SEA SURFACE TEMPERATURE STATUS: LOW AND MID LATITUDE PRODUCTS

P. Le Borgne, G. Legendre and A. Marsouin
Météo-France/DP/CMS, BP 147, 22302 Lannion, France

ABSTRACT

The OSI SAF SST fields are produced at two spatial scales: 2 km resolution SST fields are derived 4 times a day from NOAA AVHRR over the European Seas, 10 km resolution fields are produced over the whole Atlantic on a 3 hourly or 12 hourly basis as a merging of METEOSAT-8 (MSG), GOES-E and NOAA/AVHRR derived SSTs. Production with METEOSAT-8 started in operational mode on the 30th of June 2004. The status of the SST production at CMS will be presented. All SST products are validated against in situ measurements (buoy matchups) and intercompared between themselves. OSI-SAF products are also compared to the SST fields produced over the Atlantic by other agencies. These results will be presented and analyzed. The planned developments will be reviewed.

1. INTRODUCTION

The routine delivery of METOSAT-8 (MSG) SST started in July 2004. The operational production of SST within the OSI- SAF is now fully operational, with 4 satellites (NOAA-16, -17, GOES-12 and METEOSAT-8) in use. SST fields are produced over the European seas at 2 km resolution by using NOAA-16 and –17 data. The whole Atlantic Ocean (from 60 S to 60 N and from 100 W to 45 E) is covered through the combined use of GOES-12, and METEOSAT-8. NOAA/AVHRR data acquired and processed by met.no in Oslo allow extension of the coverage to 90N.

During the development phase (1997-2002) of the O&SI SAF, CMS developed operational methods to retrieve SST from GOES-East and NOAA/AVHRR. Since June 2001, these products have been produced on an operational basis. They have been made available in real time through the Ifremer web server **ftp://ftp.ifremer.fr/pub/ifremer/cersat/SAFOSI**. All the necessary information, operational validation results and last product images are available through the OSI SAF operational server: **http://www.osi-saf.org**. The O&SI SAF is at present in its Initial Operational Phase (IOP).

In section 2, this paper reviews the product availability and shows some examples. The algorithm and processing methods used are briefly presented in section 3: apart from GOES-12, SST retrievals are based on classical split-window techniques. The validation results against drifting buoy measurements show biases varying within a few tenths of degrees and standard deviations usually about 0.5K. Validation and intercomparison experiment results are presented in section 4.

The short-term developments will consist in a detailed analysis of the METEOSAT-8 errors and a re-evaluation of the algorithms. A development of new products is also envisaged, since some applications have demonstrated the interest of small space and time scales for the geostationary derived SST.

In the long term, the main goal is the development of a SST production chain for METOP.

These future developments and concluding remarks are described in section 5 and 6, respectively.

2. PRODUCTS

The OSI SAF SST products are available within 2 hours after the last satellite data acquisition over the following grids and time sampling:
NAR: Near Atlantic Regional, seven areas at 2 km resolution, 4 times a day
LML: Low and Mid Latitudes, 100W - 45E and 60N - 60S, at 0.1 degree resolution, 3 hourly
MAP: Merged Atlantic Products, 100W - 45E and 89.9N - 60S, at 0.1 degree resolution, 12 hourly

NAR SST are derived (as of March 2005) from NOAA-17 and NOAA-16 acquired and processed at CMS. They are delivered over 7 zones (see Figure 1), 1024 columns and 1024 lines in size, in polar stereographic projection.

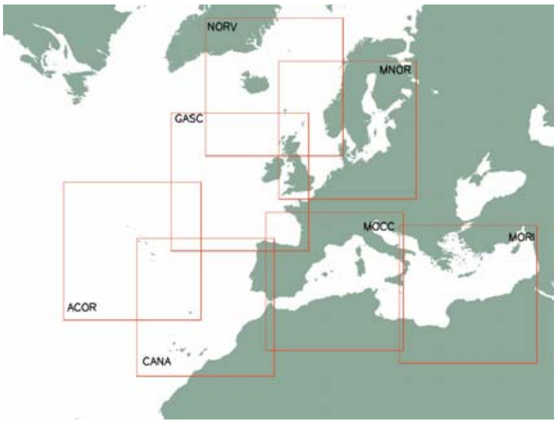


Figure 1. NAR SST zones.

LML products are derived from the geostationary satellite data (GOES on the western area, MSG on the eastern area, Figure 2 left). MAP products are built from the geostationary satellite data and from NOAA/AVHRR data processed at met.no in Oslo for areas polewards of 60 N (Figure 2 right).

Each product include the following fields: SST, time, quality index. SST are "subskin" SST, expressed in CentiKelvins . Time is the mean time of the calculated SST expressed in minutes after or before the product reference time provided in the header of the files.

Quality indexes include a confidence level corresponding to the quality of the calculated SST and information on the processing conditions.The confidence level scale is the same for all SST and radiative fluxes products. The pixels where the calculation has been attempted are labeled on a five level scale: 5 = "excellent", 4= "good", 3="acceptable", 2="bad", 1="erroneous", whereas the pixels where the calculation has not been attempted for normal reasons (out of the processed area or land) have a distinct confidence level 0="unprocessed".

These products are available under the following formats:

- GRIB format , available in near real time through RMDCN, ftp server ftp.meteo.fr and EUMETCAST (after 15 March 2005)
- HDF and NetCDF format from ftp://ftp.ifremer.fr/pub/ifremer/cersat/SAFOSI

The full archive has been available on line on the Ifremer site since the July 2001, with MSG derived products available since July 2004.

NAR SST over the Mediterranean and the 3 hourly MSG SST over the Atlantic will be available in real time in L2P format in the framework of the ESA “Medspiration” project, from April 2005 onwards.

More information, documentation and results are available through http://www.osi-saf.org.

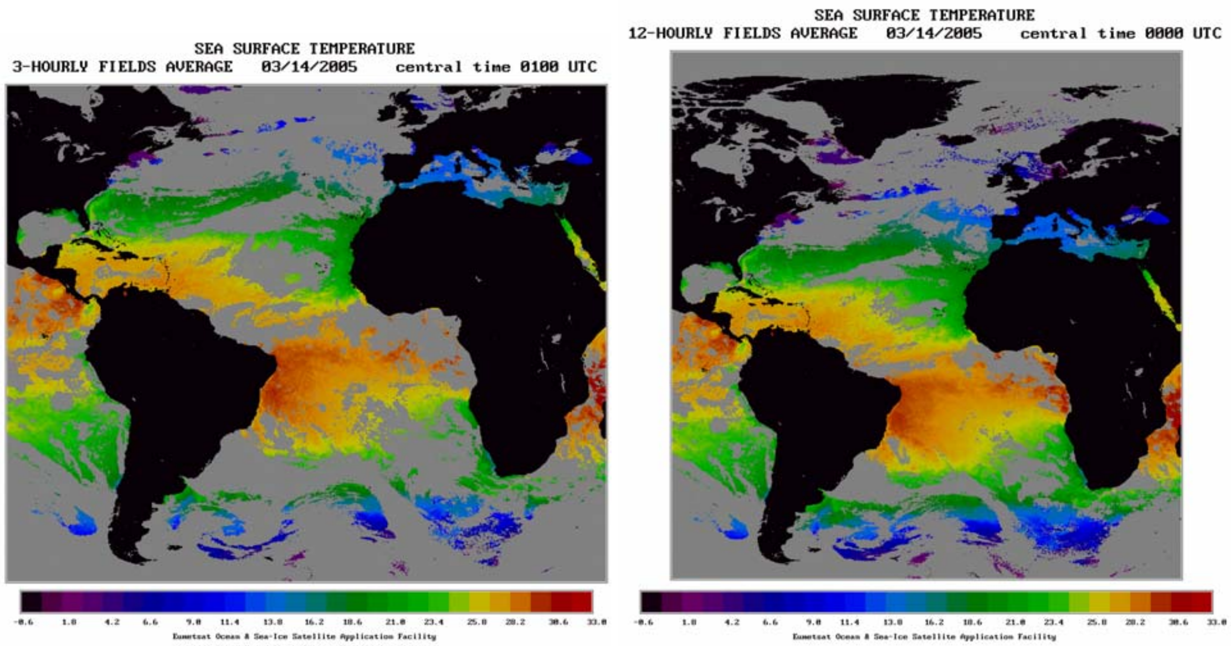


Figure 2. Examples of 3 hourly LML (left) and 12 hourly MAP (right) SST fields on the 14 March 2005.

3. ALGORITHMS AND PROCESSING METHODS

The following NL algorithm has been used for the processing (day and night conditions) of METEOSAT-8, NOAA-16 and NOAA-17:

$$T_s = a\,T_{11} + (b\,Ts_{clim} + c\,S_\theta)(T_{11} - T_{12}) + d \qquad (1)$$

There is no 12 micron channel on GOES-12. The following dual window algorithm (DW11) has been adopted, for nighttime applications only:

$$T_s = (a + b\,S_\theta)\,T_{11} + (c + d\,S_\theta)(T_{39} - T_{11}) + e\,S_\theta + f \qquad (2)$$

In (1) and (2), T_{39}, T_{11} and T_{12} are the brightness temperatures at 3.9, 11 and 12 microns.
$S_\theta = \sec(\theta) - 1$, Ts_{clim} is the mean climatological value, θ is the satellite zenith angle.

The coefficients are available on the configuration files in the product presentation pages through http://www.osi-saf.org.

The NOAA-16, -17 and GOES-12 algorithm coefficients have been determined from a simulated brightness temperature database built by applying MODTRAN 3.5 on the “SAFREE” cloud-free radio-sounding profiles, as described in Francois et al., 2002.

For METEOSAT-8, the Planck-weighted version of RTOVS (Brunel and Turner, 2003) has been used to build the brightness temperature database from SAFREE.

After a few months of use, a bias correction has been applied to the algorithms derived from simulations (Merchant and Le Borgne, 2004).

The main steps of the SST calculation are the following:

- Ingestion of IR brightness temperatures (at 3.9, 11 and 12 microns)
- Ingestion of the corresponding cloud mask calculated with the NWC SAF algorithm (Derrien and Le Gleau, 2005)
- 1st SST calculation, without smoothing of the atmospheric correction term (T_{11}-T_{12} or T_{39} - T_{11})
- Cloud mask control: pixels are considered as cloudy if the 11 micron brightness temperature diminishes by more than 0.5 K in half an hour (geostationary satellites only), or if the calculated SST is lower than a threshold derived from the local minimum climatological temperature (Faugère et al., 2001) and depending on the distance to nearest clouds (Brisson et al., 2002).
- 2nd SST calculation involving a smoothing of the atmospheric correction term over the pixels labeled as clear after control of the cloud mask. A confidence level from 0 (unprocessed) to 5 (excellent) is attributed to each pixel, in function of the distance to the nearest cloud and the difference between the calculated SST and the local minimum climatological temperature. "5" is attributed to pixels far from cloudiness with regular SST values, "4" to pixels far from cloudiness, but with SST close to the minimum, "3" to pixels close to cloudiness with regular SST values and "2" to pixels close to cloudiness with SST close to the minimum.
- Building of the match up data base
- For geostationary satellites: Averaging over 3 or 12 hours and remapping

4. VALIDATION

Validation results at CMS are based on the use of Matchup Data Bases (MDB). MDBs are constructed at CMS as follows, for all satellites. After cloud-screening and SST retrieval are applied to imagery to create SST products, satellite data are collected for 20 km x 20 km boxes centered on the available matching buoy locations (providing that no more than 40% of this area has been screened as cloudy). These collected data include the retrieved SSTs and the brightness temperatures averaged over only the cloud-free pixels of the validation box. Buoy data are collected on the RMDCN. The match-up time window is three hours for the polar orbiters and half an hour for GOES or METEOSAT. Buoy measurements only have been included in these MDBs, i.e., ship temperatures are not used. To screen out infeasible in situ measurements, only buoy temperatures within 2 K of the local climatological values have been retained. For the purpose of validating the algorithms used, only those matches where less than 10% of the validation box was cloudy ("cloud-free" cases) are used. To assess the retrieval quality of the combined cloud-clearing / retrieval scheme, all the match-ups ("all cases") are used. Since a previous study (Brisson et al, 2002) showed that there may be some differences between measures by moored buoys and drifters, only the latter are used in routine validation. Figure 3 shows the geographical distribution of the nighttime "cloud-free" cases for NOAA-17 and METEOSAT-8. In both cases, the lack of drifting buoy measurements over the Mediterranean is noteworthy.

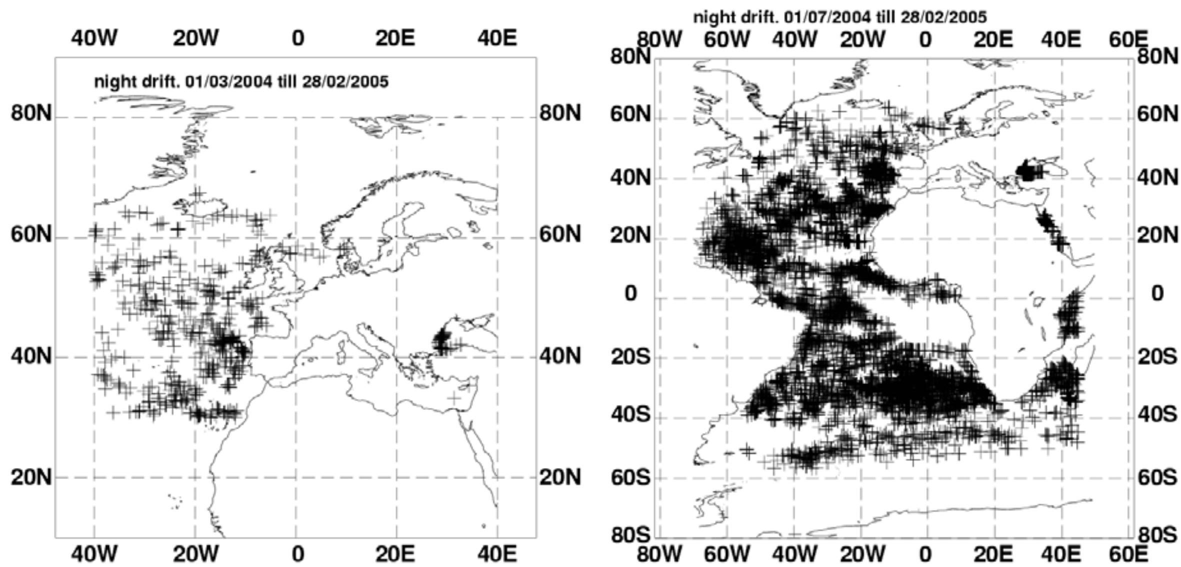


Figure 3. Drifting buoy SST nighttime measurements included in MDBs: left: NOAA-17 from March 2004 till March 2005; right: Meteosat-8 from July 2004 till March 2005.

Validation results for “cloud-free” nighttime validation cases are shown in table 1 for the satellites in use within the OSI SAF. NOAA-16 experienced problems during summer 2004 which are reflected in a high value of the standard deviation.

	NOAA-16	NOAA-17	GOES-12	METEOSAT-8
Number of points	611	952	9315	13732
Bias (K)	-0.15	-0.06	-0.13	-0.02
St. Dev. (K)	0.61	0.37	0.45	0.52

Table 1. “Cloud-free” nighttime SST validation results against drifting buoy measurements from the 1st of March 2004 (1st of July 2004 in the case of METEOSAT-8) till the 28th of February 2005.

	NOAA-16	NOAA-17	GOES-12	METEOSAT-8
Number of points	1674	2817	25664	29768
Bias (K)	-0.28	-0.15	-0.28	-0.09
ST. Dev. (K)	0.70	0.45	0.47	0.57

Table 2. Same as table 1 when all nighttime validation cases are considered (same periods).

Validation results for all validation cases are given in table 2. These results show mainly a decrease of the biases when compared to the cloud-free cases, due to the likely contamination of SSTs by undetected cloudiness. This effect is also apparent in Figure 2, showing the variation of the bias and standard deviation in function of the confidence level. Since the satellite SSTs are averaged over the cloud free part of the validation window, only the cases showing the same confidence level over more than 75% of the pixel are used in characterizing the errors by confidence levels. It is recommended that users consider these figures to filter the OSI SAF SST data according to the confidence level values in function of their application accuracy requirements.

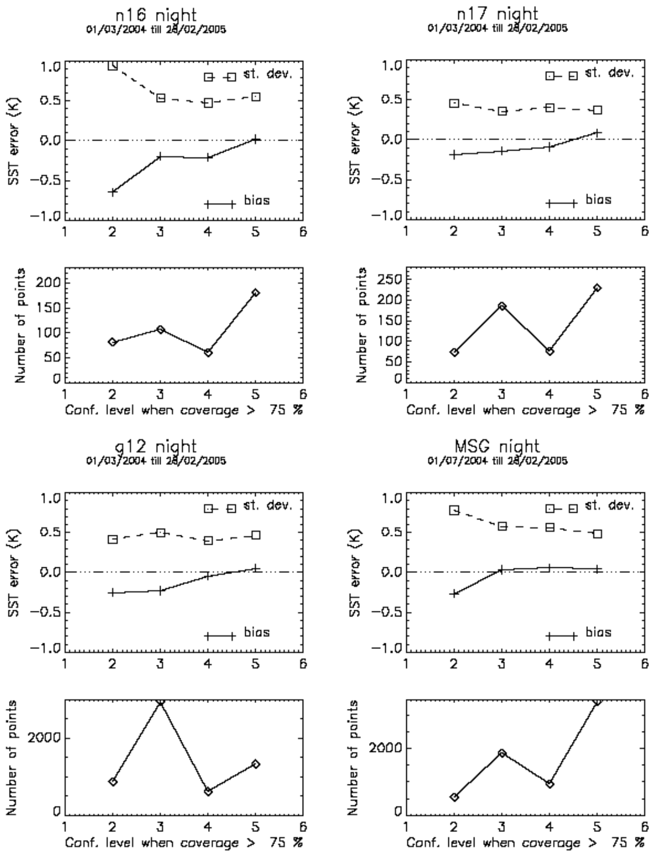


Figure 4. Nighttime error characteristics (all cases are considered) as a function of the confidence level . Top left: NOAA-16, top right: NOAA-17, bottom left: GOES-12, bottom right METEOSAT-8.

The product validation characteristics are discussed from the nighttime validation results when buoy measurements and satellite estimates should be identical. By daytime a slightly positive bias is usually observed. Figure 5 shows the variation of the validation statistics as a function of the local solar time for Meteosat-8 (cloud-free cases). Daytime and nighttime results are practically identical.

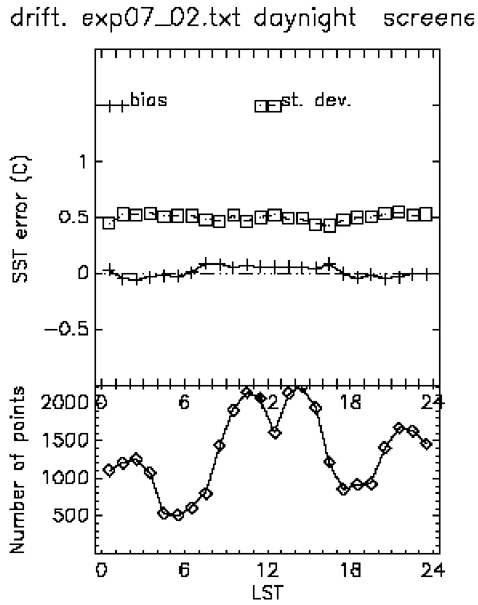
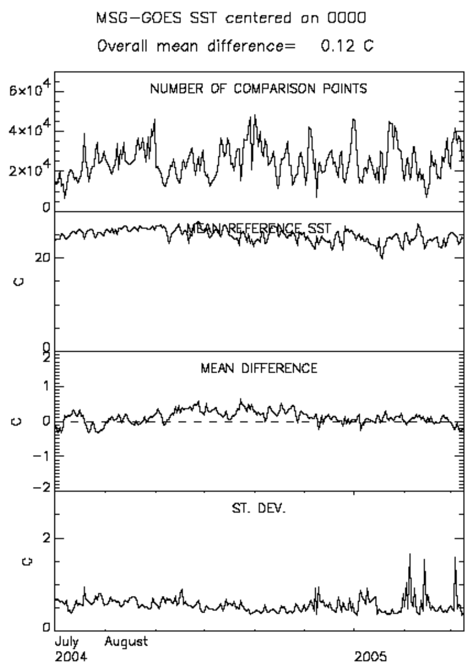


Figure 5. Variations of the METOSAT-8 error characteristics (day and night “cloud-free” cases) as a function of the Local Solar Time for the full validation area from July 2004 till March 2005.

5. INTERCOMPARISON



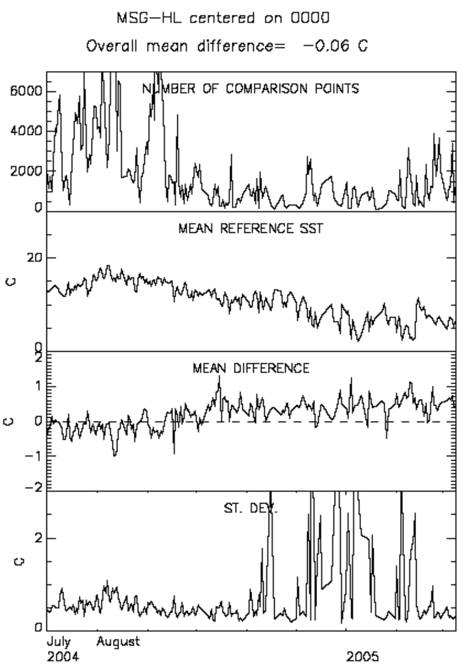


Figure 6. Nighttime METEOSAT-8 SST compared to GOES-12 SST (left) and to NOAA-17 derived HL SST (right) from July 2004 till March 2005.

The OSI-SAF SST fields have been regularly compared between themselves for confidence levels equal to 5 (i.e, METEOSAT-8 vs GOES-12, LML to HL,…) or to external data sources.

Figure 6 presents the routine intercomparison results of METEOSAT-8 against GOES-12, and against the High Latitude (HL) SST derived at met.no from NOAA-17/AVHRR. The GOES-12 versus METOSAT-8 results have been obtained in mid-Atlantic in the overlapping area centred on the 37.5 meridian from July 2004 till March 2005. The METOSAT-8 vs HL results are obtained North of 50N. In both cases the mean difference is small, but the comparison statistics with HL SSTs show very large values of the standard deviation in winter months (November-February). This is due to errors in METEOSAT-8 derived SSTs induced by not accounting for the ice mask in the SST climatology. This error, which was detected by DMI colleagues in December 2004, has been corrected in early March 2005.

The OSI SAF SSTs are also routinely compared with external data sources. Figure 7 left shows the nighttime OSI-SAF GOES-12 SST compared to the US NAVY NAVOCEANO NOAA-17 derived SST over the Atlantic during one year. On Figure 7 right OSI-SAF NOAA-17 NAR SST are compared to the CMS fine scale analysis (derived from buoy measurements and LML and NAVOCEANO products) over the Mediterranean Sea since November 2004 in the framework of the ESA funded Medspiration project. This is an independent quality assessment since NAR products do not contribute to this analysis. In both cases the daily mean differences vary by a few tenths of a degree.

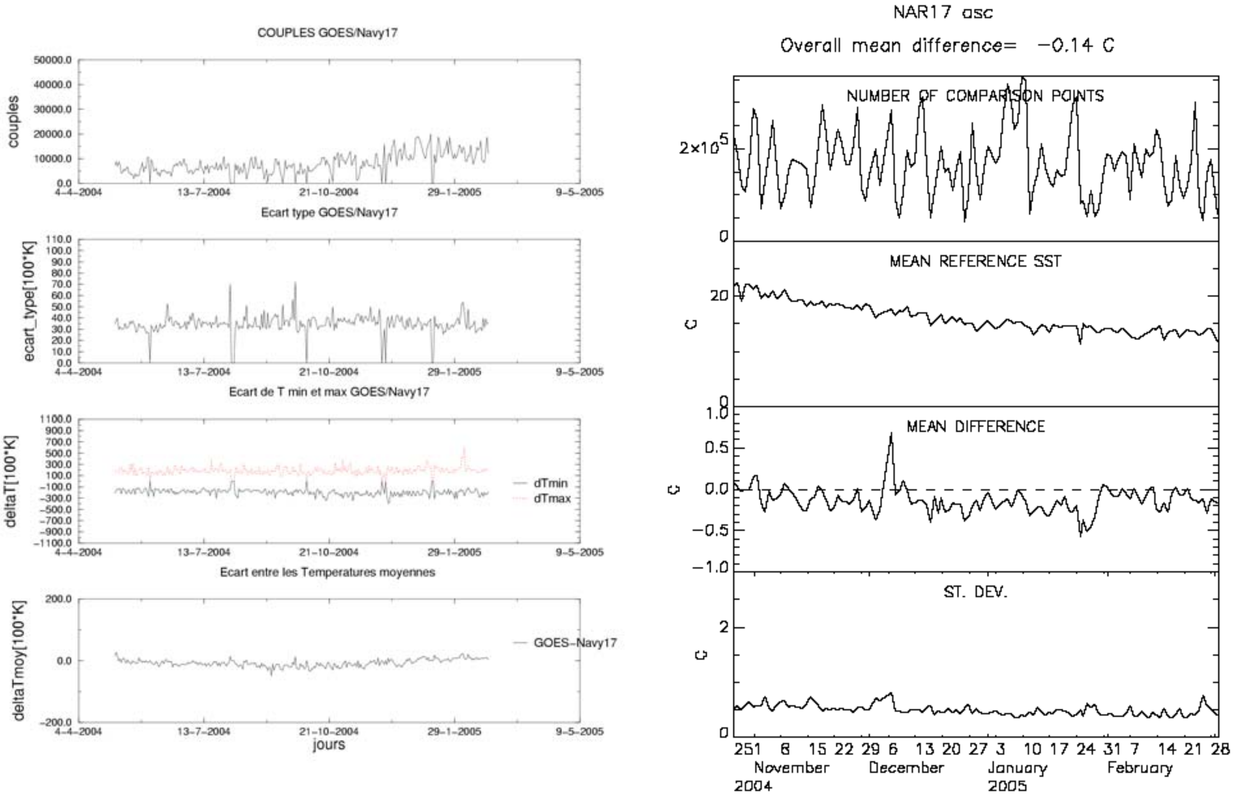


Figure 7. Left: nighttime OSI-SAF GOES-12 SST compared to the NAVOCEANO NOAA-17 derived SST. Right: OSI-SAF NOAA-17 NAR SST compared to the CMS fine scale analysis over the Mediterranean Sea.

6. FUTURE DEVELOPMENTS

The short term developments (2005) will be mainly devoted to starting the use of NOAA-18 and to consolidate the use of METEOSAT-8.

Developments on METEOSAT-8 algorithms: the preliminary validation experiments in early 2004 determined the choice of the non-linear split window algorithm (NL) for day and night processing. This option will be questioned by testing the various alternate options (use of T3.9 and 8.7 micron channel) on the MDB collected over more than one year. Furthermore, although the global statistics are satisfactory, regional error characteristics will be investigated through the MDB and dedicated intercomparison studies.
New products: Diurnal warming and ocean dynamics preliminary studies have demonstrated the usefulness of finer scale products, in terms time sampling as well as space resolution. A new hourly SST product at 0.05

degree resolution will thus be prepared for routine delivery at the end of 2005. Figure 8 by R. Legeckis at NOAA demonstrates the ability of high resolution METEOSAT-8 SST data to identify small scale sea surface thermal structures.

The longer term developments will be devoted to the building of a global SST product from METOP.

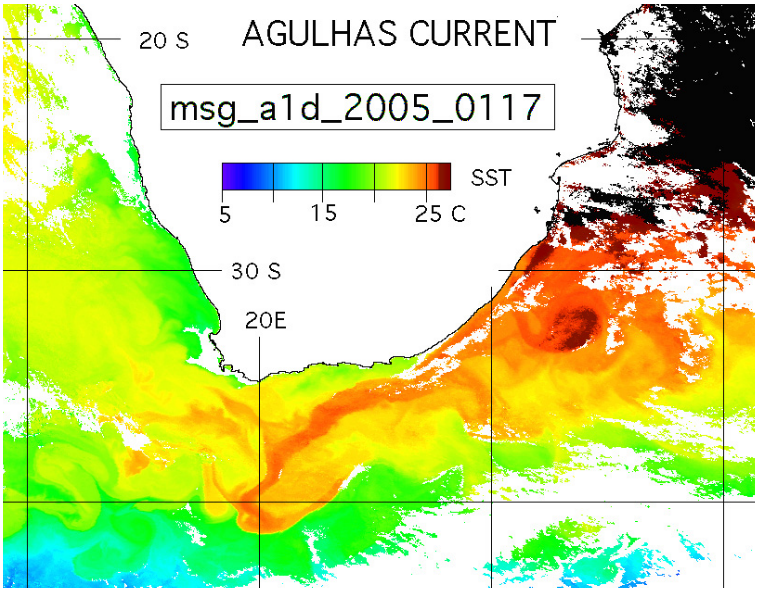


Figure 8. Aghulas current seen by METEOSAT-8 on the 17January 2005 (courtesy: Richard Legeckis).

7. CONCLUSION

The delivery of OSI-SAF SST products started in July 2001 and the full range of products (including METEOSAT-8 derived SST) has been made available since July 2004.

The production of hourly METEOSAT-8 derived SST at 0.05 degree resolution is planned to start before the end of 2005.

The routine validation results show that monthly biases are always within +/-0.3K, with standard deviation of about 0.5K, which is within the users' requirements.

Validation against buoy measurements and intercomparison of products will remain a major task of the OSI SAF team. A detailed analysis of the METEOSAT-8 errors will be undertaken in 2005. It may lead to improvements of the algorithms, which will benefit also to the SST retrieval from METOP.

As demonstrated by the remarks from DMI leading to correcting the SST calculation in case of ice, all users feed back are welcome.

8. BIBLIOGRAPHIC REFERENCES

Brisson, A., P. Le Borgne and A. Marsouin, 2002, Results of one year of preoperational production of sea surface temperatures from GOES-8, J. Atmos. Oceanic Technol.,19,1638-1652.

Brunel P. and S. Turner, 2003, on the use of Planck Weighted transmittances in RTTOV, Proceedings of the 13th International TOVS Study Conference, Ste Adèle, Canada, 29 October 2003- 4 November 2003.

Derrien, M., and H.Le Gléau, 2005, MSG/SEVIRI cloud mask and type from SAFNWC, Accepted in Int. J. Remote Sensing.

Faugère,Y., P. Le Borgne et H. Roquet, 2001, Réalisation d’une climatologie mondiale de la température de surface de la mer à échelle fine, La Méteorologie, 35, 24-35.

Francois, C., A. Brisson, P. Le Borgne and A. Marsouin, 2002, Definition of a radio-sounding database for sea surface brightness temperatures simulations: application to sea surface temperature retrieval algorithm determination, Remote Sens. Environ., 81, 309-326.

Merchant, C. and P. Le Borgne, 2004, Retrieval of sea surface temperature from space, based on modeling of infrared radiative transfer; capabilities and limitations, J. Atmos. Oceanic Technol., 21,1734-1746.