NEW OSI SAF SST GEOSTATIONARY CHAIN VALIDATION RESULTS

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Abstract

The Ocean and Sea Ice Satellite Application Facility (OSI SAF) has developed a new SST chain for the geostationary satellites, which includes an algorithm correction term simulated with a radiative transfer model and forecast atmospheric profiles. This text describes the new scheme and presents detailed validation results obtained with METEOSAT-9 and GOES-13 over 9 months, with emphasis on the algorithm correction impact.

1. INTRODUCTION

The Ocean and Sea Ice Satellite Application Facility (OSI SAF) has developed a new Sea Surface Temperature (SST) chain for the geostationary satellites GOES-East and METEOSAT. The processing scheme is similar to the one used for METOP by OSI SAF, it ingests SEVIRI data at full resolution every 15 minutes and it includes an algorithm correction term simulated with a radiative transfer model and forecast atmospheric profiles.
This new scheme has been applied routinely without correction since May 2010 and with correction since November 1st 2010. It has been declared operational in August 2011.
This text summarizes the SST operational processing (section 2) and the validation scheme (section 3). section 4 presents detailed validation results obtained with METEOSAT-9 and GOES-13, with emphasis on the algorithm correction impact.

2. SST OPERATIONAL PROCESSING

The new OSI SAF geostationary SST chain includes the following main steps (figure 1):

a) preprocessing: METEOSAT or GOES-E imager radiometric data are ingested in full time (MSG: every 15 minutes; GOES-E: every 30 minutes) and space resolution. The Nowcasting (NWC) SAF cloud mask for geostationary satellites (Derrien and Le Gléau, 2005) is applied on these data.

b) cloud mask control: several tests are applied on each pixel that concern the local gradient, the local SST, occurrence of aerosol, occurrence of ice and the temperature temporal variation. Each test is defined by two values associated to a test indicator varying from 0 to 100. The range limited by the two values corresponds to a potential problem (test indicator in]0,100[), one side of the range corresponds to a critical problem (test indicator=100) and the other side to no problem (test indicator=0). The test indicators are then averaged to obtain the so-called cloud mask indicator.

c) Multi-spectral algorithm:
The algorithms used have been kept identical to those applied in the present operational chains. The METEOSAT-9 algorithm (daytime and nighttime) and the GOES-E algorithm (nighttime only) are described by equations (1) and (2), respectively. Due to the lack of 12 μm channel in the GOES-E imager, there are no SST in daytime conditions :

$$SST = (a + b\,S_\theta)\ T_{11} + (c + d\,T_{CLI} + e\,S_\theta)\,(T_{11} - T_{12}) + f\,S_\theta + g \quad (1)$$

$$SST = (a + b\,S_\theta)\ T_{11} + (c + d\,T_{CLI} + e\,S_\theta)\,(T_{3.7} - T_{11}) + f\,S_\theta + g \quad (2)$$

where T_{11} T_{12} $T_{3.7}$ are the brightness temperatures at 10.8, 12.0 and 3.7 µm, respectively.
T_{CLI} is a climatological SST value
a, b, c, d, f and g are coefficients determined from brightness temperature simulations on a radiosonde profile database, with the offset coefficient corrected relative to buoy measurements.
S_θ = secant(θ_{sat}) –1; θ_{sat} is the satellite zenith angle

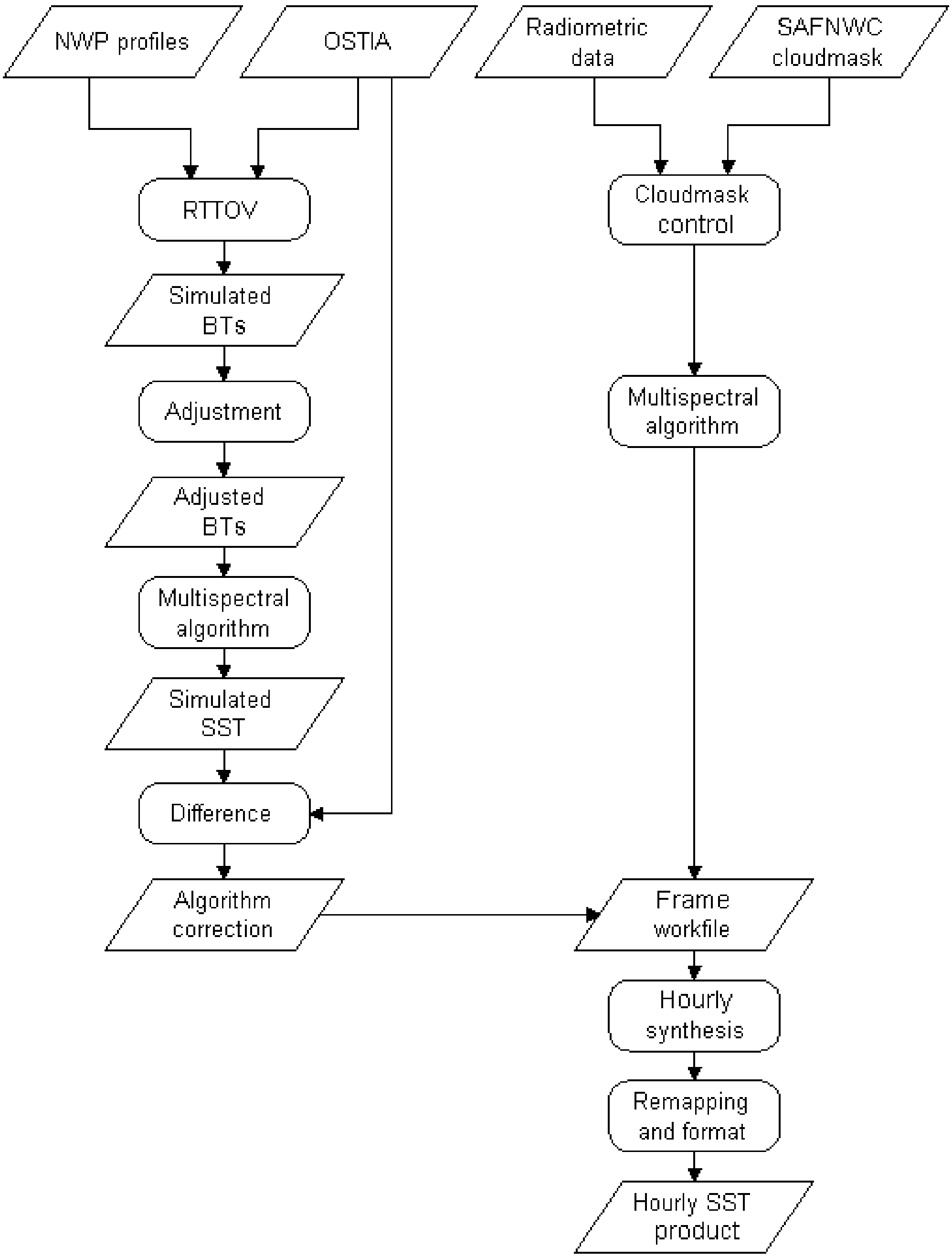


Figure 1: **Overview of the upgraded geostationary chain. Radiometric data are used every 15' (METEOSAT) or 30' (GOES-E). The algorithm correction is calculated every 3 hours and applied to the SST calculation the nearest in time.**

A Saharan Dust Index (SDI) correction term is calculated as a quadratic function of the SDI values (Merchant *et al.,* 2006), for 0.1<SDI<0.8. This correction depends on the algorithm used. No corrections are made when there is no SEVIRI observations. In these conditions there is a residual aerosol error that is flagged using the aerosol information in the NWC SAF cloud mask or the NAAPS Aerosol Optical Depth (US NAVY, 2003).

d) Algorithm correction:
Regional and seasonal biases have been detected in polar orbiter and geostationary SST products (Marsouin et al., 2010, Marullo et al., 2010); these biases being clearly due to limitations of the mutispectral algorithms (Merchant et al., 2009). A correction method has been defined (Le Borgne et al., 2011), based on applying the operational algorithms to simulated brightness temperatures (BTs). Simulations are derived from applying RTTOV to ECMWF profiles using a SST analysis (OSTIA, Stack et al, 2007) as surface temperature. The correction is calculated as the difference between the retrieved SST from simulated BTs and the SST analysis used as input to the simulations.
In operational application, BTs are simulated when model outputs are available (every 3 hours). Simulations are not perfect, due to model output errors, RTTOV errors and sampling of profiles. The adjustment of simulated to observed BTs is thus a critical step of the method. We have adopted an empirical approach based on averaging the simulated – observed BT differences over 20 day preceding the day being processed. Algorithm corrections calculated every 3 hours are applied to any SST calculations within +/- 1.5 hours from the model output time. A correction indicator reflects the amplitude of the applied correction.

d) quality level: a quality level is associated to each pixel with the following values: 0 : unprocessed, 1 : cloudy , 2: bad, 3: suspect, 4: acceptable, 5 : excellent. The quality level value is derived from the cloud mask indicator, the algorithm correction indicator and the satellite zenith angle being used as complementary criteria. Pixels considered as dubious after the cloud mask control are labeled “bad”, whereas in the METOP/AVHRR chain they where labeled “cloudy”.

e) operational product fabrication: operational products are produced by remapping over a 0.05° regular grid SST fields obtained by aggregating all SST data available in one hour time, the priority being given to the value the closest in time to the product nominal hour. The final products result from collecting data from various slots within one hour. Consequently they are considered as “L3C” (remapped collated) in the GHRSST product definition

For more details on the chain, see the Geostationary SST Product User Manual (EUMETSAT, 2011).

3. VALIDATION SCHEME

Match-up Data Bases (MDB) are built separately for GOES-E and METEOSAT. MDBs collect in situ SST measurements from ship, moored or drifting buoys, available through the Global Telecommunication System (GTS) and the coincident full resolution satellite information, within 1 hour from the in situ measurement. The satellite information is extracted in a 5x5 pixel box centered on the measurement location. The coverage of the box by clear pixels must be larger than 10%. The MDB includes the in situ measurements (platform ID, SST, auxiliary measures) and all the variables used in the SST processing. A MDB file is built daily with a 5-day delay to insure a good collection of the in situ data.

In order to calculate validation statistics, the MDB cases are selected as follows:

- drifters only,
- boxes containing only sea pixels (this rejects coastal data),
- only the cases where there is a SST value at the central pixel of the validation box
- cases where the absolute value of the difference between the in situ measurement and the climatology exceeds 5 K are eliminated,
- if several in situ measurements are available for the same satellite pixel, the closest in time is retained

With the above principles, the SST error is defined as the SST at the central pixel of the validation box minus the in situ measured SST, which is closest in time.

Some buoys may show highly erroneous values during several weeks. In order to detect them, OSI SAF has developed an automatic scheme based on the monitoring of the buoy biases over 10-day periods using several satellites (Marsouin et al., 2010). A so-called buoy blacklist is built automatically every 10 days, with an additional interactive control every 3 months. In the previous years, METOP, NOAA-18 and NOAA-19 were used in the blacklisting scheme, METEOSAT-9 and GOES-13 have been added recently, on June 10th 2011.

The statistics are calculated at three temporal resolutions: daily, to detect rapidly major problems of the processing chain, over 10 days, commonly used for most figures and plots and monthly, to obtain a better spatial coverage. The buoy blacklist is applied to filter the data. METEOSAT-9 night-time and daytime cases are considered separately, as they correspond to different cloud mask algorithms and because of a possible diurnal warming effect.

4. RESULTS

The results are relative to the 9-month period, November 2010 to July 2011, when the algorithm correction was applied. This correction is a significant step in the SST processing scheme, so the results are shown with and without correction. With the exception of figure 2, the results have been obtained on the cases having a quality level in [3,5], which is the range recommended to users.

4.1 Overall error statistics

Table 1 gives the SST error statistics of GOES-13 and METEOSAT-9, calculated over the 9 months and on the whole area seen by each satellite. The algorithm correction has a limited impact on the overall statistics: the negative bias is generally slightly reduced and GOES-13 standard deviation decreases from 0.61 to 0.51K.
The corrected SST results are rather similar for both satellites, with slight differences. GOES-13 has a lower standard deviation, 0.51, than METEOSAT-9, 0.56 by nighttime and 0.54 by daytime and a larger bias, -0.16, than METEOSAT-9, -0.07 by nighttime and -0.02 by daytime.

satellite	Corrected SST		Uncorrected SST		Number of cases
	bias (K)	st dev (K)	bias (K)	st dev (K)	
GOES-13 nighttime	**-0.16**	**0.51**	**-0.24**	**0.61**	**11212**
METEOSAT-9 nighttime	**-0.07**	**0.56**	**-0.15**	**0.57**	**91650**
METEOSAT-9 daytime	**-0.02**	**0.54**	**-0.06**	**0.55**	**143494**

***Table 1*: SST error statistics from November 1st 2010 to July 31 2011.**

The statistics are also calculated for each quality level value. As shown in figure 2, similar results are obtained for GOES-13 and METEOSAT-9. When the quality level varies from 5 to 3, the bias is nearly constant and the standard deviation increases. At a quality level of 2, the bias becomes clearly negative, in the case of GOES-13 the bias is close to -1 K and the standard deviation about 1.3 K. It should be noted that a quality level of 2 corresponds to a pixel considered as dubious after the cloud mask control and that should not be used.

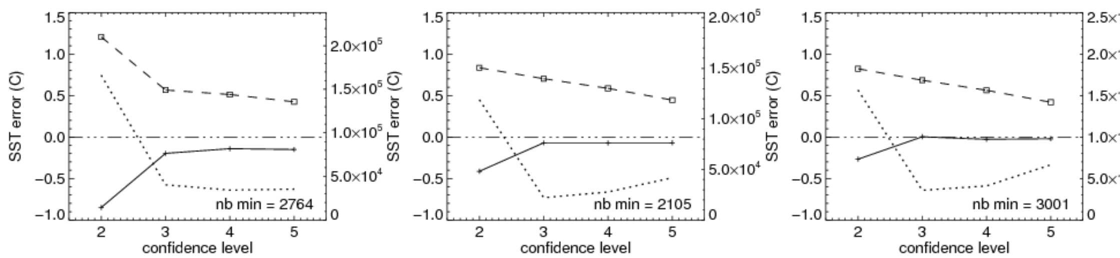


***Figure 2*: variation of bias and standard deviation with quality levels for corrected SST (November 1st 2010 to July 31 2011). The left figure shows GOES-13 nighttime, the middle figure METEOSAT-9 nighttime and the right figure METEOSAT-9 daytime. Solid line: bias, dashed line: standard deviation, dotted line: number of cases**

4.2 Geographical and temporal variation

Figure 3 shows the geographical variation of the SST error, averaged over the 9 months for GOES-13 (nighttime) and METEOSAT-9 (nighttime and daytime). The corrected SST error maps (figure 3 top) are significantly improved compared to the uncorrected SST error maps (figure 3 middle). The main areas of large positive or negative errors have been suppressed (negative error in Tropical Atlantic, positive error off the California coast with GOES-13) or reduced (nighttime negative error in Southern Atlantic, GOES-13 negative error in north Atlantic)

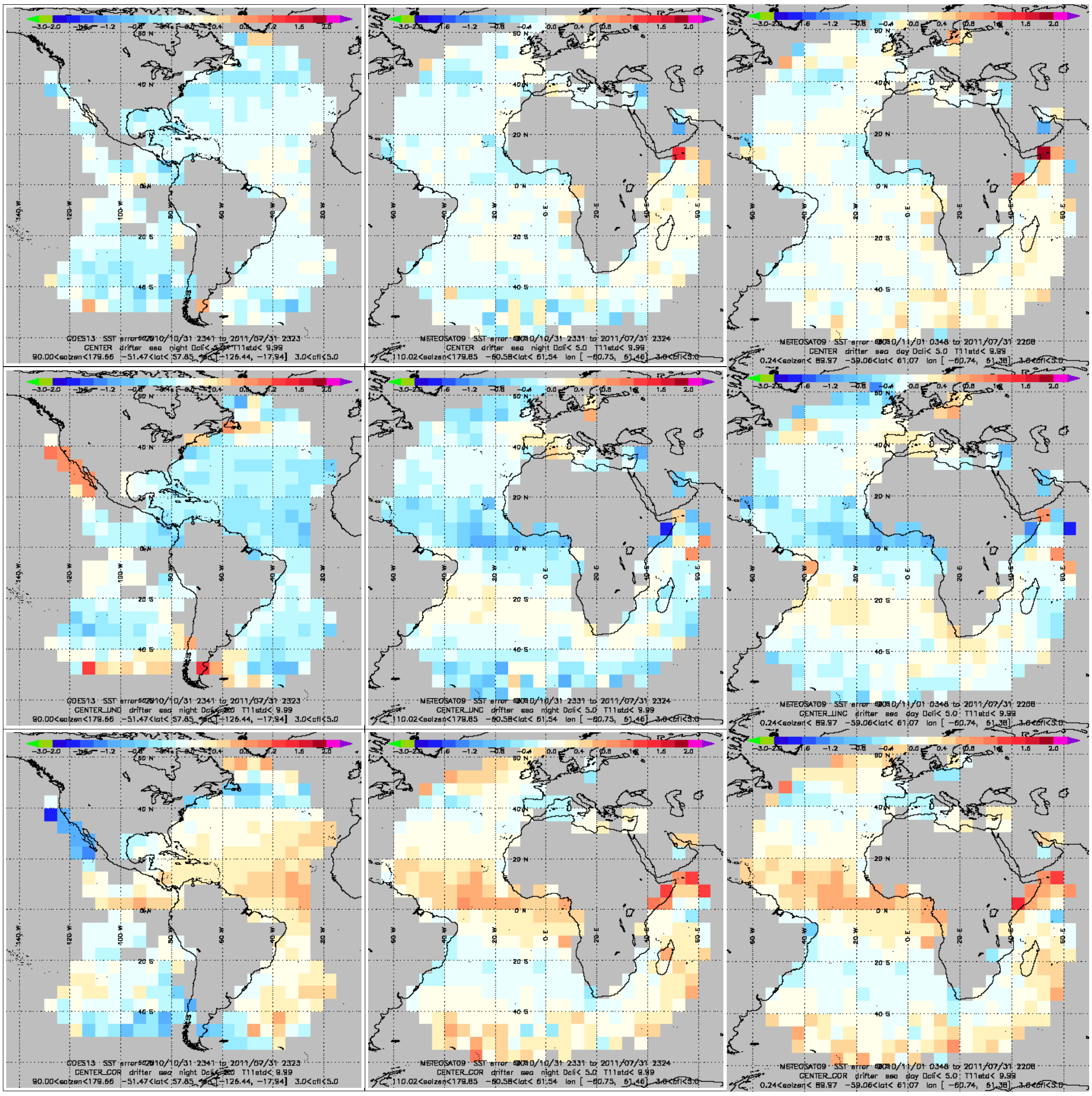


***Figure 3*: Geographical variation of the SST error for GOES-13 (nighttime) and METEOSAT-9 (nighttime and daytime). The top maps show the corrected SST error, the middle ones the uncorrected SST error and the bottom ones the algorithm correction, all maps being averaged over 9 months (November 2010-July 2011).**

The SST error varies with time, as shown by figure 4. The uncorrected SST error is generally larger and more noisy in April and July 2011 (middle and right maps) than in December 2010 (left maps). In December, the Tropical Atlantic negative error is rather low and located in the Gulf of Guinea, then it moves northwest and increases. The algorithm correction (bottom maps) follows this temporal evolution and efficiently suppress this error for all three months. But it does not succeed in suppressing the noisy patterns, mainly located in Southern Atlantic in April and July**.**

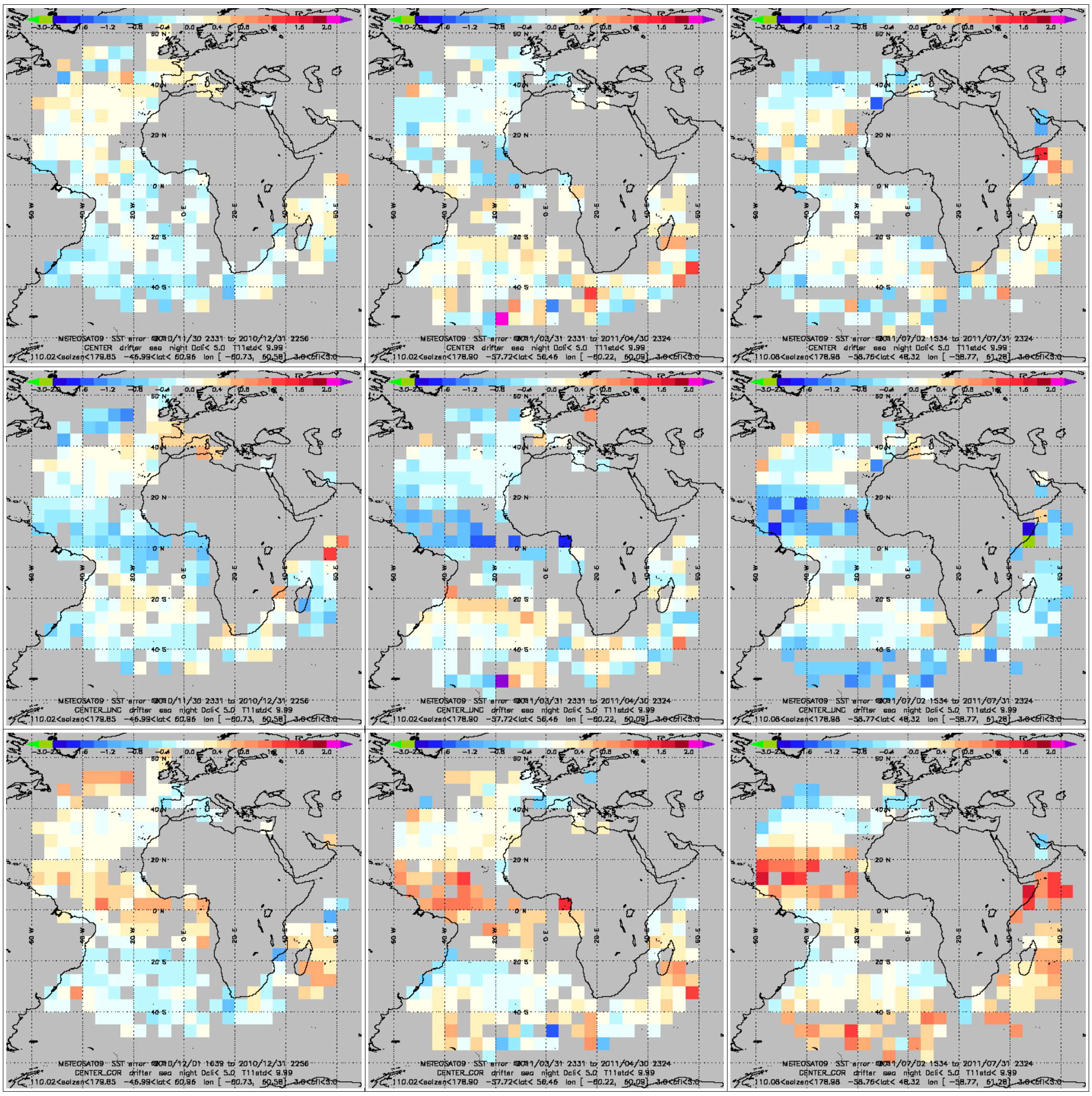


Figure 4**: METEOSAT-9 nighttime SST error for 3 months, December 2010 (left), April 2011 (middle) and July 2011 (right). The top maps show the corrected SST error, the middle ones the uncorrected SST error and the bottom ones the algorithm correction**

Figure 5 gives a finer description of the SST error temporal variation, for a few typical areas. In terms of uncorrected SST (figure 4, right), the South Atlantic is generally not problematic, the Southern Ocean has negative errors from May to July 2011, the West Mediterranean has occasional errors (November, December 2010, July 2011) and the Gulf of Guinea shows important negative errors, -0.5 to 1. K, from November 2010 to May 2011. The algorithm correction solves most of these problems (figure 4 left), however the corrected SST is not perfect, showing errors from-0.2 to 0.5 K in Gulf of Guinea from November 2010 to March 2011 and errors of about -0.3 K West Mediterranean from April to July 2011.

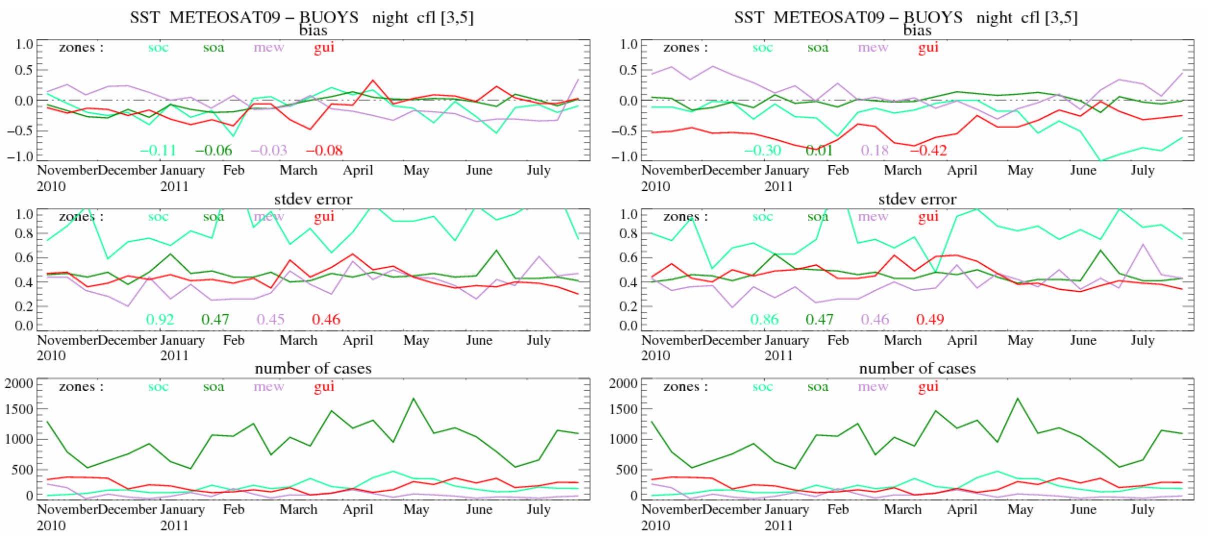
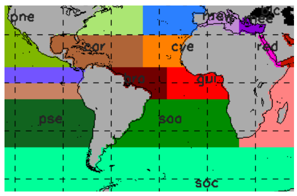


Figure 5: temporal variation of METEOSAT-9 nighttime SST error in four different geographical areas. The left plots show the corrected SST results, the right plots the uncorrected SST results. The colored curves correspond to the different geographical areas,. These areas named soc (Southern Ocean), soa (South Atlantic), gui (Gulf of Guinea) and mew (West Mediterranean) are shown on the small map to the right.



5. CONCLUSION

The OSI SAF has developed a new SST chain for the geostationary satellites, which includes an algorithm correction term simulated with a radiative transfer model and forecast atmospheric profiles The new scheme has been applied routinely to METEOSAT-9 and GOES-13 since November 1st 2010.

The validation results obtained on a 9-month period, November 2010 to July 2011, are satisfying: over the whole area, METEOSAT-9 SST shows a negligible bias and a standard deviation of 0.56 by nighttime and 0.54 by daytime, while GOES-13 SST shows a stronger bias, -0.16, and a lower standard deviation of 0.51.

The algorithm correction has a rather small impact on the overall statistics but it efficiently suppress or, at least, reduces the regional biases: negative errors in Tropical Atlantic, positive errors off California and negative errors in Southern Atlantic. The improvement is observed on average on the whole period and also on a monthly basis.

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