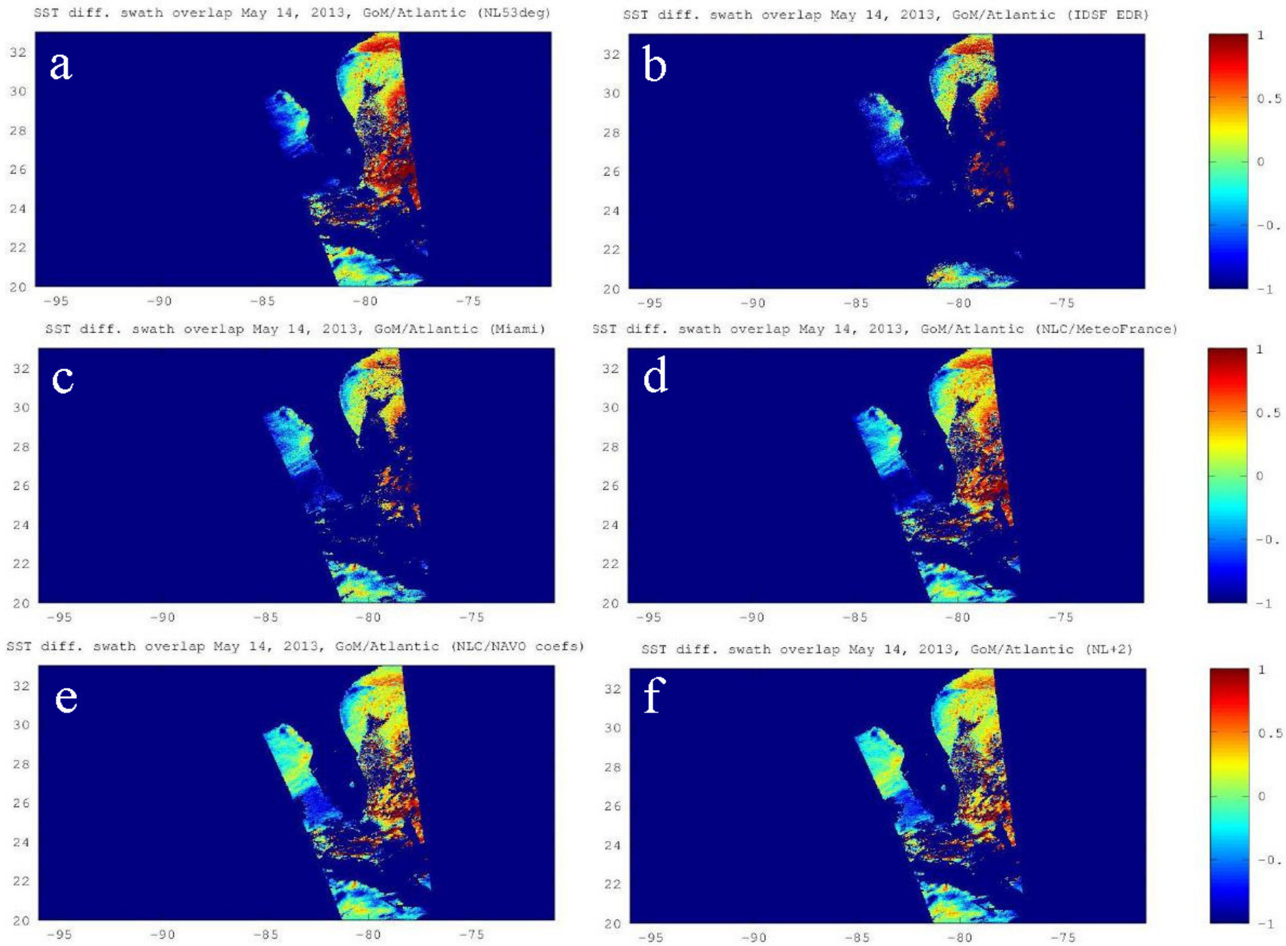

Figure 8: SST difference between successive satellite orbits for a) NL53deg SST, b) IDPS EDR SST, c) Miami Lat-Band SST, d) NLC with Météo France coefficients, e) NLC with NAVOCEANO coefficients and, f) NL+2 SST.

In Table 2, the mean bias and the mean absolute bias are estimated on a common set of retrievals that are cloud free in all SST fields. They confirm the good performance of NLC and the poor performance of NL53deg and IDPS at high satellite zenith angle. Results from a March 31, 2014 scene (same region but clouded west side) show IDPS better performance after the switch to the NLC equation.

Table 2: Mean bias and the mean absolute bias of the SST difference in the overlap region. Orange background: May 14, 2013 scene. Yellow background: March 31, 2014 scene.

	bias °C	mean abs bias °C	bias °C	mean abs bias °C
NL53deg(NAVO)	-0.23	0.51	0.19	0.35
IDPS	-0.23	0.52	0.14	0.30

Miami	-0.15	0.39		
NLC(NOAA)	-0.12	0.41	0.10	0.25
NLC(MeteoFrance)	-0.13	0.38	0.18	0.32
NLC(NAVO)	-0.09	0.27	0.10	0.27
NL+2(NAVO)	0.07	0.26	0.07	0.24

7. CONCLUSIONS

The NLC equation has been shown to perform well, although the choice of coefficients can significantly affect results. As expected NL53deg and IDPS (standard NLSST) perform poorly at high satellite zenith angles as they were not design to process such data. Full swath processing results in large regions where successive orbits overlap even at low latitude. Those overlap regions allow new ways to evaluate and analyze the SST fields. Beside Météo France; NOAA/STAR, IDPS and NAVOCEANO are using or plan to use the NLC equation.

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