OPERATIONAL SST RETRIEVAL FROM MSG/SEVIRI DATA

P.Le Borgne, G. Legendre and A. Marsouin

Météo-France/DP/CMS
BP 50747, 22307 Lannion, France

Abstract

The Ocean and Sea Ice Satellite Application Facility (OSI-SAF) of EUMETSAT has produced operational MSG/SEVIRI derived SST products since July 2004. The production chain is based on the Nowcasting SAF cloud mask and uses a classical non linear split window method to derive SST in cloud free zones. The quality of the SST estimates is closely monitored through comparison with other satellite SST data sources and in situ measurements. Information on products and validation results are available on www.osi-saf.org. Over the Atlantic, the standard deviation of comparison with drifting buoys is about 0.5C with a negligible overall bias. Similar validation results have been also found by users such as IFREMER or NAVOCEANO. Local negative biases have been however observed in regions contaminated by Saharan dust. In consequence, a method based on the use of brightness temperatures has been developed and implemented to identify Saharan Dust and correct for its effect on SST calculations. This method has been implemented operationally since the 25th of April 2006 and shows encouraging results. The MSG/SEVIRI SST products have already a variety of users, in particular through the Godae High resolution SST Pilot Project (GHRSST-PP).

1. INTRODUCTION

METEOSAT-8 is the first geostationary satellite with a capacity to retrieve sea surface temperature (SST) with a satisfying accuracy (better than 1K) over the Eastern Atlantic and the Western Indian Ocean. SEVIRI derived SST is thus one of the key products of the Ocean and Sea Ice SAF. SST have been calculated operationally since July 2004 and various validation exercises have been performed routinely. This paper reviews in a second section the method used to calculate SST from the SEVIRI brightness temperatures, and gives a brief overview of the processing chain. The third section is devoted to validation results. Checking the overall accuracy of the products, identifying and correcting for regional anomalies is indeed a priority. Section 4 presents the correction of the Saharan dust effect that we had to implement to correct for some systematic biases in the areas affected by the Saharan dust clouds. Finally, section 5 reviews some applications illustrating the diversity of users who are already clients of these OSI-SAF products.

2. METHOD

The SEVIRI radiometer onboard METEOSAT-8 (or MSG-1) has a set of window InfraRed channels at 3.9, 8.7, 10.8 and 12 micron that are usable for the calculation of SST. Similarly to what was done for the GOES-8 data processing (Brisson et al. 2002), a set of algorithms have been derived from a simulated brightness temperature database. This database has been built by applying the RTTOV radiative transfer model on the “SAFREE” radio-sounding profiles described in Francois et al., 2002.
The algorithms that showed good results for the GOES satellites are the non linear split window (1) and the triple window (2) equations whose coefficients for METEOSAT-8 are given in table 1:

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

$$Ts = (a + b\,S_\theta)\,T_{39} + (c + d\,S_\theta)\,(T_{11}-T_{12}) + e\,S_\theta + f \qquad (2)$$

T_{39}, T_{11} and T_{12} are the brightness temperatures at 3.9, 10.8 and 12 microns. $S_\theta = \sec(\theta) - 1$, θ is the satellite zenith angle and Ts_{clim} is the mean climatological value.

Note that the table 1 coefficients include the correction of bias that has been made after a few months of use; see Merchant and LeBorgne, 2004 on this point.

	a	b	c	d	e	f
NL	0.98826	0.07293	1.18116	1.30718	-	-
T39	1.03837	0.02348	0.58550	0.35686	2.12593	4.99561

***Table 1*: Coefficients of the non linear split window (NL) and triple window (T39) algorithms for METEOSAT-8, with all temperatures expressed in Celsius.**

In practice, after a period of tests, only the NL algorithm has been used in operations. Indeed, the triple window equation, which is usable only at night, showed results not significantly better than that of the split window. This point remains to be investigated in detail, but may be related to the filter function of the 3.9 micron channel being significantly broader than that of the 3.8 micron channel onboard the GOES satellites.

The main steps of the SST calculation are the following:

- Ingestion of half-hourly MSG IR brightness temperatures (at 3.9, 8.7, 10.8 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 (T11-T12)
- Cloud mask control: pixels are considered as cloudy if the 10.8 micron brightness temperature diminishes by more than 0.5 K in half an hour, 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, see figure 1.
- Building of the match up data base
- Averaging over 3 or 12 hours and remapping

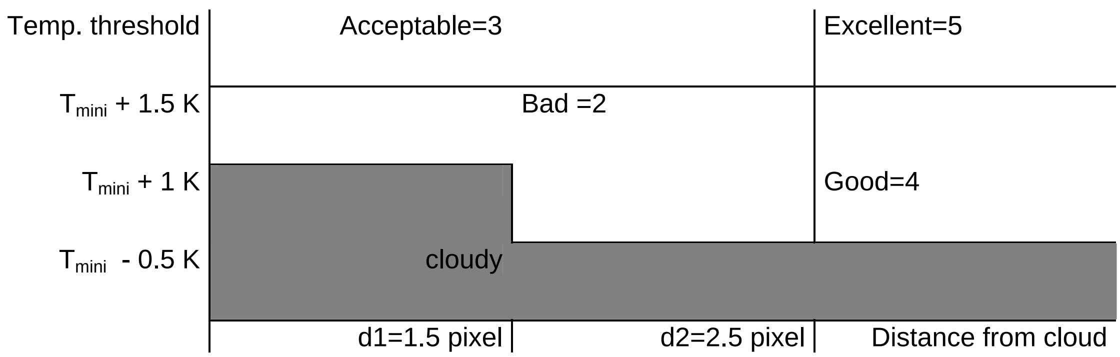

***Figure 1*: Confidence level attribution as a function of temperature and distance from cloud. T_{mini} is the local minimum climatological value. The threshold values shown here are those used for the open ocean cases.**

3. PRODUCTS

SST are calculated every hour (0100,0200 UTC,..) at full IR resolution, then averaged over time to produce 3 hourly and 12 hourly SST fields. The 3 hourly fields are the remapped over a 0.1 resolution regular grid and merged with the equivalent GOES-East derived product to provide a complete west to east coverage of the Atlantic. The 12 hourly products are also merged with NOAA/AVHRR derived SST fields produced at met.no to extend the SST coverage further North.

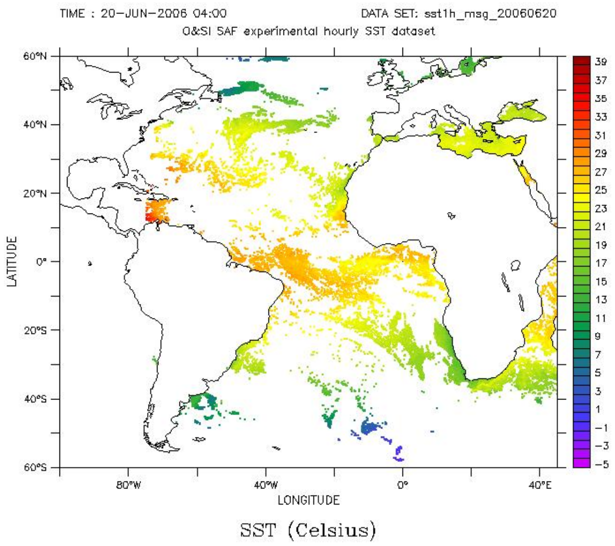

***Figure 2*: 20th June 2006: Example of 1-hourly product showing the maximum coverage of the Atlantic by Meteosat-8.**

On request of some users during the last OSI-SAF training workshop (Perros-Guirec, 2005), hourly products at 0.05 degree resolution (figure 2) have been developed on an experimental basis and are now made routinely available.
The operational OSI-SAF 3-hourly + 12-hourly products are available in GRIB, hdf or netcdf. More information on the products are their accessibility can be found through www.osi-saf.org, in particular in the product user manual (PUM).

The experimental hourly OSI-SAF products in netcdf can be downloaded through:

ftp://ftp.ifremer.fr/ifremer/cersat/products/gridded/experimental-cms/netcdf/msg .

The ESA/MEDSPIRATION project has been launched in 2004 to provide users and mainly the Godae High Resolution SST Pilot project (GHRSST-PP) with near real time SST data with consistent quality and auxiliary information and delivered in the common "L2P" netcdf format. The 3-hourly METEOSAT-8 operational OSI-SAF SST products are available in this format through ftp://ftp.ifremer.fr/ifremer/medspiration/data or
ftp://podaac.jpl.nasa.gov/GHRSST/data .

4. VALIDATION

4.1 Validation by comparison with other satellite data sources

The ESA/MEDSPIRATION project has made all operational SST products available under the same format, making the simultaneous use of various products much easier for users. Comparing the METEOSAT-8 derived SSTs with those derived from ENVISAT/AATSR, NOAA-17/AVHRR and AQUA/AMSRE has been the first application of this new capacity at CMS. This routine control produces daily nighttime synthesis of each sensor SST on a 0.1 degree regular grid. Daily differences are made out of the daily fields and averages of these differences over 10 days or a month (figure 3 and 9) have been regularly produced over the Atlantic.
Figure 3 shows the time series over 2005 of the monthly mean differences between the nighttime METEOSAT-8/SEVIRI and ENVISAT/AATSR derived SSTs, averaged over a 5x5 degree regular grid. The advantage of this mapping of errors is to display the regional distribution of the errors, which is hardly doable by comparison with buoy measurements. The most prominent feature in figure 3 is the negative bias (SEVIRI SST lower than the AATSR) that appears in spring and early summer. This situation was closely monitored and was very likely induced by Saharan dust over the Atlantic. In July

2005 two decisions have been taken: i) to mask the potentially contaminated areas by the Navy Aerosol Analysis and Prediction system (NAAPS) outputs, ii) to launch a study to characterize the Saharan dust contamination by the SEVIRI brightness temperatures themselves. The result of this study is briefly presented in section 5.

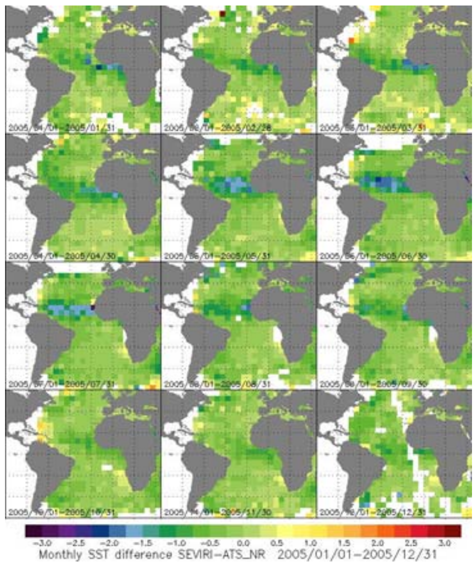

***Figure 3*: Time series of the monthly mean differences between the night-time METEOSAT-8/SEVIRI and AATSR derived SSTs. Top left: January 2005; bottom right: December 2005.**

4.2 Validation by comparison with in situ measurement.

CMS is routinely maintaining a matchup database gathering the OSI SAF SST satellite estimates and the in situ measurements collected daily through the GTS. In the case of METEOSAT-8, the hourly calculated SSTs are extracted in 5*5 pixel boxes (satellite IR full resolution) centred on the buoy location, providing the cloud coverage of the box is below 60%. The matchup time window is half an hour.
Results over the first year of production (1st of July 2004 till 1st of July 2005, before masking or correcting for the Saharan dust effects) are the following:

Cloud coverage of the box below 10% : 27756 cases; bias:-0.01K; st. dev.: 0.49K
Cloud coverage of the box below 60% (all cases) : 57974 cases; bias:-0.08K; st. dev.: 0.54K

The results over the last 12 months are available on the OSI SAF web site.
IFREMER recently started to build their own SST matchup data base. With no real time constraints, and with direct access to their extensive in situ data system (CORIOLIS), their MDB includes a large number of matchups. Figure 4 shows the results per confidence level from 01-07-2005 till 01-03-2006 obtained on the drifting buoys from the CMS MDB and figure 5 shows the same results obtained from the IFREMER database (J-F. Piolle, personal communication) over the same period of time. The total number of cases are 177064 cases for the IFREMER MDB against 74370 for the CMS MDB, that is about twice more. The comparison methods are not identical for the two MDBs, the main difference coming from the satellite data ingested: hourly values for the CMS MDB, 3-hourly values for the IFREMER MDB. It is nevertheless interesting to check that the relative distribution of the error characteristics agrees in both validation results. They underline in particular that data with a confidence level 2 should not be used quantitatively. They are provided to users to help visual interpretation of oceanic structures, for instance, and should be restricted to this type of use.

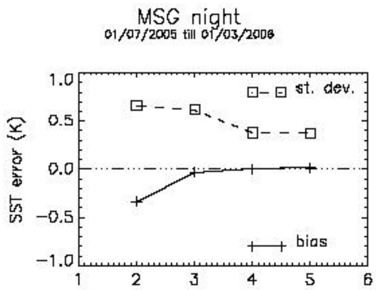

***Figure 4*: Results per confidence level from 01-07-2005 till 01-03-2006 obtained on the drifting buoys from the CMS MDB; night-time cases only.**

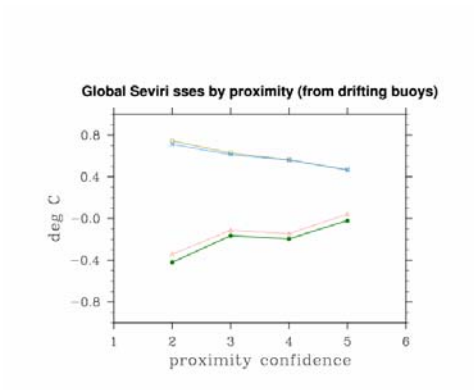

***Figure 5* : Results per confidence level from 01-07-2005 till 01-03-2006 obtained on the drifting buoys from the IFREMER database (courtesy of J-F. Piolle, IFREMER). Night-time and daytime results are shown separately, they are however almost identical. Upper curves: standard deviation; lower curves: biases.**

Table 3 show the validation results obtained by NAVOCEANO (US-NAVY) in their operational validation scheme. The period is not the same, but the values for confidence levels 3 and 5 are in good agreement with the CMS and IFREMER results and the overall trend is similar.

Conf level	% in cat	bias	St. dev.
5	29	0.01	0.48
4	3	-0.18	0.78
3	66	-0.11	0.63
2	-	-	-

***Table 3*: Meteosat-8 results from the NAVOCEANO validation database in February 2006 (courtesy of D. May, NAVOCEANO).**

5. CORRECTION OF THE SAHARAN DUST EFFECT

As shown in the previous section, contamination by dust induces negative biases on the retrieved SST. Recourse to external sources does not solve completely the problem because model outputs do not coincide exactly with the satellite data. A study has been launched in summer 2005 in cooperation with the University of Edinburgh to characterize the Saharan dust contamination with the SEVIRI brightness temperatures themselves. Figure 6 illustrates the potential effect of dust on the SEVIRI window IR brightness temperatures. This effect has two consequences: i) the split window algorithms are particularly vulnerable to the Saharan Dust; ii) it should be possible to characterize this effect through a combination of brightness temperatures. This approach has been described in Merchant et al. 2006 and Embury et al. (this conference).

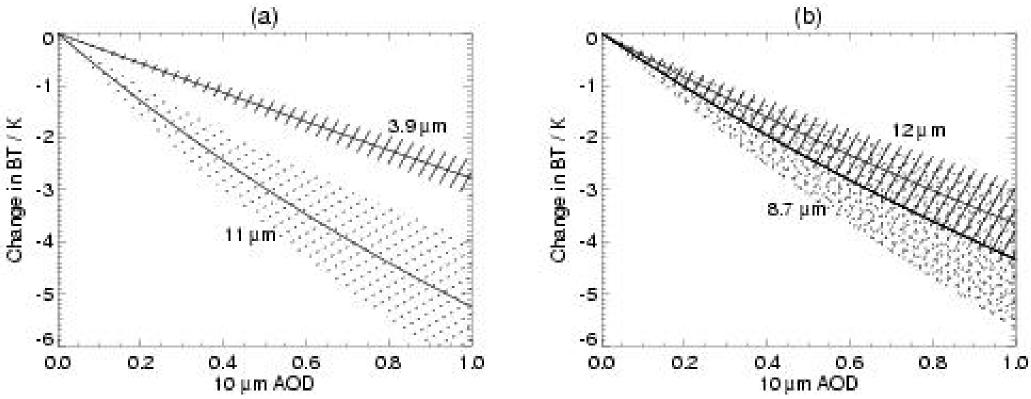

Figure 6 **(from Merchant et al. 2006): Mean (lines) and 1-σ range (shading) of change in BT versus AOD assuming a layer of aerosol evenly distributed between 2 and 3 km altitude (Haywood optical properties)**

In practice, an operational Saharan dust index (SDI) has been defined as a simplified version of the full three-dimensional equation described in Embury et al (this conference) :

$$SDI= 0.532 (T3.9-T8.7) - 0.847 (T11-T12) + 1.465 \quad (3)$$

The SDI is calculated in nighttime conditions only, due to the use of T39 in (3). A compositing technique using the most recent value over the last 24h allows to provide SDI values by day also. Figure 7 gives an example of the operational composite hourly SDI fields.

The CMS MDB results have shown a good correlation between the sdi values and the biases recorded (figure 5 middle) that allowed to derive a correction term under the form of:

$$Cor = 0.685140 \; sdi^2 + 1.10179 \; sdi + 0.200 \quad (4)$$

The method, including applying the correction term (figure 8), has been fully operational since the 25th of April 2006, and the results have been analysed through the usual intercomparison with other SST data sources (see section 4.1). Comparing the monthly differences between the SEVIRI, AATSR and AMSRE for the month of May 2005 (figure 9 left , before correction) and May 2006 (figure 9 right, after correction) shows the positive impact of the correction method.

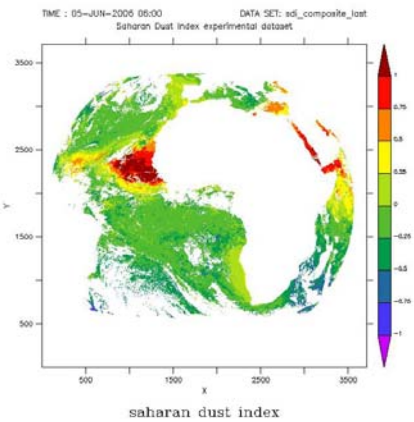

Figure 7**: (05 June 2006) Example of the operational SDI field.**

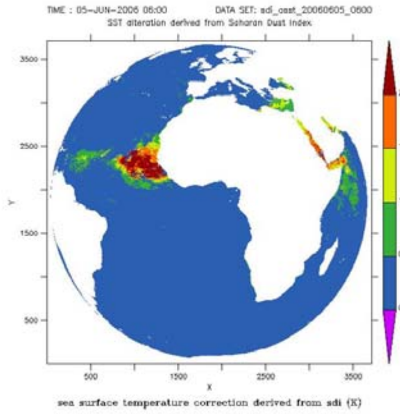

***Figure8*: (05 june 2006) the SST correction term deduced from the SDI field.**

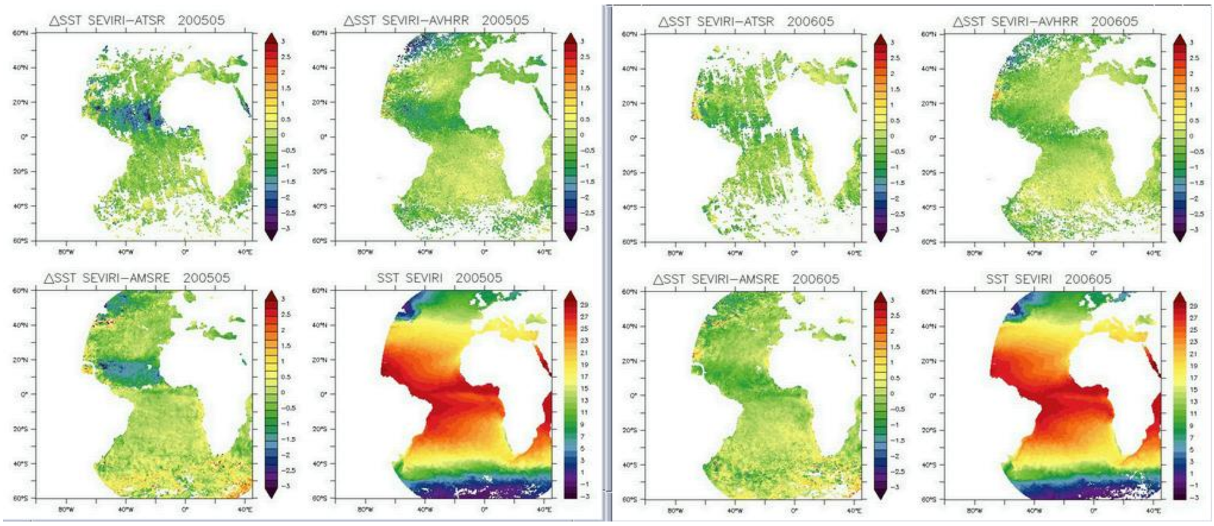

***Figure 9*: Left: Monthly differences between the SEVIRI, AATSR and AMSRE derived SST for the month of May 2005 (before correction); right: same for the month of May 2006 (after correction)**

6. APPLICATIONS

The METEOSAT-8 derived SST products are already used in a large variety of projects or operational applications such as MERSEA, ESA/MEDSPIRATION, UKMO/OSTIA, AMMA, NAVOCEANO. These applications use the potential of METEOSAT-8 to ensure a good coverage of the Atlantic thanks to its high time sampling. A more unexpected application is the use at fine scale to provide information to environmentalists or fishery specialists in the Bay of Biscay, shown as example in figure 10, or in other coastal European areas (see www.ifremer.fr/nausicaa/gascogne/index.htm). This example in June 2006 shows the development of intense diurnal warming induced warm spots in the bay of Biscay under high insolation and low wind speed conditions. METEOSAT-8 provides the adequate information to study the formation and the distribution of those warm spots over the Eastern Atlantic. This was one of the motivation to improve the time and space resolution of the operational products.

7. CONCLUSIONS

After almost two years of operational production, the SST products derived from METEOSAT-8 SEVIRI have shown satisfactory results over the Eastern Atlantic. The extensive validation studies will

continue in particular to check the efficiency of the Saharan dust correction method. Studies will have to be undertaken to improve the use of the 3.9 micron channel and to reduce or correct for the remaining regional biases. A daytime method will be defined to improve the Saharan dust correction method.
In terms of products, many users have already requested an extension to the East of the zone to include the Western Indian Ocean. This will be done in the upgrade of the OSI-SAF geostationary chains which has been scheduled in the CDOP phase of the OSI-SAF

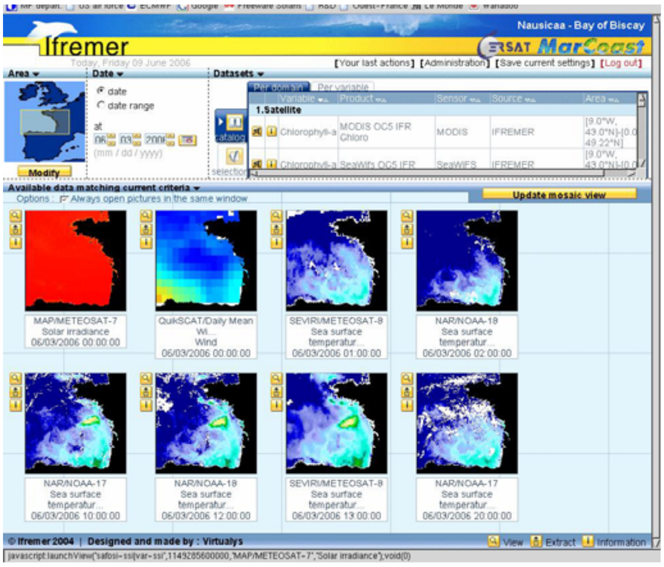

***Figure 10*: Extract from the IFREMER/NAUSICAA server showing various OSI-SAF SST fields including NOAA-17, NOAA-18 and METEOSAT-8 3-hourly SST products centered on 0100 and 1300 UTC.**

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